FACULTY OF ELECTRONICS, TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY

ARTIFICIAL INTELLIGENCE SOLUTIONS FOR PROCESS OPTIMIZATION

– ABSTRACT OF THE HABILITATION THESIS –

Associate Professor, Ph.D., Eng. BREZULIANU ADRIAN

The habilitation thesis comprises 185 pages, incorporating 62 figures and 7 tables to support the technical content. The thesis is substantiated by a diverse range of academic resources, as indicated by its 244 bibliographical references. In its abstract, the original structure of the thesis, including the table of contents and the figure numbering, has been retained to accurately reflect its composition. The abstract also contains a curated bibliography with 44 references selected from the thesis, providing a concise overview of the key literature relevant to the study.

Contents

CHAPTER 1. INTRODUCTION

1.1 Overall context of process optimization using Artificial Intelligence (AI)

Process optimization is a fundamental area in engineering that focuses on improving the performance, efficiency, and effectiveness of existing processes. Processes are understood as sequences of interconnected activities or operations performed to achieve a specific goal or desired outcome.

Defining process optimization involves identifying and applying the best possible solutions to maximize benefits and minimize the costs, time, and resources involved in carrying out a process. The ultimate goal of process optimization is to achieve superior performance in areas such as productivity, quality, delivery time, efficient resource utilization, and more.

Process optimization involves various preliminary activities, including analysis, evaluation, and modeling. It is a continuous and iterative process that includes ongoing monitoring and measurement of performance, identifying deficiencies, and implementing adjustments to achieve better results.

Within the context of process optimization, multiple aspects are considered, such as:

Efficiency: Optimization focuses on reducing the resources required to complete a process, including time, human effort, financial costs, or materials used. The objective is to improve the overall efficiency of the process, achieving the same or even better results with fewer resources.

Quality: Process optimization also involves improving the quality of the products or services obtained from the process. Quality criteria like accuracy, reliability, and compliance, are taken into consideration.

Workflow: Process optimization entails evaluating and adjusting workflows, which refers to how the activities or stages of the process are organized and interconnected. The goal is to eliminate inefficiencies and blockages to ensure a smooth flow.

Error and downtime reduction: Process optimization aims to minimize human errors and reduce downtime or delays in the process. Solutions are sought to prevent or correct errors and reduce idle times, ensuring an efficient and uninterrupted process.

Flexibility and adaptability: Process optimization also involves evaluating the capacity of processes to adapt and be flexible. It seeks to develop solutions that allow for rapid adjustment and adaptation to changes in demand, technology, or environmental conditions.

Innovation and growth: Process optimization can contribute to stimulating innovation and organizational growth. Identifying and implementing new solutions opens up new opportunities and increases competitiveness in the market.

Within the context of process optimization using AI solutions, it is important to consider the current challenges and trends due to the current limitations of AI implementations, including high costs, the need for specialized expertise, and ethical and privacy concerns.

1.2 Relevance and purpose of the thesis

The purpose of this thesis is to investigate, develop, and evaluate artificial intelligence methods and techniques to enhance existing processes in various domains. The primary objective of this thesis is to identify specific problems within certain contexts or industries and develop AI-based solutions to optimize those processes.

Process optimization has a significant impact in a wide range of fields and industries, bringing about substantial improvements in efficiency, productivity, quality, and overall performance. Here are some examples of the impact of process optimization in various domains:

- Manufacturing industry: process optimization in the manufacturing industry can lead to increased productivity, reduced production times, and cost minimization. By identifying and eliminating inefficiencies, such as waiting times, defects, or downtime, production processes can be optimized for more efficient production and better resource utilization.
- Logistics and supply chain: optimizing processes in logistics and the supply chain can reduce transport times, minimize storage costs, and enhance flexibility in managing deliveries and supplies. Using advanced technologies like GPS tracking, data analysis, and optimal routing algorithms, logistic processes can be optimized in real time, reducing delays and maximizing delivery efficiency.
- Financial sector: process optimization in the financial sector can reduce the time required for transaction processing, improve risk management, and increase accuracy and transparency in financial reporting. The use of automation technologies such as Robotic Process Automation

(RPA) and advanced data analytics can simplify and expedite banking, insurance, or investment processes.

- Healthcare: process optimization in the healthcare sector can reduce patient waiting times, improve the management of medical information, and enhance the accuracy of diagnoses and treatments. By using artificial intelligence technologies like advanced image analysis, virtual assistants, or appointment scheduling algorithms, medical processes can be optimized to ensure more efficient and personalized healthcare.
- Marketing and sales: process optimization in marketing and sales can improve the targeting and personalization of campaigns, increase efficiency in lead generation, and enhance conversion rates. Using machine learning and data analysis, more efficient marketing strategies based on customer behavior and preferences can be identified and implemented, leading to better results and increased sales.

