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Multi-Criteria Performance Evaluation of Digital Electronics Using the VIKOR Method

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Abstract: *Convolutional neural networks (CNNs) have revolutionized large-scale image recognition due to their speed and accuracy, fueling extensive research into their development. However, CNNs are computationally intensive, leading to significant processing delays. A primary challenge lies in the computation of matrix multiplications, fundamental to CNN operations, with over 80% of processing time dedicated to performing convolutions. This paper proposes a novel DEAP CNN design leveraging core silicon photonics, rendering it compatible with various device platforms. Building upon prior work on photonic CNNs incorporating DRAM, buffers, and mirroring resonators, our approach details a specific input representation and illustrates an example algorithm utilizing the MNIST dataset to demonstrate handwritten digit recognition mapped to photonic systems. The European Commission initiative SCENET aims to foster collaboration between academic and industrial sectors, facilitating knowledge transfer to drive innovation and promote new research projects within this domain. A comprehensive roadmap provides a vision for the future, addressing persisting technical challenges while reflecting on historical contexts and progress over time. The study employs the VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method, a multi-criteria decision-making technique, to evaluate the performance of various electronic categories, including Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems, across key parameters: Noise Immunity, Programmability, Integration, and Reproducibility. Through systematic calculations of Sj, Rj, and Qj values, the VIKOR method enables a quantitative assessment and ranking of these categories. The analysis reveals that Communication Systems achieve the highest overall ranking with a Qj score of 1, underscoring their paramount importance in facilitating global connectivity and information exchange. Quantum Electronics closely follow with a Qj score of 0.846963, highlighting their growing significance and potential for advancements. Control Systems, Power Electronics, and Analog Electronics secure subsequent ranks based on their respective Qj scores. The VIKOR method's comprehensive evaluation framework provides valuable insights for decision-makers, aiding strategic planning, resource allocation, and prioritization of research and development efforts within the electronics and communication sectors. The study emphasizes the importance of adopting multi-criteria decision-making approaches in evaluating complex systems and technologies, ensuring well-informed and balanced decisions amidst rapidly evolving technological landscapes.*

Keywords: *VIKOR method, Multi-criteria decision-making, Digital electronics, Communication systems, Quantum electronics, Noise immunity, Programmability, Integration, Reproducibility and Performance evaluation*

1. INTRODUCTION

The success of CNNs in large-scale image recognition is attributed to their speed and accuracy, prompting extensive research into their development. However, CNNs are computationally demanding, leading to significant processing delays. A primary challenge is the computation of matrix multiplications, which is fundamental to CNN operations. Notably, over 80% of the processing time is dedicated to performing convolutions. The DEAP CNN design leverages core silicon photonics, making it compatible with various device platforms. This advanced approach in silicon photonics has been recently developed to optimize large-scale ads with a level of sophistication necessary for seamless integration. The proposed framework is multi-layered and facilitates the activation of networks within a deep learning framework. Building upon the work of Mehrabian et al., who proposed a viable architecture for photonic CNNs incorporating DRAM, buffers, and mirroring resonators, our approach advances this concept by detailing a specific input representation and illustrating an example algorithm. We utilize the MNIST dataset to demonstrate how tasks such as handwritten digit recognition can be effectively mapped to photonic systems [1]. In this context, the European Commission is referred to as SCENET. The network aids these applications with a focus on isolation. SCENET's scope encompasses both academic and industrial sectors, fostering collaboration among groups from educational institutions. It facilitates the transfer of knowledge to the industry and drives innovation, while also promoting new research projects. A roadmap serves as a comprehensive vision for the future, meticulously detailing any associated documentation. The journey begins by reflecting on historical contexts, examining progress over time, and addressing any persisting technical challenges within applications. While scientific breakthroughs from discoveries are unpredictable, the course of science and technological advancement can be strategically planned, progressing more rapidly when specific goals are clearly defined [2]. Custom 3D shapes and their transformation are typically achieved through either 3D printing or manual assembly. When using 3D printing to create intricate geometries in a single process, the interaction between different materials is quite limited. On the other hand, manual assembly allows for the incorporation of various components, such as sensors and displays, by adding them with standard off-the-shelf touch inputs and outputs. Folios harnesses the power of folding. Their techniques apply 3D wrapping routines across various fields, from everyday objects and packaging to intricate origami, robotics, and foldable structures. These materials boast a high strength-to-weight ratio, being exceptionally thin, light, hollow, and deformable. Additionally, Folios integrates printed electronics, enabling thin sensors and outputs that can detect environmental elements and cover expansive, deformable surfaces [3]. His extensive use of mechanical methods in his work significantly contributes to the understanding of biological and quantum systems. He is dedicated to promoting a deeper comprehension of the mechanisms organisms use for energy efficiency, especially those that convert chemical energy into mechanical energy during muscle contraction. The energy efficiency of electronics, particularly computers, has become a significant issue. The exponential growth of the Internet and related systems such as supercomputers, data hubs, and personal computers account for approximately 15% of the world's total energy consumption, a figure expected to rise in the near future. Enhancing the energy efficiency of electronic systems or reducing their usage can yield substantial economic and environmental benefits, contributing to the fight against global warming, fostering sustainable economic growth, and protecting the environment. These critical and fascinating topics were extensively discussed and published by KP Tobacco in his lectures and later works [4]. Systems and their components can be analyzed to anticipate failures and mitigate unexpected events. This proactive approach reduces the likelihood of breakdowns, providing support and cost savings. By assessing the health of systems and detecting degradation before actual failures, predictive methods become crucial, especially in electronics-heavy systems prevalent today, like those found in aircraft where digital electronics govern engine and flight management functions during operation. The issue with electronics lies in the frequent occurrence of intermittent failures. These failures manifest when a system doesn't execute its intended function intermittently. Such failures involve sporadic disruptions or performance deterioration, making it challenging to predict or address them consistently. While the system may not consistently fail outright, intermittent failures can persist and recur frequently, complicating troubleshooting efforts [5]. This device has two inputs and one output. At zero frequency, it maintains power at the inputs with a higher gain factor, multiplying the difference. Operational amplifiers (OPAs) are fundamental in analog electronics due to their versatility. They serve as building blocks for various circuits through the use of feedback mechanisms, often incorporating simple components like resistors or capacitors. The characteristics of an overall circuit, such as gain and frequency response, are primarily determined by the external components used. Variations in circuit performance due to manufacturing tolerances and mismatches also play a role. By utilizing feedback circuits, a single OPA can perform multiple functions, ranging from basic operations like addition and multiplication to more complex tasks such as integration, differentiation, buffering, and filtering [6]. The signal's power is amplified at the cost of increased power consumption. Hence, an amplifier boosts a small input signal by drawing power based on its design. The output power is significantly higher under these amplifying conditions. Due to the necessity of conserving quantum energy, using individual molecules as amplifiers is not advisable and is excluded from this framework. However, transistors have another application in digital computers for processing information. In these systems, molecules can potentially be used to convert signals efficiently, representing a promising area for advancement. For a circuit with a large output current, it is essential to ensure efficient fan-out, meaning it should be capable of reliably driving multiple subsequent stages. This requires the circuit to have robust driving capabilities. Logical circuits and functions should be designed not only to perform well but also to provide sufficient power at the output to drive the inputs of multiple gates effectively. However, it is crucial that the high output of the circuit is not connected directly to the input of the same device to avoid any potential issues

