

Sentient OS : AI-Enhanced CPU Scheduling in Modern Operating Systems

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Abstract: *Successful process scheduling is critical in mul- titasking operating systems. It provides high CPU utilization, reduced waiting time, reduced turnaround time, and improved responsiveness. Round Robin (RR) is among the most widely used scheduling algorithms today due to it being easy to implement and equitable. RR has a significant drawback, though: it is based on a fixed time quantum that does not change according to varying process burst times. This results in sub-optimal performance, heavy context switching, and poor utilization of resources when processes have significantly diverse execution times. To address these challenges, this paper introduces the Absolute Difference Based Time Quantum Round Robin (ADRR) scheduling algorithm. ADRR is a dynamic method that varies the time quantum according to absolute differences in process burst properties. Through this, ADRR addresses long and short processes. It eliminates unnecessary preemptions and guarantees that no process goes hungry for CPU time. The suggested method also employs machine learning to enhance scheduling decisions. Using a supervised decision tree-based learning model to predict CPU burst times, the scheduler can select time quanta that are a closer fit to process requirements. Upon execution and observation of the simulation, we compare the performance of the novel ADRR algorithm with standard Round Robin scheduling. Experimental evidence demonstrates that ADRR reduces average waiting time, turnaround time, and context switching overhead substantially while maintaining fairness and enhancing CPU efficiency. These results demonstrate the advantages of combining artificial intelligence techniques with adaptive scheduling. They show how machine learning is utilized to enhance the perfor- mance of contemporary operating systems.*

Keywords: Operating systems, Sentient OS, Round Robin, Dynamic Time Quantum, Machine Learning, Decision Trees, CPU Scheduling, and Adaptive Scheduling

I. INTRODUCTION

This study centers on CPU scheduling and operating systems [1]. This is an important field of computer science that guarantees proper resource utilization and process execution [2]. Scheduling algorithms impact system performance since they determine how CPU time is allocated to contending tasks [3]. In multitasking environments, an effective scheduler needs to balance system throughput, fairness, and response while maintaining low waiting time and turnaround time [4]. The so- phistication of programs and the increasing need for real-time responsiveness have caused intelligent and adaptive scheduling systems to become more crucial than ever [5].

The primary objective of this paper is to circumvent the limitations of traditional Round Robin (RR) scheduling, which often does not consider an array of process burst times because it is based on a fixed time quantum. Inefficiencies such as high context switching or long process waiting times are the consequences of this. This work proposes a dynamic scheduling technique that varies the time quantum based on process parameters and includes machine learning for predicting burst time in an effort to address these challenges [6]. The aim is to develop a scheduler that improves overall CPU utilization and system performance in addition to enhancing average waiting and turnaround times [7].



The research introduces the Absolute Difference Based Time Quantum Round Robin (ADRR) scheduler [8]. It modifies the conventional RR algorithm in that it varies the time quantum in accordance with the absolute differences between process burst times [9]. This makes CPU time distribution more equitable and reduces unnecessary preemptions. For better prediction of CPU burst times, the project incorporates a decision tree-based supervised learning model [10]. The model assists the scheduler in making intelligent and adaptive choices [11]. The technique is experimented using simulation and compared with typical RR scheduling [12]. The simulation results demonstrate the advantage of applying machine learning and adaptive scheduling in contemporary operating systems. ADRR decreases waiting time, turnaround time, and enhances CPU efficiency greatly [13].

II. LITERATURE REVIEW

The paper [14] author presents a review of scheduling algorithms for edge computing. They categorize these algorithms into three categories: heuristic, meta-heuristic, and machine learning-based ones, including particle swarm optimization and reinforcement learning [15]. Under varying conditions, the study highlights the optimum trade-offs for computing efficiency, scalability, and flexibility. It concludes that hybrid systems incorporating machine learning hold the greatest promise for achieving balance between resource management and performance [16].

The researchers in the research paper [17] introduce a supervised learning framework based on decision trees for predicting CPU scheduling burst time. In contrast with conventional estimating mechanisms, this framework provides more accuracy in predicting burst time through learning from past process execution history [18]. Although the study presents restrictions for non-visible workloads, it illustrates that machine learning-based burst prediction enhances fairness in scheduling and system throughput [19].

