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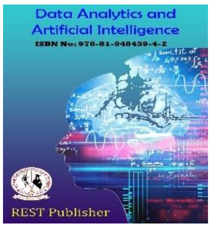

Cognitive Computing Approaches: A Comprehensive Performance Evaluation Using the Weighted Property Method

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Abstract: *In an era of rapid technological advancement, cognitive computing is emerging as a transformative paradigm that integrates methods from psychology, biology, signal processing, and mathematics to create intelligent computational systems. This research uses the Weighted Property Methodology (WPM) to comprehensively evaluate various cognitive computing approaches, analyzing their performance on important dimensions including ethical and social implications, learning rate, usability, and decision support. This study systematically examines five cognitive computing approaches: brain-inspired, human-like, adaptive, intelligent, and intelligent computing. Through rigorous multi-criteria analysis, brain-inspired computing distinguished itself as the best-performing approach, achieving a maximum priority score of 0.86755. The ability of this approach to model computational processes after human neural structures demonstrates significant potential for advanced technological development. Key findings reveal that cognitive computing is not a single concept but a complex ecosystem of interconnected methods. Human-like computing came in second, emphasizing the critical role of human-centered design in technological innovation. Adaptive computing came in third, highlighting the importance of dynamic computational reconfiguration. The research underscores the critical role of cognitive computing in addressing contemporary challenges in domains such as healthcare, web development, and decision support systems. By simulating human-like cognitive processes, these approaches offer unprecedented capabilities in processing complex, multidimensional data and making intelligent, context-aware decisions. This comprehensive analysis provides valuable insights into the evolving landscape of cognitive computing, and provides a roadmap for future research and technological innovation in a data-driven world.*

Keywords: *Cognitive Computing, Brain-inspired Computing, Decision Support Systems, Artificial Intelligence, Multidimensional Data Analysis, Neural Computation, Technological Innovation, Machine Learning and Computational Intelligence*