[7]. This list is not comprehensive. It encompasses social, industrial, scientific, and technological developments. One of the three main areas of advancement in the field includes improvements in technology. Key observations include higher speeds (or greater bandwidth), enhanced instrument sensitivity, and a continual demand for less invasive techniques. Additionally, there is growing pressure on the social sector for environmental compatibility, sustainable energy, and resource sources. Although these developments are significant and not always interconnected, political and economic pressures are expected to drive their integration over the next decade. They are utilized to cool most of the current applications. However, significantly more work is required in this area to meet society's demand for efficiency. Cry coolers with greater cooling power and performance beyond theoretical predictions are on the horizon. Currently, coolers only achieve unacceptably low efficiencies, amounting to just a few percent of the theoretical value [8]. To address the wide range of applications, high-performance and seamlessly co-integrated n- and p-channel transistors are required. However, in recent fully prepared organic CMOS circuits, despite attempts, holes exhibit less mobility, while electrons show orders of magnitude lower mobility, thus limiting their application domains. The same issue arises in thin-film silicon CMOS circuits; however, in this case, electrons have high mobility while holes have low mobility. Efforts have been made to develop a hybrid CMOS architecture using both organic and inorganic materials, but the manufacturing processes are not straightforward due to material incompatibility. Field-Effect Transistors (FETs) have seen significant progress in their fabrication and the use of gate dielectrics. They can function as substrates with high mobility, particularly when utilizing semiconductor oxides. These transistors are linked to a fixed gate capacitance, offering low resistance while enabling large current flow at specific bias voltages. The unique foam-like texture of the paper used in their construction contributes to the enhanced performance of FETs [9]. Discrete and analog components of a computer, though closely related, are typically designed independently. Prior to this, the entire system is generally conceptual and not physically tested. This challenge is further complicated by the critical time constraints faced by real-time control software, making it difficult to thoroughly test before final implementation. These factors necessitate a formal process for system specification, which we aim to introduce here. On the other hand, numerous large corporations have invested heavily in developing custom solutions tailored to their specific needs. These solutions often become the internal standard for their software development and product growth. While this approach can streamline complex systems, it can also impede development due to the involvement of multiple entities. Nonetheless, it allows for detailed control and maintains the necessary security level for proprietary information. In this paper, we present an integrated approach to address these challenges [10]. The demand for telecommunication and internet services is rising, leading to a surge in applications. This increase necessitates expanding exchange capacity and enhancing the speed of communication networks. Modern technology, which supports hundreds of gigabits per second over distances exceeding hundreds of kilometers, relies on optical connections. These connections depend on optical signals that carry information, which is modified through the interconnection of optical fibers. Rapid advancements in information technology necessitate immediate innovation. Future developments require new methods for data storage, expansion, and communication, alongside the design of novel devices. This involves replacing traditional materials to facilitate both electrical and optical signaling, and developing new principles for signal processing. Promising candidates for these advancements include organic molecules for electronics and photonic devices for enhanced perception [11]. Low-dimensional nanomaterials with scalable properties hold promise for future high-speed and low-power applications due to their unique and exceptional transport characteristics. These materials exhibit novel physics that result in distinctive electronic properties, granting access to new functionalities. Their ultra-thin dimensions contribute to the development of flexible and compact electronic devices, opening up new opportunities. Among the most significant 1D nanomaterials are single-wall carbon nanotubes (SWNTs). With diameters ranging from 1 to 3 nm, SWNTs display chirality-dependent properties. Notably, their high mobility enhances their current carrying capacity, low intrinsic capacitance, and exceptional thermal and mechanical characteristics [12]. However, linear methods like self-phase modulation (SPM) are used to offset chromatic dispersion (CD). These linear techniques do not address non-linear events. Non-optical linearity is related to optical scattering, which affects the performance of high-speed transmission systems. Optical phase coupling is a well-known technique proposed to compensate for both CD and SPM. Instead of converging at the midpoint of the optical path, a link system can have a full optical path where the "second half" is considered separately, and the "first half" is implemented digitally in the transmitter. In other words, the receiver begins by processing the waveform, and then the signal is propagated back to the transmitter. This back-propagation includes considerations for chromatic dispersion (CD) and self-phase modulation (SPM). The back-propagated signal is then used to determine the filter coefficients necessary to compensate for non-linarites in the transmitter. Numerical optimization and algebraic methods can be employed to account for the depth and count of the non-linear stages [13]. Due to the inherent characteristics of analog recording, the rate of theft is high. However, if the content is registered and copied onto a VCR, the visual quality of the first-generation copy is reduced. Successive generational copies further diminish in

