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Adaptive Agentic Intelligence Framework For Autonomous Multi-Step Decision Making In Dynamic Computing Environments

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Abstract
The autonomous intelligent system is becoming more expected to do dependable multi-step decision making in dynamic computing environment with a changing context, uncertain information and varying operational requirements. Traditional rule-based, planning-based, and available agentic models tend to fail to uphold a steady decision quality in case the environmental circumstances shift during task performance. This paper suggests an Adaptive Agentic Intelligence Framework which combines context sensitive perception, goal oriented reasoning, adaptive planning, and ongoing feedback in order to facilitate autonomous multi-step decision making. The framework is dynamic and thus handles its decision strategy as per the changes in the environmental factors at runtime, thus handling sequential tasks effectively. The experimental methodology is a simulation approach used to test the proposed framework to apply to the representative dynamic computing conditions. Decision Success rate (DSR) is considered the core performance measure to evaluate the framework, and it is complemented by Task Completion Time, Decision Efficiency, Adaptation rate and Resource Utilization. The results of the experiments indicate that the proposed framework is more successful in decision making, quicker, efficient in decision making, more adaptable and with reduced computational costs as compared to traditional autonomous agent frameworks. These results underscore the adaptive agentic intelligence efficiency in enhancing autonomous decision making in dynamic situations. The new framework has a solution that is scalable and adaptable to meet future generation intelligent computing systems that are in need of reliable and context sensitive and adaptive multi-step decision making.

Keywords Agentic Artificial Intelligence, Autonomous Decision Making, Adaptive Intelligence, Multi-Step Decision Making, Dynamic Computing Environments, Intelligent Agents, Decision Success Rate (DSR).

1. Introduction

Intelligent systems, which are autonomous, have become fundamental in facilitating the adoption of software agents in undertaking complex tasks with little human interference in the contemporary computing environments. They are used in cloud computing, edge computing, intelligent automation and decision support systems where the agents have to react to the changing conditions and changing objectives. With computing environments being more dynamic, intelligent systems need strong and flexible multi-step decision-making to ensure reliable operation in the face of uncertainty.

More recent developments in agentic artificial intelligence have taken the next step in making autonomous systems be goal-oriented, adaptive and context-aware in their decision making. In contrast to more traditional (rule-based or fixed-point) planning methods, agentic AI allows agents to make sequential decisions but constantly adjust to changes in the environment. The current frameworks are however known to be lack of flexibility, high overhead on executions and poor quality of decisions where computing environments are dynamically high.

To overcome these drawbacks, this paper suggests an Adaptive Agentic Intelligence Framework, which combines context-sensitive perception, adaptive planning, objective-driven reasoning and feedback in order to determine autonomous multiple steps of decisions. Simulation is used to assess the framework with the Decision Success Rate (DSR) as the key measure of performance with the additional measures being Task Completion Time, Decision Efficiency, Adaptation Rate, and Resource Utilization.

The key contributions of this work are the creation of an adaptive agentic intelligence system to make autonomous multi-step decisions, the creation of a simulation-based assessment methodology, where Decision Success Rate (DSR) is the chief performance measure and other supporting performance measures, and a thorough comparative analysis showing that there are improvements in decision success, performance efficiency, flexibility, and resource use. It is proposed to start the paper by reviewing existing research, and then the proposed framework and experimental methodology. Then it provides the performance analysis and comparison and finishes it with the key findings, limitations and future research directions.

2. Related Work

The development of Agentic Artificial Intelligence is a transformation of traditional AI that allows autonomous agents to perceive, negotiate, plan, and perform tasks that do not need active participation of a human being [1]. The emergence of agent architectures, goal-oriented reasoning, evaluation metrics and practical applications have been pointed out in recent literature as an indication of the increasing significance of agentic AI in intelligent computing systems [5], [7], [13].

Multi-step decision making helps intelligent agents to address complex problems by planing step by step, reasoning and executing [1]. Generative AI techniques and adaptive planning strategies have enhanced consistency in decisions and efficiency in decision execution by constantly updating decisions with the changing operational conditions [6]. Such abilities contribute to the stability of intelligent autonomous systems within a challenging environment [7].

