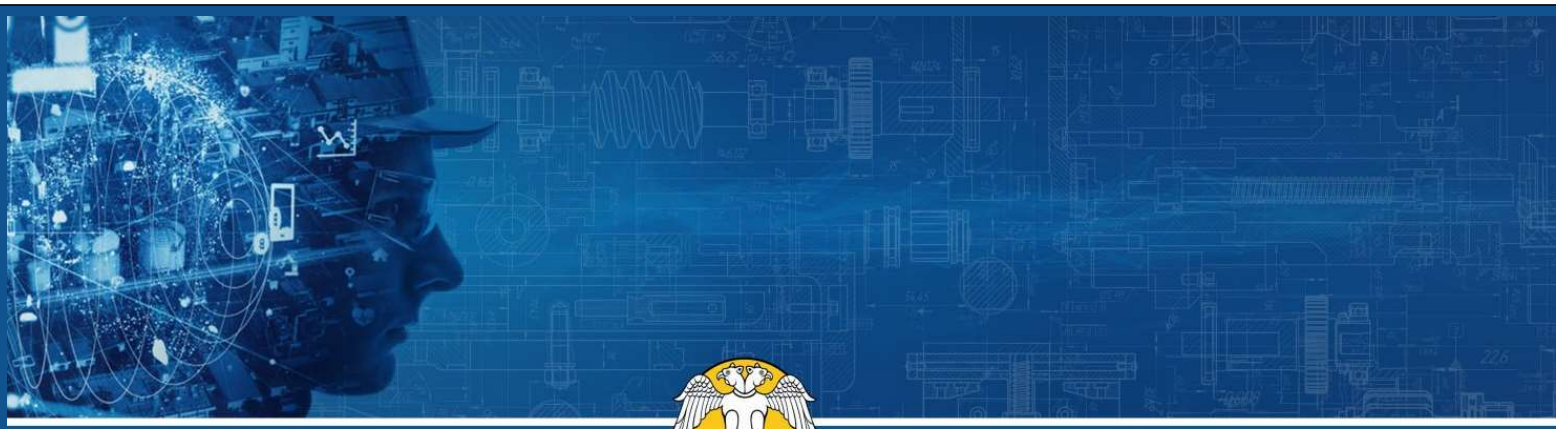




SELÇUK UNIVERSITY
FACULTY OF TECHNOLOGY

ICNAE'22

INTERNETIONAL CONFERENCE ON NEW APPROACHES

October 6-7, 2022

Konya/TURKEY

PROCEEDINGS

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SELÇUK UNIVERSITY
FACULTY OF TECHNOLOGY

**INTERNATIONAL CONFERENCE
ON NEW APPROACHES IN ENGINEERING**
• **October 6-7, 2022 - KONYA / TÜRKİYE**

**International Conference on
New Approaches**

**1st International Conference, ICNAE'22
Konya, Turkey, October 6-7, 2022**

Proceedings

**Editor
Sakir TASDEMİR**

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Konya, Turkey, October 6-7, 2022

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Her hakkı saklıdır. Bu kitabın tamamı ya da bir kısmı yazarlarının izni olmaksızın, elektronik, mekanik, fotokopi ya da herhangi bir kayıt sistemi ile çoğaltılamaz, yayınlanamaz depolanamaz. Bu karateka yayınlanan tüm yazı ve görsellerin her türlü sorumluluğu yazarlarına aittir.

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Konya Ekim 2022

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PREFACE

International Conference on New Approaches in Engineering (ICNAE'22) was organized in Konya, Turkey on 6-7 October 2022.

The main objective of ICNAE'22 is to present the latest research and results of scientists related to Engineering fields. This conference provides opportunities for the delegates from different areas in order to exchange new ideas and application experiences, to establish business or research relations and to find global partners face to face for future collaborations.

All paper submissions have been peer reviewed and evaluated based on originality, technical and/or research content/depth, correctness, relevance to conference, contributions, and readability. Selected papers presented in the conference that match with the topics of the journals will be published in the following journals:

- Selcuk University Journal of Engineering Sciences
- New Trends in Computer Sciences
- Intelligent Methods in Engineering Sciences

ICNAE'22 conference, attended by scientists from 15 different countries Albania, Bulgaria, Czech Republic, France, Italy, Latvia, Lithuania, Malaysia, Malta, R. of North Macedonia, Romania, Tunisia, Türkiye, United Kingdom, Uzbekistan (66,25% Foreign Participants Rate, Turkish Participants Rate 33,75%) from different engineering fields, especially Biomedical, Computer, Electrical & Electronics, Mechanical, Mechatronics, and Metallurgy & Materials, will continue for two days, and the papers will be presented in online-virtual sessions.

In particular, to Selcuk University Rector Prof. Dr. Metin AKSOY; we would like to thank the conference scientific committee, session chairs, referees, technical team, participants, and all our colleagues who have contributed. They have made a crucial contribution to the success of this conference. Our thanks also go to our colleagues in our conference office.

Prof. Dr. Sakir TASDEMİR
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A Survey on Machine Learning and Fuzzy Approaches for Renewable Energy in Marine Systems

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Abstract— Nowadays, growing environmental pollution and human intervention in nature have increased the need to study and monitor these adverse effects in marine waters. Therefore, intelligent marine monitoring approaches with artificial intelligence (AI) methods are needed. Consequently, the main research questions arise how are AI and intelligent technologies applied in marine monitoring systems? How does it contribute to the sustainable development of the environment? To answer these questions, this paper presents the results of the systematic mapping (SM) of papers from Web of Science (WoS) and Scopus databases and develops a keyword map. SM results show that AI techniques are applied in the control, decision, simulation, and optimization of renewable energy in marine systems. The main finding is presented in the form of the keywords map, which indicates the main trends of sustainable development in renewable energy of marine systems applying AI. However, the effective application of AI techniques for sustainable development of energy in marine system should be analyzed further in detail.

Keywords—fuzzy, machine learning, sustainable development, marine, buoys, renewable energy.

I. INTRODUCTION

The increase in environmental pollution and human intervention in nature, such as industrialization, agriculture, etc., have escalated the need to study and monitor these effects in marine waters [1, 2, 3]. Therefore, science is looking for new directions in studying emerging adverse effects on marines by applying modern intelligent technologies, like Soft Computing (SC) and Machine Learning (ML) techniques [4, 5, 6]. Moreover, incorporating those new technologies into decision-making processes allows us to simultaneously achieve the efficiency and effectiveness of sustainable decisions in marine monitoring [7].

Renewable energy can be the basis for various energy systems, including marine monitoring systems, to meet the needs of sustainable development and use [8, 9]. Consequently, due to the current energy and environmental pollution problems in marines, it is necessary to investigate the effect and trends of renewable energies by applying modern intelligent technologies.

Therefore, this research aims to investigate the development and trends of renewable energies using modern intelligent technologies in marine systems by performing a systematic mapping (SM). Those modern intelligent technologies include a variety of forms, like intelligent techniques with artificial neural networks (ANN) [10, 11],

fuzzy logic [12], particle swarm optimization [11], artificial bee colony optimization [13], etc.

The structure of the paper is as follows. Section 2 describes the methodology of a systematic mapping of the ML and fuzzy approaches for renewable energy in marine systems. Section 3 presents the results of the systematic mapping. Section 4 discusses the results and Section 5 concludes the paper.

II. SURVEY METHODOLOGY

A systematic mapping (SM) on the machine learning (ML) and fuzzy approaches for renewable energy in marine systems (MLFRE-Marine) topic is conducted as proposed in [14, 15, 16]. Its general schema is presented in Fig. 1.

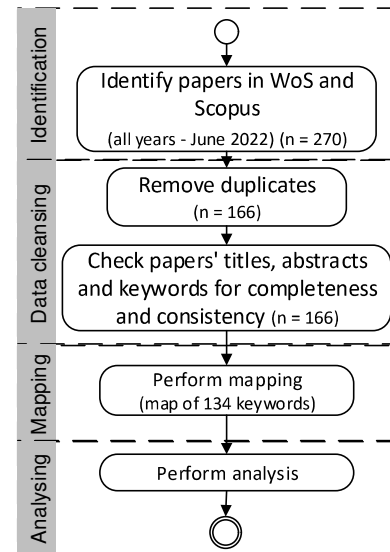


Fig. 1. The general schema for our SM.

It consists of four main steps as follows: identification, data cleaning, mapping, and analysis. The main results of the performed steps are presented in brackets. The detailed description of the steps is forwarded.

A. Identification

In this step the following activities are performed.

a) Research Questions

The main research questions (MRQ) follow: (MRQ1) *how are AI and intelligent technologies applied in marine monitoring systems?* (MRQ2) *How it contributes to the*

sustainable development of the environment? According to MRQ1-2, the following research questions (RQ) are defined:

- RQ-1: What **period** is covered by the application of MLFRE-Marin?
- RQ-2: In what **research areas** are the application of MLFRE-Marin being addressed?
- RQ-3: In which **countries** are the application of MLFRE-Marin being considered?
- RQ-4: What are the main **topics** being investigated in MLFRE-Marin?

b) The List of Search Sources

The WoS and Scopus databases were used based on the experience reported in [17]. Gusenbauer and Haddaway [18] have found that 14 of 28 academic search systems (ASS) are well-suited to SLR. Emphasizing the Computer Science research area, the main ASS are the following: ACM Digital Library, Bielefeld Academic Search Engine (BASE), ScienceDirect, Scopus, WoS and Wiley Online Library. For this SM, we need ASS, which has a full download function of search results for bibliometric analysis in a particular reference management software. Moreover, another important attribute is the quality of the presented research. Consequently, we have found that WoS and Scopus meet all those requirements.

c) Searching Query

We have identified three main groups of terms for the search as follows:

- Concepts related to AI: fuzzy and ML;
- Concepts related to sustainable development: renewable energy and sustainability;
- Concepts related to the marine systems: buoy, underwater devices, sea vehicles, sea monitoring systems, and marine sensors.

The final search query is developed based on WoS and Scopus search requirements as follows:

("fuzzy" OR "machin* learning") AND ("renewable energ*" OR "sustainab*") AND ("buoy" OR "underwater* devic*" OR "sea vehicle*" OR "marin*" OR "sea monitoring system*" OR "marine sensor*")

d) Searching by Query

We have performed a search using the defined search query in WoS and Scopus. Moreover, we have limited the search by language and document type (see Table I). We have no limited research areas, since it is related to RQ-2.

TABLE I. RESULTS OF IDENTIFICATION AND DATA CLEANSING STEPS

Databa se	Document Type	Language	Search Results
WoS	article OR proceedings papers OR review	English	124
Scopus	article OR conference papers OR review	English	146
Total:			270 ^a

^a. In this step, duplicates are not excluded.

B. Data Cleansing

In this step, we have removed duplicates using the Mendeley reference management software

(<https://www.mendeley.com/>). Also, titles, abstracts and keywords of all identified papers were checked for completeness and consistency.

C. Mapping

A set of relevant papers obtained were transferred to VOSviewer (<https://www.vosviewer.com/>), a software tool for conducting and visualizing bibliometric networks [19].

To develop a keywords map on MLFRE-Marin, we have used keywords of the relevant papers. VOSviewer uses an automatic keyword identification technique [19, 20]. It creates the map according to the closeness and strength of existing links between found keywords calculating the number of papers, in which they have occurred together. The size of the bubbles presents the occurrence of keywords.

Moreover, in this SM, we concentrate on the keywords map coloring according to Average Publication Year (APY), which indicates the average publication year of the papers in which a keyword occurs [21]. Note that APY is a positive rational number.

D. Analysing

In this SM, the content was analyzed as follows:

- Chronological visualization and analysis (RQ-1);
- Research areas visualization and analysis (RQ-2);
- Countries visualization and analysis (RQ-3);
- Keywords occurrence visualization based on APY and analysis (RQ-4).

The found keywords were analyzed quantitatively according to APY (RQ-4) as follows:

- newest keywords – those keywords' occurrence is not high (i.e., in the context of this SM, it varies in the interval [3; 10]), but their APY is new (see Fig. 5);
- continuous occurrence of keywords – those keywords' occurrence is middle (i.e., varies in the interval [11; 25]) or high (i.e., varies in the interval [25; 45]), and their APY is middle (see Fig. 5); and
- older keywords – those keywords' occurrence can be different and their APY is old (see Fig. 5).

III. MAIN RESULTS OF SM

The period of the found publications on MLFRE-Marin (RQ-1) is presented in Fig. 2. The found papers were published from 2004 to 2022 (June).

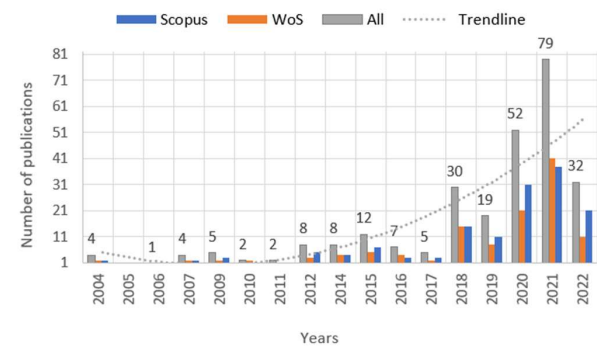


Fig. 2. The period of the found publications on MLFRE-Marin (RQ-1)

The trendline shows the increased number of publications on the analyzed topic, especially in 2018.

The found **research areas** in the application of MLFRE-Marin (RQ-2) are presented in Fig. 3. As can be seen, the leading research areas are as follows: Environmental Sciences; Engineering; Environmental Science Ecology; Economics, Econometrics and Finance; Energy. Note that Other 2 presents other research areas, with two publications in WoS or Scopus, and Other 1 has one publication in WoS or Scopus.

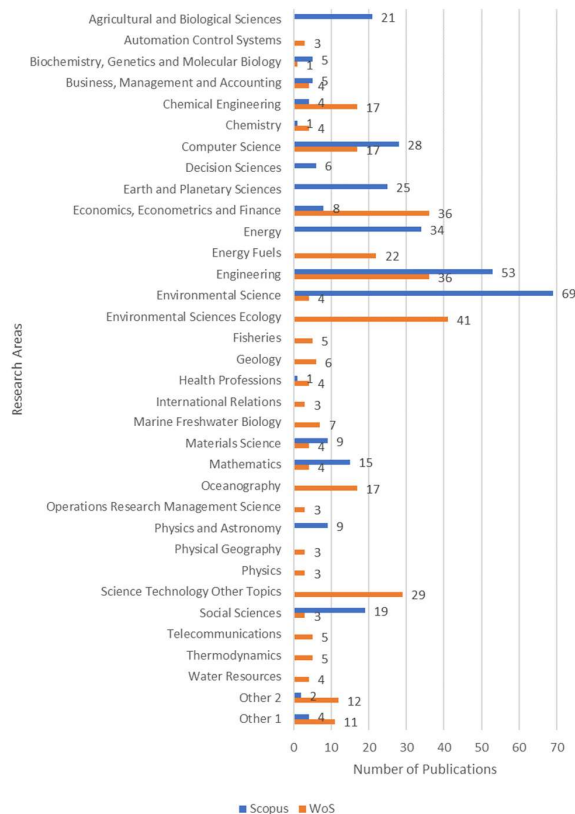


Fig. 3. The research areas in the application of MLFRE-Marin (RQ-2)

The distribution of the analyzed topic according to **countries** (RQ-3) is presented in Fig. 4. As can be seen, the five most active countries are as follows: China, the United States, Australia, Spain, and United Kingdom. Other countries are those having one publication in WoS and/or Scopus.

The developed keyword map, which presents the main **topics** being investigated in MLFRE-Marin (RQ-4) according to (APY), is illustrated in Fig. 5. It is colored as follows.

Keywords colored in yellow are found in articles published in recent years (APY ~ 2021); green – APY ~ 2019; blue – APY ~ 2017 (see Fig. 5).

Moreover, the bigger bubbles present the more occurring keywords, and the smaller bubbles – represent less occurring keywords, which can be trends or unexpanded and forgotten topics depending on their color.

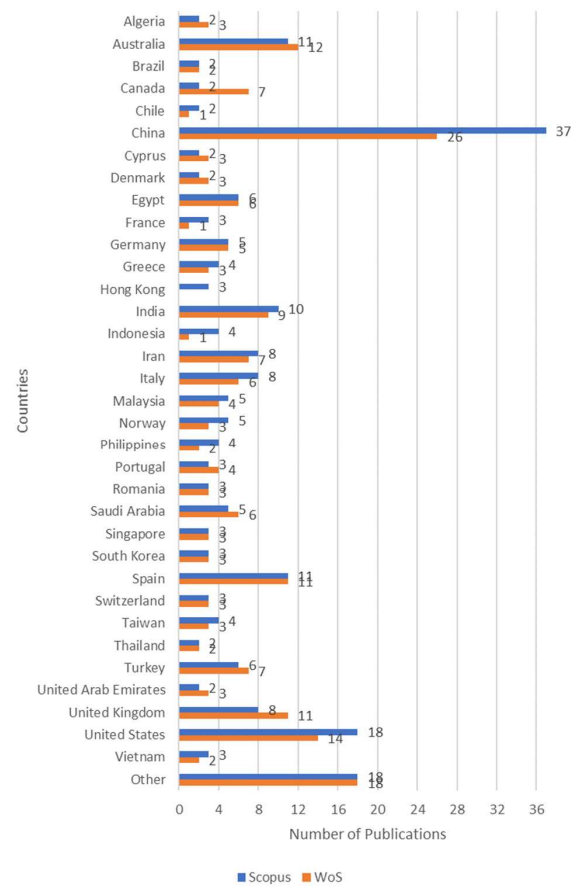


Fig. 4. Countries analyzing MLFRE-Marin (RQ-3)

Yellow bubbles represent new keywords, i.e., their APY equals current years, which means novelty and latest trends. Green and large bubbles present keywords that occur continuously throughout the analyzed period. Green and small bubbles show keywords that appear during from 2019 to 2020.

Blue bubbles present older keywords in the map (Fig. 5).

So, we can see from Fig. 5:

- the newest keywords (APY is from 2020 to 2022, color – yellow), like plastic waste, global warming, sustainability, tidal power, wave power, sustainable tourism, SVM, deep learning, etc.;
- continuous occurrence of keywords (APY is from 2020 to 2018, color – green), like decision making, selection, ANFIS, energy storage, fuzzy neural networks, optimization algorithms, forecasting, fuzzy inference, offshore wind turbines, wind velocity, energy management systems, offshore oil well production, renewable energy source (RES), wind farm, hybrid systems, ANN, AHP, ML, data handling, etc.; and
- older keywords (APY is from 2018 to 2012, color – blue), like fuzzy mathematics, fuzzy logic controller, sustainable development, GIS, uncertainty analysis, data mining, etc.

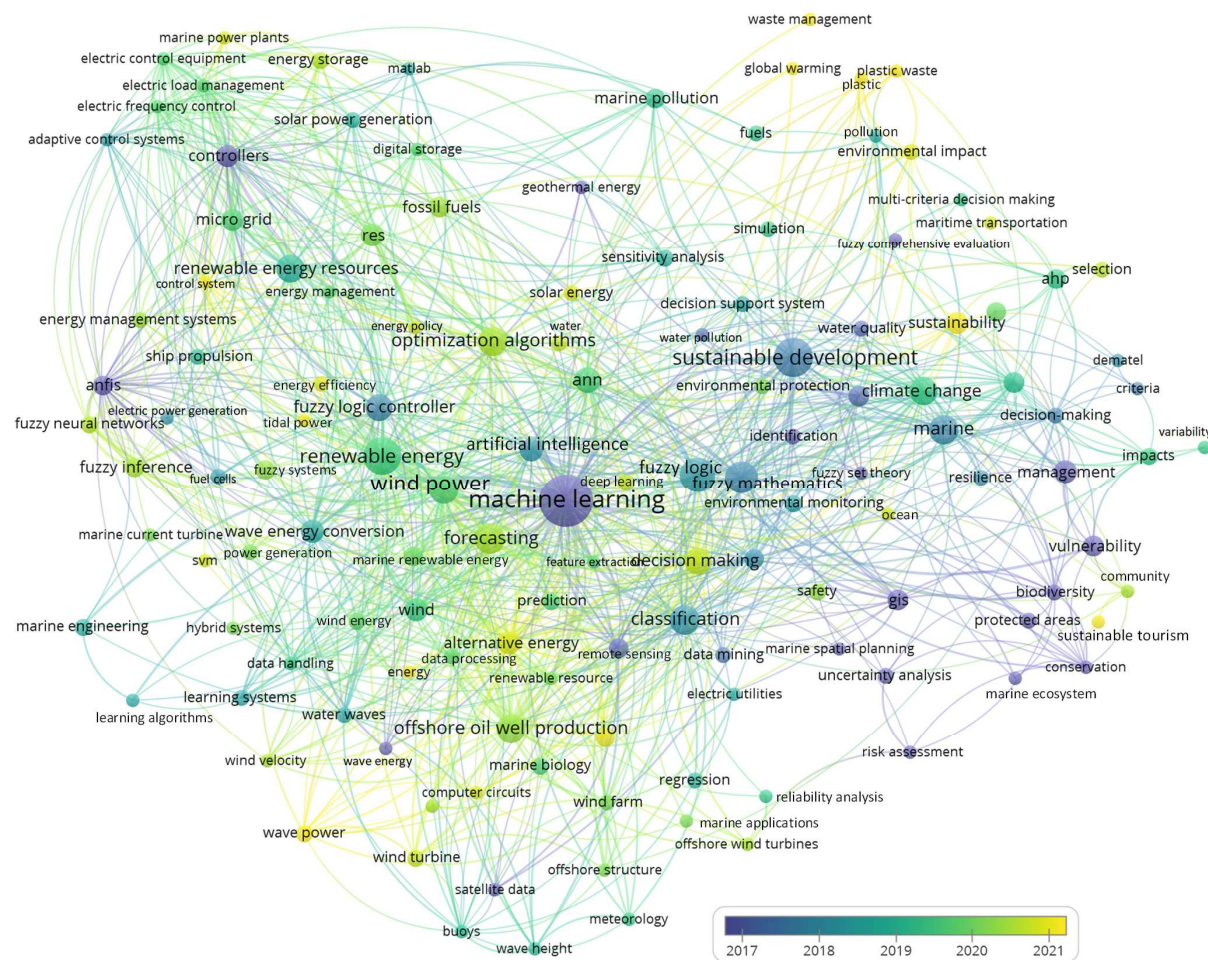


Fig. 5. The keyword map.

TABLE II. RESULTS OF CLASSIFICATION OF CONCEPTS TO AI, SUSTAINABLE DEVELOPMENT AND MARINE ENVIRONMENT SYSTEMS

APY	AI	Sustainable development	Marine systems
2021	--	wave power; energy; global warming; sustainable tourism; tidal power; waste management	control system
2020	ML; forecasting; optimization algorithms; decision making; ANFIS; fuzzy inference; fuzzy systems; deep learning; fuzzy neural networks; computer circuits; hybrid systems; SVM; selection	offshore oil well production; alternative energy; RES; fossil fuels; marine energy; energy efficiency; environmental impact; environmental protection; solar energy; energy policy; renewable resource; wind velocity	marine applications; marine current turbine; marine power plants; maritime transportation; energy storage; wind turbine; energy management systems; power generation; wind farm; offshore structure; offshore wind turbines
2019	ANN; micro grid; Analytic Hierarchy Process (AHP); fuzzy; prediction; data processing; simulation; data handling; digital storage; feature extraction; multi-criteria decision making; reliability analysis; variability	climate change; ecosystem; marine pollution; marine renewable energy; wind energy; wind power; fuel; meteorology; wave height	marine biology; ship propulsion; buoys; electric control equipment; electric frequency control; electric load management; energy management
2018	fuzzy logic; classification; AI; sensitivity analysis; decision support system; learning systems; regression; adaptive control systems; DEMATEL; learning algorithms; MatLab	renewable energy resources; fuel cells; water waves; pollution	wave energy conversion; environmental monitoring; marine engineering; resilience; solar power generation; electric power generation; electric utilities
2017	fuzzy mathematics; fuzzy logic controller; data mining; decision-making; uncertainty analysis	water pollution	remote sensing; water quality; marine spatial planning
2016	controllers; identification; risk assessment	geothermal energy; wave energy	
2015	management; fuzzy set theory	vulnerability	biodiversity; marine ecosystem; GIS
2014	fuzzy comprehensive evaluation	conservation	

According to the classification of concepts to AI (Column 2), sustainable development and renewable energy (Column 3) and marine systems (Column 4), the newest found terms are presented in Table II. Note that years are APY (Column 1) but not the actual year of the paper publication.

Based on Table II, we can see that in the analyzed scope, the found AI *methods/techniques/approaches/systems* are as follows: ML; ANFIS; fuzzy systems; deep learning; fuzzy neural networks; computer circuits; hybrid systems; SVM; ANN; micro grid; AHP; sensitivity analysis; decision support system; learning systems; regression; adaptive control systems; DEMATEL; learning algorithms; MatLab; fuzzy logic controller; uncertainty analysis; fuzzy comprehensive evaluation; optimization algorithms; reliability analysis.

The AI *processes* are as follows: forecasting; decision making; fuzzy inference; selection; simulation; prediction; data processing; data handling; feature extraction; multi-criteria decision making; classification; data mining; decision-making; identification; risk assessment; management.

The found sustainable development terms are as follows:

- *Energy*: wave power; tidal power; alternative energy; renewable energy source (res); fossil fuels; marine energy; solar energy; renewable resource; wind velocity; marine renewable energy; wind energy; wind power; wave height; renewable energy resources; fuel cells; water waves; climate change; ecosystem; marine pollution; geothermal energy; wave energy.
- *Pollution*: global warming; sustainable tourism; waste management; offshore oil well production; environmental impact; environmental protection; water pollution

The found marine systems terms can be classified into utilities are as follows:

- *Management and control*: energy management systems; electric frequency control; electric load management; control system; maritime transportation; environmental monitoring; marine spatial planning; water quality.
- *Generation*: power generation; solar power generation; electric power generation; ship propulsion; wave energy conversion.
- *Equipment*: marine current turbine; marine power plants; energy storage; wind turbine; wind farm; offshore wind turbines; buoys; electric control equipment; electric utilities; remote sensing; GIS; offshore structure.

IV. DISCUSSION

In this research, we have applied SM to answer the main research questions: (MRQ1) *how are AI and intelligent technologies applied in marine monitoring systems?* (MRQ2) *How it contributes to the sustainable development of the environment?* They were decomposed to the following sub-questions: (RQ-1) What period is covered by the application of MLFRE-Marin? (RQ-2) In what research areas are the application of MLFRE-Marin being addressed? (RQ-3) In which countries are the application of MLFRE-Marin being considered? (RQ-4) What are the main topics being investigated in MLFRE-Marin?

The conducted SM on the MLFRE-Marin topic shows a significant increase of papers since 2018 in the period between 2004 and 2022 (till June) (RQ-1). It can be explained by the development of AI techniques and their application in the analyzed topic.

The results from SM show that the top five research areas (RQ-2) in MLFRE-Marin are as follows: Environmental Sciences; Engineering; Environmental Science Ecology; Economics, Econometrics and Finance; and Energy.

The analysis of countries investigating MLFRE-Marin (RQ-3) shows that the most active and influencing five countries are as follows: China, the United States, Australia, Spain, and United Kingdom, which correspond [9].

To answer RQ-4, the mapping with VOSviewer has been performed, and the keywords map based on occurrence and APY has been developed. It shows that the newly occurring keywords in the scope of MLFRE-Marin are: sustainable tourism, tidal power, waste management, and wave power. The most visible and applicable AI methods in MLFRE-Marin are ML and fuzzy-based systems. While the newest found AI technique in this research area is support vector machine (SVM) and found approach – deep learning. Moreover, it is found that ANN, AHP, fuzzy neural networks, learning algorithms and hybrid systems are applied continuously for the studied topic. However, the application of those approaches is not deep and mature enough in the analyzed topic. This situation can be explained by the novelty of the application of AI technologies in MLFRE-Marin.

The analysis of the found sustainable development terms (RQ-4) shows that they could be grouped into energy and pollution-related terms. Energy terms cover wave, tidal, wind, and solar energy sources. In the pollution area, sustainable tourism emerged.

The found marine systems terms can be classified into utilities for management and control of the energy, generation of the sustainable energy, and equipment used for sustainable energy development and monitoring.

Summing up, AI and intelligent technologies have only recently been applicable in marine monitoring systems for the sustainable development of energy. Therefore, there is a need for more investigation.

V. CONCLUSIONS

The presented SM briefly reviews the current state of the machine learning (ML) and fuzzy approaches for renewable energy in marine systems (MLFRE-Marin). The application of AI techniques in the control, decision, simulation, and optimization of MLFRE-Marin is found and summarized.

From the current SM, it is evident that the effective application of AI techniques for sustainable energy development in the marine system is an important topic that should be analyzed further in detail. Though there are approaches on MLFRE-Marin, there is a need for their deeper analysis in future research and proper utilization in sustainable marine systems.

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Internet of Things: current state and future outlook

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Abstract— The direction of the development of the Internet of things is due to the ever-increasing need for the Internet - the communicative component for the exchange of information not only among people, but with the increase in information, receiving it from certain devices. The development of technology has led to the transition to the Internet of things (IoT), which includes a much larger number of devices that allow you to create colossal monitoring systems for various objects. All these devices are connected to a platform that allows you to analyze and process information, control and issue commands to individual devices for further activation of the process. The concept of the Internet of Things implies the connection of any things to the Internet or their interaction using some of the available technologies of any type, which may contain some communication components. These components form some systems (subsystems) that allow: to transmit information, to interact with the external environment, to receive data from outside, and are perceived as entities that can be controlled.

The Internet of Things is a system of physical objects connected by a common network with embedded sensors and software, characterized by an autonomous mode of operation and the possibility of remote control. The global task of the Internet of Things is to take over the management of huge data and develop certain actions without human participation, leaving the control functions to the person, which implies not just the exchange of signals, but the generation of advice for us.

The Internet of Things is not the distant future, but our present. In general, IoT and other infocommunication technologies that allow devices to interact with each other without passing a person are intended to serve him for the good, thereby giving people the potential to naturally change the environment, open up new opportunities to make life qualitatively better, more interesting, more comfortable. The number of smart devices connected to the network exceeds the population of the planet at least three times, in the future this number will only increase.

Keywords—internet of things, smart devices, device communication, global network

I. INTRODUCTION (HEADING 1)

The concept of the Internet of Things as an evolutionary informational revolution was announced in 1999 by the

British engineer Kevin Ashton, and by 2010 communication standards became clear, cloud technologies acquired a qualitative look, which made it possible to use them to the fullest.

The Internet of Things (IoT) is a new concept in which the Internet is evolving from the union of computers and people to the union of (smart) objects of things [1].

The idea of the Internet of Things (IoT) plays a key role in the development of the IT industry. In the United States, the Internet of Things is included in the list of groundbreaking technologies, and in China it is one of the seven strategic industries. Active development is underway in Australia, England, South Korea and Japan [2].

Sensors and detectors are the eyes and ears of smart technology, behind them is a huge layer of data transmission. The energy efficiency of devices has increased and the service life of wireless sensors without recharging is up to 10 years. Previously, it was necessary to constantly take care of the power supply of the sensor, they could only be located in places of power supply, but now they can be installed in an open field and receive information about the object.

The number of devices using Internet services is growing every day and connecting them all using wired or wireless technologies will give us a powerful source of information at our fingertips. The concept of empowering interactions between smart machines is state-of-the-art technology [3]. It should be emphasized that the Internet of things does not exclude human participation. IoT does not fully automate things, as it is human-centric and gives him the ability to access things [4].

The widespread use of portable electronics gives impetus to the development of many areas of the industry, including the Internet as a means of communication, through which we access the World Wide Web. In everyday life, those actions that only a person could do are now done for us for a long time by machines, and what could be done independently has acquired an 'online icon' (online - paying bills, - ordering food, - shopping). For uninterrupted and correct functioning, it is necessary to increase the computing power of all devices, reducing the dimension and increasing their portability. The research firm predicts that by 2025 there will

be 55.7 billion internet-connected devices in the world by IDC. The need for high speed will be needed by everyone, therefore, competition for this resource will increase.

This is an entire ecosystem that contains smart devices equipped with sensors (sensors) that provide remote control, storage, transmission and data security. The Internet of Things is an innovative solution in various areas such as healthcare, insurance, labor protection, logistics, ecology, etc. [5].

With the development of the Internet of Things, more and more items will be connected to the global network, thereby creating new opportunities in the field of security, analytics and management, opening up new and wider perspectives and improving the quality of life of the population [4].

The global history of the development of the Internet of things is based on the technologies that underlie it. The very concept of the Internet of things is very extensive, the possibilities are almost endless. The current trend is 5G-7G device technologies that provide minimal latency, lightning-fast data transfer rates. The main interest is explained by the fact that for the Internet of Things this is a very good acceleration and a very good environment in which any smart objects can interact (dialogue between devices - consumption and processing of a huge amount of information).

The new protocol is IP 6, which exponentially increases the ability to connect not only computers, not only mobile devices, but also things that we never even imagined before. The point is that, with almost any device, it will be possible to establish a direct and feedback connection using the TCP/IP 6 protocol. This is the Internet of Things. The Internet of Things, theoretically, allows absolutely all objects to communicate with each other. It allows not only making things and networks smart, but making smart practically everything, on the least - human interaction with the outside world [6].

Another problem associated with the Internet of things is cybercrime. Connecting anything and everything to the Internet opened up fabulous opportunities for cybercriminals.

With the growth of the Internet of Things market, smart device companies are striving to release products as quickly as possible in a quick marketing move, and less attention is paid to the development of adequate protection and security of devices. In this regard, many products today are not resistant to various vectors of malicious attacks, which has led to the occurrence of some of the most powerful cyberattacks [5].

IoT technology is reaching the productivity board, offering all sorts of cloud solutions of varying degrees of maturity. Cloud infrastructures are needed to receive the whole stream of data from devices. For this, there are special cloud tools IThub and eventhub that allow you to receive and store a very large amount of information with automatic scaling.

One of the leaders in this market is the AWS IoT service. In addition, AWS IoT has a comprehensive set of security capabilities that allow you to create proactive security policies and respond immediately to potential threats. And the integration of AWS IoT with artificial intelligence services enhances the intelligence of devices even when they are not connected to the Internet. Gartner analysts believe

that cloud computing will eventually lead to the concept of "everything as a service" [2].

II. RESEARCH METHODOLOGY

The first manifestation of the Internet of things was telemetry, next was developed Machine-to-Machine (M2M) technology that allowed collecting information from a much larger number and types of sensors, the first tools for managing these sensors and analyzing the data received, processing and applying to improve business processes.

The use of the Internet of things becomes ubiquitous if you imagine it as a system, it will consist of 4 parts;

- device (computers, sensors, devices that interact with the environment. The device collects data from the outside world and turns it into information or specific actions.

- communication (connection protocols and interaction of device networks)

- server (computing power), provides communication with the user through applications and programs.

- user (software).

With the advent of new standards and on the wave of modern technologies, Internet of things have moved from simple classical sensors into the category of digital communication components, which involve computing power that requires software, in particular, operating systems and some cloud technologies.

Windows 10 IoT is a product of the Windows 10 family that provides enterprise-grade performance, security, and manageability for the Internet of Things. It leverages the processes, ecosystem, and cloud connectivity of the Windows platform to enable organizations to build IoT systems with secure devices that can be quickly provisioned, easily managed, and seamlessly connected to a shared cloud system [7].

The concept of IoT plays a decisive role in the further development of the infocommunication industry. This is confirmed both by the position of the International Telecommunication Union (ITU) and the European Union on this issue, and by the inclusion of the Internet of Things in the list of breakthrough technologies in the United States, China and other countries. And although at the international level this concept is already acquiring the features of an established technology, active work is underway for it in the field of standardization of architecture, technical components, applications, but at the same time, there are just as many opinions about how exactly the Internet of things will be built [4].

The reference model of the Internet of things includes 7 levels:

1. The level of physical devices of sensors, which is essentially what is called "things" in the terminology of the Internet of things. (things - devices, intelligent boundary nodes of all types: sensors, actuators, controllers).

- sensors - form the interface of Internet of things devices. Their main purpose is to collect data from the environment (detectors) or transmit data to others (actuators) [8]. Today, with the help of sensors, it is possible to measure almost any physical parameters and situations that occur around us: these are acoustic noise, vibration, gas and

chemical components of the environment, magnetic field, humidity, temperature, radiation, navigation, positioning, optical and visual effects. Moreover, sensors make it possible to determine the psycho-emotional state of a person, the level of his fatigue or irritation [2].

- Actuators are a part of a machine that allows you to convert an electrical signal into physical actions. These actuators play a critical role as components of IoT networks [9].

2. The level of data collection from the device and the interaction of these things with each other (Internet gateways):

- connectors - data collection and automatic creation of an information model

- interface - classic data collection in tags - 450 + interfaces for collecting from various data sources

- OSIsoft Message Format (OMF) can be used to develop data collection applications on platforms and languages that are not supported by OSIsoft.

3. Vague computations (figuratively, there is a border between things and the upper level, where there are uniform rules that play a decisive role at the processing level for the interaction between the architecture and the device: data accumulation and abstraction).

Here, data is analyzed and transformed and transferred to the next level of storage;

- PI Connector Relay - a component that transmits data coming from various connectors to PI System.

- Connectors send a generalized view of the real-time assets and measurements they collect from data sources to the PI Connector Relay.

- PI Connector Relay creates elements and Event Frame in PI AF servers and PI Data Archive tags.

Pre-processing and analytics, once IoT data is digitized and aggregated, it will need to be processed to further reduce the amount of data before it gets to the data center or cloud. The edge device may perform some analytics as part of the preprocessing. Machine learning can be very helpful at this stage to provide feedback to the system and continuously improve the process without waiting for instructions from the enterprise data center or cloud [9].

4. The level of accumulation and storage of data;

- access to petabytes of data collected over decades
- from petabytes to exabytes
- saving data all the way: from the source to the archive
- thousands of values per second
- accuracy of initial data
- millions of tags

Storage levels [10]:

Block storage - Data is not stored in files, but in blocks, which speeds up input/output operations. It is more often used in networks such as SAN (Storage Attached Network). Suitable for high-performance computing, DBMS (Database

Management Systems), storage of large amounts of data, as development environments (Dev/Test).

File storage is used to store "cold" information that is not required for operational calculations. As a rule, NAS (Network Attached Storage) is built on file storages.

Object storage is focused on working with large unstructured data up to petabytes. Information is stored not as files, but as "objects" with a unique identifier and metadata. It is used in analytics, big data, machine learning, for storing "heavy" media files and backups, developing and operating applications in the cloud, and hosting websites.

The survey showed that the widest application of big data technologies was found in the telecommunications sector, as well as in engineering, insurance and finance [11].

5. The level of data processing, where single operations are performed (averaging, processing, calculations). Data processing tools:

PI Asset Framework (AF) - allows you to combine data with the parameters of their resources, determine the sequence of displaying resources and structure information, unify all hierarchies or relationship models, which is a quality tool and basis for further analysis and provision of information in a holistic context.

- structuring information
- data storage
- information integration
- information analysis
- providing access to information

PI Asset Analytics (InsightSuiteAE) - allows you to process data:

- calculation of values based on the attributes of the information model
- saving calculated values in tags
- generating event ranges based on attribute values
- calculations by schedule or by tag update
- cascading calculations

6. The level of applications with which the user interacts (report, analytics, control, reports, statistics, management).

Application component PI Notifications:

- continuous monitoring of data using predefined rules
- various triggering criteria
- various message delivery channels (E-mail, instant messages, local notifications, web services)
- confirmation and escalation

PI Vision Application Component:

- Import existing ProcessBook screens
- easy creation of new screens
- simple search for the same type of equipment
- comparison table of object model elements
- contextual navigation links

- library of graphic elements
- support for mobile browsers

7. Integration level (the level of interaction with external systems, where the Internet of things is built into a higher level of collaboration and processes, i.e. the inclusion of people and business processes)

Data analytics (PI Integrators) - integration of operational data with advanced analytics platforms, relational databases or business intelligence tools to optimize reports, find new correlations, etc.

Data analytics (PI System Access) is a set of components that provides external applications with access to technological information using standard protocols OPC, ODBC, OLE DB, JDBC, and also provides developer tools (SDK).

The ability to quickly search and the availability of information increases the efficiency of users, allowing them to focus on solving current problems. Modern business is constantly changing and developing. To ensure effective user experience, the way information is presented must also evolve. PI AF allows you to organize and regroup individual resources to perform analysis and provide a more detailed view of data. Create a structure to organize data by applying templates and linking element attributes to data sources [12].

The IoT market was focused on B2C (business-to-consumer, "business to consumer"). In the field of the Internet of things, maximum acceleration, consumer solutions will become the maximum driver of the market: gadgets, automated equipment, smartphones (TVs, watches), smart home appliances, smart home. Wearable electronics are an important part of the Internet of things (fitness trackers, implanting a set of sensors into the body to monitor the body's activities in real time), which study and control a person's vital signs.

Industrial segment: smart cities (farm), trade, unmanned vehicles, mechanical engineering and factories. Industrial IoT, thanks to which there will be a transition to fully automated digital production using cyber-physical systems and cloud computing. Smart devices will manage the processes online. Industrial IoT implies the use of the Internet of things at the production level, the implementation and optimization of business processes. It is this area that will occupy most of the Internet of things.

The future of the Internet of Things depends on the ability to remotely orchestrate and program vast, typologically complex networks of devices. When devices are connected to public and private clouds that take readings from sensors and control actuators, there will be a shift in focus from collecting and analyzing data to developing applications for complex systems. As a result, it will be possible to control objects around us and anywhere in the world using programming environments and ready-made applications.

Software development for the Internet of things is characterized by:

1. Individual IoT devices are almost always part of a larger system of interconnected devices.
2. The IoT system can never be idle, it cannot be completely turned off (devices can be turned off

individually). The system as a whole must be resistant to interruptions in the operation of individual parts or the network.

3. In the Internet of Things system, the number of computing modules is much larger than in traditional computing environments.

4. IoT devices are often embedded in the environment, they remain invisible and physically inaccessible.

5. Internet of Things systems are characterized by a high degree of heterogeneity, their computing modules can vary greatly: in terms of power, storage capacity, network bandwidth, energy costs.

III. RESULTS AND DISCUSSION

The philosophy of the Internet of things is to quickly and relatively cheaply collect data from different sources, compare, store and quickly solve emerging problems.

A relatively new standard, created specifically to work in networks where there is an active interaction of the Internet of Things. Using 6LowPAN reduces the number of bits required to write an IPv6 address from 128 to 64. This can be very useful in saving space if the 51-bit range is somehow occupied. 6LowPAN also provides various degrees of IP header compression - up to 50%, which has a positive effect on network load [13].

Automation is moving into a new qualitative format, taking into account new realities, building a new interactive world.

A special case of the Internet of things is a smart apartment - automation of routine processes (robot vacuum cleaner), - smart home (intrusion protection - video cameras control - electricity / water supply, ventilation, fire safety).

The next stage of development is a smart city - a complex interconnected system of communications and information technologies that makes it easier to manage the internal processes of the city and improve the quality of life of the population. Such a system will help solve a huge number of city problems (traffic jams, communication between residents and administration).

The highest level of the Internet of things of development is a smart planet (ideal planet), when the whole world is united into one network, using the example of the ordinary Internet.

For example, the Chinese vision of our planet in the next 30 years boils down to the fact that neuro-sensory sensors will be implanted everywhere in the body of the planet: in the seas, fields, oceans, forests, rivers, in artesian drinking water sources - in any other point where it is necessary capture and monitor information. They want to track all natural processes, primarily negative and destructive ones: earthquakes, tsunamis, hurricanes, etc. which we fear, but do not know exactly when to expect. It will be possible to control and monitor data for a specific region in real time on a regular mobile device connected to the Internet [14].

NASA, together with CISCO, is creating a system for global data collection about the Earth called Planetary Skin. Skin of the Planet is a platform for global environmental monitoring. The project uses a satellite network, unmanned aircraft and ground facilities to control the earth's resources

and collect comprehensive information, create competitive products and services for the global market in the field of Internet of Things and wireless communications technologies, primarily next-generation cellular communications (5G and 6G), industrial internet of things (IIoT) and industrial data processing [2].

Japan has built the most environmentally friendly city in the world. All houses in it use solar energy, water consumption is reduced by 30%. More than 30 percent of Fujisawa's electricity will come from alternative renewable sources, primarily solar panels [15].

Snohetta's zero-energy pilot house in Norway - producing twice as much energy as it consumes - was recently built in Norway. The applied design, engineering and technological solutions made it possible to certify the building as "active", that is, it produces more energy than it consumes. But the main achievement of the project, of course, can be considered that the authors clearly demonstrated the possibility of coexistence of modern environmental standards and technologies with good architecture and natural materials [16].

With the development of the Internet of Things, more and more items will be connected to the global network, thereby creating new opportunities in the field of security, analytics and management, opening up new and wider perspectives and improving the quality of life of the population. It is assumed that in the future "things" will become active participants in business, information and social processes, where they will be able to interact and communicate with each other, exchanging information about the environment, reacting and influencing the processes taking place in the surrounding world, without human intervention [4].

In addition to the rapid growth in the number of devices and gadgets with access to the network, the benefits from the introduction of IIoT technologies will also be significant - up to 11 trillion dollars by 2025. It is planned that in the next few years NB-IIoT coverage will be provided to all major cities [2].

The Internet of things exchanges various information among themselves, enriches itself and our ideas about objective reality become complete. At the global level, the Internet of Things is a reduction in energy costs, with the help of sensors and Internet modules, you can do almost everything from wastebaskets that signal their fullness to mobile points of city Wi-Fi. The Internet of Things solves the problem of collecting data and making decisions:

1. IIoT - solutions help businesses to actively develop, solve specific problems, and reduce costs.
2. IIoT - technologies increase process automation, transparency of operations and management efficiency.

IV. CONCLUSION

The generation of ideas of the Internet of Things is becoming more and more, which gives not only an impetus to technical development, but also an evolutionary breakthrough of man as a species from a reasonable man to a technological man.

On the threshold of the digital revolution, a large number of digital transformation programs are being created in almost all sectors of our lives.

The main features of the Internet of things:

- Firstly, the constant accompaniment of human actions
- Secondly, the person himself indicates what he needs, and not how to do it
- Thirdly, connected devices make it possible to collect a huge amount of data and analyze (optimally use resources (heat, water, light, atomic ordering of products)).

Certain technological shifts and acceleration of the Internet of Things process are identified. The point is to promote not just connecting to the cloud, as is customary now, but the distribution of computing communications between devices. We get not just sensors that react, but constitute a set of standard communicative things or a set of tools that allow you to automatically determine (communication channels, shako codes), build the chain and logic of devices that will make it valuable for a person.

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An innovative neuronal model for autonomous robot navigation

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Abstract—There are many research activities in the field of mobile robotics, particularly on its perception and interaction with the surrounding environment. However, most current researchers focus their efforts on statistical approaches or Artificial Neural Networks. Still, a fair number of researchers tend to integrate, in this context, deterministic models or models based on cerebral neurophysiology, in particular on the activities of the hippocampus. Identifying neurophysiological patterns provides rapid fusions of sensory inputs and ensures flexible, robust and deterministic solutions. This paper presents a modular architecture for the automatic navigation of a mobile robot in an unknown environment. Navigation is supported by diversified sensory systems from which to acquire the data and on which to activate the neurological network for supporting navigation in not known environments. Based on the Single Trial Learning network, it is a neurological network architecture that can learn, in a single solution, the objects present in the surrounding environment. Furthermore, the use of the appropriate neuronal connections and the mechanisms that regulate the channels in the hippocampus guarantee a rapid configuration of the network following the type of input processing observed experimentally at the cellular level.

Index Terms—Neuromorphic computing, Explainable Artificial Intelligence, XAI, robot navigations

I. INTRODUCTION

The Robot navigation task has been widely explored and studied [1]. However, because of the fast progresses achieved by Deep Learning and in particular by Deep Reinforcement Learning [2] (since now DRL) in the field of Artificial Intelligence (since now AI), strategies based on DRL have been more and more adopted in the field of robot navigation and exploration [3]–[6]. The idea behind DRL approaches is to combine the structure of classical Neural Networks with a learning rule based on a score function [1]. Most of the time the analysis of image-like data structure is performed using a Convolutional Neural Network (since now CNN) [6], in

contrast the study of sparse or highly discretized information is performed through Fully Connected layers [5]. The last year's significant breakthrough is how such networks are trained. The idea is to make the robot trial and error assigning a score to every action taken during the run. Then, the function of weights tunes weights to maximize the score during the whole run (often called reward). This is the crucial key of DRL, in fact the weights update function reinforces the high score behaviours while discourage low score behaviours.

Unfortunately recent studies [7] have shown that the most common Deep CNN used for image segmentation and object detection are vulnerable to Adversarial Noise [8]. The key idea is to generate and add a small perturbation (called Adversarial Noise) to the input of the CNN to deviate significantly its output. In literature [9] are present examples in which the Adversarial Noise is hard to detect with bare eyes, however it is sufficient to fool CNN classifiers. As pointed out in [8], this constitutes a severe vulnerability for all the systems based on Deep Learning techniques, a vulnerability that up to now has not been fully mitigated yet [9]. Adversarial noise is a very small perturbation in comparison to the input data [7], a perturbation so small that could be easily caused by low visibility or system failures, and such not intentional perturbations could lead to an unexpected behaviour of vehicles and robots driven by such AI, leading to accidents.

However, at the current state of the art, if any accident occurs there is no way to debug a Deep Neural Network. Then, the only choice is to retrain the network with the data that caused the accident, hoping that no new similar situation will occur in future. This has led to a growing interest in Explainable Artificial Intelligence [10] (since now XAI). A XAI is an algorithm that is based on rules that are easy to understand and easy to debug. Such methods are becoming increasingly popular in critical applications [11] because of the ethical and legislative issues caused by using a *not* explainable AI. In the robotic field a step in this direction has been done in [12]. In this paper has been presented a novel algorithm that can to remember a path using a Neuronal Network that is fully automatic and explainable at the same time. The algorithm proposed in [12] has been developed inside the Neuro Robotics Platform created by Human Brain Project, which is a simulator. Then this contribution aims to improve

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the real-world capability of the algorithm.

In doing this will be taken in account a simple autonomous exploration task. The task is to begin exploration from a given starting point and then explore all the buildings until the robot finds a particular object. Once the robot has found the given object it returns to the starting point. In the next run the robot will remember the shortest path to reach the given object. This task is equivalent to a rescue task like the one performed in the RoboCup Rescue competition [13], where the aim is to explore the building to find victims and other objects of interest [14].

To achieve these results, the article is organized as follows. First, section II illustrates the real world scenario in robot navigation. Then, software architecture, robotic platform and the results were presented in section III. Finally, Section IV presents conclusions on the experimentation task.

II. MATERIAL AND METHODS

A. Real-world scenario

Real-world robot navigation is the task of making a robot able to navigate in a scenario with all the characteristics of the real-world [6]. In brief, three main characteristics make a scenario real-world:

- 1) The setting of experimentation has no particular conventions that we could not find in an every day life situation and it is a physical location in real-world (e.g. the setting of [15] will not be considered real-world)
- 2) The robot is not alone during navigation, and this means that it must be continuously aware of what is happening around itself (e.g. the setting of [6] will not be considered as real-world)
- 3) The scenario is not static but dynamic (e.g. again the case of [6])

This definition of real-world has been taken to make the setting as close as possible to a real life setting.

B. The robot

The robot used in the experiments is a small size tank robot derived from [16]. This robot is equipped with a frontal depth camera on a 2-degree of freedom (yaw and rotation) mount, a 360 degrees lidar, a compass, and three infrared proximity sensors. All the components are connected to a Jetson Xavier installed on board the robot.

The robot has been designed to be an all-on-board robot. Indeed, it does not require additional connections to work. This prominent feature is a current trend in RoboCup [13] and rescue operations, because the robot must continue its task even if it loses the remote connection with the operator. Furthermore, the moving camera shows to be a helpful feature during tests (in contrast to the fixed camera mount at the centre the robot of [6]). In the case of the fixed camera, the robot cannot see on its sides because the camera is static. Therefore, the robot to look at its sides must move all the robot using motors, resulting in significant limitations in terms of efficiency and drive smoothness, because the robot in order to look for an object must continuously steer. Furthermore, in contrast to the proposed robot architecture [16], the camera has

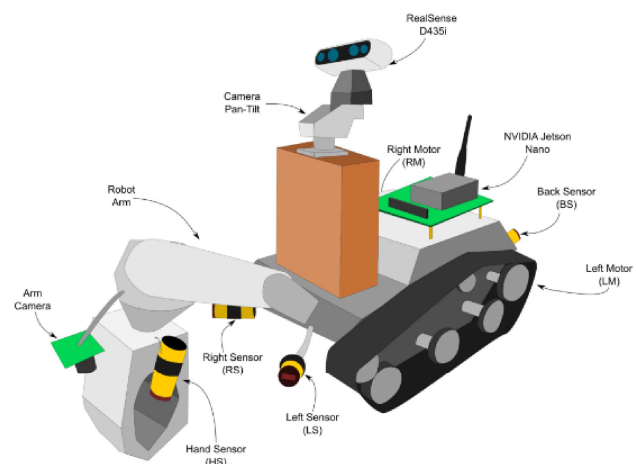


Fig. 1. Schematics of the robot in [16].

a tilt/pan mount that can make camera to rotate horizontally and vertically. Such simple modification results in an higher point of view that creates a better perspective, which is fundamental for Computer Vision techniques. At the same time, the vertical angle below the horizon focuses on the floor. In contrast, when the vertical angle is high the robot can see a whole human from a short distance, giving the robot a wide range of view. Moreover, the horizontal rotation of the camera make possible to turn safely and rapidly the camera from side to side, without any robot movement required.

The proposed architecture uses a depth camera in tandem with a 360° lidar, but many robots [3] are equipped just with the 360° lidar. However, it has turned out that such lidar scans a very thin region of space (the region crossed by lidar laser), making the interpretation of complex 3D objects difficult. For this reason a depth camera has been also used, that is a normal RGB camera that also returns the depth of each pixel (since now such information will be indicated with the notation RGB-D). The great advantage of RGB-D data is to combine Computer Vision approaches with distance based techniques without no particular merging technique, being the information structured yet. This reduces the amount of Deep Learning required in data processing, because the robot does not have to infer information with complex algorithms but to measure it. Using an RGB-D image is also possible to detect an object using classic (then explainable) CV object detection techniques and estimate its distance using its D channel, or again detect walls, surfaces and obstacles. However, the depth camera acquisition is more focused on the front of the robot, then to give to the robot a 360 degree perception, it has been equipped with a 360 degree lidar.

