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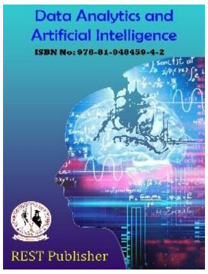

Evaluation of Embedded Intelligent real time systems by using MOORA method

***Chandrasekar Raja, M. Ramachandran, Anusuya Mohan, Arunambigai Ramesh**

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India.

*Corresponding Author Email: chandrasekarrajarsri@gmail.com

Abstract: *When facing intelligent real-time software systems integrated into larger host systems, several evaluation challenges arise. It is of utmost importance to focus on assessing these systems and ensuring their software safety, especially since they are being utilized more frequently in critical sectors such as aerospace, medicine, manufacturing, and transportation. Embedded software engineering for such systems differs significantly from conventional software engineering in various aspects. Engineers working on these systems must possess expertise in additional areas beyond standard software development. They need to be well-versed in electrical power, electronics, the physical interface between digital and analogue electronics and computers, as well as software development for embedded systems and digital signal processors (DSP). This multidisciplinary approach is crucial to guarantee the successful design and implementation of intelligent real-time software systems in various applications, where safety and reliability are paramount concerns. The field of information technology is constantly advancing, with the emergence of various decision support systems, group decision support systems, knowledge-based systems, and expert systems. Originally, these systems were created as independent technologies to offer timely and suitable decision support to users. These systems play a vital role in the operation of numerous safety-critical, large-scale systems, including air traffic control, global financial and telecommunications networks, and real-time command and control networks. There is a strong desire to further develop intelligent real-time systems that can be integrated into these complex large-scale systems to provide guidance and assist users in their actions. Versatile with unique alternatives a new method for optimization is proposed MOORA. This method is objective denotes the matrix of responses of the alternatives, however, proposing better policies, which rates are used. Well established. Multi-objective another method for optimization is used for comparison, reference point method. Then, various competitions this proved to be the best choice among the methods. Alternative parameters taken as Adaptability, Latency, Fault Tolerance, User Experience. Evaluation parameters taken as Responsiveness, Accuracy, Resource Utilization, Reliability, Power Efficiency. From the result it is seen that Accuracy is got the first rank whereas is resource utilization is having the lowest rank. Accuracy is got the first rank whereas is resource utilization is having the lowest rank.*

Keywords: *Digital control system; real-time; algorithm; latency; semi- Markov process; ergodic process*