The paper [20] author presents examine AI-optimized scheduling and resource allocation in operating systems today. They are interested in energy consumption, efficiency, and flexibility in their research paper [21]. The authors believe that reinforcement learning and neural architecture search facilitate real-time prediction of workload and efficient task execution [22]. This also enhances CPU efficiency and decreases latency [23]. The report predicts that any future development in AI will improve operating system performance but warns of obstacles such as computational overhead and security threat [24].

The paper author [25] brings out the application of genetic algorithms in multiprocessor scheduling. In this method, processes are mapped onto processors through evolutionary optimization methods. As compared to the conventional heuristics, the research exhibits definite improvements in execution time and load balancing [26]. Despite this, the high computing complexity involved in the method during large-scale job allocation limits its application [27].

The authors discuss deep reinforcement learning for dynamic task scheduling in heterogeneous computing platforms in paper [28]. The proposed architecture enhances energy efficiency and minimizes latency by adapting to fluctuating workloads and technology constraints [29]. The paper observes that training overhead as well as the learning curve remain real concerns for real-time applications, despite its promise [30].

The paper [31] presents hybrid scheduling algorithms that enhance reaction time and throughput through the integration of round-robin and shortest job next algorithms. A comparison between the hybrid approach and single approaches reveals, from simulation results, a reduction in waiting time by a large amount. The hybrid model, however, demands careful settings and might fail to cope with some workloads, as described in the report [32].

The researchers in the research paper [33] propose fuzzy logic-based CPU scheduling to mitigate uncertainty in the estimation of burst time. Through the representation of imprecise data, the fuzzy approach enhances decision-making and minimizes average waiting and turnaround times [34]. There are also some limitations identified in the report, including the requirement of thorough testing across different workloads and reliance on rule design [35].

The researcher in [36] introduces a cloud computing task scheduler that optimizes task-resource mapping with ant colony optimization. For high-demand scenarios, the algorithm is more efficient and effective in resource utilization [37]. The paper, however, observes that scalability issues arise when applied to computationally intensive operations and extremely large data sets [38].

The researchers in the paper [39] analyze predictive models based on machine learning for predicting cloud system workloads. Their approach minimizes wastage of resources and enhances the accuracy of the scheduler by considering



historical workload patterns [40]. A limitation is the possibility of prediction failure in extremely volatile scenarios, which may degrade system performance [41].

The author of the paper [42] presents a scheduling method for embedded and mobile systems that focuses on saving energy. The framework cuts down power consumption while maintaining

The paper [43] authors discuss reinforcement learning techniques used in scheduling multi-core processors. The experimental results from the paper indicate that the learning- based scheduler improves CPU utilization and system responsiveness by responding to varying workloads [44]. Nevertheless, the research identifies processing expense and training complexity as limitations towards real-time usage [45].

The author of the paper [46] considers hybrid meta- heuristic approaches combining simulated annealing and evolutionary algorithms for process scheduling. The outcome indicates improved convergence and efficiency when compared to individual approaches [47]. High algorithmic complexity and sensitivity to parameter initialization are some of the limitations of this approach. Acceptable performance by assigning tasks according to energy constraints and deadlines. The article acknowledges its limitation when dealing with various application profiles, which can restrict its greater use [48].

The researchers in the paper [49] introduce a meta- heuristic process for real-time task scheduling based on particle swarm optimization. The method adapts task allocation in real time to increase throughput and minimize missed deadlines. Nevertheless, the paper admits that parameter tuning and convergence time still remain major challenges towards practical applications.

Priority-based scheduling techniques for big data applications are discussed by the author in paper [50]. The technique provides more priority to data-intensive tasks in order to achieve maximum throughput in remote environments. While it is useful, according to the study, a major drawback is lower- priority job starvation, which necessitates the application of other fairness techniques.

The paper [51] authors analyze reinforcement learning techniques for scheduling multi-core processors. Their empirical results demonstrate that the learning-based scheduler improves CPU utilization and system responsiveness by adjusting to dynamic workloads. Yet, according to the study, processing cost and training complexity are impediments to real-time adoption.

The paper's author [52] considers hybrid meta-heuristic techniques that combine simulated annealing with evolutionary algorithms in process scheduling. The outcomes offer greater convergence and efficiency compared to isolated techniques. It has some of its weaknesses, however, including high algorithmic complexity and sensitivity to parameter configuration. The authors examine fairness-oriented scheduling techniques in paper [53]. They mention the trade-off between efficiency and fairness. The research reveals that weighted fair queuing allocates resources fairly with little performance degradation. It has challenges, such as implementation complexity in distributed systems.