1. Introduction

In recent years, advancements in computer software and hardware technologies, along with the emergence of big data and artificial intelligence, have significantly increased interest in cognitive computing across academia and industry. According to IEEE Technical Activity for Cognitive Computing, this field is defined as "an interdisciplinary research and application domain that incorporates methods from psychology, biology, signal processing, physics, information theory, mathematics, and statistics" with the goal of developing machines capable of reasoning at a level comparable to the human brain [1]. The landscape of digital healthcare is undergoing rapid change with the increasing Using electronic health data generated by medical devices during consultations and events. However, much of this vast data remains untapped, highlighting the critical need to transform it into meaningful, actionable, and timely information. However, the shortage of skilled data analysts and scientists makes it challenging to keep up with the expanding volume of big data. One potential solution is to develop computer systems capable of performing tasks traditionally done by humans and efficiently managing large datasets, with cognitive computing emerging as a promising alternative [2]. The sheer volume, velocity, diversity, and reliability of data present significant challenges in computation, algorithms, power efficiency, and computer architecture. A True North-based computational model is envisioned to address these challenges by enabling data computation, interpretation, and localized processing while excelling at sub-coding tasks to augment the current computing paradigm. Specifically, True North's low-precision, synthetic, and parallel pattern-based approach serves as a complementary counterpart for the high-precision, analytical, serial, and logic-driven paradigm of modern von Neumann computers [3]. The edge computing paradigm offers several benefits. One key advantage is its ability to alleviate backhaul traffic by providing localized computing capabilities. This is particularly crucial for applications like online gaming, which require the transmission of 60 to 120 frames per second. Instead of transmitting full visual data, the server can send essential parameters, such as character positions, timestamps, and attribute changes, while delegating the computation and rendering of visual images to the edge node [4]. Economic growth and environmental shifts within human societies have led to a rise in chronic diseases, which now constitute a significant threat to public health. Conventional healthcare systems are generally structured into three primary layers: The collection layer, transmission layer, and analysis layer work together in this system. Within the collection layer, sensors within the body area network gather data at consistent intervals and transmit it to a gateway node or base station via smart devices like smart phones [5]. The expansive nature of this phenomenon highlights two essential prerequisites for developing artificial systems with similar characteristics. First, a robust theoretical framework is needed to systematically address the numerous identified challenges associated with this endeavor. Second, large-scale experiments are necessary to validate the proposed framework, as the underlying phenomena may be complex and not easily revealed through small-scale studies [6]. Strategic decisions depend on a company's ability to process information, perform analysis, and make accurate predictions. In this context, a dynamic and bidirectional adaptive approach that balances business continuity with strategic transformation is crucial for achieving robust performance. Such organizations exhibit agility, adaptability, strong predictive capabilities, and a proactive readiness to embrace change [7]. Photonic platforms provide a viable alternative to traditional microelectronics, offering advantages such as high speed, broad bandwidth, and minimal crosstalk. These characteristics make photonics particularly suitable for high-speed, spike-based information systems. Consequently, photonic spike processors can unlock computational domains that remain beyond the reach of other technologies. Spike processing has gained prominence as an approach to harness the efficiency of analog signals in both biological systems, such as nervous systems, and engineered systems, such as neuromorphic analog VLSI. Although analog computation is naturally susceptible to noise, spike neural networks have been successfully implemented in electronics through various technologies [8]. Cognitive computing plays a pivotal role in advancing systems that rely on big data analysis. Traditional big data analysis led by humans is often time-consuming, whereas cognitive computing offers a more efficient approach to managing extensive datasets. This technology embodies essential processes including observation, interpretation, evaluation, and decision-making, corresponding to the five dimensions of big data: volume, variety, veracity, velocity, and value. Although these dimensions are crucial, they remain underexplored in current research. This paper aims to examine the relationship between big data and cognitive computing by analyzing past, present, and future studies. [9]. Web development projects have recently garnered significant interest from investors worldwide. In this domain, the concept of E-portfolio has emerged as a method to identify the most effective Portfolio for social media investors. Initially introduced by Chandanarungpauk, E-portfolio uses computer technology to collect and store portfolios in various formats. It combines the ideas of financial portfolios with web development to create this innovative approach. The primary concern when investing in e-project-based companies lies in choosing the most suitable investment securities and designing an effective E-Portfolio Management System [10]. Over the past few decades, advancements in cognitive technologies and cognitive computing have consistently enhanced people's quality of life and work. Numerous tasks have either been fully automated or are close to being replaced by computer-based methods and technologies. As a result, various industries are experiencing significant improvements in both efficiency and effectiveness. A field of law that has traditionally been resistant to the adoption of innovative technologies and solutions is now being transformed by organizations offering alternative dispute resolution processes. These processes provide users with computational tools to assess their individual cases and explore potential options before resorting to full legal action [11]. It is a collaborative combination of technologies, where each component brings distinct methods to address challenges within its respective domain. ANN models pattern recognition, decision-making, modeling, and prediction by simulating the interactions of biological neurons [12]. Addressing this question is vital not only for systems neurobiology but also for the broader field of cognitive computation research. In this review, we will explore approaches that highlight autonomic neural dynamics as a fundamental regulatory factor in cognitive information processing. Additionally, we will demonstrate that this area of research is experiencing rapid growth within both computational neuroscience and cognitive systems studies [13]. Computation serves as a fundamental concept underpinning modern cognitive science. The critical importance of computation can be encapsulated in two central theses. The first is that an appropriate computational structure is enough to replicate a mind and exhibit various mental properties, which forms the basis for the belief in the potential of artificial intelligence [14]. Nonverbal information plays a unique role in communication, aiming to reveal the internal states of the mind before any verbal thoughts or expressions occur. This article examines the technologies and tools necessary to create advanced computer interfaces capable of interpreting nonverbal information. Imagine an interface that collects data about the user and accurately detects their current cognitive state. In one situation, it might choose to disregard the information. In another, it could make the intruder's icon blink intermittently. Alternatively, with a different set of nonverbal cues, it might expand the display to position the intruder's icon within the user's direct line of sight [15].