1.3 Aims and research questions

The objectives of the thesis are as follows:

1) Identification of optimization problems: one of the primary objectives is to identify and define specific problems within the study's domain or context that can benefit from optimization using artificial intelligence.
2) Development, implementation, and description of AI solutions: another important objective is the development of artificial intelligence solutions to address the identified problems. This involves the appropriate selection and application of algorithms, the development of machine learning models, or other relevant AI techniques.
3) Performance evaluation: an essential objective is the evaluation of the performance of the developed AI solutions. This may include measuring performance based on specific metrics such as efficiency, accuracy, speed, scalability, or any other metrics relevant to the domain of the application.
4) Comparison with existing approaches: to validate the effectiveness of AI solutions, another objective is to compare them with existing or traditional approaches to demonstrate the benefits of AI technologies in process optimization.

5) Contributions to the field of artificial intelligence and process optimization.
6) Dissemination of research results through publication in specialized journals or presentation at relevant academic conferences.

In conclusion, the thesis aims to provide practical recommendations for implementing AI solutions in real and diverse contexts. These recommendations should assist organizations or industries in reaping the benefits of process optimization with the help of artificial intelligence.

Overall, the thesis objectives are to address specific problems, make significant contributions to the respective field, and offer practical solutions for process improvement in various contexts.

CHAPTER 2. CASE STUDIES

2.1 Presenting specific examples of AI implementations for process optimization in various fields

2.1.1 Solutions for medical applications

2.1.1.1 Image detection for the identification of medical pathologies

In the context of national mammographic screening programs, thousands of mammographic examinations need to be processed. Each of these consists of two standard views of each breast, and each mammogram must be visually examined by an experienced radiologist to identify any anomalies. The ability to detect an anomaly in mammographic texture is crucial for the success of mammographic screening programs, and in this study, a large number of mammograms were digitized using a highly precise scanner. Textural features were extracted from the mammograms and used as input data for a self-organizing neural network SONNET [1]. The study discusses how SONNET was used to create a taxonomic organization of the mammogram archive in an unsupervised manner. This process depends on specific choices of SONNET parameters, in numerical experiments using the craniocaudal view, and typically results in about ten categories (e.g., 39 classes of mammograms) by analyzing features from over 1000 mammographic images. The mammographic taxonomy captured subtle distinctions to differentiate mammograms, and it is suggested that it can be exploited to aid in the detection of mammographic anomalies, such as serving as a preprocessing step to simplify the task for a computational detection system or to order mammographic examinations by a taxonomic class before screening to encourage more successful visual examination. The resulting taxonomy can contribute to the training of screening radiologists and eventually may assist in resolving legal cases related to mammographic screening examinations, as the taxonomy can reveal the frequency of mammographic patterns in a population.

2.1.1.2 Medical data collection solutions through IoT Devices as a preliminary stage for data preprocessing in AI Applications for the medical field

2.1.1.2.1 Design, Manufacturing, and Testing of an IoT Device for Cardiac Health Monitoring

The expansion of the Internet of Things (IoT) concept, along with wireless sensor networks, has given rise to a diverse range of IoT applications [39] [41]. This section introduced and described the concept, the operating theory, and the practical results of a Telecare-ECG (Electrocardiogram) monitoring device designed for the remote monitoring of cardiology patients outside of the hospital. ECG monitoring using the Telecare-ECG Monitor system [2,3] provides a better quality of life for patients and greater opportunities for real-time monitoring and alerting of sporadic cardiac events by recording instant cardiac arrhythmias occurring during specific activities or in a patient's daily environment. Additionally, this device has a reduced impact on hospital resources compared to other devices. In line with the novelty and contribution of this article in the field of ECG investigations, the results obtained in the analysis, testing, and validation of the Telecare-ECG Monitor system pertain to optimizing the functionality of the mobile ECG device under conditions as close to real-world scenarios as possible [4,5]. The architecture of the Telecare-ECG Monitor system is presented in Figure 3, illustrating the data acquisition and transmission modules corresponding to ECG measurements, the IoT cloud, and the user interface.

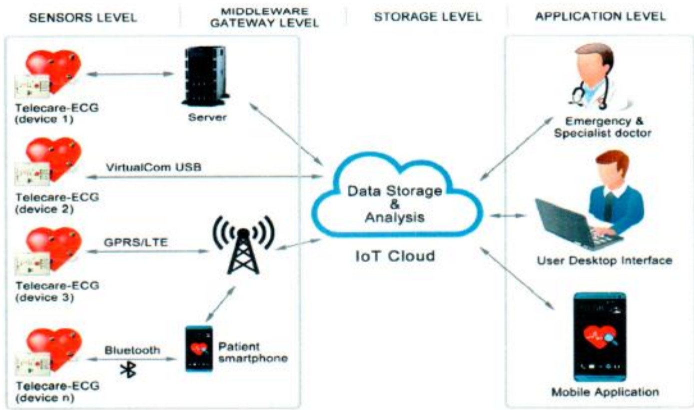

Fig. 3. The Telecare-ECG Monitor architecture designed for cardiology patients outside the hospital

2.1.1.3 Epidemiological modeling solutions and integration with GIS systems

Integrated SIR-Type Epidemiological Modeling Platform for COVID-19

Amid the COVID-19 pandemic, designing and implementing an epidemiological modeling platform that integrates through APIs with the beneficiary entities and data providers was a priority for the healthcare system. This section introduces an Epidemiological Platform (PLIS), replicable and adaptable for epidemic management, based on an integrated extended SIR model [6-8].