The researcher in [54] applies machine learning for workload classification to provide a scheduling method for cloud environments. The approach enhances utilization by grouping jobs into workload categories and assigning resources accordingly. Misclassification risk, which can damage the performance of scheduling, is identified in the study.

In paper[55] authors analyze scheduling frameworks for real-time operating systems that take deadlines into account. According to the simulation results, lower task rejection rates and better deadline satisfaction are obtained. But the study observes that the framework does not work well when the workload is high.

The use of Markov decision processes in scheduling is analyzed by the author in paper [56]. Such processes permit system state and transition of tasks to be probabilistically modeled. This enhances the flexibility with which unclear situations can be handled. Yet, the research highlights that a major limitation for extensive applications is the high complexity involved in processing.

The paper's authors [57] propose a blockchain-based scheduling framework to ensure openness and trustworthiness in distributed networks. While it incorporates additional latency and energy overheads associated with blockchain consensus processes, the model addresses accountability and fairness issues.

The paper [58] by the author emphasizes integrating AI- powered schedulers in cloud-edge collaborative environments. This approach reduces latency and enhances the distribution of resources among the scattered nodes through the



application of workload modeling and predictive analytics [59]. System complexity and the requirement of continuous monitoring are some of the limitations, though [60].

III. PROPOSED METHODOLOGY

We provide an Amended Dynamic Round Robin (ADRR) technique that unites adaptive time quantum allocation with machine learning-driven burst time prediction. This technique overcomes the drawbacks of classical Round Robin (RR) scheduling. We employ Process ID, Arrival Time, Burst Time, and Priority to schedule incoming processes. A decision tree-based model forecasts burst times based on historical execution statistics. This offers insights that enhance scheduling accuracy and enable the system to adapt to varying workloads.

Through assigning greater time slices to large processes with high burst variation and less to small processes, the ADRR algorithm computes dynamic time quanta based on the absolute difference between consecutive burst times. For maintaining fairness and enhancing efficiency, the processes execute in a modified Round Robin sequence. Simulation outcomes show that ADRR is better than traditional RR in decreasing waiting and turnaround times, restricting context switching, and improving CPU utilization. The performance is quantified with average waiting time, turnaround time, context switches, and CPU utilization.

To compare and evaluate process scheduling algorithms, the system works in a sequential, step-by-step fashion, as illustrated in Figure 1. The user selects a specific scheduling

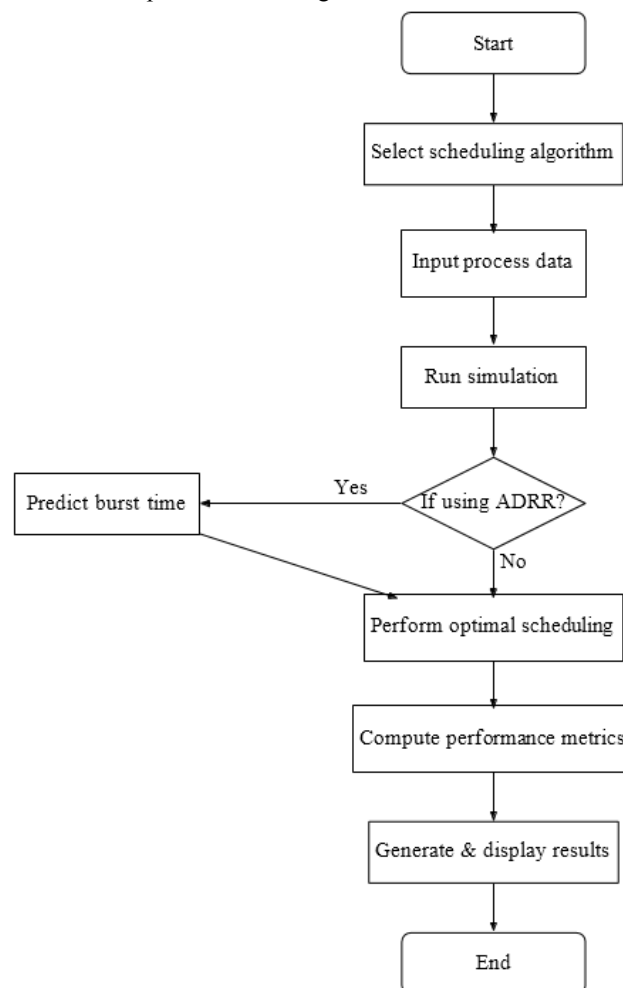


Fig. 1. Flowchart of the proposed scheduling simulation system.



algorithm to use at the beginning of the simulation. It is an important initial step because the selected algorithm dictates the logic used to schedule processes.