2. Materials and Method

Intelligent Computing: Intelligent computing involves leveraging Technologies like artificial intelligence, natural language processing, deep learning and cyber security to analyze and process complex, multidimensional data from diverse domains, enabling decision-making based on available and optimized resources.
Smart Computing: Smart computing is an interdisciplinary domain that integrates advanced computational techniques and technologies with engineering strategies to develop systems, applications, and innovative services tailored to societal needs.
Adaptive Computing: At its essence, adaptive computing relies on silicon hardware specifically optimized for particular applications. This optimization takes place post-manufacturing and can be repeated virtually unlimited times. Often referred to as "reconfigurable computing," this concept involves a logic chip capable of dynamically altering its physical circuitry. Building on programmable architectures like CPLDs and FPGAs, adaptive computing offers significantly faster reuse rates (ROR) and can reconfigure itself within nanoseconds.
Human-like Computing: Human-based computing, also known as human-assisted computing, ubiquitous human computing, or distributed human computing (analogous to distributed computing), is a computer science approach where a machine completes its tasks by delegating certain instructions to humans.
Brain-inspired Computing: Neuromorphic computing is a computational approach a neuromorphic computer or chip is any device inspired by the structure and function of the human brain. performs computational functions using artificial neurons. Biologically Inspired Artificial Intelligence (BIAI) refers to AI systems and algorithms designed based on the structure, functions, and principles of the human brain and nervous system.
Ethical and Social Impacts: Ethical considerations explore the moral impacts of scientific and technological progress on individuals and society, weighing both risks and benefits. These considerations often involve issues related to individual rights, privacy, autonomy, consent, fairness, and justice. Ethical implications encompass the moral considerations and potential outcomes associated with research or professional activities, including issues like objectivity, bias, and adherence to ethical standards such as respecting copyright and avoiding plagiarism. This interpretation is inspired by the definition from Ways to Experience Information Literacy, 2012.
Learning Rate: A suitable (or sufficiently effective) learning rate must be determined through trial and error. The learning rate usually ranges from 1.0 to. Common default values, such as 0.1 or 0.01, often provide a good starting point for tackling your problem.
Usability: Usability describes the extent to which a product or design enables a specific user to achieve a particular goal efficiently, effectively, and satisfactorily within a defined context. Designers often evaluate usability throughout different stages of development, from initial wireframes to the finished product, to ensure an optimal user experience.
Decision-Making Support: A Decision Support System is a software application designed to enhance an organization's decision-making process. It processes vast amounts of data and offers the most optimal options for the organization. The supported decision-making process involves identifying situations where an individual can make decisions independently, where they would like assistance in making decisions, and where they prefer or require someone else to make decisions on their behalf.