2.1.1.4 Analysis techniques in cardiology that use sentiment analysis solutions

Sentiment Analysis (SA) is a relatively new branch of Natural Language Processing (NLP) that measures the emotions or attitudes behind written text. The initial applications of SA in the healthcare domain involved detecting emotional polarities related to illness on social media. Now, it is possible to extract more complex attitudes (classifying attitudes from 1 to 5, assigning evaluation values, applying multiple text classifiers) or sentiments through NLP techniques, with clear benefits in cardiology. This is because emotions have been shown to be true risk factors for the development of cardiovascular diseases (CVD). Our research aimed to summarize the current directions of SA in cardiology. The literature review demonstrated the clinical potential of SA in CVD. However, many other clinical utilities, such as assessing the emotional consequences of the disease, the patient-doctor relationship, and the intuitions of doctors in CVD, have not yet been explored. These aspects represent future research directions, alongside the proposal of detailed regulations, the development of comprehensive definitions of emotional polarity, and investments in research for the development of robust SA algorithms [9].

Several artificial intelligence (AI) / machine learning (ML) technologies and other computational techniques have been proposed and have demonstrated their benefits in improving diagnostic accuracy and treatment efficacy [10-14].

The increasing use of social platforms may be the foundation for developing SA-based models applied to various fields in cardiology. A study on drug safety showed that adding SA features improves the performance of state-of-the-art methods to identify adverse drug reactions (ADR). These models used a corpus of posts from Twitter and other online forums. SA features significantly increased the F-measure of adverse reaction detection (for 81 drugs, including cardiovascular medication) from 72.14% to 73.22% in the Twitter corpus of posts. The improvement of ADR detection by SA became possible due to the rapidly growing popularity of social media and health forums [15-17].

2.1.1.6 Classification solutions for thyroid pathology identification

According to the Indian Health Line report, 12% of the population suffers from thyroid gland dysfunction. The main challenge in this condition is that the presence of hypothyroidism may not cause significant symptoms in its early stages. However, delayed treatment of this disease can lead to several other health issues, such as fertility problems and obesity. Therefore, early treatment is essential for the patient's survival.

The proposed technology could be used to predict hypothyroidism and its severity in its early stages. Although there are several classification and regression algorithms available for predicting hypothyroidism using clinical information, there is a knowledge gap regarding whether the predicted outcomes can achieve higher accuracy or not. Therefore, the objective of this research was to predict the presence of hypothyroidism with higher accuracy by optimizing the list of estimators in the pycaret classification model [18] [36].

2.1.2 Solutions for optimizing railway transport

Working in a dynamic and competitive global environment, railway companies realized many years ago that better management of their logistics operations would improve their strategic positions in the market. The financial component of daily operations is crucial today, and many companies have concluded that maximizing profit depends on integrating logistics activities with better revenue management. This section presents the system we designed [19] [44] and it consists of several components: Ferodata BOX, Ferodata MOBILE, Ferodata SYS, used to transmit information about the status and operation of an electric or diesel train to a web server. Information about the train includes data about locomotives, wagons, the train driver, route, direction, fuel or electricity consumption, speed, etc. In addition to these components, there is the optimization component, Ferodata AI. All this information is processed in real time and can be viewed in the web server application. Furthermore, the web server application can manage and report details coming from the wagons, such as valuable information about bogie wear, identifying wagons attached to a trainset, and identifying situations where a wagon or group of wagons detaches from the trainset configuration. All information about the train's status is available online, and at any time, the person responsible for management can use this data in their work [20-24].

2.1.3 Optimization solutions for cloud and networking applications

2.1.3.1 Cloud computing networks improved by modern topological invariances

Cloud computing networks used in IoT and other network architecture themes can be investigated and improved through chemoinformatics, which represents a combination of chemistry, informatics, and mathematics. Chemoinformatics involves graph theory and its tools. Any number that can be uniquely calculated by a graph is called a graph invariant. In graph theory, networks are converted into graphs, with workstations or routers or nodes as vertices and paths or connections as edges. Many topological indices have been developed for determining the physical properties of networks involved in cloud computing. We have calculated recently determined topological invariants, K-Banhatti Sombor invariants (KBSO), Dharwad invariants, quadratic-contraharmonic invariants (QCI), and their reduced forms with other forms of cloud computing networks. These are used to explore and improve the features of these networks, such as scalability, efficiency, higher throughput, reduced latency, and the most suitable topology. These features depend on the cloud topology, where different nodes, paths, and "clouds" need to be connected to achieve the best features mentioned above. We dealt with only one parameter, namely the topology of the cloud network. Improving the topology also optimizes the other characteristics, which is the primary goal of our study. Our main goal was to develop formulas so that we could verify the topology and performance of certain cloud networks without conducting experiments and before developing them [25]. The calculated results are valuable and useful for understanding the deep physical behavior of cloud networks. These results will also be beneficial for researchers in understanding how these networks can be built and improved with different physical characteristics for enhanced versions [37].