quality, leading to a significant decrease in commercial value. This degradation in quality prevents any significant impact from such copies. In today's context, efficient methods to prevent illegal analog copying have been developed and mandated for electronic devices. An example of such a system is the Macro vision technology, which modulates the analog composite video signal to prevent unauthorized copying. Research conducted by the CE and IT industries, two trusted technical teams, has revealed that encryption-based technologies render content unintelligible or transform it into an invisible form. This reversible change ensures that the content can be accurately retrieved [14].

2. MATERIALS AND METHOD

Analog Electronics: Analog electronics, in contrast to digital electronics, involve systems where signals can vary continuously rather than switching between two discrete states. These signals are used to amplify, filter noise, and perform various operations. Common components in analog electronics include resistors, capacitors, inductors, and transistors. On the other hand, digital electronics use discrete signals to represent and process information.
Power Electronics: Power electronics is a specialized area within electrical engineering focused on the conversion and control of electrical power. It involves processing voltages and currents to meet diverse requirements. The applications of power electronics span multiple fields, including industrial settings, utilities, consumer products, transportation, and space technology. This technology plays a crucial role in power systems, power supply industries, automotive sectors, and aerospace industries.
Quantum Electronics: For the study and design of electronic devices, we explore the applications of Quantum Mechanics and Quantum Optics. This includes the development of quantum-dot infrared detectors and imaging sensors, electrically-pumped quantum-dot active components, photonic crystal micro-cavity lasers, multi-spectral solar energy conversion devices, plasmatic bio-sensors, and fluorescence bio-sensing devices.
Communication Systems: The purpose of a communication system is to transmit intelligence signals to specific locations. It involves two main components: a transmitter and a receiver, which work together to facilitate the exchange of information. This model of communication is essential for the effective transfer of data between these stations.
Control Systems: A control system is a device or system utilized to regulate the behavior of a process. It consists of three primary components: a sensor, a controller, and an actuator. The sensor detects a physical quantity like temperature, pressure, or position and converts it into an electrical signal.
Noise Immunity: A circuit's capacity to withstand noisy signals is known as noise immunity. The quantitative measurement of this ability is termed the noise margin. The noise edges defined above pertain to DC noise and are referred to as edges. However, noise is generally AC, characterized by its amplitude and pulse width.
Programmability: Some machines, such as a programmable thermostat or a music synthesizer, are examples of programmable devices. These devices run programs written in a specific language, offering users various options instead of restricting them to standard packages. This flexibility allows users to select and configure the devices (whether text-based, visual, or other types) according to their preferences.
Integration: At its most basic, integration means merging two or more elements into a single entity. This process aims to achieve seamless functionality and efficiency. In a business context, integration frequently pertains to software or computer systems, involving the unification of various business operations to function cohesively as one division.
Reproducibility: "Generation" refers to instances where original research data and computer codes are utilized to reproduce results. In contrast, "Reflection" denotes scenarios where a researcher employs new data to derive findings that align with the previous study, representing a process of gathering new evidence.
VIKOR Method: Performance ratings for different criteria are measured using various units, but for accurate comparison within a matrix, these elements must be dimensionless. Cost and effectiveness are important considerations, so normalization methods have been developed to ensure that target values are accessible. These methods must adequately address engineering design situations, acknowledging both their benefits and shortcomings. This paper proposes a new version of the VIKOR method, which is a compromise solution that accounts for different criteria. The proposed comprehensive version of VIKOR addresses the main error of the traditional VIKOR with a straightforward approach. In the VIKOR method, the optimal compromise ranking is achieved by assessing the degree of proximity to the alternative solutions and reaching a compromise through mutual concessions. To simplify problem-solving and avoid numerical complexities, Chang introduced a modified version of the VIKOR method. This section focuses on further enhancing the modified VIKOR approach through the incorporation of a novel normalization technique [15]. The VIKOR method is a powerful tool for addressing intricate decision problems. It offers several variations tailored to diverse decision-making scenarios, each with its unique strengths and applications. These include Comprehensive VIKOR, Fuzzy VIKOR, Regret Theory-based VIKOR, and Interval VIKOR methods, among others.