3. WPM Method

As small screen interfaces become more popular, improving the display of text and images on these screens has become a significant usability challenge. A small screen acts like a keyhole, revealing only a limited amount of information at a time. One approach to solving this problem is to use automated dynamic presentation techniques, such as scrolling text across the screen. These methods have proven to be effective alternatives for presenting text on small screens or when only a limited area of the text is visible [16]. Orthogonal frequency division multiplexing can reduce the limitations of systems or eliminate them by replacing the Fast Fourier Transform with wavelet transforms. The spectral efficiency of OFDM systems can be improved using wavelet transforms. The PTS scheme involves several steps: first, the input signal is divided into several interleaved sub-blocks; next, the sub-blocks are transformed using the inverse FFT for OFDM and the inverse discrete frequency transform for WOFDM, the sub-blocks are rotated by phase factors; finally, the sub-blocks are grouped together. Increasing the number of sub-blocks and phase factors leads to a significant increase in computational complexity [17]. Text entry methods are often evaluated through a transcription task, also known as a copy task. In this approach, participants are required to transcribe phrases quickly and accurately. Historically, there has been no universally accepted standard for the phrases used in such assessments, prompting researchers to draw on text from a variety of sources. For example, one study of speech interfaces used excerpts from a classic Western novel [18]. Conventional techniques for assessing architectural quality and making quantitative selections are examined to highlight their limitations. As a result, the architectural evaluation process is a complex task. This research proposes a quantitative evaluation method that uses MCDA methods and multi-criteria fuzzy decision-making techniques. The proposed approach models the variation in priority based on changes in the architectural architecture, eliminating the need to repeat the entire process [19]. There are several methods for selecting optimal objects, including fuzzy logic, multi-criteria decision-making, cost analysis, the bounds property method, and the weighted property method. Among these and other object selection techniques for assessing the functional requirements of a product design, the weighted property method (WPM) is particularly useful when there are many important criteria (attributes) to compare and evaluate. In this study, the weighted property method is used to relatively evaluate selected motorcycle engine blocks, which is a critical step in developing a composite structure for the engine block material [20]. Micro-EDM is a thermo-electric micromachining method that operates without the use of mechanical forces, as the tool electrode and the work piece are physically separated. Material removal occurs by pulsed spark discharges within a dielectric fluid, which is maintained at a small gap between the tool electrode and the work piece. This technique is capable of machining any electrically conductive material regardless of its strength, hardness, or toughness. According to the literature, most research has focused on optimizing the critical parameters of the micro-EDM process. However, the type of dielectric used during machining has not been considered along with other influential process parameters. As a result, selecting the appropriate combination of process parameters for micro-EDM is limited and continues to be a challenge, as it varies depending on the specific combination of material and work piece and tool [21]. The latter serves as a benchmark for evaluating the performance of different propagation methods, taking into account factors such as accuracy, sampling density requirements, and computational effort. Compared to BPMs, WPM is significantly faster and requires significantly fewer sample points during computation. This improvement in computational efficiency greatly expands the scope of wave-optical simulations, which can be used for the characterization and design of micro-optical elements [22]. Lane detection plays a key role in driver assistance systems by helping to estimate the lateral position of the vehicle in the road geometry and environment. It is commonly used in intelligent cruise control systems for applications such as lane departure warnings, road modelling, and more. Typically, lane detection and tracking is used to identify lane boundaries in road images. This process typically involves several low-level image processing steps, including preprocessing, lane boundary detection, and post processing [23]. While a blind person can use a keyboard-based telephone without assistive technology, using today's touch screen devices is more challenging. This difficulty is further exacerbated when interface elements are filled in on the screen, as in text interfaces where all characters are displayed [24]. Data augmentation has been suggested as a technique for generating additional training data for automatic speech recognition (ASR). Velocity perturbation has been used in raw audio for low-resource speech recognition tasks. Data augmentation for keyword detection, with feature dropouts, has been investigated for training multi-stream ASR systems. More broadly, learned amplification techniques have been investigated for various transformation sequences and have achieved state-of-the-art performance in the image domain [25]. Remote radio heads are distributed in various geographical locations and are connected to the baseband unit pool via optical fiber transport links. The cloud radio access network architecture facilitates centralized signal processing, resulting in significant performance improvements. In addition, the simplicity of the RRHs allows for cost-effective dense deployment within the network. This high-density deployment reduces the average access distance to users, thereby reducing transmission power requirements [26]. Mobile applications demand efficient methods for recording and retrieving information in environments that differ greatly from those of desktop computers. The portability of mobile devices means that users' surroundings can shift quickly and unpredictably. External factors, such as people, objects, and ongoing activities, can easily divert the user's attention from the application. Furthermore, mobile users may often need to type with one hand or even hands-free, and may be unable to look at their device while performing these tasks [27]. Multicarrier modulation is frequently employed to address the increasing demand for high data rates within constrained bandwidth. To tackle these challenges, various alternatives to Orthogonal Frequency Division Multiplexing have been suggested, with wavelet packet modulation emerging as a promising alternative [28]. It is a multifaceted experience that provides knowledge, emotions, and occasionally aesthetic perception. This study does not aim to cover the entire reading experience or text comprehension. Rather, it focuses on aspects of perception, exploration, memory, and context that establish an upper limit for reading speed. Mastering this skill requires many years of practice, with each component improving significantly over time, resulting in specific learning outcomes [29]. Energy planning through multi-criteria analysis has long been focused on decision makers, providing solutions to complex energy management challenges. Traditional single-criteria decision-making typically seeks to maximize benefits by minimizing costs. However, multi-criteria methods provide an excellent platform for understanding the various aspects of decision-making, enhancing the involvement of participants in the process, promoting compromise and collaborative decisions, and gaining insights into models and analysts' perspectives in real-world situations [30].

