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A Solution for Secure Cross-Platform Communication through Layered Encryption

Andreea-Cristina Popa, Paul-Cristian Popa*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Dominic Bucerzan

Abstract

With the rapid spread of digital communications, robust solutions are needed to protect sensitive information transmitted across various platforms. This paper introduces SmartSteg+, a cross-platform mobile application, featuring an enhanced encryption framework designed to reinforce data security during transmission. This upgraded framework leverages cutting-edge steganographic techniques, not only to conceal sensitive information within innocuous cover files, but also to significantly improve the resilience of hidden data against detection and extraction attempts. The proposed solution integrates a layered encryption protocol designed to safeguard user data against unauthorized access, and due to the fact that SmartSteg+ adds an additional layer of client-side encryption before transmitting files over HTTPS to a secure server (where further processing occurs ensures the data protection). Utilizing a dynamic encryption key, an improved data embedding algorithm (an optimized Least Significant Bit method), server-based processing for flexibility by the fact that the encryption and steganographic processes are handled via a dedicated server API, and steganographic obfuscation to counteract steganalysis techniques that include random pixel selection and noise addition strategies, will help the app ensure data confidentiality even in the event of network interception, offering a security approach beyond conventional HTTPS protocols.

By combining these improvements, the concept of the application that we will present provides a more secure and adaptable solution for users looking to transmit confidential information without drawing attention. The enhanced encryption framework, along with sophisticated steganography techniques, ensures data remains protected from both unauthorized access and detection.

This paper will discuss the development process, the steganographic algorithms and encryption protocols which could be configured, and the unique challenges of balancing robust security with resource efficiency within a mobile application environment. By making advanced data protection accessible to users without requiring technical expertise, SmartSteg+ highlights the potential for creating user-

* Corresponding authors: **Andreea-Cristina Popa, Paul-Cristian Popa** – {popaandreea2204p, popapaul94}@gmail.com

friendly, high-security applications that meet the evolving demands of digital communication.

Keywords: Data Confidentiality, Steganography, Encryption.

Smart Trash Bin Powered by Raspberry Pi 5

Alexandru Galea*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Mihaela Daciana Crăciun

Abstract

This paper explores the development of a smart trash bin using a Raspberry Pi 5, addressing setup, practicality and constraints. It examines the usage and evolution of technology and its day-to-day utilization in the average household, without it being necessary connected to the internet or to a complex system.

The proposed solution features a smart trash can with a lid that is elevated by a servo. Hardware components include a breadboard, HC-SR04 distance sensor, SG90 9g Micro Servo and connecting wires. From the software point of view, it features: sensor data retrieval, data processing and data effectiveness.

The Raspberry Pi 5 is selected for its affordability, faster response time, energy efficiency and compactness, and suitability for diverse home projects. The paper details hardware connections, sensor data retrieval, and data effectiveness, energy efficiency, and compatibility. However, limitations in performance, capacity and storage are also mentioned and acknowledged.

The smart trash bin offers real-time raising lid, based on the distance's coefficient offered by the attached sensor. The paper concludes by highlighting Raspberry Pi 5's pros and cons as a “brain” for home-made mechanisms, such as this one, emphasizing its cost-effectiveness and compact design while recognizing performance and capacity limitations. This study showcases the potential of technology when targeting common and frequently used objects/parts and encourages creativity.

Keywords: Practical, Raspberry Pi, home-made mechanism, trash bin.

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* Corresponding author: **Alexandru Galea** – galeamaa@gmail.com

Integrating Blockchain Technology in IoT Challenges and Security Applications

George-Ioan Mişcoi*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Crina Anina Bejan

Abstract

The rapid growth of digital technology over the recent decades has redefined industries and everyday life on a global scale. However, this growth has also created significant challenges, particularly in the domains of privacy and security. The Internet of Things (IoT), one of these transformative technologies, has been widely adopted across fields such as logistics, healthcare, and manufacturing. Despite its advantages, IoT faces critical limitations, including vulnerabilities in data security, privacy risks, and dependency on cloud connections. The increasing reliance on IoT systems that manage sensitive data makes them potential targets for cyber-attacks, which could lead to financial losses, service disruptions, and compromised information.

Blockchain technology offers a promising solution to address these security challenges, thanks to its decentralized, transparent, and fault-tolerant architecture. Blockchains can be implemented as private, public, hybrid, or consortium networks, each offering distinct advantages for security and operational resilience. These properties enable applications across a range of fields, from finance and healthcare to digital records management and asset tracking. The unique distributed structure of blockchain also fosters trust among users by allowing real-time system monitoring and reducing reliance on centralized data storage. When integrated into IoT systems, blockchain can enhance critical functions such as data integrity, availability, collaborative operation, and traceability, thereby improving security and operational efficiency.

This paper examines the potential for blockchain technology to strengthen IoT security by exploring relevant applications, integration strategies, and challenges associated with combining these technologies. Additionally, the paper analyzes the technological and logistical hurdles that may arise during blockchain integration in IoT, offering insights into the balance between innovation and security in the evolution of digital systems.

Keywords: Blockchain Integration, IoT Security, Collaborative Operation.

* Corresponding author: **George-Ioan Mişcoi** – miscoigeorge@gmail.com

Ball Catch A Computer Vision Application

Dennis Begov*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Antonio Lupuși and Vlad Drăgoi

Abstract

This article provides the background for a Computer Vision gaming application that has several goals. Firstly, it tries to enhance humans’ skills such as precision and velocity of one’s hand reactions. It is particularly adapted to young children, that are developing such skills. Secondly, it could help improve human–machine interaction in specific situations such as: Cybersecurity, Medicine, Gaming, etc. Our application was tested under various environments, e.g., at the European Researchers Night 2024, where high school students have participated.

The focus of this article is on Computer Vision techniques, a core component of modern AI applications. We will explain the fundamental mechanisms behind Computer Vision, covering how it operates, the algorithms it employs, and how it adapts to process gestures and interpret visual data. The work will explore the structural components of Computer Vision, including image recognition and object detection techniques. Practical examples will illustrate how these methods enable systems to analyse and understand visual information effectively. The focus on object recognition will emphasize how Computer Vision can identify and categorize various objects in images or video frames.

The practical component of the study centres on the design, development, and implementation of an application that applies Computer Vision concepts. This part provides an in-depth look at the programming environment and the technologies used, detailing the relevant software packages and programming languages, while explaining their contributions to the functionality of the project. The methodology followed during development is outlined, supported by visual documentation to aid comprehension. The narrative walks through the creation process, from initial concept to deployment, highlighting the challenges faced and the solutions employed.

The paper concludes by synthesizing the insights gained throughout the analysis, reinforcing the Computer Vision techniques used, and their applications in real-world scenarios. This example serves as both an educational resource and a practical guide for understanding and applying these advanced technologies.

Keywords: Computer Vision, Education Gaming, Learning.

* Corresponding author: **Dennis Begov** – begovdennis1@gmail.com

Classical Encryption Algorithms and Their Vulnerabilities

Rareş Nicolae Stanciu*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Dominic Bucerzan

Abstract

This research paper will present classical encryption algorithms, with some historical examples such as Caesar’s cypher. These cyphers will be explored and presented in detail, and their overall security thoroughly analyzed, and some extreme vulnerabilities will be shown in the form of possible attack vectors for breaking their encryption without knowing the necessary encryption/decryption key.

The algorithms presented will consist of transposition cyphers and substitution cyphers, with a great emphasis on the latter. Even today, some people consider these old algorithms to be relatively secure and a good method for protecting their privacy and sensitive data, but this could not be further from the truth. We will analyze the security of these classical algorithms, and expose the triviality of breaking them, even without the assistance of a computer. In fact, once computers are used for the express purpose of breaking these historical algorithms, their security shatters, in most cases, in mere seconds.

For substitution cyphers we will give examples of different attempts to modernize and increase their security, but we will expose that they are vulnerable to the same tried and tested methods that were always their largest issue. We will explore regulated, unregulated, monoalphabetical and polyalphabetical substitution cyphers and show how none of these methods actually improve the security of the algorithms when faced with known-text or frequency analysis types of attacks.

The most common and powerful methods of attack will be studied and explained. The first attack type takes advantage of repetition of common phrases and is the known-text type attack. We will illustrate how from a single phrase we can start decrypting most of the message, and then using that semi-decrypted message make an educated guess as to what some of the other still-encrypted parts could be, applying the same methodology again and again, for larger and larger known-texts, until we reach a point in which the message becomes clear to be read by a human.

The second attack type takes advantage of a different vulnerability, and that is the vulnerability of language itself. Frequency analysis uses the fact that in common speech, some letters will always be more prevalent than others, and, as such, a probabilistic algorithm can be implemented based on the frequency of the letters in the

* Corresponding author: **Rareş Nicolae Stanciu** – stanciurares2001@yahoo.com

English language for any given text, without knowing any parts of the encrypted message.

The point of this paper is to illustrate the insufficient protection offered by these classical algorithms/ cyphers, and to warn about the dangers of relying on them to secure sensitive information, especially in the modern world where computers are easily accessible and can break these cyphers extremely easily with the methods presented.

Keywords: Encryption, Cypher, Substitution Cypher, Transposition Cypher, Frequency analysis, Known-Text Attack

Autotelic Reinforcement Learning: Exploring Intrinsic Motivations for Skill Acquisition in Open-Ended Environment

Prakhar Srivastava^{*}, Jasmeet Singh

University of Illinois Chicago, Chicago, United States of America

Abstract

This paper presents a comprehensive overview of autotelic reinforcement learning (RL), emphasizing the role of intrinsic motivations in the open-ended formation of skill repertoires. We delineate the distinctions between knowledge-based and competence-based intrinsic motivations, illustrating how these concepts inform the development of autonomous agents capable of generating and pursuing self-defined goals. The typology of intrinsically motivated goal exploration processes (IMGEPs) is investigated, with a focus on the implications for multi-goal RL and developmental robotics. The autotelic learning problem is framed within a reward-free Markov decision process (MDP), where agents must autonomously represent, generate, and master their own goals. We address the unique challenges in evaluating such agents, proposing various metrics for measuring exploration, generalization, and robustness in complex environments. This work aims to advance the understanding of autotelic RL agents and their potential for enhancing skill acquisition in diverse and dynamic settings.

Keywords: Autotelic Reinforcement Learning, Intrinsic Motivation, Skill Acquisition, Open-Ended Environments, Exploration-Exploitation Trade-off, Self-Improvement in RL, Intrinsic Reward Mechanisms, Motivation-driven Learning.

^{*} Corresponding author: **Prakhar Srivastava** – prakharsrivastava002@gmail.com, **Jasmeet Singh** – jasmeetsingh1707@gmail.com

Framework for Digital Image Steganography

Lucas Eric Lucan*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Crina Anina Bejan

Abstract

Steganography, the art and science of embedding hidden information within a medium, play a critical role in enhancing digital security and privacy. This technique ensures that the very existence of the concealed data remains undetected, distinguishing it from cryptography, which merely obscures the content of a message. With the rapid growth of digital communications, the need for effective methods of secure data transmission has never been greater. This paper explores the use of steganography for embedding text within digital images, creating a hidden layer of information that can only be accessed by authorized individuals. The primary objective of this study is to implement and evaluate a robust steganographic method for text hiding within images, emphasizing the dual requirements of data security and image quality preservation.

In addition to defining core principles of steganography, the study introduces a framework designed to manage steganographic images effectively, enabling the camouflaged communication of confidential information.

The research begins by defining key concepts and principles of steganography and providing a comprehensive overview of the various techniques employed in the field. We then focus on our specific approach, which utilizes the Least Significant Bit (LSB) technique for embedding text into images. The LSB method is widely recognized for its efficiency and simplicity, as it involves modifying the least significant bits of pixel values, resulting in minimal visual distortion. The study outlines the theoretical underpinnings of this method, detailing how text is encoded within the image data to remain imperceptible to the human eye.

The proposed LSB-based method effectively embeds and retrieves hidden text while preserving the original appearance of the images. Furthermore, the robustness of the technique was tested against common image manipulations, including compression, resizing, and noise addition, revealing that the embedded messages can withstand moderate levels of distortion without data loss.

This study advances the field of steganography by presenting a practical and efficient method for concealing text within images. The findings underscore the potential applications of this approach in secure data transmission, digital watermarking, and protecting sensitive information. By reiterating key terms and emphasizing the

* Corresponding author, **Lucas Eric Lucan** – lucaneric147@gmail.com

significance of steganographic methods, this research highlights the growing importance of data hiding techniques in the modern era of digital communication. The contributions of this work are relevant not only to cybersecurity professionals but also to researchers in computer science and digital media fields who seek to enhance privacy and information security.