C. Software Architecture

The key ideas behind the robot are the concept of modularity and distributed calculus, while keeping the robot functionality all on board. These two perspectives can seem not compatible,

however this has been achieved through cable connections (LAN) and a modular multiprocessing approach. The proposed architecture is based on two main classes of processes:

- 1) The critical processes: they are processes that are critical for the robot's functionality and then must be executed as fast as possible. Most of them are processes that manage the input from the sensors or control the motion outputs of the robot.
- 2) The not critical processes: they are responsible for the robot's computational analysis and constitute the core of the robot AI. In addition, they are responsible for interpreting the stream of data incoming from sensors and acting accordingly to such information.

Such distributed calculus has been achieved using a simple but powerful and flexible file based transmission protocol, which allows performing multiple routines on different machines. Such routines can be even written in different programming languages.

D. The exploration task

Autonomous exploration is the action performed by a robot when it explores a new environment looking for the exit without any clue or map provided a priori. An example is depicted in figure 2. The idea is to make the robot start from a fixed point for the first time with no a priori information (learning phase). In this test environment the robot randomly exploring will find the exit. However, while the robot navigates, it will remember some key objects. In simulation [12] the key objects are characterized by a specific colour (as can be seen in figure 2). To improve real-world capability, the proposed robot is able to remember a generic object with no particular colour through a Computer Vision based approach. Once the robot has detected an object it will remember its heading direction for the next runs. In the next run (recall phase) the robot remembers the objects encountered in the learning phase and uses them to take the most direct way possible to the exit. This task is solved using a Neuronal Network [12] that using the information apprehended in the learning phase, optimizes the path to the exit. This network is based on the concept of synaptic plasticity [17] that is a simple physiological inspired rule able to train the neuronal network. The most interesting part is that even if the training procedure is fully automatic, the weights of the network can be interpreted in a simple way, because the network is composed by few neurons characterized by a specific function inside the network. For this reason the behaviour of the proposed network is easy to understand and then debug. This approach has been successfully tested in a simulated settings, but we are still working to apply this approach in real-world environments, with some partial achievements.

III. RESULTS

A. Robot navigation in crowded environments

During the autonomous exploration experiments, the robot navigated autonomously through the corridors of the Institute of Biophysics (figure 3) during normal working activities. This



Fig. 2. Autonomous exploration task implemented in Human Brain Project Neuro Robotic Platform [12]

means that all our colleagues (not directly involved in the project) shared the corridors with the robot. The results were a long test of 100+ hours of navigation without any accidents involving the pedestrian in the corridors. Furthermore, the robot has changed multiple locations inside the building showing good generalization ability and a specific grade of coexistence capability with humans.



Fig. 3. Autonomous exploration task in the building of Institute of Biophysics (National Research Council).

B. Robot autonomous exploration in Real-world environments

The robot in the tests has explored the H-shaped corridors of the Institute of Biophysics, performing an autonomous

exploration of the environment. The Neuronal Network used is derived from [12] and uses the crossing between the corridors as colors. In his first run, the robot explores all of the environments (finding the endpoint) and finds the optimal path in this single run. This first run is called *learning run*. In each subsequent, the robot will go directly to the goal taking the shortest path explored. The subsequent runs are called *recall* runs, because the robot recalls the path learnt in the first and unique run. It has to be noted that, as pointed out in [12] in most of the Deep Learning approaches (and this is also the case of DRL) are required hundreds (or in some cases thousands) of iterations to learn a sequence.

IV. DISCUSSION

The main aim of the contribution is to create a real-world robot able to explore autonomously large buildings. But, an other important aim is to show alternatives to the Deep Learning in critical tasks like autonomous exploration and driving. In fact, autonomous robots and self driving cars are more and more diffused, and then all threats are connected to possible wrong choices taken by these algorithms [8]. For these reasons we have proposed a working algorithm fully based on deterministic and explainable techniques able to tackle real-world, focusing on the redundancy of robot hardware. On the other hand, the neuronal network proposed in [12] has shown to outperform currently available Deep Learning approaches in terms of steps required for the training, enabling the proposed robot to remember the path in just one learning run.

In conclusion, the proposed robot opens a new way for autonomous navigation but also for medicine and neuroscience.

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Gaze-Based Biometrics: Some Recent Research

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Abstract—Gaze-based biometrics analyzes the ocular behavior of individuals to obtain information about their identity or distinctive features. In recent years, studies in this field have grown considerably, also thanks to the availability of low-cost eye trackers. After a presentation of the essential characteristics of biometric techniques based on eye tracking, the paper provides a short overview of this research area, especially focusing on some projects recently developed at the University of Pavia.

Index Terms—soft biometrics, gaze-based biometrics, gaze analysis, eye tracking

I. INTRODUCTION

Eye tracking technology [1] is used to identify what a person is viewing, for example on a screen. Through eye tracking, eye movements and features can be recognized and quantified. In addition to gaze direction, further information can be typically acquired, such as pupil size, blinks, proximity to the eye tracking device, etc. Gaze sampling frequencies range from few tens to even thousands of Hertz—very high frequencies are typically useful for medical and psychological research.

Eye tracking technology has advanced significantly over the last years and eye trackers are now far more affordable than in the past. Their use can therefore potentially become common in many contexts, including biometrics.

Eye tracking techniques are almost always unable to conclusively link a subject with specific eye behaviors, but can instead provide a likelihood that specific traits match a particular person's profile: in essence, gaze-based biometrics is *soft biometrics* [2]. When paired with conventional authentication methods, soft biometrics can boost security while relieving the user of having to remember additional PINs or passwords. These methods have also the benefit of being usable by people wearing a mask, which would make conventional facial recognition solutions challenging.

This paper, after introducing the basics of biometrics and eye tracking, provides a brief outline of the area of gaze-based biometrics. Some representative works are presented, especially focusing on recent studies carried out at the University of Pavia.

II. BASICS OF BIOMETRICS

Biometrics refers to the analysis of human characteristics to identify individuals or groups of individuals. In particular, biometric features can be *behavioral* (such as gait and eye movements) or *physiological* (such as iris and fingerprints) [3]. Individuals often acquire distinctive habits depending on

their experiences in culture, society, and psychology [4]. Since behavioral biometrics cannot be as exact as its physiological equivalent, it is normally considered soft biometrics. This implies that it must be used as an extra biometric technique, in addition to other identity verification methods. On the other hand, behavioral biometrics can often be employed touchlessly and with less expensive equipment.

The two standard biometric procedures are *identification* and *verification*. Identification is the process of looking for a person who matches a biometric sample, while verification (or *authentication*) means confirming a person's claimed identity. Identification is a one-to-many classification problem, whereas verification is a one-to-one classification task.

Accuracy, *sensitivity*, *specificity*, and *precision* are four metrics frequently used to assess the performance of a biometric system [5]. Using the term *recognition* to refer to the process of identifying or verifying a subject, and indicating with TP (True Positives) the number of correctly recognized subjects, with FP (False Positives) the number of wrongly recognized subjects, with TN (True Negatives) the number of correctly recognized impostors, and with FN (False Negatives) the number of wrongly recognized impostors, a biometric system's accuracy is calculated as $(TP+TN)/(TP+TN+FP+FN)$. Sensitivity is computed as $TP/(TP+FN)$ and represents the system's capability to identify the correct person. Specificity, which is measured as $TN/(TN+FP)$, is the capability to identify impostors. Lastly, precision is the capability to be "picky" in identifying the appropriate subject and is calculated as $TP/(TP+FP)$.

The *Equal Error Rate (EER)* is often used as well, which is the error rate corresponding to the point at which the *False Acceptance Rate (FAR)* and the *False Rejection Rate (FRR)* cross—where $FAR = FP/(FP+TN)$ and $FRR = FN/(FN+TP)$.

Another possible metric is the *Area Under Curve (AUC)*, defined as the area under the *Receiver Operating Characteristic (ROC)* curve, a graphical representation with FAR on the x axis and Sensitivity on the y axis.

III. EYE TRACKING

Eye movements take the form of extremely rapid *saccades* (typically lasting less than 100 ms) that alternate with *fixations* (normally lasting from 100 to 600 ms and characterized by relatively stable eyes).

Electro-oculography, scleral contact lenses/search coils, photo-oculography (POG), video-oculography (VOG), and pupil/corneal reflection are the eye-tracking techniques that have been developed over time [1]. This last option, undoubtedly the most popular nowadays, uses pupil and corneal reflections caused by infrared or near-infrared light sources to determine gaze locations and can work consistently under various lighting conditions. Although visual stimuli are almost always shown on a screen, any visual scene in front of the user can in principle be taken into account.

Both *remote* and *wearable* eye trackers are available. Remote eye trackers, typically little “bars” placed at the bottom of regular displays, are the cheapest and the most exploited in biometrics.

IV. OVERVIEW OF GAZE-BASED BIOMETRICS RESEARCH

By using a point bouncing on the screen as a stimulus, in 2004 Kasprowski and Ober [6] proposed what can probably be considered the first research on user identification by eye behavior analysis. A comparison between keystrokes and some gaze traits observed in individuals while reading and typing was then suggested by Silver and Biggs [7] a little later. In this section, we present a brief overview of the research conducted until now in the field of gaze-based biometrics. We mainly focus on the techniques and visual stimuli used, including only some references to representative works from the literature. We omit the papers in which the University of Pavia is involved, as they are presented in the next section.

We start by considering static stimuli. Numerous gaze characteristics were exploited by Holland and Komogortsev in 2011 by analyzing people reading text [8]. In 2013, the same authors applied the two-sample Cramér-von Mises test and the Random Forest classifier in a related experiment utilizing a 1000 Hz eye tracker, yielding an EER of 16.5 percent and a rank-1 accuracy for identification of 82.6 percent [9]. By employing face images as stimuli and a graph matching approach, Rigas et al. [10], in 2012, were able to identify 15 people with an accuracy between 67 and 70 percent. In 2016, George and Routray [11] used a Gaussian Radial Basis Function Network, with several eye characteristics and text as a static stimulus. The dataset was obtained in extremely ideal conditions (a controlled laboratory with a 1000 Hz eye tracker and chin rest), which certainly played a role in the very high identification accuracy achieved by the method (more than 93 percent). In a study of 2018, Li et al. [12] took advantage of both eye movement trajectories and texture characteristics; participants had to select the correct response from a succession of questions and an authentication EER of 7.16 percent and a rank-1 identification accuracy of 81.2 percent were achieved. Still in 2018, a non-parametric statistical model was developed by Mukhopadhyay and Nandi [13]; with the dataset acquired, obtained from viewers of photographs using a 1000 Hz eye tracker, the approach produced an 81.5 percent identification accuracy. In order to study the issue of continuous authentication, in 2019 Ebertz et al. [14] used three typical stimuli (reading text, browsing the Web, and viewing

an image slideshow) and achieved EER values of 3.93 percent without calibration and 1.88 with calibration.

As regards dynamic stimuli, a video served as a stimulus for a research on task-independent authentication carried out by Kinnunen et al. in 2010 [15]; gaze coordinates were analyzed with a Gaussian Mixture Model, producing a best EER of 29.8 percent. In 2012, Cuong et al. [16] employed a Support Vector Machine classifier to identify gaze parameters using the Mel-Frequency Cepstral Coefficients; using a moving point as a visual stimulus, the recognition accuracy ranged from 91.08 to 93.56 percent. Still in 2012, the Wald-Wolfowitz test was used by Rigas et al. [17] to examine the distribution of velocity, acceleration, and other eye movement characteristics using a leaping point stimulus, with identification accuracies between 82 and 91.5 percent. A research carried out by Juhola et al. [18] in 2013 analyzed saccades and used a dot traveling along a black bar as stimulus, achieving a 93 percent accuracy. In 2015, using eye velocity, eye location, and size variations, Srivastava et al. [19] achieved a recognition accuracy of 91 percent utilizing a jumping point as a stimulus. Participants in a 2017 study by Lyamin and Cherepovskaya [20] were asked to follow a few lines displayed (in turn) on a screen, using the paired comparison technique and Naive Bayes for categorization; the EER attained ranged from 15.44 to 16.18 percent. In 2018, Sluganovic et al. [21] concentrated on reflexive saccades brought on by a red dot that appeared on a black screen and repeatedly changed its position; an EER of 6.3 percent was obtained.

V. SOME GAZE-BASED BIOMETRICS PROJECTS DEVELOPED AT THE UNIVERSITY OF PAVIA

In this section we present, in chronological order, a few gaze-based biometrics projects carried out at the University of Pavia in relatively recent years.

A. Pupil Size Analysis

The study [22] looked at the potential for employing pupil size as an exclusive biometric trait, involving twenty-five volunteer participants chosen among university students. The research was carried out over the course of two sessions in two consecutive years. Participants' ages ranged from 21 to 70 (18 males and 7 females). Every participant showed up for a minimum of three experiments, spread out across intervals of two days to a week over the same year.

A Tobii 1750 eye tracker (50 Hz sampling rate) was used. The participants' task was just to fixate a plus sign (78x78 pixels) shown for three seconds in the center of a white screen (Fig. 1). The plus sign was displayed 18 times, interleaved with some pictures shown for ten seconds each—the stimulus was actually part of the experiments carried out for the study illustrated in Section V-B.

Fifteen descriptive statistics (minimum, maximum, mean, standard deviation, variance, median, median deviation, geometric mean, harmonic mean, inter-quartile range, first quartile, third quartile, kurtosis, range, and skewness) were calculated for each of the four primary features, namely left and

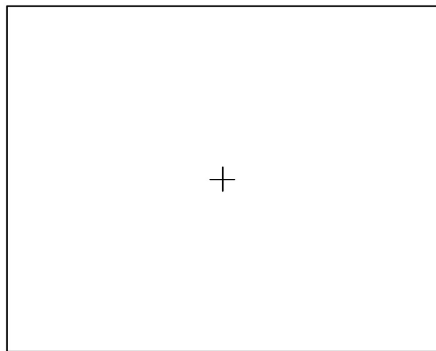


Fig. 1. Plus sign stimulus

right pupil size and ratio and difference between left and right pupil sizes. Two other statistical measures were also taken into account: the correlation between left and right pupil sizes and the sum of squares of differences between left and right pupil sizes.

Analyses were carried out for both identification and verification. The Naive Bayes, Neural Network (NN), Support Vector Machine (SVM), and Random Forest (RF) classifiers were used to perform the classification tasks. Training and testing data were made up of 70 percent and 30 percent of the total data, respectively. The average value of stratified random data repeated 10 times served as the categorization outcome.

Regarding identification, while the SVM classifier performed best (0.7187) using a selection of 29 feature (chosen using the SVM weight approach), the NN classifier achieved the greatest accuracy (0.708) with all the 62 features. As for verification, the NN classifier exhibited the best accuracy (0.9773) using all 62 features.

Despite the relatively small number of testers who participated in the trials, the results showed that pupil diameter alone can deliver accurate outcomes for both identification and verification. However, the very high accuracy in verification was obtained by randomly splitting the whole dataset into training and test sets (instead of considering separate sessions for the two sets) and with a complete re-training of the whole dataset for each participant (that would be impracticable with many subjects). These are certainly two limitations of the study, which, nonetheless, has on its side the fact that it is one of the first on the subject.

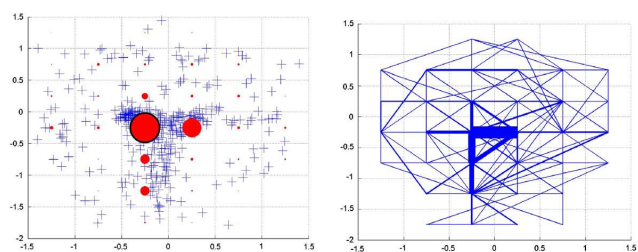
B. Free Observation of Face Pictures

This research [23] explored eye activities to test the hypothesis that a person can be characterized by the way he or she observes an image (specifically, a face photo).

The Tobii 1750 remote eye tracker was used to collect the data, using 16 images of human faces as experimental stimuli. Every face was divided into 17 Regions Of Interest (ROIs). All of a specific participant's observations (fixation sequences while gazing at each of the face stimuli) were combined together. Since a particular ROI (e.g., the right or left eye and mouth) could be positioned in somewhat different locations in

distinct face photos, and the sizes of faces varied slightly, a normalizing step was necessary.

The goal of this work was also to develop a completely automated gaze analysis system that can track which facial features an observer tends to stare at, also detecting for how long and in what order. Fixation points were used to create a graph whose arc weights are directly related to the density of fixations, the amount of time spent in a particular ROI, and the observation path. Since the fixation cloud had a large number of points, they were first aggregated into fewer nodes: the cloud was split into a 7x6 grid, with a node centered in each cell (Fig. 2). Weights were assigned to each node based on *Density* (the total number of fixations in the cell) and *Duration* (the total amount of fixations in the cell, measured in milliseconds).

Fig. 2. Examples of *density graph* (left) and *weighted arcs graph* (right)

The weights for the the graph's arcs were calculated considering that 16 different observations were merged together: for each face picture, every time an observer's gaze shifted from a node A to a node B and vice versa, the weight of an arc connecting them was increased. Two 7x6 matrices, one for densities and one for durations, with each cell corresponding to a node, were used to define the weights, and a 42x42 adjacency matrix was employed to represent weighted arcs. In order to compare observers based on densities, durations, and arcs, the distance between pairs of matrices of the same feature was calculated using the Frobenius norm of the matrices' difference.

The trials involved 112 volunteer observers, 73 males and 39 females, aged between 17 and 80. Face images were interleaved with blank white screens (displayed for three seconds) with a small plus sign at their center, to ensure a common starting location for stimulus exploration. Participants were instructed to look at the cross when the blank screen was displayed and to freely watch wherever they wanted when the images were presented. Each face picture was shown for 10 seconds.

The experiments used sixteen black-and-white images with close-up portraits of eight men and eight women, randomly presented. Eighty eight subjects took part in a first set S_1 of trials. One year after S_1 , a second round of tests S_2 was conducted involving 34 subjects (ten of whom had already participated in S_1). For both S_1 and S_2 , three distinct sessions (in which the same subjects repeated the test) were organized.

The results for verification were overall satisfying, with a minimum EER of 0.2719 and a maximum AUC of 0.7932. The quality of identification was expressed through the *Cumulative Match Curve (CMC)*, which evaluates the ranking capability of an identification system (like a verification system's ROC curve reflects the quality of a 1-to-1 matching system) [24]. The highest CMC value obtained was 0.3043.

This study is particularly important due to the large number of testers involved, with experiments repeated after one year. Furthermore, the ocular behavioral analysis techniques employed are also relatively new.

C. PIN Entry with Biometric Analysis

The study [25] explored the combination of gaze biometric data with the very traditional authentication method of entering a PIN. Through a virtual keypad presented on a screen, the PIN is "typed" through the gaze: the idea is to use eye tracking data as a further verification mechanism. For instance, the PIN could have been stolen, and if the system notices that it is entered differently than usually, it may demand additional verification.

Forty five volunteer testers (36 males and 9 females, 39 students under the age of 30) were asked to enter four randomly generated 6-digit PINs (dictated by the test conductor) using the on-screen keypad shown in Fig. 3.

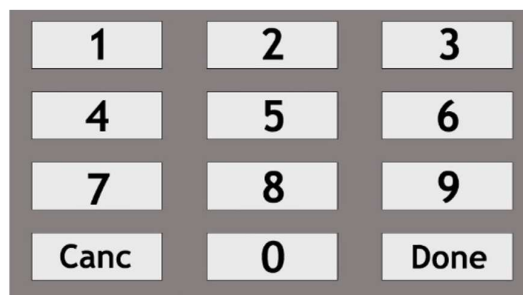


Fig. 3. On-screen keypad

A key was "pressed" by staring at it for two seconds, after which an acoustic signal was also played. This *dwell time* is an acceptable balance between efficiency and user comfort, especially for those who have never used gaze input before. The *Done* key was used to confirm the PIN, and, in case of mistakes, the last digit could be deleted through the *Canc* key. As an eye tracker, we used the *Eye Tribe* (30 Hz), one of the most affordable devices available till the end of 2016.

Six categories of features were used to characterize the participants: Fixations, Pupil Size, Lost Gaze Samples, Saccades, User Behavior, and Physiological. For each of them, several statistics were calculated. Four classifiers—Naive Bayes, Random Forest, Neural Network, and AdaBoost—were used, with 70 percent of (randomly selected) data exploited for training and 30 percent for testing (with ten times repetition). The investigation was carried out using both all the 42 features and a selection of them (obtained with the *gain ratio* method).

Moreover, both aggregated data for the full 6-digit PIN and the data for the single keys were used.

The best accuracy for identification was 0.82 (with Neural Network) for the whole PIN and 0.89 (again with Neural Network) for the single key. Regarding verification, the best accuracy was 0.88 (with Naive Bayes) for the whole PIN and 0.95 (with Random Forest) for the single key.

When compared to the entire PIN analysis, the single key analysis performed somewhat better (about +5 percent in classification accuracy). Selected features resulted in a slightly increased accuracy. In general, Naive Bayes performed worse than Neural Network and Random Forest. AdaBoost had a less consistent behavior, occasionally outperforming Random Forest and Neural Network but providing worse results in other cases.

D. Free Observation of Different Kinds of Images

This research [26] studied the potential of exploiting gaze data extracted while a subject freely observes different kinds of photos for identification and verification purposes.

The experiments (carried out in three sessions) involved 40 volunteer participants, 32 males and 8 females, ranging in age from 21 to 65. Eye data were captured using a 30 Hz *Eye Tribe* eye tracker. Participants were instructed to freely look at a series of pictures that would show up on the screen (interleaved with a grey screen with a little cross in the middle). Twenty gray-scale photos were used as stimuli, with five images in each of four categories (Generic Objects, Cars, Animals, and Scissors—representative pictures from each category are shown in Fig. 4). The 20 photos were presented in random order, for six seconds each. The blank screen with the cross between photos was shown for two seconds.



Fig. 4. Sample images used as stimuli

Pupil, gaze, and fixation features were exploited for the analysis, calculating several statistics for each of them. Data were analyzed both considering each test image as a whole and subdividing each picture into Areas Of Interest (AOIs). Each image category was assigned a different number of AOIs, with

each region containing distinctive components of the image's particular content. Naive Bayes, Neural Network, Random Forest, and AdaBoost were the four classifiers employed for the investigation. Stratified 10-fold cross-validation was used, including only subjects who took part in at least two of the three test sessions.

The best identification accuracy (0.85) was obtained with the Neural Network classifier and the subdivision into AOIs. The best verification accuracy (0.94) was achieved with the Random Forest classifier (still with the subdivision into AOIs).

Overall, the results can be considered very satisfying, especially because one of the purposes of the study was to experiment gaze-based biometrics "in the wild", without setting specific restrictions on the user and exploiting a very cheap eye tracker.

E. Free Observation of Moving Elements

The study [27] focused on gaze-based biometrics exploiting dynamic elements as stimuli, without any preliminary calibration of the eye tracker.

Four 15-second animations, each including one or more white squares moving on a black background, were employed (Fig. 5): Random Motion (a square moving along a non-predefined trajectory), Radial Motion (a square moving according to a linear and predictable pattern, radially), Spiral Motion (a square moving along a predictable non-linear trajectory, a spiral path), and Volcano Motion (multiple squares moving radially but randomly, from the center).

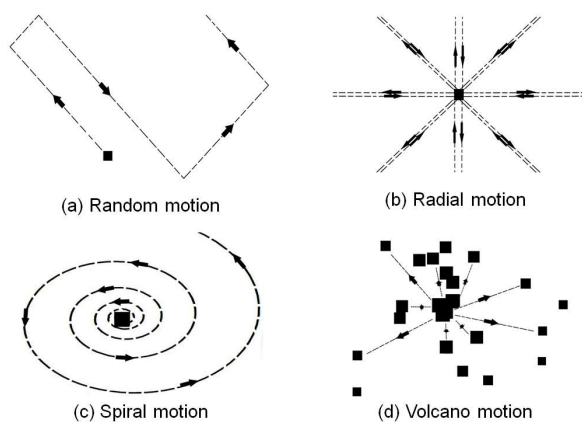


Fig. 5. Schematic representation of the four animations

The trials involved a total of 44 volunteer participants (30 males and 14 females, aged between 19 and 68), the majority of whom (35) were university students. Gaze data were acquired by means of a GazePoint GP3 HD eye tracker (150 Hz). Each subject took part in the experiment nine times throughout three sessions (in different days). The test was performed three times ("trials") in each session. The four animations were shown sequentially in random order throughout each trial. Additionally, each animation began with a 70x70 pixel white cross displayed in the middle of a black background.

Fixation and gaze sample data were used to build the dataset, from which 73 features were obtained. Each trial in each session produced four feature vectors (one for each animation), each consisting of 73 features for each participant.

Two types of analysis were taken into consideration for both identification and verification: one randomly splitting the entire dataset into training (80 percent) and test (20 percent) sets, and one utilizing training data from the first two sessions and testing data from the third session.

For identification, different classifiers and various preprocessing methods were tested. With random split, the best accuracy (0.7476) was achieved with Nu-Support Vector Machine; with session split, the best accuracy (0.5189) was obtained with Neural Network. This worse performance with session split might be attributed to the fact that the algorithms were trained on a reduced set of data (66.6 percent instead of 80 percent), as well as to potential inter-session variability. Although less satisfying, these results are unquestionably more realistic, because the division into sessions more closely mimics the actual use of a biometric system (in which user samples are initially collected and used for training).

As for verification, the best accuracy was 0.9091 with random split (Random Forest classifier) and 0.8560 with session split (Nu-Support Vector Machine classifier). With accuracy levels between 89 percent (random split) and 84 percent (session split), even when simulating external "intruders" (whose data were surely not used in constructing the user model), the results were very good. The four animations were also considered separately: with a maximum accuracy of 88.69 percent, Random motion with Random Forest produced the best results for random split, and Random motion also obtained the best overall performance (85.5 percent) with session split (Support Vector Machine). Moreover, in addition to the entire 15-second animations, the performance with shorter durations was also checked, obtaining an accuracy higher than 81 percent with only 5 seconds (Random motion, Support Vector Machine).

In the end, three main aspects of this study can be considered its main novel elements: the particular animations used (different from others available in the literature); the experimental conditions, which were more realistic than those taken into account by most state-of-the-art approaches (no calibration or user restraints were used); and the fact that this study is one of the few gaze-based biometrics investigations that use verification with clearly separated training and testing sessions throughout time. Overall, the results obtained can therefore be considered very satisfying.

VI. CONCLUSIONS

In this paper we have provided a brief overview of gaze-based biometric techniques, especially focusing on some relatively recent research carried out at the University of Pavia.

Eye trackers are now inexpensive, portable, and easy to use in a variety of application scenarios, and eye-based biometrics has the great benefit of allowing contactless interaction. Even though gaze-based approaches can only implement soft

biometrics (and thus cannot be used alone to find a univocal correlation between eye traits and a specific subject), they can considerably advance the area of biometrics when used in conjunction with conventional authentication techniques (such as those based on passwords or PINs). We believe that research in this field, which is currently still in a state of relative immaturity, should continue and be expanded, in order to discover its full potential.

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An intelligent sensors for measuring the angular displacement of the rotating mechanisms of agricultural robot-manipulators (for tomato-harvesting robot-manipulator).

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Abstract— The use of robots is of great importance in the development of digital farming, the elimination of existing problems in agriculture, their timely identification and timely notification, and continuous information about them. This paper presents an energy-efficient, intelligent robot project for tomato harvesting. The product harvested by the robot consists of red (ripe) tomatoes. The purpose of this study is to measure and control the angular displacement of the rotary mechanisms of the (energy-saving) robot-manipulators used in agriculture for the development of digital farming, to save energy and to harvest quality products. The novelty of this research is that various processes and images are placed in a special processor for processing, and this robot processes the image according to the size of the tomato plant and tomatoes and moves to harvest.

Keywords—*robots, digital farming, agricultural, energy-efficient, intelligent robot, angular displacement.*

I. INTRODUCTION (HEADING 1)

The development of digital farming will allow to find solutions to pressing problems in agriculture in the future. The rapid growth of the world's population imposes requirements to control the quality and quantity of all products [1]. Digitization or automatic control of farm and farm is a method that can be used in all areas of agriculture. That is, it is said to automate the processes from sowing the seeds to harvesting the ripened agricultural product. The data presented in the studied literature show that these robots are capable of harvesting tomatoes with good quality, and this robot vision proves that agricultural robots will achieve high efficiency in the future [2], [3], [4]. The use of robots allows for perfect agricultural design. Using agricultural robot-manipulators, it is possible to obtain continuous information about the specified area and analyze many problems encountered in farming. Many examples can be given as agricultural robot-manipulators. Drones allow for regular monitoring of fields and crop management [5]. It is advisable to use special agricultural machinery during harvesting. It is known that it is more convenient to use robot-hand manipulators for harvesting. Robotic hand-manipulators are also capable of harvesting. Because the hand part of the robot hand manipulators is designed to catch and collect various fruits[6], [7], [8], [9]. A special camera is needed to ensure

accuracy during harvesting and to perform the cutting operation accurately. As the dimensions of modern cameras are getting smaller, they do not put too much weight on robotic manipulators. It is recommended to install the camera on the monitor in two ways: by hand and inside the hand. That is, the camera is designed to be installed on the arm (itself) of the robot manipulator or anywhere on the robot. Both of these methods have their advantages and disadvantages. A camera installed anywhere (except for the hand) of robotic manipulators has a low ability to detect objects. If the camera is mounted on the arm, the camera has the ability to detect the object, but there is a high probability of getting stuck in the branches of the plant. The camera must process the image to distinguish the photographed object (product) from the background. This way, the robot arm knows which ones to pick and cut and which ones to ignore. For example, it is important to determine the location of fruits in relation to plants. To increase the reliability of the robot arm, it is recommended to use a distance sensor to determine the exact location of the product [10], [11], [12], [13], [14], [15], [16]. This article presents the project of using a robotic manipulator as a harvesting robot. It is equipped with an ATMEGA microcontroller as a controller for the base of servo motors to move the robot arm, a special "Raspberry Pi3" chip for image processing, a special camera for capturing object images, and a distance sensor for providing information. about the distance between the robot and the object. The purpose of this research is to increase the role of robots in agriculture and to develop a project for high-quality and safe harvesting of fruits and vegetables. The novelty of this study is that this method is simple and convenient for image processing and storage of captured images.

II. DESIGN OF ROBOT-MANIPULATOR

This section presents the design of a robot-manipulator that collects and collects tomato products. Figure 1 shows the functional diagram of the robot manipulator, Figure 2 shows the electrical diagram, and Figure 3 shows the 3D design of the robot arm manipulator. Figure 1 shows the components of the input and output processes. The camera takes a picture of the factory, sends the image to the Raspberry Pi3 and the PC. The distance sensor is designed to determine the distance

between the product and the device that collects it. In this project, a web camera and a distance sensor are installed on the arm part of the manipulator as an "eye" product picking device.

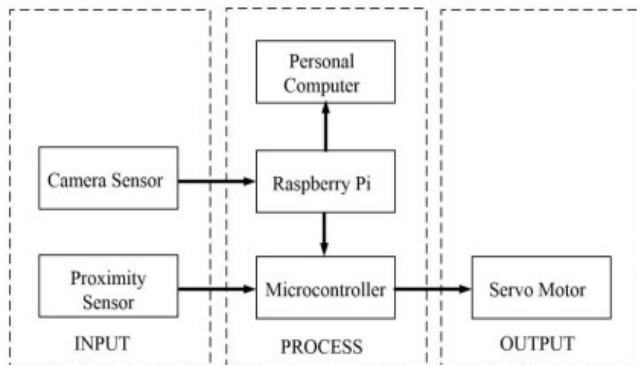


Fig1. Diagram block of the proposed method

The process in Figure 1 involves processing the raw image (detected output) from the camera on a PC. Sends the image to the Raspberry Pi3 for processing. A detected tomato product gives the number "1" in the binary cod system and sends it to the microcontroller. The "output" part (block diagram) in Figure 1 consists of servo motors that move the robotic manipulator's arm closer to the tomato crop. Here, servo motors are placed on the joints of the robot-manipulator and perform the necessary movement depending on the identified object [5].

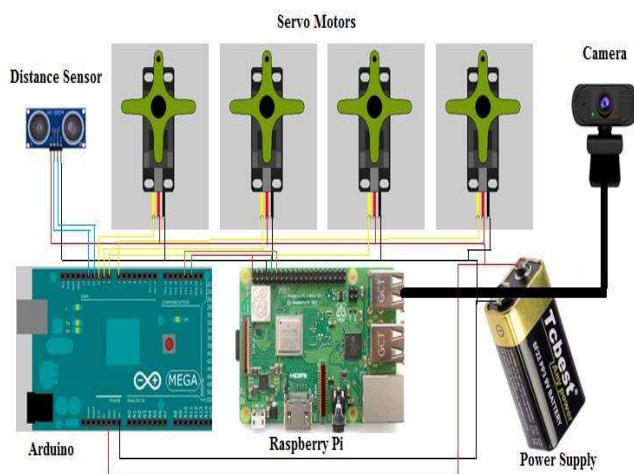


Fig.2. The electrical connection among the components of the harvesting robot.

Figure 2 shows the electrical diagram of the harvesting robot. The camera used in this project is a very common webcam that plugs directly into the Raspberry Pi3 board. HC-SR04 ultrasonic sensor is used to determine the distance between the product and the monitor. The range of this sensor is 2cm to 400cm and the sensing angle is 30°. This sensor can be connected to Arduino board. The 3D view and electrical schematic of this research model is assembled and consists of a Raspberry Pi3 processor for image processing, an Arduino Mega 2560 as the main device, and Servo motors connected through actuators. The robot arm in this model consists of 2 joints and these joints are controlled by Servo motors.

Figure 3 shows the movement states of the robot. It shows the dimensions of the robot arm's base, joints, legs, and overall height. This mode of operation is designed according to the size of the tomato plant and can be adjusted according to the size of the plant.

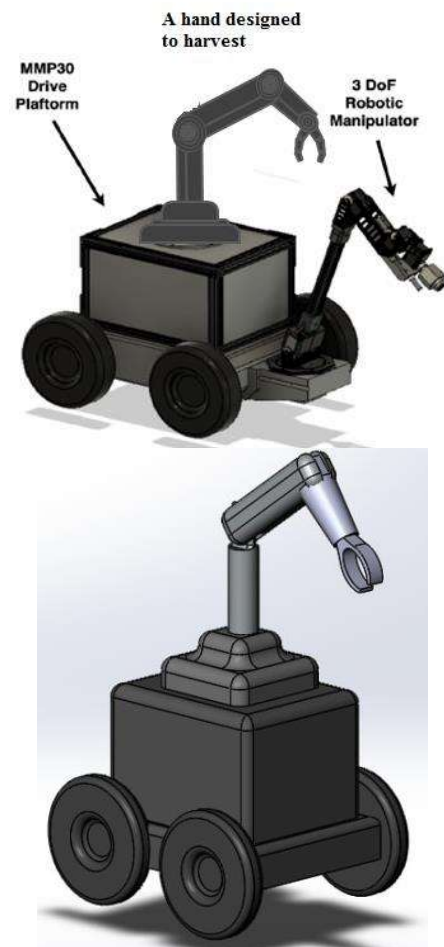


Fig.3. 3D model of the device

The 1st stage of the tomato harvesting robot-manipulator consists of cleaning the tomatoes. Table 1 shows the power consumption of Servo motors that provide robot movements in picking tomatoes. These motors are connected in Figure 2. The voltage values maintain how the robot moves in and out of the state. The robot is powered by a servo motor that supports the manipulator to print and position it to the right. Servo motors on link 1 and 2 are activated to load up and down. Systematic control of angular displacement of rotating mechanisms of robotic manipulators remains an urgent problem. An attack on the use of transformer-transformer angular displacement sensors in the measurement and control of angular displacements over a wide range is discussed [17], [18], [19].

CONCLUSION

This article presents a project of a tomato picking robot. Therefore, the developed robot is adapted to the size of the tomato tree and tomato. This time difference does not depend on the color of the tomato, but on the distance of the robot to the tomato. The experiment shows that the robot successfully harvests tomatoes under the conditions presented in this study and proves the effectiveness of this robot design as an agricultural robot. It should be noted that research on the

creation of agricultural robots has been developing very slowly in the last 20 years. Robotics has not yet reached commercial scale for use in agriculture. With the reduction of the labor force and the increase of the production cost, in recent years, more attention has been paid to the research areas of cleaning and harvesting of robotic livestock farms. Existing problems of quality harvesting of agricultural products can be solved by using a robot, providing continuous information about the area where it is located, and by correctly analyzing many aspects of the farm. The lack of accurate control of the movement of the bursa of the rotation mechanisms of existing robots leads to a decrease in the speed of product collection. To solve the existing problem, a sensor for controlling the rotation mechanisms of robotic manipulators was developed. The reliability of the proposed angular displacement sensor is higher than the reliability of the existing sensor. In addition, it is capable of measuring angular displacements of up to 180 degrees in precise values.

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Neuro-cognitive Evaluations using Deep Learning and Wearable Sensorial Devices

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Abstract—Evaluation and analyze of different neurocognitive disorders is an important research area in intelligent healthcare systems based on wearable sensorial devices. The paper presents solutions for Parkinson's disease patients evaluation using two types of wearables: a sensorial bracelet and sensorial insoles. First, a complex system based on a new developed bracelet is presented, the framework involving deep learning technique for data evaluation and cloud technology. Then, a gait evaluation system is proposed. The gait analysis is mostly performed on temporal and spectral feature extraction in which there is a high rate of missing important features. As it was observed, monitoring and quantification of Parkinson's disease patients imply many therapeutic challenges in terms of severity analysis of motor symptoms such as freezing of gait (FOG) and continuous remote monitoring of patients. A smart insole dataset has been used in this study for applying the computational methods focusing on gait analysis. The results emphasize that the new developed system proposed by us works efficiently with the accuracy of 96.5% in gait variability analyzing three cohorts i.e. adults, elderly, and Parkinson's disease (PD) patients and 91% for analyzing the gait symptoms in different severity stages of PD patients.

Keywords— *neuro-cognitive disease, cloud computing, deep learning, severity estimation, wearable devices*

I. INTRODUCTION

Predominance of neurocognitive disorders in adult patients requests the use of wearable devices to increase the success of the future solutions dedicated to mental health. Recent development in wearable technology determined an essential role in diagnosis, rehabilitation, assessment and monitoring. The research work of the last years, on this topic, analyzed and used different types of wearable devices, essential in improving early diagnose and monitoring, emphasizing their role in improving the quality of life, differentiating the various fitness and gait wearable-based exercises and their impact on the regression of disease and on the motor diagnosis tests and finally addressing the available wearables and their role in rehabilitation.

The research findings proved that sensor based wearable devices like smart insoles or bracelets help not only in monitoring and diagnosis but also in tracking numerous exercises and their positive impact towards the improvement of quality of life among different Parkinson and neurocognitive patients.

Today, millions of people suffer from cognitive impairment [1]. There is an extensive range of neurocognitive disorders specified as Alzheimer's disease, Parkinson's disease, traumatic brain injury, Lewy body disease, vascular disease, front temporal lobar degeneration etc. [2,3]. Parkinson's disease (PD) is the second most frequently observed neurodegenerative disease [4]. Around seven to ten million people in the world are having Parkinson's disease.

Screening for Parkinson's disease is difficult. Even if research has been done for decades, there is still no automatic robust evaluation solution that can serve as the best way in analyzing it because the signs and symptoms of Parkinson's disease vary from one person to other and its characteristics are very similar to other diseases [5]. PD can be investigated incorrectly and can be interpreted as other diseases. Characterization of tremors in hands and gait features plays a vital role in diagnosis and long term monitoring of Parkinson patients. Typical gait disorders of PD can be described as freezing of gait (FOG), stooped posture, shuffling steps and falling [6].

Current clinical solutions for detecting gait use motion sensing technology i.e. camera-based optical motion-capture system, markers attached with body, force plated on the ground to measure pressure, equipped treadmills with different sensors and for quantifying tremors, laser displacement sensors and electromyography (EMG) systems [7, 8] are used. For diagnosis, assessment and monitoring there is a need of continuous data from patient and the solution lies in wearable technology [9]. The role of wearables is multi fold and it starts from continuously capturing the motion data [10] that helps in diagnosis, monitoring and tracking the changes compliance with an exercise training, boosting also clinical trial data.

While treating PD patients, the neurologists recommend Levodopa (L-dopa), a naturally occurring amino acid that is metabolized to dopamine in the brain and considered as the most adequate symptomatic therapy available for PD. But its effects and body reactions and the possible side-effects have to be carefully analyzed.

Till now, researchers have focused on the prediction of cardinal motor symptoms, assessing disease progression by using deep learning DL that outperforms a classical machine

learning model applied to hand-crafted features in this time series classification task [11], [12]. Contrary to the existing solutions our study proposes an eHealth monitoring system for PD patient based on deep learning and cloud technology. This study is aimed at creating a DL model that can predict the response of patients suffering from PD to L-dopa drug. The insights obtained from this analysis will provide means to improve patients' quality of life by providing useful information to their clinicians in terms of dose optimization (thus reducing medication risk effects).

In this context, the paper presents our findings following the two already discussed aspects: a cloud-based architecture that uses deep learning on the data acquired by a new wearable bracelet developed by us (Section 2) and, secondly, the deep

learning approach for gait evaluation using wearable sensorial insoles (Section 3). The final section provides conclusions and discussions.

II. CLOUD BASED FRAMEWORK

In comparison to other controlled studies, we are proposing an integrated system which addresses most of the problems in remote and continuous monitoring of PD Patients and assimilates diverse aspects such as patient's physical health in ON and OFF state while performing different tasks: walking, swing and all sort of internal and external physical activities. Likewise, it generates precise, viable and opportune capacity and handling of gathered inertial sensors data, effective data analysis, processing and producing accurate and authentic information to the respective end users.

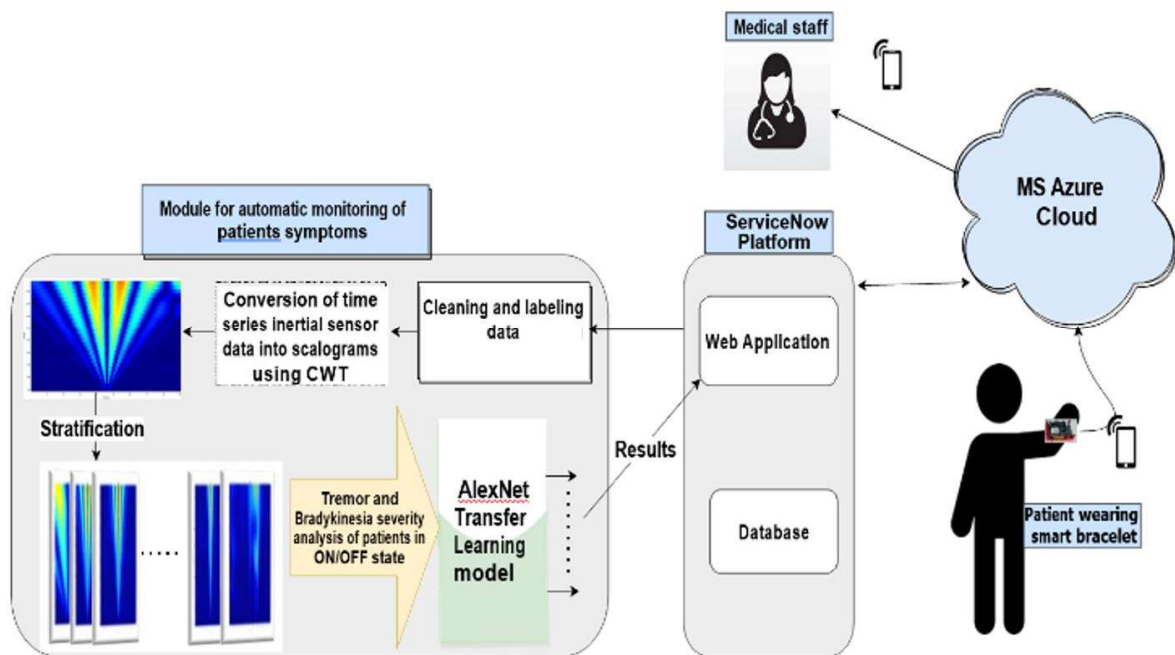


Fig. 1. The block diagram of the proposed PD monitoring system. The person is wearing a sensorial bracelet (the new proposed AWEAR device) and is performing some movements by his/her most affected limb. The device is wirelessly connected with MS azure cloud which provides ServiceNow platform in the form of a web application where a database is created of motion data transferred from the bracelet. That data goes to the module developed for monitoring and assessment of PD patients symptoms. First, the module converts the inertial sensor data to scalograms using CWT and then passes it to AlexNet transfer learning module to find the severity level. At last, the results are updated in the ServiceNow stage which can be checked by the patient as well as by the clinical expert who received access to cloud administration

Fig.1 presents the architecture of the proposed cloud based PD monitoring system. The information gathered by the sensors are sent to the smartphone which locally stores the information for a brief period of time and finally sends the information along with the metadata to the cloud server through the mobile Internet and/or Wi-Fi. The web application at the cloud side pre-processes the information, separates the significant features from the sensor data using continuous wavelet transform (CWT) and estimates the severity or reaction of clinical therapy of the PD symptoms using DL model. Finally, the results are stored in the cloud database and also send back to the PD patients as a report for their monitoring.

A. Wearable Device Description

The proposed wearable device is a bracelet (called AWEAR) that helps in data collection. This data will be further used for diagnosis and quantification. Different versions of them have been developed by us in the last research year, improving each feature that can increase the

data quality and the way the data sets are saved and processed. More details can be found in [13]. The current version is using MediaTek MT3620 microcontroller which is a highly integrated, high performance IoT microcontroller unit (MCU) with the undeniable high level of security important for modern, robust internet connected devices (Fig. 2).

The bracelet has EMG sensor along with accelerometer, uses BLE (Bluetooth Low Energy) connection and has android app (interface). Its light weight makes it to be easy for the patients to wear on wrist even the whole day. The bracelet connects to a smartphone using Wi-Fi, storing and analyzing data on a cloud platform.

B. Study Protocol

To assess clinically relevant measures of the severity of Parkinson's disease signs, including the fluctuation of motor symptoms in response to levodopa medication, on the first day of data collection, study participants came to the laboratory in an ON state (i.e. after taking their medication), they answered

demographic questions as well as medical history. Then they performed some daily routine tasks.

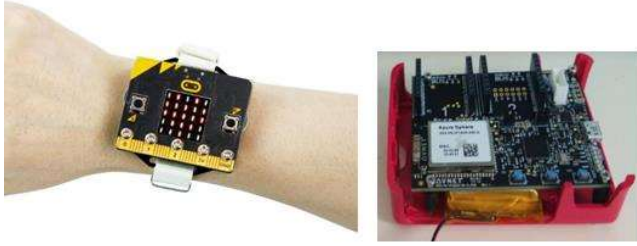


Fig. 2. Wearable device for PD severity analysis

The list of tasks performed include standing, walking in a straight line for 30s, walking in a straight line for 30s while counting backwards, walking upstairs, walking down stairs, walking through a narrow corridor, executing finger-to-nose exercise for 15s (twice with each arm), alternating hand movements for 15s (twice with each arm), drawing, typing on a keyboard for 30s, opening a bottle and pouring water, arranging sheets of paper in a folder (twice), assembling nuts and bolts for 30s, folding a towel three times, and sitting. This set of tasks lasted approximately 20 minutes. For each instance of each task performed, clinical labels of symptom severity and/or symptom presence were provided by a clinician.

During Day 2 and Day 3, study participants were instructed to conduct their usual activities. The subjects were also asked to perform a short set of motor tasks like alternating hand movements for 30s (once with each arm), finger-to-nose for 30s (once with each arm), and sitting quietly for 30s every 30 minutes, for a total of 7 times on each of the two days at home. On Day 4, subjects were asked to come to the laboratory in a practically defined OFF state (i.e., medication(s) were withheld overnight for approximately 12

hours). The same procedures that were performed on Day 1 were performed once again on Day 4.

C. Signal Processing using Continuous Wavelet Transform (CWT)

In the past, numerous research studies used Fourier transform or Short Time Fourier transform to extract features for PD motor symptoms either from lower body motion signals or upper limb motion signals. However, in both methods, it cannot be exactly identified where an event occurs; in order to deal with this, a huge number of features are extracted and as the number of features increases, the energy consumption and the latency affect the data storage and the processing and analyzing of the events.

Since CWT provides both time and frequency domain features, in this research study we employed CWT method on recorded accelerometer signals from standard hand movements exercises as well as from daily life activities of PD patients with varying severity scores. There is a coordinated correspondence between the scale and the frequency, given the sampling rate and the picked wavelet family. In our case, the 'Morlet' wavelet has been used.

D. AlexNet Transfer Learning Model for Classification

The objective of this research is to classify the scalograms built using CWT with high success into various stages of the PD disease patients in their ON and OFF state. With passing time there is a massive growth observed in patients impaired by PD. That is why it is needful to rank the patients into different stages of disease from mild to severe in a swift manner. In the present research, the AlexNet architecture is the kind of experiment to alter it in different weights to get best results. The architecture is shown in Fig. 3 and we increased the classification accuracy in finding the severity level that can be further considered as a better assessment for the doctors.

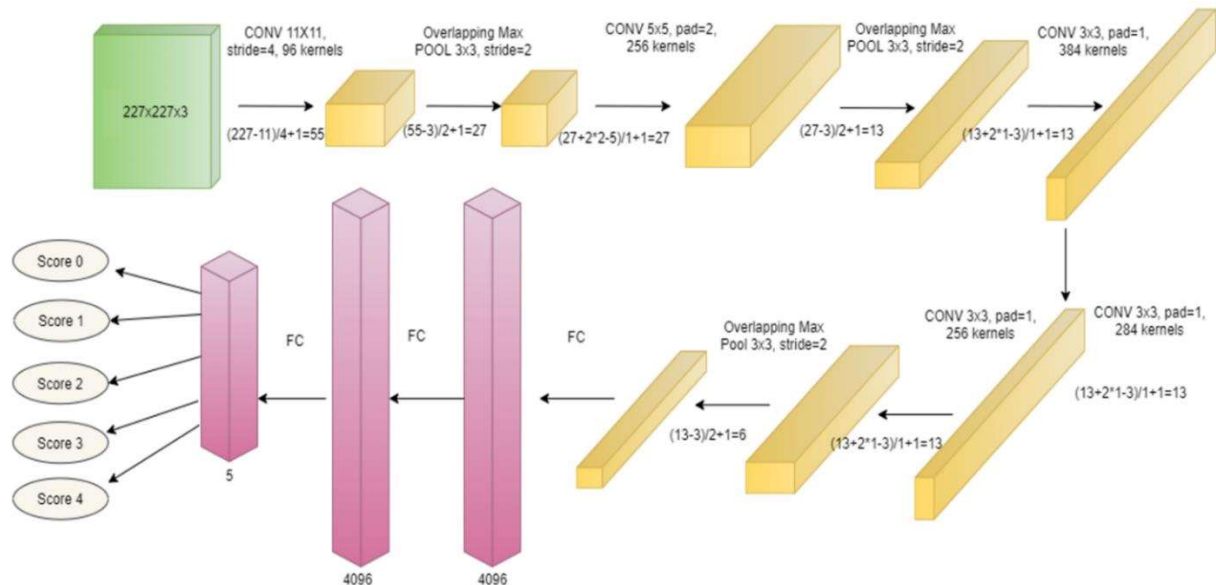


Fig. 3. AlexNet Transfer Learning model architecture

The initial step is to resize the input scalograms to the size of $227 \times 227 \times 3$, which are transferred to the convolutional layer, the max pooling layer, again convolution then max pooling and then 3 convolution layers following max pooling and finally the fully connected layers. In each layer there is performed a mathematical operation defined using the formula 3, where n is the image height and weight (pixels), s is stride, f is filter used and p is for padding: $(n + 2p - f)/s + 1$.

However, the model is trained on 70% data and tested on 30% data images. For bradykinesia the model gives 84% accuracy and for the tremor severity score analysis it gives 90%.

E. Cloud-based Data Processing and Analysis

The role of cloud technology in the proposed system is multifold. For instance, it stores the hefty amount of motion data from the inertial sensors, pre-processes the samples of motor signals and converts to scalograms by utilizing CWT and examines the severity level using AlexNet model; this process runs continuously and upgraded. The patient associates with the authority over the cloud through the web using their shrewd phones. In cloud, the ServiceNow platform [14] is implemented. This platform can be used as a “gateway” between the wearable device and the deep learning computation method. The whole computing and processing services are provided in a distributed manner.

The cloud stage helps in maintaining clients' privacy as well as the data security. It is done in various different stages in the framework, data assortment, information transmission and data storage in the cloud. While gathering the data, all data is passed to the mobile device in an encrypted format. Also in case of data transmission, encrypted data is transmitted to the cloud and only the approved clients can get to it.

F. Results

The performance metrics for severity estimation of motor state from sensor data of PD patients using the algorithm is depicted in the form of sensitivity and specificity for each class. The model is trained and tested separately for tremor and bradykinesia severity score analysis. AlexNet model shows very promising results by giving 84% accuracy for bradykinesia estimation and 90% for tremor with a good sensitivity and specificity in terms of each scoring class. Considering the existing methods which show poor interpretability, our study shows promising results in extracting potentially useful features using CWT for identifying symptoms that are often overlooked by manual features.

III. PARKINSON'S DISEASE GAIT EVALUATION THROUGH WEARABLE INSOLES

Gait evaluation is important for the detection and management of various neurocognitive disorders. Monitoring and quantification of Parkinson's disease patients raise many therapeutic challenges in terms of severity analysis of motor symptoms such as freezing of gait (FOG). The objective of this part of study is to use a smart insole dataset for the evaluation of computational methods focusing on gait analysis. As discussed in the previous section, we use again

continuous wavelet transform (CWT) to convert time series signals into images instead of using the traditional techniques for dealing with time series. The results evidence that the proposed system works efficiently with the accuracy of 96.5% in gait variability analyzing three cohorts i.e. adults, elderly, and Parkinson's disease (PD) patients and 91% for analyzing the gait symptoms in different severity stages of PD patients.