2.1.3.2 Challenges and Compatibility of Mobility Management Solutions for the Networks of the Future

Wireless network devices can achieve the necessary level of Quality of Service (QoS) and maintain connectivity even after disconnecting from an access point. This disconnection (mobility) requires various mobility management (MM) mechanisms, which pose numerous challenges due to the exponential growth of wireless devices and user requirements. The network needs to be heterogeneous and dense to handle such a significant traffic escalation, the increasing number of devices, and various user requirements. These factors will seriously stress MM solutions, ultimately making networks infeasible in terms of reliability, adaptability, scalability, and energy consumption. Therefore, new perspectives on MM mechanisms for 5G and beyond networks are desired. This section introduces an innovative discussion on the functional requirements of MM mechanisms for advanced wireless networks [26]. We provide comprehensive arguments on whether the prevalent mechanisms considered by standard organizations manage to meet the outlined requirements. We complement this discussion with innovative qualitative assessment. We evaluate each of the discussed mechanisms in terms of their ability to meet the criteria of reliability, adaptability, scalability, and energy consumption for future MM schemes. Furthermore, we demonstrate the findings and the identified gaps/challenges for the planning and implementation of 5G MM frameworks. We then present the capabilities and potential MM solutions for addressing the identified gaps/difficulties. We conclude our discussion by proposing an MM architecture for 6G based on defined parameters [27,28].

2.1.4 Optimization solutions for marketing applications

The targeted marketing strategy is an important topic that has received significant attention both from industry and academia. Market segmentation is a widely used approach in investigating the heterogeneity of customer buying behavior and profitability. It is important to note that conventional market segmentation models in the retail industry are predominantly descriptive methods, lack sufficient market information, and often fail to identify sufficiently small segments. This research leverages the dynamics involved in the Hadoop distributed file system for its capability to process large datasets.

Based on previous studies on market segmentation in the retail sector, 'Recency, Frequency & Monetary' (RFM) has been extensively used. This model can categorize customers into groups, allowing retailers to decide how to efficiently utilize their limited resources to provide effective services to customers through their categorization. However, RFM also has its limitations [29], because it only focuses on the best scores of customers, providing less meaningful scores for recency, frequency, and monetary aspects for the majority of consumers [30-33]. Our research proposes a more advanced and user-friendly market segmentation modeling method than the conventional RFM method, which integrates Customer Lifetime Value (CLTV) and the newly proposed RFM variations (PQ) (T) into a closed-loop model, representing different variations of customer purchasing behavior.

Three different market segmentation experiments were conducted [34] using the 'best-fit' regression, namely the Expectation-Maximization (EM) algorithm and K-Means++ clustering. These results are twofold: i) Insights into the purchasing behavior of customers revealed for each Customer Lifetime Value (CLTV) segment; ii) the clustering algorithm's performance in accurately producing market segments. The analysis indicated that the average customer lifetime was only two years, and the churn rate was 52%. Therefore, a marketing strategy based on these findings was developed and implemented in the department store's sales. Marketing records showed that the sales rate increased from 5% to 9% [42],[43].

2.1.6 Low-code solutions as data collection and preprocessing platforms

This section presents an integrated information system model designed for use by public entities in Romania. This system is part of a research project that promotes the partnership between the public and private sectors in Romania. Therefore, the primary objective of the presented research was to develop an Integrated Information System for Activity Management (IISMA) for managing the information of public institutions through the use of resources and activities, functional software modules, and open-source applications. The proposed solution ensures the simplification of the information flow, improves resource management, and inter-institutional interoperability, providing a versatile, secure, and resilient solution that can be customized according to the specific requirements of public entities [35]. IISMA is based on open-source solutions and specialized functional software modules, aiming to reduce the complexity of conceptual separation. IISMA ensures the functional decoupling of modules (while maintaining interoperability), standardization of functional modules, the implementation of extensibility features, and component reusability, as well as data protection for processed, used, and stored data.

CHAPTER 3. PROPOSED SOLUTIONS AND INNOVATIONS

3.1 Identifying the current challenges and limitations of AI methods for process optimization

Identifying the current challenges and limitations of artificial intelligence methods for process optimization is essential to fully understand the current state of technology and to develop more efficient solutions in the future. Here are some of the current challenges and limitations:

- Limited data and quality: most AI methods for process optimization rely on training datasets. Having access to high-quality and sufficient data is crucial. However, data collection and cleaning can be costly and challenging. Data may also contain errors or biases that can influence algorithm outcomes.
- Complexity of optimization problems: many real-world processes are highly complex, with a large number of variables and constraints. Developing AI algorithms that can handle this complexity and provide optimized solutions in a reasonable time can be a significant challenge.