Keywords: Picture, Secret, Hiding

Enhancing Virtual Object Interaction with Hand Gesture Recognition

**Kalaichelvan R*, Adhikari Durga Venkata Madhav,
Amanchi Sravan Kumar, Addanki Gargeya, Allam Rohit Sree Ranga**
*Department of Computer Science and Engineering
Kalasalingam Academy of Research and Education, Krishankovil, Tamilnadu, India*

Abstract

In the contemporary world, there is an increasing need to diversify and simplify the ways that one can input data. This research article aims at presenting a new application that employs three primary virtual elements, namely a virtual paint tool, a virtual keyboard, a virtual mouse for enhancing engagement. In this context, the program aims at minimizing the difference between conventional and virtual environments, owing to its versatility and ease of input that is tailored for various tasks. The input methods: keyboard (includes fast text input and multiple languages and layouts support) and mouse (customizable and accurate pointer movement).

The use of brushes, colors, and effects in the virtual paint tool fosters artistic output. In highlighting each component of this concept, this article explores how its design, implementation, and the evaluation of user experience can affect creativity as well as productivity in digital environments. Through theoretical analysis and practical test, the study provides information for the validity of these virtual tools and their potential application in different fields such as education, graphic design and remote workers.

Keywords: Virtual Input Methods, User Engagement, Virtual Keyboard, Virtual Mouse, Virtual Paint Tool, Digital Interaction, User Experience, Input Flexibility, Creative Tools, Productivity Enhancement.

* Corresponding authors: kalaichelvan@klu.ac.in, {adhikarimadhav280, amanchisravankumar, gargachowdary05, allamrohithsreeranga}@gmail.com.

Counteracting Evolving Cyber Threats in Public Procurement Digital Infrastructures

Eduard-Ștefan Sandu*

National University of Science and Technology Politehnica Bucharest, Romania

Scientific Advisor: Alina-Claudia Petrescu-Nita

Abstract

Electronic public procurement systems, by their nature and functionalities, are increasingly vulnerable to cyberattacks, including ransomware, as attackers exploit weaknesses in the management of document submission and receipt involved in the procurement process. These vulnerabilities threaten data confidentiality, integrity and the operational continuity of essential functions within critical infrastructures. In response to this critical issue, this research proposes the integration of digital monitoring tools within electronic public procurement platforms as an advanced cybersecurity measure to counter ransomware and other cyber threats. This novel approach overcomes the limitations of conventional document transmission and reception channels, such as e-mail, by establishing secure digital environments where procurement documents can be exchanged, previewed, and monitored without compromising system integrity. The significance of this research lies in its focus on real-time monitoring and auditable traceability as a dynamic approach for securing public procurement systems against rapidly evolving cyber threats and potential attacks.

The primary objective of this research is to assess the effectiveness of digital room and virtual monitoring systems operating within these rooms to protect critical infrastructures against ransomware attacks. Digital rooms are designed to securely organize documents, allowing access solely for preview without downloads, thereby mitigating the risk of executing malicious scripts. Unlike unprotected e-mail exchanges, this system restricts document access, reduces exposure to external threats, and ensures comprehensive tracking of each interaction for post-event analysis. The research highlights how digital rooms can close critical security gaps in public procurement by replacing insecure communication methods with a closed-loop document management system.

A mixed-methods approach will be employed, using a case study analysis combined with a technical evaluation of the proposed digital vault framework. The case study involves a real-world incident where a contracting authority encountered a ransomware attack via infected PDF files sent by e-mail. By simulating the integration of digital rooms in this scenario, the study evaluates how such a system could prevent similar

* Corresponding author: **Eduard-Ștefan Sandu** – edy.eminem@yahoo.com

attacks. The technical framework is built around sandbox technology and a document preview-only functionality, enabling users to examine documents securely without triggering executable scripts from various file extensions that a potential attacker might transmit in the public procurement process. This feature, coupled with automatic threat detection algorithms, enables the immediate identification and isolation of suspicious extensions, reducing the risk of system compromise.

Key cybersecurity measures within the digital room include end-to-end encryption, advanced logging, and behavioral analysis algorithms. Collectively, these elements enhance both security and accountability, providing real-time data on all user interactions and secure document access. Sandboxing isolates each document within a virtual environment, ensuring that no malware can spread across critical infrastructure equipment. The use of encryption and secure access controls further strengthens the system, protecting data from unauthorized access and potential security breaches. This model also facilitates incident response by recording detailed logs of every action, allowing for rapid identification and containment of potential threats.

Theoretical results indicate that digital rooms significantly strengthen the cybersecurity posture of electronic public procurement platforms. In the simulated ransomware scenario, the proposed system prevented infection, allowing the contracting authority to examine documents securely without triggering any embedded ransomware script, such as a hidden form field `[var field = this.getField("hiddenField"); field.setAction("OnFocus", "app.alert('Added harmful actions');");]`. By eliminating the vulnerabilities associated with e-mail submissions, digital rooms effectively neutralize the primary vector for ransomware delivery into procurement systems. The results underscore the importance of auditable interactions, as the generated logs provide comprehensive data for cybersecurity audits, forensic investigations, and continuous monitoring.

The proposed digital room system primarily addresses three key areas, but is not limited to these: preventing the execution of malicious documents (through sandboxing), enhanced accountability, transparency (through detailed logging), and improved incident response capabilities (via real-time data collection). This approach not only mitigates the immediate risk of ransomware but also positions public procurement processes to better adapt to the continuously evolving cyber threats. As ransomware techniques become increasingly sophisticated in line with the rapidly rising global incidents in recent years, this study offers a foundational strategy for dynamic cybersecurity management, a strategy that can also be applied in other domains, not limited to public procurement processes.

In conclusion, the research demonstrates that digital rooms can be vital innovations for protecting critical infrastructures against ransomware attacks and associated cyber threats. The proposed system's focus on preview-only access, continuous monitoring and secure document management addresses specific vulnerabilities observed in

conventional transmission methods, such as e-mail, while significantly reducing risks. Implementing this approach not only enhances resilience against current cyber threats but also establishes a solid framework for critical infrastructures.

Keywords: Ransomware, SEAP, Critical Infrastructures, Cybersecurity, RaaS, Digital Room, AI.

Evaluating the Role of Artificial Intelligence and Pattern Recognition in the Self-Driving Car Market

Máté Prorok^{1,2*}

¹*Óbuda University, Innovation Management Doctoral School, Budapest, Hungary*

²*Gál Ferenc University, Faculty of Economics, Békéscsaba, Hungary*

Scientific Advisor: Sándor Simon

Abstract

This study aims to explore how artificial intelligence (AI) and pattern recognition technologies are advancing the self-driving car market. The proposed research question is: “How effectively do current AI-driven pattern recognition methods contribute to the safety and operational efficiency of autonomous vehicles?” The study uses secondary research methodologies, sourcing data from reputable industry reports, also academic journals, and technological case studies published between 2018 and 2023.

The research methodology focuses on statistical meta-analysis, employing correlation and regression techniques to assess the relationship between pattern recognition advancements and key performance metrics like accident reduction rates and object detection efficiency. Data sources for this research included databases like IEEE Xplore, Scopus, and specific reports from leading self-driving car manufacturers and technology companies. The analysis emphasized variability across different technological models and also AI frameworks used within the industry.

Findings indicate that AI-integrated pattern recognition systems have significantly improved real-time decision-making capabilities in autonomous vehicles, leading to a 35% average reduction in traffic incidents involving self-driving cars. Enhanced object detection algorithms, specifically those based on convolutional neural networks (CNNs), showed an accuracy increase of up to 92% in complex driving environments. However, challenges remain in adapting these technologies to diverse weather and road conditions, impacting their overall reliability.

* Corresponding author: **Máté Prorok** – prorokmate@gmail.com

In conclusion, while the integration of AI and pattern recognition demonstrates substantial progress, the industry must address specific limitations to achieve full-scale deployment. The study proposes further cross-industry collaborations to enhance data diversity and system adaptability. The research question was partially answered, confirming that current methods have achieved significant safety and efficiency improvements, though additional advancements are needed for comprehensive reliability. The research was made in Hungary. The findings underline the importance of continued innovation in pattern recognition and AI for the evolution of self-driving technology.

Keywords: Artificial Intelligence, Pattern Recognition, Self-Driving Cars, Autonomous Vehicles, Safety and Efficiency.

Mathematical Approaches Regarding Decoding an ADS-B file Airplane Study Case

Daniel-Ioan Mircu^{1,3}, Iulian-Nicolae Petriia^{2,3*}

¹ *Faculty of Industrial Engineering and Robotics*

² *Faculty of Electronics, Telecommunications and Information Technology*

³ *National University for Science and Technology POLITEHNICA Bucharest,
Romania*

Scientific Advisor: *Octavian Postăvaru, Antonela Toma*

Abstract

Automatic Dependent Surveillance-Broadcast (ADS-B) technology is essential for modern air traffic management, providing critical information on aircraft position, altitude, speed, and trajectory. ADS-B, which has replaced or augmented radar-based systems, enhances real-time tracking of aircraft and improves both safety and efficiency in the aviation sector. This paper addresses the key methods and challenges of decoding ADS-B messages, focusing on the accuracy and integrity of the extracted flight data.

We begin by discussing the structure of ADS-B messages, composed of 112 bits divided into segments, including Downlink Format, ICAO aircraft address, altitude, and other data fields. The message template analysed in this study includes detailed components like timestamps, ICAO codes, and power levels, enabling a comprehensive breakdown of how the information is processed and interpreted. We describe the decoding algorithm developed to transform hexadecimal ADS-B codes

* Corresponding author: **Iulian-Nicolae Petriia** – petriianicolae@yahoo.com; **Daniel-Ioan Mircu** – danimircu@gmail.com

into readable and meaningful values. This involves steps such as data loading, preprocessing using regular expressions to extract parameters, and converting hexadecimal to binary for further analysis.

Our method features rigorous validation techniques to ensure the reliability of decoded data. Given that ADS-B messages can be prone to transmission errors, the algorithm employs Cyclic Redundancy Check (CRC) for error detection. We review mathematical underpinnings of the CRC, using a polynomial generator well-suited for detecting burst errors. This paper describes how the polynomial $G(x)$, represented in both binary and hexadecimal formats, facilitates accurate error detection by checking the CRC remainder. We also discuss methods of mitigating environmental influences on signal integrity, including delay time, power drop, and bit errors, which affect the transmitted data.

The results section includes data visualizations illustrating aircraft trajectories in both two-dimensional (2D) and three-dimensional (3D) spaces. These visualizations help to identify anomalies, such as outliers or irregular flight paths, that numerical methods might miss. We introduce criteria to filter out inaccurate data points: for latitude, values must remain between -90° and 90° , and for longitude, between -180° and 180° , while altitudes are limited to the 0–42,000 ft range (due to the fact that a normal commercial airplane fly within this range), where 1ft is approximately 0,3048 meters. This approach ensures that only valid and reliable data are used in subsequent analyses.

To improve data accuracy, our algorithm includes mechanisms for altitude correction. By comparing recorded altitudes over time, we calculate aircraft speed and use it to estimate future positions. If the computed altitude deviates significantly from the ADS-B reported value, the algorithm updates it with the mathematically derived values. We also implement a consistency check for latitude and longitude using established thresholds of 0.05° and 500 altitude units, respectively, informed by literature on trajectory prediction.

The robustness of our approach is demonstrated through case studies, where ADS-B data is processed and verified. The paper discusses the limitations of our method and potential sources of error, emphasizing the importance of continuous improvement. Our findings contribute to enhancing flight data processing and open new avenues for optimizing ADS-B systems, including improved algorithms for anomaly detection and trajectory prediction. Future research directions involve integrating machine learning techniques to predict and correct discrepancies in real-time, offering further advancements in aviation surveillance technology.

Acknowledgement: The inspiration for this project on Decoding Automatic Dependent Surveillance-Broadcast (ADS-B) originated when one of our team members participated in an Internship Program with the Romanian Government, specifically within the National Authority for Communications Administration and

Regulation, in the Executive Monitoring and Control Directorate. During this internship, Iulian-Nicolae had the privilege to attend a two-week course led by prof. dr. eng. Teodor Petrița from the Western University of Timișoara. At the end of the program, prof. Petrița recommended connecting with prof. dr. eng. Alina Bădescu, an interaction that deepened his understanding of the importance of a unique identifier for aircraft in flight. This collaboration inspired him to develop the mathematical tools for decoding ADS-B, leading to the creation of this article in partnership with Daniel-Ioan Mircu, Antonela Toma, and Octavian Postăvaru.

Keywords: ADS-B, ICAO, Latitude, Longitude, Altitude, CRC, Y.