The dataset used in this study is available publicly on Biomedical Informatics Laboratory (BMI) at: bmi@hmu.gr [15]. The data is collected using wearable insoles developed using pressure sensors. The data is collected from three cohorts which counts 29 subjects.

The insoles weight around 80 grams and look and feel like regular insoles incorporated with 16 pressure sensors. The power supply, the storage, and the data transmission unit are integrated into the insole. The insole operates completely wireless and includes a 6-Axis IMU sensor for acceleration and angular rate data. These insoles have been validated in previous research studies in terms of functionality and accuracy such as in [16].

The dataset comprised of 29 recordings from participants who are divided into three categories. One of the group is the control one, in which healthy subjects aged between 20-59 years were included. The second group includes elderly citizens, in which people above the age of 60 years were included. For these two cohorts, volunteers having musculoskeletal or neurological diseases that could perform their gait or balance were excluded from participation. One of the important group consists of PD patients irrespective of their age. All subjects with PD received their medication as normally scheduled. In case of the patients and the subjects that would find hard to complete all tasks, the number and repetitions were adjusted so that they felt comfortable.

In the case of patients with PD, the following three tests have been mostly performed: (1) the Timed Up and Go test (TUG test), where the participants rise from a sitting position, walk a 3 m distance, turn, walk back and sit on a chair; (2) walking in a corridor with obstacles, and (3) the Dual-Task test, where the participants walk and at the same time undertake a second process, such as an arithmetic operation, conversation, transferring an object, etc.

The proposed system methodology is explained in Fig. 4. The data from wearable insoles is in the form of time series generated by pressure sensors. These raw signals are first pre-process and filtered. Afterwards the sliding window of 3s is used to create scalograms by using continuous wavelet transform (CWT), converts the time series data into images which are further analyzed for gait abnormality and severity estimation of PD symptoms following stratification by means of deep learning convolutional neural network model.

As discussed in the previous section, CWT method has been proven to be an effective method since it defines both time and frequency components. In this care, the 'Haar' wavelet has been used. As our dataset is already filtered out and labeled, the 'Haar' wavelet type suits perfectly to our problem. Figure 5 shows the scalograms generated using CWT. The difference in scalograms explains the change in gait features of different cohorts. Before generating scalograms a sliding window is created that takes samples of same activity and create scalogram of that specific task.

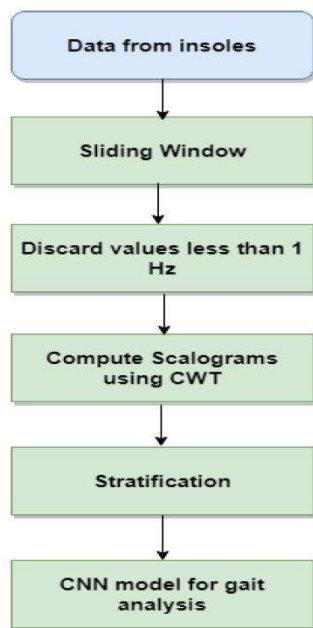


Fig. 4. The method of building the gait analysis model

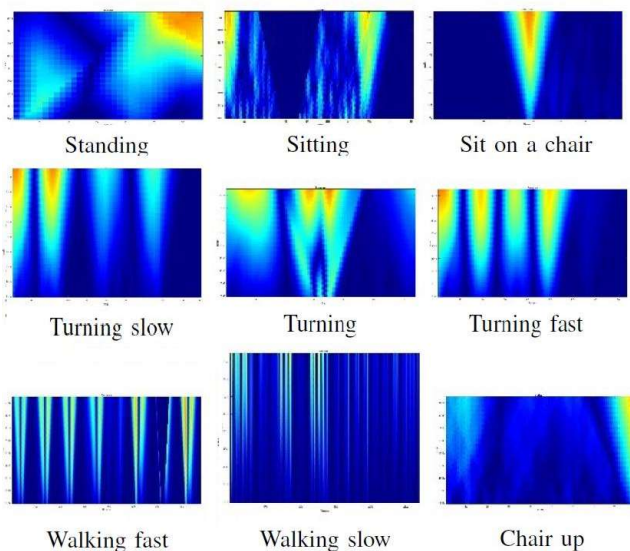


Fig. 5. Scalograms of different motor tasks performed by one of the PD patients

Another important factor we considered while changing time series data to images was to have frequency content less than 1 Hz. From scalograms the variation in colors illustrates the changes in gait variability of all cohorts. The total number of scalograms created are around 7500 images.

Our goal was to classify the scalograms built using CWT with high success various stages of the PD patients as well the diagnosis of gait features in all cohorts clearly. In the present work, the ConvNet architecture was used for experiments to alter it in different weights and to get best results. First, the input scalograms are resized to 227x227x3 comparing to the breadth and height and the three color channels. This is transferred to the convolutional layer input images in a series of convolutional filters, each of which activates certain features from the images, then ReLu and max pooling layer, again convolution then max pooling and then 3 convolution layers, following max pooling and finally the fully connected

layers. The model has been trained on 70/30, training/testing data.

IV. CONCLUSIONS

This research proposed and discussed solutions based on wearable devices and deep learning technique for clinical assessment in the case of tremor, bradykinesia and gait variability in PD patients. The first system helps clinicians to identify subtle changes in motor performance that characterize PD patients in response to their recommended treatment. In this work the patients while wearing a sensorial device developed by our team perform various physical activities in ON and OFF state and the data acquired goes directly to MS azure cloud. For extracting temporal and spectral features, CWT creates scalograms which are further classifies using AlexNet. The users can access the updated results in the form of a medical report on the web application. The whole system is very robust developed and easy to implement.

The second neuro-cognitive evaluation solution discussed in the paper used sensorial insoles to evaluate the gait of elderly and PD patients when reviewing their progress and the effects of any treatments. The system creates again the scalograms using CWT, processing them in a CNN model, getting promising results. In this way, this research work proposed a novel gait analysis and CWT-based approach to diagnose idiopathic Parkinson's disease severity level as well as gait variability in age-matched individuals. In the next step the system will gather both wearable devices offering a complete evaluation in neuro-cognitive disorders.

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A KBM Based Algorithm Using F5 Methods for Video Steganography

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Abstract—Steganography refers to techniques that hide information into the cover object. In this study, a new technique for the F5 method was performed with the Discrete Cosine Transform (DCT) method, Key Block Matrix (KBM) consisting of different sub-pattern blocks, and additional security algorithms. This paper evaluates the applications of different algorithms and their results which can be chosen by users for video steganography using F5 methods. To evaluate the results Mean Square Error (MSE), Structure Similarity Index Measurement (SSIM), Peak Signal Noise Ratio (PSNR), and Structural Similarity Index Measure (SSIM) quality metrics were used. The fact that the KBM structures are variable increases data security in the proposed algorithms and fills the gap of security issues in the video steganography. The quality metric values obtained showed that the proposed approach can compete with the results obtained in the literature regarding PSNR, MSE, and SSIM values.

Keywords—F5 method; Secret key; Variable block; Block matrix

I. INTRODUCTION

Technological developments have made it important with data security. By this development, many studies have been carried out for the secure transmission or hiding of data with wide usage of the internet and multimedia. Hiding the data in multimedia tools is called steganography and the multimedia tools such as music, video, text, or image files where the secret data is hidden are called stego-objects. Many different methods and techniques are used in the studies related to steganography. One of them is video steganography too.

Video steganography has become more famous and useful recently that the human visual system is less sensitive to the small changes of digital video.

In this study, a new approach developed by the F5 method was proposed to improve the data security in video steganography. The proposed approach uses a 64x64 pixel key block matrix (KBM) structure that we used in our previous work to see its effects on LSB [1] and DCT [2] methods. KBM is designed that can be changed its structure depending on user preference. For secret data hiding into the video frames, 8x8 block structures were used. The user chooses the hiding algorithms with the combination of KBM, F5 blocs, and additional security algorithms.

By comparing the stego object obtained by each of the F5 block structures obtained by proposed methods and the original video the video defects were examined. MSE, SSIM, and PSNR were used as quality metrics for comparison aim.

A. Related Works

In this section, literature studies using the F5 method and block-based methods are presented.

Researchers proposed a method based on the distribution of pixel diversity in images using histogram, equalization, contrast stretching, brightness and gamma correction values, and DCT and F5 techniques [3]. In their study, the PSNR values obtained in their studies ranged from 32 dB to 38 dB. They obtained an average PSNR value of 36.7 dB.

Researchers developed a steganalysis method for F5 steganography in another study [4]. At proposed method was tried to estimate the data by measuring the distribution distance between a certain image and the histogram coefficient of an estimated stego image. They used the estimated modification rate to distinguish stego images. Researchers stated that their proposed method gave more successful results against F5 steganography than existing steganalysis methods.

Researchers have proposed a steganography method using the F5 algorithm based on the quantification table in their studies [5]. They claimed that they developed a method with high imperceptibility thanks to its high embedding capacity and anti-shrinkage on the picture. They used the structural similarity metric SSIM (Structural Similarity Index Measure) as well as the PSNR value to evaluate the results of their study. The PSNR values they obtained vary between 38 dB and 49 dB, and the SSIM values are between 0.6799 and 0.9971.

In a research study, researchers proposed an algorithm for data hiding using quantified DCT coefficients [6]. They used the algorithm, they proposed in the study with also F5 techniques as well as DCT. Researchers stated that the results obtained with the F5 technique were more successful. It was stated that the PSNR values obtained from their studies were 17.26 dB.

The proposed video steganography method has a 64x64 pixel KBM that can shift in four directions (up-down-right-left) and rotate up to 0°-270°. The movement to choose the direction/degree for the next 64x64 pixel block is determined

with logical operations. For embedding the data, the method has the ability to different block areas of the video frames and the ability to choose different channels of the RGB of a pixel. These properties ensure to increase in the robustness of the proposed video steganography application. Experimental results have been showing that the proposed method generally has attained good perceptual quality compared to the other video steganography methods that include classical F5 and other F5 based approaches by its KBM, block structure etc.

The results obtained from the evaluation metrics show that the suggested methods work well. When the metric values obtained from the results of the previous studies are compared with the metric values obtained from our study, it is seen that the PSNR values we obtained appear to be competitive with studies conducted.

II. METHODOLOGY

A. KBM Structure

The key block structure consists of a 64x64 pixel main block and 16 pattern blocks in 16x16 pixel. The pattern blocks are randomly selected from 18 pre-coded source pattern blocks with a pixel size of 16x16. The selected pattern blocks are placed in the key block from left to right [1, 2]. The KBM was created with the aim of determining the data-hiding pixel areas to involve the binary-coded form of the key block structure [1, 2]. The KBM for the fields corresponding to black and white and bit values on the key block structure is created as follows.

- i. 0 for pixel areas corresponding to the black colour (0) value in the block
- ii. 1 for pixel areas corresponding to the white colour (255) value in the block.

The pixel areas represented by 0 within the key block matrix are used as closed areas where data is not embedded while the pixel areas represented by 1 are used as open areas suitable for data-hiding.

“Fig. 1 a” shows the sample key block, “Fig. 1 b” shows the layout of the pattern blocks that constitute this block and Figure 1 c shows the pattern block matrix structure of pattern block number 18.

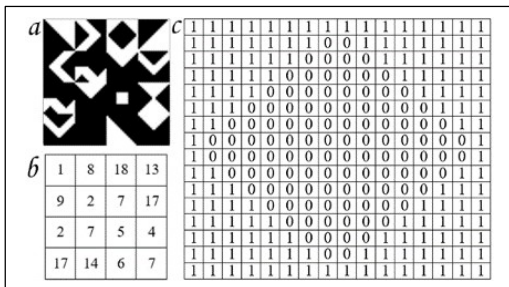


Figure 1. a) Sample key block structure b) The layout of the pattern blocks that constitute the key block c) The 16x16 pixel pattern block matrix structure of pattern block number 18

B. Performance Analysis

Video quality is a measure of the perceived video distortion of a video obtained by going through a particular video processing system compared to the original video [7]. Various metrics are used to approximate video quality. The most widely used metrics are mean squared error (MSE), peak signal-to-noise ratio (PSNR) and structural similarity index measure (SSIM) [1, 2]. We also used these metrics in our study. These metrics use a pixel-by-pixel comparison method of source video signals with test video signals.

C. Determining Suitable Block Areas for Data Hiding

The user selects the algorithm combinations to determine blocks where data can be hidden on video frames. The data hiding options are depending on user selection. According to the selection, the user creates the data hiding algorithm as following options.

- i. For block structure; fixed, shifting, rotating and shifting-rotating structures,
- ii. For determine the data hiding areas in video frames; Sequential, Sequential in All Frames or Non-Sequential in All Frames methods,
- iii. For colour channels use in data hiding; RGB, R, G or B colour channels.

KBM is placed in the first 64x64 pixel area of the video frame that will be used for data hiding. After data is hiding according to F5 block structures in this area according to selected algorithms, the KBM structure can change. Changes in the KBM structure can be made according to the selected block structure for the next 64x64 pixel block area, the colour channel selection made and the conversion factor (DC) value of the DCT block area for F5 processing where the last data hiding process was performed.

KBM can rotate 90°, 180° and 270° in right-left and up-down directions. The movement direction and step controls of DCT blocks and KBM are selected according to the DC coefficient of the DCT block structure for F5 processing.

The data is hidden in DCT blocks in a left-to-right order according to the KBM value. If the KBM value corresponding to the first bit of the DCT block is suitable for hiding data, data embedding is performed within the DCT block. The direction and status of the next DCT block are determined by moving the data on the area determined by the 64x64 pixel KBM pattern structure of the first bit data of the hidden DCT block. The pixel areas suitable for data hiding on all video frames that make up the video are determined by marking the DCT blocks and the pixel areas of these blocks that are suitable for data hiding on the KBM.

D. Data Hiding Into Pixel Areas

For data hiding according to the selection of data hiding algorithms and the KBM structure. Each video frame is divided into 64x64 pixel blocks to represent an integer. 8x8 DCT blocks are placed in these 64x64 pixel block areas. The last 64x64 pixel block of each video frame is separated into the control block used to hide selected in the data hiding.

The index value cell (0,0) in the DCT transformation matrix of the DCT block represents the DC value and the DC coefficient value calculated for each block is used as the key value to be used for the F5 processing technique. The scheme of this technique is shown in "Fig. 2".

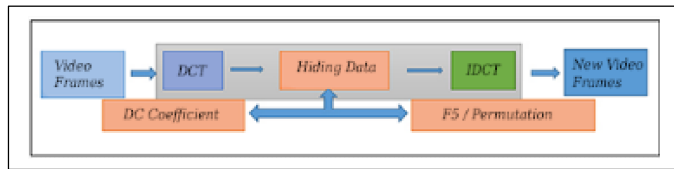


Figure 2. Block scheme for F5 methods

The data bit value to be hidden is placed in the DCT block by replacing the bit values of the DCT transform matrix suitable for data hiding. Only 1 bit of data is hidden in each DCT block suitable for data hiding.

No changes are made to the colour pixels and the DC coefficient for data hiding. The data bits to be hidden are hidden according to the displacement of the cell (4,0) and cell (3,1) pixel values in the DCT transformation matrix of the DCT block suitable for data hiding. This movement is shown in "Fig. 3".

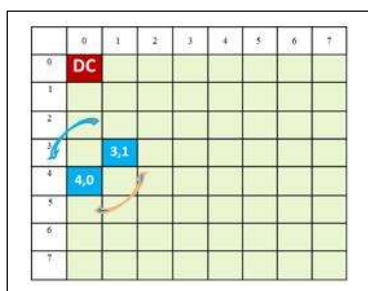


Figure 3. DCT transformation movement for data hiding

If the data to hide is 1, cell (4,0) is expected to be bigger than the cell (3,1). If equality is not achieved, cell (4,0) and cell (3,1) are replaced. Cell (4,0) is increased 1 if the cells are equal. If the data to hide is 0, cell (4,0) is expected to be smaller than the cell (3,1). If equality is not achieved, cell (4,0) and cell (3,1) are replaced. Cell (4,0) is decreased 1 if the cells are equal.

III. PROPOSED METHOD STRUCTURE

The proposed video steganography structure mainly consists of the processes of creating the stego object (encoding) and obtaining the hidden message (decoding). For the encoding and decoding processing the KBM structure and F5 blocks, mentioned previously are used.

A. Encoding Processing

The methods used to generate the stego object are created by the user making a selection from 3 different sections. These sections are algorithm structure, block structure and colour structure.

The steps of the embedding process are as follows.

Step 1. Selecting the data hiding algorithm.

The user selects the algorithm to be used in the data-hiding process among algorithms structure, the KBM structure to be used in the data-hiding process among block structure and the colour channel where data will be hidden in the data-hiding process among colour channels.

Step 2. Entering data which will be hidden.

A .txt file containing ASCII encoded data to be hidden is entered by the user. The entered ASCII data is converted to the corresponding values in the binary system and binary input data is obtained.

Step 3. Video recording for the stego object.

Video recording is made for the cover object which is to be used in the creation of the stego object. The cover object is created dynamically by recording a momentary image via a camera. Video frames and audio files are recorded separately. These records are to be combined afterwards. Each video frame is given a number based on the order of recording in the folder and saved as a .png file format. On the other hand, the audio file is saved as a .wav file format.

Step 4. Creating of KBM.

Structural features of KBM were previously mentioned in part "KBM Structure". According to this structural feature, KBM is created that will be used for data hiding.

Step 5. Hiding control values in video frames.

To extract hidden data, the control parameters are recorded. These parameters are the method parameters to be applied to create the stego object, the data size to be hidden, the colour channel and the KBM structure used for hiding data. Control values are hidden in each video frame's last 64x64 pixel area where data can be hidden.

The control values are hidden starting from the first video frame where data can be hidden and going on in the following frames sequentially.

After each control value is hidden, one video frame is left blank and in the following video frame hiding the next control value is continued.

The DC value of DCT blocks in the 64x64 pixel block area reserved for hiding the control values on the video frames is as follows [1, 2].

7	6	5	4	3	2	1	0
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If $(XOR(R(7-1)) \text{ AND } XOR(G(7-1)) \text{ AND } XOR(B(7-1))) = 0$ the first element of the layout matrix is hidden in the DCT block here. It moves sequentially from left to right within a 64x64 pixel block. To determine next DCT block area the logical expression of $(XOR(R(7-1)) \text{ AND } XOR(G(7-1)) \text{ AND } XOR(B(7-1))) = 0$ is checked. If the result is 0, data is hidden within the pixel area. If the result of the operation is 1, data is not hidden in this pixel area. The process is continued until all elements of the layout matrix are embedded. For example, shifting-rotating block structure from control parameters are as follows.

For the shifting-rotating block structure: $B = 1, G = 1, R = 1$

Step 6. Hiding data in video frames.

First, the amount of data to be hidden in each video frame is calculated. This calculated process is taking into account in line

with the selected algorithm, the capacity of the video frame and the length of the message.

The data is hidden in the video frame starting from the first 64x64 pixel block until the last 64x64 block matrix structure sequentially according to the DCT block structure and KBM structure. DCT block structure is designed at 8x8 pixel size for the F5 blocks.

The data hiding process is performed according to the selected colour channel, KBM structure and the suitability for data hiding for the pixel area that the movement index represents.

The data bits are hidden in the DCT block with the F5 technique according to the colour channel selection and the appropriateness of the first bit of the DCT block matrix of the video frame corresponding to the KBM data-hiding area. Data hiding operations are as follows.

- i. First data block is hidden,
- ii. Next, a state & direction check is made for the transition to the next 8x8 DCT and 64x64 pixel blocks,
- iii. The next step, whether the data can be hidden or not in the destination pixel is checked.

After this operation to hide data for into the next block, the corresponding field in the KBM structure and data hiding state control data must be suitable for data hiding. The KBM structure to be used for the next 64x64 pixel block is changed according to the DC coefficient value of the 8x8 DCT block, which is the last data hidden in the first 64x64 pixel block structure.

Thus, data hiding is performed with the user-selected algorithm. After the data is hidden in each video frame in order to the selected algorithm, a new video frame called the stego object is created.

Step 7. Creating of stego object.

When the data hiding process is completed, the resulting video frames and audio files are combined to create a stego object in the '.avi' file format.

B. Decoding Processing

In the process of obtaining the secret message, the user only uses the stego object as the input parameter. The user does not have any information about the control parameters that are used to hide the message. With which control values the message is hidden, is obtained from the stego object.

The structure of the decoding process is similar to that of the encoding process. Control parameters selected by the user in the encoding process are extracted from the stego object in the decoding process.

The steps of the embedding process are as follows.

Step 1. Determine the path for the stego object.

The user is primarily asked to identify the stego object path that is the input parameter for the data extraction process.

Step 2. Obtaining the control parameters.

Control parameters are obtained from the stego object by reading the data hidden in the last 64x64 pixel block areas of video frames. Determining the suitable pixel areas where control data may be hidden is in the same structure as

determining the suitable pixel areas for data hiding in the process of hiding control values.

Considering the block area structure where the control data is placed in the video frames and the situation of passing a video frame blank as a result of the placement of each control parameter, possible video frames in which the control values may be hidden are determined. Control data are obtained in the order of embedding. The KBM block structure, data hiding algorithm structure, colour channel used and DCT block structure are obtained as the control parameters.

Step 3. Obtaining the hidden data

According to the control parameters, the data hidden in the stego object are extracted in the same structure as hiding data in video frames and encoded in binary format. Finally, a secret message is obtained by transforming the data obtained in binary format into ASCII characters.

IV. APPLICATION AND ASSESSMENT OF THE RESULTS

In this section, the application results of the proposed methods were presented.

Among the developed applications, data hiding processes were carried out in line with the KBM created using the F5 technique with 8x8 DCT block structure.

In order to hide data in DCT blocks, the locations of the determined pixels are changed without making any changes on the colour pixels of the DCT block values and the DC coefficients. In the data hiding process, cell [4,0] and cell [3,1] matrix elements of each block were used for 8x8 pixel DCT blocks.

In order to evaluate the proposed methods, a dynamically recorded video was used. Video frames and audio files belonging to this video were used for each application. The video has a pixel resolution of 640x480 pixels and 330 video frames.

To ensure application reliability, a 64x64 pixel KBM consisting of the same pattern blocks was used in each application.

2 different secret message data that are consist of 93369 bit-10,4 kb and 376193 bit-42,8 kb that are hidden and obtained for each recommended application were used.

The comparison of the original and stego frames was made based on the PSNR, MSE and SSIM values. For a healthy assessment of the results, the frames used by each algorithm in data-hiding were used in the assessment process. The results obtained are displayed comparatively for each application with used 1st and 2nd secret messages and are respectively shown in Table 1 and Table 2.

The Python PyCharm IDE was used in the program-writing process for data-hiding and outcome analysis.

For the 1st secret message, the best quality metric values are obtained in data hiding processes using KBM and proposed data hiding algorithms for DCT blocks that are used for F5 as "Sequential Data Hiding In All Frames " & "Data Hidden Color Channel-RGB " & "Rotating Block Structure".

For the 2nd secret message, the best quality metric values are obtained in data hiding processes using KBM and proposed data

hiding algorithms for DCT blocks that are used for F5 as "Sequential Data Hiding " & "Data Hidden Color Channel-G " & "Shifting-Rotating Block Structure".

TABLE I. F5 EVALUATION RESULTS FOR 1TH SECRET MESSAGE

Shifting-Rotating				Rotating				Shifting				Fixed				Block Structure	
B	G	R	RGB	B	G	R	RGB	B	G	R	RGB	B	G	R	RGB	Data Hidden Color Channel	
																MSE	SSIM
16,58539	14,16176	15,91743	29,57815	18,72251	15,48771	15,55569	27,86884	17,01260	14,15993	14,77478	25,00689	19,42972	15,44432	16,00046	28,28258	Sequential Data Hiding	
0,98954	0,98974	0,98785	0,99335	0,98886	0,98901	0,98705	0,99307	0,98902	0,98967	0,98754	0,99399	0,98830	0,98867	0,98660	0,99292	SSIM	
35,95281	36,66375	36,16813	33,49324	35,44943	36,27974	36,25547	33,74775	35,88927	36,69157	36,46222	34,19301	35,28446	36,27970	36,14950	33,67891	PSNR(dB)	
5,87822	5,61803	5,46792	4,58600	6,04077	5,55944	5,42123	4,42091	6,98472	5,77010	5,96752	4,32526	6,44789	5,63374	5,46789	4,42318	MSE	
0,99345	0,99321	0,99184	0,99657	0,99323	0,99344	0,99202	0,99682	0,99296	0,99338	0,99176	0,99642	0,99313	0,99320	0,99193	0,99673	SSIM	
40,49497	40,64446	40,77474	41,58724	40,34758	40,70093	40,81225	41,73558	39,83497	40,57982	40,44576	42,00837	40,11865	40,64964	40,80505	41,73350	PSNR(dB)	
5,82072	5,71166	5,43977	4,68531	6,01728	5,64714	5,42478	4,44882	6,95015	5,90026	5,94438	4,34834	6,46614	5,67114	5,46216	4,38641	MSE	
0,99347	0,99320	0,99186	0,99654	0,99326	0,99338	0,99201	0,99684	0,99295	0,99336	0,99177	0,99640	0,99311	0,99319	0,99193	0,99675	SSIM	
40,54114	40,57354	40,79572	41,50832	40,36387	40,63585	40,81652	41,71887	39,85260	40,48739	40,46826	41,99535	40,08431	40,61543	40,81112	41,76200	PSNR(dB)	

TABLE II. F5 EVALUATION RESULTS FOR 2ND SECRET MESSAGE

Shifting-Rotating				Rotating				Shifting				Fixed				Block Structure	
B	G	R	RGB	B	G	R	RGB	B	G	R	RGB	B	G	R	RGB	Data Hidden Color Channel	
																MSE	SSIM
16,65085	13,80906	16,05857	29,61747	18,40409	15,19655	15,62258	27,93537	17,21744	14,35816	15,07420	25,72180	19,50430	15,22152	16,03384	28,24593	Sequential Data Hiding	
0,98951	0,98974	0,98783	0,99338	0,98890	0,98907	0,98707	0,99306	0,98901	0,98966	0,98754	0,99393	0,98828	0,98868	0,98661	0,99293	SSIM	
35,93352	36,79008	36,12789	33,49091	35,51740	36,36165	36,23875	33,74405	35,84205	36,63257	36,37168	34,07474	35,26593	36,34932	36,14652	33,69937	PSNR(dB)	
16,39540	14,16997	16,11939	30,15025	18,63467	15,49231	15,68017	28,13180	17,27210	14,14195	15,08749	25,54192	19,45081	15,31536	15,96697	28,41786	MSE	
0,98951	0,98972	0,98780	0,99330	0,98886	0,98899	0,98705	0,99305	0,98897	0,98966	0,98749	0,99394	0,98829	0,98866	0,98663	0,99290	SSIM	
35,99598	36,67337	36,11764	33,42144	35,46264	36,27724	36,22233	33,71094	35,83367	36,69994	36,37738	34,11041	35,27312	36,32301	36,15932	33,66698	PSNR(dB)	
16,51589	14,20263	16,11879	30,22975	18,82014	15,73198	15,77238	28,79555	17,14424	14,41174	14,98693	25,67593	19,43744	15,62181	16,08534	29,02073	MSE	
0,98961	0,98983	0,98789	0,99333	0,98892	0,98908	0,98716	0,99306	0,98909	0,98972	0,98764	0,99399	0,98835	0,98879	0,98673	0,99294	SSIM	
35,97405	36,65962	36,11808	33,40890	35,43228	36,21221	36,20881	33,62261	35,86100	36,62278	36,40043	34,07828	35,28524	36,23865	36,14358	33,59038	PSNR(dB)	

Changes in MSE&PSNR values occur due to the change in the amount of data hidden in the video frame. If the amount of hidden data increases, it is found that MSE decreases and PSNR increases in the sequential data hiding algorithm. When non-sequential data-hiding in all frame algorithm considered MSE

increases and PSNR decreases if the amount of the hidden data increases.

When the SSIM quality metric is considered, it's seen that the rate of change in video quality is quite small whatever the proposed algorithms are used. It means that structural similarity between the frames is high and there is no noticeable change in the perceived visual quality of the video.

V. RESULTS

Data security is one of the most important issues of steganography. KBM structures used for data hiding in the proposed methods increase the security of the hidden data. The positioning of the key blocks, the variable pattern structures, the selective placement of the areas to be hidden in the pattern, direction and state controls, and shifting & rotating the pattern structure for each block increase the security of the hidden data for the proposed method.

In this study, video frame structures were analyzed before and after the data hiding process in order to observe the changes in video frames and the results obtained were presented.

No visual problems were encountered on the video frames during data hiding with the 8x8 DCT block structure that is used for F5.

There seems to be little difference between the best PSNR quality metric obtained from the proposed methods for each

secret message and the PSNR quality metric obtained using the "non-sequential data hiding in all frames" algorithm.

Considering data security, in line with the quality metrics obtained from the proposed methods for each secret message, the "non-sequential data hiding in all frames" algorithm and "shifting-rotating" block structure are recommended as the most successful of data security.

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Audio & Video Forensics – A New Direction for Electronic Engineering Lecturing

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Abstract—Across the UK, the number of students wishing to study a degree in Electrical/Electronic Engineering is on the decline, hence University departments need to find additional areas of teaching. Liverpool John Moores University has found one area where our knowledge of mathematics, signal processing and technology is pivotal in forensic analysis of audio and/or video recordings. The paper describes how we created an MSc in Audio and Video Forensics, the reasoning behind the course and its importance within the UK Criminal Justice System.

Keywords—*curriculum design, audio forensics, video forensics.*

I. INTRODUCTION

Merseyside Police are the UK police force centred around the city of Liverpool. In recent years, some of its senior officers had raised the issue that there was inadequate professionalisation for its law enforcement specialists in the areas of audio and visual forensics. At the same time research work at Liverpool John Moores University (LJMU) highlighted a significant gap between the technological capabilities of audio & video processing and the knowledge of these abilities by forensic operators and members of the UK Justice System. Through a chance meeting between members of Merseyside Police and LJMU staff, both parties recognised this common concern, and thus led to a decision to collaborate in an attempt to address the shortfall.

Additionally, it was noted that recent technological advances were not being utilised within the audio/video forensic sector, and that these advances could provide significant benefit for the processing of audio/video evidence. Furthermore, the UK's Forensic Science Regulator was making a number of proposed improvements across the forensic sector, with particular impact on audio/video analysis.

Staff and research students within the School of Engineering (SoE) at LJMU, work on a range of aspects of audio and video forensics within the UK Justice System, collaborating with colleagues from the School of Pharmacy and Biomolecular Sciences (PBS), and the School of Law, as well as members of the legal profession, the judiciary and the Ministry of Justice. The work encompasses a range of topics including technical aspects of sound localisation, audio zooming aligned with video zoom, removing distortion (from movement) in fingerprints using video technology, technological awareness within professionals working in the

justice system, and standards for audio/video evidence processing and analysis.

II. INITIAL IMPACT OF RESEARCH ON CURRICULUM

In relation to undergraduate teaching, there is Final Year module on '*Audio Restoration and Digital Enhancement*' on the BSc(Hons) in Audio and Music Production, which provides students with an introduction to the skills and methods required for forensic analysis of audio signals. The module has proven popular and well received, with excellent student module evaluation results. Additionally, SoE staff present sessions on the PBS Final Year module '*Advanced Forensic Methods*', which exposes students on the BSc(Hons) in Forensic Science to some of the latest technological systems available within the forensic world. Students have reported they found the sessions both enjoyable and informative.

The success of these modules led to the School of Engineering developing the MSc in Audio Forensics and Restoration, which was designed with the critical delivery aspect of in-depth knowledge development, practical application of skills and associated technological aspects related to modern and historical recording/playback devices. The programme includes a '*Courtroom Skills*' module offered by PBS. The success of the programme can be demonstrated by a number of students from the first cohort obtaining employment with the Audio/Video section within Forensic Units of various police forces including Cheshire Police, Merseyside Police and West Midlands Police.

III. EVIDENCE IN THE UK LEGAL SYSTEM

'Evidence is the information with which the matters requiring proof in a trial are proved' [1], with Munday [2] stating '*the evidence of a fact is that which tends to prove it... something that may satisfy an inquirer of the fact's existence*'. Arguably, in a court of law the principle of evidence is used to determine a belief in something [1], whether it is through verbal or physical evidence, such as witness testimony or fingerprint evidence. Thus, the notion of evidence is an extremely important factor, since it establishes the court's ability to not only detect but handle the possibility of both perverting the course of justice, and miscarriages of justice through doctored evidence or inappropriately analysed evidence.

All evidence, whether it is body fluids, fingerprints, audio, video, etc. must be handled correctly to avoid corruption or contamination [3], as Horsman and Sunde [4] state '*evidence*

must be reliable if it is to be used as part of any legal decision making'. Camacho et al. [5] state *'an audio recording can be used as evidence in a legal process only if the integrity of the recording is demonstrated... the file has not been manipulated either by the victim, the suspect or by a third part'*. This demonstrates the lack of knowledge and understanding within the justice system relating to possible manipulation of audio/video evidence since currently, there are no identifiable practices defined either by custom or statute to properly handle this type of evidence. For example, if the evidence introduced into court had already been manipulated prior to seizure by the police [5], this creates serious concerns regarding the fairness of the law [6].

A. Audio and video Forensics

Video evidence within the justice system is an ever-growing phenomenon, encapsulating different types of recordings such as from, mobile phones, vehicle dash cameras, CCTV, police body cameras, and Ring™ doorbells [6]. Examples of audio evidence are ever-present within the justice system [7], whether it is audio on a tape recording, recorded phone conversations or audio obtained through recorded police interviews, and of course video recordings that contain an audio channel [8].

The presence of such audio/video evidence throughout the justice system creates a range of complex issues [9], highlighting the need for debate around court processes and procedures, and the awareness of legal professionals, of both handling and understanding the physics/technology of this type of evidence, e.g. how a camera lens might distort an image.

The British Standards Institute [10] assert *'an organisation should adopt policies and plans to assure the preservation of digital evidence and... the organisation should maintain processes that assure the integrity of investigations, the independence of experts, and the evidential value of binary information'*. Thus, it is concerning to note that within the UK, police forces currently have no agreed national standardised processes or procedures to establish, maintain or preserve the integrity of audio/video digital evidence [11]. This often leads police forces to adopt policies and procedures at a local level which potentially leads to inconsistencies in the delivery of justice outcomes.

The case of Victoria Breeden [7] demonstrates how law authorities are sometimes blind to the possibility of manipulation of digital evidence, particularly audio [7]. This case involved a recording of Breeden stating *'how easy would it be to make someone disappear'* [7], with respect to hiring someone to kill her ex-husband. In this instance, the police took the recording at face value, apparently carrying out no work to determine the authenticity of the recording since it was made by a third party.

IV. ISSUES WITHIN THE UK JUDICIAL SYSTEM

Considering the lack of information currently available [12], it is clear that many professionals within the UK justice system are unaware of the technological capabilities of audio/video editing software. This situation presents a serious issue within the justice system, because not only are legal professionals not looking for manipulated evidence, but, even

if they were, they may not notice [10]. As Lv et al. state [13], *'digital audio recording is much convenient nowadays... even non-professionals can modify audio without leaving any visible traces'*, for example the free software Audacity (audacityteam.org), is simple to use whilst having powerful audio editing/mixing facilities.

UK family lawyer Byron James represented a father in a child custody case where manipulated audio recordings were presented by the mother as evidence of the father's inappropriate behaviour. After the court case James stated, *'this was the first instance in around 30 years of legal practice that he had seen such a case of 'deep faking''* [6]. Further, James argues, *'courts take evidence such as audio recordings, visual footage and written documents at face value'*, when in reality courts should be sceptical, adding, *'the whole legal system needs to catch up, it's not good at technology, there are really easy ways to manipulate the system'* [6].

It is obvious that audio and video recordings are now an inherent part of everyday life and are key technologies for both the general public and the police service [14]. However, evidence showing police awareness of how such evidence can be manipulated is sparse, arguably suggesting that they are still unaware of technological capabilities, and their associated malicious capabilities [14].

Similar to police officers, the majority of Audio/Video Evidence Operatives¹ (AVEO) are sometimes unaware of such technological capabilities, and their far-reaching capabilities [14], deepfakes being one area of particular concern [15]. This is illustrated through the expectations of the qualifications for AVEOs, where many UK police forces do not require a degree qualification and frequently do not even expect proven knowledge of audio/video theory. Arguably, AVEOs need to be appropriately aware of both theory, as well as technology and its capabilities since audio/video evidence is widely used in criminal proceedings [3], which potentially might have been manipulated or faked.

V. CREATING THE MSC IN AUDIO AND VIDEO FORENSICS

In 2019 the UK Forensic Regulator, Dr Gillian Tully, wrote in her annual report to the UK Government *"The reality is that forensic science has been operating on a knife-edge for years, with particular skills shortages in digital forensics. It is important that our ability to use science effectively in the criminal justice system does not lag behind technologically-enabled criminals. Quality is not optional. Standards need to be implemented across the board if the sector is to learn from the past and improve for the future"* [17].

The UK recently passed a law giving the Forensic Standards Regulator the statutory powers to close-down and potentially prosecute forensic service providers who do not adhere to the codes of practice [16], with all UK police forces working towards compliance.

The above plus the earlier issues detailed in Section IV, along with the authors' knowledge of audio/video signal processing, artificial intelligence, legal proceedings and forensic science were the driving force behind developing a postgraduate study programme aimed at current and future audio/video forensic operators.

¹ Across the UK a range of job titles are used to describe any role related to the forensic analysis of audio and video. For ease, in this

paper the term Audio/Video Evidence Operatives is used to describe these roles.

A. Requirements Specified in Job Adverts

Programme Teams use their academic knowledge and industrial experience to help them design the curriculum and assessment of a programme, as well as utilising input from a group such as an Employer Consultative Panel. This combination should provide students with an educational experience that gives them knowledge and skills required for gainful employment. This process, however, does not consider a significant resource that is underutilised, namely the requirements actually detailed in job adverts.

It is necessary to institute a more valuable interchange between Programme Teams and market demands, particularly with respect to transversal competencies. For effective professional work, beyond all the technical knowledge, it becomes ever more important for Forensic professionals to develop appropriate skills and attitudes such as communication skills, teamwork, self-reflection, critical review and time management amongst others. Thus, it is extremely important to identify which skills police forces and forensic services require from their employees.

We ascertained and analysed the expectations of the current employment market for audio/video forensic technologists with respect to knowledge, abilities and skills. We extracted job adverts from UK police forces, and then identified and quantified the transversal competencies demanded by the employment market. An exemplar job advert can be seen in Table I.

TABLE I. EXEMPLAR FORENSIC JOB ADVERT

Full Job Description	
An exciting opportunity has arisen for a Forensic Audio Visual Technician to join Thames Valley Police on a permanent basis, to provide specialist support in the forensic preservation, recovery, enhancement and presentation of multimedia material.	
In this role you will preserve, extract, analyse, copy and repair analogue and digital multimedia evidence at a scene or in the laboratory by using various specialist computer-based hardware and software to deliver an evidential product on a range of media to internal and external customers. As well as, enhancing and editing analogue and digital multimedia evidence as required by using various specialist computer-based hardware and software in order to achieve the highest evidential standard.	
The successful candidate will have a good standard of education including excellent numeracy and literacy skills with recent experience in report writing. You will also have proven, detailed and extensive knowledge of video and audio principles, including different formats, and editing hardware and software.	

Through analysing the core competencies demanded in the audio/video forensic job market, we were able to reflect on how well academic programmes are currently developing these abilities/skills in students. In addition, the industry itself requires certain attributes: standards for procedures and personnel are consistently evolving with the Criminal Justice System now demanding ISO 17025/27037 accredited laboratory standard procedures for Digital Media work [18]. Using both sources led us to being able to appropriately define the curriculum, teaching and/or assessments to help students fully develop these competencies during their studies and thus increase their knowledge, capabilities, employability and professionalism.

B. Course Design and Content

Discussions with senior officers from Merseyside Police led to the idea of developing an MSc in Audio and Video Forensics. This programme focuses on the technological

theories and systems crucial to the forensic investigation and analysis of audio/video evidence. The programme was designed such that students can undertake a Postgraduate Certificate (60 credits) covering the fundamental knowledge and skills, or complete a Postgraduate Diploma (120 credits) after studying the more advanced features of audio/video forensics, or students can complete an individual project to gain the full MSc award (180 credits).

Having determined the general structure of the programme, we turned to the curriculum. During this phase, Merseyside Police practitioners were instrumental in the course design. Their practical implementation knowledge provided the basis for the syllabus, and ensured that the curriculum met the needs of the police and the community.

Teaching contact is approximately five hours per week per semester, with self-study bringing the total study time to 20 hours per week. Teaching within modules is normally through online sessions delivering core knowledge and underpinning theory which is reinforced by the use of tutorials and practice sessions. During the practice sessions, a student-centred approach is normally taken, aimed at encouraging students to “*learn by doing*”. Learning is heavily focused on applied learning related to the work many of the intended applicants will do on a daily basis. The modules for each award level are presented in Table II.

TABLE II. PROGRAMME CONTENT

Postgraduate Certificate	Audio Forensics CCTV and Video Forensics Forensic Standards, Regulations and Procedures Media Formats
Postgraduate Diploma	Research Skills Advanced Audio Forensics Advanced Video Forensics Artificial Intelligence, Deepfakes and the Future
MSc	Dissertation (project)

Each module in the course has been specifically designed to build and broaden the skillset students may have already built up in their current role or developed in allied areas of study to the professional disciplines of Audio/Video forensics. Furthermore, the modules are intended to help convert current related qualifications and/or skills into high value specialisms that can serve the many industries that now require qualified informed audio and video forensic expertise.

The Audio and Video Forensics modules develop or enhance students' careers with the police. Additionally, the Forensic Standards module provides students with skills and knowledge that are equally applicable for work with the new professional private investigative services operating in this ever-expanding industry. While the Artificial Intelligence module provides students with an indication of the theory and applications of AI in audio/video systems with a particular view towards deepfake technology.

The programme has two entry points a year as well as being part-time in delivery, to provide employed AVEOs with every opportunity to enhance their skills and knowledge.

C. Course Philosophy and Teaching approach

One of the central tenets of the teaching philosophy is that the programme is 'Student Focused' which translates into caring for our students to give them a transformational University experience.

Another tenet is that SoE and PBS staff are seen as facilitators as well as educators, not just for the students but also for police forces, and our other collaborative partners. This is partially accomplished through our partnerships, leading to us using the latest world-leading audio/video forensic software for teaching and assessment purposes.

In relation to audio/video theory the teaching approach employed is to focus less on the mathematical underpinning but rather concentrate on the forensic application and related consequences. Thus teaching is highly practical in its approach. This extends to the assessments utilised within the programme, which frequently require students to undertake critical review of another student's piece of work – similar to the work undertaken by prosecutor and defence lawyers during a court case.

Programme design was geared to also support and adhere to the plans set out by the Forensic Capability Network (fen.police.uk) published in their 'Digital Forensic Science Strategy' [19]. This document outlines that compared to other forensic disciplines, digital forensic science requires that continual learning is critical to the maintenance of a capacity to handle emerging technologies. The report goes on to state "*We need a multifaceted approach, encouraging practitioners to take responsibility for their own development and to make continuous learning part of their day to day work*" [19]. The report also proposes a 70:20:10 Model of Learning, where 70% of learning is through doing the job, 20% comes from colleagues and 10% from formal learning activities, such as academia. These recommendations were incorporated into the MSc programme design.

In addition to our computing resources, we utilise the University's Exemplar Houses for CCTV footage as part of their functions as Crime Scenes. This is linked to an Exemplar Audio/Video Analysis Laboratory (designed to comply with ISO 17025/27037) that we are developing which will allow students to gain hands-on experience in a controlled environment. This is part of the need to move quickly and adapt to the fast changing regulatory requirements.

D. Working In Partnership

During the design, development and implementation of the MSc programme we have collaborated with a range of organisations as illustrated in Table III. It is only through this wide-base of collaborators that we have been able to ensure a postgraduate programme that sits at the cutting-edge of audio/video forensics.

Since the launch of the MSc programme, other organisations and commercial companies started discussions with us, including Cedar Audio Ltd. who are a leading supplier for law enforcement, security, anti-terrorism agencies and military intelligence. This has led to LJMU becoming the first University worldwide to have the CEDAR Cambridge Forensic System software for teaching. This system is one of the leading systems for speech enhancement. This enhancement to our teaching resources means that students on the MSc are learning not just the latest theories, but also

gaining experience using the cutting-edge software tools used across the world by leading law enforcement agencies.

TABLE III. ILLUSTRATIVE COLLABORATIVE PARTNERS

National Organisations	Police Forces	Commercial Companies
Chartered Society of Forensic Sciences	Cheshire Constabulary	AMPED Software
College of Policing	Merseyside Police	iZotope
Forensic Science Regulator	Suffolk Constabulary	
House of Lords	West Midlands Police	
National Police Chiefs' Council		

E. Initial Outcomes from the Programme

The first cohort comprised 21 students, with 18 coming from Merseyside Police - where the Police are funding the students as part of the National Police Chiefs Council plan to improve UK national standards in audio and video forensics.

We were fortunate to have the former UK Forensic Science Regulator Dr Gillian Tully accept the role as External examiner for the MSc programme, providing both the academic rigour and regulatory conformity for the programme. Thus far, Dr Tully has been pleased and impressed with the programme, complementing the approach, students and assessment.

Furthermore, while working on their assignments when the AVEOs identified any issues it empowered them to debate and think about how processes and tools could be utilised in a manner that maintained forensic integrity, and followed current Multimedia handling guidelines. Their results are now being fed into building informed work disciplines, thus the exercise helped the AVEO teams understand the true value and impact of using such tools and could communicate that to colleagues and decision makers within the police.

The material taught in the course has helped AVEOs to justify the use of a variety of filters within the software systems because they now understand the theory behind them. In addition, it supports the AVEOs in understanding and explaining the capabilities and limitations of software systems to their colleagues from other departments, police officers and supervisors, which encourages teamwork, collaboration and so on.

It is often the case that it is police officers who are sent to the crime scenes to download the audio/video material instead of the AVEOs. Frequently these people lack knowledge of the process resulting in twice the time spent to obtain the same footage, because AVEOs usually have to go to the crime scene to correctly gather the evidence. This risks the video being deleted by the time it is realised that the initial download was unsuccessful. In addition, police officers often screen capture the video or record it with their phones/body cams and think that this is an equivalent of getting a copy of the stored video. Empowering AVEOs with appropriate standards and enhanced knowledge means that they can take a professional position over police officers and insist that audio/video evidence is collected by them following set processes and procedures.

VI. VIEWS FROM AN END USER – MERSEYSIDE POLICE

A significant partner during the whole process has been Merseyside Police, and Detective Superintendent Helen Bennet in particular. Det. Supt. Bennett is tasked with helping develop the digital capabilities within Merseyside Police with a particular focus on the Forensic Unit. When appointed to the role she inherited a CCTV Unit with little to no professional development, little diversity of thought, minimal investment in people, and technology. There has been an exponential growth in digital devices and digital recording opportunities in society, leading to a far greater expectation for digital legitimacy within the Criminal Justice System.

The journey of collaboration between Merseyside Police and LJMU commenced (School of Engineering, and School of Pharmacy and Biomolecular Sciences) to strive towards integrity within police Digital Forensic practices, such that the staff within the Audio/Video Forensic Unit were given the right knowledge and skills, and had pride in the work they undertake. Merseyside Police brought the evidential requirements expertise, while LJMU brought the technological expertise. The outcome is that together we devised a set of postgraduate awards to professionalise the discipline and hence be a lead in the UK and across Europe.

At an early stage of the development of the MSc, Det. Supt. Bennett commented *“There are high expectations of our people with no training/professionalisation with none available in the world that was fit for UK law enforcement”*. Det. Supt. Bennett also stated *“Collaborating with staff at Liverpool John Moores University means that we are working with like-minded people who are positive about advancement and change”*.

After students had completed just a fraction of the programme, Det. Supt. Bennett said *“I am bursting with pride that we now have a professionalised, enthusiastic, progressive, diverse visual evidence workforce....and now forces from around the UK visit us at Merseyside Police to see best practice in action”*.

VII. CLOSING COMMENTS

The research undertaken at LJMU into audio and video forensic technology and standards has had a clear and direct impact on the modules and programmes delivered. Further, the link between curriculum, employability and skills enhancement is very clear. On the small scale, *‘Audio Restoration and Digital Enhancement’* at Final Year provided the springboard for developing the MSc in Audio Forensics and Restoration, which in turn has had a number of its graduates gain employment within the Forensic Units across a number of Police Forces in the UK.

Across all the programmes involved, student module evaluation has been extremely positive, with students providing feedback on how the skills and knowledge gained has been very beneficial in them gaining employment in careers either directly or indirectly related to audio/video forensics.

Our teaching and research work has been recognised by television companies (both UK and EU) who wish to use our expertise in upcoming documentaries on criminal cold-cases. In addition, the range of taught programmes & modules offered has attracted interest from world leading companies in audio/video forensic software, resulting in the School of Engineering having licenced copies of top-class software used

by Security Services and Police Forces around the world. Recently, the team have been working on creating materials for outreach events at schools and colleges to attract younger people to the field of audio/video forensics.

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EVALUATION OF THE POWER TRANSFER CAPABILITY OF INVERTERS CONNECTED TO SOLAR PANELS, DEPENDING ON THE CHANGE IN GRID VOLTAGE

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Abstract. In the article, it is considered that the capability curve of the inverter depends on the network voltage, which serves to connect solar photovoltaic stations to the electric network. It was observed that if the voltage of the grid falls below the nominal value, the ability of the inverter to transmit active power and the ability to transmit or consume reactive power are significantly reduced. When the grid voltage was changed to +15%, +10%, -5%, -10% and -20%, the power transfer capability of the inverter showed the lowest result at +15% and the highest result at +10%. At the nominal value of the grid voltage, the inverter is shown to operate at its nominal power transfer capability.

Key words: inverter, grid voltage, solar panels, active power, reactive power, capability curve of inverter.

I. INTRODUCTION

In the world, renewable energy sources have managed to enter the electric power system at high rates. Today, everyone understands that renewable energy sources, including solar and wind power plants, are absolutely harmless, and are also related to the efficient use of natural resources and the protection of the environment [1].

In our country, large-scale work is being carried out in this regard, including the 100 MW Solar Photoelectric Power Station, which has been commissioned in the Karmana district of the Navoi Region, the 100 MW Wind Power Station being built in the Beruni district of the Republic of Karakalpakstan, and similar stations that will be

built by large investors until 2030 on the scale of the Republic.

As we know, it is an important task to maintain the voltage in the electric power system, and for this, the national dispatch center has set various requirements for the power generating stations in this regard [5; 8]. One of these requirements is the ability of the station to generate reactive power when needed. The reactive power transmission capability of the inverter, which converts direct current into alternating current in solar photovoltaic stations, determines the reactive power transmission capability of the entire station. In this article, the requirements for reactive power transmission to solar photovoltaic stations, the active and reactive power transmission capabilities of the inverter and how they depend on the grid voltage are considered.

II. MATERIAL AND METHODS

In the modeling of the solar photoelectric plant, it is defined as a voltage source that converts direct current into alternating current and is connected to the network, and in each of its phases there are two IGBTs (*Insulated-gate bipolar transistor*) and a transformer. Considering that these devices have inductive properties [2], it is defined as L_f . As a three-phase voltage source, the electric network is defined as its inductance L_g , and the total active resistance is not considered (Fig. 1).

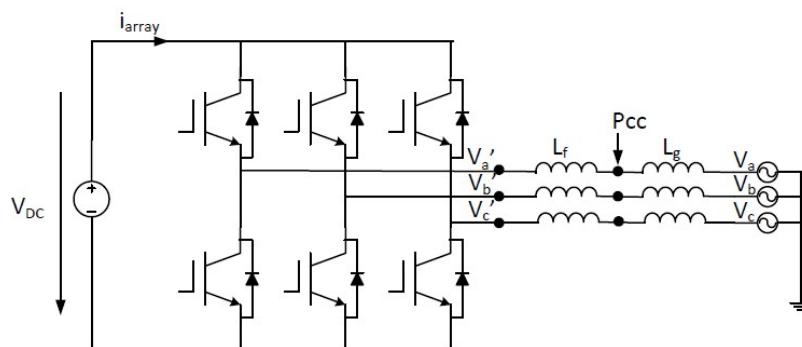


Fig. 1. PV inverter interconnected with the grid

When converting DC to AC through the inverter, a modulation method was used that maximizes the current being close to a sinusoid [3]. The dependence of the inverter output line voltage ($V_{a'b'}$) on the constant voltage (V_{DC}) at the inverter input and the modulation index (M) represents

PWM-pulse-width modulation (Fig. 2). If the modulation index is between 0 and 1, the variation of AC with respect to DS will be linear. But when the modulation index exceeds one value, the AC/DC loses its linear variability and the

$$V_{a'b'} = M \frac{\sqrt{3}}{2\sqrt{2}} V_{DC} \quad (1)$$

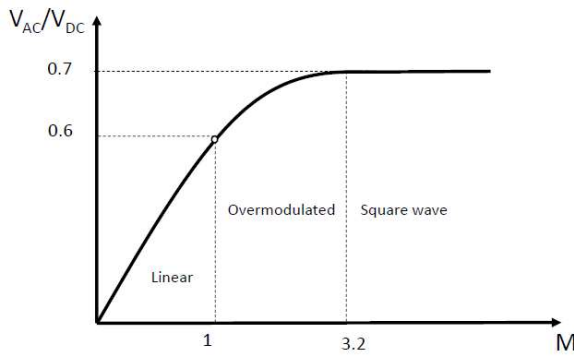


Fig. 2. Output voltage and dc voltage in relation with Modulation index

When the inverter output voltage change is $0 \leq M \leq 1$, the calculation is given in expression (1).

To analyze the inverter's power transfer capability curve, it is necessary to take into account the voltage, current and power limitations of the devices connected to it.