- Interpretability and transparency: understanding and explaining the decisions made by AI algorithms is paramount. Many advanced optimization methods, such as deep neural networks, are often considered "black boxes" that are difficult to interpret. This can raise questions about trust in algorithm results, especially in fields where interpretability is critical, such as medicine or finance.
- Computational costs: some AI methods for process optimization may require significant computational resources, such as specialized hardware or server clusters. This can make the implementation of these solutions costly and inaccessible for smaller organizations with limited budgets.
- Generalization and scalability: the ability to generalize solutions to similar problems or scale algorithms to handle larger and more complex datasets is also essential. An optimization algorithm that works well in one specific context may not be as efficient in another domain or for a different problem.
- Ethics and algorithm bias: developing AI algorithms that make ethical choices and are free from bias is a growing concern. Using biased data or datasets that perpetuate discrimination can have serious consequences for society.
- Data security and privacy: to optimize processes, AI algorithms may require access to sensitive data. Protecting this data and ensuring that algorithms are not vulnerable to cyberattacks or manipulations is another significant challenge.
- Interaction with human factors: in many process optimization scenarios, interaction with human factors is paramount. AI algorithms need to consider human preferences and decisions in the optimization process. This can be challenging, as human behavior can be difficult to model and can vary based on context and individuals.
- Adaptation to changes: real-world processes are dynamic and change over time. AI algorithms for process optimization must be able to adapt to these changes and update solutions to remain relevant and efficient. A lack of adaptability can quickly render algorithms obsolete.
- Learning with a limited budget: in some fields, such as medicine or space exploration, data collection or experimentation can be costly and budget-constrained. Developing AI methods that can achieve meaningful results with limited data or budgets is a significant challenge.

- Algorithm selection and configuration: choosing the right AI algorithms and configuring them correctly for a specific problem can be a daunting task. Adjusting algorithm parameters to achieve the best performance may require expertise and considerable time.
- Integration with existing systems: implementing AI solutions for process optimization often requires integration with an organization's existing systems and infrastructure. Ensuring compatibility and interoperability can be challenging, especially with older technology systems.
- Responsibility and ethics: using AI in process optimization can raise complex questions of responsibility and ethics. Who is accountable if algorithms make incorrect or discriminatory decisions? How can it be ensured that algorithms are used ethically and in compliance with laws and regulations?
- Education and training: as AI technology advances, there is a need for proper education and training to use and manage these technologies efficiently and responsibly. Ensuring that professionals have the necessary skills to work with AI algorithms is a challenge in itself.

AI methods for process optimization hold promise, but they come with several significant challenges and limitations. However, ongoing research and technological developments may help overcome these obstacles and lead to more advanced and efficient optimization solutions.

3.2 Proposing innovative solutions for enhancing the performance and applicability of these methods

Improving the performance and applicability of artificial intelligence methods in process optimization can be achieved through innovative solutions and new approaches:

- Fusion with emerging technologies:
  - Blockchain: integrating blockchain technology to create trust systems for recording and managing data in optimization processes.
  - Internet of Things (IoT): using IoT devices to collect real-time data, allowing optimization algorithms to make more precise decisions and respond quickly to environmental changes.
- Closed-loop machine learning:
  - Developing AI models that can continuously learn from real-time data to dynamically optimize processes.

- Multi-objective optimization:
  - Developing AI algorithms capable of optimizing multiple objectives simultaneously, which can be useful in complex situations with multiple optimization criteria.
- Interpretability and comprehensibility:
  - Creating AI algorithms that can provide explanations for their decisions, increasing user trust, and facilitating their adoption in critical industries.
- Transfer learning and meta-learning:
  - Using transfer learning and meta-learning to enable AI models to adapt more rapidly to new domains and efficiently optimize processes.
- Decision support systems:
  - Developing AI systems that provide recommendations and suggestions to humans instead of making decisions on their behalf, enhances the human experience and increases confidence in AI technology.
- AI hardware optimization:
  - Investing in specialized hardware development to accelerate AI model training and inference, enabling faster data processing and real-time decision-making.
- AI cloud platforms and services:
  - Utilizing AI cloud platforms and services that offer powerful tools and resources for the rapid development and implementation of AI optimization solutions.
- Interdisciplinary collaboration:
  - Encouraging collaboration among AI experts, engineers, mathematicians, and process specialists to develop more comprehensive and applicable solutions.
- Security and ethics:
  - Paying increased attention to data security and ethics in the development and implementation of AI optimization systems to avoid risks and negative consequences.

Improving the performance and applicability of AI methods in process optimization requires a holistic approach and adaptability to technological changes and the specific needs of each industry or application domain.

3.3 Justification of the advantages and potential impact of the proposed solutions

The innovative solutions mentioned above have significant potential to improve the performance and applicability of artificial intelligence methods in process optimization. Here are arguments supporting the advantages and impact of these solutions:

- Efficiency and cost reduction:
  - Innovative solutions can significantly increase process efficiency, resulting in substantial cost savings for organizations.
- Rapid response to changes
- Accuracy and error reduction:
  - Artificial intelligence can work with high precision at detailed levels. This helps eliminate human errors and increases decision-making accuracy.
- Scalability and flexibility:
  - AI-based solutions can easily scale to meet growing demands or adapt to new requirements. This flexibility allows organizations to grow without compromising quality or efficiency.
- Innovation and competitiveness:
  - Organizations adopting innovative AI solutions can gain significant competitive advantages in the market. The ability to offer better and more efficient products or services can attract more customers and partners.
- Enhanced user experience:
  - AI systems that provide explanations and recommendations can improve the user experience. This can increase trust in technology and make people more willing to adopt these solutions.
- Real-time processing:
  - Using IoT devices and AI-based optimization can enable real-time data processing, which is essential in fields such as manufacturing, logistics, and healthcare.
- Innovation in critical fields:
  - AI solutions can be applied in critical fields like medicine, where they can assist in the development of personalized treatments and rapid disease diagnosis.