4. Results And Discussion

TABLE 1. Cognitive Computing

	Ethical and Social Impacts	Learning Rate	Usability	Decision-Making Support
Intelligent Computing	14.00	21.10	55.00	84.23
Smart Computing	11.00	89.30	88.00	97.15
Adaptive Computing	15.00	55.60	77.00	59.62
Human-like Computing	16.00	87.90	66.00	86.42
Brain-inspired Computing	17.00	77.60	44.00	91.46

Table 1 provides a comparison of various cognitive computing approaches (WPM method) in terms of ethical and social impacts, learning rate, usability, and decision support. Intelligent computing shows moderate ethical and social impacts (14.00) and learning rate (21.10), with a high decision support score (84.23). In contrast, smart computing excels in usability (88.00) and decision support (97.15), with a significant ethical and social impact (11.00). Adaptive computing offers a balanced approach in learning rate (55.60) and usability (77.00), but its decision support (59.62) lags behind the others. Human-like computing balances high usability (87.90) with ethical and social implications (16.00), while brain-inspired computing scores well in decision support (91.46) and usability (77.60).

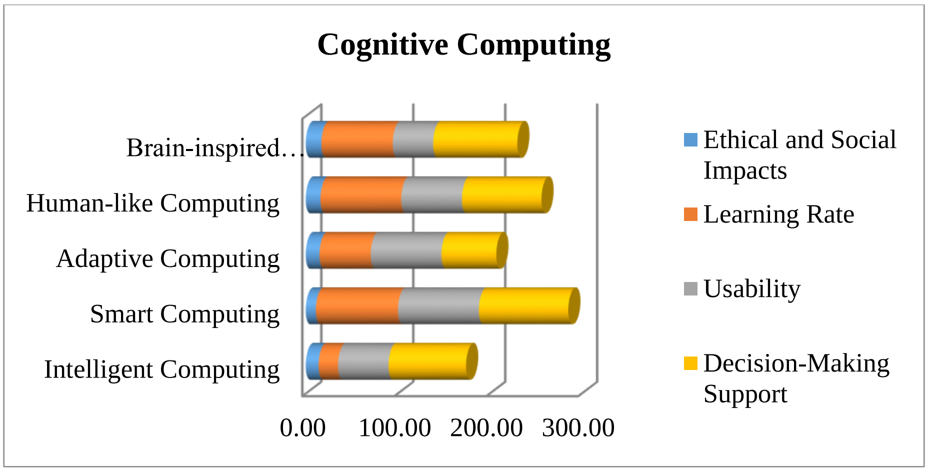

FIGURE 1. Cognitive Computing

Figure 1 illustrates cognitive computing approaches (WPM method), showing their ethical and social implications, learning rates, usability, and decision support. Smart computing leads in usability and decision support, while intelligent computing has the highest decision support. Adaptive computing exhibits moderate learning rates, and brain-inspired computing excels in decision support.

TABLE 2. Performance value

	Performance value			
Intelligent Computing	0.82353	0.23628	0.80000	0.70782
Smart Computing	0.64706	1.00000	0.50000	0.61369
Adaptive Computing	0.88235	0.62262	0.57143	1.00000
Human-like Computing	0.94118	0.98432	0.66667	0.68989
Brain-inspired Computing	1.00000	0.86898	1.00000	0.65187

Table 2 presents the performance values of various cognitive computing approaches using the WPM method. Brain-inspired computing achieves the highest performance value in one category (1.00000) and excels in others with scores such as 0.86898, showing strong overall performance. Human-like computing shows solid results with values close to 1.0 in some areas, especially 0.98432. Adaptive computing shows the highest score in one aspect (1.00000), indicating its strength in that dimension, while intelligent computing maintains strong performance in all categories, especially at 0.80000. Smart computing has mixed performance with a perfect score in one area (1.00000).