The active and reactive power that the inverter can transmit to the electric network is expressed by the following formulas:

$$P = 3 \frac{V_g V_{AC}}{X} \sin(\delta) \quad (2)$$

$$Q = \frac{3V_g}{X} (V_{AC} \cos(\delta) - V_g) \quad (3)$$

where V_g is the grid voltage, V_{AC} is the inverter output voltage, X is the total resistance to the common connection point, and δ is the angle between the grid and the inverter output voltage. The maximum power delivered to the network from the inverter is calculated as follows [6; 7]:

$$S = \sqrt{3} V_g I_{PCC} \quad (4)$$

where I_{PCC} is the current flowing from the common connection point, taking into account that $S = P^2 + Q^2$:

$$P^2 + (Q + 3 \frac{V_g^2}{X})^2 = (3 \frac{V_g V_{AC}}{X})^2 \quad (5)$$

Using the above formulas, the power transmission capability of the selected inverter was compared by modeling.

SG350HX type inverter is modeled and considered in DigSilent software. The technical data of the inverter is presented in Table 1.

Table 1

Inverter basic parameters	
SG350HX Inverter	
Type	SG320HX
Rated Power	295 kVA, 50°C(PF1)
Nominal AC output current	254 A
Nominal AC voltage	800 V
AC voltage range	640–920 V
Nominal grid frequency / Grid frequency range	50 Hz / 45–55 Hz
Power factor at nominal power / Adjustable power	> 0.99 / 0.8 leading – 0.8 lagging
Max. efficiency	99.01 %
Total Harmonic Distortion	<3 % (at nominal power)

III. SIMULATION & RESULT

Below, a model of a solar photovoltaic plant with one hundred inverters is created in *DigSilent*. The total production capacity of the station is 32 MW. The 0.8kV

voltage at the output of the inverter is first changed to 33kV and then to 220kV through step-up transformers and connected to the central power grid (Fig. 3).

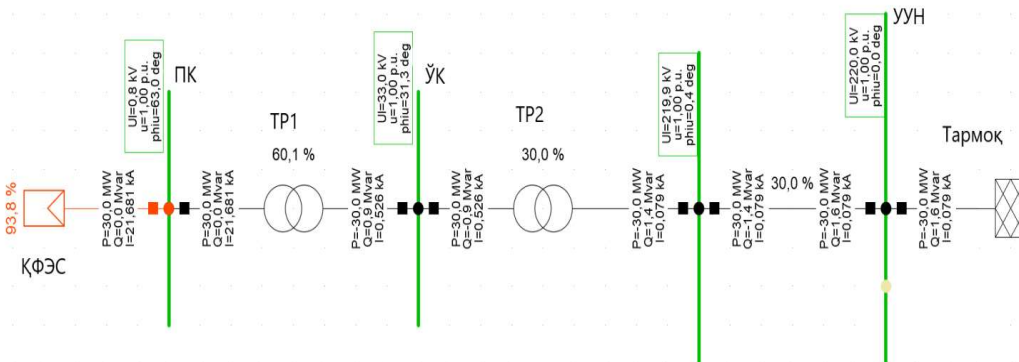


Fig.3. SG350HX Model of PV Plant in DigSilent program

Information provided by the manufacturer on whether inverters are inductive (capable of consuming reactive

power) or capacitive (capable of producing reactive power) is presented in Table 2.

Reactive power capability of inverter										
P_{PV} MW +Cap -Ind	0 ±	0.16 ±	0.18 ±	0.2 ±	0.22 ±	0.24 ±	0.26 ±	0.28 ±	0.3 ±	0.32 ±
V_g p.u										
0.9	0.211	0.211	0.211	0.211	0.19	0.17	0.13	0.	0.	0
1	0.211	0.211	0.211	0.211	0.211	0.211	0.19	0.15	0.11	0
1.1	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.15	0

Using the above information, the power transfer capability of the inverter is modeled in DigSilent software (Figure 4).

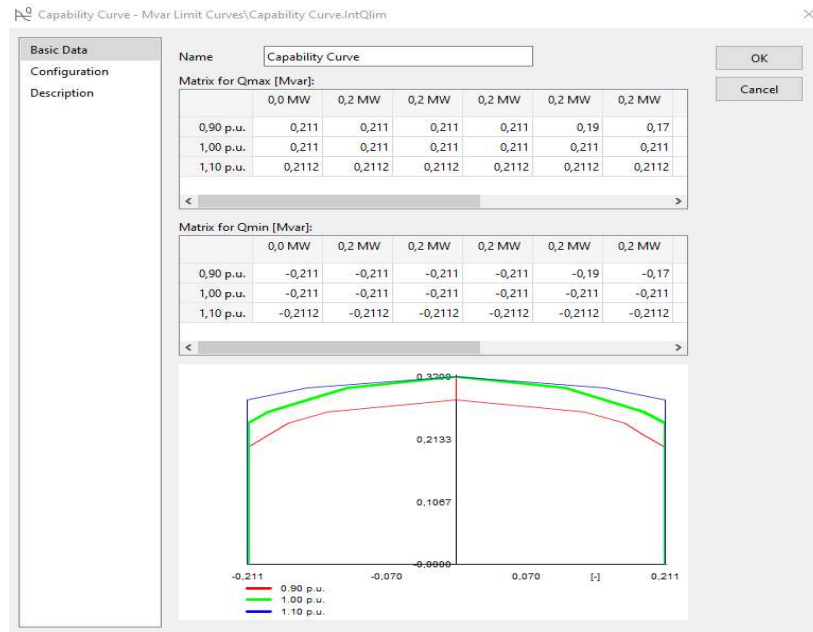


Fig. 4. SG350HX Inverter capability curve in DigSilent software

Consumers and producers connected to the central electricity grid, including power plants such as wind and solar, have high reactive power requirements. These requirements are reflected in the GRID CODE developed with the participation of the Ministry of Energy of the Republic of Uzbekistan and the World Bank.

According to it, the solar photoelectric station connected to the power grid should be able to transmit or consume reactive power based on the following conditions.

- able to capture the power factor at the common connection point at a value of 0.95;
- able to normalize the voltage drop at the common connection point through reactive power;
- able to consume 40% reactive power and deliver 35% reactive power compared to the maximum transmitted active power.

Based on the above conditions, when the station indicators were analyzed, the station clearly demonstrated its ability to provide reactive power.

Based on the condition of constant power factor, the ability of the inverter to provide active and reactive power is shown in Figure 5. When the grid voltage was 1.05 and 1.1, the inverter operated with 268.8 kW active power, 201.6 kVar reactive power and 336kVA total power. At rated voltage, 256 kW of active power, 192 kVar of reactive power, and 320 kVA were observed operating at their full rated power.

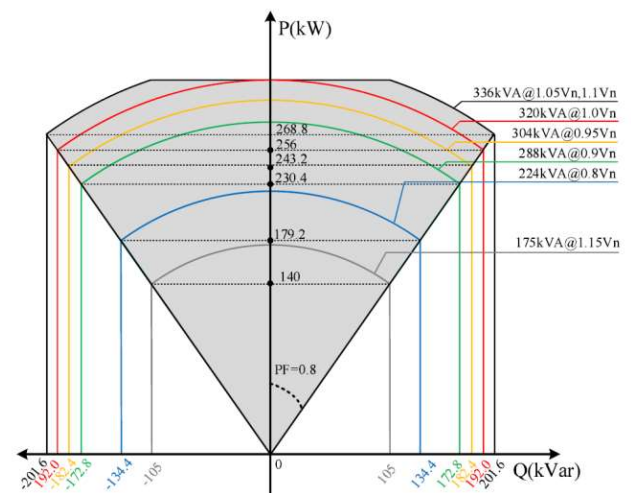


Fig. 5. Power transfer capability of SG350HX Inverter against grid voltage

When the mains voltage was 0.8, it was observed that the power transfer capability of the inverter was reduced, by producing 230.4 kW of active power and 134.4 kVar of reactive power, the full power transfer capability of the inverter was reduced to 224 kVA. The inverter showed its worst power transfer capability when the mains voltage exceeded the permissible +10% threshold value (1.15). According to it, the possibility of full power transmission through 140 kW active power and 105 kVar reactive power transmission was 175 kVA.

Thus, strict requirements are imposed on the ability to transmit reactive power to the solar photovoltaic power station connected to the central power grid. If the power transmission capabilities of the inverter used in the solar PV plant are satisfactory as discussed, the reactive power capability of the entire plant will be sufficient. If the power transfer capability of the inverter is not sufficient with

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October 6-7, 2022, Konya, TURKIYE respect to the reactive power, then it is necessary to install additional reactive power compensators in the solar PV plant before the common connection point. In addition, maintaining the voltage value at the common connection point at the nominal level ensures that the inverter can operate at its full potential. Exceeding the nominal value of the voltage at the common connection point is also considered extremely dangerous for the inverter, causing the station to not work at its full capacity.

Multi-scale thermo-viscoelastic modeling of PVC foam based on DMA test

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Abstract:

Cyclic fatigue loading on PVC foam specimens shows a temperature increase during the tests. This phenomenon is caused by to the transformation of the energy dissipated by viscosity of the material into heat and it is called self-heating.

In order to predict the properties of the PVC foam in fatigue loading, the self-heating phenomenon has been experimentally demonstrated and modeled according to two methodologies.

The experimental tests carried out consists of a torsional fatigue tests on a PVC foam specimen under different loading cases. These tests aim to determine the effect of the loading level and the frequency on the phenomenon of self-heating.

The first finite element model is based on a UMAT subroutine developed on Abaqus and contains the viscoelastic behavior of the material. On the other hand, the second finite element model was developed using the DMA test results. The second model presents a good agreement with the experimental results and a strong thermomechanical coupling than the first model.

Keywords

PVC foam beam, self-heating, DMA, bending test, strain measurement, finite element model

Green IT: An option or necessity

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Abstract— The energy consumption of data centers has been increasing significantly especially since the pandemic. Total electricity consumed by data centers in world has increased by 56% from 2005 to 2010. The fraction of the electricity consumed in datacenters made up 1% of the global electricity consumption in 2020. Data centers are estimated to be responsible of 13% of the energy consumed in the world by 2030. The exponential increase of electricity consumed in data centers indicates the requirement of urgent action. There are many subunits that consume electricity in data centers. Measures can be taken separately in each of these sub-units. Green IT covers the measures to be taken in this area. Today, green IT has ceased to be an option, it has become a necessity.

Keywords—Green IT, data center, energy efficiency.

I. INTRODUCTION

Server performance demand and the data size of the data centers is increasing significantly which results in increase in electricity consumption. Data centers consist of sub-units such as Uninterruptible Power Supplies, Power Distribution Units, cooling systems, servers, switch devices, and data storage arrays. Cooling systems of data centers consume nearly 38% of the electricity, IT equipment 52%, and 10% the remaining equipment [1]. The total electricity consumed in DCs has increased by 56% between 2005 - 2010 [2] and which consists of 1% of the global electricity consumption in 2020 [3]. Data centers are foreseen to consume 13% of the electricity worldwide 2030 [4].

Green IT is a term that refers to environmentally sound IT systems, applications and practices. Green IT comprises of three complementary IT-enabled approaches to improve sustainability as shown in Fig 1.

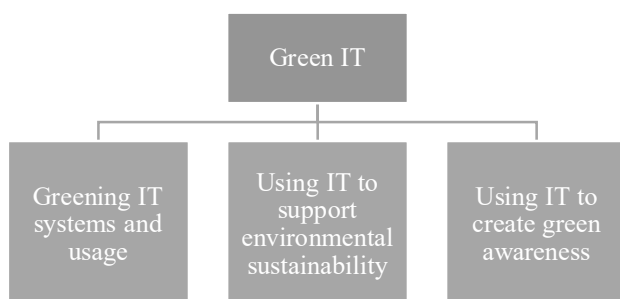


Fig. 1 Dimensions of Green IT

Efficient and effective design, manufacture, use and disposal of computer hardware, software and network systems is the first key of Green IT. Then it is significant that the IT and information systems to empower, that is, support, other

enterprise wide environmental initiatives. Finally, the harnessing of IT to help generate awareness among people, stakeholders and promote the green agenda and green initiatives [5].

Green IT is not dealing with energy-efficient IT systems (hardware, software and applications), but also with the use of IT to green.

To address the environmental impacts of IT, a holistic approach that addresses the problems has been developed [5] which are;

- Green design. Design energy-efficient and environmentally sound components, computers, servers and cooling equipment.
- Green manufacturing. Manufacture electronic components, computers and other associated subsystems with minimal or no impact on the environment.
- Green use. Reduce the energy consumption of computers and other information systems, and use them in an environmentally sound manner.
- Green disposal. Refurbish and reuse old computers, and properly recycle unwanted computers and other electronic equipment.
- Green standards and metrics. These are required for promoting, comparing and benchmarking sustainability initiatives, products, services and practices.
- Green IT strategies and policies. These effective and actionable strategies and policies add value and focus on both short- and long-term benefits. These are aligned with business strategies and practices, and are key components of greening IT.

Of late years, nearly zero, zero or positive energy data centers have been developed, of which's energy demand are meet by renewable energy systems.

II. GREEN DATA CENTERS

In order to reach zero energy data center target, first energy demand has to be minimized by using energy efficiency devices, energy management systems and energy aware softwares. In addition, waste heat produces by IT equipments will be used for heating of buildings. Then the minimized energy demand will be supplied by renewable energy systems.

Zero energy consumption data centers consume zero fossil based energy during and generate as much renewable energy as they consume on annual basis [6].

Especially in mega-size data centers with huge data storage sizes, many studies are being carried out in order to achieve the goal of data centers with zero energy consumption. Free cooling system is the indispensable of zero energy data centers. Data centers of Apple located in Ireland, and Denmark are powered by 100 % renewable energy. Wind turbines near the Denmark produce 62 GWh/year electricity. The surplus energy is given into the grid. In addition to wind turbines, photovoltaic power plant is installed to supply energy to the Apple. The wind and solar power plants supply energy to the Apple's newly completed zero energy data center [7].

Similar to Apple, companies with high data areas are making plans to build zero energy data centers supplied by renewable energy systems. Parasol is a research platform green DC which is composed of a energy system of PV panels, a battery bank, and a grid connection. GreenSwitch model dynamically schedules the workload and selects the available source of energy. Energy management in data centers may reduce the cost significantly [8]. LuxConnect is another company that makes green solutions for data centers. LuxConnect's energy demand is supplied by hydroelectric dams in Norway and Pv panels [9].

Lefdal Mine is one of the most efficient data centers of Europe. Lefdal Mine is located in Norway. It is situated next to a deep which saves the data center from sun shine and extreme air conditions. The supply of energy is obtained from hydroelectric dams. There are six levels underground which are divided into 75 chambers with a potential white space area of 120.000 m². The underground plan of Lefdal Mine is given in Figure 1 [10].

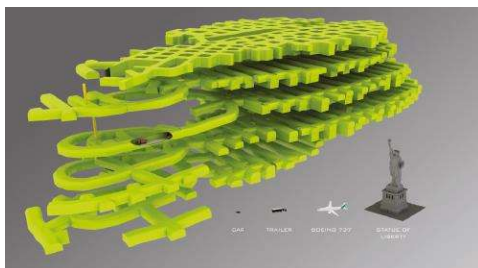


Fig. 1 Underground floor plan of Lefdal Mine

The cooling system of Lefdal Mine is given in Fig. 2.

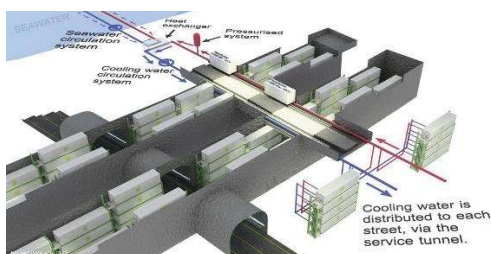


Fig. 2 The cooling system of Lefdal Mine

The cooling solution of Lefdal Mine leads to a PUE of 1.08-1.15. Less than 3% of the power spent on IT is used for cooling with a 5 KW/rack configuration. Cooling system of Lefdal Mine is based on circulation of cold seawater through a heat exchanger. The seawater is 8 C seawater year around [10].

A. Free cooling systems

The most practical way to decrease the electricity consumption in old data centers is to upgrade cooling system. Nearly 70 % of DCs are being cooled by floor standing cooling systems which consume electricity close to IT systems. These data centers have Power Usage Effectiveness (PUE) values of 1.7 or higher [11]. The PUE is the ratio of the total electricity consumed by a data center, to the electricity consumed by IT. Next generation DCs, that combine energy optimization of servers with cooling infrastructure, can lower PUEs to almost 1.1 [11]. New technologies are introduced to reduce the cooling demand of the DCs. Nowadays free cooling system is the most favorable cooling system that makes use of cooler environments such as outdoor air, lake water, and seawater to cool the data centers.

Free cooling systems is the key equipment of zero energy consumption data centers. Free cooling system makes use of cold outdoor environment through a heat exchanger in case of low outdoor temperature. Performance of a free cooling system is related to the geographical location of the data center.

The widely used two kinds of free cooling systems are airside and water side systems. On that account, cold climates yield higher electricity savings. Water side free cooling system circulate water pipes through data center. Water pipes are getting warm by the heat removed from IT devices. Hot water is transferred to the outdoor environment by pumps and lamellas with extensive surface area are used to cool the water in outdoor environment.

Free cooling system operates at three modes according to the temperature of outdoor environment which are free cooling mode, partial free cooling mode and mechanical cooling mode. System runs at free cooling mode when outside air temperature is lower or equal to desired supply temperature and at mechanical cooling mode when outdoor temperature is equal or higher than return temperature.

In addition to the water or another liquid, air can be used as a heat transfer medium. Airside free cooling transfers the outside air to the inside which may lead to the transfer of particules in air to the data center, increase in humidity and corrosion of IT components. Risks are eliminated by indirect airside free cooling [12].

B. Waste heat reuse systems

Data centers produce hot air during 12 months. The hot air should be removed from data center rooms. The hot air, which is the problem of the data center, is the need of another environment. Therefore, waste heat reuse systems are developed to make use of waste heat in data centers which transfer the waste heat to the indoor spaces that have to be heated. Different type of waste heat reuse systems are developed that use different liquids [13] and absorption cooling machines [14]. Lefdal Mine Datacenter makes use of the heat emitted from IT equipments. The cooling system of Lefdal Mine transfer the heat to the heat exchangers. The heated return air is transformed to heated water and then transported back to the heat exchangers where the cold sea water is heated and transported out of the facility. This heated return water Lefdal Mine Datacenter aim to use to reduce the footprint for the facility and our customers. Currently we are working on several projects on how to optimize the effect obtainable from the heated water [10].

C. Green Data Storage

Data storage requirements are growing drastically. Storage systems in data centers consume significant amounts of energy, mainly between 24% and 40% of total IT power usage. So, besides making IT equipment energy efficient, the design of the data makes importance [5].

Several approaches including MAID (Massive Array of Idle Disks), disk spin down, tiered storage and solid-state drives (SSDs) are being used to decrease the electricity consumption. At system-level, storage virtualization, thin provisioning (TP) and data de-duplication techniques reduce storage area demand and relatively energy consumption.

D. Green Software

Algorithm of the software affects the response time and relatively energy consumption in data centers. Software affects the overall energy consumption and computational efficiency.

Green software is environmentally friendly and can be classified into four categories [5]:

- Green Software consumes less energy to run;
- Embedded software that assists other things in going green (smart operations);
- Sustainability reporting software, or carbon management software (CMS) makes awareness;
- Software for understanding climate change, assessing its implications and forming suitable policy responses.

Sustainable software development refers to creating software supplying environmental requirements and awareness. During development stage of the software, modifiability, reusability and portability and performance attributes should be taken into account. The computational time, efficiency, usability and dependability are the indicators of software's environmental impact.

III. CONCLUSION

This study refers to the measures to be taken on energy efficiency in data centers whose energy consumption is increasing rapidly.

The demand on server performance and the data size of the data centers and relatively electricity consumption is increasing significantly. The precautions to slow down the increase in electricity consumption of data centers are free cooling systems, waste heat reuse systems and utilizing energy efficient IT equipments. In addition to the physical systems, the software, data storage design and network traffic should be optimized to decrease energy consumption. Finally the location of the buildings should be selected to minimize

the cooling demand. In case all these precautions taken into action, energy demand of the data center can be minimized. The lowered energy demand is easily will be supplied by renewable energy systems and the way to reach the goal of zero energy consuming data center will be opened.

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An Innovative Guide System Design and Simulation in Weld Seam Tracking

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Abstract— In processes conducted with welding robots, distortions may occur as a result of thermal deformations, especially in materials with high thicknesses. These shape distortions can be detected with the sensor systems connected to the end effector, which is the last joint of the robot system. As a result of these deformations, the weld bead path may change, and the position information previously introduced to the welding torch may also be incorrect. In order to find a solution to this problem, bead tracking systems using laser-based sensor have been developed. Although laser sensor systems have many advantages, they also have some disadvantages. This study aimed to develop an innovative Guide system as an alternative to laser seam tracking. The design studies of the system were completed with the Solidworks program and modeled with the PID algorithm in the MATLAB Simulink program. In Simulink software, the main elements of the Guide system were angle sensors, and values in degrees were obtained from these sensors at certain time intervals. When it was determined that there was a difference between these values and the degree values defined as the reference, optimizations were applied to the system in order to minimize the error at these points. It has been tested in the RoboDK simulation environment that the lead system can detect this situation in cases where deformation may occur even if fixtures are used in the weld seam tracking. As a result of the simulation, it has been observed that the robot system can rearrange the joint angle information and the system can continue to follow the weld seam without any problems.

Keywords— *Guide System, Weld Seam Tracking, MATLAB Simulink, PID*

I. INTRODUCTION

Welding is a method used especially for joining metal or thermoplastic materials. Welding is done by using heat and pressure separately or together. Welding, which is used in many areas of production and assembly, is an especially important operation in the modern world. Gas metal arc welding, on the other hand, is a type of welding that provides a high amount of metal per unit time, can be processed quickly, and can be used in all positions. This type of welding, which allows joining of the wire electrode by melting, has been widely used in the manufacturing industry since the 1940s for the welding of a wide variety of iron-based products and non-ferrous metals [1]. Among the mixed gases used with this source, inert gases such as Helium and Argon are preferred in stainless steel processes, and active gases such as CO₂ are preferred in carbon steel processes [2].

Gas metal arc welding is carried out with three different methods, manual, mechanized, or robot-assisted. The manual welding method is an operator-driven process. In the mechanized method, the welding tool is carried out by a fully mechanized machine instead of by hand. The manual welding method can be used in spot welding, which is the preparation phase of the robot-assisted welding process. However, one of the disadvantages of the manual method is that processes cannot be carried out stably with individuals who do not have sufficient training and experience. However, it is difficult to keep the weld quality and thickness at the same level with this method. Compared to this method, robot-assisted systems are much faster, the probability of error is very low and there are no working time restrictions [3]. For these reasons, the transition to robotic welding in the manufacturing industry has accelerated.

A fixture is a tool used to fix or position the workpiece in welding processes. In robotic welding applications, three different systems are used in autonomous arc welding, which is used to manufacture with or without fixtures and to weld various parts in the same workstation. These are the gap to weld detection and tracking method with a laser sensor, the gap to weld detection method by touching, and the gap to weld tracking methods by arc [4]. The most preferred among these methods is the laser sensor method.

The main purpose of laser systems in bead tracking is to determine the position of the gap to be filled with welding due to thermal expansion or errors while fixing the part with the fixture, in real-time without contact, and to control the welding torch position accordingly. However, these sensors are not very efficient on materials with glossy surfaces and their costs are quite high. The study aims to design and simulate an innovative, contacting Guide system with mechanical feedback that can perform the same function instead of laser sensor systems.

II. LITERATURE STUDIES

Studies have been conducted on the use of laser sensors in weld seam tracking. In their study, Wei and Radovan created an image processing-based system with a laser sensor. This system consists of a laser diode module, an image acquisition module, and a motion control module. With these modules, the welding process could be controlled, and the results could be monitored. While determining each processing point, coordinate information and width measures could be obtained. In addition, the geometric properties of

the welded joints can be deduced from the cross-sectional area [5].

In another laser sensor-based study by Braunreuther et al., it was aimed to find a solution to the deflections between the weld seam path, which can change as a result of thermal expansion, and the real lines of the workpiece, and to increase the quality even more. They were able to solve this problem by using industrial imaging. They were able to obtain information about the workpiece with a laser scanner, which uses the same optical path as the laser beam connected to the camera [6].

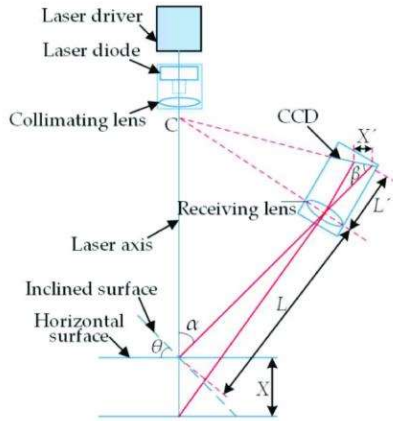


Figure 1. The working principle of the triangulation method [7]

The triangulation method shown in Figure 1 is used to measure distance in the laser sensor, which can be used in gas metal arc welding processes. The main function of this method is to calculate the distance to the ground on the material on which the beam falls [7]. However, the common use of triangulation in gas metal arc welding is to find the geometry of the weld line. Here, the detection of the points to be filled with the weld is completed with the principle of scanning the beam along the gap to the weld [8].

In Thompson's study, which states that there may be errors in the use of laser sensors, research has been carried out on materials with high reflectivity. It has been determined that there may be problems in the use of laser sensors at some points during the welding of materials with these properties, that many tests may be required to verify their functionality and that there may be high maintenance costs [9]. Laser sensor systems perform measurements from a certain distance ahead of the welding torch in the weld line detection.

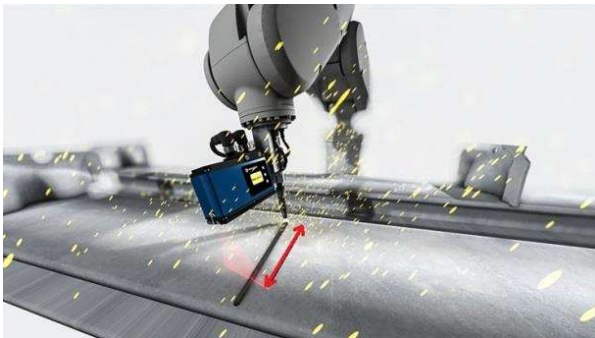


Figure 2. Distance Difference in Laser Sensor Systems

The data obtained due to this distance difference, which is indicated by the red arrows in Figure 2, is applied to the system after a certain time delay. Since this time delay cannot be adjusted very well in some applications, the system may process the processed data at the wrong gap to the weld point.

III. MATERIAL AND METHOD

This study, it is aimed to complete the most appropriate design of the Guide system in the material part. Angle sensor was selected during the design phase and Solidworks software was preferred for solid modeling of this sensor. The designs of the 6-axis robot obtained from the Guide system and GrabCAD library were imported into the MATLAB program. Along with these designs, the PID controller is mathematically modeled with the Simulink Toolbox of the MATLAB program. With this modeling, PID parameters were obtained in MATLAB's automatic tuning method. Simulation studies for the Guide system, whose design and mathematical modeling were completed, were carried out in the RoboDK program. The collision detection method of this program and the coordinate information of the Guide system were compared at certain time intervals. In the experiments on the RoboDK, cases, where deformations were applied in the workpiece and cases where the lead system was not used, were simulated. The design, modeling, and simulation stages of the proposed system are given in detail, respectively.

A. Guide System Design

In this study, qualities such as aesthetics, innovation, usefulness, longevity, and simplicity were prioritized in the design of the Guide system on which studies will be carried out. Accordingly, 2 angle sensors, which are both economical and desired to have a high protection class, were selected as the RCB 3100 given in Figure 3. Solid modeling of the Guide system was completed in the Solidworks design program, with dowel metal pin-shaped parts each connected to the angle sensor and coming into contact with the surface.

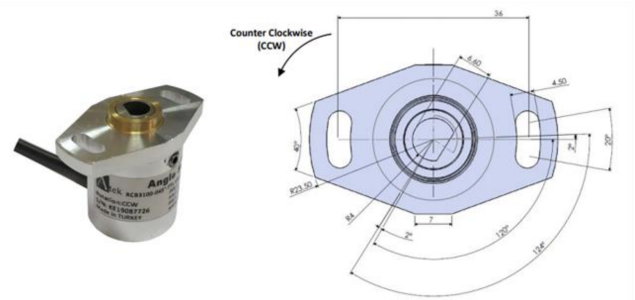


Figure 3. RCB 3100 Angle Sensor and Technical Measurements [10]

The technical specifications of the RCB 3100 model angle sensor, which is the Guide system main element, are given in Table 1. The instantaneous measurements to be obtained by contact from the angle sensors of this system, which is proposed as innovative to other existing systems, will be compared with the targeted angle values at certain time intervals. If an error occurs in these measurements, which is 0.150 degrees or more, which is the sensitivity of the sensors, the system will be able to detect it. The error degrees in these determinations will be calculated in the PID controller, and the new values that should be in the robot joints will be transmitted to the robot controller as feedback and the robot joint degrees will be rearranged [11].

TABLE I. RCB 3100 TECHNICAL SPECIFICATIONS [10]

Output Signal		Ratiometric	0...10VDC	4...20 mA
	Supply Voltage	5 VDC	15...32VDC	9...32 VDC
	Load	≥ 1KΩ	≥ 1KΩ	0...250 Ω
Material		Body		Shaft
		Aluminum		Stainless Steel
Response Frequency		250 Hz		
Resolution		12 bit		
Linearity		±0.5 FS		
Electrical Angle		up to 360°		
Mechanical Angle		124°±3 mechanical stop		
Protection Class		IP54		
Operating		-25°C ... +85°C		

B. Guide System Mathematical Modeling

In this paper, all the joints of the Kuka brand 6-axis robot arm shown in Figure 4 to be used in MATLAB Simulink simulation studies were created by using the GrabCAD solid modeling library that can be used in the SolidWorks design program [12]. In robotic systems, an end effector is an element designed to interact with the robot and can be attached to the last joint of this robotic arm. Angle sensors of the Guide system, each with a single axis rotary joint, are included in this system as end effectors and adhere to references.



Figure 4. Solidworks Drawing of a 6-Axis Kuka Robot

As a result of adding end effectors to the robot system, the motion control of the robot arm can be regulated. A PID-controlled algorithm was adapted in the model designed with MATLAB Simulink Toolbox, according to the measurements to be obtained by the Guide system. In line with these relations, the Guide system has been modeled in MATLAB/Simulink environment and the inputs and outputs of the model are shown in blocks in Figure 5.

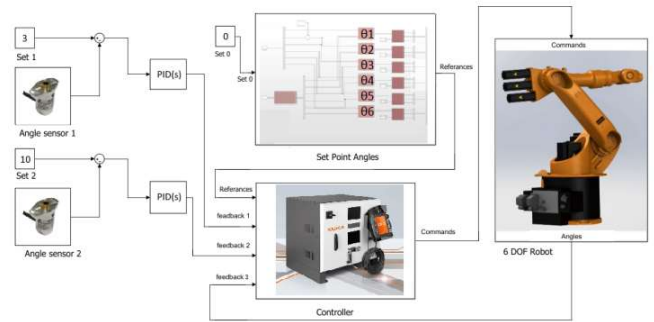


Figure 5. MATLAB Simulink Model of the Guide System

In this study, a closed-loop system was created by using PID, which is one of the most used controller types today. The Guide system compares the angle information received from its two different angle sensors and the set angle values in 0.1 second periods. If a error value is detected as a result of these comparisons, the PID controller will reduce these error values and reduce them to zero. Thus, the PID controller will provide feedback signals to the 6-axis robot controller and help to complete the weld bead process with minimum error.

C. RoboDK Simulation Studies

RoboDK is a software that can generate code for several types of robots from more than 40 manufacturers and simulate welding, assembly, and machining processes. RoboDK simulations are a program that allows a new system to be tested without interrupting the robot process and offers very realistic results [13].

All of the fastening apparatus that provide positioning and centering to prevent stresses that may occur in welding processes are called fixtures. Thanks to this apparatus, the quality of the weld beat improve, but the error rate cannot be reset [14]. In the literature, some studies have been conducted on the negative effects of fixing the fixture incorrectly on the material to be processed and the disruptive factors that may occur due to fixture placement forces.

As a result of a study carried out on this subject, it has been observed that the effect of errors caused by the fixture connection point and reaction forces can increase up to 30% on the change in the forces applied to the workpiece [15]. Another study, it was aimed to minimize the effect on the displacement of the deformable sheet metal part by selecting fixture application points. To solve this problem, linear equations and matrices are obtained. According to these equations, the analysis was made in the MATLAB program and it was determined to which points the fixture clamps should be connected [16].

In the simulation studies carried out in this study, it has been tested to detect the deformations that may occur on the metal part surfaces during the welding process with the Guide system, even if fixtures are used, and to make changes in the joint angle values of the system accordingly. In the first simulation process shown in Figure 6, when deformation occurs on the metal part surface due to weld

shrinkage, how the Guide system will respond to this has been tested. Accordingly, the constant values in one or both of the sensors that measure the points where the surface deformations occur have changed. The detection of this deformation was determined by comparing the coordinates on the metal part surface and the coordinates of the angle sensor detection part at certain time intervals thanks to the collision detection mode in the RoboDK library.

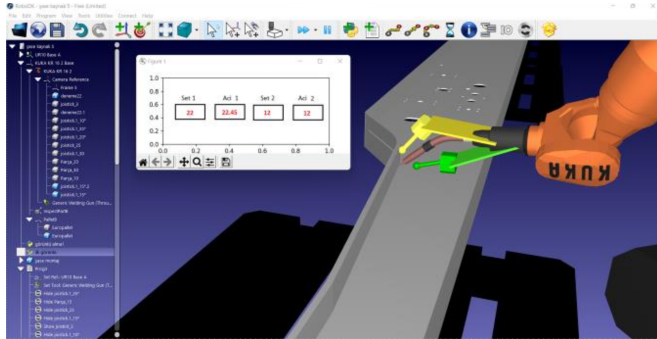


Figure 6. Error Detection in RoboDK Simulation

In the simulation shown in Figure 6, 2 different fixed values are set to the system. When the first point where deformation occurred in the system, the value of one of the angle sensors increased and the other remained constant. Accordingly, while the fixed Set 1 value in the simulation was 22, the Angle 1 value was calculated as 22.450. Changes in the system's joint angle values were tested with the inclusion of a PID controller so that the angle 1 value could be 22 again. Accordingly, the angle information of the welding robot joints could be re-optimized so that translational motions could be done on the x-axis. When a second deformation point was seen in the later stages of the simulation, changes in Angle 2 value were observed this time. In the optimization for this, the angle information of the welding robot joints can be optimized so that translational motions can be done on the y-axis.

The RoboDK simulation program enables embedded testing of python or C++ based codes, thanks to its program writing toolbox. In this study, a PID control coded with Python programming language was used.

During the second simulation process shown in Figure 7, the welding robot will pass through all predetermined points while it is running. In this simulation, no deformation was created on the treated sheet surfaces, so it was observed that there was no change when the coordinate information was compared in the collision detection mode. Therefore, the welding robot has never deviated from the seam tracking

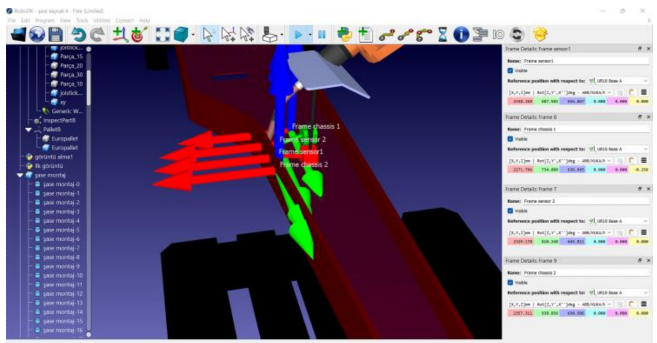


Figure 7. Coordinate Information of Guide System in RoboDK

In the simulation study shown in Figure 8, it was observed that the robot system was exposed to the deflection indicated by the red line after deformation in the weld seam tracking without a Guide system. In this simulation study, the welding torch collided primarily with one surface of the material to be processed. Afterward, with the impact of the collision, the welding torch moved away from the seam tracking. Since this situation could not be detected by a sensor, the system continued the welding process without being optimized. From this simulation it can be concluded that without a Guide system, serious errors can occur.

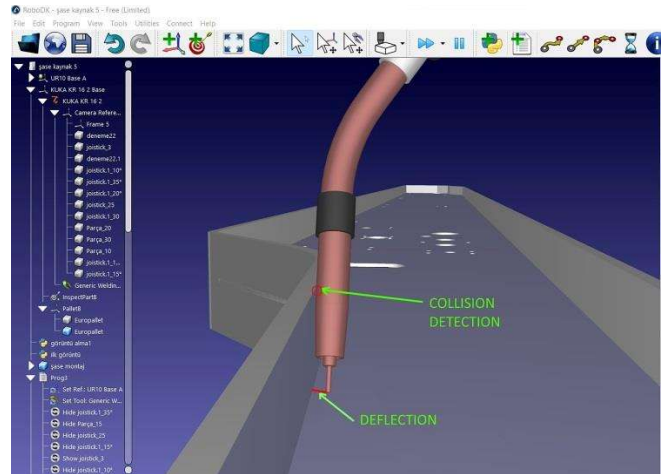


Figure 8. RoboDK Deflection after Collision

IV. RESULTS

Various systems have been developed to minimize the weld bead defects that may occur after thermal deformation in robotic welding applications. The majority of the literature studies have been conducted on laser sensor systems. As a result of the studies carried out with these systems, very high sensitivity detection was achieved, and the processes were optimized very well with the margin of error as low as ± 0.1 mm.

However, it has also been observed that these sensors can fail on materials with glossy surfaces. In this paper, a prototype design of a Guide system that can provide mechanical feedback by contact instead of a laser sensor weld bead tracking system has been created. It is concluded that this design can be a useful study as a result of MATLAB Simulink modeling. It has been determined that the accuracy of ± 0.15 degrees in the technical specifications of the RCB 3100 model sensors, which is the main element in the design, will be sufficient. It has been determined that the cost of the Guide system, which has taken its final form in the design, is much more economical when compared to the cost of systems with laser sensors.

To experiment on the robotic arm, the cost of procuring both a real robot and an industrial robot is required. Moreover, performing real tests can waste time and work. In this study, RoboDK, one of the programs that allow us to perform tests in a simulation environment, was preferred. Although there are very few libraries and studies on welding robot systems in RoboDK, a Guide system has been created in the simulation environment. According to the change values of the deformation points detected by the angle sensors of this system, the PID controller was used. MATLAB auto-tuning method was used to determine the

PID parameter values. With this method, the values were obtained as $K_p=2.135$, $K_i=10.457$, and $K_d=0.013$, respectively. The joint angles of the welding robot were re-optimized by taking advantage of these values in the errors detected by the Guide system. Accordingly, the problem was solved in the simulation environment with a positioning error of ± 0.2 mm in the weld bead of 6 mm sheet material.

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Validation of the SHAP value's utility in Decision Tree-Based Model Interpretation

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Abstract— It's crucial to give interpretability when developing a prediction model using machine learning so that users can determine which characteristic has helped the model learn in what way to better understand data. In the marketing sector, in particular, it is frequently necessary to obtain interpretability of the variables that influence Key Performance Indicators and how they affect them in addition to offering a system to model and predict relevant Key Performance Indicators using machine learning. In recent years, an index for assessing the contribution of the input characteristics to model learning has been developed and garnered interest. It is known as a SHAP value. Using decision tree-based models, which are frequently used to represent table data, we demonstrate in this study that SHAP value may relatively accurately estimate the contribution of features to model learning.

Keywords—SHAP value, machine learning, decision tree-based model, feature importance.

I. INTRODUCTION

Machine learning modelling with tabular data and training data frequently employs decision tree-based models like random forests and XGBoost [1]. To confirm whether the model is accurate or not, that is, to gauge the significance of the feature, it is crucial to analyse the data and enhance the model.

What kinds of variables affect the scale and how they affect them are crucial considerations, particularly in the marketing sector, in addition to developing a framework for modelling and predicting relevant Key Performance Indicators using machine learning [2]. Depending on the model, many techniques have been developed to estimate feature relevance. It is required to confirm how precisely the SHAP value [1, 2] can assess feature relevance in order to use it in practice for analysing data and models that were developed.

We demonstrate that the SHAP value may typically accurately assess the contribution of features to model learning using an experiment in which the SHAP value is derived for a model trained by XGBoost using table data produced in an XGBoost model.

II. BASIC CONCEPT OF SHAP VALUE

Cooperative game theory [3], which uses the assumption that numerous individuals can collaborate to play games, examines each player's behaviour quantitatively and determines the best way to divide rewards [4]. The concept of the SHAP value, which is defined in [5,6], is based on the

Shapley value, which in cooperative game theory quantifies the level of contribution a member has made in a partnership.

When the number of features is M , the input $x' \in \{0,1\}^M$, which is a simplified input vector x , is locally linearly approximated by the model f .

Using f_x , the contribution of feature i ϕ_i to model f is calculated as follows:

$$\phi_i(f, x) = \sum_{z' \subseteq x'} \frac{|z'|!(M-|z'|-1)!}{M!} [f_x(z') - f_x(z' \setminus i)] \quad (1)$$

Then, $z' \in x'$ is the whole subset of x' nonzero elements and $|z'|$ represents the number of nonzero elements in the feature vector z' .

For all input combinations that can be compared with and without feature i , take the average of the differences $f_x(z') - f_x(z' \setminus i)$. The process of simplification of the model and inputs, and the formulation of conditions such as local accuracy, missingness, consistency that the simplified model should satisfy are omitted here.

III. EXPERIMENT

Below we show the process and results of two experiments to verify the usefulness of the SHAP value. When the amount of distinct values that each feature may accept varies significantly between features, that is when we want to pay close attention. When a feature's variance in values is obviously lower than that of other features, or when the feature's resolution is low, such as with XGBoost based on metric gain according to reports [7], settings like the default Feature Importance. This value that indicates how much a certain feature value has improved the evaluation criteria on average for a trained model [8]. In this experiment, the difference in resolution between features is reproduced and the SHAP value is calculated.

A. Experiments on data without difference in resolution

Let us consider the case where there is no difference in resolution between features.

In this study, five features x_i ($i = 1, 2, 3, 4, 5$) follow a normal distribution $N(0, 30^2)$ with mean 0 and standard deviation 30, and error term b is generated, and using it, the training data is generated by the following formula:

$$y = 15x_1 + 10x_2 + 5x_3 + x_4 + 0.3x_5 + b \quad (2)$$

The amount of unique values that each feature can take should be roughly the same as the five characteristics are

created as random number sequences using the same distribution.

The following hyperparameter settings are used by XGBoost to train this dataset as a regression problem using the package mind and given in Table 1.

Table 1. The hyperparameter settings

learning rate	0.01
colsample bytree	0.3
max depth	5
alpha	10

The values that are calculated and shown using the SHAP value package [4] are shown in Figure 1.

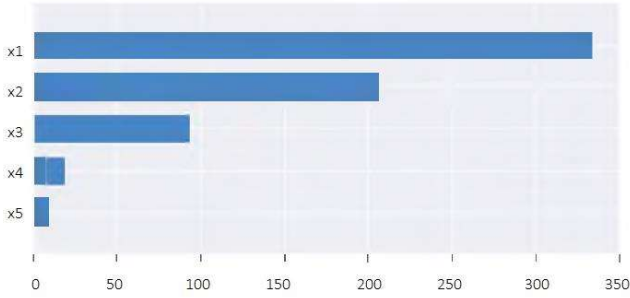


Figure 1. mean (|SHAP value|) (average impact on model output magnitude) of Experiment A

The x_i coefficient in Eq. (2) is thought to accurately reflect the genuine feature importance in this situation since the five characteristics, x_i ($i = 1, 2, 3, 4, 5$), are generated with an equal mean and variance. The SHAP value calculated in Figure 1 is x_1 : 334.1, x_2 : 206.6, x_3 : 93.3, x_4 : 18.6, x_5 : 9.6. However, since the ratio is about the same as each term's coefficient in Eq. (2), it appears that the feature value importance can be roughly and fairly precisely calculated.

For comparison, the default Feature Importance of the XGBoost package is also calculated and presented in Figure 2.

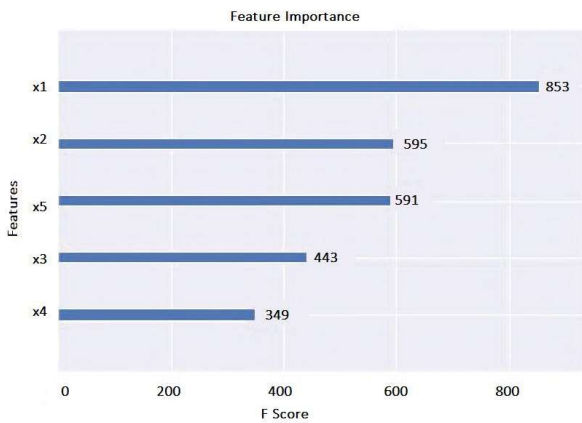


Figure 2. XGBoost Feature Importance of Experiment A

The feature value of x_5 in the XGBoost default is greater than x_3 , x_4 , and virtually equal to x_2 , which runs counter to how Eq is generated (2).

When taking this into account and comparing Figure 1 and 2, it appears that SHAP can more properly determine the feature relevance.

B. Experiments on data with difference in resolution

Let us consider the case where there is a difference in resolution between features. For simplicity, we generated the feature x_i ($i = 1, 2, 3, 4, 5$) in the same way as in Section 3.1, and then rounded the feature x_2 to the tenths to lower the resolution. In addition, the training data y is generated by the following formula:

$$y = 10x_1 + 10x_2 + 5x_3 + x_4 + 0.3x_5 + b \quad (3)$$

In Section 3.1, Focusing on x_1 and x_2 , which have the same coefficient but different resolutions, the XGBoost model is trained using this data set. Figures 3 and 4 illustrate the determined SHAP value and the default Feature Importance of XGBoost, respectively.

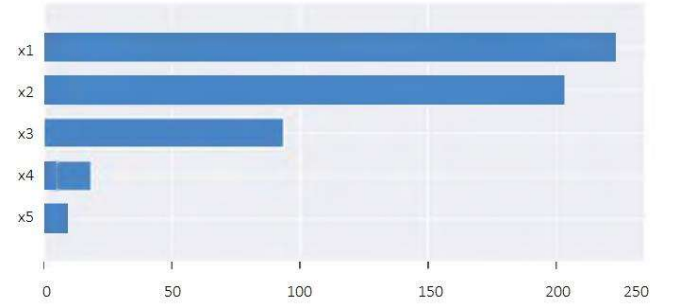


Figure 3. mean (|SHAP value|) (average impact on model output magnitude) of Experiment B

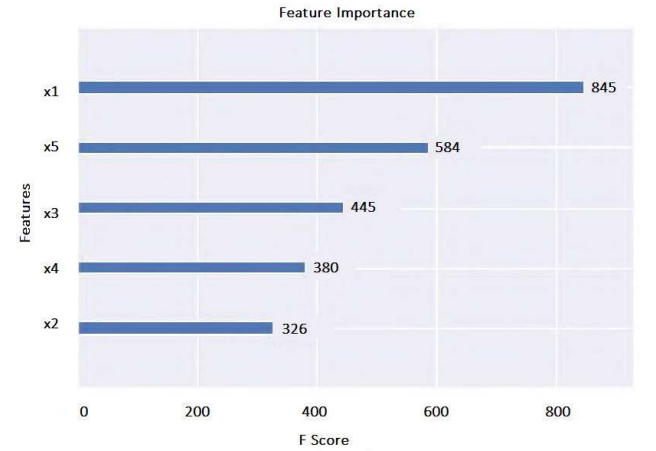


Figure 4. XGBoost Feature Importance of Experiment B

IV. CONCLUSION

We tested the precision with which SHAP can assess the contribution of features to decision tree-based model learning in this article. It is confirmed that when the model is used, the contribution to model learning can be evaluated generally accurately. As a result, it is essential to assess the SHAP function after creating a more accurate data set. To determine whether the SHAP value is effective as a trustworthy analysis technique, we also carry out a comparable verification.

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Classification of Raisin Grains Using Some Machine Learning Methods

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Abstract—Raisins are one of the agricultural products with high nutritional value. Millions of tons of raisins are produced and consumed in the world every year. In this study, classification of two different raisin varieties in our country was carried out by machine learning. The 2-class data set with 7 different features obtained as a ready-made data set was classified by machine learning algorithms K-NN and Naive Bayes. In the analyzes performed, 81.44% classification accuracy with K-NN and 83.44% classification accuracy with Naive Bayes was obtained. (Abstract)

Keywords—machine learning, k-nearest neighbors, naïve bayes, raisin grains,

I. INTRODUCTION

Among the countries engaged in viticulture in the world, there are 6 countries with an annual grape production of 4 million tons or more. According to the latest statistics, 16% of the world's grape production, which is approximately 74.5 million tons, is met by China, followed by the USA, Italy, Spain, France and Turkey. When an evaluation is made in terms of world vineyard areas, 13.1% of the 7.12 million hectares of vineyard areas is formed by Spain, followed by China, France, Italy, Turkey and the USA. Turkey ranks 5th among the world countries in terms of vineyard areas with 467,093 ha, and 6th place in terms of fresh grape production with 4,175,356 tons [1].

Viticulture agriculture has an important place in Turkey's plant production and constitutes 1.83% of the total agricultural land. According to 2016 statistics, the distribution of vineyard areas and grape production amounts in 7 geographical regions of Turkey is given in Figure 1. Accordingly, about 52% of the total grape production in our country is Aegean, 18% is Southeastern Anatolia, 12% is Mediterranean, 8% is Central Anatolia, 6% is Marmara, 3% is Eastern Anatolia and 1% is 1%. It is supplied from the Black Sea Region [2].

In the food industry, it is often difficult to distinguish different quality and types of the same food. Doing this manually is costly and cumbersome. Also, this process will not be subjective. In recent years, image processing techniques have been successfully applied to distinguish the characteristics of food such as type and size. [3].

Studies in this field:

Cinar et al. [4] took the images of raisins in the box with the help of a camera in the system they designed. The obtained statistical data were classified using 3 different machine algorithms. Classification results were obtained by using LR, MLP, SVM algorithms. Among these methods, the highest value belongs to SVM with 86.44%.

Okamura et al. extracted features from raisin images. They used naive bayes algorithm to classify these features. They were more successful than manual classification of raisins. [5].

Omid et al., they developed a mechanism that extracts the size and color characteristics of raisins with image processing methods. They made classification based on these extracted features and achieved 96% success.

Yu et al. used SVM to classify raisins. They divided the raisins into four different classes and obtained the highest classification success from SVM with 95%. [7].

In this study, the Raisin Grain [8] dataset, which is composed of features obtained from the images of two varieties of raisins grown in Turkey, has been classified with two of the machine learning algorithms.

In the second part of the study, the characteristics of the data set, performance evaluation and cross-validation are given. In the third chapter, information about the classification models used in the study is given. In the fourth chapter, the results obtained in the study are explained in detail. In the last section, discussion topics are given.

II. MATERIAL AND MEDHODS

A. Dataset

In this study, Raisin Dataset [8] was used. In this data set, there are 900 raisin image data containing 7 features. There are 2 classes in this dataset. It consists of 450 Besni and 450 Kecimen species grape data. Sample images from the data set are given in Figure 1.

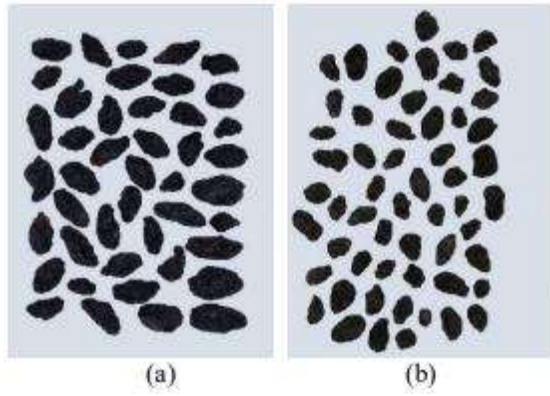


Fig. 1. Picture examples from which the data set was obtained a) Besni b) Kecimen

There are seven features in this dataset. These features are given in Table I.

TABLE I. FEATURE LIST OF RAISIN DATASET

Feature	Min.	Mean	Max.	Std. Dev.
Area	25387	87804.128	235047	39002.111
Perimeter	619.074	1165.907	2697.753	273.764
MajorAxisLength	225.63	430.93	997.292	116.035
MinorAxisLength	143.711	254.488	492.275	49.989
Eccentricity	0.349	0.782	0.962	0.09
ConvexArea	26139	91186.09	278217	40769.29
Extent	0.38	0.7	0.835	0.053
Class	Kecimen	Besni		

The features given in Table 1 are as follows.

MajorAxisLength: Gives the length of the main axis, which is the longest line that can be drawn on the raisin grain.

MinorAxisLength: Gives the length of the small axis, which is the shortest line that can be drawn on the raisin grain.

Eccentricity: It gives a measure of the eccentricity of the ellipse, which has the same moments as raisins.

ConvexArea: Gives the number of pixels of the smallest convex shell of the region formed by the raisin grain.

Extent: Gives the ratio of the region formed by the raisin grain to the total pixels in the bounding box.

Area: Gives the number of pixels within the boundaries of the raisin grain.

Perimeter: It measures the environment by calculating the distance between the boundaries of the raisin grain and the pixels around it.

B. Machine Learning Algorithms

In this study, machine learning algorithms K-NN and Naïve Bayes are used. The theoretical explanations of these methods are given below.

C. K-Nearest Neighbors Algorithm

k- Nearest Neighborhood Algorithm (k-NN) is used to determine which class a new observation to be added to the sample belongs to, by making use of the observation values in a sample set with certain classes. The k nearest neighbors to

an unknown taken for classification in the algorithm are determined, and by looking at the classes these neighbors belong to, the unknown to be classified is at the closest distance from these classes, or more than one is assigned.