Depending on the complexity of the problem and the preferences of the decision maker, these methods can be employed to generate insightful results. In utilizing the VIKOR method, images are often utilized to enhance comprehension, providing visual aids that align with the problem at hand and the decision maker's requirements. These methods are adaptable to various decision-making contexts, sharing common characteristics while offering distinct mathematical formulations to address specific needs. Central to the VIKOR method is its ability to rank performance across multiple criteria, providing a comparative analysis that facilitates decision-making. Through mathematical formulas and algorithms, the method evaluates alternatives across different categories, enabling decision makers to identify optimal solutions [16]. This study employs the VIKOR method for multi criteria decision making (MCDM), utilizing a compromise ranking approach known as multiple response to enhance the process. The proposed systematic approach considers various responses' quality by evaluating both the mean and variance of losses. By prioritizing a smaller overall average loss and ensuring minimal variation in quality loss across responses, the method aims to improve quality outcomes. The effectiveness of this approach is demonstrated through two case studies involving Plasma-Enhanced Chemical Vapor Deposition and copper chemical mechanical polishing. So, in the realm of multi criteria decision making (MCDM), this study suggests a fresh perspective by employing the VIKOR method for handling multiple responses. The aim is to address optimization challenges in various processes. The proposed approach introduces a new MCDM procedure to identify the best possible solution, particularly useful in resolving conflicts and evaluating multiple alternatives. Essentially, reconciliation becomes a multifaceted aspect in this context [17]. The primary aim of this job is to assess customers' needs more accurately, thereby enhancing the effectiveness of product design and promoting objectivity. This study introduces a novel approach to evaluating design concepts, which focuses on analyzing the cost and benefit characteristics instead of solely relying on design criteria and customer preferences. A team of designers collaborates to identify the most suitable concept that best meets the imposed constraints. The study applies the Modified Vlsekriterijumska Optimizacija I Kompromisno Resented (VIKOR) method, utilizing rough number assessment, and extends it by incorporating interval numbers. This modified approach, termed as Modified Rough VIKOR (MR-VIKOR) analysis, is presented in two phases, primarily at a conceptual level [18]. Summarizing RES planning initiatives in the power sector involves gathering various sources and equipment for converting renewable energy sources (RESs) efficiently. It entails monitoring power demand and optimizing the integration of RESs into the grid. This process encompasses decision-making regarding technology, economics, and environmental and social considerations, including balancing requirements. Maintaining ecological balance and promoting sustainable development are key objectives. Selecting the most suitable RES presents a significant challenge for decision-makers due to the multitude of available options. Ensuring compatibility between RES and grid supply is also a major challenge, requiring efforts to maintain harmony [19]. So, rather than employing traditional approaches, a different approach was adopted. In this research, a revised version of the VIKOR method was utilized to address lean tool selection within manufacturing systems. The study proposed solutions to various challenges, aiming to assist trainers in enhancing their skills by generating potential solutions tailored to individual criteria. This modified VIKOR method potentially involves triplicating alternatives, using both common and unique criteria, instead of relying solely on general criteria. In this thesis, we propose a modified VIKOR method as a solution for selecting lean tools in systems where alternatives possess their own production criteria. To showcase the effectiveness of our proposed model, we present two solved problems and provide numerical examples, along with a case study, for verification purposes. The results not only validate the applicability of our modified method but also demonstrate its efficiency in practical scenarios, highlighting its utility in real-world applications [20]. Decision-making is a universal aspect of human behavior, regardless of complexity. Real-life problems often present paradoxes and involve various criteria, making them intricate. Many structured problems require the consideration of multiple criteria or attributes. Multiple Criteria Decision Making (MCDM) methods provide tools to determine the best solution among alternatives. These methods involve calculating the utilities of alternatives and ranking them, with the alternative solution offering the highest utility being considered optimal. This document presents a compromise ranking list, settlement, and initialization of the solution reached through weighted considerations. Priority stability is ensured by weighing stability, which determines intervals. In the presence of conflicting attributes, the focus is on methodically ranking and selecting alternatives. The VIKOR method is utilized to optimize team utility while minimizing the opponent's advantage and personal dissatisfaction. It's considered the optimal solution, as it incorporates attribute ranking indices based on a specific measure of closeness [21]. So, this study introduces a fresh approach, called VIKOR, aimed at addressing this issue. This novel method suggests breaking down projects or features into intervals to better grasp and accomplish objectives. These intervals, which represent significant control elements, are utilized to enhance project management and also facilitate decision-making by enabling ranking. The underlying concept revolves around finding compromise solutions, with a particular emphasis on the VIKOR method. Furthermore, this research illustrates the relevance of the new approach by applying it to information security risk assessment and offers an example of its implementation for improvement. The findings underscore the effectiveness of this innovative method [22]. This study finds it challenging to rank the alternatives due to ambiguity. To address this, we enhance the ELECTRE I method within this specific context. While ELECTRE II and III methods can be employed, they come with their own set of issues. For instance, ELECTRE III introduces a significant complexity, particularly in establishing a fine degree of reliability between two alternative outcomes. This complexity makes the method intricate and challenging to elucidate. The suggested approach addresses decision-making data and addresses ambiguity within group decision-making processes by incorporating linguistic variables as criteria, prioritizing the intensity of preferences. This method enables a group of decision-makers to independently express their opinions within established norms, utilizing a fuzzy decision matrix and criterion weights for integration [23]. The Fuzzy VIKOR method is used for ranking and selecting alternatives in ambiguous contexts within multi-criteria decision-making processes. This method emphasizes accuracy as a crucial criterion and employs weights defined by fuzzy set theory to represent the importance of each criterion. To handle imprecise data, it utilizes trigonometric fuzzy numbers. The VIKOR method is based on cumulative ambiguity and uses the Qi measure to represent the distance of an alternative from the best possible solution. Fuzzy functions and procedures are employed for ranking fuzzy numbers, which are integral to the development of the VIKOR algorithm. A numerical example demonstrates the application of the Fuzzy VIKOR method in water resource planning, illustrating its practical justification. This approach is both conceptual and descriptive, ensuring the functional verification of its application to real-world problems [24]. Competition in both domestic and global markets, along with the need for sustained operations, emphasizes the importance of controlling costs. The locations of manufacturing and service operations significantly impact these costs, thereby affecting pricing strategies. The effort to reduce costs begins with selecting the right facility location. Hence, choosing a convenient and strategic location is crucial for entrepreneurs. This decision is strategic because changing it in the short term is both difficult and expensive. For conducting essential production activities, the facility's location should be advantageous for procurement, production, storage, and distribution. Therefore, a company should select a facility location that ensures lower costs and maximizes long-term profits. The selection of a facility location is a critical aspect of production planning and is closely related to manufacturing control, material handling, and overall facility organization [25]. Due to the typically conflicting nature of selection criteria, a compromise solution is often preferred. This optimal solution is determined using a specific measure of "closeness," aiming for the smallest distance to the positive ideal solution. The best alternative is chosen based on this criterion, where the risk of the results is considered less significant than the objective of maximizing profits. The VIKOR method is well-suited to these conditions. Its main advantage lies in its ability to balance the preferences of the majority and the minimum adversary, effectively trading off between group benefits and personal regret. Additionally, the necessary calculations for the VIKOR method are simple and straightforward [26]. First, all the information is provided by decision makers. The intuition behind individual interval values is ambiguous. We employ a hybrid geometric operator to composite the values in the interval-valued intuitionistic fuzzy decision matrix. Then, using the score function of each attribute value, we calculate the scores and create a scoring team based on the joint interval-valued intuitionistic fuzzy decision matrix. Additionally, using the provided attribute weight information, we optimize to determine the weights of the attributes. We then establish a model to determine the interval-valued intuitionistic positive-best solution and the interval-valued intuitionistic negative-best solution. Finally, to calculate the specific degree of closeness for each alternative to the interval-valued intuitionistic positive-best solution, we utilize different distance measures [27]. Decision support systems (DSS) are valuable tools designed to enhance decision-making through the use of computers. These systems provide computer-based support, aiding in decision-making processes that require specialized skills. DSS are particularly effective in managing semi-structured problems, where decisions are made amidst uncertain outcomes. To reduce this uncertainty, it's crucial to gather accurate information about existing and potential conditions and process a large amount of data. This allows for the identification of alternative actions that can maximize expected benefits. In this research, a decision support system based on the VIKOR method is proposed. The VIKOR method is known for its effectiveness in handling multiple attributes and criteria. It systematically collects and processes all relevant data, ensuring that decisions are made based on comprehensive and efficient criteria selection. This approach is particularly useful for drawing conclusions that involve multiple attributes and criteria, leading to more informed and beneficial decision-making outcomes [28]. Conflict arises when two or more individuals or groups have a disagreement, opposition, or struggle. It involves parties attempting to thwart each other's intentions or goals, often leading to hostile interactions and significant friction. This situation occurs when people resist each other's ideas or goals, or when goals are incompatible. In this discussion, conflicts are seen as disagreements based on differing values and needs, rather than violent confrontations. Conflict management often emerges in scenarios where shared resources must be allocated among groups with differing objectives [29].