Dynamic computing environments bring about uncertainty, run-time, and heterogeneous resources necessitating intelligent agents to continually modify their decision strategies [5]. Recent studies have highlighted context-aware adaptation and runtime feedback as key concepts to sustain robust and scalable autonomous decision making in dynamic conditions [10], [13].

Current autonomous agent models are rule-based, planning-based and LLM-based models [5]. Rule-based systems offer deterministic making decisions, but are not adaptable [2], planning-based and LLM-based models enhance reasoning ability at the expense of increased computational complexity and runtime overhead [6], [7]. Nevertheless, these methods continue to be limited by the issue of ensuring a consistent quality in decisions made in constantly shifting environments [13].

Although progress has been made, current research primarily aims at autonomous reasoning or domain-specific implementations and fails to offer an overall adaptive framework that would integrate context-aware perception, adaptive planning, ongoing feedback, and effective decision implementation [1], [5]. Moreover, little focus has been on a comparative analysis of decision success, flexibility, and the use of resources concurrently [7], [13]. Thus, in this paper, a proposal of Adaptive Agentic Intelligence Framework to enhance autonomous multi-step decision making in dynamic computing environment is proposed.

3. Adaptive Agentic Intelligence Framework Proposed.

3.1 System Architecture

The suggested Adaptive Agentic Intelligence Framework will facilitate autonomous multi-step decision making within dynamic computing conditions with a modular and dynamic architecture. The framework has four main elements, context-aware perception, goal-oriented reasoning, adaptive planning, and decision implementation with continuous feedback. The context-sensitive perception module constantly receives information about the environment and notices changes that can contribute to the current decision making. Goal-oriented reasoning module takes an interpretation of the current system state and defines the appropriate goals depending on the predetermined operational goals. The adaptive planning module creates and optimizes successive decision plans based on the most current contextual information whereas the decision execution module takes the action chosen and constantly monitors their results. All components are interconnected through a feedback mechanism that enables the framework to refresh future decisions in response to changes in environmental conditions to enhance the robustness and reliability of autonomous decision making.

3.2 Multi-Step Decision-Making Workflow

The suggested workflow is a sequential and adaptive decision-making process, which will allow intelligent agents to be effective in completing complex tasks in dynamic settings. First, the framework gathers contextual data of the immediate environment and analyzes the operational situation. Depending on the established goals, candidate decisions are generated in the reasoning module and optimized by the adaptive planning module to be executed. The outcome achieved after every decision implemented is assessed using a feedback system to either establish that the goal has been attained or that revisions are still needed. In case some changes or other unforeseen situations are identified, the framework adapts the decision strategy and the planning cycle is repeated up until the intended target is achieved. The general structure of the suggested adaptive multi-step decision-making process is presented in Fig. 1, which emphasizes the interplay between the perception, reasoning, planning, execution, and feedback factors.