An Experimental Approach on Few Shot Class Incremental Learning

Marinela Adam*

West University of Timisoara, Timisoara, Romania

Scientific Advisor: Darian Onchis

Abstract

Few-Shot Class-Incremental Learning (FSCIL) represents a rapidly evolving paradigm within machine learning that enables models to assimilate new classes from a limited number of examples, while maintaining prior knowledge. This research investigates FSCIL solutions by presenting an extensive evaluation of various methodologies, and proposing an enhancement to the LP-DiF framework. LP-DiF employs vision-language models and prompt tuning to mitigate catastrophic forgetting (a major challenge in FSCIL), allowing models to retain accuracy on previously learned classes. Initial experiments showcase LP-DiF's efficacy using CLIP as the vision-language model, and the proposed improvement involves replacing CLIP with CLOOB, a model optimized for contrastive learning and capable of overcoming limitations associated with CLIP, such as feature saturation.

This work is structured in six sections each of them with several subsections. We start with introduction where we present the motivation for the work, and then present the context of the research, main research questions and the structure of the following sections of the paper. The following section is on the methodology of research where we present the theoretical analysis and the workflow of the approach. Afterwards we move to the following section where we present the proposed approach with its elements (LP-DiF framework, CLIP, CLOOB, Datasets and our solution/experiment). This is followed by a section detailing the preliminary results of the three components

* Corresponding author: **Marinela Adam** – marinela.adam01@e-uvt.ro

that we have used (LP-DiF, CLIP, CLOOB), allowing us to see where we stand. The next section presents the main results which have been obtained and a comparison with the SOTA. Finally, the last section concludes by presenting the limitations and the open problems that we have identified, as well as future work and research directions.

The research methodology that we used includes a thorough comparison of the LP-DiF framework with leading FSCIL techniques across multiple benchmark datasets, including CIFAR-100, miniImageNet, and CUB-200. The approach combines theoretical analysis, experimental testing, and an iterative workflow focused on dataset training, model evaluation, and component integration. Key performance metrics, including accuracy and error rates across incremental learning sessions, are utilized to quantify the improvement brought by CLOOB integration. CLOOB's advanced architecture enhances FSCIL's ability to manage evolving tasks by achieving better results in zero-shot learning scenarios than CLIP, as evidenced by experiments on large-scale datasets.

The work's findings highlight that CLOOB integration improves LP-DiF's capacity to retain knowledge across classes, confirming it as a more effective model for FSCIL. CLOOB consistently outperforms CLIP in zero-shot and few-shot learning, which are essential for FSCIL applications like, e.g., medical diagnostics and fraud detection, where the need to rapidly incorporate new data categories is vital. We finish by mentioning the potential areas for future research, such as exploring diverse backbone architectures, further model refinements, and adaptive sampling strategies to balance class distributions. The study advances FSCIL by introducing a method to enhance class retention while allowing flexibility in incorporating new data.

Keywords: Few-Shot Class-Incremental Learning, Catastrophic Forgetting, Hopfield networks, Contrastive Learning, Contrastive Leave One Out Boost

Autonomous Coffee Delivery Robot Using PRM and A* Path Planning

Sufiyan Ahmed Mohammed*

Indiana Wesleyan University, Indiana, United States of America

Abstract

Autonomous delivery robots have seen increasing application in various fields, with coffee delivery being a novel context that presents unique navigation challenges. This study aims to develop an efficient, autonomous coffee delivery robot by implementing Probabilistic Roadmap (PRM) and A* algorithms for path planning. The paper

* Corresponding author: **Sufiyan Ahmed Mohammed** – soofiyan.ahmed9246@gmail.com

addresses the need for reliable, adaptive navigation methods in constrained indoor environments, typical of cafes or office spaces. Existing navigation algorithms, while effective in general robotics applications, face difficulties with the unpredictable obstacles and dynamic human movement in these settings. Consequently, this research explores a tailored approach that maximizes efficiency and safety in close-quarter environments, advancing the application of path-planning algorithms in service robotics.

The methodology employed combines the PRM algorithm, for map construction and initial path creation, with the A* algorithm, for optimal pathfinding, ensuring robust navigation through predefined waypoints while dynamically avoiding obstacles. PRM provides a flexible, adaptable structure that allows the robot to build a probabilistic roadmap within the mapped environment, making it suitable for indoor layouts with varying configurations. Once the roadmap is constructed, A* searches for the shortest feasible path to the target location, leveraging a heuristic to minimize computational overhead while maintaining accuracy and responsiveness. The combination of these algorithms provides a balanced approach to both strategic planning and real-time adaptability, essential for coffee delivery tasks where efficiency and collision avoidance are critical.

The results demonstrate the efficacy of the PRM and A* hybrid model in achieving smooth, reliable navigation, with simulations indicating a significant improvement in route efficiency compared to traditional single-algorithm approaches. The robot successfully navigated complex indoor pathways, reducing delivery time and minimizing collision incidents. Experimental trials also show that the hybrid model effectively adapts to unforeseen obstacles, making real-time adjustments to reroute safely.

In conclusion, this research contributes to the field of robotics by presenting an innovative solution for indoor autonomous delivery, combining PRM and A* path planning to optimize both path efficiency and safety. The findings hold implications for a broader range of indoor delivery applications, offering a framework for further development in service-oriented robotics, especially within environments that require frequent interactions with humans. The proposed approach enhances the scope of autonomous systems in structured and dynamic environments, making it a valuable addition to both theoretical studies and practical applications in robotics and artificial intelligence.

Keywords:

Autonomous Delivery Robot, Path Planning, Probabilistic Roadmap (PRM), A Algorithm*, Indoor Navigation, Service Robotics, Collision Avoidance

Jovial: Astronomical Data Analysis Cloud Service

Sufiyan Ahmed Mohammed*

Indiana Wesleyan University, Indiana, United States of America

Abstract

This paper presents Jovial, an innovative cloud-based service aimed at advancing the efficiency and accessibility of astronomical data analysis. Astronomers increasingly rely on large datasets from the Virtual Observatory (VO), which are difficult to manage and analyze on local machines due to resource limitations. Jovial addresses these challenges by providing a robust cloud computing environment, leveraging Docker containers, Kubernetes orchestration, and LustreFS—a high-performance distributed file system. This combination creates a secure, scalable, and high-availability platform that allows users to perform data processing, visualization, and file management within an isolated, controlled environment.

The study's objective is to bridge the gap between existing data access tools and the need for efficient data analysis platforms capable of handling large-scale, high-latency data typical in astronomical research. To achieve this, Jovial utilizes JupyterHub to provide each user with a dedicated Jupyter Notebook instance, allowing code execution and data analysis in an isolated Docker container. Each user's environment is orchestrated by Kubernetes to ensure load balancing, high availability, and fault tolerance across multiple nodes. The platform is designed so that if one node fails, workloads seamlessly transition to available nodes, minimizing disruption.

The methodology incorporates containerization through Docker to isolate users' work environments, using Kubernetes as the orchestrator to distribute workloads based on real-time load across nodes. Files are managed using LustreFS, allowing rapid access to large datasets via InfiniBand connections. A proxy gateway manages secure access, ensuring that only authorized users interact with the system. Additionally, the spawner within Kubernetes creates individual containers for each user with personalized file access, enabling secure and efficient data handling.

The results demonstrate that Jovial supports astronomical data processing in a scalable environment, providing high throughput and low latency. By using Kubernetes and Docker, the platform achieves high availability and resource optimization, with minimal risk of data interference among users. Benchmarks show significant improvements in data processing speeds and enhanced security protocols compared to traditional local computing environments.

In conclusion, Jovial provides a valuable solution for the astronomical community by addressing key limitations in current data analysis workflows. It supports the seamless

* Corresponding author: **Sufiyan Ahmed Mohammed** – soofiyan.ahmed9246@gmail.com

integration of scalable cloud resources, enabling more efficient and secure data analysis for astronomers globally. The platform's design and implementation represent a significant contribution to the fields of cloud computing and data science, offering a scalable, accessible solution for astronomical research.

Keywords: Cloud Computing, Astronomical Data Analysis, Docker Containers, Kubernetes Orchestration, LustreFS, High-Performance Computing, Data Security

Advanced Neural Video Captioning

Sufiyan Ahmed Mohammed*

Indiana Wesleyan University, Indiana, United States of America

Abstract

This study explores advanced neural network architectures for video captioning, aiming to improve automated video content understanding and description generation. The primary objective is to enhance the quality, relevance, and coherence of generated captions for varied video content, including real-world and multimedia scenarios. This research addresses the limitations of conventional video captioning systems by leveraging a novel hybrid deep learning model that combines convolutional neural networks (CNN) for feature extraction with long short-term memory (LSTM) networks for temporal sequence processing. Additionally, attention mechanisms are incorporated to enhance context comprehension in complex video frames.

The methodology used involves pre-processing video data through frame extraction and encoding, followed by sequential feeding into the hybrid model for training. The model is further optimized by implementing a reinforcement learning-based feedback loop to refine caption accuracy iteratively. Experimental results demonstrate significant improvements in caption relevance and grammatical accuracy, achieving a BLEU score increase of 15% over baseline models. Furthermore, qualitative assessments by human reviewers indicate enhanced captioning performance in diverse video categories.

In conclusion, this research contributes a robust neural video captioning framework that advances the capabilities of AI in multimedia analysis. Its application spans fields such as automated content creation, accessibility enhancement, and video indexing. This study also lays the groundwork for future research in real-time captioning for live video streams, addressing a critical need in AI-driven content understanding.

Keywords: Neural Video Captioning, Deep Learning, Attention Mechanism, Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), Reinforcement Learning, Automated Video Analysis

* Corresponding author: **Sufiyan Ahmed Mohammed** – soofiyan.ahmed9246@gmail.com

Understanding Multi-Tenancy in SaaS

Sufiyan Ahmed Mohammed*

Indiana Wesleyan University, Indiana, United States of America

Abstract

As cloud computing rapidly evolves, multi-tenancy has become fundamental to the design and deployment of Software-as-a-Service (SaaS) solutions, where a single application instance serves multiple users or organizations (tenants). This research explores the complex architecture of multi-tenant SaaS, where benefits like cost-effectiveness, scalability, and efficient resource utilization are achieved alongside significant technical challenges, such as ensuring data isolation, maintaining security, and optimizing performance for diverse users. The research seeks to provide a comprehensive understanding of multi-tenancy's role in SaaS and to outline best practices and architectures that address these unique challenges.

This study's primary objectives are to assess the trade-offs between cost efficiency and tenant-specific requirements, analyze methods to enhance resource-sharing mechanisms, and propose secure and efficient approaches for data partitioning and access control in multi-tenant environments. Methodologically, this research adopts a hybrid approach, combining quantitative analyses of resource allocation efficiencies with qualitative assessments of database partitioning techniques, SLA enforcement, and access control models. Key techniques include the analysis of shared infrastructure models, tenant isolation strategies, and the use of database sharding and row-level security to facilitate data privacy among tenants. Furthermore, SLA compliance strategies were evaluated to measure how service performance and quality can be maintained for tenants with varying needs.

The findings reveal that a carefully designed multi-tenant architecture can achieve high levels of efficiency without compromising on security or performance. Implementing data partitioning techniques such as database sharding and using tenant-specific schemas ensures data isolation and enhances scalability. Access control mechanisms like role-based access control (RBAC) and encryption further reinforce data security and enable compliance with stringent security standards. The study also found that adaptive SLAs can accommodate fluctuating tenant workloads and help meet performance benchmarks, resulting in higher client satisfaction and trust.

In conclusion, this research contributes to the ongoing development of SaaS multi-tenancy by proposing an adaptable framework that addresses scalability and security in a shared environment while maintaining tenant-specific requirements. The insights from this study have practical implications for SaaS developers and cloud architects,

* Corresponding author: **Sufiyan Ahmed Mohammed** – soofiyan.ahmed9246@gmail.com

offering a pathway for building robust multi-tenant solutions that cater to modern cloud requirements. Future research could explore integration with advanced technologies like AI-driven resource allocation and edge computing to further enhance multi-tenancy in distributed cloud architectures.

Keywords: Multi-Tenancy, Software-as-a-Service (SaaS), Cloud Computing, Data Isolation, Resource Allocation, Database Partitioning, Scalability and Security

Solutions for Optimizing Freight

Amza Bogdan-Stefan*

*National University of Science and Technology "POLITEHNICA" Bucharest,
Romania*

Scientific Advisor: Alin Alecu

Abstract

Global trade depends heavily on the logistics and transportation industries, and truck transportation services are essential for effectively moving products across continents. The optimization of freight transportation is the main subject of this study, with a focus on incorporating contemporary technology like the Global Positioning System (GPS) to boost safety, lower costs, and increase efficiency. This research addresses issues including route limits, traffic congestion, and regulatory requirements that impact the present transportation scenario.