- Environmental impact:
    - By optimizing processes and reducing resource consumption, AI solutions can contribute to reducing organizations' carbon footprint and promoting sustainability.
- Safety and security:
    - Integrating blockchain technology and security measures into AI solutions can help protect data and prevent unauthorized access.

In conclusion, these innovative solutions have the potential to transform how organizations operate and make decisions, with a significant impact on their performance and competitiveness in an increasingly digitized world. With proper implementation and responsible management, their potential is enormous.

CHAPTER 4. CONCLUSIONS

4.1 Summary of the main results and conclusions of the thesis

This thesis conducts a rigorous analysis and evaluation of artificial intelligence methods in the field of process optimization. The primary findings indicate that these methods significantly enhance process efficiency across diverse industrial sectors. Economically, the adoption of artificial intelligence techniques results in decreased operational costs and improved efficiency in resource utilization. This efficiency notably contributes to increased profitability within organizations, a critical aspect in the context of economic sustainability. The adaptability of artificial intelligence methods to variable environments and complex issues is also highlighted. This adaptability makes them particularly suitable for process optimization under fluctuating conditions, an essential quality in rapidly evolving industrial landscapes.

Furthermore, the scalability of these methods is evident, confirming their wide applicability across various domains, including manufacturing, logistics, healthcare, and energy sectors. A key finding of this research is the heavy reliance of artificial intelligence methods on the quality and quantity of data available for training. This dependence underscores the necessity for high-quality data inputs for effective process optimization. Additionally, the thesis emphasizes the need for enhanced interpretability of AI models and the addressing of ethical issues related to automated decision-making.

In conclusion, the thesis underscores the substantial positive impact of artificial intelligence methods on process optimization. It highlights that these methods, when responsibly applied with consideration for data quality and ethical issues, can significantly improve organizational efficiency, reduce costs, and increase competitiveness. The ongoing importance of research and development in this field is thus underscored, positioning artificial intelligence as a pivotal element in future advancements in process optimization.

4.2 Discussing the thesis's contribution to the field of AI-based process optimization

This thesis introduces a novel and innovative perspective on the application of artificial intelligence for solving optimization problems across various industries and domains, thereby contributing significantly to the advancement of this field and enhancing process performance and efficiency. It advances the knowledge in the field by not only presenting and analyzing innovative AI methods and their impactful results but also by paving the way for new research directions, potentially inspiring other researchers to explore similar techniques.

In demonstrating the effectiveness of AI methods in process optimization, the thesis provides compelling evidence and detailed case studies, thereby substantiating the efficacy of these methods and potentially encouraging organizations and industries to adopt and invest in AI technologies. A key aspect of this work is its focus on the practical applicability of AI, exploring real-world implementations in various industries through the development of prototypes or experiments to demonstrate how AI methods can be successfully integrated into production or business environments.

Furthermore, the thesis addresses specific and unresolved issues in the field of process optimization by proposing new AI-based solutions or approaches, which could have a direct and significant impact on industry practices and professional standards. Additionally, it advocates for the adoption and use of AI methods by professionals in the field of process optimization, thereby highlighting the practical benefits and improvements these technologies can bring to the industry.

REFERENCES

1. Howard, D.; Roberts, S.C.; Ryan, C.; Brezulianu, A. Textural Classification of Mammographic Parenchymal Patterns with the SONNET Selforganizing Neural Network. *Journal of Biomedicine and Biotechnology* **2008**, *2008*, 526343, doi:10.1155/2008/526343.
2. Zagan, I.; Găitan, V.G.; Petrariu, A.-I.; Iuga, N.; Brezulianu, A. Design, Fabrication, and Testing of an IoT Healthcare Cardiac Monitoring Device. **2020**, *9*, 15.
3. Zagan, I.; Gaitan, V.G.; Iuga, N.; Brezulianu, A. m-GreenCARDIO embedded system designed for out-of-hospital cardiac patients. In Proceedings of the 2018 International Conference on Development and Application Systems (DAS), 24-26 May 2018, 2018; pp. 11-17.
4. Sun, J.; Jones, M.; Reinauer, S.; Zimmer, V. *Embedded Firmware Solutions: Development Best Practices for the Internet of Things*; Springer Nature: 2015.
5. Smithamol, M.B.; Rajeswari, S.J.A.i.E.; Engineering, C. Hybrid solution for privacy-preserving access control for healthcare data. **2017**, *17*, 31-38.
6. Brezulianu, A.; Popa, I.; Geman, O.; Chiuchisan, I.; Nastase, C. Integrated Extended SIR-type Epidemiological Modeling Platform for COVID-19. In Proceedings of the 2022 E-Health and Bioengineering Conference (EHB), 17-18 Nov. 2022, 2022; pp. 1-5.
7. Brezulianu, A.; Geman, O.; Arif, M.; Chiuchisan, I.; Postolache, O.; Wang, G. Epidemiologic Evolution Platform Using Integrated Modeling and Geographic Information System. **2021**, *67*, 1645--1663.
8. Udroiu, A.-M.; Sandu, I.; Dumitrache, M. Integrated Information System for the Management of Activities in the Organization. *Studies in Informatics and Control* **2022**, *31*, 25-35, doi:10.24846/v31i2y202203.
9. Ligthart, A.; Catal, C.; Tekinerdogan, B. Systematic reviews in sentiment analysis: a tertiary study. *Artificial Intelligence Review* **2021**, doi:10.1007/s10462-021-09973-3.
10. Briganti, G.; Le Moine, O. Artificial Intelligence in Medicine: Today and Tomorrow. **2020**, *7*, doi:10.3389/fmed.2020.00027.
11. Ghassemi, M.M.; Al-Hanai, T.; Raffa, J.D.; Mark, R.G.; Nemati, S.; Chokshi, F.H. How is the Doctor Feeling? ICU Provider Sentiment is Associated with Diagnostic Imaging Utilization.

Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference **2018**, *2018*, 4058-4064, doi:10.1109/embc.2018.8513325.

12. Gohil, S.; Vuik, S.; Darzi, A. Sentiment Analysis of Health Care Tweets: Review of the Methods Used. *JMIR Public Health Surveill* **2018**, *4*, e43-e43, doi:10.2196/publichealth.5789.
13. WHO. Cardiovascular diseases (CVDs). Available online: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) (accessed on 5th of July).
14. Eberly, L.A.; Khatana, S.A.M.; Nathan, A.S.; Snider, C.; Julien, H.M.; Deleener, M.E.; Adusumalli, S. Telemedicine Outpatient Cardiovascular Care During the COVID-19 Pandemic. **2020**, *142*, 510-512, doi:doi:10.1161/CIRCULATIONAHA.120.048185.
15. Korkontzelos, I.; Nikfarjam, A.; Shardlow, M.; Sarker, A.; Ananiadou, S.; Gonzalez, G.H. Analysis of the effect of sentiment analysis on extracting adverse drug reactions from tweets and forum posts. *Journal of Biomedical Informatics* **2016**, *62*, 148-158, doi:https://doi.org/10.1016/j.jbi.2016.06.007.
16. Nikfarjam, A.; Sarker, A.; O'Connor, K.; Ginn, R.; Gonzalez, G. Pharmacovigilance from social media: mining adverse drug reaction mentions using sequence labeling with word embedding cluster features. *Journal of the American Medical Informatics Association* **2015**, *22*, 671-681, doi:10.1093/jamia/ocu041 %J Journal of the American Medical Informatics Association.
17. Brezulianu, A.; Burlacu, A.; Popa, I.V.; Arif, M.; Geman, O. "Not by Our Feeling, But by Other's Seeing": Sentiment Analysis Technique in Cardiology—An Exploratory Review. **2022**, *10*, doi:10.3389/fpubh.2022.880207.
18. Devi, M.S.; Kumar, V.D.; Brezulianu, A.; Geman, O.; Arif, M. A Novel Blunge Calibration Intelligent Feature Classification Model for the Prediction of Hypothyroid Disease. **2023**, *23*, 1128.
19. Brezulianu, A.; Aghion, C.; Hagan, M.; Geman, O.; Chiuchisan, I.; Balan, A.-L.; Balan, D.-G.; Balas, V.E. Active Control Parameters Monitoring for Freight Trains, Using Wireless Sensor Network Platform and Internet of Things. **2020**, *8*, 639.
20. Sussman, J.M.; Bronzini, M.S. A Review of:"Perspectives on Intelligent Transportation Systems" Springer, New York, NY, 2005, 232 pages, $125.00. **2006**.