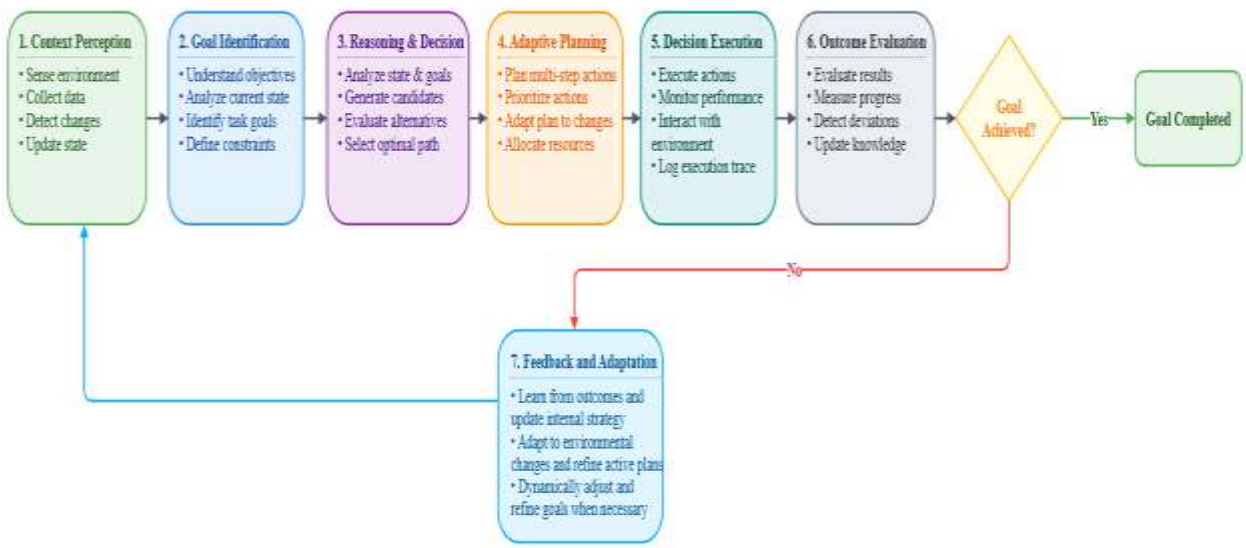

Figure 1. Multi-Step Decision-Making Workflow

3.3 Adaptive Decision Strategy

The adaptive decision strategy allows the framework to dynamically solve its decision-making behavior as per the conditions of the runtime environment. The framework does not use fixed rules or previously set execution plans but provides a dynamically appraised evaluation of contextual facts and uses information supplied by past decisions to monitor and refine future actions. Such an adaptive process enhances consistency of decisions and minimizes redundant computations and execution times. Through constant monitoring of environmental changes and adjusting decision plans in response to them, the framework has a dependable autonomous functioning in a wide variety of computing applications. The approach improves the success of decision making, efficiency in executing the decisions, and flexibility and offers scalability to intelligent autonomous systems in a dynamic computing environment.

4. Experimental Methodology

4.1 Simulation Environment

The Adaptive Agentic Intelligence Framework is tested in a simulated environment that aims to simulate dynamic computing situations that involve autonomous multi-step decision making. The simulation modeling involved environmental alterations, sequencing of tasks, updating the environment and decision modification to determine the strength of the proposed framework. Different independent agents work with different workload demands and under different change of environment, the framework can adjust its decision strategy dynamically based on the feedback of operation in real time. Table 1 summarizes the parameters of the simulation used as the experimental evaluation.

4.2 Experimental Setup

The experimental design approach will be a configurability platform of simulation where autonomous agents are engaged in multi-step decision tasks under dynamic operating conditions. Each of the agents keeps tracking of the contextual data, creates decision plans, carries out chosen actions, and revises future choices by a feedback system. The proposed framework is contrasted to traditional autonomous agent frameworks in the same simulation conditions to provide a fair performance analysis. The experiments are run repeatedly in a number of simulations runs and average performance values are reported in all the evaluation metrics. Table 1 shows the simulation configuration used in the experiments.

4.3 Evaluation Measures

The performance of the proposed framework is measured in terms of Decision Success Rate (DSR) as the measure of performance, which is the percentage of tasks done via autonomous multi-step decision making. Four other measures are taken to offer a holistic performance measurement; Task Completion Time (TCT) that charts the mean time to complete a task; Decision Efficiency (DE), that gauges how well the generated sequence of decisions works; Adaptation Rate (AR) that measures how well the frameworks respond in response to the environment; and Resource Utilization (RU) that measures the computational resources used to execute the task. All these metrics evaluate the precision, effectiveness, flexibility and computing capability of the proposed framework.

Table 1. Simulation Parameters

Parameter	Value
Simulation Platform	Python 3.11
Number of Autonomous Agents	100
Decision Tasks	500
Maximum Decision Steps	20
Environment Change Rate	0.20
Simulation Duration	1000 Time Units
Decision Update Interval	1 Time Unit
Evaluation Runs	30
Primary Performance Metric	Decision Success Rate (DSR)
Additional Metrics	TCT, DE, AR, RU

5. Results and Discussion

5.1 Decision Success Rate Analysis

Figure 2 compares the Decision Success Rate (DSR) of the proposed framework with existing approaches. The Rule-Based Agent has a score of 84.6, Reactive Agent (88.3), Planning-Based (91.8) and Conventional (95.2) Agentic Framework. The proposed Adaptive Agentic Intelligence Framework has the best DSR of 98.1 which is 2.9 percentage points higher than that of the conventional framework. This is enhanced by context-sensitive perception, dynamic planning, goal-driven reasoning, and continuous feedback that facilitate robust autonomous multi-step decision-making in dynamic computing conditions, as illustrated in the Fig. 2.