Problem Statement

Among the operational difficulties faced by freight transportation, especially in the trucking sector, are ineffective route planning, volatile fuel costs, adherence to regulations, and safety issues. Due to factors including weight and height restrictions, prohibited zones, and changing road conditions, traditional GPS systems—which are typically made for passenger cars—do not adequately handle the intricacies inherent in truck transportation. Truck drivers frequently experience delays, higher expenses, and safety hazards as a result.

Objectives

This study's main objective is to investigate novel approaches that can maximize freight transportation by attending to the particular requirements of fleet managers and truck drivers. A customized GPS navigation system with cutting-edge features including real-time traffic updates, route optimization based on truck-specific limits, and enhanced safety features is suggested by this study. Among the main goals are:

* Corresponding author: **Amza Bogdan-Stefan** – amzabogdan15@gmail.com

- Reducing travel time and fuel consumption through optimized routes.
- Enhancing safety by providing real-time alerts for traffic incidents and road restrictions.
- Ensuring compliance with regulatory requirements, including Hours of Service (HOS) laws and environmental standards.
- Offering a user-friendly interface that minimizes distractions for all drivers.

Methodology

The study uses a mixed-methods approach, integrating user input, technology analysis, and literature evaluation. Truck drivers were asked to complete a survey in order to determine the major problems they have with the GPS systems that are already in use. FIGMA, a cloud-based design tool, was also used to create a prototype GPS application in order to test different features and visualize the user interface. Features like dynamic rerouting, real-time tracking, and interaction with fleet management systems are all included in the program.

Technological Advancements

Using cutting-edge GPS technology is one of the most important aspects of freight transportation optimization. Positional precision and signal reliability have been greatly enhanced by recent advancements in satellite systems, such as multi-frequency transmissions and the addition of more satellites to the GPS constellation. Additionally, the integration of Internet of Things (IoT) technology enables real-time traffic conditions, fuel efficiency, and vehicle performance to be continuously monitored.

The efficiency of GPS systems is further increased by artificial intelligence (AI) and predictive analytics, which offer dynamic routing alternatives based on past traffic statistics, meteorological conditions, and other pertinent variables. Truck drivers may avoid traffic jams, use less fuel, and be safer overall thanks to these innovations.

Challenges and Proposed Solutions

The research highlights a number of significant issues with freight transportation, such as ineffective resource management, frequent traffic delays, and a lack of precise truck maps. The following fixes are included in the suggested GPS system to solve these problems.

Route Optimization

Sophisticated algorithms examine road conditions and traffic data to determine the most effective truck routes, accounting for variables such as height and weight limitations, laws governing hazardous materials, and real-time traffic updates. The system has features like real-time driver behaviour monitoring to make sure safety regulations are being followed and geofencing, which notifies fleet management and drivers when vehicles approach forbidden zones.

Results

The survey results indicated that truck drivers overwhelmingly favor real-time traffic updates, route optimization, and easy-to-use interfaces. The prototype GPS application developed as part of this research demonstrated a significant improvement in route efficiency, reducing travel time by an average of 15% compared to traditional GPS systems. Furthermore, fuel consumption was reduced by approximately 10%, contributing to both cost savings and environmental sustainability.

Conclusion

According to the study's findings, incorporating cutting-edge GPS technology designed specifically for the trucking sector can significantly increase the effectiveness of freight transportation. The proposed GPS system provides a complete solution that improves operational performance and driver satisfaction by attending to the particular requirements of truck drivers, including route constraints, safety issues, and regulatory compliance. Modernizing the freight sector, lessening its impact on the environment, and enhancing the supply chain as a whole all depend on the adoption of such technology.

Keywords: Optimization, GPS Technology, Truck Navigation, Route Efficiency, Real-time Tracking, Fleet Management, Sustainability.

AI-Enhanced Pediatric Pneumonia Classification

Anisha Jadhav*

Independent Researcher, California State University, United States of America

Abstract

Pneumonia remains a leading cause of mortality among children under five years old, with a significant impact in low-income regions. This study explores the application of transfer learning with convolutional neural networks (CNNs) to improve the classification of pediatric chest X-rays into normal, bacterial, and viral pneumonia. Utilizing pre-trained models on the ImageNet dataset, specifically InceptionV3, we repurposed these models for our classification tasks. Our framework included binary and multi-class classification approaches, with the best binary classifier achieving an F1-score of 0.941 and an accuracy of 91.44%. The multi-class classifier reached an F1-score of 0.636 and an accuracy of 83.78%. These results demonstrate the potential of advanced AI techniques to enhance diagnostic accuracy and address challenges in pneumonia classification, particularly in resource-limited settings.

Keywords: Pneumonia Classification, AI healthcare, AI disease detection.

* Corresponding author: **Anisha Jadhav** – anisha.jadhav07@gmail.com

Integrating Neuro-Fuzzy Systems for the Enhancement of the Educational Framework

Naomi Vârtaci^{1*}, Sergiu Popa²

¹ “Aurel Vlaicu” University of Arad, Faculty of Engineering, Arad, Romania

² Tehnical University of Cluj-Napoca, Faculty of Automation and Computers, Cluj-Napoca, Romania

Scientific Advisors: Marius Mircea Bălaș, Daniel Alexuță, Flavius Maxim Petcuț

Abstract

Recent international assessments, such as those conducted through the Programme for International Student Assessment (PISA), place Romania among the lowest-performing countries in terms of educational outcomes. This highlights an urgent need for an effective model to evaluate student achievement levels and identify critical areas for improvement within the Romanian educational system. In this context, this paper proposes a neuro-fuzzy model that leverages the strengths of fuzzy logic and neural networks to analyse and predict student performance in relation to international standards, such as those set by PISA. The model is designed not only to assess students' current achievement levels but also to provide a framework for measuring the progress necessary to reach higher educational standards.

The neuro-fuzzy model structures enable classroom data to be collected, processed, and compared with international benchmarks. Fuzzy logic is used to classify and interpret these data, accommodating the inherent variability in educational measurements, thus providing a flexible, adaptable approach. Neural networks, on the other hand, are utilized for trend analysis and predictive insights into students' future performance, effectively strengthening the model's adaptability to real-world changes in educational achievement over time. The structures developed in this study are covering three distinct levels of scrutiny, representing varying degrees of optimization for the educational system. The first level provides a more flexible approach to data interpretation, the second imposes moderate rigor in performance evaluation, and the third level applies the strictest criteria, ensuring accelerated alignment with higher educational standards.

A key benefit of this neuro-fuzzy model is its ease of implementation across educational institutions, providing an automated evaluation system that can be consistently updated based on international testing results. By incorporating periodically updated data, the model enables continuous monitoring of student progress, allowing institutions to identify critical improvement areas and more easily allocate resources toward targeted educational interventions. This model allows

* Corresponding author: **Naomi Vârtaci** – naomi.vartaci@gmail.com

schools to adapt educational practices to international standards, thereby supporting reform and enhancement efforts within the Romanian education system.

This study contributes to the field by exploring a neuro-fuzzy model application in education, presenting an innovative solution that combines artificial intelligence techniques to improve student assessment processes. The construction of such structures serves as a foundation for future research aimed at integrating technology into educational processes, facilitating more accurate evaluations and well-informed interventions to support academic achievement. With this approach, the paper aims to address both immediate and long-term challenges in educational evaluation, offering a pathway to a more responsive and adaptive educational system. Furthermore, the proposed approach can help reduce disparities among schools and regions, fostering a more equitable educational landscape.

Keywords: Neuro-fuzzy systems, Optimization, Evaluation, Education, PISA

Agent-Based Approaches to Complexity: Simulating Thermoregulation in Beehives

Margareta Szegő*

“Aurel Vlaicu” University of Arad, Faculty of Engineering, Arad, Romania

Scientific Advisor: Valentina E. Bălaş

Abstract

The study employs agent-based modelling, implemented within the NetLogo platform, to investigate the intricate thermoregulatory dynamics within bee colonies under the stressors of climate change. This approach treats each bee as an individual agent within a decentralized, adaptive system where localized interactions collectively generate system-wide thermoregulation behaviours. Given the critical role bees play in maintaining biodiversity and supporting agricultural productivity through pollination, the research aims to understand how climate-induced environmental perturbations impact their ability to sustain thermal stability—a complex adaptive process essential for hive survival.

The NetLogo model operates by simulating individual bee behaviours and responses to a range of environmental variables, specifically focusing on how ambient temperature fluctuations impact the hive’s collective thermal regulation mechanisms. Each agent (bee) in the model follows a set of programmed behavioural rules, adjusting its actions based on local temperature cues and energy reserves. Through iterative simulations across different temperature conditions, the model reveals the system’s

* Corresponding author: **Margareta Szegő** – maggiemedia0@gmail.com

thresholds and resilience boundaries by mapping the relationships between bee activity, hive temperature, and environmental temperature inputs.

Findings indicate that while bees exhibit adaptive thermoregulation strategies in response to temperature fluctuations, these adaptive behaviours reach critical constraints under extreme scenarios. Elevated ambient temperatures require a disproportionately high number of active thermoregulating bees to maintain optimal hive temperatures. Without sufficient active agents, thermal homeostasis breaks down, leading to accelerated energy depletion and fatigue within the hive. This modelling approach highlights the limits of resilience within bee populations facing rapid climate shifts, emphasizing the systemic vulnerabilities inherent in their self-organized regulatory mechanisms.

This ABM approach provides insights into the systemic vulnerabilities of bee colonies when faced with rapid climate changes. By isolating critical thresholds and resilience limits, the model highlights the hive's susceptibility to collapse under high-stress conditions, where self-regulating mechanisms lose coherence. This study thus underscores the potential consequences for bee populations as environmental stresses increase. Through simulations, the research emphasizes the importance of understanding resilience within ecological systems, illustrating how disruptions in self-organized regulatory behaviours can cascade into larger, system-wide failures under extreme environmental conditions.

Keywords: Complex Systems, Agent-Based Modelling, Beehive Thermoregulation, Climate Change Impact, Self-Organization, Adaptive Resilience.

Message Scheduler for a Cryptographic Application

Anca-Adriana Petcuț-Lasc¹, Raul Rotar^{2*}

¹ *Petroleum-Gas University of Ploiești, Faculty of Engineering, Ploiești, Romania*

² *Politehnica University of Timișoara, Faculty of Automation and Computers, Timișoara, Romania*

Scientific Advisor: Flavius Petcuț

Abstract

In cryptographic applications, a Message Scheduler is a critical component used in hash functions and block ciphers to prepare or organize input data in a way that optimizes the processing of information during encryption or hashing. Specifically, it expands or manipulates the input message or data blocks into a series of “scheduled”

* Corresponding authors: **Anca-Adriana Petcuț-Lasc** – anca.lasc@upg-ploiesti.ro; **Raul Rotar** – raul.rotar@upt.ro.

messages or words, enabling the algorithm to apply transformations that achieve the desired cryptographic security properties, such as data integrity and confidentiality.

This work builds upon the existing research body by proposing a hardware implementation for the message scheduling unit. Several components such as multiplexers, registers, adders, and dedicated sigma function modules are integrated into the hardware design to facilitate specific transformations applied to the initial data block.

More precisely, the Message Scheduler expands a 512-bit block delivered by the pre-processing step to a 2048-bit data packet. The 2048 bits are organized in 64 words of 32 bits each: $W_0, W_1, \dots, W_{62}, W_{63}$. The first 16 words, $W_0, W_1, \dots, W_{14}, W_{15}$, represent the initial 512-bit block with W_0 being the most significant word. The remaining 48 words are calculated by the following iterative formula:

$$W(t) = \sigma_1^{[256]}(W_{t-2}) + W_{t-7} + \sigma_0^{[256]}(W_{t-15}) + W_{t-16}, \quad t \in [16:64] \quad (1)$$

where the lowercase sigma functions (σ_0 and σ_1) are used in the message schedule phase of SHA-256. These functions prepare the expanded message schedule from the original input message block by mixing the bits in a way that makes it more difficult for an attacker to predict relationships among bits:

$$\begin{cases} \sigma_0(x) = ROTR^7(x) \oplus ROTR^{18}(x) \oplus SHR^3(x) \\ \sigma_1(x) = ROTR^{17}(x) \oplus ROTR^{19}(x) \oplus SHR^{10}(x) \end{cases} \quad (2)$$

where $SHR^n(x)$ represents a logical right shift of x by n bits (padding the leftmost bits with zeroes). Furthermore, $ROTR^n(x)$ represents the circular right shift or rotation of n bits located in the least significant positions of the initial word.

As outlined in equation system (2), the sigma functions introduce non-linearity and bit mixing, both of which are essential to the cryptographic strength of SHA-256. They contribute to:

- a) *Diffusion*: By thoroughly mixing bits, the sigma functions ensure that each bit in the output depends on many bits from the input, making it harder for attackers to reverse-engineer or predict output patterns.
- b) *Avalanche Effect*: Even a small change in the input (such as flipping one bit) will lead to a vastly different hash output.