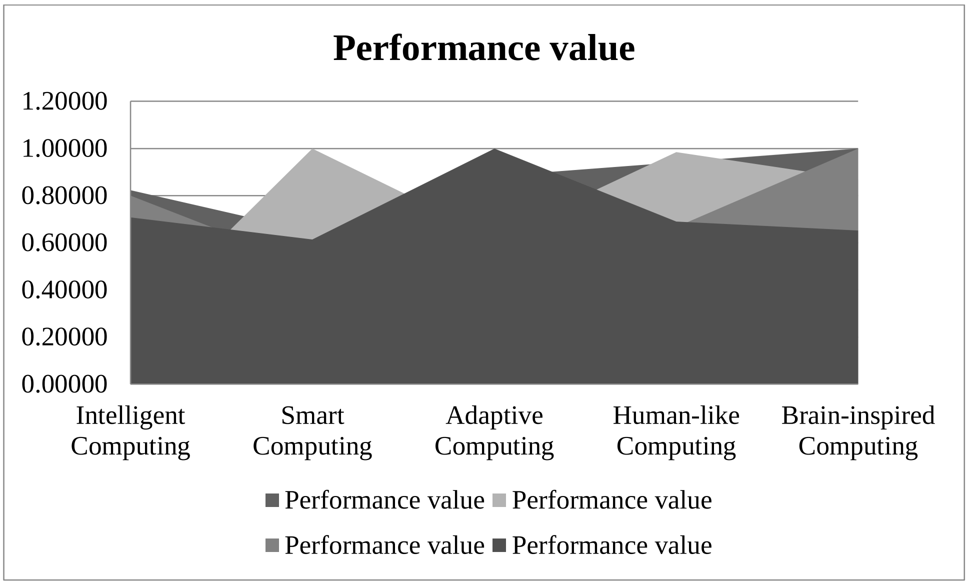

FIGURE 2. Performance value

Figure 2 shows the performance values of cognitive computing approaches using the WPM method. Brain-inspired computing achieves the best performance in both categories (1.00000), followed by human-like computing with high values. Adaptive computing excels in one category with the best score (1.00000), while intelligent and smart computing show varying performance across the metrics.

TABLE 3. Weight ages

Weight			
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

Table 3 shows equal weightings for all criteria in the WPM method, with each factor (ethical and social implications, learning rate, usability, and decision support) receiving a weight of 0.25. This even distribution ensures that each factor contributes equally to the overall evaluation of cognitive computing approaches.

TABLE 4. Weighted Normalized Decision Matrix

	Weighted normalized decision matrix			
Intelligent Computing	0.95262	0.69720	0.94574	0.91724
Smart Computing	0.89688	1.00000	0.84090	0.88509
Adaptive Computing	0.96919	0.88829	0.86944	1.00000
Human-like Computing	0.98496	0.99606	0.90360	0.91137
Brain-inspired Computing	1.00000	0.96550	1.00000	0.89855

Table 4 presents the weighted normalized decision matrix for various cognitive computing approaches using the WPM method. The matrix reflects the performance of each model on four criteria: ethical and social implications, learning rate, usability, and decision support, with the values adjusted by their respective weight ages. Brain-inspired computing scores higher in both categories (1.00000), indicating strong overall performance. Adaptive computing shows the best results with a perfect score in decision support (1.00000). Intelligent computing, human-like computing, and smart computing show competitive scores, ensuring a balanced assessment of the performance of each approach.