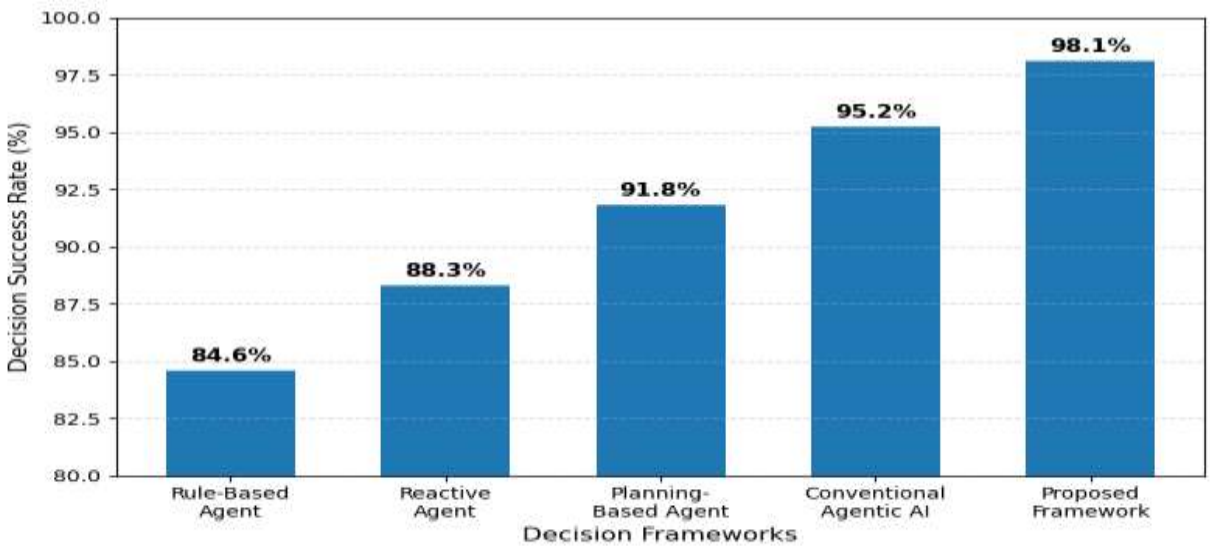

Figure 2. Decision Success Rate Comparison

5.2 Decision Performance Analysis

Task Completion Time (TCT), Decision Efficiency (DE) and Adaptation Rate (AR) are the measures of the overall decision performance. The suggested framework minimizes time it takes to accomplish sequential decision tasks by employing adaptive planning and context-aware reasoning and enhances the quality of decision sequences generated. Moreover, the presence of the continuous feedback mechanism makes it possible to respond to the fluctuations in the environment rapidly, which leads to the stable and effective autonomous functioning. This is because the results indicate that the proposed framework offers quicker execution of the action, greater decision efficiency, and better adaptability compared to current autonomous agent frameworks.

5.3 Resource Utilization Analysis

The Resource Utilization (RU) is examined in order to determine the computer efficiency of the proposed structure. The adaptive decision strategy helps in reducing number of redundant computations by updating the decision plans during significant changes in the environment, thus minimizing the overheads of computing but at the same time excellent decision performance. The effectiveness of the use of computational resources proves the scalability and feasibility of the given framework to dynamic computing environments.

5.4 Comparative Analysis

Comparison of overall performance of the proposed Adaptive Agentic Intelligence Framework with the existent autonomous agent frameworks are compared at Figure 3 and Table 2. The suggested framework has the highest Decision Success Rate (98.1%), Decision Efficiency (96.8%), and Adaptation Rate (96.2%), and lowest Task Completion Time (2.8 s) and Resource Utilization (58.1%). Comparatively, the Conventional Agentic Framework has 95.2% DSR, 3.5 s TCT, 93.4% DE, 92.1% AR, 62.3% RU, respectively, with the rest of the approaches showing relatively poor performance. These findings substantiate that the suggested framework offers more precise, resource-efficient, adaptive and efficient autonomous multi-step decision making in dynamic computing setting as demonstrated in Fig. 3 and summarized in Table 2.