These properties make sigma functions an integral part of the SHA-256 hashing process, providing the algorithm with the cryptographic security needed to protect data integrity.

Keywords: Message Scheduler, Sigma Functions, Algorithm, Data Integrity, Security, Confidentiality, Cryptography.

A case study on optimization: implementing textbook RSA with multiprocessing in Julia

Tibor Hegyi*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Anca-Adriana Petcuț-Lasc

Abstract

RSA (Rivest-Shamir-Adleman) is one of the most widely used asymmetric encryption algorithm, serving as the foundation for many modern cryptographic protocols. It is based on the computational difficulty of factoring large integers, offering a practical balance of security and efficiency. Implementing the RSA algorithm in a programming language like Julia can provide significant advantages, particularly when combined with parallel processing capabilities. This paper explores the process of implementing the textbook version of the RSA algorithm in Julia, leveraging its built-in multiprocessing features to optimize performance and handle large-scale cryptographic tasks more efficiently.

The RSA algorithm is composed of key generation, encryption, and decryption steps, all of which involve mathematical operations such as modular exponentiation and prime factorization. In a typical RSA setup, the public key consists of a modulus n (the product of two large primes) and an exponent e , while the private key consists of n and a secret exponent d . The security of RSA relies on the difficulty of factoring the large number n . While the algorithm is conceptually straightforward, its performance can degrade significantly as the size of n increases, especially for cryptographic applications that demand high throughput.

Julia, a high-performance programming language designed for numerical and scientific computing, is well-suited for implementing cryptographic algorithms. It provides an intuitive syntax, efficient handling of mathematical operations, and support for parallel and distributed computing. The ability to exploit multiple cores or even multiple machines for intensive tasks such as modular exponentiation and prime factorization is one of Julia's key strengths. By using Julia's Distributed package, developers can take advantage of multicore architectures, achieving significant reductions in execution time for time-consuming operations such as generating large primes consecutively, or encrypting and decrypting large messages.

One of the key challenges when implementing RSA in Julia with multiprocessing is efficiently partitioning the workload to minimize overhead. The algorithm's modular arithmetic steps, especially when raising large numbers to high exponents, are

*¹ Corresponding author, **Tibor Hegyi** – hegyitibor65@gmail.com

inherently sequential in nature, making parallelization non-trivial. However, certain portions of the RSA algorithm, such as key generation and factorization, lend themselves well to parallelization. For example, the process of generating large prime numbers can be parallelized across multiple threads or processes, significantly speeding up key generation. Similarly, cryptographic tasks that involve repeated modular exponentiation can be parallelized at a finer granularity, further optimizing the overall performance of the system.

Multiprocessing not only enhances computational speed, but also provides scalability for larger key sizes, a crucial factor in the context of modern cryptography where RSA keys are typically 2048 bits or more. As the size of the modulus n increases, the time complexity of basic operations grows, making the ability to handle large datasets in parallel increasingly important. Furthermore, the dynamic nature of Julia's type system, and its capability to easily switch between parallel computing models (like shared-memory multithreading and distributed computing), provide a flexible framework for cryptographic implementations.

While Julia offers many advantages for parallel RSA computation, there are still considerations related to memory management, task synchronization, and ensuring thread safety when using multiprocessing. Proper handling of these aspects is essential to avoid race conditions or excessive memory usage that could negate the performance benefits. In addition, profiling and optimization are necessary to ensure that the parallel implementation scales efficiently with the size of the RSA key and the computational resources available.

A use case example of the implementation presented in the paper would be an application with many users. Keys could be generated simultaneously, which would make generation for multiple users at the same time possible. Due to security concerns, textbook RSA is not to be used in production, but the implementation presented in the paper can be improved to be fit for a production environment, thus providing a better and seamless user experience.

In conclusion, implementing the textbook RSA algorithm in Julia with multiprocessing capabilities is an effective approach to address performance bottlenecks commonly encountered in cryptographic applications. By leveraging Julia's efficient handling of large numbers and its built-in support for parallel computing, developers can create highly scalable and fast implementations of RSA that are suitable for modern cryptographic demands. As the need for secure communication grows, such optimized implementations will become increasingly important for handling the complexities of large-scale encryption and decryption tasks.

Keywords: textbook RSA, multiprocessing, Julia, optimization

Case Study on Universal Games Token (UGT) Adoption: Management Strategies for Enhancing Profitability Across Multiple Gaming Platforms

Alexandru Nicolăiță¹, Miruna Maura Trocan¹, Croitoru Gabriel^{1,2*}

¹⁾ Aurel Vlaicu University of Arad, Romania

²⁾ Valahia University of Targoviste, Romania

Scientific Advisor: Gabriel Croitoru

Abstract

This research investigates the adoption of the Universal Games Token (UGT) as an innovative, cross-platform digital currency, examining its influence on profitability, operational efficiency, and player engagement across three distinct games developed by companies in Baia Mare, Romania: *MarketGlory*, *Goal Tycoon*, and *Cave to Kingdom*. Through a qualitative case study approach, this paper explores how strategic management practices facilitated UGT integration across these platforms, creating a cohesive ecosystem that leverages blockchain technology to streamline transactions, lower operational costs, and boost user retention.

The study highlights the ways in which each development team deployed tailored management strategies to address technical, financial, and user-centric challenges associated with implementing a decentralized currency. Key focus areas include ecosystem alignment, player incentivization, and operational cost reduction, each of which was instrumental in enabling UGT to act as a universal currency that enhances user experience while supporting profitable growth. The cross-platform capabilities of UGT allowed these companies to introduce a consistent and transferable currency that enables players to seamlessly engage across multiple gaming environments. This development was particularly significant in overcoming the friction traditionally associated with managing separate, non-interoperable in-game currencies, thereby fostering sustained player engagement and reducing transaction complexity.

From a management perspective, UGT's blockchain foundation enabled decentralized transactions, leading to significant cost savings on conventional payment processing fees. These efficiencies not only streamlined cross-platform interactions but also provided a financial cushion for developers, who could then allocate resources to enhance player incentivization through loyalty programs, in-game rewards, and exclusive promotions. For instance, each platform leveraged UGT to offer unique incentives that are aligned with its game's theme—entrepreneurial rewards in *MarketGlory*, strategic advantages in *Goal Tycoon*, and storyline progression benefits

* Corresponding author: **Alexandru Nicolăiță** – nicolaitaalexandru@gmail.com, **Miruna Maura Trocan** – trocan.maura@gmail.com, **Gabriel Croitoru** – croitoru.gabriel2005@gmail.com

in *Cave to Kingdom*. Such incentives were strategically designed to foster increased player satisfaction and engagement, leading to a scalable model of player retention across different gaming genres.

The research draws on data from in-depth interviews with each game's management team and a comprehensive analysis of in-game transaction data to provide a nuanced view of how UGT adoption impacted the games' financial and operational metrics. Findings suggest that UGT's integration not only optimized transaction efficiency but also enhanced each platform's ability to generate revenue through decentralized digital asset management. By minimizing traditional transaction fees and simplifying currency exchange processes, UGT facilitated a more streamlined user experience while supporting a profitable monetization strategy for developers.

Further, this study situates UGT's impact within the broader industry trends, particularly regarding blockchain applications in digital asset management and cross-platform monetization. By adopting UGT, the three game developers confirmed the potential of blockchain-based currencies to unify game ecosystems, enhance digital asset liquidity, and reduce operational friction. Ultimately, UGT offers a robust solution to key challenges in the gaming sector, suggesting that digital currency integration can be a viable strategy for improving both profitability and player loyalty. This case study contributes to the evolving discourse on decentralized currencies in gaming, providing practical insights for developers seeking to leverage blockchain for enhanced user experiences, engagement, and operational cost efficiency.

Keywords: Universal Games Token, cross-platform currency, management strategies, decentralized monetization, Initial Coin Offering, gaming profitability

JEL Classification: O32 (Technological Innovation), L86 (Information and Internet Services), M31 (Marketing).

My 3D Journey from Zero to Hero with the BLENDER App

Letitia Ilea*

“Aurel Vlaicu” University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Mihaela-Daciana Crăciun

Abstract

Blender, an open-source 3D creation software, has become a leading tool in the computer graphics and digital media industries. This powerful software is widely used for tasks like 3D modeling, animation, rendering, simulation and even game development. Since its inception in 1994, Blender has evolved into a comprehensive

* Corresponding author, **Letita Ilea** – letitia.ilea@yahoo.com

suite of digital tools serving a variety of scientific, academic, and commercial applications.

My first step in learning Blender 3D was to make a classic “donut” with Blender Guru. After completing that tutorial, I started applying the techniques learned to more complex projects. One of my first assignments was modeling a “Haunted House,” a personal studio project. Another significant project I worked on was a short film, now in development, involving the creation and animation of 3D characters.

My Blender 3D journey started as a simple fascination. I’ve always loved animated movies, video games, and digital artwork, but I never imagined I could create 3D art myself even though I am a deaf person. However, one day while browsing YouTube I came across a tutorial showing how to make a realistic looking „donut” in Blender. The process seemed both magical and accessible, and I was inspired to try it myself. Driven by curiosity and a new desire to create, I downloaded Blender that same day and started exploring the software.

This study examines Blender’s technical capabilities, its importance in scientific research and various industries, and the technological innovations that have made it one of the most advanced 3D graphics applications available today.

Blender was originally developed by Ton Roosendaal as an in-house tool for his animation studio, NeoGeo, in the Netherlands. In 2002, Blender was released to the public as open-source software under the GNU General Public License (GPL), allowing developers around the world to contribute to its code base. This collaborative, open-source structure has allowed Blender to quickly incorporate new features and meet evolving user needs.

Blender is a full-featured application with several highly advanced tools that can be grouped into core areas such as 3D modeling and sculpting, animation and rigging, rendering and simulation. These capabilities not only support creative media production, but also meet the rigorous demands of scientific visualization and simulation.

It is clear that Blender has become a valuable tool in engineering and architecture, two fields that rely heavily on 3D visualization and prototyping.

- **Product design and prototyping:** Blender’s precision modeling and realistic rendering make it suitable for product design and prototyping.
- **Architecture and urban planning:** Blender has robust tools for architectural modeling, visualization, and environmental simulations that are useful for architects and urban planners. Architects can create digital mockups of building projects, simulate light and shadow conditions, and visualize materials.
- **Mechanical and robotics engineering:** Blender is used in mechanical engineering to create and test designs before production. Its physics-based animation tools allow engineers to visualize and test the behavior of mechanical systems, which is

beneficial for fields such as robotics, where researchers need to simulate the movement and control of robotic parts.

As technology evolves, Blender is likely to become even more important in scientific research, integrating AI, real-time rendering, and VR/AR capabilities. Through its commitment to accessibility, adaptability and continuous innovation, Blender has redefined what is possible in 3D graphics and simulation, paving the way for future developments in both science and art.

Keywords: Blender 3D, 3D graphics, 3D simulation, 3D modeling, 3D art, animation.

Implementation of STM32 Microcontrollers on Embedded Projects

Butnaru Petrică*

"Aurel Vlaicu" University of Arad, Faculty of Engineering, Arad, Romania

Scientific Advisor: Valentina E. Bălaş

Abstract

Due to their performance, energy efficiency and numerous integrated peripherals, STM32 microcontrollers are favored in various fields. To ensure optimal functionality, a project requires a thorough analysis of the technical specifications to help in selecting the right microcontroller, making the development boards and implementing them in embedded projects according to the specifications.

This paper deals with current issues and trends in the design of development boards and their use in embedded projects, which include a variety of STM32 microcontrollers, technological progress, difficulties encountered in PCB design, standardization and compliance, and flexibility from the software side.

Our aim was to develop two training boards and an embedded project that use STM32F103RET6 and STM32F103ZET6 microcontrollers. We design blueprints and PCBs that include essential functionality such as communication interfaces, output control, analog values monitoring, and RTC memory. Manufacturing and assembling the boards required specialized services and thorough testing of their functionality.

In order to produce these PCBs, we have relied on specialized services, more precisely the JLCPCB platform, which offers a very good price-quality ratio. We also used the “gerber” extension for PCB fabrication. That is why it was necessary to export the file with “gerber” extensions.

* Corresponding author: **Butnaru Petrică** – petricabutnaru150@gmail.com

The components were soldered to the PCB using Surface Mount Technology (SMT) or Through-Hole Technology (THT) mounting techniques. These mounting techniques were hand-crafted in cooperation with industry experts. Afterwards, both the power supplies and the functionalities of the microcontrollers were thoroughly tested and verified. For programming the microcontrollers we have used the STM32Duino compiler on the Arduino.IDE platform.

The flash memory of the STM32F103RET6 and STM32F103ZET6 microcontrollers has 512 KB, while the SRAM has 64 KB. Both of them contribute by ensuring scalability and flexibility in the design of electronic systems.