1. INTRODUCTION

One of the most important aspects of evaluating embedded intelligent real-time systems is to determine how well they operate, function, and work. The automotive, aerospace, healthcare, and industrial automation sectors, among others, all heavily rely on these technologies, which integrate embedded systems with AI capabilities. The development of embedded intelligent real-time systems highlights their value in tackling challenging problems under real-time limitations. In order to analyze data, make wise decisions, and carry out activities in real-time, where prompt answers are essential for system stability and dependability, these systems use AI algorithms and methods. Real-time responsiveness, computing efficiency, accuracy, robustness, safety, and adaptability must all be carefully taken into account when evaluating embedded intelligent real-time systems. Researchers and developers can guarantee the successful implementation and utilization of these technologies across diverse industries by conducting extensive analyses. [1] For a specific kind of software, an EIRTS, we concentrate on software complexity. EIRTS fulfill three key tasks: they act as a part of a larger system (their host); they reason using the information at hand; and they carry out their duties in real-time. Thus, EIRTS collect data from other parts, systems, and/or the outside world; they then process, monitor, control, and display that data; and they give their host the conclusions of their reasoning. EIRTS must adhere to clear, bounded reaction time limitations in order to avoid severe repercussions, including failure, and are thus responsive to and constrained by the performance of their host. As a result, EIRTS often strike a balance between competing demands for timeliness and accuracy. [2] The requirement to manage multiple tasks on a constrained number of processing units is a common characteristic of real-time embedded systems. It is challenging to arrange these jobs on processors in a way that satisfies real-time requirements. However, there are a number of options accessible to designers who must make a difficult choice between efficiency and safety. [3]Process control, nuclear power plants, agile manufacturing, intelligent vehicle highway systems, avionics, air traffic control, telecommunications (the information superhighway), multimedia, real-time simulation, virtual reality, medical applications (such as telemedicine and intensive-care monitoring), and defence applications (such as command, control, and communications) are just a few of the important application areas where real-time computing is an enabling technology. Particularly, real-time systems include the majority of embedded computer systems and practically all safety-critical systems. Real-time technology is also becoming more significant and widespread; for example, the global infrastructure is increasingly dependent on it [4]. The majority of software systems—95%—are embedded. Systems that are embedded can function in reactive and time-limited contexts. An embedded system can be roughly divided into two parts: software, which provides the majority of the functionality and flexibility in the system, and hardware, which provides the performance required for the application (as well as other system aspects like security) [5]. Schedule validation is the process of ensuring that the timing requirements and deadlines of tasks and events are met in a predictable and dependable way in the context of embedded reactive real-time systems. Schedule validation is an essential component of the construction and operation of these systems since they are built to respond to external events or stimuli within constrained time frames. Schedule validation for embedded reactive real-time systems is a strict and iterative procedure that guarantees the system can operate properly under the time-critical situations it is designed for, while also satisfying the set criteria and expectations.[6] Reconstructing the three-dimensional details of a scene that was caught from two different points of view is the primary difficulty of stereo vision, also known as stereo sis. Finding pixel correspondences between the two photos will help with this. Contrariety is the horizontal shift of corresponding pixels. For traditional stereo vision, two parallel-mounted cameras are used to create a stereo camera arrangement known as a stereo camera head. It records a picture from both the left and right cameras in a synchronized stereo pair. A quick stereo matching technique is created to quickly calculate depth information from stereo images or video streams, making it ideal for embedded real-time applications. To estimate the 3D structure of the scene, this method is frequently employed in robots, autonomous driving, and augmented reality applications. Fast stereo matching technique for embedded real-time systems strikes a compromise between precision and speed, putting real-time performance first while supplying accurate depth estimation for a range of applications in the computer vision and robotics fields.[7] Modern processor designs provide architectural improvements like pipelines, caches, branch prediction, and out-of-order execution that improve performance on average. However, these characteristics make analyzing worst-case execution times more difficult and result in extremely conservative estimations. JOP (Java Optimized Processor) approaches this issue from an architectural standpoint by offering a processor architecture in which WCET analysis is prioritized over average case performance due to its simplicity and accuracy. The Java virtual machine is implemented in hardware by JOP. JOP is designed for use in embedded real-time systems, and field programmable gate arrays are used as its main implementation technique. This research shows that a hardware Java virtual machine implementation results in a minimal design for devices with limited resources. [8] For embedded real-time systems, dynamic voltage scaling (DVS) is a useful low-power design strategy. Many DVS algorithms have been put forth recently in an effort to lower the energy consumption of embedded hard real-time systems. The proposed DVS algorithms, however, were not statistically assessed using a unified framework, making it challenging to choose the best DVS algorithm for a given application or system. In this study, we examine a number of important DVS algorithms that have been recently suggested for demanding real-time periodic task sets, evaluate their energy efficiency, and quantitatively explore the performance differences. Our evaluation findings provide quantifiable responses to a number of significant DVS queries. [9] Dedicated computer programmers known as embedded hard real-time systems are required to adhere to strict time limits, i.e., they must ensure that crucial tasks are completed before their due dates. Scheduling plays a significant part in fulfilling this criterion. Runtime and pre-runtime scheduling are the two main strategies for task scheduling. Runtime scheduling uses a priority-driven method to compute the schedule as tasks are received online. However, there are some circumstances in which this method can limit the likelihood of discovering a workable plan, even when such a schedule already exists. [10] Embedded systems often operate in harsh environmental conditions that necessitate the use of fault-tolerant computing techniques to ensure dependability. Presently a lot of embedded CPUs have the capability to dynamically scale the operating voltage. Recent innovations have been made to balance real-time responsiveness with low-energy job execution because a decrease in voltage causes a commensurate decrease in processor speed. [11] An embedded controller's interpretation of an algorithm is modeled using a semi-Markov process. The description of the generation of transactions in digital controllers caused by random wandering on semi-Markov process states. It is possible to obtain mathematical equations for evaluating time lag densities between transactions and stochastic properties. In real-time embedded digital control systems, latencies between transactions are regarded as a crucial characteristic for the effective synthesis of control algorithms.[12] For embedded real-time systems, dynamic voltage scaling (DVS) is a useful low-power design strategy. Many DVS algorithms have been put forth recently in an effort to lower the energy consumption of embedded hard real-time systems. Selecting the best DVS algorithm for a particular application or system is challenging because the proposed DVS algorithms were not statistically analysed within a unified framework. In this study, we examine a number of important DVS algorithms that have been recently suggested for demanding real-time periodic task sets, evaluate their energy efficiency, and quantitatively explore the performance differences. For embedded real-time systems, dynamic voltage scaling (DVS), which dynamically modifies the supply voltage and matching clock frequency, is an efficient low-power design approach. Lowering the supply voltage Vdd is one of the most efficient strategies to cut the energy consumption because the energy consumption E of CMOS circuits depends quadratic ally on that voltage.[13] A microcontroller, which is a microprocessor and a collection of peripherals integrated on the same device, is typically the foundation of embedded system architecture. Microcontrollers can be pre-packaged items like the Atmel AT90 family or fully customized ASICs based on a common CPU core (Ericsson's Bluetooth core, for instance, uses an ARM7). [14] There are two sorts of tasks in hard real-time systems: periodic and sporadic. When a job samples an object of interest regularly and at a set rate, it is considered periodic. When it can randomly activate, it is sporadic, although the shortest time between activations is known. The only kind of jobs that can be scheduled in pre-runtime scheduling are recurring ones. A sporadic task can, however, be converted into a comparable periodic one. Despite the random nature of sporadic activities, information regarding sporadic events can be stored in a buffer until it can be processed by periodic tasks. [15]