3. ANALYSIS AND DISCUSSION

TABLE 1. Determination of best and worst value of Digital electronics using VIKOR method

	Noise Immunity	Programmability	Integration	Reproducibility
Analog Electronics	10.2	11.21	98.77	25.036
Power Electronics	20.3	22.31	79.44	23.632
Quantum Electronics	30.4	33.41	59.66	52.304
Communication Systems	40.5	44.51	69.11	62.123
Control Systems	50.6	55.61	29.33	16.123
Best	**10.2**	**55.61**	**98.77**	**16.123**
Worst	**50.6**	**11.21**	**29.33**	**62.123**

The VIKOR method, a multi-criteria decision-making technique, was applied to determine the best and worst values of digital electronics across four parameters: Noise Immunity, Programmability, Integration, and Reproducibility. As shown in Table 1, five categories of electronics were evaluated: Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems. The best values for each parameter are as follows: Noise Immunity (10.2 from Analog Electronics), Programmability (55.61 from Control Systems), Integration (98.77 from Analog Electronics), and Reproducibility (16.123 from Control Systems). Conversely, the worst values recorded are: Noise Immunity (50.6 from Control Systems), Programmability (11.21 from Analog Electronics), Integration (29.33 from Control Systems), and Reproducibility (62.123 from Communication Systems). These extreme values highlight the strengths and weaknesses across different types of electronics, providing a clear framework for assessing their performance using the VIKOR method.