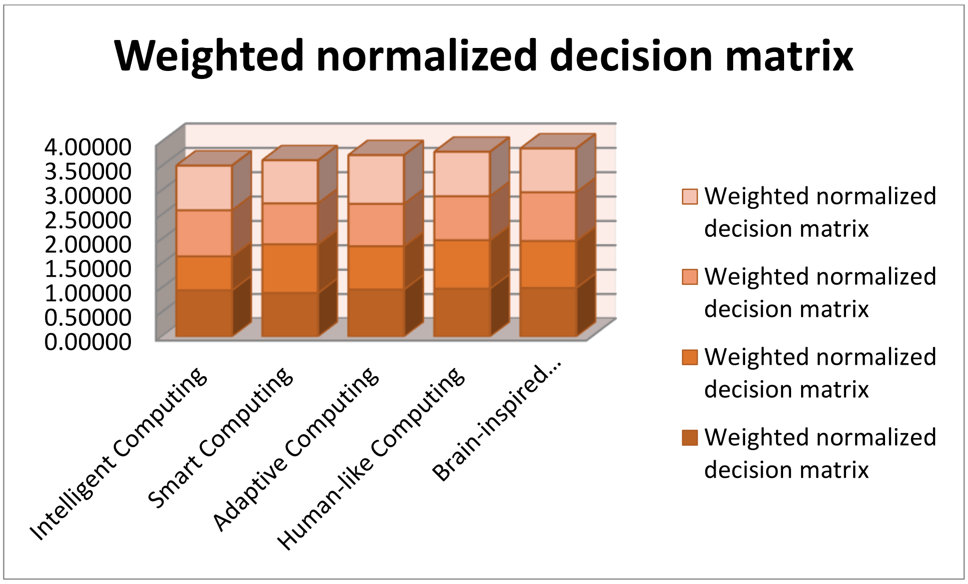

FIGURE 3. Weighted Normalized Decision Matrix

Figure 3 shows the weighted normalized decision matrix for cognitive computing approaches using the WPM method. Brain-inspired computing scores the highest in both categories (1.00000), while adaptive computing excels in decision support (1.00000). Other approaches, including intelligent and human-like computing, show strong, competitive performance across all criteria.

TABLE 5. Preference Score & Rank

	Preference Score	Rank
Intelligent Computing	0.57614	5
Smart Computing	0.66752	4
Adaptive Computing	0.74853	3
Human-like Computing	0.80793	2
Brain-inspired Computing	0.86755	1

Table 5 presents the preference scores and rankings for various cognitive computing approaches using the WPM method. Brain-inspired computing receives the highest preference score of 0.86755, ranking first, reflecting its best overall performance on the assessed criteria. Human-like computing follows closely with a score of 0.80793, ranking second. Adaptive computing is third with a preference score of 0.74853. Smart computing and intelligent computing receive the lowest scores, ranking fourth (0.66752) and fifth (0.57614), respectively. These rankings indicate the strengths and weaknesses of each approach in terms of overall performance.