2. MATERIAL AND METHODS

2.1 Adaptability: Adaptability refers to the ability of an individual, system, or organization to adjust and thrive in response to changes in their environment, circumstances, or requirements. It involves being flexible, open-minded, and capable of embracing new challenges or situations. An adaptable person can easily modify their approach or behavior to meet the demands of different situations, while an adaptable system or organization can efficiently adjust its processes, strategies, or structures to stay relevant and effective in a dynamic world. Adaptability is a valuable skill in personal, professional, and social contexts as it allows individuals and entities to respond positively to change and uncertainty.

2.2 Latency: Latency refers to the time delay between the initiation of a process or action and the response or result. It is commonly used in various contexts, including computing, telecommunications, and human-computer interactions. In computing, latency refers to the delay between sending a request to a system or server and receiving a response. In telecommunications, it represents the time taken for data to travel from the source to the destination.

2.3 Fault Tolerance:

When a fault occurs in a fault-tolerant system, it should be able to detect the fault, isolate the affected component or area, and then continue operating without disrupting the overall functionality. Fault tolerance is achieved through various techniques and strategies, such as redundancy, error detection and correction mechanisms, graceful degradation, and failover mechanisms.

2.4 User Experience:

A positive user experience is essential for ensuring customer satisfaction, engagement, and loyalty. It involves understanding user needs, designing intuitive interfaces, and considering factors such as usability, accessibility, aesthetics, and performance. By focusing on creating a seamless and enjoyable user experience, businesses and organizations can enhance their products' effectiveness and foster lasting relationships with their users.

2.5 Responsiveness:

Responsiveness refers to the ability of something, such as a system, device, or person, to respond quickly and appropriately to changes, stimuli, or requests. It indicates how swiftly and efficiently a system or individual can react to various inputs or situations. In the context of technology, responsiveness often pertains to the speed and smoothness with which software applications or websites react to user interactions. In interpersonal communication, responsiveness involves actively listening and promptly addressing others' inquiries or concerns. Overall, being responsive is crucial for maintaining effective communication, ensuring efficient systems, and delivering satisfactory user experiences.

2.6 Accuracy:

Accuracy refers to the degree of correctness or precision in conveying information while paraphrasing. A paraphrase is considered accurate when it effectively captures the main ideas and key points of the original text without distorting or misrepresenting the intended meaning. Achieving accuracy in paraphrasing is crucial to maintain the integrity of the source material and to ensure that the new version remains faithful to the original message. It involves skillfully rewording the content while maintaining coherence, context, and the overall essence of the original text. Properly citing the source is also essential when paraphrasing to give credit to the original author and avoid plagiarism**.**

2.7 Resource Utilization:

Resource utilization refers to the efficient and effective use of various resources, such as human capital, materials, equipment, time, and money, to accomplish specific goals and objectives. It is a critical aspect of management and planning in both businesses and various other organizations.