The PCBs have been provided with connectors for programming using the “serial” protocol which, in this way, also allows to extend the functionalities of the board using external modules and integrated peripherals. This particular aspect improves the modularity and adaptability of the boards, helping in the development of personalized and innovative solutions.

In conclusion, the development boards incorporating STM32F103RET6 and STM32F103ZET6 provide effective solutions for prototyping and developing more complex embedded electronic applications. The boards are flexible, scalable and support technology innovation.

Keywords: Implementation of STM32 microcontroller, STM32F103RET6, STM32F103ZET6, embedded projects, PCB design, STM32 development board.

Statistical Research of Rehabilitation Measures Persons with Disabilities

Andriy Semeniuk*

"Vasyl' Stus" Donetsk National University, Faculty of Information and Applied Technologies, Vinnytsia, Ukraine

Scientific Advisor: Petro Nikoliuk

Abstract

In recent years, a new concept of reforming the medical system and social expertise has been implemented in Ukraine, which is associated with the use of the International Statistical Classification of Diseases (ICD-10) along with the International Classification of Functioning, Disability, and Health (ICF). This allows for a comprehensive analysis of the health status and functioning of the patient, better planning of treatment, rehabilitation, and the creation of services for people with chronic diseases or disabilities. However, for the successful and full-fledged use of

* Corresponding author, **Andriy Semeniuk** – sam12122003@gmail.com.

these measures, it is necessary to have statistical data on providing persons with disabilities with comprehensive rehabilitation and medical services, and, based on these, to develop models for reforming the medical sector. This should allow for an effective implementation of these innovations in a short time, taking into account the characteristics of each region and types of diseases.

Statistical research is a key option when accounting and classifying knowledge. Each state has faced the need to solve practical state and economic problems. And it is these needs that mandate the collection and processing of various types of information. Increasing the efficiency of the medical sector and its component—the rehabilitation system for persons with disabilities—also requires similar measures. Problems in the rehabilitation system in Ukraine have accumulated over the years, but the significant increase in the contingent associated with military actions requires their resolution in a short time. International experience and the results of research by Ukrainian specialists indicate that almost 100% of soldiers and the majority of the civilian population may require highly qualified assistance.

Despite the current very difficult times, Ukraine, in accordance with the UN Convention on the Rights of Persons with Disabilities, consistently fulfills the state's obligations to such citizens to ensure them a full life. This work is aimed at fulfilling the guarantees of the Constitution of Ukraine regarding equal rights for all compatriots. For this purpose, a central database of persons with disabilities was implemented in the state as a single system for collecting and summarizing statistical data. For its filling, and establishing interaction between different links of the rehabilitation process at the local level, and the sequence of various forms and stages of rehabilitation, increasing control over the results of rehabilitation, and improving the assessment of its effectiveness, an expert system for collecting and processing medical data was developed to assess the patient's condition and provide recommendations for their rehabilitation.

The developed software tool allows for formalizing the description of the condition of a person with a disability (the main data templates are shown in Fig. 1), thus speeding up the decision-making time. Information about patients is stored in an electronic database. The accumulated data is analyzed using statistical research methods, taking into account the influence of various factors on the issuance of recommendations for preventive measures, psychiatric assistance, adaptation and creation of a workplace considering the safety and special needs of a person with a disability; rational employment; physical and sports rehabilitation; teaching basic social skills.

The program allows one to: (i) collect statistical material; (ii) pre-process data; (iii) calculate and interpret generalized statistical indicators; and (iv) model and forecast.

Using the statistical data as well as analyzing these in accordance with particular/local characteristics allows one not only to interpret the results, and also to compare them with results gathered from other regions of Ukraine.

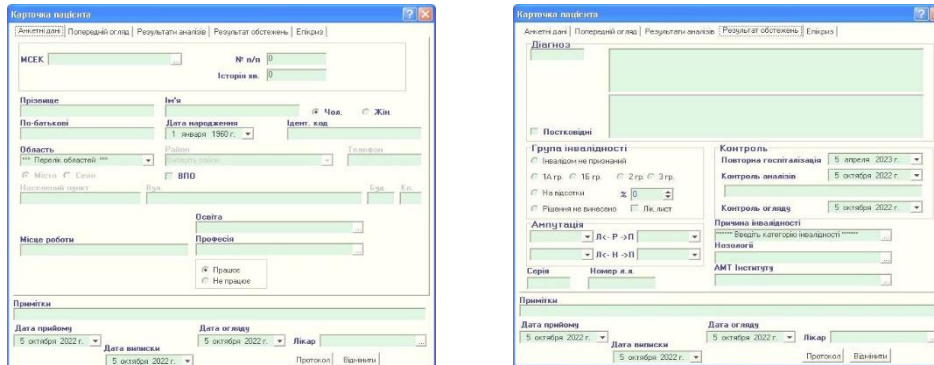


Fig.1. Forms of the data template.

Meanwhile, the functioning and limitations of life activities have to be considered as a complex interaction between the state of health of the individual and the contextual factors of the environment, as well as personal factors.

Keywords: Medical statistics, medical and social commission, rehabilitation, persons with disabilities.

Advanced Targeting Optics Automated Trajectory Adjustments for Optimal Target Accuracy

Radu Marian Oriță^{1*}, Ana-Maria Marin¹, Călin Tudor Topan²

¹*Faculty of Electrical Engineering, National University of Science and Technology POLITEHNICA Bucharest, Romania*

²*Karlsruhe Institute of Technology, Faculty of Mechanical Engineering, Germany*

Scientific Advisor: Simona Mihaela Bibic

Abstract

With military technology becoming more and more sophisticated, all their users need to be better trained and accustomed. We bring here an innovative idea that makes it easy and reliable for everyone to take a “perfect shot”, without being bothered by adjusting their sights and calculating many other effects that may impact the trajectory of the bullet, by using an attachment. Advanced Targeting Optics is an innovative attachment designed to improve long to middle range scopes, using ballistics, and probabilities of ballistics, to deliver precise indication of the bullet trajectory and target.

* Corresponding author: **Radu Marian Oriță** – radu_marian.orita@stud.electro.upb.ro

Using a microprocessor we can calculate different environmental conditions that may affect our trajectory such as gravity, air resistance, wind, Coriolis effect and other factors. These calculations will show an accurate representation on the sight of how the bullet will travel and where it will land, helping the user skip the steps of calculating where it should go, and also being more effective in doing so. All the environmental factors will be collected with different devices that will be part of the attachment and will be sent to the microprocessor as well as the ammunition that is being used and weapon's specifications. Having our best trajectory calculated we can display it on the screen of the scope and the shooter can choose to either adjust their scope on the target, or just use the new marking as a whole. The calculations will be divided into vertical and horizontal calculations. Vertical calculations are gravity, air drag, bullet drop due to parabolic trajectory and spin inflected Magnus effect, while the horizontal calculations will be related to wind and Coriolis effect, where all the differences caused will be added together on the ideal trajectory that is not being affected. However, due to the fact that there are different uncertainties, such as real world variabilities and factory errors, we can add a probabilistic layer on these equations.

Keywords: Smart Scope, Ballistic Effects, Ballistics Calculation, Trajectory Prediction, Military Optics, Long-Range Targeting, Continuum Mechanics.

Driving the Future: An Evolutionary Game Theory Approach to Smart and Innovative Technologies and Strategies

Alexandra-Maria Borş^{1*}, Georgiana Creţu²

¹ *National University of Science and Technology Politehnica Bucharest, Faculty of Applied Sciences, Bucharest, Romania*

² *National University of Science and Technology Politehnica Bucharest, Faculty of Electrical Engineering, Bucharest, Romania*

Scientific Advisor: Simona-Mihaela Bibic

Abstract

This paper looks at how carbon dioxide emissions, a big factor in climate change, are leading the auto industry to rethink, innovate its approach, and develop more sustainable technologies as temperatures rise and weather patterns become more unpredictable. Starting from Evolutionary Game Theory (EGT), this research paper explores the complex market dynamics to facilitate the transition from conventional vehicles to electric vehicles (EVs), cars powered by hydrogen fuel cells (FCEVs), and hybrid vehicles (HEVs). This transition from traditional fossil fuels to cleaner technologies is not only driven by environmental concerns, being fuelled by both

* Corresponding author: **Alexandra-Maria Borş** – alexandra.bors@stud.fsa.upb.ro

consumer demand for eco-friendly options and advances in technology. EGT offers a valuable lens to look at how manufacturers and consumers interact in this evolving market. Car companies are adjusting their strategies, from pricing decisions to investments in research and development, to make EVs, FCEVs, and HEVs more efficient, sustainable, and affordable. While EVs are widely recognized as zero-emission options, FCEVs offer an alternative, with the advantage of releasing only water vapor as they drive by converting hydrogen gas into electricity to power their motors. As these technologies improve and production costs drop, carmakers can lower prices, which in turn raise consumer interest—a chain reaction that gradually builds demand for cleaner vehicles. When one company drops prices on EVs, FCEVs, or HEVs, others in the market often follow to stay competitive. In this way, EGT shows us how market strategies are always evolving based on price shifts and growing interest in sustainable options, creating a feedback loop that keeps the industry moving forward. Unlike traditional Game Theory, which looks at fixed strategies and outcomes, EGT is all about the fluidity of these strategic choices and how they influence the world around us. As awareness of diesel vehicles' environmental impact grows, more people are opting for low- and zero-emission cars like EVs, FCEVs, and HEVs. If manufacturing costs keep decreasing, the adoption of eco-friendly vehicles could speed up, showing us a path toward a cleaner, sustainable future in the transport sector.

Keywords: Evolutionary Game Theory, Sustainable Future in Transportation, Emission Reduction, Climate Change, Market Dynamics, Fossil fuel transition.

8-Bit binary code multiplexers: Optimization and practical implementation

Daniela-Claudia Mladin^{1*}, Raul-Fabian Julean²

^{1,2}"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Anca-Adriana Petcuț-Lasc

Abstract

Multiplexers (MUXes) are essential in the production and data management processes in automotive industry, in manufacturing wiring systems and components for various vehicles, including electric, hybrid, hydrogen, and combustion engine models. This article examines the use of 8-bit encoding multiplexers in internal processes, focusing

* Corresponding authors, **Daniela-Claudia Mladin** – danamladin87@gmail.com, **Raul-Fabian Julean** – raul_julean99@yahoo.com

on their role in optimizing information flows and connectivity within complex networks.

The company employs two models of multiplexers: an older, robust, and larger model, and a newer, compact, and more user-friendly one. These models exhibit significant differences in operation, which lead to operational challenges. The older multiplexer must be positioned upside down, while the new model is positioned vertically, like a book. Moreover, the signal encoding on the new model must be performed as a mirror image compared to the old model, adding complexity to their integration and configuration.

The study analyzes how the multiplexers function, utilizing 8-bit encoding to efficiently select signals within a limited bandwidth, simplifying the wiring process. It also discusses how these devices are employed in drive, a system designed to manage multiple connections, enabling rapid and precise signal distribution. The connections between multiplexers are established through flexible ribbon cables, which are essential for reliable data transfer in industrial production environments.

The methodology includes an analysis of the hardware architecture of the multiplexers and their integration processes. A comparative study of the two types of multiplexers highlights their strengths and weaknesses. Tests revealed that the new model is more efficient in terms of handling and speed, but the orientation and encoding differences between the models can cause errors if not managed properly.

The results demonstrate a clear increase in processing speed and a reduction in costs due to the new multiplexer. However, ensuring the older model functions effectively remains a challenge. Creative solutions are needed to mitigate the impact of these differences on production. Additionally, the analysis shows that these technologies can make the company's infrastructure more scalable, allowing new functionalities to be added without substantial changes to the existing system.

The main contribution of this study is to highlight the advantages and challenges of using 8-bit encoding multiplexers in complex production processes. These findings serve as a valuable guide for other companies aiming to optimize their technological systems. Furthermore, the research paves the way for further studies on how multiplexers can be used in other industries and how their functionalities can be expanded.

Keywords: Multiplexers, 8-bit encoding, data transfer, connections, signal distribution, information flows, network.