"Euclidean Distance" is generally used as the distance measurement method that needs to be determined in order to apply the nearest neighbor algorithm method. [9].

D. Naïve Bayes

Naive Bayes classifier data mining, machine widely used in the field of learning, emotion analysis, etc. It is an algorithm in the supervised learning class. Clear probability that a feature set belongs to a particular class. used to predict. In classification, Bayesian decision is based on the theorem [28], using probability calculations [10].

E. Performance Metrics

There are some criteria to evaluate the classification success of the machine learning methods used on the data set. The confusion matrix specified in Table 7 is used to calculate these criteria. The confusion matrix indicates the prediction accuracy success in the created model as a 2x2 matrix. It provides comparison of the actual values with the predictions [11].

Accuracy: It is the ratio of correctly predicted values to all values. The formula is given below (2).

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+FN+T} \quad (2)$$

Precision: It is the ratio of correctly predicted values to the sum of incorrectly predicted values and correctly predicted values. The formula is given below (3).

$$\text{Precision} = \frac{TP}{TP+FP} \quad (3)$$

Sensitivity: It is the ratio of correctly predicted values to the sum of correctly predicted values and incorrectly predicted values. The formula is given below (4).

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad (4)$$

Specificity: It is the ratio of True Negative to the sum of true negative and false positive. The formula is given below (5).

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (5)$$

F-Measure: It is the value given to us by the precision and sensitivity values, whose harmonic average is taken. It is a measure of the precision and robustness of the model. The formula is given below (6).

$$\text{F-Measure} = \frac{2 \times TP}{2 \times TP + FP + FN} \quad (6)$$

III. RESULTS

In this study, performance measurements were obtained on the raisin dataset using 2 different machine learning algorithms.

The confusion matrix obtained as a result of the classification and the statistical data obtained from it were used as performance measurement. The confusion matrix of the algorithm is shown in Table II.

TABLE II. THE CONFUSION MATRIX OF THE ALGORITHMS

Algorithms KNN, Naive Bayes		Predicted	
		Kecimen	Besni
Actual	Kecimen	396 416	81 34
	Besni	86 115	364 335

Looking at the average classification based on Table 3, where we see the performance measurements and comparisons for each method and class, the method that gives the highest accuracy-based value is Naïve Bayes with a value of 83.44%. When the k-NN algorithm was applied to the same dataset, 81.44% classification accuracy was obtained. Sensitivity, Specificity, Precision and F-Measure values are also shown in Table III.

TABLE III. CLASSIFICATION AND PERFORMANCE RESULTS.

Performance Measure	K-NN	Naive Bayes
Accuracy	0,8144	0,8344
Sensitivity	0,8301	0,9244
Specificity	0,8035	0,7444
Precision	0,8215	0,7834
F-Measure	0,8258	0,8481

IV. DISCUSSION

When the results obtained from the study are examined and evaluated, higher classification successes can be achieved by increasing the number of image sets and adding morphological features as well as color layer, shape and

texture features in addition to the features obtained from the products.

In addition to the machine learning techniques in the current study, different machine learning techniques or hybrid models can be created and studied on the relevant data set.

V. CONCLUSION

Among the raisin varieties used in this study, there are products produced and exported in Turkey. For other products produced in our country, it can be beneficial to benefit from the image processing techniques we used in this study, to create data sets and new models derived from the relevant data set. In this way, automatic systems can be designed for the calibration or different processes of products using data sets for classification.

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A Survey on Machine Learning and Fuzzy Inference Based Prediction with Small Datasets

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Abstract— Different machine learning (ML) algorithms are popular for solving nonlinear knowledge-intensive problems, like predicting natural disasters or disease risk for populations, classifying cancer patients into high or low-risk groups, etc. However, training those algorithms requires sufficient or ever big digital data that is not available in real-world applications. The authors of various articles suggest how to solve the problem of small data when applying ML algorithms in a particular subject area. Nevertheless, the main research question arises what are the main trends in solving the problem of small data in ML and fuzzy inference based prediction? To answer the defined question, this paper presents a survey based on the articles extracted from the Web of Science (WoS) and Scopus databases. The results show that this topic has become more relevant, and popular algorithms, like SVR, clustering, Naïve Bayesian algorithms, decision trees, etc., are adopted to work with small data.

Keywords— machine learning, fuzzy inference, small data, prediction.

I. INTRODUCTION

Nowadays, different machine learning (ML) algorithms are popular to solve nonlinear knowledge-intensive problems, like predicting natural [1] or ecological [4] disasters, predicting disease risk for populations [2], classifying cancer patients into high or low risk groups [3], etc. ML algorithms rely on large datasets for training ML models to handle complex tasks requiring human knowledge (i.e., knowledge-intensive problems) [5]. However, in real-world applications, sufficient or ever big digital data is not available in all cases [6]. For example, energy optimization problems [1], analysing the chemical and physical properties of various materials [7], oil spills in the water environment [8], predicting cardiovascular diseases [2], etc.

The authors of various articles suggest how to solve the problem of the small dataset when applying ML algorithms in a particular subject area, like using surrogate data [2] for the prediction of cardiovascular diseases, using cluster analysis in the problem of medicine for small data [1], qualitative selection of features important for the prediction and choosing a suitable regression algorithm to perform computer simulations [9], using an interpolation and data visualization approaches for prediction in ecology [10], applying deep neural networks [11], etc.

Additionally, to the small dataset problem, particular attributes of a phenomenon are expressed in intervals that complicate the prediction [12]. To resolve such uncertainty, L.A. Zadeh [13] proposed the theory of fuzzy sets, whose elements have degrees of membership, in 1965. Afterward, they have been applied successfully in approximate reasoning,

fuzzy controllers, pattern recognition, decision making, etc. [14].

However, the main research question is left as follows: *what are the main trends of solving the problem of a small dataset in machine learning and fuzzy inference based prediction?*

The main aim of this paper is to analyse the main trends of solving the problem of a small dataset in ML and fuzzy based prediction by applying a survey of scientific articles from Web of Science (WoS) and Scopus databases.

We study this question because, as our related works have shown, the real world is full of application domain areas where the problem of the small dataset is relevant and the prediction task becomes more difficult. Therefore, it is currently most important to understand the trends and structure of solving the problem of a small dataset in ML and fuzzy based prediction, and to grasp the main ideas and results.

This research increases the body of knowledge on the main trends of solving the problem of a small dataset in ML and fuzzy inference based prediction by providing a keywords map of the subject and grasping the main topics in the research field.

Additionally, the results of this research can help scientists and practitioners become familiar with the body of knowledge on the ML and fuzzy inference based prediction with small dataset topic.

The structure of the paper is as follows. Section 2 describes the methodology of the performed survey on machine learning and fuzzy inference based prediction with small datasets. Section 3 presents the main obtained results. Section 4 discusses the results and Section 5 concludes the paper.

II. SURVEY METHODOLOGY

A survey on the ML and fuzzy inference based prediction with small datasets topic consists of two main parts as follows: identifying the main set of scientific articles as described in [15], and developing a keywords map using a VOSviewer (<https://www.vosviewer.com/>) software tool for developing and visualizing bibliometric maps [12] (see Fig. 1).

It consists of three main steps, which are described below.

A. Preparing for the Survey

a) Defining Research Questions

The main research question (MRQ) is as follows: What are the main trends of solving the problem of a small dataset in machine learning and fuzzy inference based prediction systems?

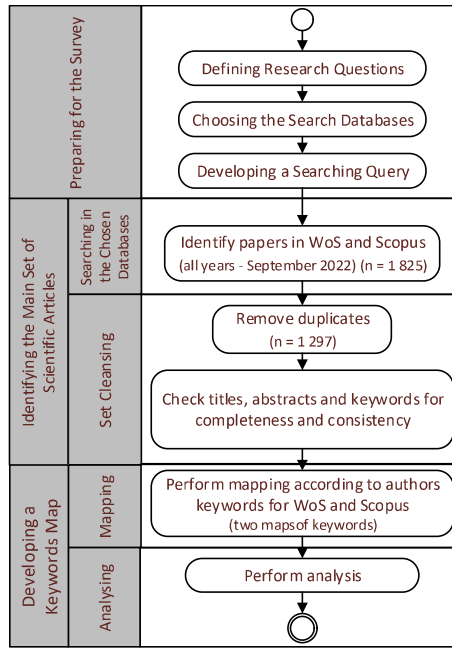


Fig. 1. The general schema for our survey.

Consequently, the analysis object of the research is the problem of a small data in machine learning and fuzzy inference based prediction systems.

According to MRQ, the following RQs are defined:

RQ1: When were the articles on the small dataset in machine learning and fuzzy inference based prediction systems topic published?

RQ2: Which countries are participating in the research of the small dataset in machine learning and fuzzy inference based prediction systems topic?

RQ3: What topics are analysed in the small dataset in machine learning and fuzzy inference based prediction systems?

RQ4: What are the visible trends for the small dataset in machine learning and fuzzy inference based prediction systems topic?

b) Choosing the Search Databases

The WoS and Scopus databases were used in the survey based on the experience reported in [16] and results of Gusenbauer and Haddaway [17] research.

c) Developing a Searching Query

We have identified two groups of terms for the search as:

- Term related to prediction: fuzzy and machine learning;
- Terms related to small dataset: small data and small set of data.

The final search query is developed based on WoS and Scopus search requirements as follows:

("small data*" OR "small set" of data") AND
("fuzzy*" OR "machine learning")

where an asterisk "*" represents any group of characters, including no character.

B. Identifying the Main Set of Scientific Articles

a) Searching in the Chosen Databases

We have performed a search using the defined search query in WoS and Scopus. Also, we have limited the search by language, document type, and Subject Area (Computer Science) (see Table I).

TABLE I. RESULTS OF IDENTIFICATION AND DATA CLEANSING STEPS

Database	Document Type	Language	Search Results
WoS	article OR proceedings papers OR review	English	607
Scopus	article OR conference papers OR review	English	1218
Total:			1825^a

^a. In this step, duplicates are not excluded.

b) Set Cleansing

Here, we removed duplicating articles using the Mendeley reference management software (<https://www.mendeley.com/>). Also, titles, abstracts and keywords of all identified articles were checked for completeness and consistency.

C. Developing a Keywords Map

a) Mapping

The mapping of keywords was performed using VOSviewer, which employs a visualization of similarities (VOS) mapping technique [18], where the distance between any pair of objects reflects their similarity. Objects (i.e., keywords) having a high similarity are located close to each other, whereas objects having a low similarity are located far away from each other. The size of a bubble is in direct proportion to the number of occurrences of a keyword [19] and the link between bubbles represents the number of co-occurrences of those keywords. Higher the number of co-occurrences between two keywords, lesser is the distance between them.

b) Analysing

In this survey, the content was analysed as follows:

- Chronological visualization and analysis (RQ1; RQ4);
- Countries visualization and analysis (RQ2; RQ4);
- Keywords maps developing and analysis (RQ3; RQ4).

The found keywords are analysed quantitatively and according to their years of occurrence (RQ3, RQ4).

III. MAIN RESULTS OF THE SURVEY

The chronological distribution of the articles found in WoS and Scopus are presented in Fig. 2 (RQ1). They were published in the period from 1994 to 2022 (September).

The polynomial trendline (Poly. (All)) shows the increased number of articles on the analysed topic, especially in 2018. From Fig. 2, we can identify three periods of the publishing growth as follows: 1) until 2007 an insignificant number of articles (~4%) in the analysed topic was observed; 2) from 2007 to 2017 there is a certain increase in publishing articles of the analysed topic (~21%); 3) from 2018 till now there is a notable increase of articles on the analysed topic (~75%). This third increase can be associated with the growth interest and application of ML and fuzzy inference based prediction systems (RQ4).

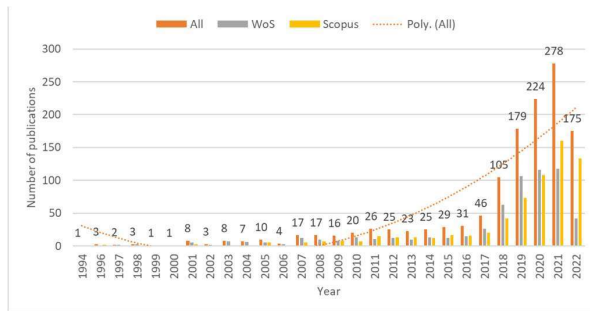


Fig. 2. The chronological distribution of the found articles on the small dataset in machine learning and fuzzy prediction based systems topic (RQ1).

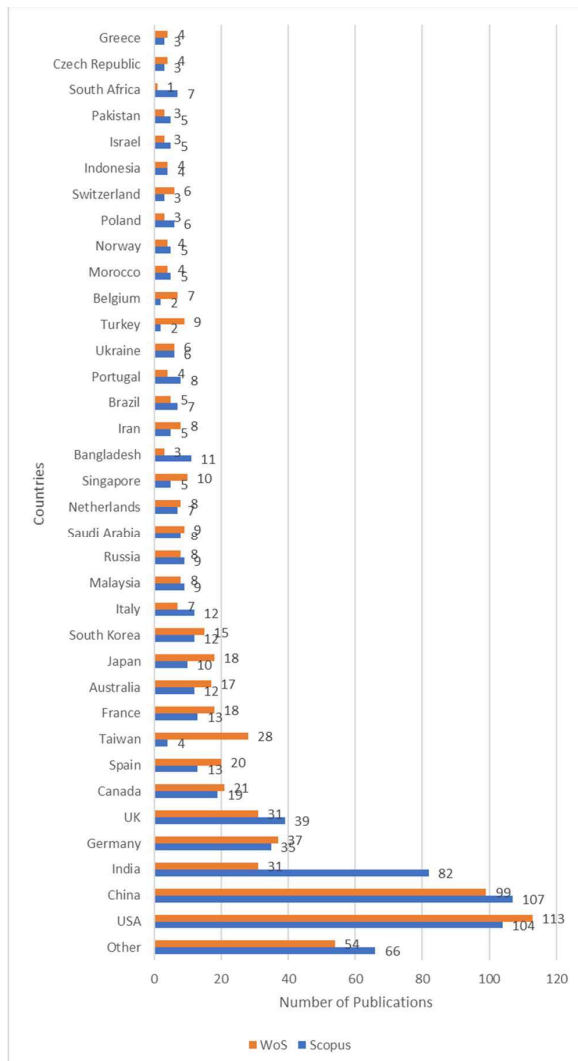


Fig. 3. Countries participating in the research of the small dataset in ML and fuzzy inference based prediction systems (RQ2)

The countries participating in the research of the small dataset in ML and fuzzy inference based prediction systems (RQ2) are shown in Fig. 3. The five most publishing countries in the researched topic are as follows: The United States of America (USA), China, India, Germany and the United

Kingdom (UK). Other are the countries those having one publication in WoS and/or Scopus. This activity of countries can be explained by their population and technological development (RQ4). Moreover, in some of these leading countries there is a governmental support for the scientific research.

We have developed two keyword maps, presenting the main **topics** on the small dataset in ML and fuzzy inference based prediction systems, for WoS (see Fig. 5) and Scopus (see Fig. 4) article sets.

The bigger bubbles present the more occurring keywords, i.e., the most investigating topics. The smaller bubbles present the less occurring keywords, which can be trends or unexpanded and forgotten topics depending on the year of their publication.

As can be seen from Fig. 4 and Fig. 5, the mostly occurring keywords in both keyword maps are close similar. *Note* that occurrences in WoS and Scopus differ because the Scopus article set is larger than WoS article set (see Table I). However, the trend of the most repeated keywords remains the same (RQ4).

TABLE II. THE MOST OCCURRING KEYWORDS IN WoS AND SCOPUS

Scopus		WoS	
Keyword	Occurrence	Keyword	Occurrence
deep learning	162	deep learning	66
transfer learning	86	ann (artificial neural network)	40
cnn (convolutional neural network)	78	classification	35
ann	68	transfer learning	31
classification	63	svm	30
svm (support vector machine)	50	feature extraction	28
feature extraction	39	cnn	21
artificial intelligence	26	artificial intelligence	17
image classification	26	data mining	15
data augmentation	24	big data	13
		image classification	12

Although ML and deep learning algorithms work well and accurately with a large dataset, a challenge for them is working with a small data set. Given that there is not enough data, noise, outliers, or the algorithm may overfit can also become a problem [20], [21].

Authors of [22] have proposed a lattice machine, i.e., a conservative generalisation based learning algorithm that learns by generalising data in a consistent, conservative and parsimonious way for solving the small data challenge.

According to [23], Bayesian method can learn causal relationships among data and handle an incomplete dataset. A deep neural network is more suitable for perception and reasoning based on this perception. Based on research presented in [4], to solve the problem with small data, different authors use surrogate data [3], cluster analysis [1], data visualization [24], and fuzzy logic [25], as in ANFIs [26].

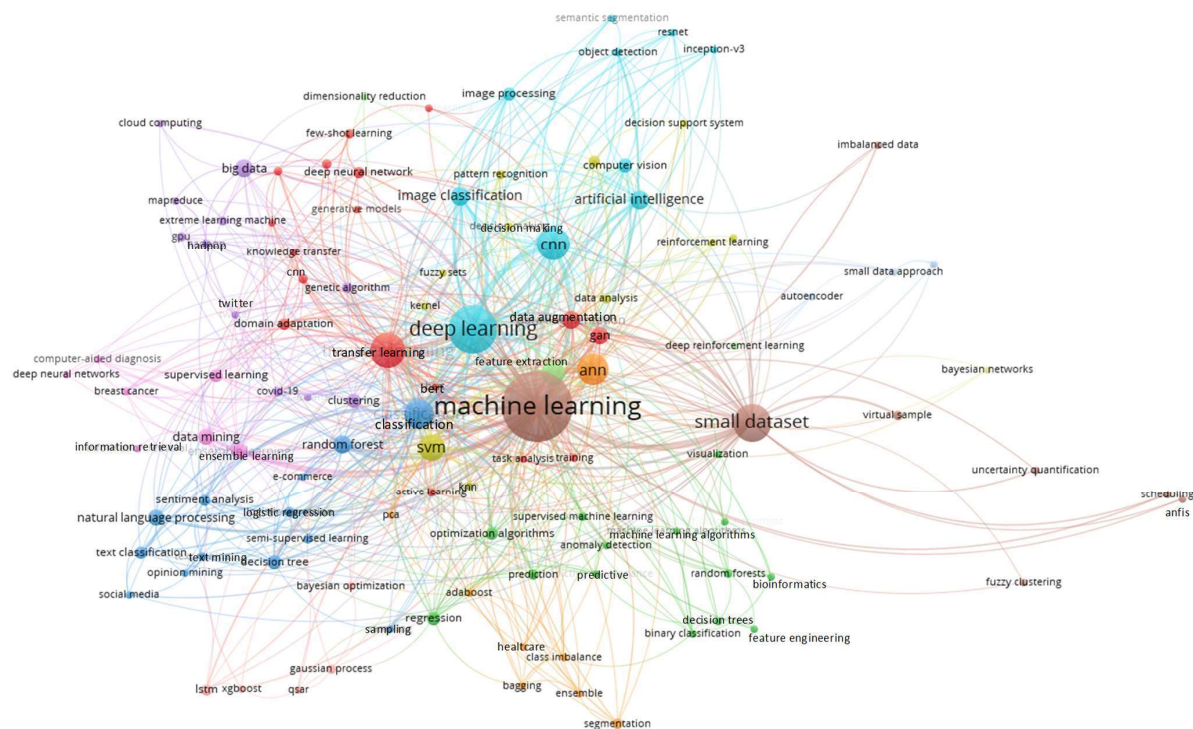


Fig. 4. The Scopus keyword map.

The most occurring keywords according to the years are presented in Table III and Table IV. As can be seen from Table III, until 2007 the emphasis was placed on fuzzy sets and different type of knowledge based systems. From 2007, the researchers have emphasized learning systems more and different methods of ML, like random forest, support vector machine, etc. And from 2018, the era of deep learning begins (RQ3, RQ4).

Also, as can be seen from Table III, the main tasks solved by the found approaches or techniques at all times remain the classification of information (RQ4).

TABLE III. THE MOST OCCURRING KEYWORDS ACCORDING TO YEARS IN SCOPUS

Year	Keywords (occurrence)
1994	artificial intelligence (1), commercial reality (1), computer circuits (1)
1995	artificial intelligence (2), additive systems (2), knowledge based systems (2)
1996	fuzzy sets (2), inductive learning (2), knowledge based systems (2)
1997	additive systems (2), back-fitting (2), classification (2)
1998	decision making (2), hypothesis testing (2), pattern recognition (2)
1999	artificial intelligence (1), cluster analysis (1), clustering algorithms (1)
2000	algorithms (1), database systems (1), fuzzy sets (1)
2001	neural networks (6), learning systems (4), soft computing (4)
2002	artificial intelligence (3), data mining (3), classification (of information) (2)
2003	fuzzy logic (4), genomics (3), learning algorithms (3)
2004	algorithms (3), artificial intelligence (2), clip4 (2)
2005	artificial intelligence (4), fuzzy sets (4), learning systems (4)
2006	anfis (2), data trend (2), flexible manufacturing system (2)
2007	learning systems (7), neural networks (6), support vector machines (6)

Year	Keywords (occurrence)
2008	learning systems (6), rough sets (5), artificial intelligence (4)
2009	random forests (6), robot learning (5), artificial immune systems (4)
2010	artificial intelligence (6), classification (5), fuzzy logic (4)
2011	data sets (9), learning systems (9), artificial intelligence (7)
2012	learning systems (7), artificial intelligence (6), algorithms (5)
2013	learning systems (7), machine learning techniques (5), neural networks (5)
2014	learning systems (11), artificial intelligence (7), fuzzy logic (6)
2015	artificial intelligence (21), learning systems (19), algorithms (9)
2016	learning systems (14), artificial intelligence (8), classification (of information) (6)
2017	learning systems (30), artificial intelligence (14), classification (of information) (13)
2018	deep learning (43), learning systems (42), neural networks (26)
2019	deep learning (75), learning systems (62), classification (of information) (42)
2020	deep learning (88), learning systems (79), transfer learning (46)
2021	deep learning (150), classification (of information) (65), transfer learning (65)
2022	deep learning (115), transfer learning (38), classification (of information) (35)

The analysis of relations among “small data” and other keywords (see Fig. 4) shows that in Scopus it is more often found with keywords, like virtual sample (7), support vector regression (svr) (5), transfer learning (5), and support vector machines (svm) (4).

In Table IV, we can investigate the similar effect, but rather in smaller proportion, since the analysed set of WoS articles is smaller (see Table I) as follows. The main task solved by the found approaches or techniques remains the classification of information.

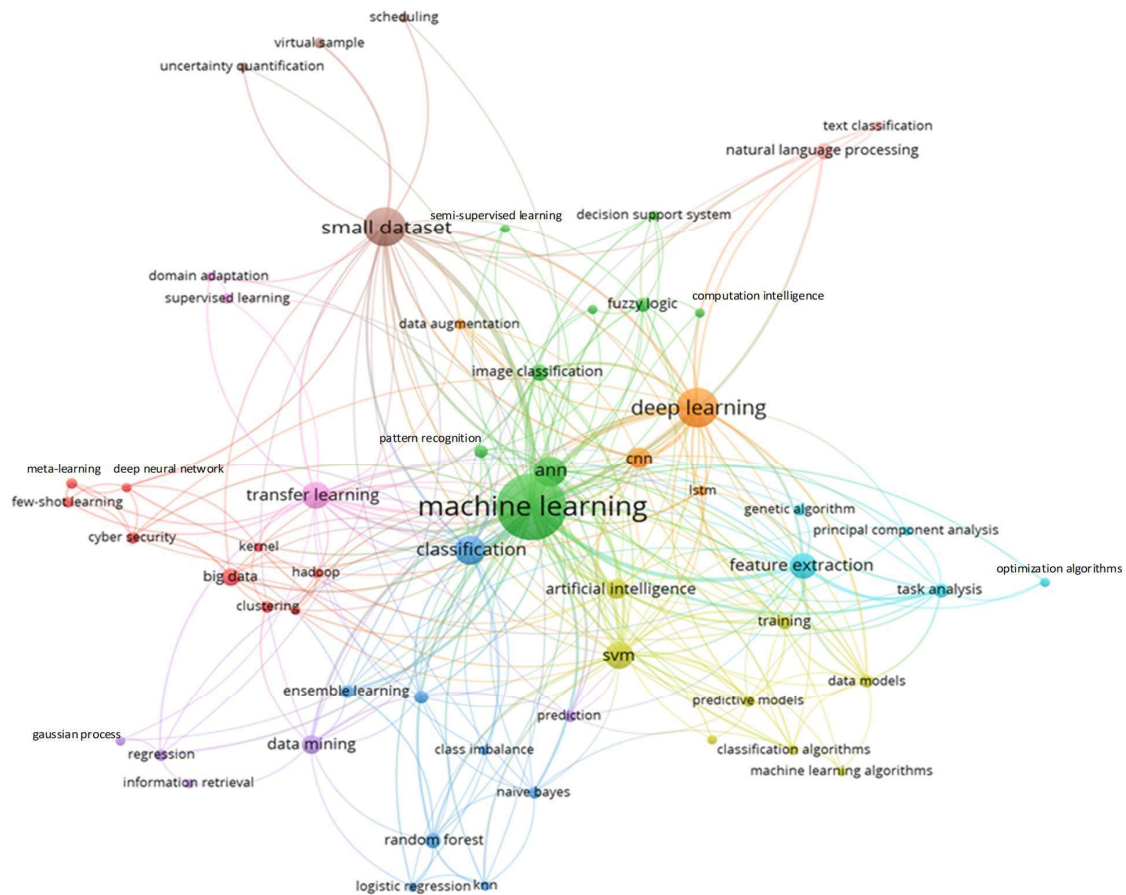


Fig. 5. The WoS keyword map.

The era of the deep learning keyword begins a bit earlier in WoS, since 2016. Moreover, from Table IV, in the WoS article set we can find more ML techniques, like decision trees, adaptive boosting, support vector machine, Naive Bayes, k-nearest neighbours (knn) (RQ4). In both sets, i.e., WoS and Scopus, from 2020 the transfer learning becomes popular (RQ4).

TABLE IV. THE MOST OCCURRING KEYWORDS ACCORDING TO YEARS IN WOS

Year	Keywords (occurrence)
1995	classification (3), abusive language (1), anisotropic distance measure (1)
1996	bell shaped membership functions (1), c-1 class interpolation (1), fuzzy reasoning (1)
1997	additive systems (1), back-fitting (1), classification (1)
1998	classification (1), confidence function (1), decision making (1)
2001	data scaling (1), data set characteristic (1), fourier-transform infrared spectroscopy (1)
2003	algorithm configurations (1), algorithm recommendation (1), analysis of variance (1)
2004	artificial intelligence (1), bone age assessment (1), clip4 (1)
2005	decision tree (1), effort prediction (1), empirical evaluation (1)
2006	anfis (1), data mining (1), data trend (1)
2007	data mining (2), decision tree (2), algorithm (1)
2008	mega-fuzzification (2), animation (1), classification (1)
2009	artificial immune systems (2), data mining (2), naive bayes (2)
2010	classification (3), fuzzy logic (2), semi-structured documents (1)
2011	binary classification (2), semi-structured documents (1), arima model (1)

Year	Keywords (occurrence)
2012	classification (3), adaboost (1), artificial neural networks (1)
2013	3d reconstruction (1), active shape model (1), attribute reduct (1)
2014	big data (2), classification (2), clustering (2)
2015	adaptive boosting (1), bioinformatics (1), classification algorithms (1)
2016	deep learning (2), time series analysis (2), adaptive algorithm (1)
2017	deep learning (4), big data (3), analyst intuition (2)
2018	deep learning (8), svm (5), knn (4)
2019	deep learning (11), natural language processing (5), big data (4)
2020	deep learning (14), transfer learning (11), feature extraction (6)
2021	deep learning (16), transfer learning (11), classification (10)
2022	deep learning (10), artificial intelligence (4), feature selection (4)

The analysis of relations among “small data” and other keywords (see Fig. 5) shows that in WoS it is more often found with keywords as: svm (3), transfer learning (3), and visual sample (7).

IV. DISCUSSION AND CONCLUSIONS

In this research, we performed a survey to answer the main research question – (MRQ) *what are the main trends of solving the problem of a small data in ML and fuzzy inference based prediction?* – by answering sub-questions as follows.

The conducted survey on the analysed topic shows that a notable increase of articles on the analysed topic (~75%) from 2018 till now (RQ1). It can be associated with the growth

interest and application of ML and fuzzy inference based prediction systems (RQ4).

The five most active countries in the researched topic are as follows: The United States of America (USA), China, India, Germany and the United Kingdom (UK) (RQ2). This activity of countries can be explained by their population and their technological development (RQ4).

The analysis of the most researched topics on the small dataset in ML and fuzzy inference based prediction systems (RQ3) shows that until 2007 the emphasis was placed on fuzzy sets and different type of knowledge based systems, from 2007 – learning systems and different methods of ML, like random forest, support vector machine, etc.; and from 2016-2018 – the era of deep learning begins. Such changes can be explained by a technical development of computer processors and GPU. With this technical development, it became possible to perform complex calculations and analyse a large amount of data (i.e., big data) (RQ4). In the WoS article set, different ML techniques, like decision trees, adaptive boosting, support vector machine, Naive Bayes, k-nearest neighbours, are used (RQ4). In both sets, i.e., WoS and Scopus, from 2020 the transfer learning becomes popular (RQ4).

The relationship analysis of the “small data” and other keywords shows that it is more often found with keywords as virtual sample, support vector regression (svr), transfer learning, and support vector machines (svm) (RQ4).

Summing up, according to the historical overview the analysed topic on the problem of a small data in ML and fuzzy inference based prediction becomes more and more recent and from 2016 has the highest increase in its relevance. The problem of small dataset was and remains relevant in prediction. However, over the years, different approaches have been used to solve it, such as the use of artificial neural networks and fuzzy logic. Nowadays, popular algorithms, like svr, clustering, Naïve Bayesian algorithms, decision trees, etc., are adopted to work with small data.

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Recent Trends on Frameworks and Methodologies for IoT

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Abstract—Nowadays, all the activities of our life, professional or personal, are highly related to technology. We are being surrounded by smart devices, which can interact with each other, collect information from our environment and use it in different applications for several purposes. We are part of this IoT network which is growing larger and larger. Due to the size of these kind of systems and the diversity of areas where they may be applied, building them can be a very challenging and complex process. So, it is very helpful to use frameworks in IoT application development. Frameworks are able to face different challenges related to IoT systems and can assist in the fulfilment of their requirements. In this work a systematic literature review is presented about the usage of the frameworks that facilitate IoT application development process in the aspect of programming and architectural design, security, and testing. A review protocol is predefined and executed in order to identify a collection of frameworks. For each framework we present its main characteristics, the impact in the facilitation of the development process for the developer, solutions it offers for addressing issues in IoT and its applications in real-life scenarios.

Keywords—Internet of Things systems, IoT applications, IoT frameworks, IoT challenges, IoT reliability and performance.

I. INTRODUCTION

This paper introduces a systematic literature review on frameworks that are used for developing IoT applications. IoT can be defined as a collection of physical devices, objects (things) which relate to each other and collaborate in order to accomplish some common objectives. The challenges in developing IoT applications, are frequently discussed in various research community groups [1], [4], [12], [17]. The utilization of IoT frameworks deals with the obstacles of IoT technology and assists the developers in their work. Different IoT frameworks are developed in correspondence with the gateway capabilities like specific industrial gateways or more versatile general-purpose gateway devices like smartphones.

Many research studies, propose strategies, methods, or frameworks to solve IoT challenges based on approaches and technologies like Artificial Intelligence, blockchain, cloud, mobile wireless, etc. As far as we know, any systematic literature review that discusses IoT application frameworks has been published. The most recent review related to IoT development frameworks, is an article, published on 2018 [1]. The objective of that paper was to identify existing frameworks integrated in the development process by grouping the frameworks according to their strengths and weaknesses, but there were no constraints about the sources of

information and the selection and quality criteria were not clearly described.

In our paper we systematically review the literature by following a predefined protocol, in order to identify the existing frameworks used in IoT application development. Specifically, those frameworks that can be used for programming and architectural design, securing, and testing of IoT applications. By ‘framework’ we mean those standard methodologies, tools, platforms, and conceptual approaches, which can facilitate the IoT application development by providing guidelines for the development process, by providing better programming and design patterns, by handling several low-level functionalities and let the developer focus on high-level functionalities. The second objective of the paper is the classification of literature findings, by the solutions they propose, their methodology and the development stage where they contribute.

The research questions (RQ) covered in this review are stated below:

RQ1: Which is the overall trend of publications about IoT application development frameworks during the period 2018-2022?

RQ2: Which are the exiting frameworks used in IoT application development and how can they be classified based on approaches, objectives, and/or technologies used?

RQ3: What challenges do IoT development frameworks face in the development process?

RQ4: How do the IoT frameworks improve the reliability and performance of IoT systems in real-life applications?

The paper is organized as follows: In section II we discuss about main challenges in IoT application development. Section III describes the methodology of our systematic review. Section IV presents the answers for each Research Question. Finally, the conclusions of the research are shown in section V.

II. CHALLENGES IN IOT APPLICATION DEVELOPMENT

In this section we describe the main challenges during IoT application development process, and we discuss about how useful the frameworks can be in the application development process.

Adaptability. The IoT system changes its state by connecting or disconnecting devices in response to factors like

connectivity problems, the fluctuations of resources demands and the shortage of power [1].

Heterogeneity. Each device in IoT domain would be subject to several restrictions like energy consumption, processing capacity, security and communication bandwidth [17]. Different protocols used in different devices raise many integration issues in IoT applications.

Maintainability. IoT applications need to be self-adaptive and self-corrective to ensure the communication between the components. IoT system is distributed over a wide geographical area.

Security. Data security, authorization, authentication, and confidentiality are some essential security issues to be addressed in IoT application development [17].

Evaluation. The testing of an IoT system would guarantee the reliability to operate in critical situations. But testing non-functional requirements like performance or security is very difficult, because the system consists of several components and technologies that should be also specifically evaluated [1].

Other issues, that we have to deal while developing IoT applications, may include scalability, reliability, data management, context-awareness, energy management, etc. Our research focuses on frameworks used to ease the development of IoT applications by allowing the developer to focus on high-level functionalities and resolving some of the above-mentioned issues.

III. SYSTEMATIC REVIEW METHOD

After identifying the research questions, our research strategy in the literature review follows three main phases: search string identification, scientific databases selection and search execution.

A. Search String and Inclusion and Exclusion criteria

To select the most relevant studies we selected the following search strings:

- S1: design framework AND IoT application development
- S2: architecture model AND IoT application development
- S3: programming framework AND IoT application development
- S4: security-aware framework AND IoT application development
- S5: security-driven AND IoT application development
- S6: testing framework AND IoT application development
- S7: evaluation framework AND IoT application development

Furthermore, several inclusion and exclusion selection criteria are specified to identify studies, that may better answer to our research questions. The defined inclusion and exclusion criteria for this review are presented in Table I.

TABLE I. INCLUSION AND EXCLUSION CRITERIA

No.	Inclusion Criteria	Exclusion Criteria
1	Studies in English that provide answers to the research questions.	Studies that are not written in English.

No.	Inclusion Criteria	Exclusion Criteria
2	Studies that focus on frameworks used for programming and designing IoT applications.	Studies that don't answer to the research questions.
3	Studies that focus on frameworks used for securing and testing IoT applications.	Studies in which presented information is non-justified and not based on evidence.
4	Studies that are published from 2018 and up to 2022.	Studies that are duplicated or exists in several versions.

B. Scientific Database Selection

To select the most relevant primary studies that satisfy the identified search strings, we selected 5 well-known scientific databases in the field of ICT.

- ACM Digital Library (<http://portal.acm.org>)
- IEEE Xplore (<http://www.ieee.org/web/publications/Xplore/>)
- ScienceDirect – Elsevier (<http://www.elsevier.com>)
- SpringerLink (<http://www.springerlink.com>)
- Wiley Inter Science (<http://www3.interscience.wiley.com>)

While searching these databases using the defined terms/keywords, our objective is to select a representative set of studies for our systematic literature review.

C. Search Execution

We executed the search strings in each of the selected scientific databases and we obtained in total 284 scientific papers. We filtered the studies based on the inclusion criteria based on their APA style citation. We had to exclude some research papers written in languages other than English or papers published more than 4 years ago. Then we filtered the remaining papers by their titles and abstracts. Finally, the papers were scanned through full paper reading by considering some quality criteria to ensure their relation to IoT applications' frameworks. We checked that the study, is supported by facts/reasoning/experiments and follows a well-defined research methodology. Furthermore, the study must present the architecture of the proposed framework and its impact in the development process. Finally, a total of 46 primary studies is selected as shown in Table 2 and Fig. 1.

TABLE II. NUMBER OF INCLUDED STUDIES BY THE SOURCE OF PUBLICATION

Scientific Database	Number of selected papers
ACM	11
IEEE	26
ScienceDirect	4
SpringerLink	4
Wiley Interscience	1

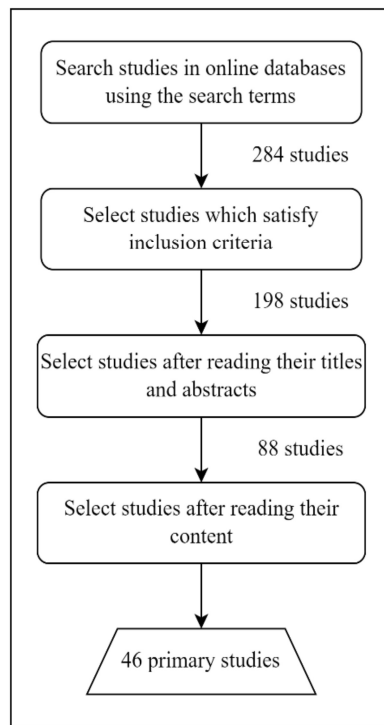


Fig. 1. Search Process Result

From each primary study we extracted the most important information to use for answering the research questions. The information extracted from the studies, is described in Table 3.

TABLE III. PAPER STRUCTURE DATA

Extracted Data	Description
Identity of the study	Unique identifier Title Author Publication source Year of publication
Impact of the study	The objectives of the study. The motivation of the study. The proposed framework.
Result of the study	The main characteristics of proposed framework. The contribution of the study for easing the development of IoT applications. The contribution of the study for facing challenges introduced in development process.
Methodology for evaluating results of the study	Techniques for evaluating the proposed solutions. E.g., the application of a proposed solution in the context of IoT real scenarios, experiments, interviews, etc.

IV. FINDINGS AND RESEARCH QUESTIONS' ANSWERS

RQ1: Which is the overall trend of publications about IoT application development frameworks during the period 2018-2022?

In the charts in Fig. 2 and Fig. 3 we present the number of studies for each year of publication, from 2018 to 2022. Most of the studies are published in 2018 and 2019 (around 54%). In general, the overall trend of publications is constant during

the 2018-2021 interval, with an increase in 2019. The 2022 is an exception, because it is not examined as a full year, but only for its first two months. As a result, we can say that IoT application development using frameworks is a topic which is discussed often by researchers, in a constant level, during the recent years.

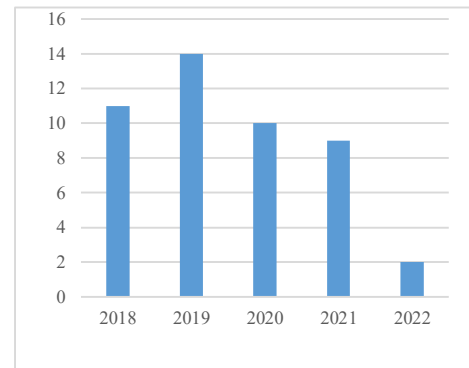


Fig. 2. Number of included studies by the year of publication

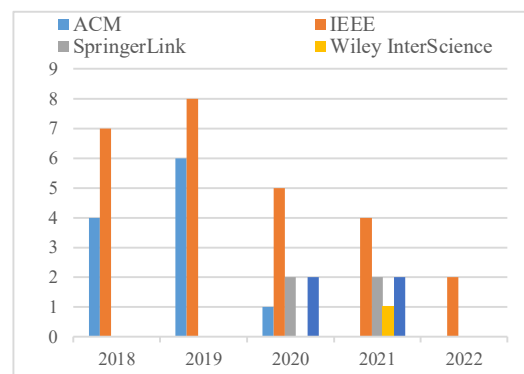


Fig. 3. Studies by year and source of publication

RQ2: Which are the exiting frameworks used in IoT application development and how can they be classified based approaches, objectives, and/or technologies used?

We identified four main categories of IoT frameworks: programming frameworks, architectural frameworks, security frameworks and testing frameworks, Fig. 4. In order to identify the approaches they propose, the technologies they use, their common motivation or similarities that exist between them, we divided them into several subcategories as shown in Table 4 and Fig. 5.

TABLE IV. CLASSIFICATION OF IDENTIFIED FRAMEWORKS

Category			<i>The identified frameworks and the primary studies that propose them</i>
<i>Main category</i>	<i>Subcategory</i>	<i>Description</i>	
Programming frameworks	Model-driven development	This type of frameworks uses MDE to effectively design and implement the IoT application.	CyprIoT [9], BrainIoT [7] and IoT Composer [13]
	User-driven development	This type is very helpful for those developer with minimal knowledge about MDE.	AutoIoT [6]
	Attribute-driven development	The development process, in this type, is driven by the functional and non-functional requirements.	IADev [5]
Architectural frameworks	Microservice architecture	These frameworks apply microservices architecture model to organize the IoT system.	The frameworks proposed by [2] and [3]
	Service-oriented architecture	These frameworks apply service-oriented architecture model to organize the IoT system.	iXen [14] and FlexyIoT [10]
	Edge framework	This type of framework utilizes edge computing and benefits from its features.	EdgeX [15], DeepEdge [49] and EdgeShare [47]
	Cloud framework	This type of framework utilizes cloud computing and benefits from its features.	CloudWoT [8] and framework proposed by [51]
	Intelligent-edge framework	These frameworks utilize AI, distributed over edge nodes.	BrainyEdge [46] and framework proposed by [48]
Security frameworks	Blockchain-based frameworks	Blockchain technology represents the core of these frameworks.	The proposed frameworks by [29], [30], [36], [37] and [52]
	SDN-based frameworks	This type of frameworks uses software-defined networking technology to design a secure structure for IoT system.	SD-DRFC [32] and SDN-SF [33]
	OPC-UA based frameworks	The architecture of this type of framework is based on the security model given by OPC-UA.	A framework proposed by [26]
	Model-driven securing frameworks	This type of framework use MDS to improve software system security by defining and designing requirements using system models.	MDSIoT [25]
	Cloud-fog-edge based securing frameworks	This type of framework utilizes the concept of cloud, fog or edge computing to enhance the efficiency and security level.	EdgeKeeper [28] and the frameworks, proposed by [34] and [35]
	Other security frameworks	In this category are grouped these frameworks, proposing specific more secure communication mechanism and system architecture.	IoT-HarPSecA [27] and IoT-Sphere [31]
Testing frameworks	Automated-testing frameworks	These frameworks make use of test patterns to test the application in an effective and easy manner.	Izinto [19], Héctor [23], PatIoT [24] and frameworks proposed by [31] and [50]
	Security-testing frameworks	These frameworks intend to evaluate security requirements of the system.	IoT-PEN [21] and Artorias [20]

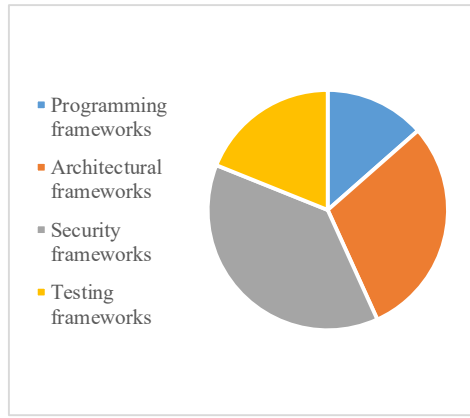


Fig. 4. Classification of frameworks

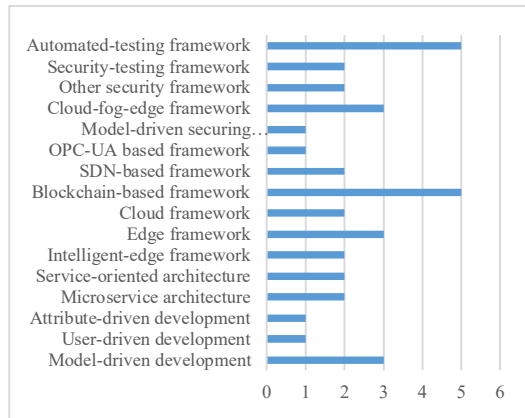


Fig. 5. Number of frameworks for each subcategory

The primary studies in [2]-[14], [46]-[49] and [51] are related to programming and architectural design of IoT applications using frameworks. Then, studies in [19] – [24], [31] and [50] discuss the testing aspect, and studies in [25] – [43] and [52] are related to security-driven development.

RQ3: *What challenges do IoT development frameworks face in the development process?*

IoT frameworks deal with different IoT challenges by proposing strategies for making the development process more effective and achieving higher quality for the final product.

We realized a mapping between the IoT development challenges, and the primary studies/frameworks which deal with each challenge. In Table V we show for each challenge the primary studies that propose approaches for overcoming them.

TABLE V. MAPPING BETWEEN IOT CHALLENGES AND THE PRIMARY STUDIES THAT HANDLE THEM

Challenges	Primary studies/Frameworks
Heterogeneity	[5], [6], [7], [9], [10], [14], [25], [29], [37], [47]
Adaptability	[3], [7], [8], [10], [15], [48]
Maintainability	[5], [7], [10], [14], [48]
Security	[20], [21], [26], [28], [29], [31], [33], [34], [47], [52]
Data Integrity	[26], [28], [30], [35], [36], [37]
Efficiency	[26], [27], [32], [34], [35], [36], [37], [49]
Evaluation	[19], [22], [50]
Scalability	[7], [8], [15], [29], [37]
Reliability	[2], [3], [5], [7], [8], [14], [15], [49]
Data management	[2], [7], [8], [51]
Context awareness	[2], [7], [8], [14], [46], [48], [49]

We notice that some frameworks can handle different challenges simultaneously. For example, the framework BrainIoT [7] that uses AI technologies to analyze the information can handle heterogeneity, adaptability, maintainability, scalability, reliability, data management and context awareness. Whereas the frameworks in [19] and [22] handle only the Evaluation challenge because they deal with testing the system in bottleneck cases while constantly checking the quality attributes of the IoT network. The challenges, that frameworks try to solve, are strongly related to the area where IoT will be applied. IoT may be used in different scenarios where features like security, low-latency communication, low power consumption, etc., can be required. Therefore, one framework must be equipped with right technologies in order to guarantee the fulfillment of any of above-mentioned requirements.

It is very difficult to realize an IoT system which would be able to deal with all these requirements at the same time. Practically, there is not a unique framework to face all the challenges of IoT development. A one-fits-all model of IoT framework would be very complex and highly inefficient. Each of the identified IoT frameworks is focused on solving some of the challenges and have specific objectives, regarding the scenario where IoT system will be used. So, they propose changes, follow different design strategies, exploit different communication mechanisms in order to satisfy their area-specific requirements.

RQ4: *How do the IoT frameworks improve the reliability and performance of IoT systems in real-life applications?*

In this paragraph we present some arguments on improved reliability and performance of an IoT application, built by using a framework, and introduce some real-life applications of the identified frameworks.

We can be sure that an IoT system, which is developed using a framework, would be more reliable and robust than without using one. This is certain because frameworks guide the development process on some well-defined steps, which are the outcome of decision-making process in building IoT systems through years. So, we can use others experience to make the right decisions for our product avoiding the repetition of past mistakes that would lead to a non-performant and not reliable IoT application.

IoT frameworks, depending on the nature of IoT application and its essential requirements, follow different

strategies to assure that the implemented IoT system will be reliable and performant. Some of the identified frameworks have implemented mechanisms to test and evaluate the IoT systems' requirements during all the development phases. They make use of automated test sets and thoroughly evaluate the system in bottleneck situations to check its performance. In other applications, where security is a critical issue and the most important requirement, frameworks have proposed advanced encryption and authentication techniques, and have adopted the Blockchain technology for very reliable and secure communication through the IoT network.

Other frameworks have proposed new ways of designing the IoT system in order to achieve a more efficient energy consumption and a better allocation of workload among resource constrained IoT nodes. Some others propose flexible architecture model for maximizing users' experience. IoT frameworks are also widely used in industrial application, which is an area which states some critical requirement like high response time and robustness. This is another argument for the increased reliability of IoT application when frameworks are being used.

The identified frameworks in this paper have proven their contribution in improving IoT development process in several IoT scenarios, where they have been successfully applied and good results have been obtained in terms of development time, product reliability and user experience. The real-life experiments of frameworks guarantee us about their correct behavior. Each scenario has the specific objective to show that each IoT framework can ease effective programming and design of the IoT system, help in building a more secure IoT system and testing the system to ensure that its requirements are all satisfied. Some of the frameworks and their real-life experiments are presented in Table 6.

TABLE VI. THE FRAMEWORK'S APPLICATION IN AN IOT SCENARIO

Primary study	The framework's application in an IoT scenario
<i>Programming frameworks</i>	
[5]	The proposed framework is applied in a smart vehicle scenario. The final product successfully satisfies all architectural requirements and stakeholders needs. The standard methods, used during development process, improve the developers' experience and the application code generation is fast and effective.
[9], [13], [7]	The proposed frameworks are applied in a smart house and smart warehouse scenario. Using the provided modelling languages, the developer declares objects of the house/warehouse as IoT things, specifies rules about their behavior and about the way they interact between them. It is demonstrated that less time and effort is needed during the development process. Due to the automatization of the development process, the produced application code tends to contain less errors. [7] applies smart behaviors to achieve smart control features on certain actuators in warehouse scenario.

<i>Architectural frameworks</i>	
[8]	The introduced framework is experimented in two scenarios: smart farming and automated driving. In the first case, the sensors in field gather information about insects and weather changes. Then information is sent in a middleware which filters it and produces a common data format. The edge computing nodes can control actuators to perform actions on the farm. The cloud is used for storing and processing large amounts of data. In the second case, a network of connected vehicles forms the IoT system. Vehicles, traffic elements, like signs or lights, represent the system's sensors and actuators. The collected information is also sent to the middleware that produces the restructured information. Edge nodes, based on the received information, can control actuators to influence the traffic flow by giving directions about speed, stopping vehicle, alerting about the road conditions, etc. The large amount of generated data is moved to cloud for storing and for further processing and analysis.
<i>Security frameworks</i>	
[26], [29], [33]	These frameworks test their proposed mechanisms for enhanced security like authentication and encryption schemas, smart contracts in prototype networks using hardware of various capabilities. They use performance metrics to evaluate their functioning.
[27], [28], [32]	The proposed frameworks are experimented by simulating many different test scenarios, testing it like it war in a possible real-life situation. In this way the functional and nonfunctional requirements are being evaluated. Testing metrics are compared to other existing frameworks and these frameworks have illustrated their advantages in satisfying business requirements.
[31]	The proposed framework is experimented on some IoT devices like cameras and google home by attacking the devices. On the camera was carried a DoS attack with an unallowed IP. On the other hand, google home was tested when the attack comes from a trusted source. The proposed framework was able to handle both those attacks.
<i>Testing frameworks</i>	
[22]	This framework is evaluated by using the EMU-IoT platform, which stands for Emulated Internet of Things. It is a platform developed by York University. EMU-IoT is a IoT emulation environment that allows software defined IoT devices to simulate the traffic on IoT networks that is as close to genuine as possible.
[20]	Artorias is experimented and it was able to identify common problems in mobiles apps, online interfaces and cloud connections.

V. CONCLUSIONS

Developing IoT applications is a difficult process due to the complexity that characterizes IoT systems. They are large systems with many components that have to communicate with each-other. Based on the areas where they are applied, they have various functionalities. When building IoT applications, we must deal with challenges like heterogeneity, adaptability, maintainability, security, evaluation and testing, scalability, context-awareness etc. The objective of this review was to select scientific papers that propose frameworks that facilitate the IoT development process. We selected 46 primary studies that present solutions and strategies for overcoming the above-mentioned challenges. The identified frameworks present a collection of helpful and assisting tools for programming and designing IoT applications, securing and testing them. For each of the identified frameworks, we present their main attributes, their

impact in easing the development process and the main technologies they use. We have classified the frameworks into four main categories: programming, architectural, security and testing frameworks.

This systematic literature review introduces to the reader some relevant approaches related to IoT application development. The proposed frameworks in this paper offer several points of view about how you can build IoT systems in an easier way. They suggest methods to program the IoT applications, to design their architecture, to make it secure and to validate and test it whether it satisfies all the requirements or not. This work can be a starting point for exploring possible future solutions and alternative approaches that would transform IoT application development into an easier and more efficient process.

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Geometrical Parameters Study from Squeal Index Formulation of the Surface Topography Squealing Disc Brake

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Abstract— Brake squeal is a very complex phenomenon and remains a challenging issue to vehicle manufacturers due to its complicated interaction between structural dynamics and tribological behavior. Brake squeal has turned out to become an active brake noise research topic. It can be seen by a number of published papers every year involves numerous disciplines such noise and vibration, friction composition, friction layer, wear, thermal effect, third body or wears debris and environmental issue. Despite massive information related to brake squeal has been presented and highlighted, there less information on the main mechanism of brake squeal generation on the tribological particularly in geometrical aspect. In fact, there is no information available in the open literature on the contribution of foreign particles such as road sand and debris particles on brake squeal occurrences. This study is to identify correlation between squeal generation and geometrical character of the pad surface topography, wear and friction coefficient. Squeal index proposed by Sheriff (2004) is performed in order to verify the correlation.