2.8 Reliability:

Reliability refers to the consistency and accuracy of results or outcomes in a given context. In various fields, such as science, engineering, psychology, and statistics, reliability is a crucial aspect that assesses the dependability of measurements, data, methods, or systems. A reliable measurement or process produces consistent results over time and under similar conditions. In scientific research, a reliable experiment will yield consistent results when repeated multiple times. In the context of data analysis, reliable data is trustworthy and free from significant errors or biases, ensuring that the conclusions drawn from it are valid. There are different methods to assess reliability, depending on the context, such as test-retest reliability, inter-rater reliability, internal consistency, and others. High reliability indicates that the results are more likely to be accurate and can be trusted; while low reliability suggests that the results may be inconsistent or subject to significant variability.

2.9 Power Efficiency:

Power efficiency refers to the ability of a system, device, or process to utilize energy in an effective and economical manner, minimizing energy wastage while achieving desired results. In various contexts, power efficiency can be measured and expressed differently: Electronic Devices: In the realm of electronics, power efficiency is often associated with how well a device or component converts input electrical power into useful output power. This is particularly relevant for devices like CPUs, GPUs, and power supplies, where higher efficiency translates to less heat generation and longer battery life.

MOORA (Multi-objective Optimization on the basis of Ratio Analysis): Rational multi-objective analysis (MOORA) This optimization was achieved. The second MOORA property is dimensionless numbers. The foundation will be this. ultimately compares the disparities in wellbeing throughout Lithuania's 10 counties in light of all the goals. The three affluent districts stand in stark contrast to some of the least fortunate ones. A key issue that symbolizes income is the labor migration from all other districts to Vilnius district. Condemned is automatic redistribution. instead Commercialization and industrialization should develop in some areas[16].concrete multi-objective optimization The system can be simultaneously improved within restrictions or more conflicting attributes (notes). Design issues with products and multi-goal optimization There are various areas where the best decisions must be made. 2. or between competing interests when there are commercial exchanges. increasing sales and lowering product costs enhancing performance while lowering automobile fuel consumption, minimizing weight while amplifying problems, and[17].There are three main reasons why MOORA is preferred over other multiple standards decision-making (MCDM) techniques. First Moora refers to a brand-new MCTM technique that was created with knowledge of the weak points of more traditional techniques. We therefore believed it should be entirely practical. The second reason is the processing time needed by MOORA to resolve the issue, as shown by the MCDM literature. Finally, MOORA requires little to no setup because the literature implies that it takes time and has a constant personality [18].The MOORA device is a decision-support tool for picking college students who get scholarships in order to boost academic success. The institution has a tool meant to help with decision-making called MOORA that may be used to tackle a variety of issues. Utilizing a machine selection process, scholarship candidates can be chosen swiftly to increase educational performance while benefiting needy students[19]. Amazing is MOORA. A green multi-criteria selection method for a thorough analysis of options that deals with significant heterogeneity and a variety of helpful components. For the purpose of effectively resolving complicated decision-making issues, the MOORA approach is presented. This method typically produces grades that are rigidly contradicting. Thinks about and tries to choose the optimal solution while taking into account both favourable and unfavourable standards. Some of MOORA's decisions are rewarded for their technique[20].A MOORA is a technique for multi-objective optimization. There are several types of traits and techniques that are used for some people to go through and progress at the same time. MOORA is all about trying different things. a useful approach strategy. Constraints[21].The MOORA method is able to remember all characteristics and their respective weights, leading to a higher evaluation of alternatives. The MOORA approach may be simple to understand and apply. The suggested method is generic and is applicable to any size and quality Combining the features leads to more precise targeting and a more straightforward decision-making process. Additionally, this strategy can be applied to any type of decision problem[22].MOORA, or multiple criteria or multiple features, stands for multi-goal optimization based mostly on ratio analysis. Optimization is an upgrading mechanism that simultaneously considers two or more attributes that are in dispute (notes). This timed offers a wide range of programmes for decision-making in the contentious and a difficult aspect of the environment of the supply chain Choosing the location of the warehouse, the supplier, the product, and the method design are only a few examples. MOORA can be employed when the best options are needed[23].According to the failure prioritising achieved by the use of the extension in MOORA, it is evident that every single failure that has been identified is listed in excellent priorities. In other words, the suggested strategy seeks to mitigate a number of significant drawbacks of RPN score and also for selection method in regular MOORA Provides reliability by connecting the use of range idea. Ultimately, deliver logical results to the decision-maker. of this method The comparison of the outcomes with the two various conventional procedures reveals that complete prioritization of catastrophes is carried out and that disasters are discovered[234].THE ANALYSIS BY MOORA Again, the study of earlier scholars is more recent, and as a result, MOORA and MOOSRA techniques are thought to utilise the most recent statistics available. for the first method of selection Basically. As a result of the explanation above, MOORA and MOOSRA method is used for the choice problem. Complementary, resulting in variety and non-conventional In a production setting, this approach is quite reliable. If this ratio is expressed, it is advantageous at the expense of the denominator. It is a favored performance for measuring economic welfare because the value becomes the same for the ratio. As a result, this MOORA and The MOOSRA methodology is compatible from an ideological standpoint with other mounting performance evaluation approaches [25].both the ratio device and the benchmark MOORA technique with component component. We choose the kind and significance of goals and options because our simulation of port planning is all that is important to us. The relevant parties include local, state, and federal governments as well as cooperating organizations. Only implicitly is consumer sovereignty related to the industrial process. However, authorities have also been regarded as legitimate clients' representatives.