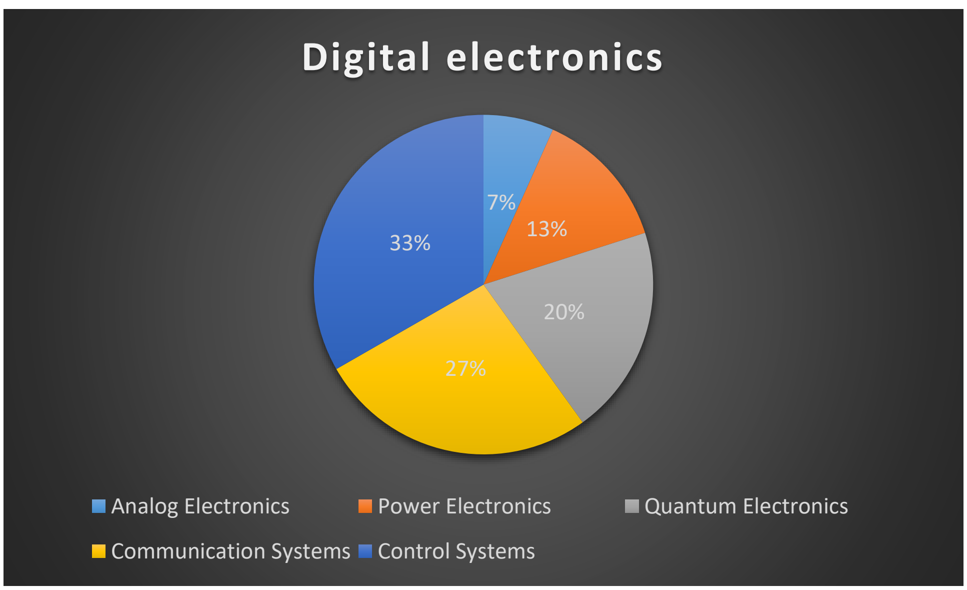

FIGURE 1. Determination of best and worst value of Digital electronics

Figure 1 illustrates the application of the VIKOR method in determining the optimal and suboptimal values of digital electronics across four key parameters: Noise Immunity, Programmability, Integration, and Reproducibility. The table presents data from various categories of electronics, including Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems. For each parameter, the best and worst values are identified. Notably, Analog Electronics excels in Integration with a score of 98.77, while Control Systems demonstrate superior Programmability with a value of 55.61. Conversely, Control Systems exhibit the lowest Reproducibility score of 16.123, indicating room for improvement in this aspect compared to other electronic categories.

TABLE 2. Calculation Sj and Rj

	Noise Immunity	Programmability	Integration	Reproducibility	Sj	Rj
Analog Electronics	0	0.25	0	0.04844	0.29844	0.25
Power Electronics	0.0625	0.1875	0.069592	0.04081	0.360402	0.1875
Quantum Electronics	0.125	0.125	0.140805	0.196636	0.587441	0.196636
Communication Systems	0.1875	0.0625	0.106783	0.25	0.606783	0.25
Control Systems	0.25	0	0.25	0	0.5	0.25

Table 2 presents the calculation results for Sj and Rj parameters using the VIKOR method, aiding in the assessment of Noise Immunity, Programmability, Integration, and Reproducibility across different types of electronics. Each category, including Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems, is evaluated based on its respective scores. Analog Electronics score highest in Programmability with 0.25, while Control Systems receive the highest score in Integration with 0.25. Quantum Electronics achieve the highest score in Noise Immunity and Reproducibility, with values of 0.125 and 0.196636, respectively. These calculations enable a comprehensive comparison of the performance of various electronic categories, aiding decision-makers in identifying strengths and weaknesses to optimize digital electronics effectively. The Sj and Rj values provide a quantitative basis for prioritizing improvements and strategic decision-making within the realm of digital electronics development and implementation.