21. Ghosh, S.; Lee, T.S. *Intelligent Transportation systems: smart and green infrastructure design*; CRC press: 2010.
22. Sammouri, W.; Côme, E.; Oukhellou, L.; Aknin, P.; Fonlladosa, C.-E. Floating train data systems for preventive maintenance: A data mining approach. In Proceedings of the Proceedings of 2013 International Conference on Industrial Engineering and Systems Management (IESM), 2013; pp. 1-7.
23. Budai-Balke, G. *Operations research models for scheduling railway infrastructure maintenance*; Rozenberg Publishers: 2009.
24. Shrestha, P.L.; Hempel, M.; Rakshit, S.; Sharif, H.; Punwani, J.; Stewart, M. Performance evaluation of hybrid technology networking for real-time monitoring in freight railroad operations. In Proceedings of the ASME/IEEE Joint Rail Conference, 2013; p. V001T003A007.
25. Hamid, K.; Iqbal, M.W.; Abbas, Q.; Arif, M.; Brezulianu, A.; Geman, O. Cloud Computing Network Empowered by Modern Topological Invariants. **2023**, *13*, 1399.
26. Mukhtar, M.; Yunus, F.; Alqahtani, A.; Arif, M.; Brezulianu, A.; Geman, O. The Challenges and Compatibility of Mobility Management Solutions for Future Networks. **2022**, *12*, 11605.
27. Hamid, K.; Waseem Iqbal, M.; Abbas, Q.; Arif, M.; Brezulianu, A.; Geman, O. Discovering Irregularities from Computer Networks by Topological Mapping. **2022**, *12*, 12051.
28. Arif, M.; Wang, G.; Geman, O.; Balas, V.E.; Tao, P.; Brezulianu, A.; Chen, J. SDN-based VANETs, Security Attacks, Applications, and Challenges. **2020**, *10*, 3217.
29. Dempster, A.P.; Laird, N.M.; Rubin, D.B. Maximum Likelihood from Incomplete Data via the EM Algorithm. *Journal of the Royal Statistical Society. Series B (Methodological)* **1977**, *39*, 1-38.
30. Wei, J.-T.; Lin, S.-Y.; Wu, H.-H. A review of the application of RFM model. *African Journal of Business Management December Special Review* **2010**, *4*, 4199-4206.
31. Aggarwal, N.; Aggarwal, K.; Gupta, K. Comparative Analysis of K-means and Enhanced K-means clustering algorithm for data mining. 2012.
32. Fader, P.; Hardie, B.; Lee, K. "Counting Your Customers" the Easy Way: An Alternative to the Pareto/NBD Model. *Marketing Science* **2005**, *24*, 275-284, doi:10.1287/mksc.1040.0098.
33. Lefait, G.; Kechadi, T. *Customer Segmentation Architecture Based on Clustering Techniques*; 2010; pp. 243-248.

34. Yoseph, F.; Ahamed Hassain Malim, N.H.; Heikkilä, M.; Brezulianu, A.; Geman, O.; Paskhal Rostam, N.A. The impact of big data market segmentation using data mining and clustering techniques. *Journal of Intelligent & Fuzzy Systems* **2020**, *38*, 6159-6173, doi:10.3233/JIFS-179698.

35. UDROIU, M.; DUMITRACHE, M.; SANDU, I.; BREZULIANU, A. Implementing an Integrated Information System Designed for Romanian Public Entities. *Studies in Informatics and Control* **2018**, *27*, 369-376.

36. Munisamy Shyamala Devi, Venkatesan Dhilip Kumar, Adrian Brezulianu, Oana Geman, Muhammad Arif (2023) "A Novel Blunge Calibration Intelligent Feature Classification Model for the Prediction of Hypothyroid Disease", https://www.mdpi.com/1424-8220/23/3/1128

37. Khalid Hamid, Muhammad Waseem Iqbal, Qaiser Abbas, Muhammad Arif, Adrian Brezulianu, Oana Geman (2023) "Cloud Computing Network Empowered by Modern Topological Invariants", https://www.mdpi.com/2076-3417/13/3/1399

38. Yousaf, M W Iqbal, M Arif, A Jaffar, A Brezulianu, O Geman (2022) "Adoption of Conceptual Model for Smartphones among Older People", *Appl. Sci.* **2022**, *12*(24), 12703; **https://doi.org/10.3390/app122412703**, https://www.mdpi.com/journal/applsci/stats.

39. A Burlacu, C Brinza, A Brezulianu, A Covic, "Accurate and early detection of sleepiness, fatigue and stress levels in drivers through heart rate variability parameters: a systematic review", Reviews in cardiovascular medicine, vol. 22, 3, pp. 845-852, 2021, http://venus-pro-bucket.s3.amazonaws.com/journal/RCM/22/3/10.31083/j.rcm2203090/2153-8174-22-3-845.pdf

40. Sebastian Balos, Daniel Howard, Adrian Brezulianu, Danka Labus Zlatanovi, "Perforated Plate for Ballistic Protection—A Review", Metals 2021, 11(4), 526, https://doi.org/10.3390/met11040526 https://www.mdpi.com/journal/metals.

41. Brezulianu, A.; Geman, O.; Zbancioc, M.D.; Hagan, M.; Aghion, C.; Hemanth, D.J.; Son, L.H. IoT Based Heart Activity Monitoring Using Inductive Sensors, Sensors 2019, 19, 3284, https://www.mdpi.com/1424-8220/19/15/3284 https://www.mdpi.com/journal/sensors/imprint

42. Daniel Howard, Adrian Brezulianu, Joseph Kolibal - Genetic Programming of the Stochastic Interpolation Framework: Convection Diffusion Equation, Soft Computing, Springer, ISSN 1432-

7643.

43. Daniel Howard, Joseph Kolibal, Adrian Brezulianu - Engineering Presentation of the Stochastic Interpolation Framework and its Applications, Soft Computing, Springer, ISSN 1432-7643, .

44. Brezulianu, A.; Geman, O.; Popa, I.V. Artificial Intelligence Component of the FERODATA AI Engine to Optimize the Assignment of Rail Freight Locomotive Drivers. Appl. Sci. 2023, 13, 11516. https://doi.org/10.3390/app132011516,.