3. RESULT AND DISCUSSION

Table 1 Embedded Intelligent real time systems

	Adaptability	Latency	Fault Tolerance	User Experience
Responsiveness	5.7	4.31	3.5	1.18
Accuracy	5.88	5.01	2.01	1.29
Resource Utilization	5.63	4.72	3.22	1.65
Reliability	5.5	4.29	2.33	1.7
Power Efficiency:	5	5	2.11	1.88

Table 1 shows Embedded Intelligent real time systems Alternative: Adaptability, Latency, Fault Tolerance, User Experience. Evaluation preference: Responsiveness, Accuracy, Resource Utilization, Reliability, Power Efficiency. Use this table.

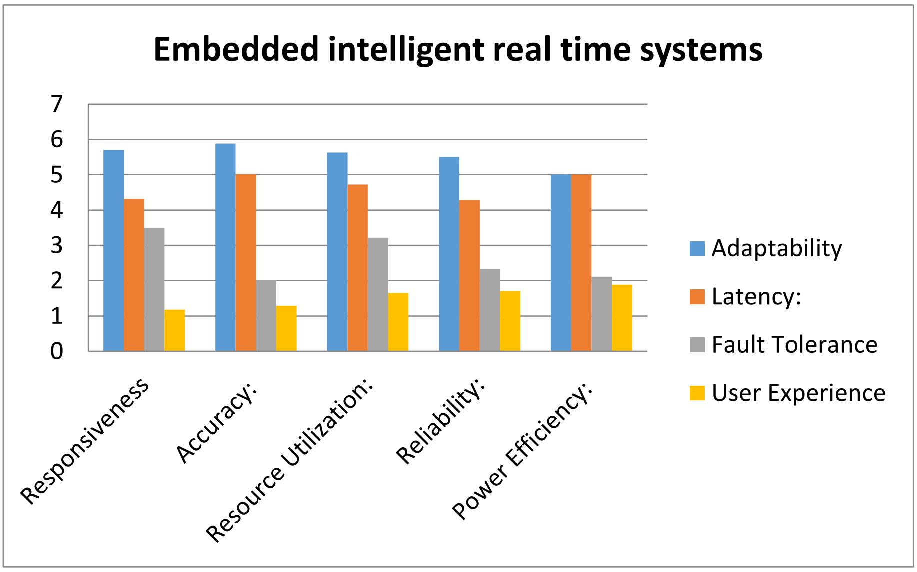

FIGURE1. Embedded intelligent real time systems

Figure 1 showing adaptability it is seen that accuracy is showing the highest value and power efficiency is showing the lowest value. Latency it is seen that accuracy is showing the highest value and reliability is showing the lowest value. Fault tolerance it is seen that resource utilization is showing the highest value and accuracy is showing lowest value. Reliability it is seen that power efficiency is showing the highest value and reliability is showing the lowest value

TABLE 2. Divide & Sum

32.4900	18.5761	12.2500	1.3924
34.5744	25.1001	4.0401	1.6641
31.6969	22.2784	10.3684	2.7225
30.2500	18.4041	5.4289	2.8900
25.0000	25.0000	4.4521	3.5344
154.0113	**109.3587**	**36.5395**	**12.2034**

Table 2 shows the Divide & Sum matrix formula used this table.