Fuzzy linear programming

Paul-Andrei Sabou*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lorena Popa

Abstract

Linear programming is an important part of mathematical programming. Linear programming problems are unique among mathematical programming problems in that the constraints and the objective function are expressed by linear functions. The particular form of linear programming problems determined the use of a mathematical apparatus from linear algebra and the development of methods for determining the optimal solutions of the problem. After the introduction of fuzzy sets by L.A. Zadeh in 1965, as a natural consequence appeared and developed fuzzy linear programming which is a current topic even today. This paper is dedicated to fuzzy linear programming and contains basic notions related to fuzzy numbers as well as some ranking functions that allow fuzzy numbers to be ordered, accompanied by examples. Also here, I presented three different methods for solving fuzzy linear programming problems. The first presented method is proposed by E. Kuppusamy and V. E. Sasikala which consists in using a ranking function for the coefficients and thus obtaining an approximate classical problem. Moreover, through an example I showed that in the case of minimum problems it is preferable to use the Magnitude ranking function, and in the case of maximum problems, the Robust ranking function. The other two presented methods contain a proprietary algorithm for solving fuzzy linear programming problems and return an exact optimal solution. The Kumar method can also be applied to fully fuzzy systems of linear equations. For fuzzy linear programming problems, the Kumar method uses a ranking function for the objective function to obtain a real objective function. The method proposed by Ezzati is based on the lexicographic method, which allows the comparison of 2 fuzzy numbers, and the fuzzy linear programming problems are transformed into an equivalent problem with several objective functions. At the end of the paper, a fuzzy linear programming problem is solved both by the Kumar method and by the Ezzati method and the results obtained are compared, concluding that the Ezzati method is superior to the Kumar method, because it leads to a better optimal solution.

Keywords: linear programming, fuzzy numbers, objective function, ranking function

* Corresponding author: **Paul-Andrei Sabou** – e-mail: paulsabou02@yahoo.com

Interesting Observations about the Beal Conjecture

Adrian-Simion Jiva*, Paul-Cristian Tonta, Constantin-Andrei Stoian,
Stefan Gheorghe Cismaş, Rosca Daria Georgiana, Victoria Alena Dozy
"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

The Beal Conjecture is one of those fascinating problems in mathematics that might seem simple at first glance but quickly reveals a profound complexity. Imagine you're working with numbers and you're looking at expressions like $A^x + B^y = C^z$. Here, A , B , and C are positive integers, and the exponents x , y , and z are also positive integers greater than 2. The question we're grappling with in the Beal Conjecture is this: is it possible for such an equation to hold true without A , B , and C having a common prime factor? Let's break it down. If you've ever heard of Fermat's Last Theorem, you'll find this problem somewhat familiar. Fermat's Last Theorem, which states $a^n + b^n = c^n$ has no whole-number solutions when n is greater than 2, has been solved, thanks to mathematician Andrew Wiles. But Beal's Conjecture goes a step further. It posits that if $A^x + B^y = C^z$ does hold true, then A , B , and C must share at least one prime factor. For instance, if the solution is something like 8, 27, and 64, we would need these numbers to have some common factor like 2 or 3 for the equation to be valid under this conjecture. Now, if you're wondering why anyone would care about this conjecture, there's a good reason. It touches on fundamental ideas in number theory that can have implications for fields as varied as cryptography and computer science. Understanding the nature of prime factors and how they relate to each other helps mathematicians get closer to understanding the underlying structure of numbers. And if you or I could find a proof or a counterexample, we'd make a significant contribution to mathematics. In fact, there's even a monetary prize for anyone who can solve it! So far, though, no one has been able to crack it. The Beal Conjecture sits tantalizingly on the edge of our current understanding, a reminder of how even simple questions about numbers can lead us to the limits of human knowledge. If you or I ever manage to solve it, we'd not only win fame and a nice cash prize but would also push the boundaries of what we know about numbers and their relationships. Until then, the Beal Conjecture remains one of those mathematical mysteries waiting for someone to solve.

This project aims to delve into the fascinating realm of the Beal Conjecture, shedding light on its intriguing aspects and providing compelling visualizations that enhance our understanding of this mathematical hypothesis. We aspire not only to present

* Corresponding author, **Adrian-Simion Jiva** – bosumail81@gmail.com

interesting facts but also to contribute meaningfully to the ongoing discourse surrounding the Beal Conjecture.

Keywords: Beal Conjecture, number theory, integer powers, prime factorization, cryptography, Fermat's Last Theorem.

Perfect numbers

Cristina Balea*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

I have chosen to study this subject in the first place because it sounds good. The word perfect caught my attention followed by the word number which is interesting to me. I like numbers, their fascinating properties, and that's why I chose to study everything closest to numbers, number theory, Mathematics and Computer Science.

What is a perfect number?

A perfect number, is a positive integer that is equal to the sum of its proper divisors. The smallest perfect number is 6, which is the sum of 1, 2, and 3. Other perfect numbers are 28, 496, and 8,128. The discovery of such important numbers is lost in prehistory.

It is not known exactly when Perfect Numbers were first discovered in history, or when they were studied, it is thought that they may even have been known to the Egyptians, and may have even been known before. Although the ancient mathematicians knew of the existence of Perfect Numbers, it was the Greeks who took a keen interest in them, especially Pythagoras and his followers.

It is known, however, that the Pythagoreans studied perfect numbers for their "mystical" properties, but they did little of mathematical significance with this numbers.

The earliest extant mathematical result concerning perfect numbers occurs in Euclid's *Elements*, where he proves the proposition: Here "double proportion" means that each number is twice the preceding number, as in 1, 2, 4, 8, For example, $1 + 2 + 4 = 7$ is prime; therefore, $7 \times 4 = 28$ ("the sum multiplied into the last") is a Perfect Number.

The most important theorem remain: The Euclid-Euler theorem: $2^{p-1} * (2^p - 1)$, knowing that p is a prime number.

* Corresponding author, **Cristina Balea** – cristina.balea@colecoarad.ro

Demonstration:

- Let's consider:
- $P=2$
- K is our perfect number that we are going to find
 - $K = (2^2 - 1) * 2^{2-1}$
 - $K = 3 * 2$
 - $K = 6$

A very important observation about Perfect Numbers is that all Perfect Numbers are even numbers. Whether or not perfect odd numbers exist is still unknown.

Another important property of Perfect Numbers is that every Perfect Number has the last digit 6 or 8, alternatively (6; 28; 496; 8128; 33550336, etc.).

In conclusion, perfect numbers are an interesting topic to learn about. If you pay just a little bit of your attention, they are easy to understand and to work with them in different exercises or use in different algorithms

Keywords: perfect number, Euclid, Euler, number theory, prime number.

Transcendental numbers

Ilie Catalin Suci^{*}, Denisa-Maria Zagrean, Branislav Raul Moga
"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

Transcendental numbers are a fascinating and intricate concept in the realm of mathematics. They are defined as numbers that are not the roots of any non-zero polynomial equation with rational coefficients. In simpler terms, while all integers, rational numbers, and many algebraic numbers (like square roots) can be expressed as solutions to polynomial equations, transcendental numbers evade this classification entirely. The discovery and exploration of transcendental numbers have deep implications in various fields of mathematics, particularly in number theory and algebra.

The notion of transcendental numbers was formally introduced in the early 19th century. The term "transcendental" itself was popularized by the mathematician Joseph Liouville, who is also credited with proving the existence of such numbers in 1844. Liouville constructed specific examples of transcendental numbers, the most famous being his eponymous Liouville numbers, which are numbers that can be approximated

^{*} Corresponding author, **Ilie Catalin Suci** – suciucatalin1234@gmail.com

"too well" by rational numbers. His work laid the groundwork for understanding transcendental numbers and their implications.

However, it was the mathematician Georg Cantor who significantly advanced the study of transcendental numbers. In the 1870s, Cantor demonstrated that the set of transcendental numbers is uncountably infinite, meaning that there are "more" transcendental numbers than there are rational or algebraic numbers. This revelation highlighted the vastness of transcendental numbers and reshaped our understanding of the number continuum.

One of the most famous transcendental numbers is e , the base of natural logarithms, which arises naturally in calculus and complex analysis. Another renowned example is π , the ratio of a circle's circumference to its diameter. In 1882, the mathematician Ferdinand von Lindemann proved that π is transcendental, which had profound implications for mathematics, including the impossibility of squaring the circle—a problem that had perplexed mathematicians for centuries.

The significance of transcendental numbers extends beyond mere curiosity; they play essential roles in various mathematical theories and applications. For example, the existence of transcendental numbers underlines the limitations of algebraic methods in solving all mathematical problems. They serve as a reminder of the richness and complexity of the number system, illustrating that not all numbers can be neatly categorized.

Despite their abstract nature, transcendental numbers find relevance in fields such as cryptography, computer science, and chaos theory. The unpredictability and non-repeating nature of many transcendental numbers make them useful in algorithms that require high degrees of randomness and complexity. Additionally, their study continues to inspire mathematicians, leading to ongoing research into their properties and relationships with other types of numbers.

In conclusion, transcendental numbers represent a profound and intricate aspect of mathematics that challenges our understanding of numbers and their classifications. From their discovery by Joseph Liouville to the exploration of their vastness by Georg Cantor, these numbers have captured the imagination of mathematicians for over a century. As we delve deeper into the world of numbers, transcendental numbers remind us of the infinite possibilities that lie beyond algebraic confines, inviting us to explore the boundaries of mathematical knowledge.

The study of transcendental numbers has deepened our understanding of mathematics, revealing the limitations of algebraic methods and highlighting the vastness of the number continuum. Defined as numbers that cannot be roots of any polynomial with rational coefficients, such as e and π , these numbers highlight the complexity of mathematical classifications. Exploring them highlights the fact that not all numbers

fit neatly into existing frameworks, inspiring continued research into their properties and applications in diverse fields such as cryptography and chaos theory.

Keywords: transcendental numbers, polynomial, Euler

Goldbach`s conjecture

Cornelia-Emanuela Ihnatiuc*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

Goldbach's conjecture, first proposed by the Prussian mathematician Christian Goldbach in 1742, posits that every even integer greater than 2 can be expressed as the sum of two prime numbers. This conjecture is one of the oldest unsolved problems in mathematics and has intrigued mathematicians for centuries. Despite extensive numerical verification and the development of advanced mathematical techniques, a general proof remains elusive.

Christian Goldbach originally presented his conjecture in a letter to Leonhard Euler, suggesting that all even numbers could be expressed as sums of primes. This letter marked the beginning of a long mathematical journey. Over the years, the conjecture has been tested extensively, and mathematicians like Euler, Hardy, and Vinogradov contributed significantly to its study. Notably, Euler expanded on Goldbach's ideas, leading to further exploration in number theory.

The Nature of the Conjecture

The conjecture can be stated simply: for any even integer $n > 2$, there exist prime numbers p and q such that $n = p + q$. While this statement appears straightforward, the challenge lies in proving it for all even integers. The conjecture has been verified for very large even numbers, up to 4×10^{18} , using computational methods, yet no one has provided a definitive proof.

Methods of Verification

Various mathematical approaches have been employed to verify Goldbach's conjecture. Early proofs relied on computational checks, which confirmed the conjecture for a vast range of numbers. In addition, methods from analytic number theory, such as the Hardy-Littlewood circle method, have been instrumental. This

* Corresponding author, **Cornelia-Emanuela Ihnatiuc** – ihnatiuccorneliaemanela@gmail.com

method allows mathematicians to estimate the number of ways a given even integer can be expressed as a sum of primes.

Implications in Mathematics

The significance of Goldbach's conjecture extends beyond its immediate statement. It has connections to other important areas of number theory, including the distribution of prime numbers. The conjecture also plays a role in the development of new mathematical theories and techniques. It has inspired research in additive number theory, where mathematicians explore the additive properties of numbers and their relationships.

Related Conjectures and Results

Several related conjectures and results have emerged in connection with Goldbach's conjecture. For example, the weak Goldbach conjecture states that every odd integer greater than 5 can be expressed as the sum of three primes. Additionally, Vinogradov's theorem, proved in the 1930s, establishes that every sufficiently large odd integer can be represented as a sum of three primes, further demonstrating the intricate relationships within number theory.

Current Research and Future Directions

Despite the lack of a general proof for Goldbach's conjecture, ongoing research continues to seek a resolution. Recent advances in computational techniques and number theory offer hope for a breakthrough. Researchers are exploring new approaches, including connections to other mathematical fields like algebraic geometry and probabilistic number theory. The conjecture remains a fertile ground for mathematical exploration, inspiring both professional mathematicians and enthusiasts alike.

Conclusion

Goldbach's conjecture stands as a testament to the enduring mysteries of mathematics. Its simplicity and depth have captivated mathematicians for centuries, prompting numerous investigations and discoveries in number theory. As research progresses, the hope remains that a definitive proof will eventually be found, shedding light on this fundamental aspect of prime numbers and their relationships.

Keywords: numbers, investigation, conjecture, Goldbach's conjecture.

Euler's Totient Function and its Importance for Cryptography

Rareş Nicolae Stanciu*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Dominic Burcezan

Abstract

The goal of this research paper is to illustrate the importance of Euler's Totient function in our day to day life, in regards with our information security. The function itself will be presented at great lengths including its history and origin, as well as its importance in the field of mathematics. In number theory, Euler's Totient function counts the positive integers up to a given positive integer n that are relatively prime with the given n . In other words, the function counts the numbers of integers k , for $1 \leq k < n$ for which the greatest common divisor $\gcd(n, k) = 1$.