Keywords: Brake squeal, geometrical aspect, foreign particles, squeal index, surface topography

I. INTRODUCTION

The analysis of squeal instabilities is an important approach in spite of the numerous research method associate with works focusing on the subject of tackling the unwanted noise. In recent years, qualitative analysis has been gaining popularity in examining disc brake squeal behavior. Sheriff (2004) used basic statistical geometrical parameters from squeal index formulation to measure the surface topography of squealing disc brake and to identify the mechanism from the result of squealing varnishing or triggering. By assuming all the asperities summit to be spherical Figure 2.23, he defined the squeal index as;

$$\gamma = \sqrt{\sigma/\beta} \quad (1.1)$$

and the plastic index (ψ) is;

$$\psi = E'/H (\sqrt{\alpha/\beta}) \quad (1.2)$$

where the standard deviation of contact surface;

$$\sigma = \sqrt{\sigma_p^2 + \sigma_d^2} \quad (1.3)$$

$$\sigma_p = (R_q)p \quad (1.4)$$

$$\sigma_d = (R_q)d \quad (1.5)$$

with σ_p and σ_d is a standard deviation of height distribution of asperities for pad and disc surfaces while mean radius of asperities;

$$\beta = \frac{\beta_p + \beta_d}{\beta_d \beta_p} \quad (1.6)$$

$$\beta_p = \frac{(S_m^2)p}{32(R_p)p} + \frac{(R_p)p}{2} \quad (1.7)$$

$$\beta_d = \frac{(S_m^2)d}{32(R_d)d} + \frac{(R_d)d}{2} \quad (1.8)$$

with β_p mean radius of pad and β_d is mean radius of disc surface and S_m is a mean spacing between profile peaks of mean line.

In addition, Yoko and Nakai (2007) found that sound generated in friction contacts area increased the noise level parallel along with increased of rough surface area. Furthermore, the surface behavior of contacting layer was related to change of squeal behavior in brake systems. The stylus which contacts with the rough surface reveals that the roughness of larger amplitude will contribute larger amplitudes of sound pressure level. Moreover, at increased sliding speed and at lower roughness amplitudes will contribute higher frequency sound level. This supported the previous finding of Eriksson (2004) and Sheriff (2004) who introduced a “squeal index” indicated that the increasing number of small size of plateaus or asperities are prone to generate squeal noise compared to smaller number of large plateaus and the roughness generation of the surface area was

highest during squeal propensity. Nouby et al. (2009) on their experiment investigated the factor that influence brake disc squeal through a statistical technique to find the relationship between the negative damping ratio and the various factors of the disc brake using multiple variable regression analysis. They constructed the relationship between the brake squeal and the brake pad through various geometrical configurations with the influences of young's modulus, thickness, chamfer and distance between two slots, slot width and angle of the slot. They correlated the statistical analysis with a mathematical prediction model based on the most influencing factor using variance analysis (ANOVA) to verify the significance of the factors. From the result, they found that brake squeal tendency tended to reduce by increasing Young's modulus of the back plate and modifying the shape of friction material. Oberst and Lai (2011) established a technique to analyse brake squeal data and to evaluate the correlation between the time-averaged friction coefficient and the peak sound pressure level. The experimental results were evaluated based on the noise index calculation and cumulative noise distribution. The noise index calculation was evaluated by summing up the weighted numbers of occurrences with a specific frequency and reflects the peak sound pressure level (SPL) of noise occurrences using a weighting factor. While for cumulative noise distribution was used to establish the acceptability of the brake system in term of squeal. Two types of statistical analyses were done to perform the significant test by quantifying the population distribution of friction coefficient (μ) and sound pressure level (SPL). They found a nonlinear character on squeal and the capability of nonlinear statistical analysis in analysing squeal occurrence. Hetzler and Willner (2012) used the basic statistical analysis to study the topography layer of different brake pads on wear behavior. The topography layers of brake pad demonstrate the wear surface tend to smooth the peak surfaces and embedded the valleys with debris particles. This process will reduce the summit height of standard deviation drastically. Their results also reveal that that the contact stiffness of the surface properties has contributed to the effect on the frictional vibrations particularly of brake squeal at low and medium contact pressures. Thus, they conclude that the stability behavior of friction surfaces occurred at all variations between the relation of contact stiffness and pressure. Sueti (2013) proposed a method to qualify the occurrence and behavior of noise in a set of braking noise index from 0 to 10 which could be used in the dynamometer and vehicle test analysis. He used the analytical equation with the function of speed, temperature, frequency, noise duration with a number of braking. The method proposed result found compatible with the graphical analysis. Bonnay et al. 2015 and Ghorbel et al. 2019 proposed new approach from the brake pad geometry in brake squeal by developing a new dynamic model of disc brake squeal improved model led to a better understanding of the unwanted squeal phenomenon. In this paper, we proposed a correlation between squeal generation and geometrical character of the pad surface topography, wear and friction coefficient by applying the squeal index method which earlier introduced by Sheriff (2004)

II. EXPERIMENT TEST PROCEDURE

The experimental test brake test rig (Fig. 1) is powered by an 11 kW DC motor and operated at a maximum torque of 413 Nm at 20 bars hydraulic pressure. A number of transducers such as accelerometer, pressure sensor, microphone, thermocouple, torque sensor and speed sensor are used to capture the squeal and brake operating data and the data are then recorded using 16 channels Dewetron data acquisition system (DAQ). A small hopper is fitted at the middle shaft support to hold and disperse external grit particles. Squeal tests are carried out and recorded at various operating conditions where speeds of the disc are set at 25, 50, 75, and 100 rpm while hydraulic brake line pressure is applied up to 2.0 MPa. Prior to the squeal tests, warming up process (bedding-in) is conducted to deposit an even layer of friction material, or transfer layer on the rubbing surface of the disc. This process needs to be done at a low disc speed (6 rad/s or 57 rpm) with a brakeline pressure of 1.0 MPa for half of an hour.

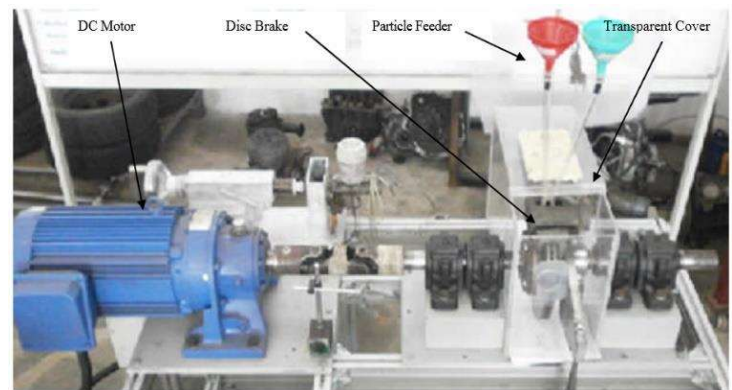


Fig. 1. Brake Squeal Test Rig and External Particles Feeder

A. Brake Friction Material

Brake pad materials used in this work is based on two different samples of Non-Asbestos Organic (NAO) and it is composed by six (6) main constituents including phenolic resin, reinforcing fiber, friction modifiers, abrasive particles, fillers, solid lubricant and metal oxide. The disc material is made of a commercial gray cast iron which contains of graphite flakes in a pearlite matrix with small quantity of free ferrite and homogeneous structure.

B. The Airborne Emission Particles

In this work the airborne particle with the size of 100–400 μm is selected. This particle size is selected due to their common present at the road surfaces environment. in Malaysia. Fig. 2 show SEM image and composition of grit particles, respectively.

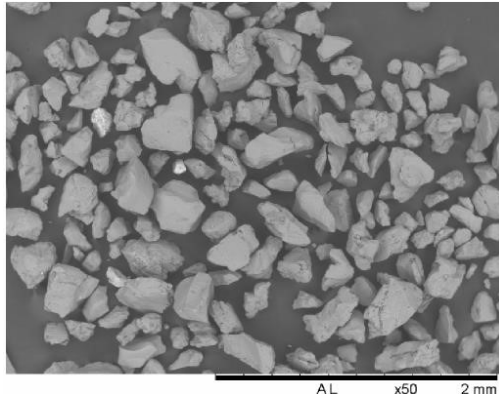


Fig. 2. SEM images of Airborne Particles at different size ranges of 400- 500 μm at 50X magnification

C. Brake Squeal Index

The brake squeal index proposed by Sherif (2004) was adopted in this work with the aim of measuring surface properties' contribution towards squeal occurrences. Silent and squealing pad surfaces was classified as a function of the standard deviation and mean radius of sliding surface called asperities or harshness. When two flat surfaces brought into contact forming asperities (rough surface), squeal is established due to the pad glazing (friction layer formation) on a sliding disc and pad. Furthermore, the tearing away of elastic asperities with weak stiffness under the action of fatigue cycles (crack asperities are tearing and remove continuously) promote the squeal noise. The squeal index (γ) is defined as;

$$\gamma = \sqrt{\sigma/\beta} \quad (1.1)$$

Where;

β : is the mean radius of asperities of pad/disc assembly,

γ : is the squeal index.

σ : is the standard deviation of the height distribution of asperities

By assuming all asperities summits to be spherical the mean radius (β) of asperities of pad and disc is given as;

$$\beta = \frac{\beta_d \beta_p}{\beta_d + \beta_p} \quad (1.6)$$

$$\beta_p = \frac{(S_m^2)_p}{32(R_p)_p} + \frac{(R_p)_p}{2} \quad (1.7)$$

and

$$\beta_d = \frac{(S_m^2)_d}{32(R_p)_d} + \frac{(R_p)_d}{2} \quad (1.8)$$

And the mean standard deviation σ of the pad and disc contact surface is expressed as;

$$\sigma = \sqrt{\sigma_p^2 + \sigma_d^2} \quad (1.3)$$

With

$$\sigma_p = (R_q)_p \quad \text{and}$$

$$\sigma_d = (R_q)_d$$

Where

β_d : is the mean radius of the asperities of disc surface,
 β_p : is the mean radius of the asperities of pad surface
 S_m : is the mean spacing between profile peaks at mean line,

$(R_p)_{p \& d}$: is the maximum height of profile above mean line pad and disc,

σ_p, σ_d : is the standard deviation of height distribution of asperities pad and disc

$(R_p)_{p \& d}$: is the r.m.s. parameter corresponding to centreline average

The geometry of the asperities of Sheriff (2004) theory is illustrated in Fig. 3:

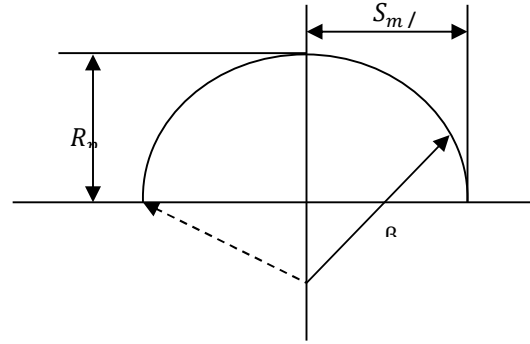


Figure 3: The geometry of spherical asperities

The following roughness parameters (R_a , R_p and S_m) were selected to describe the surface texture and to calculate the noise index data of Eq. (1.3 to 1.8). The parameters are illustrated graphically in Fig. 4.

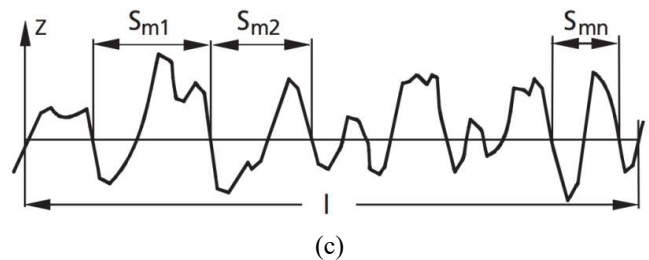
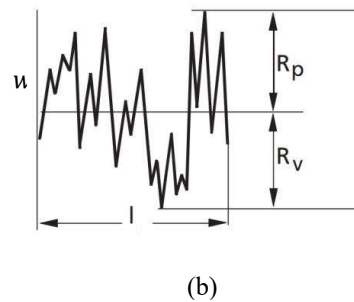
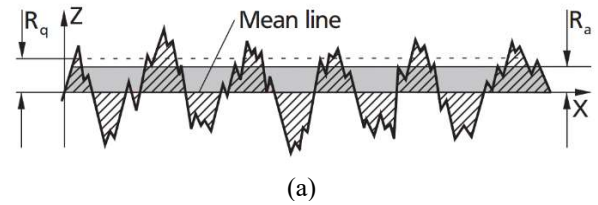


Fig. 4. Surface roughness parameter (a) roughness value Ra, (b) maximum height of profile above mean line (Rp), and (c) mean spacing between profile peaks at mean line (Sm) (Gadelmawla, 2002)

III. RESULT AND DISCUSSION

The result of Tab. 1 shown the surface roughness parameter of new and squeal test pad samples with and without foreign particles. The roughness parameter result was compared with the squeal sample tested data of SLM and the squeal index factor. The roughness data were taken at nine (9) points of the pad sample's surface area, on both the finger and piston sides which cover the lower, middle, and upper area. The average for the whole area was taken as the roughness data for the sample test.

A. Squeal Index

The result of Fig. 5 represents the squeal index results of pad samples 1 and 2, tested without and with particle effect. The squeal index results follow the roughness result pattern, whereby the increasing particle size reduces the squeal index value. Figure 4 for sample 1 shows that the index value for a new pad is 0.308, which reduces to 0.109 during both the sliding and squeal occurrences. It decreases significantly with the increasing number of particle sizes of both silica sand and road sand particles.

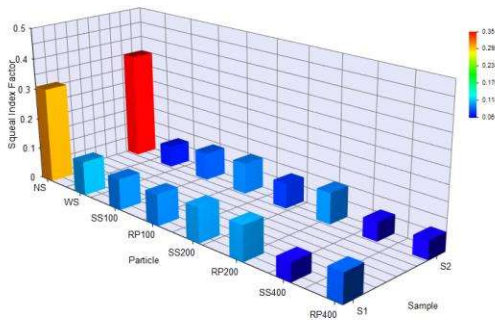


Fig. 5. The squeal index (γ) of new (NS), without particle (WS), and with silica sand (SS) and road particle (RP) effect of sample 1 (S1) and sample 2 (S2)

Prior to the result of sample 1, the reduction of squeal index also occurred on sample 2 whereby the value was reduced from 0.346 to 0.071 for the squeal pad without particle effect, and decreased significantly with decreasing particle sizes. As recommended by Sheriff (2004) the squeal event is established at an index value of below 0.1 regardless of sliding speed and pressure. The gradual reduction of squeal index with the increasing size of particles shows that particle types and sizes play an important factor in determining the squeal behavior of pad samples in which particle sizes and types influence the surface topography of sliding surface, hence changing the mechanical properties of the pad and disc samples, resulting in the occurrence of noise and vibration. In addition, the result also demonstrates the squeals are triggered due to the decrease of contact stiffness resulting from a gradual reduction of squeal index because of the

wearing process. Furthermore, squeal vanishing contributes to the production of wear debris, which means an increase in the squeal index.

B. Determination of Squeal Factor

The squeal factor is defined as the squeal index of a new sample (γ_n) divided by the squeal index of a squeal sample (γ_s). The factor of noise transition from silent to squeal is presented in Tab. 2. These results represent the relation of sound pressure level (SPL) and index number of each sample with the existence of silica sand particles and road particles of sizes 100, 200 and 400 μm . These results are then compared to those without particle effect. The results indicated that the squeal index γ of samples 1 and 2 without particle effect fell by a factor of 3 (92 dB) and 5 (93 dB) with the reduction of 0.3083 to 0.1093 and 0.3459 to 0.0712 for sample 1 and sample 2.

TABLE 2. SQUEAL FACTOR AND SOUND PRESSURE LEVEL OF TESTED SAMPLES

Particle Type & Size		Squeal Factor (Sample 1)	SPL dB(A)	Squeal Factor (Sample 2)	SPL dB(A)
New Samples Without Particle		1	Silent	1	Silent
Squeal Samples Without Particle		3	93	5	93
Silica Sand	100 μm	3	80	4	87
	200 μm	3	80	5	85
	400 μm	5	79	6	80
Road Particle	100 μm	3	84	3	90
	200 μm	3	79	3	80
	400 μm	4	76	5	79

A similar trend was observed in the test with silica sand and road particles for sample 1, showing an increment of squeal factor with increasing particle size as shown in Fig. 6 to 7. In addition, an increasing size of particles tends to reduce the squeal noise level (SPL) and increase the index number of each sample. This is supported by the results of sample 2 with the increasing trend of squeal factor for both road and silica sand particle types by a factor 3 to 4 at (80 to 87 dB) of particle size 100 to 150 μm , 3 to 5 at (80 to 85 dB) of particle size 200 to 300 μm and 5 to 6 at (79 to 80) of particle size 300 to 400 μm . Thus, it was concluded that the lower the squeal factor, the higher the squeal level (Tab. 2). It is shown that particles play an important role in reducing the noise level on the pad surface as well as increasing the value of the index number.

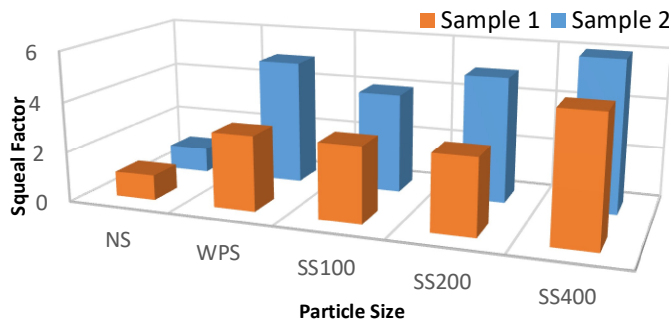


Fig. 6. Squeal index factor of sample 1 and 2 with the effect of silica sand particle

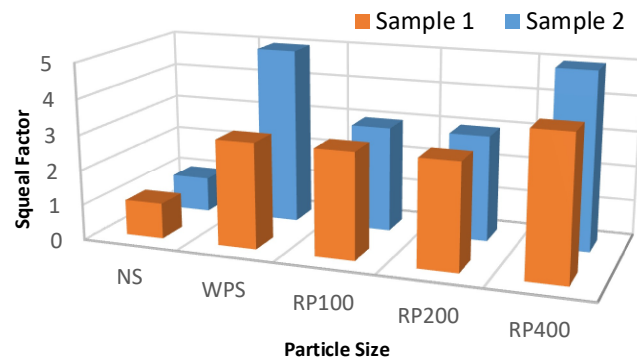


Fig. 7. Squeal index factor sample 1 and 2 with the effect of road particle

C. Squeal Index

In this study, the squeal index (SI) proposed by Eriksson (2000) and brake noise objective index (BONI) developed by Attia et al. 2006 were adopted. Brake squeal index, also known as noise index, is based on the subjective ratings for brake squeal annoyance taken from squeal index number. It provides a reliable prediction of the annoyance of brake squeal on a rating scale from 1 (unbearable) to 10 (non-hearable) Tab. 3.

TABLE 3. SQUEAL ANNOYING RATING SCALE BONI (ATTIA ET AL. 2006)

1	2	3	4	5	6	7	8	9	10
Unbearable Squeal		Heavy Squeal		Moderate Squeal		Little Squeal		Trace of	No
								Trace of No Squeal	

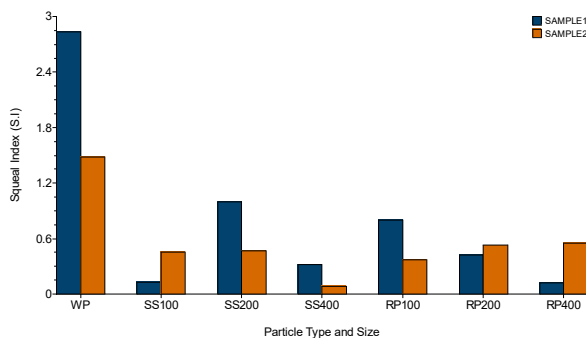


Fig. 8. The squeal index number of pad sample 1 and 2 with and without foreign particles

The squeal index is calculated by dividing a number of squeals generated (sound classified as squeal) over a total number of brake applications (total number of measurement). Fig. 8 shows the squeal index number with and without particles of silica sand and road grit. Through the squeal index, the squeal generation of samples is well described either with and without particle effect. It is found that squeal index for pads without foreign particles is higher than pad with foreign particle for both pad samples.

IV. CONCLUSION

The complexity of material interaction at the sliding interface between the pad and the disc is considered to be one of the most challenging and complicated research studies since it is highly complex. In addition, the exploration of the geometrical aspect and the analysis has revealed several conclusions as follows:

- The presence of foreign particles of different types and sizes on the friction layer has changed the performance of the brake pad. This promotes squeal propensity,
- The high value of roughness of the new pad compared to used ones (with and without particle effect) is believed by some researchers such as Maruyama et al. (2004) to be related to the rougher surface and the larger amplitude of roughness.
- These produce larger sound amplitudes and shorter wavelength of roughness. The increase of speed and pressure also would generate sound of higher frequency as seen on the results of squeal pad samples.
- The rougher surface area causes abrasive wear and avoids (impedes) the formation of a stable transfer film, which leads to higher values of COF and decreases the level of noise (Saha et al., 2011).
- The gradual reduction of squeal index and the increasing friction coefficient with the increasing size of particles shows that the squeal behavior of pad samples strongly depend on the surface topography of sliding surface which associated with the wear particle compaction, effective contact area and adhesion of the foreign particle in the brake pad to the friction surface of the disc brake.

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GRINDING PELLETIZED MATERIALS

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Abstract—The paper experimentally shows that the grinding of pelletized materials in turboblade apparatuses can be significantly intensified by the use of wedge-shaped rods of various taper angles along the rotation of the working shaft. In addition, to the zones of loading and unloading, the zone of coarse, fine and fine grinding of solid materials is sequentially placed in the apparatus. It has been established that pelletized chalk, which had a particle size distribution of 84% before grinding with a fractional composition of 0,5 to 4,0 mm, after grinding, the particle size distribution was 91,5% with a fractional composition from 0,01 to 1,0 mm. Moreover, fractions from 0,02 to 0,2 mm amounted to 85%. By comparing the results on changing the surface of the particles, the optimal region of rotation of the working shaft was established, which provides a significant increase in the heat exchange surface of the particles.

The achieved intensification of the grinding process allows, with the same performance in the optimal region, to increase the surface of the particles by 1,95

Keywords — grinding, grinding degree, turboblade apparatus, angular velocity, wedge-shaped rods, placement step, fraction, granulometric composition, intensification, particle surface, reduction of energy costs.

I. INTRODUCTION

The choice of the optimal process and apparatus for processing various raw materials requires knowledge of their physical, mechanical and thermal properties. Knowing the characteristics and patterns in their changes, one can judge the physical properties, structure, etc. [1,2,3], which helps to identify the kinetics and mechanism of processes, indicate ways to control and intensify technological processes.

It is known that the efficiency of processing solid materials largely depends on various factors [4]: temperature, humidity, porosity, density, etc. One of the main factors, of course, is the porosity of the material and its physical density.

Grinding of solid materials is currently one of the most energy-intensive, material-intensive and widespread processes. It is carried out, as a rule, by mechanical destruction of large fragments by impact or squeezing action in apparatuses of various designs. Every year, several billion tons of various materials, such as ore, coal, cement, mineral fertilizers, are subjected to crushing and grinding, which consumes about 7-10% of all electricity produced in the world is spent annually on these processes [1-2].

The problem of crushing and grinding is dealt with by researchers from many countries, who have identified the main regularities of the grinding process, developed methods for calculating grinders and mills. The patterns, mainly of an empirical nature, between the energy costs and the fineness of the crushed raw materials are adequate in a narrow range of fineness of a limited number of materials [1,2].

However, none of the previously published theories and none of the empirical laws of grinding is correct in the field of fine and superfine dispersion, and, moreover, none of them takes into account the influence of the external environment on the process and energy of destruction [5,6,7]. Research in recent years has not changed the situation. The Kick, Rittinger, and Bond refinement laws are still the subject of analysis and discussion [8,9,10]. Failures in the search for universal laws of grinding are due to a one-sided mechanical interpretation of the processes that occur during the destruction of solids and do not take into account the role of the external environment in them [11].

There is a method of grinding particles by swelling due to the created pressure difference when supplying plant materials and preliminary drying at a temperature of 75-150°C [4]. To obtain a powder of vegetable raw materials, it is crushed to a homogeneous state, mixed with dry vegetable components to a dry matter content in the mixture of 20-30% and sprayed into a carbon dioxide gaseous medium at a temperature of 150-180 °C and a pressure of 150-250 kPa. The drying process is carried out under vacuum at a pressure not exceeding 50 kPa [12]. However, in the technologies used, methods based on impact and cutting are most widely used [2]. In addition to traditional grinding methods, there are: air peeling, the method of cyclic changes in the pressure of the medium, the method of electrohydraulic effect, etc. [13]. However, none of the above methods has found industrial application due to the impossibility of achieving complete splitting or significant energy costs.

To carry out the grinding process, a large number of different crushers and grinders have been designed, which are used in industry. An apparatus for grinding various products is known, which is configured to drive the cutting body into rotation and an anti-cutting plate adjustable relative to it, the two opposite ends of which are connected to the corresponding adjusting device so that the position of the clearance of the anti-cutting plate relative to the cutting body is changeable. Changing the position of the lumen of the shear

plate provides the control of the adjusting devices, which prevents damage to it and damage to the shear plate [14].

Disadvantages of this design: knives are often dull, and when sharpening the cutting edges, the edge is removed from the knives, which greatly affects the distance between the counter-cutting plates, and worsens the grinding process; too much gap between the plates leads to incomplete cutting, and too little gap leads to chipping of the knife material or damage to machine parts.

A device for grinding materials [15] is known, which contains a housing with a loading pipe, a screw connected to the shaft, and a cutting body consisting of a knife and a grate. The device additionally includes a pendulum pusher and a storage tray passing into the loading pipe, which is made in the form of a curved chamber of rectangular section, mating with the working chamber of the body to form a receiving window with a sharp edge in its lower part, which is inclined to the axis of rotation of the screw. This invention allows to reduce the power consumption for grinding, increases the speed of processing materials.

As disadvantages, it should be noted an increase in the lateral load on the attachment point of the device to the electric motor and a sharp increase in the intensity of oxidative processes as a result of heating and mechanical destruction.

A centrifugal impact grinder has been developed, which contains a cylindrical body with a loading device and an unloading chamber, left and right discs are coaxially located in the grinder body with annular grooves in the form of alternating triangular protrusions and trapezoidal depressions in the radial section of the disk, on which knives are installed [16]. The protrusions of one disk enter the cavities of the other with the formation of a gap. Chopper, which includes two coaxially arranged and rotating towards each other disks with annular grooves in the form of alternating triangular-shaped protrusions and cavities, on which trapezoid-shaped cavity knives are installed, while the tops of the protrusions of one disk are displaced relative to the tops of the obtuse angles of the depressions of the other disk by the step size.

The disadvantages of this design are low productivity and high energy costs, as well as blunting of the knives, which leads to the need for their frequent replacement.

Silvano B. created a roller mill for grinding and sorting bulk materials, containing a pair of rollers rotating in opposite directions, between which a gap is formed for the passage of the material to be crushed, and a sieving device combined with rollers to separate the grinding products in accordance with the particle size of the ground material [3].

One of the promising methods for grinding solid materials is the high-speed grinding of various solids in turboblade type apparatuses [17, 18]. Of particular note is the fact that the residence time of the crushed material in the apparatus is several seconds, which ensures high economic efficiency of this grinder design. Along with the above advantages, the grinding of pelletized materials in turbo-blade shredders makes it possible to obtain a homogeneous material with a high particle size distribution and, most importantly, with a good presentation.

II. EXPERIMENTAL SETUP AND METHODOLOGY FOR CONDUCTING EXPERIMENTS

Laboratory plant of turboblade type, horizontal design is designed for grinding pelletized and some hard materials. The device has 5 zones: loading "A", medium grinding "B", fine grinding "C", fine grinding "D" and unloading "E".

The device consists of a cylindrical body mounted on two supports, inside which a shaft with wedge-shaped and round rods is located along the horizontal axis. The shaft is mounted on bearings on both sides and is seated in a glass, which rotates inside the bushing on a sliding fit. The shaft performs both rotational and reciprocating motion.

To carry out the rotational movement, the end of the shaft located on the side of the loading zone is connected to the electric motor by means of a coupling. The reciprocating movement of the shaft is carried out by means of a pneumatic cylinder, which is connected to the other end of the shaft by means of a flexible coupling that connects it to a DC motor. In turn, the pneumatic cylinder is connected to the compressed air cylinder through a device that ensures the periodic supply of compressed air to the pneumatic cylinder and, as a result, a shaft movement of 20 mm is achieved.

The feedstock, pelletized or solid materials in the form of pieces of solid products or chemical production wastes enter through the fitting, and the crushed material is unloaded through the fitting. Superfinely crushed dust-like particles are discharged through the fitting, at speeds equal to the speed of their entrainment. The second end of the shaft, like the first, is mounted on a bearing, and the outer race of the bearing is fixedly fixed in a glass, which slides and rotates in the sleeve. A rubber gasket is installed between the flanges and the bushing and tightened with bolts.

In the loading area "A" blades are installed in the amount of 5 pieces at an angle of 720 to control the supply of feedstock into the space between the cylindrical body and the shaft. The spacing of the blades in the loading area is $t=2,5 \cdot d$. This design ensures good mixing and efficient feeding of material into the grinding zone "B". The grinding zone "B" is 1/4, while the fine grinding zone (C) is 1/4 and the fine grinding zone is 1/2 of the total length of the grinding zones.

In the pre-grinding zone "B", on a shaft with a diameter d_b , rods are located only in one perimeter. Naturally, there are several such perimeters and their number depends on the properties of solids.

In the pre-grinding zone (B), the radial rods are located at an angle of 600 and have design features, consisting in the fact that the cross section has a wedge-shaped (at an angle of 300) shape and the ends of the rods have a beveled end. The wedge shape of the rod with an angle of 300 is explained by the fact that in this zone the dominant method of grinding is splitting or cutting lumps of the crushed material. Moreover, the pointed part of the rod is installed along the rotation of the working shaft. The wedge-shaped rods in the coarse grinding zone are placed with a step $t=(1,2-1,5) \cdot d$. Such an interval of the pitch of the placement of wedge-shaped rods is due to the fact that the numerical values of the degree of grinding at such a pitch are quite high. The efficiency of grinding the material is ensured both by splitting and by abrasion and impact on the wedge-shaped rods.

In the zone of coarse grinding with a rod pitch $t/d < 1.2$, the sizes of the resulting particles are not the same and have an

irregular shape. Each product has certain requirements that dictate the size of a particular material. In particular, red beet particles should have a marketable product diameter of 1-2 mm. If the particle diameter of the material is less than or greater than the specified size, then it is considered non-standard.

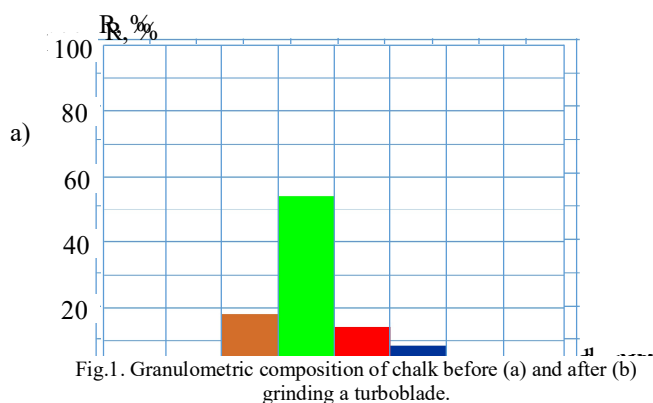
In the coarse grinding zone at $t=(1,2-1,5)d$ the sizes of the obtained particles do not differ much from each other and the granulometric composition is not uniform. At $t>1,5d$ it is very difficult to obtain a final product with a uniform granulometric composition. An increase in the spacing of the rods in the coarse grinding zone reduces the number of "solid body-rod" collisions, which leads to the formation of particles of various sizes, and therefore to a deterioration in the uniformity of the granulometric composition of the finished product. In this zone, the rods form a helix along the shaft rotation. The special, wedge-shaped design of the rods improves the grinding process, increases the yield of commercial fraction with a high value of uniformity of particle size distribution.

The fine grinding zone is designed to obtain a fraction in the range of 2.0-10 mm. In the zone of fine grinding on a shaft with a diameter of d in one perimeter there are rods in the amount of 12 pieces. Moreover, the wedge-shaped rods are pointed in the direction of rotation at an angle of 45° . In the zone of fine grinding, the rod is pointed in the direction of rotation at an angle of 60° . All ends of the rods are beveled at an angle of 20° . A characteristic feature of the developed apparatus is that the shaft with rods can carry out both rotational and reciprocating motion. The rotary motion is from 100 to 2880 rpm, and the reciprocating motion ranges from 30mm. The upper limit of the reciprocating movement of the shaft with rods of 20 mm is associated with the possible sticking of material in each zone of grinding of solid material. Experimental data were processed by known methods.

III. RESULTS OF AN EXPERIMENTAL STUDY

To date, industrial grinders in various industries use two or more staged grinding with an appropriate number of devices to obtain finely divided materials. Elimination of the above disadvantages is possible only by intensifying the grinding process and combining several stages of the process in one apparatus, which will reduce energy and material costs. These requirements are met by the method of successive grinding of pelletized materials in one apparatus of a turboblade type with zones of coarse, fine and fine grinding.

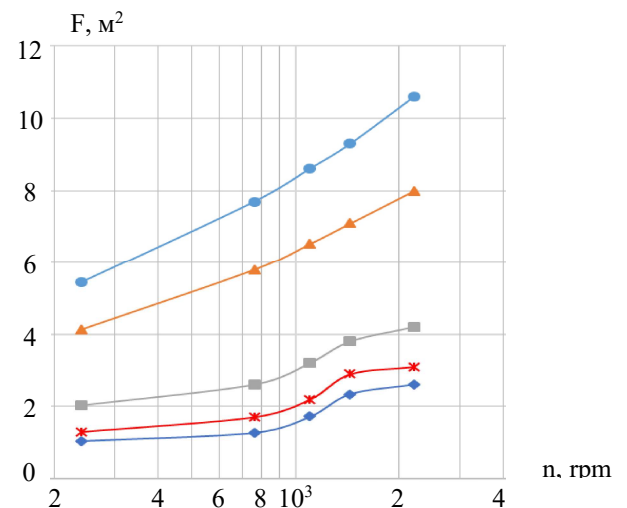
Figure 1a shows the granulometric composition of the initial chalk before granulation, which has the following composition: a fraction of up to 1,0 mm is 30%, the proportion



of a fraction of 1,0-2,5 mm is 61%, a fraction in the range of 2,5-3,0 mm is 5%, the share of 3,0-3,5 mm is only 4%, the share of the fraction 3,5-4,0 mm is 3%. Granulometric composition 84%

Figure 1b shows the granulometric composition of chalk after grinding, with the number of revolutions of the working shaft $n=2200$ rpm, chalk consumption $G=0,045$ kg/s. As you can see, the granulometric composition has improved significantly, and the fraction up to 0.01 mm was 7%, the proportion of the fraction 0,01-0,05 mm was 18%, the fraction in the range of 0,05-0,1 mm was 54%, the proportion was 0,1-0,2 mm 11%, the share of 0,2-0,5 mm 8,5% and finally, particles from 0,5 to 1 mm amounted to only 1,5%. Granulometric composition – 91,5%.

Figure 2 shows the results of experimental studies on the change in the surface of particles of crushed materials in a high-speed apparatus of a turboblade type. It can be seen that with an increase in the number of rotations of the working shaft n , the degree of grinding i increases, and, accordingly, the specific surface of the particle layer increases.



$d=0,02$ mm; $\blacktriangle$ - $d=0,1$ mm; $\blacksquare$ - $d=0,5$ mm; $*$ - $d=1,5$ mm; $\blacklozenge$ - $d=2,5$ mm.

This pattern is preserved for all values of the equivalent diameter of crushed particles. So, for example, at the number of revolutions of the working shaft $n=240$ rpm, the fraction with a diameter $d_e=0,020$ mm will have a total surface $F=5,44$ m², at $n=1100$ rpm the particle surface is equal to $F=8,61$ m², and accordingly, with a total surface $F=10,6$ m². An analysis of the experimental data shows that an increase in the rotation number of the working shaft with rods from $n=240$ rpm to 2200 made it possible to increase the proportion of particles with an equivalent diameter of 20 μ m, and, accordingly, the surface of the particles by 1,95 times.

Similar patterns were recorded for fractions with equivalent diameters in the range $d_e = 0,1-2,5$ mm, and the increase in the surface of the particles, respectively, fluctuates in the range of 1,94-2,38, depending on the d_e particles. And if we take into account that along with grinding, the cooling process simultaneously proceeds, then the above-mentioned phenomenon has a positive effect on the second jointly

occurring process. During the grinding process, the particle size decreases, i.e. the granulometric composition undergoes fundamental changes, which leads to an increase in the contact surface of solid particles with cooling air. In addition, in a turbulent mixed layer, the heat transfer coefficient depends not only on the particle size distribution, but also on the size and porosity of the layer. Thus, with fine grinding, the equivalent particle diameter decreases to 0,01 mm.

This is due to the fact that the grinding of solid particles by the splitting method is carried out over the entire height of the pointed wedge. Both surfaces of the wedge are working and grinding is carried out on them by the methods of impact and friction.

Conclusion. Due to the fact that with an increase in the degree of grinding in the process of crushing solids, the energy expended increases accordingly. Therefore, it is not necessary to grind solid materials unnecessarily in order to save energy costs. Therefore, it is proposed to solve the problem by combining the three grinding methods and implementing them sequentially in one apparatus. The presence of zones of coarse, fine and fine grinding leads to an increase in the degree of grinding and the heat exchange surface, which positively affects the convective heat transfer during grinding of pelletized materials and contributes to the intensification of heat transfer.

When used in each of the three wedge-shaped rods with different sharpness angles in turboblade devices, they are most effective in the range of angular velocity numbers $\omega=10-25 \text{ c}^{-1}$, depending on the properties of the crushed material. In the optimal region of the speed of rotation of the working shaft, when grinding pelletized chalk, it was possible to obtain a finely ground fraction.

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Virtual and Augmented Reality in Education

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Abstract—The use of virtual and augmented reality technologies in education has increased in the last decades because of the development of low-cost equipment. The paper describes the utilization of the technology of virtual and augmented reality in educational institutions. The paper contains the definition of both concepts' virtual reality and augmented reality and depicts the equipment and necessary software to run applications. An overview of applications within education is provided too.

Keywords—*virtual reality, augmented reality, education, styling, insert*

I. INTRODUCTION

Virtual Reality/Augmented Reality (VR/AR) technology offers a new way of learning that overcome the limitations of the current learning systems. The best way to use VR/AR is when the content allows students to explore and interact with the concepts. This drastically increases students' engagement by capturing their attention.

Additionally, the technology offers the flexibility of learning and supports the statement that one size doesn't fit all. Considering VR/AR technology supports learning by using gamification and challenge-based activities, it helps students to develop skills for making quick decisions, overcoming obstacles, etc. When this is accompanied by immediately rewarded points it provides instant gratification which can increase student motivation.

The paper describes the present state of VR/AR technology and provides insight into how the technology can be used within the educational system. Several examples present different possibilities, but the authors do not pretend that they describe the full power of the technology or all possibilities. The paper is organized as follows. The next section defines virtual reality (VR) and augmented reality (AR). The section three depicts the required technology (hardware equipment and software tools). Several examples of how to use VR/AR in education are described in section four. Sections five and six discuss the advantages and disadvantages of VR/AR in education. The final section is the conclusion.

II. DEFINITION OF VR/AR

There exist a lot of definitions related to virtual and augmented reality. For the aim of the paper, we will consider the following definitions.

A. Virtual reality

Virtual reality is a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more

senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world). [1]

According to this definition, the key elements of VR technology include a virtual world, immersion, sensory feedback, and interactivity.

A *virtual world* represents the content of a simulation. The content consists of objects described by their 3D appearance and behaviour. The most important characteristic of objects in the virtual world is that they exist independently from the user.

Immersion defines the extent to which simulated reality claims the attention of the user or how much the user is present in the virtual environment. We divide VR according to the user's immersion within the virtual world into non-immersive, semi-immersive and fully immersive VR.

Sensory feedback defines another feature of the virtual world which considers the response to the user input using human sensory systems. Sensory feedback could be established by visual (3D world), audio, tactile, olfactory, (taste....) signals. The most common sensory feedback provided in a VR environment is by using visual and audio signals. Other human sensory systems are not commonly used at present.

To consider 3D simulation as a virtual world it must be *interactive*. Interactivity means the system reacts to user activities in the virtual world with feedback like the real world. The interactivity enables camera (view) control; navigation and travelling in the virtual world; selection and manipulation with virtual objects. The minimal interaction 3D simulation to be considered a virtual world requires user view tracking (view control) and adapting the scene according to this information. [1]

B. Augmented reality

Augmented Reality uses technology to add a layer of information to the real world with the help of digital visual and audio elements, or other sensory stimulations. [2]

The key elements of AR technology include AR application, content, interaction, and the physical world. *AR application* is a computer program that orchestrates and controls different aspects of the AR experience. *The content of the AR* considers all objects, ideas, stories, sensory stimuli, and laws of nature; computational simulations, or any other aspects of the content and added objects. Every AR experience must be *interactive*. Minimal interaction in AR considers tracking participants to enable viewing the world from different physical points. *The physical world* is considered an important part of the AR experience. So, the main issue in AR systems is the synchronization of the worlds - real and virtual.

As an enhanced version of reality, in AR, users see layers of digital information covering real-world images. The most common approaches to mixing objects from the real world with virtual objects include:

- location-based, where the users are provided with information based on their geolocation;
- projection-based, where the software enlightens the physical object to create an interactive dashboard in the real-time environment; and
- superimposition-based which allows users to replace the actual image completely or partially, adding new elements to the viewpoint.

III. EQUIPMENT

VR/AR education programs and solutions are widely available to everyone and in any location, if they possess adequate equipment. The equipment considers both hardware and software. The hardware for VR/AR enables tracking the current user position, accepting user input commands, storing descriptions of virtual worlds, running simulations, and presenting output to the user.

A. VR Equipment

Table 1 presents the equipment required for VR systems. The equipment is depicted according to the type of VR, and only input and output devices related to different types of VR are presented. Each row considers the existence of at least a computer system with or without a network environment.

TABLE I. VR INPUT/OUTPUT DEVICES

Type of VR	Type of Equipment	
	Input Devices	Output Devices
Non Immersive VR		
	Tracking devices (position of head and/or hand), User actions (input devices, audio devices, haptic equipment)	Visual devices (computer monitor & glasses), Autostereoscopic devices , Audio devices , Haptic equipment
Semi Immersive VR		
	Tracking devices (position & orientation of head & other body parts) User actions (input devices, audio devices, haptic equipment)	Visual devices (projectors or stacked TV & glasses), Audio (stationary, dynamic) Haptic equipment (data gloves, end effectors,) Other senses (olfactory, taste, vestibular)
Fully Immersive VR		
	Tracking devices (position & orientation of head & other body parts) User actions (input devices, audio devices, haptic equipment)	Visual devices (Head Mounted Devices) Audio (stationary, dynamic) Haptic equipment (data gloves, end effectors,) Other senses (olfactory, taste, vestibular)

The increased utilization of VR in education is a result of the development of low-cost equipment. In minimal case, the low-cost VR system consists of a smartphone, which acts as a computer and tracking device (internal sensors) and an optic device that in connection with the smartphone screen is used as an output device. Examples of visual devices for fully immersive VR systems include HTC Vive [3]; Meta Quest [M4], etc. Examples of visual devices for mobile VR systems

include Google Cardboard [5], SAMSUNG Gear VR [6] etc. Fig. 1 presents the technology for fully immersive VR.



Fig. 1. VR technology for fully immersive VR.
(By ESA, CC BY-SA IGO 3.0, CC BY-SA 3.0 igo,
<https://commons.wikimedia.org/w/index.php?curid=62840930>)

B. AR Equipment

Table II presents the equipment required for AR systems.

TABLE II. AR SYSTEMS

Augmented Reality System Equipment		
Input Devices	Computer System	Output Devices
Tracking Sensors optical (with or without markers), GPS, gyroscopes, accelerometers, audio tracking devices	AR Applications viewer, browser, standalone apps, cloud client apps	Visual Displays computer displays, glasses, stereoscopic displays
Environmental Sensors pH, voltage, radio frequency information, and other specific aspects of the physical world	Hardware Handheld system, Desktop/laptop, VR-based hardware combination with/without connection to the server	Other Devices Audio displays Haptic displays Other sensory displays
User Input Devices buttons, touchscreens, keyboards, and other typical UI devices.		

C. VR/AR Software

Software for VR/AR enables the creation of the content of the virtual worlds/objects, processing of input signals, generating a new state of the world and feedback for the user. Software for VR/AR is classified as content development tools, AR/VR development tools and AR/VR applications.

The content development tools enable the creation of virtual elements, which consider the definition of representation of objects - senses, fidelity, 2D & 3D objects, and animations. The objects can be created by

- using programming tools,
- editing tools,
- scanning real-world objects and converting information to digital representation, or

- downloading already developed objects from different repositories.

Examples of the developing tools include OpenGL (programming library) [7], Maya from Autodesk (software) [8], 3ds Max (software) [9], etc..

AR/VR development tools include programming libraries and development tools. They enable combining the following functions: 3D recognition and tracking, image recognition and tracking, facial tracking, motion tracking, placement of virtual objects as 3D models in a real-world environment, virtual buttons, localized occlusion detection using virtual buttons, video overlay, integration with external plugins, etc.

Table III presents VR development software tools, while Table IV AR development tools.

TABLE III. VR DEVELOPMENT TOOLS

<i>Tool</i>	<i>Supported Devices/ Platforms (OS)</i>
Unity 3D	Devices - Oculus Rift, Steam VR/Vive, Play station VR, Gear VR, Microsoft HoloLens OS - Mac OS X, Android, iOS, Windows, Nintendo Wii, Xbox 360, and PlayStation.
Unreal Engine 4	Devices - Oculus Rift, HTC Vive, Samsung Gear, Google VR, and Leap Motion, etc. OS - Windows PC, PlayStation 4, Xbox One, Mac OS X, iOS, Android, Linux, HTML5,...
Blender	Devices - CAVE/VideoWall, Head-Mounted Displays OS - Windows, Mac OS, and Linux platforms.
Amazon Lumberyard	Devices - Major Head Mounted Devices OS - Xbox One, PlayStation 4, iOS, Android, Windows and Linux
CryEngine	Devices - Oculus Rift, OSVR, PSVR, HTC Vive. OS - Windows, Linux, PlayStation 4, Xbox One,
AppGameKit	OS - Windows, Mac, Linux, iOS, Android including inc Google, Amazon & Ouya, HTML5, Raspberry Pi.
JanusVR	more a web browser than a development tool OS - Windows 7 or a newer version.
React 360	a framework for 3D, 2D and VR interfaces, building photo and video viewers, 360 tours, adventure, games, 3D board games, etc
A-Frame	a web framework that is used to build immersive virtual reality experiences

AR/VR application performs the following activities during runtime of VR/AR system: environmental acquisition, sensor integration, application engine, and rendering software. Most applications are developed and customized for the concrete system and hardware equipment.

IV. AR AND VR IN EDUCATION

VR/AR allows complex concepts to be represented in a much more realistic and accurate fashion. This enables the learner to understand the quickly and intuitively concepts by seeing and experiencing them in real-time. This section depicts several general topics where VR/AR can be used in the learning process. [1, 2]

Healthcare: By using VR/ AR technology, healthcare learning is gradually becoming much safer and faster. The most common example is the development of virtual surgery training systems where students can take part in virtual surgeries and other medical treatments to earn valuable experience without hurting anyone. These enable medical students to practice as much as they want and keep repeating until they are completely sure about how to perform the task. [10]

TABLE IV. AR DEVELOPMENT TOOLS

<i>Tool</i>	<i>Operating Systems</i>
Apple ARKit	iOS
Vuforia	iOS, Android
Google ARCore	Android, iOS, cross-platform AR applications
ARToolKit	iOS, Android, Windows, Mac OS, Linux platform
MixedReality Toolkit (HoloLens)	Microsoft Windows,
DroidAR	Android
AR.js	Android, iOS 11 and Windows mobile. Runs on a user web browser
HP Reveal Studio	Android and iOS
Amazon Sumerian	Android and iOS

Chemistry: VR/AR makes it possible to conduct experiments, mix substances, and learn about chemistry through first-hand experiences. This is safer and cheaper than traditional laboratory experiments because schools won't have to buy various chemical substances. [11, 12, 13]

History and Geography: Students enjoy stories about ancient worlds but it's difficult to learn and memorize so much information hidden within history and geography books.

The Giza Project developed by Harvard University curates records of the Giza Pyramids in ancient Egypt. The students can undertake virtual conservation work and can build architecture from scratch using evidence such as studies of parallel buildings. The project helps students to visualize how ancient Egypt would have looked and offered them opportunities to contribute to digital research with their own builds. [14]

Time Passport Inc. developed an AR application that enables the user to visit The Hanging Gardens of Babylon. The application for iOS can be downloaded from the Apple app store. The application allows exploring a full-scale replica of The Hanging Gardens of Babylon in any open area or viewing a small-scale replica. [15]

HistoryMaker VR allows students to explore key moments, events, and figures in history. They can use the system to create their own virtual reality content, too. The system can be used with Oculus Rift devices and classroom virtual reality systems. The content is also accessible on the Steam platform. When students acquire access to the HistoryMaker VR environment, they can embody the roles of influential historical figures and can design their characters, create the scene, including props, write a script, and export the content they create. [16, 17]

More examples of applying VR/AR in history education can be found at [18, 19]. Examples of using VR/AR in geography can be found at [20]

Physics: The best way to teach students physics is by allowing them to experiment with the concepts. AR technology can make it happen, so students can experience more impressive studying methods than us. For example, learning about the cosmos can be done through virtual field trips. For example, they can visit the Orion Nebula, the rings of Saturn, the moons of Jupiter or the canyons of Mars.

[21] present an immersive VR application for physics education. It utilizes a physics engine developed to simulate physical experiments correctly and accurately. Students can build their own experiments and study them. A variety of tools are provided to analyze forces, mass, paths and other properties of objects before, during and after experiments.

Art and Culture: Many galleries and museums offer VR/AR tours. Examples include Kremmer museum where viewers can see 74 paintings from Flemish and Dutch Masters. [22].

A mobile app called Prisma transforms photos and videos into works of art using the styles of famous artists such as Edvard Munch or Pablo Picasso. This example of superimposition-based AR shows how AR can stimulate people to play and simultaneously learn about the history of art and culture. [23]

Languages: The best way to learn a language is to live in a country where the language is native. But this approach is too expensive for many and almost impossible to be achieved. So, by using VR/AR virtual field trips to a certain country each user can experience not only the culture of the country but will have the opportunity to learn the language in a more authentic environment.

Teaching children about nature: AR apps are being used to engage schoolchildren and bring topics to life. The Museum Alive application is developed by Alchemy Immersive in partnership with Sir David Attenborough. It allows students to place extinct animals and their natural habitats in the real world by activating their smartphone camera to "project" animations into their living room. This is coupled with other learning resources, such as voiceovers, soundscapes, maps, written information, and pre-recorded films. [24]

The list of potential applications of VR/AR in education cannot be reduced only to these fields of interest. On the contrary, there are many more things and subjects to consider in that regard. Examples of using VR technology in different topics can be found in [25].

V. ADVANTAGES

VR/AR provides visual communication with concepts that isn't possible in the traditional classroom. This considers visualizations of complex concepts, simulations of processes, etc. This approach leads to the increased interest of students in the presented topic and their engagement in the learning process. [1, 2, 26]

Considering that one of the basic elements of VR/ AR is interaction, the students are given the opportunity to interact with the presented information. It's entertaining and engaging. Interaction makes easier the perception and understanding of

contextual information displayed around the classroom, following the lectures, and understanding complex themes.

VR/AR enable learning anywhere and anytime. There is not necessary anymore to travel to real classrooms and institutions and students will be able to attend virtual classes and online courses from their homes. Anytime also provides flexibility to choose the timing, and to avoid fixed and rigid schedules. This makes the future learning experience cheaper, faster, and more productive.

Adding gamification elements in VR/AR experiences increases the engagement of students and stimulates them to participate in practical tasks and the corresponding debates.

VR/AR allow personalized learning and enable students to choose from a wide variety of courses. They can select the existing course from a bunch of credible online classes that can suit certain pupils more than traditional courses.

Additionally, AR usually does not require special equipment and low-cost VR needs investment only in the low-cost optic devices, so they can take over paper-based textbooks, physical models, handbooks, etc. and provide convenient and less costly learning materials.

Another advantage that we can take with the use of VR/AR is professional training. Reproduction of real conditions can guide in mastering the practical skills necessary for a certain career.

VR/AR are universally applicable to any level of education and training. It can be used for gaming in kindergarten or for the purpose of training a trainee on the job.

VI. DISADVANTAGES

Learning in a fully immersive VR environment reduces interpersonal communication among peers and human connections. For this reason, it is preferred to use headsets only when needed. [1, 2, 26]

Although VR/AR technology enables teachers to share knowledge much quicker and more efficient, tools that implement artificial intelligence are getting smarter each day and there is a danger they could make professors feel unwanted or obsolete.

As students will get the possibility to learn anywhere and anytime, it could reveal the problem of self-discipline. It is difficult to force kids to study even with the help of the most advanced IT tools, especially if the tools are not well designed. Teachers will have to pay special attention to this issue and control the learning process continuously.

Modern pupils learn things faster using VR/AR gadgets. But in that context, they receive and memorize much more information which can lead to the reduction of real-life communication.

Even the COVID-19 pandemic has changed the way of thinking, the current education systems are changing very slowly toward using VR/AR technology, and it will take a long time before schools, systems, and entire countries begin accepting the benefits of VR/AR in everyday teaching practice. This can be the result of the reluctance of the teachers to look out of their environment and institutions with the vision to apply VR/AR in the education system. The reluctance is mainly the result due to lack of knowledge and as they do not have sufficient knowledge and skills.

Maybe the main reason why VR/AR is not widely applied in education is dependence on the hardware of some systems and content portability issues. Some systems require special equipment to run and are not compatible with the equipment that schools have. Content portability issues mean that the application is created and needs to run on all types of hardware, devices and platforms. Yet it is impossible to create an application that generates equal results on all sorts of hardware and devices.

VII. CONCLUSION

Education systems traditionally slowly accept technological changes and most of them still prefer a face-to-face approach. But the last few years proved that the traditional face-to-face approach must be changed. The new reality has also influenced the increase of virtual and augmented reality-based education.