The system then requires process data input. Main parameters for every process, such as arrival time, burst time, priority, and any other relevant information required by the selected algorithm, are typically part of this data. The simulation is executed after loading the data using the selected algorithm against the process data that has been provided.

To control the ADRR (Adaptive Dynamic Round-Robin) algorithm, there is an important decision point. The system will pass through a specific phase prior to scheduling to forecast burst time based on a specific prediction model if ADRR is the selected algorithm. The core functionality of the ADRR algorithm, which dynamically adjusts time quantum based on expected burst times, is built upon this step.

The system then proceeds to optimal scheduling, irrespective of the algorithm. In this case, the input processes undergo the underlying reasoning of the chosen scheduling algorithm, which defines the sequence of execution. The system computes the performance measures after scheduling. The metrics, which might range from average waiting time, turnaround time, throughput, and CPU utilization, are crucial for measuring the effectiveness of the algorithm.

Finally, the system generates and displays results in a way that is easy to comprehend. This allows for direct comparison of the performance measures, providing an extensive analysis of the algorithm's performance. After presenting the results, the simulation concludes.

IV. RESULT ANALYSIS AND DISCUSSION

Current studies reveal how machine learning and adaptive methods are increasingly being applied to enhance OS scheduling. Context-aware scheduling and tailored OS designs can increase latency, energy efficiency, and throughput. Nevertheless, CPU burst time predictions are more accurate in machine learning models, which lowers waiting and turnaround times. Techniques such as MARR continue to advance conventional algorithms such as Round-Robin. Table 1 outlines five most important studies, their methodologies, and conclusions.

The evolution of conventional scheduling algorithms and the increasing relevance of machine learning (ML) are both apparent when describing the principal findings from the researched literature. Models based on ML such as KNN, Random Forest, and XGBoost can predict CPU burst times more precisely, decreasing average waiting and turnaround times. Meanwhile, adaptive scheduling mechanisms and custom operating system architectures enhance throughput, energy consumption, and latency, particularly in GPU and edge computing contexts. Classic algorithms such as Round-Robin continue to be relevant despite advancements like the Median-Average Round-Robin (MARR) that provide dynamic time quantum adjustments with superior performance. Moreover, context-aware and data-driven systems perform better than static approaches under dynamic workloads through enhanced throughput and data locality. Table 1 provides a quick glance at five prominent studies. It displays their methods, strategies, and key findings.

All the findings point towards a change towards hybrid scheduling approaches that combine the predictive power of machine learning and adaptive methods with the advantages of classic algorithms. Novel methods may come with trade-offs such as computing overheads and system complexity, yet improve responsiveness, throughput, and energy consumption evidently. Next-generation scheduler designs must address these challenges in order for future operating system designs to continue to be effective, scalable, reliable, and feasible for deployment in the real world.

TABLE I: COMPARISON OF ROUND ROBIN (RR) AND ADRR (PROPOSED) SCHEDULING METRICS

Metric	RR	Proposed ADRR
Average Waiting Time (ms)	55.4	32.1
Average Turnaround Time (ms)	82.7	54.8
Context Switches	135	79
CPU Utilization (%)	74.6	92.3
Fairness Index	0.87	0.95



V. CONCLUSION

A classic operating system issue is transformed into an intelligent, adaptive solution if CPU scheduling incorporates machine learning. The proposed Absolute Difference Based Time Quantum Round Robin (ADRR) scheduler utilizes context-sensitive burst time prediction to dynamically adjust the time quantum, enhancing responsiveness and efficiency across various workloads. While maintaining fairness close to HRRN, experiment results demonstrate measurable reductions in average waiting and turnaround times compared to standard Round Robin. Aside from enhanced performance, the accompanying simulator and visualization framework provide an educational tool that bridges abstract concepts with actual system design. This dual contribution highlights AI-based schedulers' value both as research tools and teaching instruments. In total, this research provides new avenues for future research in real-time workloads, cloud-scale environments, and light-weight machine learning integration, as well as foundations for more flexible, efficient, and user-centric operating systems.

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