TABLE 3. Normalized Data

	Adaptability	**Latency**	**Fault Tolerance**	**User Experience**
Responsiveness	0.4593	0.4121	0.5790	0.3378
Accuracy	0.4738	0.4791	0.3325	0.3693
Resource Utilization	0.4537	0.4514	0.5327	0.4723
Reliability	0.4432	0.4102	0.3855	0.4866
Power Efficiency	0.4029	0.4781	0.3491	0.5382

$$X_{n1} = \frac{X1}{\sqrt{((X1)^2+(X2)^2+(X3)^2 \ldots)}} \qquad (1).$$

Table 3 shows the various Normalized Data, Alternative: Adaptability, Latency, Fault Tolerance, User Experience. Evaluation preference: Responsiveness, Accuracy, Resource Utilization, Reliability, Power Efficiency. Normalized value is obtained by using the formula (1).

TABLE 4. Weight

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 4 shows the Weight All same value.

$$X_{wnormal1} = X_{n1} \times w_1 \qquad (2).$$

TABLE 5. Weighted normalized decision matrix

Weighted normalized decision matrix			
0.1148	0.1030	0.1448	0.0844
0.1185	0.1198	0.0831	0.0923
0.1134	0.1128	0.1332	0.1181
0.1108	0.1026	0.0964	0.1217
0.1007	0.1195	0.0873	0.1345

Table 5 shows the weighted normalized decision matrix. Alternative: Adaptability, Latency, Fault Tolerance, User Experience. Evaluation preference: Responsiveness, Accuracy, Resource Utilization, Reliability, Power Efficiency the weighted default result is calculated using the matrix formula (2).

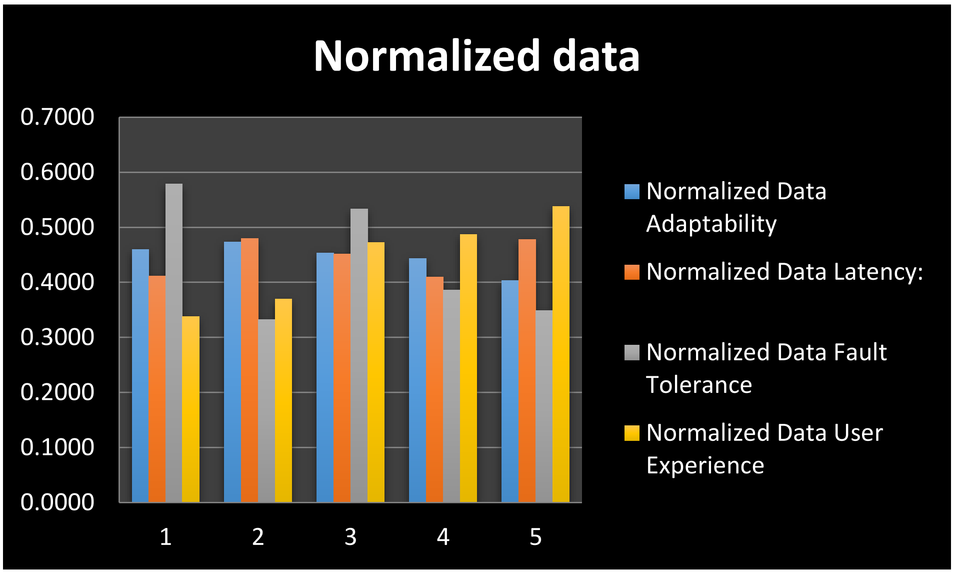

Figure 2 shows the various Normalized Data. Alternative: Adaptability, Latency, Fault Tolerance, User Experience. Evaluation preference: Responsiveness, Accuracy, Resource Utilization, Reliability, Power Efficiency. Normalized value.

TABLE 6. Assessment value& Rank

	Assessment value	Rank
Responsiveness	-0.0113	4
Accuracy	0.0628	1
Resource Utilization	-0.0250	5
Reliability	-0.0047	3
Power Efficiency	-0.0016	2

$$\text{Assesment value} = \sum X_{wn1} + X_{wn2} - X_{wn3} \qquad (3).$$

Table 6 shows the Assessment value& Rank value used. Assessment value for Responsiveness -0.0113, Accuracy 0.0628, Resource Utilization -0.0250, Reliability -0.0047, Power Efficiency -0.0016, the final rank of this paper, the Reliability is in 3rd rank, Power Efficiency is in 2nd rank, Responsiveness is in 4th rank, Resource utilization is in 5th rank, and the Accuracy is in 1st rank. The final result is done by using the Moora method.