Using AR tools or VR headsets, students will be able to experience learning in a completely new way. They can organize virtual field trips, visit historical places, conduct experiments, and test a wide range of devices. VR/AR add gamification elements to classical education, making the whole process more appealing and engaging.

At the same time, learning with VR/AR becomes more inclusive, accessible, and affordable. Even at present, VR/AR equipment is cheap enough that almost everyone can use them daily.

But there are also a few side effects as well. Too much VR can isolate students and affect their socialization with other children. Additionally, professors will at least partly lose control over the teaching process. The technology still needs to acquire accreditation from state authorities to become fully operational.

However, all these obstacles cannot change the fact that AR and VR will play an important role in the future of learning.

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Secured with biometric protection local resource sharing within a community

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Abstract—Universities and scientific institutions share a community with enormous potential. In the last decade, a lot has been done to support collaboration in this community – eduGAIN, eduroam, eduVPN were created. This research aims to extend the existing solutions and offers a novel way for sharing local resources (printing resources, access to labs, etc.) between the members of the community. An important constraint of the research is to provide a secure way to identify the user identity, a flexible and scalable architecture and minimal investment by the community members in the integration of the solution. This is achieved by using the benefits a powerful tool that all the users nowadays hold in their pockets – smart phones. The users' devices could be used as biometric readers (finger prints, face recognition, etc.), so we may have full user identification. Moreover, these smart devices can read QR codes and RFID tags.

Keywords—*MARLIN native app, sharing local resources, biometric authentication*

I. INTRODUCTION

The scientific organizations collaborate by working on projects, scientific researches, training programs, etc. This way, the organizations form a powerful community with enormous potential. There are various solutions that aim to support the scientific institutions in the process of providing local resources to the members of the community, such as eduGAIN, eduroam, eduVPN, but at the same time these solutions cannot provide the users with an access to local resources managed by an organization, which is not his or her own organization [1, 2, 3]. In other words, if the user is temporary on the territory of another organization, he or she cannot use any of the local resources of this organization. This limits the capabilities of the community.

This study is focused on the ability of scientists, members of one scientific organization, to access local resources of another scientific organization while they are located on its territory, but at the same time, the authentication of users is performed by their own scientific organization.

According to the stats of published by Statista Research Department in August 2022, around 80% of the population of the world has a smartphone or another smart device [4]. The following research offers a novel way to access local resources by simply reading QR codes and using secure authentication and authorization mechanism, together with the ability to acknowledge the user's identity, using biometric data through smart devices. In other words, we are talking about optimizing the processes necessary to provide access to local resources, but not at the cost of lowering security. At the same time, the organizations do not need to make huge investments in

infrastructure, equipment or development of complex software systems.

II. COMMUNITIES – CREATED BY SCIENTIFIC ORGANIZATIONS AND UNIVERSITIES

Nowadays, the scientific organizations work together on various projects, scientific researches, training programs, etc. It is a typical practice for scientists and teachers from one scientific organization to visit another organization during their joint work or during an organized seminar. This way, the organizations form a powerful community with enormous potential.

Scientific institutions are expected to work on researches as well as to teach students, but while this researches and the learning process is carried out by the scientists and teachers who are members of an organization, the administration of the organizations has the responsibility to provide the necessary resources to enable the scientists and the teachers to carry out their work successfully. Nowadays, for every professional, regardless of the field in which he or she works, it is of utmost necessity to have Internet connectivity, as well as access to a printing resource. Scientists are no exception to this, and in addition they need special laboratories, conference rooms, etc.

III. COOPERATION BETWEEN THE PARTICIPANTS WITHIN A COMMUNITY

There are various solutions that aim to support the scientific institutions in the process of providing local resources to the members of the community. Thus, for example, scientific organizations part of the international interfederation service "EduGAIN" have the opportunity to securely exchange information related to identity, authentication and authorization between participating federations [1]. In other words, scientific organizations can easily identify the members of other scientific institutions as well as the institutions themselves. On the other hand, thanks to "eduVPN", members of the scientific institutions can access the local network resources of their organization remotely, being on the territory of another institution, and in a secure way provided by a VPN tunnel [2]. The necessary Internet connectivity is provided by another solution called "eduroam", which allows each member of a scientific institution to use the Internet through a WiFi network provided by the organization in whose territory he or she is currently located, and the user's authentication itself is carried out by his or her own scientific organization [3]. We could summarize that these solutions aim to support the work of the members of the scientific institutions, but at the same time the provided resources that cannot be recognized as local

resources to any remote organization in which the users are temporary located.

This study is focused specifically on the ability of scientists, members of one scientific organization, to access local resources of another scientific organization while they are located on its territory, but at the same time, the authentication of users is performed by their own scientific organization. In other words, we follow the idea of eduroam, in which the scientific organizations authenticate their users and thus provide them with a way to get Internet connectivity in a network maintained by another scientific organization. However, the idea is further extended so that user authentication is not limited to Internet connectivity, but is focused on local resources of the remote institution: 1.) printing resources; 2.) access to halls, class rooms, laboratories, etc. If the models developed as part of the research are further developed and step on the possibilities offered by eduGAIN, we could talk about even greater possibilities to identify users and automatically provide them with the access to special resources or customized permissions. However, integration with eduGAIN was not addressed as part of the research and remains the subject of future work by the team.

IV. EXISTING SYSTEM ARCHITECTURE OF SOLUTIONS USED BY SCIENTIFIC INSTITUTIONS

The organizations have a built-in network infrastructure, thanks to which they can provide their users (teachers, scientists) with printing resources, Internet connectivity and other services typical of a local network (Fig. 1). They themselves maintain their local networks, as well as the resources provided through them, with each organization having one or more administrators. These administrators help the users to set up their computers and install the necessary drivers to use available network printers.

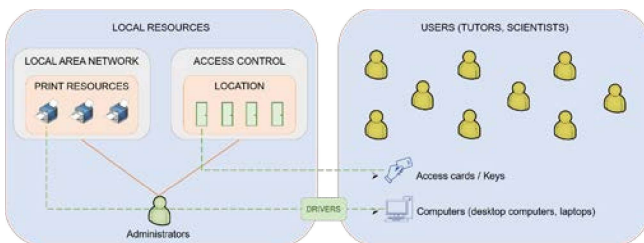


Fig. 1. Existing system architecture of solutions used by scientific institutions

Usually, all premises such as halls, class rooms, laboratories, computer rooms, etc. are protected by some sort of an access control system, which is again maintained by the organizations themselves. The administrators are responsible for the proper organization of access rights to these premises, usually this is done through access cards or simple keys. These systems are often integrated with the rest of the security system used by the organization.

Users must have access cards with them to use the available resource of locations. The configuration for using network printers is also relatively static and limited to a particular computer used by a member and in case of a failure of this computer or any kind of a replacement with another computer presupposes the need for a new setup by an administrator.

Thanks to eduroam users (teachers, scientists), members of a scientific organization have the opportunity to establish an Internet connectivity on the territory of another scientific organization, and in combination with eduVPN and to access local resources from their own scientific organization remotely (access to their local computer, for example) (Fig. 2). At the same time, these users would not be able to get easy access to the local resources of the organization in which they are currently located. This includes access to printers, halls, laboratories, classrooms, etc.

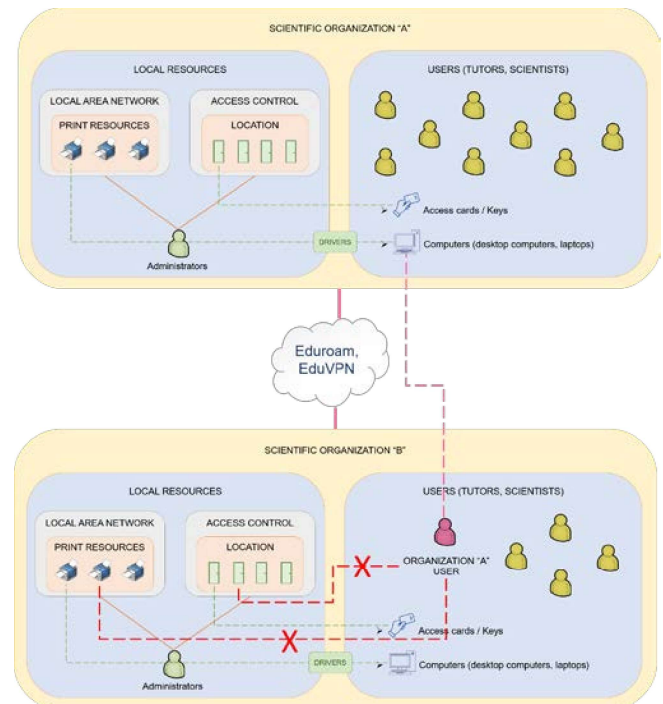


Fig. 2. Existing system architecture of solutions used by scientific institutions to share resources with members of another institutions

V. TAKING ADVANTAGE OF SMART TECHNOLOGIES THAT ARE PART OF OUR EVERYDAY LIFE

According to the stats of published by Statista Research Department in August 2022, around 80% of the population of the world has a smartphone or another smart device. [4] The mobile devices that we carry in our pockets are so powerful and offer such kind of features that it is a shame not to use them in our favor. They could be used as biometric readers (finger prints, face recognition, etc.), so we may have full user identification. Moreover, these smart devices can read QR codes and RFID tags.

The natural question is – How we could use this fact in our benefit? The following research offers a novel way to access local resources by simply reading QR codes and using secure authentication and authorization mechanism, together with the ability to acknowledge the user's identity, using biometric data through smart devices. In other words, we are talking about optimizing the processes necessary to provide access to local resources, but not at the cost of lowering security. At the same time, the organizations do not need to make huge investments in infrastructure, equipment or development of complex software systems.

VI. ACCESS LOCAL AND REMOTE RESOURCES USING NOTHING BUT USERS' OWN DEVICES

The following research offers a novel way to access local resources by simply reading QR codes and using secure authentication and authorization mechanism, together with the ability to acknowledge the user's identity, using biometric data through smart devices.

The model developed as part of the research is divided into 2 parts: 1.) A model oriented to the local solution, which should be implemented by the organizations that are willing to join the idea of expanding the opportunities that the community offers; 2.) A model oriented towards the global solution that should be implemented so that local implementations can interact with each other. However, for the overall solution presented in the research to work successfully, both models should be implemented.

A. Local solution

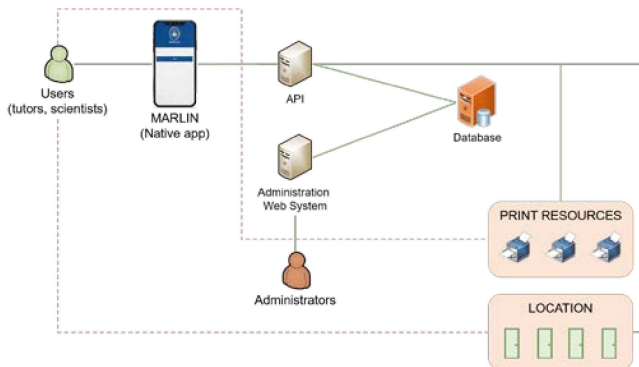


Fig. 3. Local solution using MARLIN

The proposed solution assumes that organizations will continue to manage their printer resources, as well as the access control systems for halls, classrooms, labs, etc., as they have done until now. Moreover, they should continue to manage their users as they have done so far. So, for example, if the scientific organization used “Active Directory” [5] to manage its users, it can continue to use the same user management tool, it just needs to integrate it with the rest of the system framed by the paper.

The new elements in the solution that characterize the presented model are the presence of an API of a software system, an administration system, as well as a mobile application (called by us “**MARLIN**” – **M**obile **A**pplication for **R**emote and **L**ocal resources and through secure user **I**dentification over the **N**etwork) (Fig. 3):

- **MARLIN** – this is the mobile application designed as part of the research. The users should install this mobile application on their smart devices, which in turn must have fingerprint recognition capability and a working camera (this is a prerequisite for the user device to be used). Through this application, the users have the opportunity to access their files and add them to a printing queue, and then print them by scanning a QR code label by the system administrators on the printers. Again, the users may access any room, which meant to have restricted access, controlled by an access control system and used to require an access by an RFID card, by simply scan another QR code label next to the door of the room.

- **API** – the mobile application communicates with the rest of the system through an API, which should be located locally in the scientific organization. Moreover, the machine on which it is located must be able to communicate with the available printers (by means of installed drivers for them and have proper configuration applied), as well as the access control system (most such systems offer this kind of functionality via API)
- **Administration web system** – through this system, the administrators configure the printers, rooms and other local resources and make them “visible” to the API with which the system shares a database. Moreover, through this system, the administrators link the existing user with their trusted devices. In other words, this system offers the ability to perform CRUD (Create Read Update Delete) operations performed on the database containing the configurations used by the API.

The implementation of this solution provides additional advantages to the scientific organization:

- **Safe printing** – in a classic implementation the user sends a file to the printer, so it could be printed, but the printer itself may be located far away from the user, so someone else may get the printed file consciously or unconsciously. In contrast, with the solution suggested the user just adds the file to the printing queue, but the actual printing process is activated by the user once he or she scans the QR code labeled on the printer.
- **Managing the access control using users' personal mobile devices** ensures to a greater extent that the means of unlocking rooms, laboratories and others will be available to the user, as practice shows that the users often forget their access cards. However, it is less likely to forget their mobile phones.

B. Inter-organization solution

The inter-organization solution assumes that each autonomous scientific organization has already implemented the local solution model. The individual organizations remain responsible for the administration of their users, printers, access control to halls, laboratories, etc. At the same time, the concept of “Shared service” is introduced into the model (Fig. 4). This system contains the data for all organizations that have implemented the solution described by this research. This data is not confidential and should not conflict with the internal information security rules. The system contains a list of organizations, their unique IDs, and their base URL to access their local API.

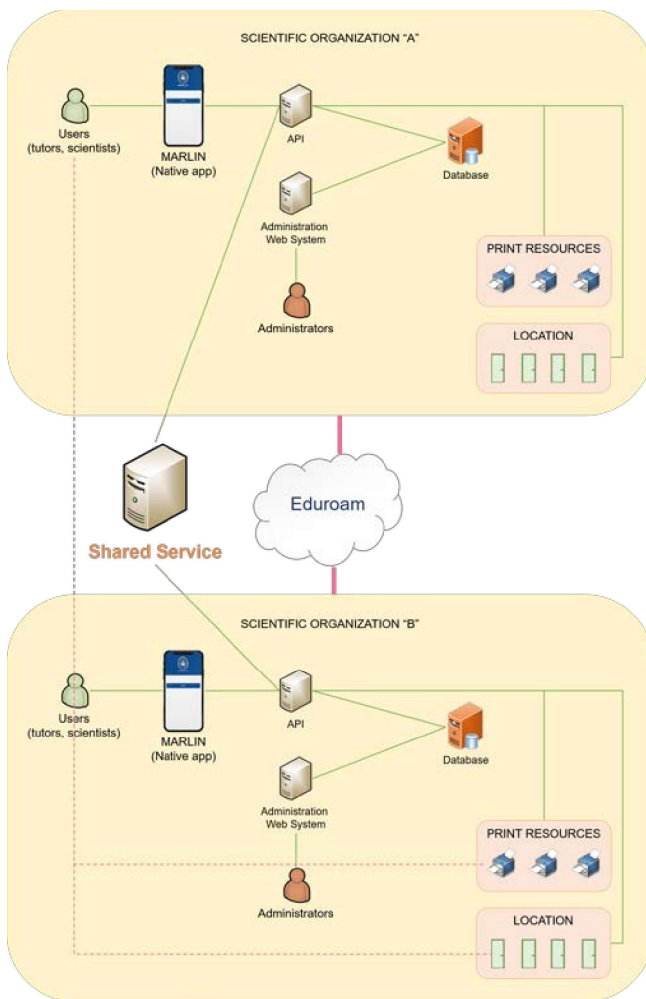


Fig. 4. Inter-organization solution using MARLIN

The mobile application is the same for all scientific institutions, but through the configuration set in the Shared service it can be used by users of all possible institutions. In other words, there is no need to create a new version of the mobile application when adding a new institution, as the configuration is dynamic and users of the new institution will be able to use the application as soon as the configuration is updated in the Shared service.

Users will be able to access the local resources of the institutions in whose territory they are located. They will simply scan the QR codes when they need to print or access a room, lab, etc. Since the QR codes contain data about the unique ID of the organization for which they were created, MARLIN will check whether this ID matches the user's organization ID, and if that is not the case, it will check against the Shared service, what is the correct base URL (of the API) to send the request. There is not much of a difference between opening a location with a restricted access control from a local or a remote organization. However, the main difference between printing a file to a printer located in the local intuition of the user and printing a file in a remote institution is the print queue with the file is going to be copied from the server of one organization to the server of the other organization. The rest of the printing process remain the same.

VII. CONCLUSIONS

The opportunities to support the scientific organizations in their collaboration processes are of utmost importance to

increase the capabilities of the community they form. Although solutions such as eduroam, eduVPN, etc. already exist, these solutions are limited to providing Internet connectivity to users and remote access to their own local networks. The presented solution aims to provide secure access to the local resources of any organization by all members of the community using a specially created native application – MARLIN, biometric authentication and the mobile devices of the users themselves. In other words, apart from being innovative, the solution does not require large investments from the scientific organizations willing to implement it. At the same time, the possible applications of the solution are not limited to the focus of this research – providing users with access to printing resources and locations with restricted access, but can be further developed.

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The Green Digital Opportunity

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Abstract— In today's world, modern society or modernity is defined as people living together in the present time. Within this framework, rapid technological developments, education (knowledge and skills), communication and mobility, equality and awareness define current time. They are also indispensable elements for a sustainable economic order. With all these, it is not possible to ignore the environment. In the context of environmental economy, digital and green are perspectives that need to be considered. Digital technologies such as the internet of things, remote monitoring, industrial robots, 3D printing, big data analysis and artificial intelligence in the manufacturing industry promise to make traditional production safer, more efficient, more sustainable and more cost-effective. Digital technologies are also known to convert steel mill carbon emissions into usable fuels and plastics. Therefore, it can be said that a digital transformation opportunity that includes the environment is indispensable for a sustainable environment and economy. With this study, it has been tried to express that a more sustainable structure can be built by using digital competencies and opportunities.

Keywords— *Green, digital opportunity, sustainability*

Comparative study of computational methods for determinants

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Abstract—This paper presents the results of a comparative study of several computational methods for determinants. The run times obtained with the applications performed for the methods studied, for determinants with orders from 4 to 10, for the same input data, were compared. It was analyzed, for each method, the dependence of run times on determinant order.

Index Terms—determinants, computational methods

I. INTRODUCTION

In this paper we have presented the result of a study dedicated to the computation of determinants using applications realized with programming languages. The C++ language (CodeBlocks 20.03) was used. The programs were run on the same computer, under the same load conditions, the same data types and the same input files were used, i.e. determinations were made for identical data. Execution times were determined only for the computation sequence and do not contain the steps of reading data or displaying results. For an accurate determination of the computation times, the sequence used for calculating the determinant value was repeated, in some cases, 1,000,000 times.

As test data, 7 sets (of 5 files each) were randomly generated, one set for each order from 4 to 10. The results shown are the arithmetic averages of the execution times obtained for the examples in each test. The runtime values in the tables are expressed in milliseconds.

In the paper we denote by $A = (a_{ij})_{i,j=1,n} \in M_n(\mathbb{R})$ the quadratic matrix of dimension n , with real elements, for which we propose to compute the value of the determinant. In this study we have considered 8 methods dedicated to the computation of determinants.

II. METHOD BASED ON THE DETERMINANT DEFINITION

The determinant, according to the definition, is the value obtained as the result of the sum

$$\det(A) = \sum_{\sigma \in S_n} \text{sgn}(\sigma) a_{1\sigma(1)} a_{2\sigma(2)} \dots a_{n\sigma(n)} \in \mathbb{R},$$

where S_n denoted the set of permutations of a set with n elements (S_n has $n!$ elements).

The program for the computational method based on the determinant definition contains, as an important sequence, the generation of permutations of a set with n elements and the computation of their signature. I chose a less natural but

faster method of generating permutations. The program itself is simple, it boils down to calculating a sum of products.

After running the program, for the seven sets of files, the results in Table I were obtained.

TABLE I
COMPUTING TIMES OBTAINED FOR THE METHOD BASED ON THE DETERMINANT DEFINITION

Order of determinant	Computing time
4	0.001050
5	0.006384
6	0.058652
7	0.719504
8	7.343420
9	76.836000
10	889.462500

A. Main part of the code

```

t=1;
s=0.0;
sp=1.0;
pr=1.0;
for (i1=1; i1<=n; i1++)
for (j=1; j<=n; j++)
a[i1][j]=w[i1][j];
for (j=1; j<=n; j++)
{
    p[j]=j;
    i[j]=j;
    d[j]=-1;
}
for (l=1; l<=n; l++)
pr*=a[l][p[l]];
s+=pr*sp;
do
{
    for (j=n; j>1; j--)
    {
        m=i[j]+d[j];
        if ((m>n) || (m==0))
        {
            d[j]=-d[j];
            if (j==2) t=0;
        }
        else
            if (p[m]>=j)
            {
                d[j]=-d[j];
            }
        }
    }

```

```

    if (j==2) t=0;
  }
  else
  {
    p[i[j]]=p[m];
    i[p[m]]=i[j];
    p[m]=j;
    i[j]=m;
    sp=1.0;
    for (l=1; l<n; l++)
      for (j=l+1; j<=n; j++)
        if (p[l]>p[j])
          sp=-sp;
    pr=1.0;
    for (l=1; l<=n; l++)
      pr*=a[l][p[l]];
    s+=pr*sp;
    break;
  }
} while (t==1);

```

III. RECURSIVE METHOD

The recursive method is constructed based on the property of alternating multilinear applications which is transcribed in the formula "development after a row or a column":

$$\det(A) = \sum_{j=1}^n (-1)^{i+j} a_{ij} A_{ij}, \text{ where } i \in \overline{1, n}$$

or

$$\det(A) = \sum_{i=1}^n (-1)^{i+j} a_{ij} A_{ij}, \text{ where } j \in \overline{1, n}.$$

The recursive method involves reducing the computation of the determinant of order n to the computation of the determinants of order $n-1$, then to the computation of the determinants of order $n-2$ and so on until one arrives at determinants of order 2 which are computed according to the definition. The recursive method is useful for obtaining a simple algorithm that allows to make a short and compact program for computing determinants.

In the program is used a recursive function which follows the algorithm of the method: it reduces the computation of the determinant of order k , $k \in \{n, n-1, \dots, 3\}$, to the computation of the determinant of order $k-1$. For $k=2$ the determinant is calculated according to the definition.

The method, like any recursive method, uses a lot of memory and a relatively long execution time. Table II lists the values, in milliseconds, of the execution times.

TABLE II
COMPUTING TIMES OBTAINED FOR THE RECURSIVE METHOD

Order of determinant	Computing time
4	0.000671
5	0.003504
6	0.021161
7	0.151171
8	1.196380
9	10.799500
10	107.522750

A. Main part of the code

```

long double det(int n, long double a[21][21])
{
  int i, j, semn, k;
  long double b[21][21], s=0.0;
  if (n==1)
    return a[1][1];
  else
    if (n==2)
      return a[1][1]*a[2][2] - a[2][1]*a[1][2];
    else
    {
      for (k=1; k<=n; k++)
      {
        if ((n+k)%2==1) semn=-1;
        else semn=1;
        for (j=1; j<k; j++)
          for (i=1; i<n; i++)
            b[i][j]=a[i][j];
        for (j=k; j<=n; j++)
          for (i=1; i<n; i++)
            b[i][j]=a[i][j+1];
        s+=semn*a[n][k]*det(n-1, b);
      }
      return s;
    }
}
...
d=det(n, a);

```

IV. LAPLACE METHOD

The Laplace method extends the recursive method. To be able to present it briefly, we will use some notations.

If $A = (a_{ij})_{i,j=1,n} \in M_n(\mathbb{R})$ is a matrix and $1 \leq i_1 < i_2 < \dots < i_p \leq n$, $1 \leq j_1 < j_2 < \dots < j_p < n$, $i \leq p < n$, we write

- $a_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p}$, the determinant of the matrix formed by the elements of the matrix A located at the intersections of the rows $i_1, i_2, \dots, i_p$ with the columns $j_1, j_2, \dots, j_p$;

- $\Delta_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p}$, the minor of order $n-p$ associated with the determinant $a_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p}$; $\Delta_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p}$ is the determinant of the matrix obtained from matrix A by eliminating the rows $i_1, i_2, \dots, i_p$ and the columns $j_1, j_2, \dots, j_p$;

- $A_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p} = (-1)^{\sum_{k=1}^p (i_k + j_k)} \Delta_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p}$, the algebraic complement of the determinant $a_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p}$.

With these notations, Laplace's Theorem can be written as follows:

A determinant is equal to the sum of all products between the minors formed with the elements of p given lines (columns) and their algebraic complements.

$$\det(A) = \sum_{1 \leq j_1 < j_2 < \dots < j_p \leq n} a_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p} A_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p},$$

$$1 \leq i_1 < i_2 < \dots < i_p \leq n \text{ or}$$

$$\det(A) = \sum_{1 \leq i_1 < i_2 < \dots < i_p \leq n} a_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p} A_{i_1, i_2, \dots, i_p; j_1, j_2, \dots, j_p},$$

$$1 \leq j_1 < j_2 < \dots < j_p \leq n.$$

The program for the Laplace method uses a recursive function that splits the determinant lines into two sequences of approximately equal lengths thereby reducing the order of the determinant until determinants of order 3 or 2 are reached which are calculated according to the definition. Like the recursive method, it requires relatively large memory space. It also uses a program sequence that generates the combinations to identify all the minors involved in the computational method.

The values determined for the execution times are shown in Table III.

TABLE III
COMPUTING TIMES OBTAINED FOR THE LAPLACE METHOD

Order of determinant	Computing time
4	0.000536
5	0.001143
6	0.002914
7	0.022806
8	0.079561
9	0.221829
10	0.598342

A. Main part of the code

```

int exista(int k,int m,int v[21])
{
    int i=1,t=0;
    do
    {
        if (k==v[i])
            t=1;
        i++;
    }
    while ((t==0)&&(i<=m));
    return t;
}

long double det(int n,long double a[21][21])
{
    if (n==1) return a[1][1];
    else
    if (n==2)
        return a[1][1]*a[2][2]-a[2][1]*a[1][2];
    else
    if (n==3)
        return a[1][1]*a[2][2]*a[3][3]+
        a[3][1]*a[1][2]*a[2][3]+
        a[2][1]*a[3][2]*a[1][3]-
        (a[1][3]*a[2][2]*a[3][1]+
        a[2][3]*a[3][2]*a[1][1]+
        a[3][3]*a[1][2]*a[2][1]);
    else
    {
        int i,j,v[21],t=0,k,m,p1,p2,semn;
        long double b[21][21],c[21][21],d=0.0;
        m=n/2;
        for (i=1;i<=m;i++)
            v[i]=i;
        v[m]--;
        do
        {
            v[m]++;
            if (v[m]>n)

```

```

        {
            t=1;
            k=m-1;
            do
            {
                v[k]++;
                if (v[k]>n-(m-k))
                    k--;
                else t=0;
            }
            while ((t==1)&&(k>0));
            if (t==0)
            {
                for (i=k+1;i<=m;i++)
                    v[i]=v[i-1]+1;
            }
        }
        p1=0;
        p2=0;
        for (j=1;j<=n;j++)
            if (exista(j,m,v))
            {
                p1++;
                for (i=1;i<=m;i++)
                    b[i][p1]=a[i][j];
            }
        else
        {
            p2++;
            for (i=1;i<=n-m;i++)
                c[i][p2]=a[i+m][j];
        }
        semn=0;
        for (i=1;i<=m;i++)
            semn=semn+i*v[i];
        if (semn%2==0)
            semn=1;
        else
            semn=-1;
        d+=semn*det(m,b)*det(n-m,c);
    } while (t==0 && v[1]<n-m+1);
    return d;
}

...
d=det(n,a);

```

V. GAUSSIAN ELIMINATION METHOD

Gauss's elimination method, used especially for solving systems of linear equations, can also be used for the calculation of determinants. It involves the successive cancellation of the elements below the main diagonal and the reduction of the initial determinant to an upper triangular determinant whose value is equal to the product of the elements on the main diagonal.

$$\begin{vmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{vmatrix} \dots \begin{vmatrix} a_{11}^{[1]} & a_{12}^{[1]} & a_{13}^{[1]} & \dots & a_{1n}^{[1]} \\ 0 & a_{22}^{[2]} & a_{23}^{[2]} & \dots & a_{2n}^{[2]} \\ 0 & 0 & a_{33}^{[3]} & \dots & a_{3n}^{[3]} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & a_{nn}^{[n-1]} \end{vmatrix}$$

For this method, as can be seen in Table IV, the computation times are significantly lower compared to the previous methods.

TABLE IV
COMPUTING TIMES OBTAINED FOR THE GAUSSIAN ELIMINATION METHOD

Order of determinant	Computing time
4	0.000357
5	0.000623
6	0.000994
7	0.001435
8	0.001971
9	0.002676
10	0.003513

A. Main part of the code

```

k=1;
t=0;
semn=1;
for (i=1; i<=n; i++)
for (j=1; j<=n; j++)
a[i][j]=w[i][j];
do{
max=fabs(a[k][k]);
p=k;
for (i=k+1; i<=n; i++)
if (max<fabs(a[i][k]))
{
max=fabs(a[i][k]);
p=i;
}
if (max==0.0) t=1;
else
{
if (p!=k)
{
semn=-semn;
for (j=k; j<=n; j++)
{
s=a[k][j];
a[k][j]=a[p][j];
a[p][j]=s;
}
}
for (i=k+1; i<=n; i++)
for (j=k+1; j<=n; j++)
a[i][j]=a[i][j]-a[i][k]*a[k][j]/a[k][k];
k++;
}
}while ((k<n)&&(t==0));
if ((t==1)|| (a[n][n]==0.0)) d=0.0;
else
{
d=1.0*semn;
for (i=1; i<=n; i++)
d*=a[i][i];
}

```

VI. METHOD BASED ON THE SUBSTITUTION LEMMA

The Substitution Lemma is found in linear algebra and states the conditions under which a vector of a vector space can replace an element of a basis of the space. It also specifies

the method of obtaining the coordinates of any vector of the vector space in the new basis. Starting from this lemma, methods were generated for: solving systems of linear equations, determining the rank of a matrix, calculating the inverse of a non-singular quadratic matrix, calculating the value of a determinant.

To calculate the determinant using the method based on the Substitution Lemma, start with a table in which the elements of the matrix $A = (a_{ij})_{i,j=1,n} \in M_n(\mathbb{R})$, for which we will calculate the determinant, are written. For each line k , $1 \leq k \leq n$, of the table, a non-zero element, the pivot, is chosen. If it does not exist, the determinant is null and the algorithm stops. For the chosen pivot (be it $a_{k\sigma(k)}$) the table is processed:

- All the elements on its line are divided at the pivot,

$$a'_{kj} = \frac{a_{kj}}{a_{k\sigma(k)}}, j \in \{1, 2, \dots, n\} \setminus \{\sigma(k)\};$$

- The pivot is replaced by 1 and the other elements in its column are replaced by 0, $a'_{i\sigma(k)} = 0, i \in \{1, 2, \dots, n\} \setminus \{k\}$, $a'_{k\sigma(k)} = 1$;
- All elements a_{ij} outside the pivot line and column are replaced by

$$a'_{ij} = a_{ij} - \frac{a_{i\sigma(k)}a_{kj}}{a_{k\sigma(k)}},$$

$i \in \{1, 2, \dots, n\} \setminus \{k\}, j \in \{1, 2, \dots, n\} \setminus \{\sigma(k)\}$, operation known as the rectangle rule. At each step the value of the pivot is retained.

After completing all the lines, the value of the determinant will be the product of the pivots chosen during the processing of the tables multiplied by the signature of the sigma permutation.

TABLE V
COMPUTING TIMES OBTAINED FOR THE METHOD BASED ON THE SUBSTITUTION LEMMA

Order of determinant	Computing time
4	0.000758
5	0.001314
6	0.002116
7	0.003260
8	0.004653
9	0.006393
10	0.008611

A. Main part of the code

```

d=1.0;
for (i=1; i<=n; i++)
{
p=1;
max=fabs(a[i][1]);
for (j=2; j<=n; j++)
if (max<fabs(a[i][j]))
{
max=fabs(a[i][j]);
p=j;
}
if (max==0.0)

```

```

{
  d=0.0;
  break;
}
else
{
  v[i]=p;
  piv=a[i][p];
  b[i]=piv;
  for(k=1;k<=n;k++)
  if(k!=i)
  for(j=1;j<=n;j++)
  if(j!=p) a[k][j]=(a[k][j]*a[i][p]-
    a[k][p]*a[i][j])/piv;
  for(j=1;j<=n;j++)
  a[i][j]/=piv;
  for(k=1;k<=n;k++)
  a[k][p]=0.0;
  a[i][p]=1.0;
}
}
if(d!=0.0)
{
  for(i=1;i<=n;i++)
  d*=b[i];
  for(i=1;i<=n-1;i++)
  for(j=i+1;j<=n;j++)
  if(v[i]>v[j]) d=-d;
}

```

VII. CHIO METHOD

The principle of the method is the successive processing of the initial determinant with the aim of reducing the order of n to 2.

The transition from the determinant

$$D_k = \begin{vmatrix} a_{11}^{[k]} & a_{12}^{[k]} & \dots & a_{1,n-k}^{[k]} \\ a_{21}^{[k]} & a_{22}^{[k]} & \dots & a_{2,n-k}^{[k]} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n-k,1}^{[k]} & a_{n-k,2}^{[k]} & \dots & a_{n-k,n-k}^{[k]} \end{vmatrix},$$

$1 \leq k \leq n-2$, $D_0 = \det A$, to the next determinant D_{k+1} is conditional on the value of the element $a_{11}^{[k]}$ which must be non-zero. If $a_{11}^{[k]} = 0$ and all other elements in the first column are nil, so $a_{i1}^{[k]} = 0, \forall i \in \overline{1, n-k}$, then obviously the determinant is nil and the algorithm ends. If $a_{11}^{[k]} = 0$, but in the first column there is $a_{p1}^{[k]} \neq 0, 2 \leq p \leq n-k$, then at the first row the p row is added, which does not change the value of the determinant. The elements of the new determinant are calculated with the formula

$$a_{ij}^{[k+1]} = a_{11}^{[k]} a_{i+1,j+1}^{[k]} - a_{i+1,1}^{[k]} a_{1,j+1}^{[k]}, 1 \leq i, j \leq n-k-1.$$

At each step it is necessary to retain the value of element $a_{11}^{[k]}$. The determinant of order 2 is calculated elementary. The value of the original determinant is obtained by dividing the value of the determinant of order (2) by the product

$$\left(a_{11}^{[0]}\right)^{n-2} \left(a_{11}^{[1]}\right)^{n-3} \dots \left(a_{11}^{[n-3]}\right).$$

The advantage of this method is that it requires only one division. The disadvantage is the large values of the elements of the determinants D_k if n is large. The values of the computation times are small compared to the previous methods.

TABLE VI
COMPUTING TIMES OBTAINED FOR THE CHIO METHOD

Order of determinant	Computing time
4	0.000195
5	0.000343
6	0.000565
7	0.000886
8	0.001306
9	0.001803
10	0.002475

A. Main part of the code

```

d=1.0;
for(i=1;i<=n;i++)
for(j=1;j<=n;j++)
a[i][j]=w[i][j];
for(k=1;k<=n-2;k++)
{
  if(a[k][k]==0.0)
  {
    max=0.0;
    p=k;
    for(i=k+1;i<=n;i++)
    if(max<fabs(a[i][k]))
    {
      max=fabs(a[i][k]);
      p=i;
    }
    if(max==0.0)
    {
      d=0.0;
      break;
    }
    else
    {
      for(j=k;j<=n;j++)
      a[k][j]+=a[p][j];
    }
  }
  for(i=k+1;i<=n;i++)
  for(j=k+1;j<=n;j++)
  a[i][j]=a[i][j]*a[k][k]-a[i][k]*a[k][j];
}
if(d!=0.0)
{
  d=a[n-1][n-1]*a[n][n]-a[n][n-1]*a[n-1][n];
  m=1.0;
  for(i=1;i<=n-2;i++)
  for(j=i;j<=n-2;j++)
  m=m*a[i][j];
  d=d/m;
}

```

VIII. DODGSON METHOD

The Dodgson method [2] involves generating a sequence of matrices, starting from the initial matrix $A = A_0 =$

$(a_{ij}^{[0]})_{i,j=1,n} \in M_n(\mathbb{R})$, of dimension $n-1 \times n-1$, $n-2 \times n-2$ to a matrix of dimension 1×1 whose element is equal to the value of the determinant of the initial matrix. In order to apply without further processing, it is necessary that all matrices of size greater than 2×2 have an interior consisting only of non-zero elements. By the interior of a matrix $A = (a_{ij})_{i,j=1,n} \in M_n(\mathbb{R})$ we mean the elements a_{ij} for which $i, j \neq 1, n$. We first construct the matrix A_1 by calculating the elements according to the formula

$$a_{ij}^{[1]} = \begin{vmatrix} a_{ij}^{[0]} & a_{i,j+1}^{[0]} \\ a_{i+1,j}^{[0]} & a_{i+1,j+1}^{[0]} \end{vmatrix}, 1 \leq i, j < n.$$

Then, for $k = \overline{2, n-1}$, generate the matrices of size $n-k$ using a similar formula

$$a_{ij}^{[k]} = \frac{1}{a_{i+1,j+1}^{[k-2]}} \begin{vmatrix} a_{ij}^{[k-1]} & a_{i,j+1}^{[k-1]} \\ a_{i+1,j}^{[k-1]} & a_{i+1,j+1}^{[k-1]} \end{vmatrix}, 1 \leq i, j \leq n-k.$$

TABLE VII
COMPUTING TIMES OBTAINED FOR THE DODGSON METHOD

Order of determinant	Computing time
4	0.000244
5	0.000515
6	0.000940
7	0.001548
8	0.002394
9	0.003392
10	0.004711

A. Main part of the code

```

for (i=1; i<n; i++)
for (j=1; j<n; j++)
b[i][j]=a[i][j]*a[i+1][j+1]-
a[i+1][j]*a[i][j+1];
for (i=1; i<n-1; i++)
for (j=1; j<n-1; j++)
c[i][j]=(b[i][j]*b[i+1][j+1]-
b[i+1][j]*b[i][j+1])/a[i+1][j+1];
for (k=n-1; k>2; k--)
{
for (i=1; i<=k; i++)
for (j=1; j<=k; j++)
a[i][j]=b[i][j];
for (i=1; i<k; i++)
for (j=1; j<k; j++)
b[i][j]=c[i][j];
for (i=1; i<k-1; i++)
for (j=1; j<k-1; j++)
c[i][j]=(b[i][j]*b[i+1][j+1]-
b[i+1][j]*b[i][j+1])/a[i+1][j+1];
}
d=c[1][1];

```

IX. MONTANTE METHOD

The Montante method, which is based on the Bareiss algorithm [1], is similar to the Gauss elimination method.

The method involves traversing the main diagonal of matrix $A = (a_{ij}^{[0]})_{i,j=1,n} \in M_n(\mathbb{R})$. Thus, at step k , ($1 \leq k < n$), the

elements located at the intersections between lines $k+1, k+2, \dots, n$ and columns $k+1, k+2, \dots, n$ are processed using the formula

$$a_{ij}^{[k]} = \frac{a_{kk}^{[k-1]} a_{ij}^{[k-1]} - a_{ik}^{[k-1]} a_{kj}^{[k-1]}}{a_{k-1,k-1}^{[k]}}, k+1 \leq i, j \leq n$$

It is considered $a_{00}^{[0]} = 1$. Finally, the value of the determinant is equal to the element $a_{nn}^{[n-1]}$.

TABLE VIII
COMPUTING TIMES OBTAINED FOR THE MONTANTE METHOD

Order of determinant	Computing time
4	0.000202
5	0.000356
6	0.000598
7	0.000934
8	0.001373
9	0.001941
10	0.002685

A. Main part of the code

```

a[0][0]=1;
for (k=1; k<n; k++)
{
if (a[k][k]==0.0)
{
max=0.0;
p=k;
for (i=k+1; i<=n; i++)
if (max<fabs(a[i][k]))
{
max=fabs(a[i][k]);
p=i;
}
if (max==0.0)
{
d=0.0;
break;
}
else
{
for (j=k; j<=n; j++)
a[k][j]+=a[p][j];
}
}
for (i=k+1; i<=n; i++)
for (j=k+1; j<=n; j++)
a[i][j]=(a[i][j]*a[k][k]-
a[i][k]*a[k][j])/a[k-1][k-1];
}
if (d!=0.0)
d=a[n][n];

```

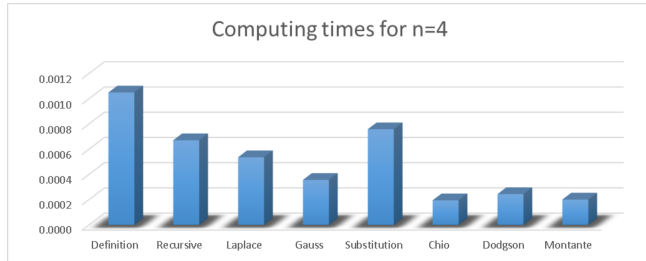
X. ANALYSIS OF COMPUTING TIMES

In this section, for each order of determinant analyzed, are compared the computing times obtained for the 8 studied methods.

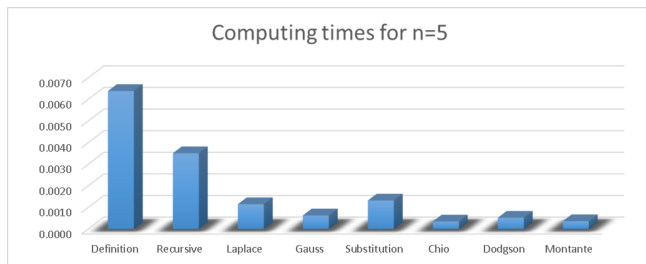
For $n \geq 7$, due to the very large difference between the computing times obtained for the method based on the

definition of the determinant and the Chio method, the decimal logarithms of the calculation times multiplied by 10000 have been represented.

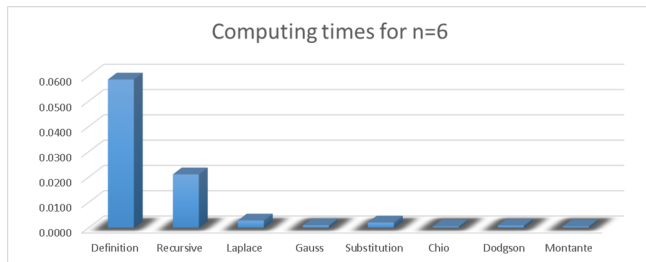
A. $n = 4$



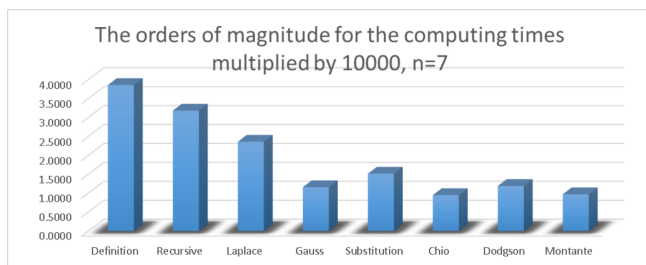
B. $n = 5$



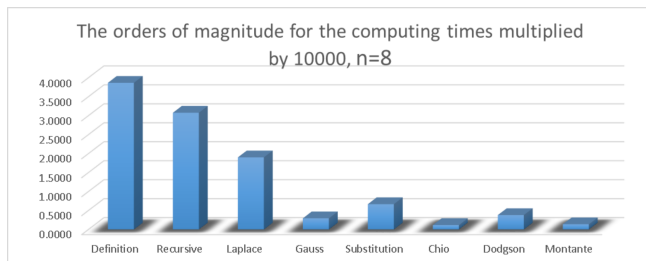
C. $n = 6$



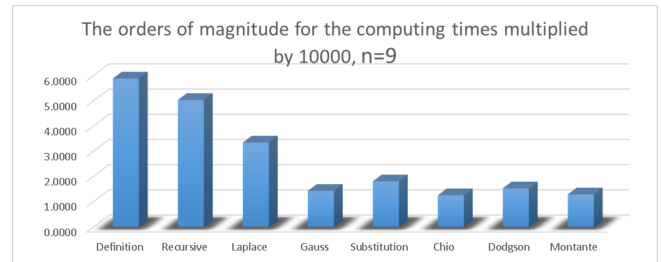
D. $n = 7$



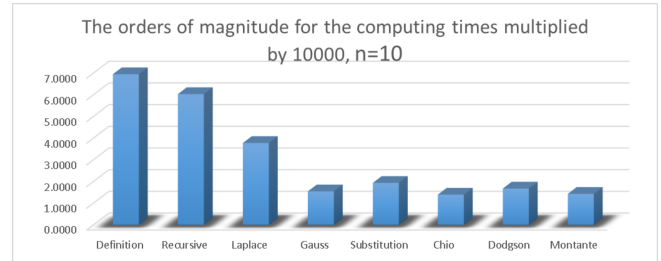
E. $n = 8$



F. $n = 9$



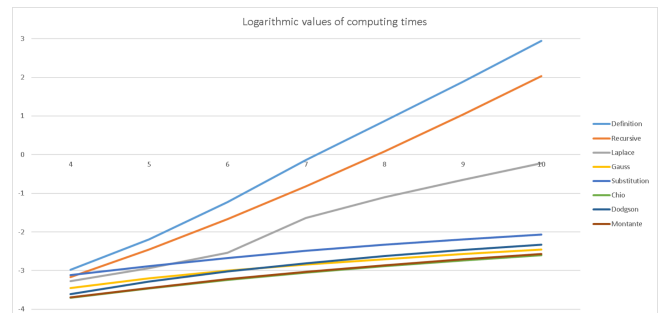
G. $n = 10$



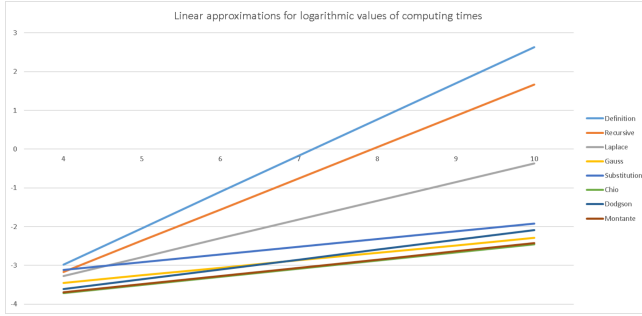
As can be seen from the previous representations and from the tables with the computing time values, the order of efficiency of the analyzed computing methods, for $n > 6$, is: Chio, Montante, Gauss, Dodgson, Substitution, Laplace, Recursive and Definition.

XI. CONCLUSIONS

This study carried out for the 8 methods of computing the determinants allows an estimation of the computing times for large values of n , starting from their determination for a reduced set of tests. The following graph shows the data determined for each method and each n from 4 to 10. The values used for the graph are the decimal logarithms of the computing times.



As can be seen, with few exceptions, the growth is almost linear. For each method, a coefficient was determined as a weighted average of the slopes of segments M_0M_i , where M_0, M_i are the points on the graph with coordinates $(4, \lg(t_4))$, respectively $(i, \lg(t_i))$, $4 < i \leq 10$, and t_i is the computing time obtained for the respective method, for $n = i$, with the order of the determinant. In the following graph, the linear approximations were represented, with the previously determined coefficients.



In conclusion, for the chosen algorithms, for the programming language used, for the computer on which the programs were run, the following coefficients were determined.

TABLE IX
COEFFICIENTS OBTAINED FOR LINEAR APPROXIMATION

Method	Coefficient
Definition	0.935621
Recursive	0.807116
Laplace	0.483956
Gauss	0.192613
Substitution	0.200183
Chio	0.208124
Dodgson	0.253916
Montante	0.211575

With these coefficients, if we keep the conditions under which they were obtained, we can make a sufficiently accurate estimate for the value of the computing time for higher values of n .

Therefore, if we want an estimate of the computing time for large values of n , it is sufficient to determine the coefficient of the method and use linear approximation, as above.

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Synchronous Generator Excitation Control System Using Fuzzy Sliding Mode Controller

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Synchronous generator excitation systems are important to provide reliability of operation, stability and fast transient response. This paper proposed an fuzzy sliding mode control of excitation method to produce power to micro hydropower plant with synchronous generator. Although sliding mode control is a robust control method for disturbance and parameter variations such as switching systems, the control sysetem have chatring problem. For the elimination of chtring problem, there exist a lot of paper and one of them is fuzzy logic based sliding mode controller. Based on fuzzy logic, the disadvantages of the sliding mode control method is performed for an acceptable level. Numerical simulations show that the efficiency of the proposed fuzzy sliding mode control through for Synchronous Generator Excitation Control System of micro hydropower plant. We show that proposed control system is able to eliminate the chattering problem in systems output and control input.

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Optimizing Si-Content on E6013 Weld Metal to Improve Impact Toughness for Naval Industry

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Abstract—In this study, effect of Si content in rutile coating of shielded metal arc welding (SMAW) on mechanical properties, especially on impact toughness, is presented. In this investigation, four rutile-coated electrodes of the AWS A5.1 E6013 type were prepared by reducing silicon gradually in their coatings without exceeding the AWS A5.1 and ISO 2560 limits. Four test pads were prepared using the four electrodes with different composition to determine the mechanical properties of the welds. Tensile and Charpy V-notch test were conducted in order to determine mechanical properties. Experimental results showed that, impact toughness of E6013 weld metal at -20 °C improved by reducing silicon. The results suggested that decreasing Si content increased slag basicity and kept, or even improved the typical excellent operational characteristics of E6013 type electrodes.

Keywords—cryogenic toughness, rutile electrodes, arc welding

I. INTRODUCTION

During the last twenty to thirty years, there has been a world-wide tendency to replace manual welding with coated electrodes by other processes offering a higher deposition rate and/or capable of automation [1]. However, due to some particular features of the manual metal arc process [2], a wide variety of coated electrodes continues to be manufactured for many different purposes. Among the range of manual coated electrodes, rutile electrodes of the types ANSI/AWS A5.1 [3]. E6013 is very popular for welding C-Mn steels due to stability of arc, easy handling for all positions, smooth bead appearance and availability in the market.

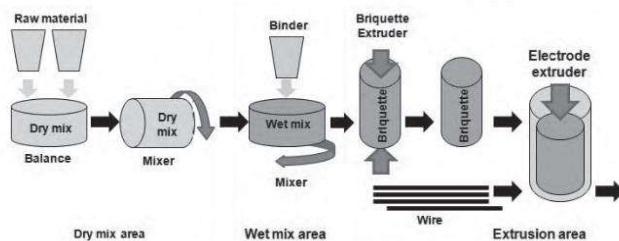


Figure 1. Schematic view of electrode production steps.

E6013 rutile type coated electrodes are still used quite extensively in numerous applications, ranging from sheet-metal work to shipbuilding and underwater welding. Nowadays, underwater wet welding is receiving a great emphasis. Basic electrodes are not adequate for this application. The most suitable electrodes for this purpose are the rutile type [6-8]. The requirements of international

classification societies (ABS, BV, DnV, LR) establish three grades for the classification of rutile electrodes [4] for naval applications according to the temperature at which 47 J minimum, on average, is obtained from the Charpy V-notch impacts.

They are;

Grade 1: +20°C (68°F),

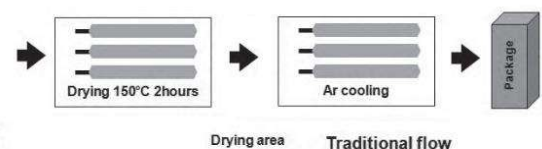
Grade 2: 0°C (32°F) and

Grade 3: -20°C (-4°F) demanding 47 J minimum for each individual value with a single lower value acceptance. It is generally accepted that toughness is related to several factors; hardness values, tensile properties, microstructural characteristics and the type, quantity and size distribution of inclusions [9-12]. Keeping every other parameter as constant as possible and enhancing the sub-zero impact toughness is only possible by optimizing the alloying elements [13-15]. For these reasons and due to a grade 3 rutile electrode inquiry from a customer, a study has been made about upgrading the current Grade 2 E6013 rutile electrodes to Grade 3.

II. EXPERIMENTAL

In this work, effect of Si on and mechanical properties of E6013 weld metal was investigated. Stick electrodes were fabricated by Gedik Welding Inc. in Turkey. Production steps of electrodes were shown on Fig. 1.

Different than current commercial product, named PANTERA, three modified electrodes were also produced and



under the names of PANTERA-S1, PANTERA-S2 and PANTERA-S3 (Hereinafter, the electrodes shall be referred to

as P-S0, P-S1, P-S2 and P-S3 in order). All-weld-metal test assemblies with three passes per layer in total of nine layers (Fig. 2) according to ISO 2560-73. standard [5] were manually welded in the flat position, applying DC(-) current.

The base material used was ASTM A36 low carbon steel. RIGAKU ZSX Primus II X-Ray fluorescence device is used for chemical analysis and LECO CS600 for analyzing carbon and sulfur content. Throughout the series, the C-content remained reasonably constant, and there was the expected increase in the Mn-content with the decreasing Si-content.

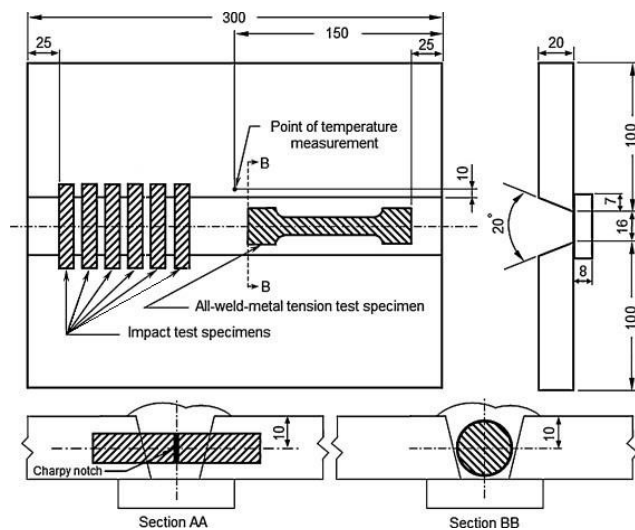


Figure 2. All-Weld Test Metal Assembly.