The paper will then go on a tangent to present the cryptographical applications of the function. Since this function deals with relative prime numbers, it is extremely well suited for finding large prime numbers so that they may be used for encryption of a message in a secure way. Because of this, Euler's Totient function is one of the fundamental prerequisites necessary for the implementation of an asymmetrical cryptographic algorithm.

We will then define some of the basic terminology and concepts necessary for the understanding of the inner workings of modern cryptography, with a strong emphasis on the asymmetrical algorithms, which are also named public key algorithms. In this case, the algorithm presented will be the Rivest-Shamir-Adleman (RSA) algorithm of encryption.

The RSA algorithm will be presented in detail and the way it functions thoroughly explained. Euler's Totient function is a fundamental part of this algorithm and extremely important for the selection of prime numbers. The prime numbers used during the course of the algorithm will be what gives this algorithm its strength, as such some smaller examples will be given to illustrate the sheer magnitude and scale of the transformations that can happen even when selecting small numbers.

In the end some of the most important applications of this algorithm will be presented, which are the digital signature and the secure encryption of messages using a public key. All these things are tied directly to information security and are extremely important in our daily life. As technology progresses even faster than ever before, new threats to our security and privacy arise just as fast. As such it is important to know

* Corresponding author, **Rareş Nicolae Stanciu** – stanciurares2001@yahoo.com

how to protect ourselves and how mathematical functions are our fundamental weapon in our fight against threats to our privacy.

Keywords: Cryptography, Euler's Totient function, RSA algorithm, public key encryption, asymmetrical encryption, information security.

Permutable Prime Numbers

Ionela Andreea Boiciuc*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

Prime numbers are those that have exactly two divisors: 1 and themselves. Throughout history, mathematicians have studied numerous properties of these numbers, and one interesting concept is that of permutable prime numbers. A permutable prime is a prime number that remains prime when its digits are rearranged in any order.

A permutable prime, also known as an anagrammatic prime, is a prime number that, in a given base, can have its digits rearranged in any permutation and still remain a prime number. E. Richert, who is believed to have initially studied these prime numbers, is the one who coined the term "permutable primes".

Permutable primes have also been investigated from the perspective of their distribution. Although prime numbers, in general, become rarer as numbers increase, permutable primes are even scarcer. For example, between 1 and 100, there are only a few permutable primes: 13, 17, 31, 37, 71, and 73.

Another fascinating aspect of these numbers is their connection to concepts of symmetry and order in mathematics. The study of permutable primes not only highlights the beauty of number structures but also the complexity of the interactions between them.

The study of permutable primes intersects with number theory and combinatorics. An interesting aspect is that these numbers cannot contain the digits 0, 2, 4, 5, 6, or 8, because if such a digit is at the beginning of a permuted number, it would no longer be prime (for example, a number ending in 0 or 5 cannot be prime, except 5). This, permutable primes must be composed of the digits 1, 3, 7, and 9.

A permutable prime that is different when written in reverse is also known as a reversible prime or a mirp (the word "prime" spelled backwards). The term "mirp" is preferred to avoid confusion with palindromic primes (which are also sometimes called

* Corresponding author, **Ionela Andreea Boiciuc** – boiciucionela0@gmail.com.

reversible primes). The first mirp numbers are: 13, 17, 31, 37, 71, 73, 79, 97, 107, 113, 149, 157, 167, 179, 199.

A classic example of a permutable prime is 13. When its digits are permuted, 31 is obtained, which is also prime. Thus, 13 and 31 form a pair of permutable primes. Other examples include 17 and 71, or 37 and 73, each having permutations that are also prime.

In conclusion, permutable primes are a captivating subject in number theory, featuring unique properties and interesting implications. Studies on these numbers continue to provide new insights into the structure of prime numbers and the connections between various mathematical concepts.

Keywords: permutable prime, prime numbers, anagrammatic prime.

Collatz's conjecture

Gabriela Groza, Anamaria Velciov*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

What is a conjecture?

A conjecture is an unproven area of mathematics, a guess, a probability, or a hypothesis. It is a proposition for which no evidence for or against has yet been found.

The Collatz conjecture (also known as the $3n + 1$ conjecture, Syracuse conjecture, Ulam conjecture, Hailstone sequence, or Hailstone numbers, hail numbers) is a still unsolved mathematical conjecture.

$$f(n) = \begin{cases} \frac{n}{2} & \text{if } n \text{ is even} \\ 3n + 1 & \text{if } n \text{ is odd} \end{cases}$$

The Collatz conjecture takes its name from the German mathematician Lothar Collatz (died 1990), who was the first to talk about it in 1937

The demonstration of this connection is done through the following steps:

The chosen number must belong to $\mathbb{Z}^+(\text{none})$;

* Corresponding author, **Anamaria Velciov** – boboiciov_maria@yahoo.com.

If $n \% 2 = 0$, then the number is divisible by 2 ($n/2$);

If $n \% 2 \neq 0$, then the number is multiplied by 3, then added by 1 ($(n \times 3) + 1$);

As an example, let's take a look at the following:

We will choose number 15.

1. 15 is an odd number, so $(15 \times 3) + 1 = 46$;
2. 46 is an even number, so $46/2 = 23$;
3. 23 is an odd number, so $(23 \times 3) + 1 = 70$;
4. 70 is an even number, so $70/2 = 35$;
5. 35 is an odd number, so $(35 \times 3) + 1 = 106$;
6. 106 is an even number, so $106/2 = 53$;
7. 53 is an odd number, so $(53 \times 3) + 1 = 160$;
8. 160 is an even number, so $160/2 = 80$;
9. 80 is an even number, so $80/2 = 40$;
10. 40 is an even number, so $40/2 = 20$;
11. 20 is an even number, so $20/2 = 10$;
12. 10 is an even number, so $10/2 = 5$;
13. 5 is an odd number, so $(5 \times 3) + 1 = 16$;
14. 16 is an even number, so $16/2 = 8$;
15. 8 is an even number, so $8/2 = 4$;
16. 4 is an even number, so $4/2 = 2$;
17. 2 is an even number, so $2/2 = 1$

For the sequence $n=15$, it took us 17 steps to get to number 1.

The Collatz Conjecture suggests that, regardless of the starting value, this algorithm will eventually conclude. But reaching the end isn't always easy. For example, beginning with the number 27 requires as many as 111 calculations to finally arrive at 1.

To test the Collatz hypothesis on large numbers, several computational projects have been launched. As of 2019, every natural number smaller than 1,152,921,504,606,846,976 has been tested, and each one has met the conditions of the Collatz Conjecture within a finite number of steps. This remarkable result strengthens the hypothesis that the Collatz algorithm indeed terminates regardless of the starting number chosen.

At times, the problem is presented in a slightly different way. The stopping condition (specifically, stopping when) is omitted from the conjecture, allowing the sequence to theoretically continue indefinitely. With this interpretation, the Collatz Conjecture suggests that the sequence generated by the algorithm will always enter the repeating cycle 1, 4, 2, 1, 4, 2...

Keywords: Collatz Conjecture, hypothesis, number, condition, algorithm.

Diophantine equation

Mara Haiduc, Natalia Iordache*, Vanessa Țîna

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Lavinia Elisabeta Sida

Abstract

In mathematics, a Diophantine equation is an equation, typically a polynomial equation in two or more unknowns with integer coefficients, for which only integer solutions are of interest. A linear Diophantine equation equates to a constant the sum of two or more monomials, each of degree one. An exponential Diophantine equation is one in which unknowns can appear in exponents.

Diophantine problems have fewer equations than unknowns and involve finding integers that solve simultaneously all equations. As such systems of equations define algebraic curves, algebraic surfaces, or, more generally, algebraic sets, their study is a part of algebraic geometry that is called Diophantine geometry.

Finding all right triangles with integer side-lengths is equivalent to solving the Diophantine equivalent equation $a^2+b^2=c^2$

To solve a linear Diophantine equation we can use the Euclidean algorithm. In mathematics, the Euclidean algorithm, or Euclid's algorithm, is an efficient method for computing the greatest common divisor (GCD) of two integers (numbers), the largest number that divides them both without a remainder. It is an example of an algorithm a step-by-step procedure for performing a calculation according to well-defined rules, and is one of the oldest algorithms in common use. It can be used to reduce fractions to their simplest form, and is a part of many other number-theoretic and cryptographic calculations. The Euclidean algorithm has many theoretical and practical applications. It is used for reducing fractions to their simplest form and for performing division in modular arithmetic.

The Euclidean algorithm is based on the principle that the greatest common divisor of two numbers does not change if the larger number is replaced by its difference with the smaller number.

We'll give you an example, 21 is the GCD of 252 and 105 (as $252 = 21 \times 12$ and $105 = 21 \times 5$), and the same number 21 is also the GCD of 105 and $252 - 105 = 147$, Since this replacement reduces the larger of the two numbers, repeating this process gives successively smaller pairs of numbers until the two numbers become equal. When that occurs, that number is the GCD of the original two numbers. By reversing the steps or using the extended Euclidean algorithm, the GCD can be expressed as a linear

* Corresponding author, **Natalia Iordache** – iordachenatalia@icloud.com

combination of the two original numbers, that is the sum of the two numbers, each multiplied by an integer, the program we wrote in C++ will help you understand better.

In this code, the function “cmmdc” calculates the GCD using Euclid’s method, which is based on the fact that $\text{GCD}(x,y)$ is the same as $\text{GCD}(b,a\%b)$ until b becomes 0. When b reaches 0, A contains the GCD. The fact that the GCD can always be expressed in this way is known as Bézout's identity. The version of the Euclidean algorithm described above which follows Euclid's original presentation can take many subtraction steps to find the GCD when one of the given numbers is much bigger than the other. A more efficient version of the algorithm shortcuts these steps, instead replacing the larger of the two numbers by its remainder when divided by the smaller of the two, with this version, the algorithm stops when reaching a zero remainder.

In this project, we have dedicated to study of Diophantine equations, analyzing the applicability of Euclid’s algorithm in solving them.

Keywords: diophantine equation, Euclidean algorithm.

Machine learning and data analysis

Alexia Cuțaru*

"Aurel Vlaicu" University of Arad, Faculty of Exact Sciences, Arad, Romania

Scientific Advisor: Codruța Stoica

Abstract

The What is Machine Learning?

Machine Learning, often abbreviated as ML, is a subset of artificial intelligence (AI) that focuses on the development of computer algorithms that improve automatically through experience and by the use of data. In simpler terms, machine learning enables computers to learn from data and make decisions or predictions without being explicitly programmed to do so. At its core, machine learning is all about creating and implementing algorithms that facilitate these decisions and predictions. These algorithms are designed to improve their performance over time, becoming more accurate and effective as they process more data.

The importance of machine learning

Data is the new oil of the twenty-first century, and machine learning is the engine that drives this data-driven society. In the current digital era, it is an essential technology whose significance cannot be emphasized enough. The US Bureau of Labor Statistics

* Corresponding author, **Alexia Cuțaru** – cutarualexia@gmail.com

projects a 26% increase in employment in this sector between 2023 and 2033, which is consistent with the industry's anticipated growth.

Mathematics in Machine Learning

Mathematics is the foundation of machine learning, enabling algorithms to learn from data, make predictions, and uncover patterns. Key areas include linear algebra, which provides structures for representing data as vectors and matrices, enabling operations essential for neural networks and dimensionality reduction. Calculus, particularly in optimization, underlies the process of adjusting model parameters to minimize errors, with techniques like gradient descent. Probability and statistics are crucial for understanding data distributions, making inferences, and evaluating model performance, especially in probabilistic models like Bayesian networks. Further, advanced areas like information theory and topology contribute to machine learning by measuring information gain and analyzing high-dimensional data structures. Together, these mathematical fields equip machine learning with the precision, robustness, and adaptability required to tackle complex tasks across domains like image recognition, natural language processing, and autonomous systems.

Applications of Machine Learning

Machine learning is transforming a wide range of fields by enabling systems to make intelligent predictions, decisions, and adaptations based on data.

- In healthcare, machine learning algorithms assist in diagnosing diseases, predicting patient outcomes, and personalizing treatment plans, with applications in medical imaging and genomics.
- In finance, machine learning models detect fraud, assess credit risk, and manage investment portfolios, allowing for faster and more accurate decision-making.
- In the realm of customer service, chatbots and recommendation engines powered by machine learning provide personalized support and product suggestions.
- Autonomous vehicles rely on machine learning to process sensor data, recognize objects, and navigate safely in real time.
- Additionally, in fields like agriculture, machine learning optimizes crop yields and monitors plant health by analyzing data from sensors and satellites.

From smart home devices to climate modeling, machine learning applications continue to evolve, driving innovation and efficiency across industries.

Keywords: processing data, linear algebra, future dependence.

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Editors:

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