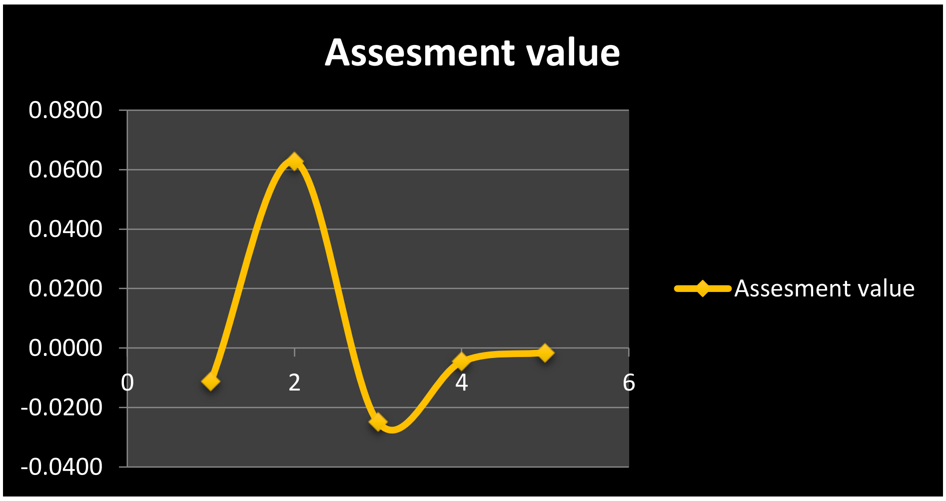

FIGURE 3. Assessment value

Figure 3 shows the Assessment value for Assessment value for Responsiveness -0.0113, Accuracy 0.0628, Resource Utilization -0.0250, Reliability -0.0047, Power Efficiency -0.0016. Liner assessment value y= 0.0055x+ 0.0839 R^2 0.2125

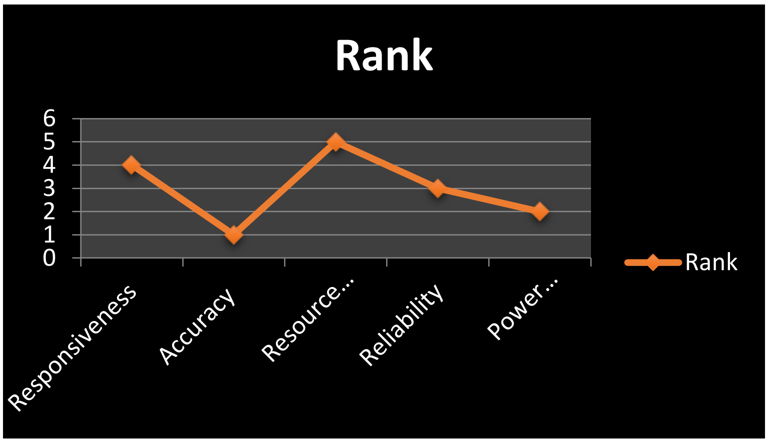

FIGURE 4. Rank

Figure 4 shows the graphical view of the final rank of this paper the Reliability is in 3rd rank, Power Efficiency is in 2nd rank, Responsiveness is in 4th rank, Resource utilization is in 5th rank, and the Accuracy is in 1st rank The final result is done by using the moora method.

4. CONCLUSION

Embedded intelligent real-time systems have proven to be a significant advancement in various domains, offering enhanced capabilities and efficiency. Through this evaluation, it is evident that these systems have a multitude of advantages, including improved responsiveness, increased automation, and better decision-making abilities. By integrating artificial intelligence and real-time processing into embedded devices, these systems can handle complex tasks with greater accuracy and speed. Moreover, the evaluation highlights that the implementation of such systems requires careful consideration of hardware, software, and AI algorithms to ensure seamless integration and optimal performance. While the benefits are substantial, challenges such as resource constraints and security vulnerabilities must be addressed to fully harness their potential. In conclusion, Embedded Intelligent real-time systems hold great promise for revolutionizing industries and everyday life, but their success depends on the careful design, robust development, and continued research to overcome existing limitations. As technology progresses, these systems are likely to become even more prevalent and indispensable in various applications, contributing to a smarter, more interconnected world.

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