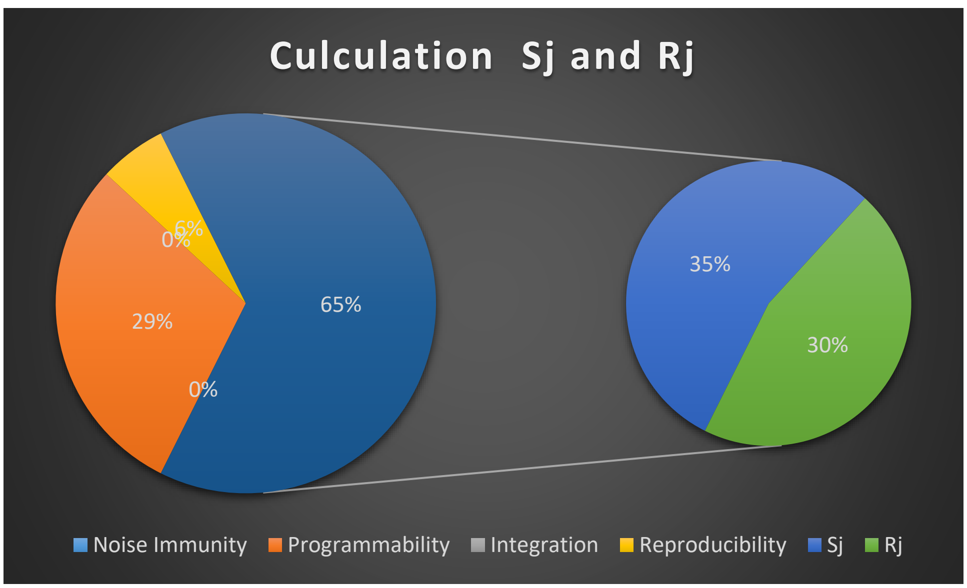

FIGURE 2. Calculation Sj, Rj

Figure 2 showcases the calculation outcomes for Sj and Rj parameters utilizing the VIKOR method, facilitating a comparative analysis of Noise Immunity, Programmability, Integration, and Reproducibility among different electronic categories. Each category, such as Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems, is evaluated based on its respective scores. Notably, Control Systems attain the highest score in Integration and overall Rj value, indicating strong performance in this aspect. Conversely, Analog Electronics excel in Programmability, while Quantum Electronics demonstrate notable scores in Noise Immunity and Reproducibility. These calculations provide valuable insights for decision-makers in optimizing digital electronics performance and strategizing improvements effectively.

TABLE 3. Final Result of Calculation Qj

	Sj	Rj	Qj	Rank
Analog Electronics	0.59688	0.29844	0.007883	5
Power Electronics	0.588712	0.360402	0.100476	4
Quantum Electronics	0.980713	0.587441	0.846963	2
Communication Systems	1.106783	0.606783	1	1
Control Systems	0.75	0.5	0.482506	3

Table 3 presents the final results of the Qj calculation derived from the VIKOR method, which integrates Sj and Rj parameters, allowing for a comprehensive evaluation of Noise Immunity, Programmability, Integration, and Reproducibility across different electronic categories. Each category, including Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems, is assessed based on its combined Qj score. Communication Systems achieve the highest Qj score of 1, indicating superior overall performance across all parameters and securing the top rank. Quantum Electronics follow closely behind with a Qj score of 0.846963, reflecting strong performance across Noise Immunity, Programmability, Integration, and Reproducibility. Analog Electronics, Power Electronics, and Control Systems secure ranks based on their respective Qj scores, providing valuable insights for decision-makers to prioritize improvements and optimize the performance of digital electronics effectively using the VIKOR method.

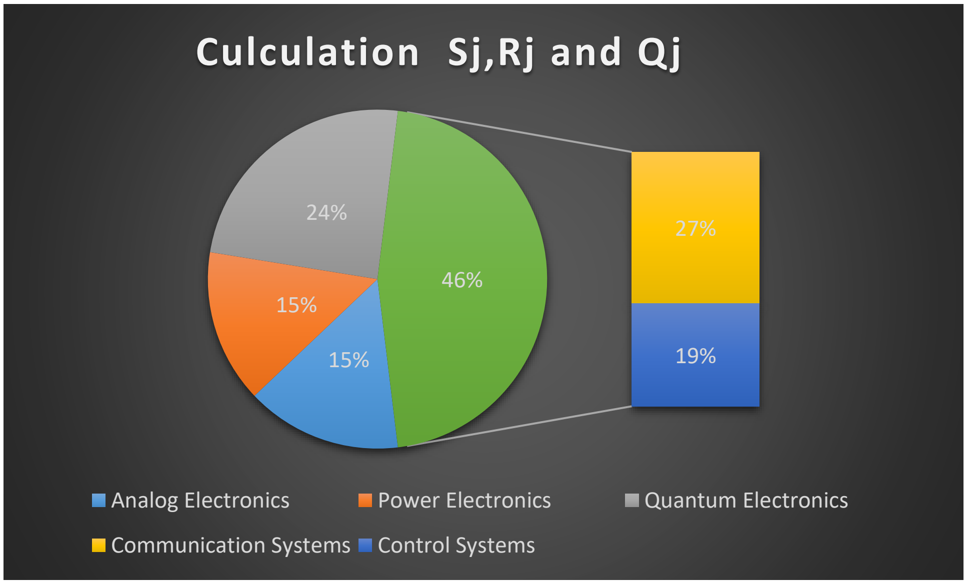

FIGURE 3. Calculation Sj, Rj and Qj

Figure 3 illustrates the final outcomes of the Qj calculation using the VIKOR method, amalgamating Sj and Rj parameters to assess Noise Immunity, Programmability, Integration, and Reproducibility across diverse electronic categories. Communication Systems secure the top rank with a Qj score of 1, showcasing exceptional performance across all parameters. Quantum Electronics closely follow with a Qj score of 0.846963, indicating strong overall performance. Analog Electronics, Power Electronics, and Control Systems are ranked based on their respective Qj scores, offering insights for prioritizing enhancements and optimizing digital electronics effectively. This final assessment provides a comprehensive overview for decision-makers, aiding in strategic planning and improvement initiatives within the realm of digital electronics.