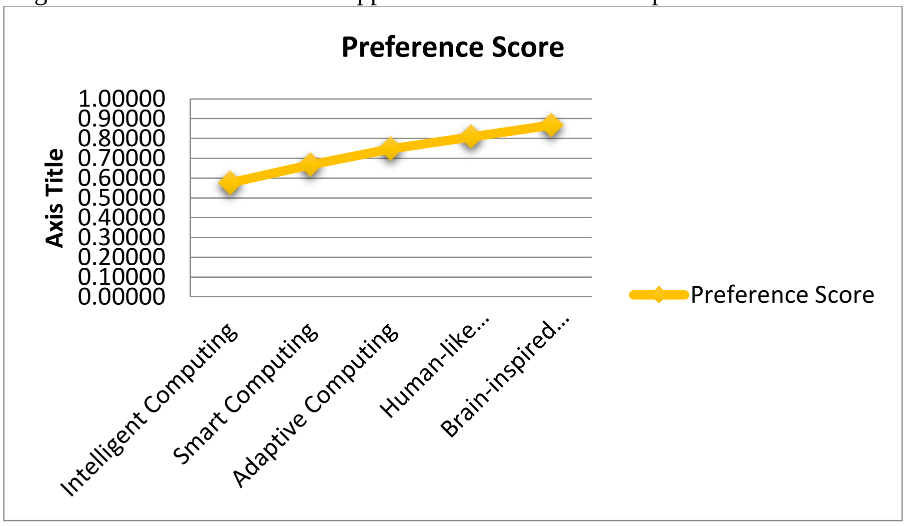

FIGURE 4. Preference score

Figure 4 shows the preference scores and rankings for cognitive computing approaches. Brain-inspired computing ranks first with a score of 0.86755, followed by human-like computing in second place (0.80793). Adaptive computing ranks third (0.74853), while smart and intelligent computing rank fourth (0.66752) and fifth (0.57614), respectively.

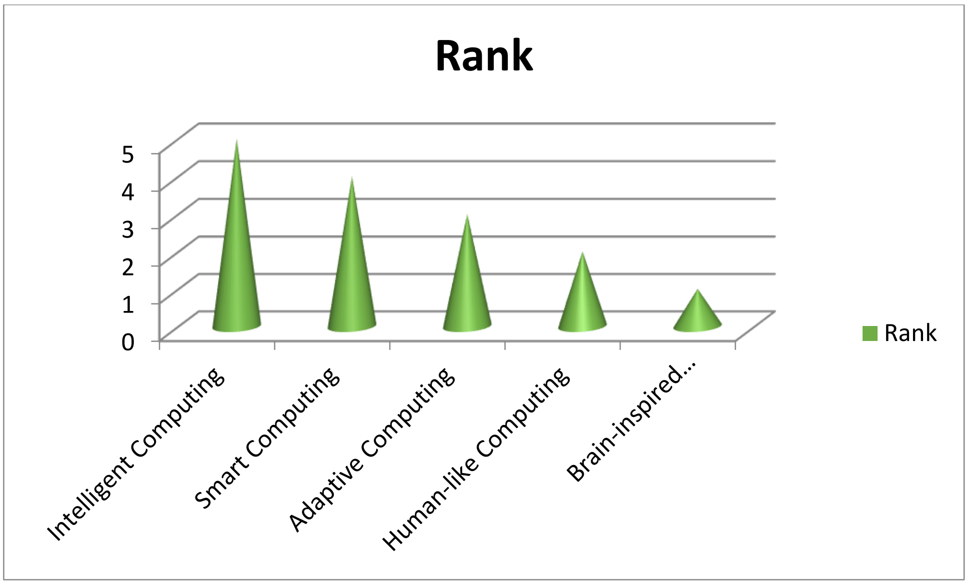

FIGURE 5. Rank

Figure 5 illustrates the rankings of cognitive computing approaches using the WPM method. Brain-inspired computing ranks first and human-like computing ranks second. Adaptive computing ranks third, smart computing ranks fourth, and intelligent computing ranks fifth, reflecting the overall performance of each approach.

5. CONCLUSION

The research, conducted using the Weighted Property Method (WPM), provides a nuanced assessment of various cognitive computing approaches, revealing important insights into their performance, capabilities, and potential future applications. Brain-inspired computing emerged as the best-performing approach, demonstrating exceptional results across multiple dimensions. With a high priority score of 0.86755 and ranking first, this approach shows significant potential in decision support, usability, and overall computational performance. Its ability to model computational processes after Structure and function of the human brain offers a promising path for advanced technology development. Human-like computing followed closely, ranking second with a priority score of 0.80793. This approach highlights the importance of integrating human-centered design principles into computing systems, and emphasizes the potential for intuitive and adaptive technologies. The study revealed that cognitive computing is not a single concept, but rather a diverse landscape of approaches, each with unique strengths. Adaptive computing ranked third, demonstrating flexibility and the ability to dynamically reconfigure computational resources. Smart computing and intelligent computing, while Fourth and fifth places, respectively, show significant potential in specific areas such as decision support and ethical considerations.

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