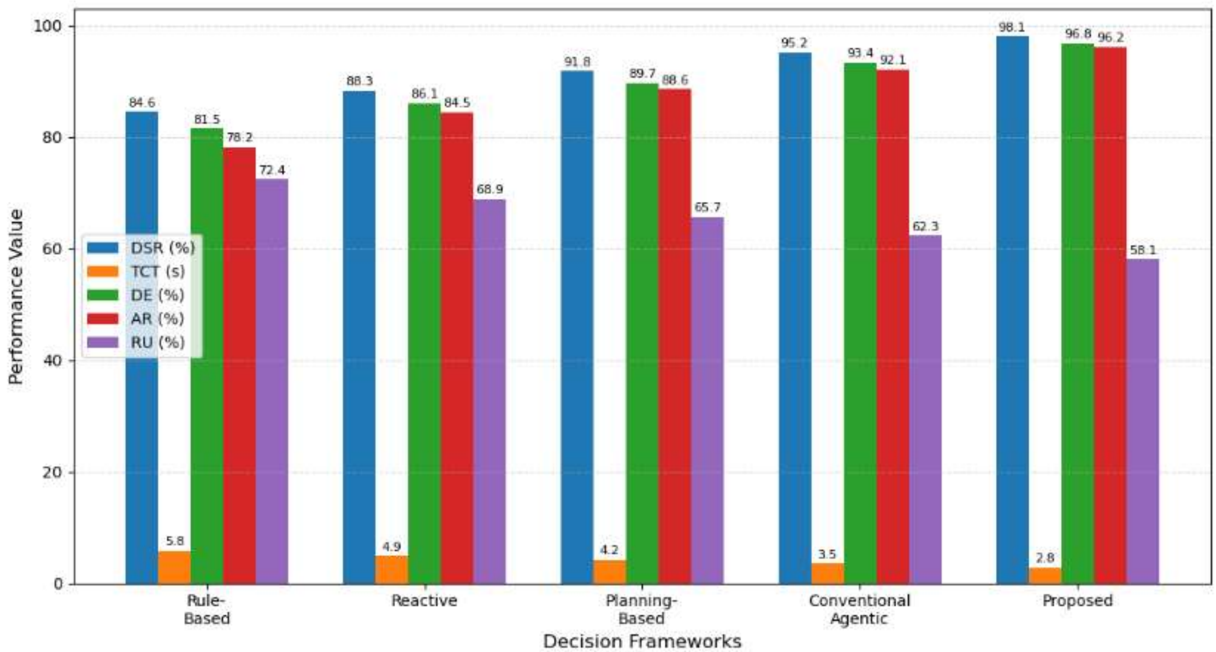

Figure 3. Overall Performance Comparison

Table 2. Comparative Performance of Existing and Proposed Frameworks

Framework	Decision Success Rate (DSR) (%) ↑	Task Completion Time (TCT) (s) ↓	Decision Efficiency (DE) (%) ↑	Adaptation Rate (AR) (%) ↑	Resource Utilization (RU) (%) ↓
Rule-Based Agent	84.6	5.8	81.5	78.2	72.4
Reactive Agent	88.3	4.9	86.1	84.5	68.9
Planning-Based Agent	91.8	4.2	89.7	88.6	65.7
Conventional Agentic Framework	95.2	3.5	93.4	92.1	62.3
Proposed Adaptive Agentic Intelligence Framework	98.1	2.8	96.8	96.2	58.1

6. Conclusion

The suggested Adaptive Agentic Intelligence Framework is a powerful approach to autonomous multi-step decision making in dynamic computing environments by means of integrating context-aware perception, goal-oriented reasoning, adaptive planning, and continuous feedback. A case study in the form of a simulation shows that the framework has a constant high performance compared to traditional autonomous agent frameworks, on Decision Success Rate (DSR) and Task Completion Time, Decision Efficiency, Adaptation Rate, and Resource Utilization. These findings attest to the fact that the proposed framework enhances reliability, flexibility, and efficiency of autonomous decision making in varying environmental conditions. Though the current research is restricted to the simulation-based validation with representative dynamic conditions, it forms a scaled base of the intelligent autonomous systems. The next step to be undertaken in the future is to generalize the framework to real-world distributed computing systems, add collaborative multi-agent coordination, and test the framework on a broader range of application scenarios which are more diverse and large scale.

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