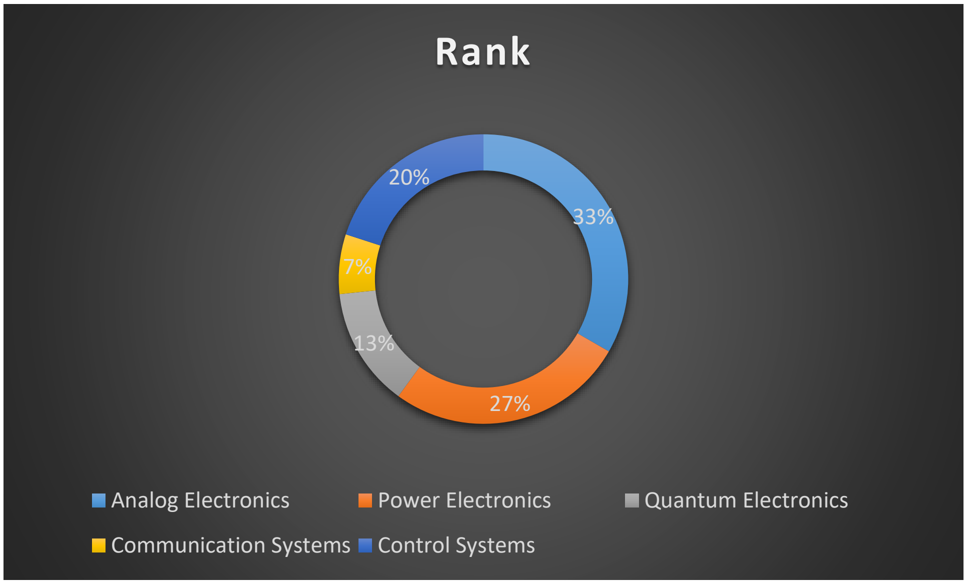

FIGURE 4. Shown the Rank

In Figure 4, the VIKOR method assigns ranks to various fields within electronics and communication systems. Analog Electronics holds the fifth position, indicating its significance but not the highest priority. Power Electronics follows closely behind in fourth place, suggesting its substantial role in contemporary technology. Surprisingly, Quantum Electronics secures the second rank, hinting at its growing importance and potential for advancement. Communication Systems claim the top spot, underscoring their paramountcy in modern society, facilitating global connectivity and information exchange. Control Systems, although crucial, are placed third, reflecting their vital yet slightly lower priority compared to communication technologies. The VIKOR method's ranking provides a structured understanding of the relative importance of these fields, aiding decision-making processes in research, investment, and development within the realm of electronics and communication systems.

4. CONCLUSION

The VIKOR method, a multi-criteria decision-making technique, has proven to be an effective tool for evaluating the performance of various electronic categories across multiple parameters, including Noise Immunity, Programmability, Integration, and Reproducibility. The study comprehensively assessed five distinct categories: Analog Electronics, Power Electronics, Quantum Electronics, Communication Systems, and Control Systems. The application of the VIKOR method allowed for a systematic and quantitative comparison of these electronic categories, enabling the identification of their strengths and weaknesses. The calculations of Sj, Rj, and Qj values provided a robust framework for ranking and prioritizing improvements within the realm of digital electronics. The analysis revealed that Communication Systems achieved the highest overall ranking, securing the top position with a Qj score of 1. This outstanding performance can be attributed to the paramount importance of communication technologies in facilitating global connectivity and information exchange, which are fundamental components of modern society. Quantum Electronics closely followed in second place, with a Qj score of 0.846963, indicating its growing significance and potential for future advancements. Control Systems secured the third rank, reflecting their vital role in various applications, albeit slightly lower in priority compared to communication technologies and quantum electronics. Power Electronics and Analog Electronics ranked fourth and fifth, respectively, highlighting their substantial contributions to contemporary technology while underscoring the need for continuous improvements to enhance their performance. The VIKOR method's ranking provides valuable insights for decision-makers, aiding in strategic planning, resource allocation, and prioritization of research and development efforts within the electronics and communication sectors. By identifying the relative strengths and weaknesses of each electronic category, stakeholders can make informed decisions to optimize performance, foster innovation, and address emerging challenges effectively. Furthermore, the study underscores the importance of adopting a multi-criteria decision-making approach in evaluating complex systems and technologies. The VIKOR method's ability to incorporate multiple parameters and reconcile conflicting objectives ensures a comprehensive assessment, leading to well-informed and balanced decisions. As technology continues to evolve rapidly, the findings of this study emphasize the need for ongoing research, collaboration, and investment in emerging fields such as quantum electronics and communication systems. By leveraging the insights provided by the VIKOR method, stakeholders can strategically allocate resources, foster interdisciplinary collaboration, and drive advancements that address societal demands for more efficient, sustainable, and secure electronic systems. The application of the VIKOR method has proven invaluable in assessing the performance of digital electronics across various categories. The analysis provides a structured framework for decision-makers to prioritize improvements, optimize resource allocation, and foster innovation within the electronics and communication sectors, ultimately contributing to the development of cutting-edge technologies that drive societal progress and enhance our quality of life.

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