Consequently, the carbon equivalent (CE) value computed as $C_{eq} = Mn/6 + Si/4$ which is related to strength and hardness of mild and C-Mn weld metal, remained within a narrow scatter range of 0.15-0.17. While Tab. 2 shows the chemical compositions of E6013 weld metals, Tab. 1 summarizes the welding conditions used in this study.

Table 1. The welding parameters used to produce weld metals

Parameters	P-S0	P-S1	P-S2	P-S3
Weld Pass	27	27	27	27
Preheat and Interpass (°C)	150	150	150	150
DC(-) Current (A)	130	140	145	150
Voltage (V)	34	33	33	32
Weld speed (mm/min)	210	202	196	180
Heat Input (kJ/mm)	1.5	1.4	1.5	1.5

Table 2. Chemical composition of modified E6013 weld metals (wt%)

	C	Si	Mn	P	S	Ni
P-S0	0.076	0.368	0.480	0.023	0.007	0.049
P-S1	0.081	0.279	0.519	0.022	0.007	0.068
P-S2	0.071	0.242	0.578	0.024	0.006	0.052
P-S3	0.074	0.199	0.591	0.024	0.011	0.048

Tensile tests were carried out at room temperature using Zwick / Roell at a constant cross-head speed of 1 mm.min^{-1} which corresponds to strain rate of $6.67 \times 10^{-4} \text{ s}^{-1}$. Charpy impact test was also employed to determine toughness of the weld metals. Charpy impact test was conducted with 300 J capacity Losenhausen impact test machine at -20°C . Hardness tests were conducted with ATM QNESS 60 M EVO microhardness tester using 1kgf load.

III. RESULTS AND DISCUSSIONS

A. Arc Characteristics

All electrodes presented a stable arc for DC (-) current and spray type of metal transfer was dominant with the four electrodes. By decreasing Si-content an improvement in the vertical position welding performance was observed together with a slight detrimental effect that of the flat welding position such as slightly bigger and more spatter and relatively tolerable difficult slag removal, but the typical excellent operational properties of rutile electrodes were maintained with all the electrodes and welding positions.

B. Mechanical Properties

Mechanical test results of the specimens were given in Table 3. Both, the yield stress (YS) and the ultimate tensile strength (UTS) values remained remarkably close for all the electrodes in the series (Fig. 3), as the rising Si-content was compensated by lowering the Mn-content in the weld metal.

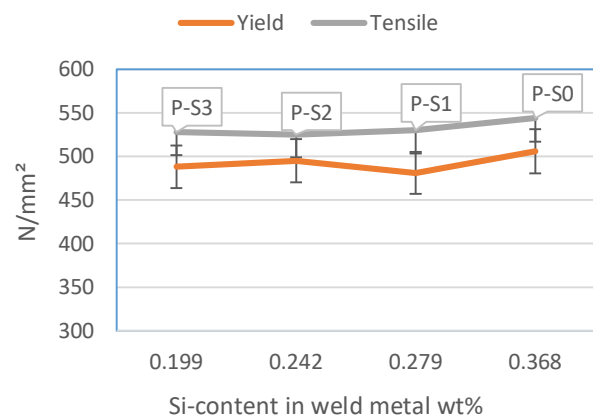


Figure 3. Relationship between the Si-content and tensile strength.

Although all the four weld metals showed very similar strength level, their Charpy toughness appeared to vary markedly. Fig. 3 shows the drastic change on toughness values by changing Si-content of weld metal.

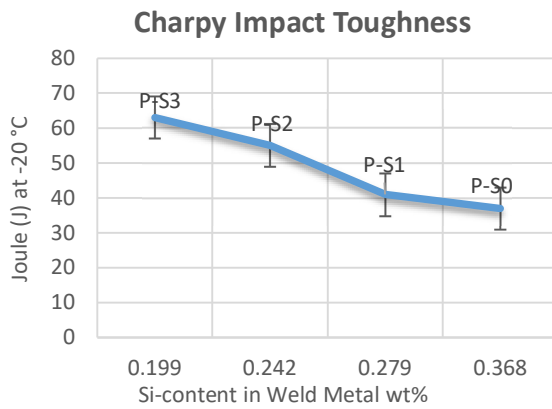


Figure 4. Relationship between the Si-content and absorbed energy in Charpy impact test at -20 °C.

Table 3. Mechanical results of specimens.

Specimen	Yield Strength N/mm ²	Tensile Strength N/mm ²	Elongation (%)	Impact Toughness (J) -20 °C	Avg. Impact Toughness (J)
P-S0	506	544	24	38/28/34/30/40/51	37
P-S1	481	530	23	32/48/46/38/38/42	41
P-S2	495	525	24	60/54/62/43/56/54	55
P-S3	488	528	26	68/62/58/52/72/66	63

Vickers hardness test is also conducted to the effect of increasing Si content in weld metal and heat affected zone (HAZ). Hardness test results were given as graph on Fig. 5.

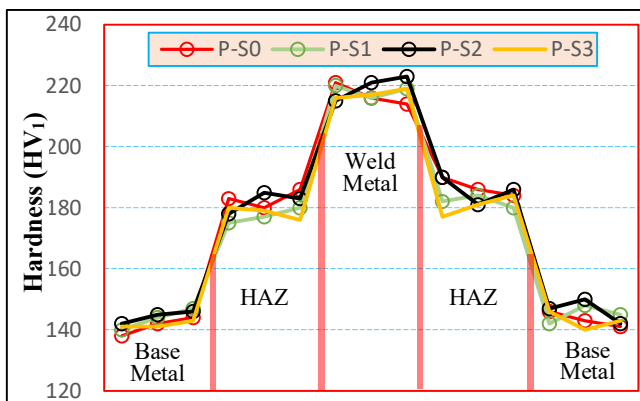


Figure 5. Hardness graph of welded specimens.

It is seen on the hardness graph that; hardness values have increased drastically from base metal to weld metal for all specimens. This phenomenon can be explained by higher C and Mn content of the filler metal compared to base metal. Also, there are very minor differences between the specimens. Thus, increasing Si content didn't effect the hardness properties of the weld metal.

IV. CONCLUSIONS

Using four E6013 rutile all-positional electrodes with identical mineral ingredients in the coverings, it was possible to obtain all-weld metal deposits with a very similar strength level, by favorable changes in their Mn- and Si-contents. From the results of this study the following conclusions can be drawn:

- It was necessary to increase the current by decreasing Si-content to achieve appropriate operational properties in

the flat position. Voltage decreased with decreased Silicon.

- The Si-content appears as the major and most conspicuous compositional variable, so the correlation between the mechanical properties and composition was sought as a function of the Si-content alone, rather than using the parameter of carbon equivalent.
- By decreasing the Si-content, impact toughness showed significant improvement.
- Even though adequate impact toughness for ABS Grade 3 classification was achieved with 0.24 wt% Si, the best results are found around ~0.2 wt% Si content.
- Decreasing Si substances on electrode coating showed deteriorations on smooth rutile arc characteristic. Fifth formulation with 0.15 wt% Si-content had given very poor weld bead and miscellaneous sizes of porous. Therefore, investigations lower than 0.2 wt% Si weld metal need not seen.

ACKNOWLEDGMENT

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A research on fatigue analysis with artificial intelligence: A review

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Abstract—Fatigue damage is a mechanical behavior that can occur in materials without any prior indication and therefore needs to be carefully examined. In addition to the material type and shape, loading amplitude and size, which affect fatigue; There are many parameters such as production technology, environmental conditions, microstructure of the material. Considering these complex parameters when evaluating material fatigue is very important for correct evaluation. With various artificial intelligence applications, it may be possible to obtain more consistent and accurate results in subjects such as fatigue life and damage diagnosis by recording these parameters and processing the resulting large data. Within the scope of this study, the publications in the literature that combine material fatigue and artificial intelligence applications were scanned and examined.

Keywords—fatigue damage, artificial intelligence, fatigue life

I. INTRODUCTION

A. Artificial Intelligence

Artificial intelligence as a computer science first emerged in the mid-1950s[1]. Artificial intelligence can be defined in different ways [2]. Today, artificial intelligence can generally be expressed as mathematics translated into source code that makes learning difficult for traditional developers. Because mathematics is a prerequisite, not an option in artificial intelligence. Artificial intelligence often requires solving a difficult problem that even an expert in a particular field cannot express mathematically [3].

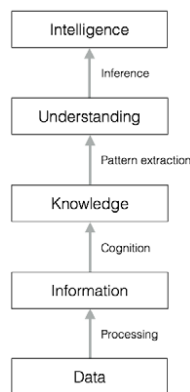


Fig. 1. Conversion of data into intelligence [2].

Machine learning is an approach that is mostly used in large-scale data. Big data, on the other hand, can be defined as datasets collected from different places such as social sites, cameras and various sensors on the internet. Machine learning also refers to the techniques used to make predictions from this big data. In general, it can be grouped into three classes as supervised learning using pre-labeled data, unsupervised learning using unlabeled data, and reinforcement learning that changes

the state of the environment and determines its action by using the reward as well as the new situation [4].

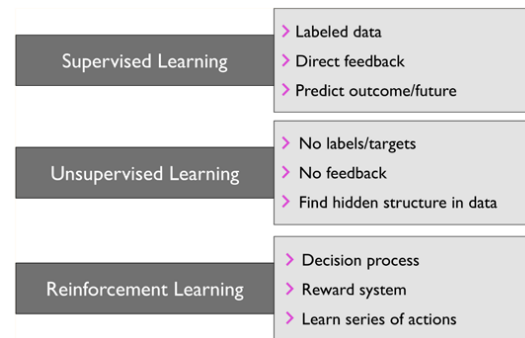


Fig. 2. Classes of machine learning[5].

Deep learning is a subclass of machine learning [6]. Deep learning is making great progress in solving problems that artificial intelligence has been struggling for many years. It has been found to be very good at solving complex structures in high-dimensional data [7]. When it is considered as a sub-branch of machine learning, it is possible to show deep learning as in the Fig. 3

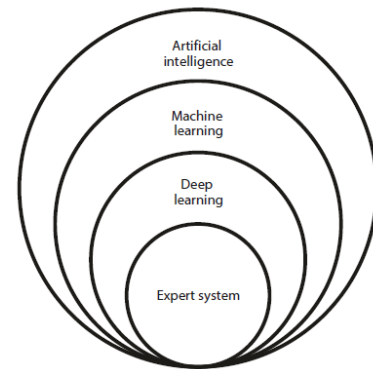


Fig. 3. The relationship between deep learning machine learning and artificial intelligence [8].

Artificial neural networks, which have the ability to learn and apply what they have learned, have been created based on biological neural networks [9]. Artificial neural networks, which are used in many engineering problems with complex and large data, can obtain fast and more accurate results by including many parameters that cannot be included in the problems, with the help of developing computer technologies.

Artificial neural networks (ANN) and Genetic algorithm (GA) can be given as examples of artificial intelligence methods inspired by the functioning of living organisms [10]. Artificial neural networks are information processing elements that can learn automatically and consist of elements

connected by weighted connections. They can perform basic functions such as prediction, classification and control [11].

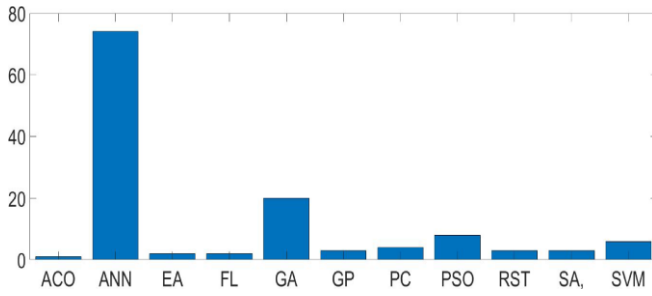


Fig. 4. ACO, ant colony optimization; ANN, artificial neural network; EA, evolutionary algorithm; FL, fuzzy logic; GA, genetic algorithm; GP, genetic programming; PC, polynomial classifier; PSO, particle swarm optimization; RST, rough set theory; SA, simulated annealing; SVM, support vector machine[12].

Many algorithms related to artificial intelligence are used. Considering Fig. 4. Artificial Neural Networks (ANN) and Genetic Algorithm (GA) are the most preferred algorithms [12].

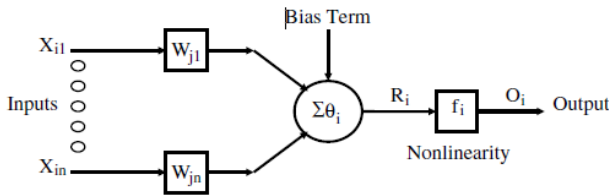


Fig. 5. Basic model of artificial neuron [13].

Artificial neural networks are basically grouped into two main categories: supervised and unsupervised. In supervised learning, an output signal is generated and compared with the target output. If the actual and target output are different, an error signal is generated and used to calculate the required adjustment with the weights. Unsupervised learning, on the other hand, does not require a target output and arbitrarily categorizes it during the training session [13].

Genetic algorithms eliminate unsuitable solutions and stop when the specified loop criterion is met. The solutions created in genetic algorithms are examined simultaneously and they can work without getting stuck with the local best solutions [14].

B. Material Fatigue

In order to evaluate the effects of defects, the basic mechanism of fatigue must first be understood [15].

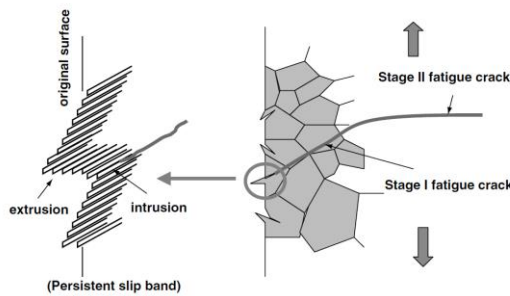


Fig. 6. Fatigue process: a thin plate under cyclic tensile loading [16].

Fatigue occurs in materials as a result of cyclic loading. Fatigue refers to a process consisting of crack initiation, propagation, and fracture. In this process, in a cyclic loading, crack initiation occurs as a result of plastic deformation at the highest stress region. With increasing number of cycles, the crack length increases and fracture occurs [16].

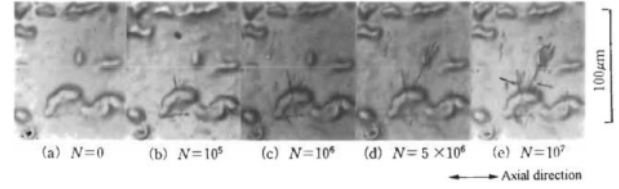


Fig. 7. The sequence of development of an unexpanded crack observed at the fatigue limit ($\sigma_f \approx 181$ MPa) of annealed 0.13% carbon steel [15].

The number of cycles, amplitude and tension are very important in fatigue. Fatigue, which generally has a cycle higher than 10^5 and is applied to stresses less than the yield strength, is called high cycle fatigue. Low cycle fatigue is usually less than 10^4 cycles [17].

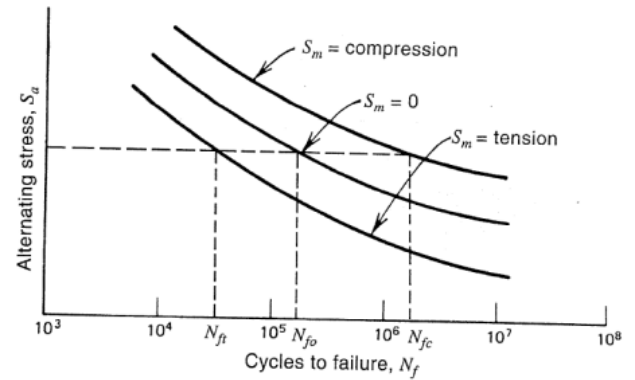


Fig. 8. Effect of average stress on fatigue life [18].

II. METODOLOGY

The publications were created using the WOS and SCOPUS database. The publications for the study to be carried out were examined in detail after a preliminary evaluation. Material fatigue and artificial intelligence were used as search terms.

III. RESULTS

A. Number of Publications by Year

Accordingly, the distribution of the examined publications by years is as shown in Fig. 9

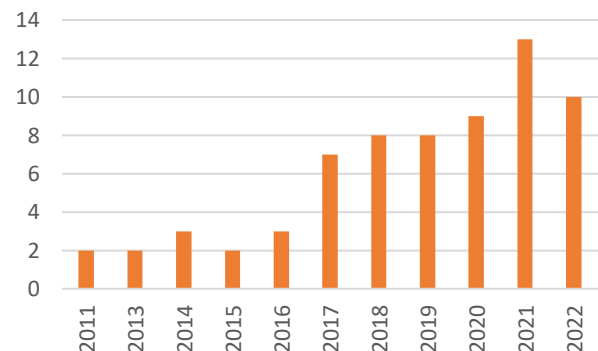


Fig. 9. Number of publications by year

There has been an increase in studies on the subject in recent years.

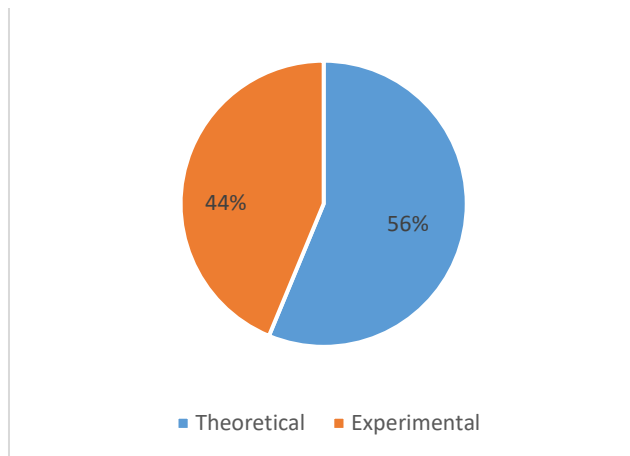


Fig. 10. Experimentation rates of the reviewed articles

44% of the reviewed articles consist of experimental studies and 56% of them are theoretical studies.

B. Publication Types

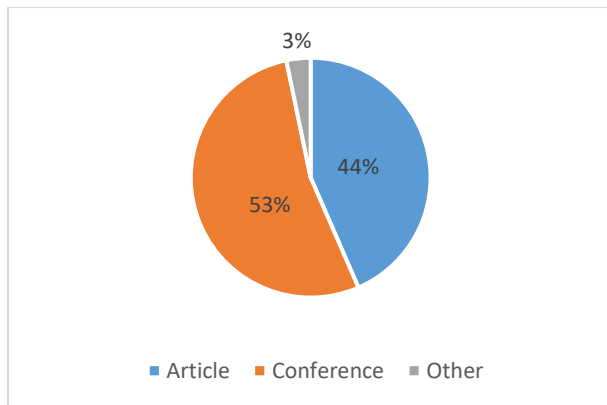


Fig. 11. Publication Types

Most of the publications are conferences and articles. The number of conference papers is 9% more than the number of articles.

C. Materials Used in Publications

In the articles reviewed, the percentage of materials used in different fatigue analyzes such as fatigue life estimation, fatigue damage diagnosis, or monitoring of fatigue loads and damage is shown in Fig. 12.

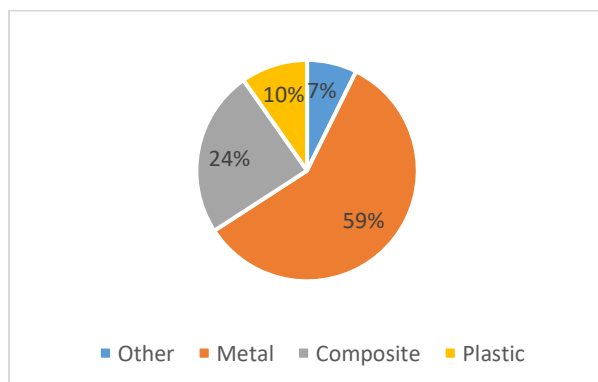


Fig. 12. Materials used in publications

The majority of the materials used in the articles examined according to the graphic are metals and composites.

D. Software Used in Publications

In artificial intelligence applications, quite different programming languages are used. Table I contains the programs used in the reviewed articles.

TABLE I. SOFTWARE USED IN PUBLICATIONS

Matlab	Deng et al. [19], Kabaldin et al. [20], Shao et al. [21], Kalaycı et al. [22], Li et al. [23], Rana et al. [24], Fathalla et al. [25], Sun et al. [26], Wang et al. [27], Selek & Kahramanlı [28]
Python	Schneller et al. [29], Adel et al. [30], Kalia et al. [31], Kurashige et al. [32], Serradilla et al. [33], Ramazani et al. [34], Fong & Marcal [35], Marcal et al. [36]
Other	Teixeira et al. [37], Vassilopoulos & Georgopoulos [38], Riemer-Sørensen et al. [39], Ramachandra et al. [40], Jiang et al. [41], Cheung et al. [42], Shiraiwa et al. [43], Rovinelli et al. [44], Petrone et al. [45], Kahn & Parhi [46], Benerjee [47], Huang [48], Fan et al. [49], Lee et al. [50]

In the Other category, there are programs that perform finite element analysis and programs written using programming languages. If the table is examined, it is seen that Matlab and Python are more preferred.

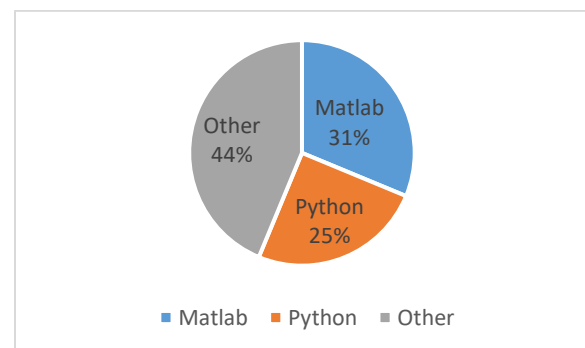


Fig. 13. Matlab and python usage rates

More than half of the programs used in fatigue analysis with artificial intelligence are Matlab and Python languages.

IV. CONCLUSION

Fatigue is an important criterion to be considered in material design. The large number of parameters affecting fatigue enables the efficient use of artificial intelligence technology in this area. In this study, an evaluation of the publications examined under the title of material fatigue and artificial intelligence is presented.

Due to the fact that the parameters and data are many and complex, artificial intelligence applications such as machine learning and deep learning have been concentrated in this area.

Being able to accurately predict the fatigue life will play an important role in preventing malfunctions and accidents that may occur.

When the publications examined in this study are evaluated, it is seen that artificial intelligence is a widely used method for fatigue. Matlab and Python, on the other hand, can be said to be at the forefront of the programs used to develop algorithms. The reason for this is the high number of artificial intelligence application libraries for both Matlab and Python.

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Wind Turbine Selection using Interval-Valued Picture Fuzzy TOPSIS

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Abstract— There are types of wind turbines such as Multi-rotor, Three bladed turbines and Multi-bladed farm windmill; each has different features which requires a multi criteria decision making method to be employed. Besides, because of the nature of the assessment, linguistic terms are used for the criteria values. These terms are represented by picture fuzzy sets in this paper in order to capture the vagueness and impreciseness in the linguistic assessments. Interval-valued picture fuzzy TOPSIS has been used to determine the optimum wind turbine alternative. The paper has been concluded with finding and future research suggestions.

Keywords— *Picture fuzzy set, MCDM, TOPSIS, wind turbine, multi expert*

I. INTRODUCTION

Wind turbines widely used today are three-bladed horizontal axis and these wind turbines rotate in the wind direction of the tower. Vertical axis wind turbines, on the other hand, represent about 5% of the market after the 1990s, but are almost no longer used today due to various problems such as the difficulty of mounting on high towers and other design problems.

Wind turbines come in many different sizes for different applications. The nameplate capacity rating refers to a turbine's peak energy output. Turbines in use today range from less than 1 kW to 3 MW or more in nameplate capacity. Due to the development of technology and the importance given to sustainable development, many wind turbine manufacturers are rapidly developing even larger machines.

It is important that the features such as reliability, wind source, size, spare parts availability, warranty, usability and proximity of operation and maintenance teams are suitable for the turbine that is decided to be constructed.

Fuzzy sets can capture the vagueness and impreciseness in the linguistic assessments. After the introduction of ordinary fuzzy sets, several new extensions have been proposed in the literature such as type-2 fuzzy sets, intuitionistic fuzzy sets, picture fuzzy sets, spherical fuzzy sets, Pythagorean fuzzy sets, and neutrosophic sets. Pythagorean fuzzy sets are the extensions of intuitionistic fuzzy sets proposed for providing a larger domain area of membership and non-membership degrees. Picture fuzzy sets are defined by three parameters, namely membership, non-membership, and hesitancy degrees. The refusal degree is the difference of the sum of these parameters from one.

In this paper, we use interval-valued picture fuzzy sets in TOPSIS multi-criteria decision making method for selecting

the best wind turbine. Linguistic terms are used in the decision matrix based on a picture fuzzy linguistic scale.

The rest of the paper is organized as follows. Section 2 presents the wind turbines and gives the selection criteria. Section 3 includes the preliminaries of interval-valued picture fuzzy sets. Section 4 presents the steps of interval-valued picture fuzzy (IVPF) TOPSIS method. Section 5 shows the application of the IVPF-TOPSIS method for the wind turbine selection problem. Section 6 concludes the paper.

II. WIND TURBINES

Wind energy prevents or minimizes harmful greenhouse gases arising from fossil energy sources. Investments in wind energy are relatively expensive, limiting the use of wind energy. Therefore, it is very important to choose the appropriate technology both to increase the use of wind energy and to increase the efficiency obtained from wind energy [1]. Besides, wind energy technology is in a position to be the most promising alternative to traditional energy systems with the rapid development in recent years. Wind turbines, which have the ability to convert the movement energy of the wind into electrical energy, constitute the most important part of wind energy technologies [2].

Wind energy technology selection should be made by considering the characteristics of the wind turbine, the environmental conditions and suitability of the region where the wind turbine will be installed. Wind turbines cannot fully utilize all the energy of the blowing wind due to inefficiencies caused by rotor blade friction and drag, Betz's law, gearbox losses, and generator losses. Besides, wind turbines are disabled for certain wind speeds. Therefore, the power/speed function of the wind turbine should be taken into account in order to make the most efficient use of wind energy. The type of wind turbine has a strong influence on wind power generation performance. However, the selection of a suitable wind turbine is often limited to the field knowledge of the decision makers and requires consideration of many complex factors [1].

Based on the literature review, we can list the criteria to be considered for the selection of a suitable wind turbine as follows. Reliability includes the current reputation of the supplier in terms of reliability, services, practices and overall reputation of the supplier. It also indicates the level of satisfaction with the supplier in the market [1], [2], [3], [4]. Technological development shows the technological development and the maturity of the technology used in the wind turbine [2], [4]. Technical characteristics includes technical features that affect production volume such as

generator, hub height, blade and rotor diameter [1], [2], [4], [5]. Maintenance shows the maintenance services provided by suitable alternative organizations that can maintain the turbines and the quality of these services [1], [2], [3]. Cost includes installation costs including initial investment costs, infrastructure works at the facility's location, purchasing cost, and operating costs such as maintenance costs [1], [2], [3] [4], [5]. System integration capability indicates the hardware and software capability of wind turbine systems, including equipment, components and personnel [1], [2], [4]. Operating performance shows the result of the measured value in the power curve or the price of the generation unit (kWh or MWh) [1], [4]. Availability of spare parts shows the ease of finding the part that needs to be replaced as the result of a breakdown [1], [2], [3].

III. PRELIMINARIES: INTERVAL-VALUED PICTURE FUZZY SETS (IVPFS)

Definition 1. A picture fuzzy set (PFS) on the universe X is an object of the form $\tilde{A} = \{x, \mu_{\tilde{A}}(x), \eta_{\tilde{A}}(x), \nu_{\tilde{A}}(x) | x \in X\}$. Let $\tilde{A}$ be an interval valued picture fuzzy number (IVPFN), where $\mu_{\tilde{A}}(x) \in [0, 1]$ is named as the "degree of positive membership of $\tilde{A}$ ", $\eta_{\tilde{A}}(x) \in [0, 1]$ is named as the "degree of neutral membership of $\tilde{A}$ " and $\nu_{\tilde{A}}(x) \in [0, 1]$ is named as the "degree of negative membership of $\tilde{A}$ ", and $\mu_{\tilde{A}}(x)$, $\eta_{\tilde{A}}(x)$, and $\nu_{\tilde{A}}(x)$ satisfy the following condition: $0 \leq \mu_{\tilde{A}}(x) + \eta_{\tilde{A}}(x) + \nu_{\tilde{A}}(x) \leq 1, \forall x \in X$. Then for $x \in X$, $\pi_{\tilde{A}}(x) = 1 - (\mu_{\tilde{A}}(x) + \eta_{\tilde{A}}(x) + \nu_{\tilde{A}}(x))$ could be named as the degree of refusal membership of x in $\tilde{A}$ [6].

Let $\tilde{A} = (\mu_{\tilde{A}}, \eta_{\tilde{A}}, \nu_{\tilde{A}})$ and $\tilde{B} = (\mu_{\tilde{B}}, \eta_{\tilde{B}}, \nu_{\tilde{B}})$ be two single valued picture fuzzy numbers. The operations with these numbers are as follows.

$$\tilde{A} \oplus \tilde{B} = (\mu_{\tilde{A}} + \mu_{\tilde{B}} - \mu_{\tilde{A}}\mu_{\tilde{B}}, \eta_{\tilde{A}}\eta_{\tilde{B}}, \nu_{\tilde{A}}\nu_{\tilde{B}}) \quad (1)$$

$$\tilde{A} \otimes \tilde{B} = (\mu_{\tilde{A}}\mu_{\tilde{B}}, \eta_{\tilde{A}} + \eta_{\tilde{B}} - \eta_{\tilde{A}}\eta_{\tilde{B}}, \nu_{\tilde{A}} + \nu_{\tilde{B}} - \nu_{\tilde{A}}\nu_{\tilde{B}}) \quad (2)$$

$$\lambda \tilde{A} = (1 - (1 - \mu_{\tilde{A}})^\lambda, \eta_{\tilde{A}}^\lambda, \nu_{\tilde{A}}^\lambda), \lambda > 0 \quad (3)$$

$$\tilde{A}^\lambda = (\mu_{\tilde{A}}^\lambda, 1 - (1 - \eta_{\tilde{A}})^\lambda, 1 - (1 - \nu_{\tilde{A}})^\lambda), \lambda > 0 \quad (4)$$

Definition 2. Let $\tilde{A} = ([\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U], [\eta_{\tilde{A}}^L, \eta_{\tilde{A}}^U], [\nu_{\tilde{A}}^L, \nu_{\tilde{A}}^U])$ be an interval-valued PF (IVPFN). It must satisfy the condition: $0 \leq \mu_{\tilde{A}}^U + \eta_{\tilde{A}}^U + \nu_{\tilde{A}}^U \leq 1$. The degree of refusal membership is defined as an interval $[\pi_{\tilde{A}}^L, \pi_{\tilde{A}}^U]$ where $\pi_{\tilde{A}}^L = 1 - (\mu_{\tilde{A}}^U + \eta_{\tilde{A}}^U + \nu_{\tilde{A}}^U)$ and $\pi_{\tilde{A}}^U = 1 - (\mu_{\tilde{A}}^L + \eta_{\tilde{A}}^L + \nu_{\tilde{A}}^L)$ [6].

Definition 3. Let $\tilde{A} = ([\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U], [\eta_{\tilde{A}}^L, \eta_{\tilde{A}}^U], [\nu_{\tilde{A}}^L, \nu_{\tilde{A}}^U])$ and $\tilde{B} = ([\mu_{\tilde{B}}^L, \mu_{\tilde{B}}^U], [\eta_{\tilde{B}}^L, \eta_{\tilde{B}}^U], [\nu_{\tilde{B}}^L, \nu_{\tilde{B}}^U])$ be two interval-valued picture fuzzy numbers (IVPFNs). The operations with these numbers are as follows [6].

$$\tilde{A} \otimes \tilde{B} = ([\mu_{\tilde{A}}^L\mu_{\tilde{B}}^L, \mu_{\tilde{A}}^U\mu_{\tilde{B}}^U], [\eta_{\tilde{A}}^L + \eta_{\tilde{B}}^L - \eta_{\tilde{A}}^L\eta_{\tilde{B}}^L, \eta_{\tilde{A}}^U + \eta_{\tilde{B}}^U - \eta_{\tilde{A}}^U\eta_{\tilde{B}}^U], [(1 - \eta_{\tilde{A}}^L)\nu_{\tilde{A}}^L + (1 - \eta_{\tilde{A}}^U)\nu_{\tilde{A}}^U, (1 - \eta_{\tilde{B}}^L)\nu_{\tilde{B}}^L + (1 - \eta_{\tilde{B}}^U)\nu_{\tilde{B}}^U]) \quad (5)$$

$$\tilde{A} \oplus \tilde{B} = ([\mu_{\tilde{A}}^L + \mu_{\tilde{B}}^L - \mu_{\tilde{A}}^L\mu_{\tilde{B}}^L, \mu_{\tilde{A}}^U + \mu_{\tilde{B}}^U - \mu_{\tilde{A}}^U\mu_{\tilde{B}}^U], [\eta_{\tilde{A}}^L\eta_{\tilde{B}}^L, \eta_{\tilde{A}}^U\eta_{\tilde{B}}^U], [(\mu_{\tilde{A}}^L + \mu_{\tilde{B}}^L - \mu_{\tilde{A}}^L\mu_{\tilde{B}}^L), (1 - \mu_{\tilde{A}}^U)\nu_{\tilde{A}}^U + (1 - \mu_{\tilde{B}}^U)\nu_{\tilde{B}}^U]) \quad (6)$$

$$\lambda \tilde{A} = \{[1 - (1 - \mu_{\tilde{A}}^L)^\lambda, 1 - (1 - \mu_{\tilde{A}}^U)^\lambda], [(\eta_{\tilde{A}}^L)^\lambda, (\eta_{\tilde{A}}^U)^\lambda], [(1 - \mu_{\tilde{A}}^L)^\lambda - (1 - \mu_{\tilde{A}}^L - \nu_{\tilde{A}}^L)^\lambda, (1 - \mu_{\tilde{A}}^U)^\lambda - (1 - \mu_{\tilde{A}}^U - \nu_{\tilde{A}}^U)^\lambda]\} \text{ for } \lambda > 0 \quad (7)$$

$$\tilde{A}^\lambda = \{[(\mu_{\tilde{A}}^L)^\lambda, (\mu_{\tilde{A}}^U)^\lambda], [1 - (1 - \eta_{\tilde{A}}^L)^\lambda, 1 - (1 - \eta_{\tilde{A}}^U)^\lambda], [(1 - \eta_{\tilde{A}}^L)^\lambda - (1 - \eta_{\tilde{A}}^L - \nu_{\tilde{A}}^L)^\lambda, (1 - \eta_{\tilde{A}}^U)^\lambda - (1 - \eta_{\tilde{A}}^U - \nu_{\tilde{A}}^U)^\lambda]\} \text{ for } \lambda > 0 \quad (8)$$

Definition 4. Let $\tilde{A} = ([\mu_{\tilde{A}}^L, \mu_{\tilde{A}}^U], [\eta_{\tilde{A}}^L, \eta_{\tilde{A}}^U], [\nu_{\tilde{A}}^L, \nu_{\tilde{A}}^U])$ and $\tilde{B} = ([\mu_{\tilde{B}}^L, \mu_{\tilde{B}}^U], [\eta_{\tilde{B}}^L, \eta_{\tilde{B}}^U], [\nu_{\tilde{B}}^L, \nu_{\tilde{B}}^U])$. Then the Euclidean distance between these PFSs is given by Eq. (9):

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{(\mu_{\tilde{A}}^L - \mu_{\tilde{B}}^L)^2 + (\mu_{\tilde{A}}^U - \mu_{\tilde{B}}^U)^2 + (\eta_{\tilde{A}}^L - \eta_{\tilde{B}}^L)^2 + (\eta_{\tilde{A}}^U - \eta_{\tilde{B}}^U)^2 + (\nu_{\tilde{A}}^L - \nu_{\tilde{B}}^L)^2 + (\nu_{\tilde{A}}^U - \nu_{\tilde{B}}^U)^2}{2}} \quad (9)$$

Definition 5. Let $\tilde{A}_1, \tilde{A}_2, \dots, \tilde{A}_n$ be IVPFNSs, which are the corresponding numbers in the linguistic scale. Aggregation of these IVPFNSs assigned by experts with respect to each criterion. Are made by using IVPFWG operator given in Eq. (10).

$$IVPFWG(\tilde{A}_1, \tilde{A}_2, \dots, \tilde{A}_n) = \left[\prod_{i=1}^n (\mu_{\tilde{A}_i}^L)^{\lambda_i}, \prod_{i=1}^n (\mu_{\tilde{A}_i}^U)^{\lambda_i}, [(1 - \prod_{i=1}^n (1 - \eta_{\tilde{A}_i}^L)^{\lambda_i}), (1 - \prod_{i=1}^n (1 - \eta_{\tilde{A}_i}^U)^{\lambda_i})], [(\prod_{i=1}^n (1 - \eta_{\tilde{A}_i}^L)^{\lambda_i} - \prod_{i=1}^n (1 - \eta_{\tilde{A}_i}^L - \nu_{\tilde{A}_i}^L)^{\lambda_i}), (\prod_{i=1}^n (1 - \eta_{\tilde{A}_i}^U)^{\lambda_i} - \prod_{i=1}^n (1 - \eta_{\tilde{A}_i}^U - \nu_{\tilde{A}_i}^U)^{\lambda_i})] \right] \quad (10)$$

Definition 6. The score function (S) and accuracy function (A) for the IVPFN is given by Eq. (11) and Eq. (12), respectively.

$$S = \frac{\mu^L + \mu^U - \eta^L - \eta^U}{2} \quad (11)$$

$$A = \frac{\mu^L + \mu^U + \eta^L + \eta^U}{2} \quad (12)$$

IV. IVPF TOPSIS

The steps of the proposed IVPF TOPSIS method are presented in this section. The experts use the following linguistic scale for the evaluation of both alternatives and criteria.

Step 1. Define the alternatives ($i = 1, \dots, n$) and criteria ($j = 1, \dots, m$).

Step 2. Collect the linguistic evaluations from the experts by using the scale given in Table 1 for decision matrices (Eq. 13) and criteria weights for each expert from experts (Eq. 14) where K is the number of experts ($k = 1, \dots, K$). Experts can have different weights based on their experiences ($\lambda_k, k = 1, \dots, K$).

$$\tilde{D}_k = \begin{bmatrix} \tilde{x}_{11k} & \dots & \tilde{x}_{1mk} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{n1k} & \dots & \tilde{x}_{nmk} \end{bmatrix}, k = 1, \dots, K \quad (13)$$

$$\tilde{W}_k = (\tilde{w}_{1,k}, \dots, \tilde{w}_{m,k}), k = 1, \dots, K \quad (14)$$

Step 3. Aggregate the decision matrices and criteria evaluations by using the IVPFWG aggregation operator given in Eq. (10). Obtain the aggregated decision matrix in Eq. (15) and aggregated criteria weights vector in Eq. (16).

$$\tilde{D}_{agg} = \begin{bmatrix} \tilde{x}_{11} & \dots & \tilde{x}_{1m} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \dots & \tilde{x}_{nm} \end{bmatrix} \quad (15)$$

$$\tilde{W}_{agg} = (\tilde{w}_1, \dots, \tilde{w}_m) \quad (16)$$

Step 4. Calculate the weighted decision matrix by using Eq. (5) and obtain weighted aggregated decision matrix given in Eq. (17).

$$\tilde{D}_{w,agg} = \tilde{D}_{agg} \otimes \tilde{W}_{agg} = \begin{bmatrix} \tilde{r}_{11} & \cdots & \tilde{r}_{1m} \\ \vdots & \ddots & \vdots \\ \tilde{r}_{n1} & \cdots & \tilde{r}_{nm} \end{bmatrix} \quad (17)$$

TABLE I. INTERVAL VALUED PICTURE FUZZY SETS

Evaluations for Alternatives	Abb.	Evaluations for Criteria	Abb.	IVPFN
Absolutely High	AH	Absolutely High Important	AHI	([0.7,0.85],[0.05,0.1], [0,0.05])
Very High	VH	Very High Important	VHI	([0.6,0.75],[0.05,0.1],[0.05,0.15])
High	H	High Important	HI	([0.5,0.65],[0.05,0.1],[0.1,0.25])
Slightly High	SH	Slightly High Important	SHI	([0.4,0.55],[0.05,0.1],[0.2,0.35])
Moderate	M	Moderate Important	MI	([0.3,0.45],[0.05,0.1],[0.3,0.45])
Slightly Low	SL	Slightly Low Important	SLI	([0.2,0.35],[0.05,0.1],[0.4,0.55])
Low	L	Low Important	LI	([0.1,0.25],[0.05,0.1],[0.5,0.65],[0.6,0.75])
Very Low	VL	Very Low Important	VLI	([0.05,0.15],[0.05,0.1],[0.6,0.75])
Absolutely Low	AL	Absolutely Low Important	ALI	([0,0.05],[0.05,0.1], [0.7,0.85])

Step 5. Determine the positive ideal solution $\tilde{PIS} = (\tilde{r}_1^+, \tilde{r}_2^+, \dots, \tilde{r}_m^+)$ and the negative-ideal solution $\tilde{NIS} = (\tilde{r}_1^-, \tilde{r}_2^-, \dots, \tilde{r}_m^-)$ as given in Eq. (18) and Eq.(19), respectively, by using the score function defined in Eq.(11).

$$r_j^+ = \begin{cases} \max_{1 \leq i \leq n} \{S_{co}(r_{ij})\}, & \text{if } f_j \in F_1 \\ \min_{1 \leq i \leq n} \{S_{co}(r_{ij})\}, & \text{if } f_j \in F_2 \end{cases} \quad (18)$$

$$r_j^- = \begin{cases} \min_{1 \leq i \leq n} \{S_{co}(r_{ij})\}, & \text{if } f_j \in F_1 \\ \max_{1 \leq i \leq n} \{S_{co}(r_{ij})\}, & \text{if } f_j \in F_2 \end{cases} \quad (19)$$

where $\tilde{r}_j^+ = ([\mu_{PISj}^L, \mu_{PISj}^U], [\eta_{PISj}^L, \eta_{PISj}^U], [v_{PISj}^L, v_{PISj}^U])$ and $\tilde{r}_j^- = ([\mu_{NISj}^L, \mu_{NISj}^U], [\eta_{NISj}^L, \eta_{NISj}^U], [v_{NISj}^L, v_{NISj}^U])$ are associated fuzzy value of r_j^+ and r_j^- . $F_1 = \{f_1, \dots, f_b\}$ is the set of benefit attributes, $F_2 = \{f_1, \dots, f_c\}$ is the set of cost attributes and $b + c = m$, $1 \leq j \leq m$.

Step 6. Calculate the distance of each alternative to $\tilde{PIS}$ and $\tilde{NIS}$ according to Eqs. (20) and (21) respectively.

$$d(\tilde{A}_i, \tilde{PIS}) = \frac{1}{m} \sum_{j=1}^m \sqrt{\left((\mu_{A_j}^L - \mu_{PISj}^L)^2 + (\mu_{A_j}^U - \mu_{PISj}^U)^2 + (\eta_{A_j}^L - \eta_{PISj}^L)^2 + (\eta_{A_j}^U - \eta_{PISj}^U)^2 + (v_{A_j}^L - v_{PISj}^L)^2 + (v_{A_j}^U - v_{PISj}^U)^2 \right)} \quad (20)$$

$$d(\tilde{A}_i, \tilde{NIS}) = \frac{1}{m} \sum_{j=1}^m \sqrt{\left((\mu_{A_j}^L - \mu_{NISj}^L)^2 + (\mu_{A_j}^U - \mu_{NISj}^U)^2 + (\eta_{A_j}^L - \eta_{NISj}^L)^2 + (\eta_{A_j}^U - \eta_{NISj}^U)^2 + (v_{A_j}^L - v_{NISj}^L)^2 + (v_{A_j}^U - v_{NISj}^U)^2 \right)} \quad (21)$$

where $i = 1, \dots, n$

Step 7. Compute closeness coefficients (C) for each alternative using Eq. (22).

$$C_i = \frac{d(\tilde{A}_i, \tilde{NIS})}{d(\tilde{A}_i, \tilde{PIS}) + d(\tilde{A}_i, \tilde{NIS})}, \quad 0 \leq C_i \leq 1, i = 1, \dots, n \quad (22)$$

Step 8. Rank the alternatives in descending order. The largest closeness coefficient indicates the best alternative.

V. APPLICATION: WIND TURBINE SELECTION

In a European country an energy farm wants to determine the type of the wind turbine they will invest in. there are four alternatives which are Multi-rotor, Cross-wind Savonius, Three bladed turbines and Multi-bladed farm windmill. These alternatives are numbered A1, A2, A3, and A4 but not respectively. The alternatives are assessed with respect to by five criteria which are Reliability (C1), Technical characteristics (C2), Cost (C3), System integration capability (C4) and Operating performance (C5). Three decision makers whose weights are 0.4, 0.25, and 0.35, respectively, evaluate these alternatives and criteria as given in Table 2 and Table 3 by using the scale given in Table 1.

TABLE II. LINGUISTIC DECISION MATRICES FROM THREE DMS

	DM1				DM2				DM3			
	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
Reliability -C1	VH	H	SL	M	H	VH	SL	SL	H	H	SH	M
Technical characteristics-C2	H	VH	M	SH	AH	VH	H	M	SH	H	VH	M
Cost-C3	M	VH	H	SH	H	H	VH	H	VH	H	SH	H
System integration capability-C4	L	M	H	M	SH	H	VH	SL	M	SH	H	SH
Operating performance-C5	M	H	VH	SL	M	VH	SH	SH	SL	VH	H	M

TABLE III. LINGUISTIC IMPORTANCE OF EACH CRITERION BY DMs

	DM1	DM2	DM3
C1	SH	H	SH
C2	VH	AH	H
C3	M	L	SL
C4	M	SH	SL
C5	H	VH	H

By using the aggregation operator given in Eq. (10) the aggregated weights of the criteria are obtained as in Table 4.

TABLE IV. AGGREGATED WEIGHTS OF THE CRITERIA

C1	([0.423,0.573],[0.05,0.1],[0.176,0.327])
C2	([0.585,0.736],[0.05,0.1],[0.056,0.164])
C3	([0.198,0.281],[0.05,0.1],[0.141,0.264])
C4	([0.28,0.508],[0.05,0.1],[0.242,0.392])
C5	([0.523,0.674],[0.05,0.1],[0.088,0.226])

The decision matrices of three DMs are aggregated by the operator given in Eq. (10) and presented in Table 5.

TABLE V. AGGREGATED DECISION MATRIX

	A1	A2
C1	([0.538,0.688],[0.05,0.1],[0.08,0.212])	([0.688,0.05],[0.1,0.08],[0.212,0.523])
C2	([0.503,0.656],[0.05,0.1],[0.113,0.244])	([0.656,0.05],[0.1,0.113],[0.244,0.563])
C3	([0.434,0.59],[0.05,0.1],[0.171,0.31])	([0.59,0.05],[0.1,0.171],[0.31,0.538])
C4	([0.208,0.374],[0.05,0.1],[0.368,0.526])	([0.374,0.05],[0.1,0.368],[0.526,0.377])
C5	([0.26,0.412],[0.05,0.1],[0.337,0.488])	([0.412,0.05],[0.1,0.337],[0.488,0.558])
	A3	A4
C1	([0.05,0.1],[0.08,0.212],[0.523,0.674])	([0.1,0.08],[0.212,0.523],[0.674,0.05])
C2	([0.05,0.1],[0.113,0.244],[0.563,0.713])	([0.1,0.113],[0.244,0.563],[0.713,0.05])
C3	([0.05,0.1],[0.171,0.31],[0.538,0.688])	([0.1,0.171],[0.31,0.538],[0.688,0.05])
C4	([0.05,0.1],[0.368,0.526],[0.377,0.529])	([0.1,0.368],[0.526,0.377],[0.529,0.05])
C5	([0.05,0.1],[0.337,0.488],[0.558,0.708])	([0.1,0.337],[0.488,0.558],[0.708,0.05])

The aggregated decision matrix in Table 5 is multiplied by the criteria weights and weighted aggregated decision matrix in Table 6 is obtained.

TABLE VI. WEIGHTED AGGREGATED DECISION MATRIX

	A1	A2
C1	([0.227,0.395],[0.098,0.19],[0.23,0.415])	([0.395,0.098],[0.19,0.23],[0.415,0.221])
C2	([0.294,0.483],[0.098,0.19],[0.155,0.327])	([0.483,0.098],[0.19,0.155],[0.327,0.329])
C3	([0.086,0.166],[0.098,0.19],[0.272,0.435])	([0.166,0.098],[0.19,0.272],[0.435,0.106])
C4	([0.058,0.19],[0.098,0.19],[0.491,0.62])	([0.19,0.098],[0.19,0.491],[0.62,0.105])
C5	([0.136,0.278],[0.098,0.19],[0.374,0.532])	([0.278,0.098],[0.19,0.374],[0.532,0.292])
	A3	A4
C1	([0.098,0.19],[0.23,0.415],[0.221,0.386])	([0.19,0.23],[0.415,0.221],[0.386,0.098])
C2	([0.098,0.19],[0.155,0.327],[0.329,0.525])	([0.19,0.155],[0.327,0.329],[0.525,0.098])

C3	([0.098,0.19],[0.272,0.435],[0.106,0.194])	([0.19,0.272],[0.435,0.106],[0.194,0.098])
C4	([0.098,0.19],[0.491,0.62],[0.105,0.269])	([0.19,0.491],[0.62,0.105],[0.269,0.098])
C5	([0.098,0.19],[0.374,0.532],[0.292,0.477])	([0.19,0.374],[0.532,0.292],[0.477,0.098])

From Table 6, negative and positive ideal solutions are determined by using the score function given in Eq. (11). The determined ideal solutions are presented in Table 7.

TABLE VII. NEGATIVE AND POSITIVE IDEAL SOLUTIONS

	NIS	PIS
C1	([0.108,0.235],[0.098,0.19],[0.428,0.575])	([0.235,0.098],[0.19,0.428],[0.575,0.227])
C2	([0.197,0.359],[0.098,0.19],[0.287,0.451])	([0.359,0.098],[0.19,0.287],[0.451,0.329])
C3	([0.106,0.194],[0.098,0.19],[0.199,0.372])	([0.194,0.098],[0.19,0.199],[0.372,0.086])
C4	([0.058,0.19],[0.098,0.19],[0.491,0.62])	([0.19,0.098],[0.19,0.491],[0.62,0.146])
C5	([0.136,0.278],[0.098,0.19],[0.374,0.532])	([0.278,0.098],[0.19,0.374],[0.532,0.292])

The distance of each alternatives to negative and positive ideal solutions are calculated as in Table 8 by using Eq. (20) and Eq. (21).

TABLE VIII. DISTANCE TO NEGATIVE AND POSITIVE IDEAL SOLUTIONS

	A1	A2	A3	A4
$d(\tilde{A}_i, \tilde{NIS})$	0.1332	0.237	0.168	0.039
$d(\tilde{A}_i, \tilde{PIS})$	0.1565	0.052	0.122	0.251

Based on the distances to ideal solutions, the closeness coefficients are obtained as in Table 9 by using Eq. (22).

TABLE IX. CLOSENESS TO IDEAL SOLUTIONS AND RANKING OF ALTERNATIVES

A1	A2	A3	A4
0.4598	0.819	0.5788	0.134
3	1	2	4

VI. CONCLUSION

Wind turbine selection is a multi-criteria decision making problem with several conflicting criteria and vague assessments. Picture fuzzy sets can handle this vagueness and impreciseness with the assignment of three parameters for each assessment. TOPSIS is one of the most used multi-

criteria decision making methods in the literature, whose extensions has been developed such as intuitionistic fuzzy TOPSIS, spherical fuzzy TOPSIS, and neutrosophic TOPSIS. IVPF-TOPSIS have been successfully used for the assessment of wind turbine alternatives. For further research, we recommend IVPF AHP method to be used for comparison purpose.

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Silica microsphere WGMR-based Kerr-OFC light source for telecommunication applications

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ABSTRACT

Kerr optical frequency combs (OFCs) based on silica microsphere whispering gallery mode resonator (WGMR) have already shown different applications, and in particular, their applications in fiber optic communication systems replacing laser light sources at specific wavelengths [1]. In addition, OFC generators are used in technologies such as optical clocks [2], ultra-stable microwave generation [3], applications requiring accurate optical frequency reference, spectroscopy [4], sensors [5], quantum applications [6], and optical communications [7], etc. The application of WGMR-OFC light sources in wavelength division multiplexed (WDM) fiber optic communication systems covers application scenarios ranging from short reach, such as data center interconnection (DCI) to access layer fiber optic networks [1, 8]. More specifically, the WGMR-based Kerr OFC comb generators physically realized on silica microsphere demonstrate [1] a new concept that provides an attractive solution to intra-DCIs due to low cost and energy consumption. Potentially cost-effective solutions for the realization of data transmission in optical WDM networks are OFC generation in silica whispering gallery mode resonator – microspheres manufactured from melted telecom fiber, e.g. from Corning SMF 28e (ITU-T G.652) [1], which is realized as the pumping of a high-quality (high-Q) optical resonator with Kerr nonlinearity using a single continuous-wave laser. Kerr microresonator OFCs can achieve bandwidths of hundreds of nanometres covering different (e.g. E-, S-, C- and L-band) telecommunication bands. An Kerr OFC source can produce the grid of equally spaced (according to ITU-T G. 694.1 recommendation) optical spectral lines (carriers) needed to sustain the data channels. We have experimentally shown a silica microsphere WGMR-based Kerr OFC as a light source where generated 400 GHz spaced carriers provide low-cost and low-complexity intensity modulation direct detection (IM/DD) scheme for transmission of non-return to zero (NRZ) on-off keying (OOK) modulated data up to 50 Gbps/λ over 2 km single-mode fiber (SMF) link.

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