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Article *in* International Journal of Computer Trends and Technology · August 2025

DOI: 10.14445/22312803/IJCTT-V73I8P102

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International Journal of Computer Trends and Technology
ISSN: 2231–2803 / https://doi.org/10.14445/22312803/IJCTT-V73I8P102
Volume 73 Issue 8, 7-14, August 2025

Original Article

Integrating Generative AI and Model Context Protocol (MCP) with Applied Machine Learning for Advanced Agentic AI Systems

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Received: 08 June 2025 Revised: 12 July 2025 Accepted: 30 July 2025 Published: 18 August 2025

Abstract - *Generative AI, Model Context Protocol (MCP), and Applied Machine Learning (ML) combine to provide a compelling means to power advanced agentic AI systems that are able to make decisions autonomously and to learn how to do better over time. This paper explores how these technologies can be integrated to improve the performance, flexibility, and intelligence of agentic AI systems.*

With generative AI, businesses can generate new data and, therefore, new insights, but MCP is what ensures these AI models are contextually aware and can function in different environments or conditions. Applied ML adds a new level of realism to model training and real-world deployment, proving that AI can learn, adapt, and make intelligent decisions on the fly. This paper presents the synergy of these building blocks and proposes a unified framework that combines their strength to develop intelligent context-aware agents that work independently in dynamic, complex environments. This integrated framework is widely applicable in domains like healthcare, finance, and robotics, where adapting decision-making abilities is important.

Keywords - *Generative AI, Model Context Protocol, Applied Machine Learning, Agentic AI, Autonomous Decision-Making, Adaptive Systems.*

1. Introduction

The area of Artificial Intelligence (AI) has seen massive growth in the last few years, especially with the advent of Generative AI, Machine Learning (ML) and Agentic AI systems [1]. These powerful technologies have even greater potential when used together.

One specific example of a combination would be Generative AI, Model Context Protocol (MCP), and Applied ML to build sophisticated agentic AI systems. These systems can act independently, adapting to their environment, creating new knowledge or information and performing other complex real-world tasks [2].

Generative AI models create new content of any type, such as text, images or even data. These models extract patterns from big data and return some reasonable results consistent with the training data [3]. Recent developments in deep learning have greatly expanded the reach of Generative AI, opening new possibilities in content creation, language modeling and problem solving. In the realm of agentic AI, being able to create new data or alternate universes gives agents more/fresher/expanded/and creative responses, so they can act on their own in a wider variety of environments [4].

Integrating contextual information in AI systems: the case of Model Context Protocol (MCP). MCP makes the AI model stay mindful of its operational context and in the environment it is operating in, the task that is at play, and any other relevant considerations shaping the model's behavior [5]. This is an adaptable model for AI, allowing it to consume contextual signals and use them to make decisions so it can, in real-time, react and change strategy or responses. The inclusion of MCP allows agentic AI systems to address issues caused by inflexible or fixed models, thereby enhancing decision-making in uncertain and dynamic environments [6].

AMLS (Applied Machine Learning Science), as opposed to theoretical ML, is concerned with the deployment of machine learning into production, with research studying how to learn and improve through deployment [7]. For agentic AI, applied ML helps AI systems learn and adapt to new data in the real world to better operate in evolving and real-world environments. Applied ML, in feedback loops, can allow this agentic AI to learn its decision-making strategies, making it output more accurate and relevant outputs per the system's growing experiences encountering further varieties of contexts [8].

The combination of Generative AI, MCP, and Applied ML is a powerful way to enable the construction of agentic AI systems that are adaptive and context sensitive, able to make autonomous and intelligent decisions. Such complementary technologies can further address the existing limitations in AI, e.g. lack of flexibility, adaptability, and context awareness in real-world scenarios [9]. Powerful agentic AI systems can handle large volumes of real-time data, extract insights, adapt courses of action and take matters into their own hands, and can prove invaluable in a wide range of dynamic industries, from healthcare, finance or robotics and beyond [10].

Despite the rapid advancements in Generative AI, Model Context Protocol (MCP), and Machine Learning (ML), there remains a significant gap in the integration of these framework that combines and harmonize them into an autonomous context-aware Agentic AI to make decisions. One one side, each of these individual technologies has witnessed extensive study, but their intersection, e.g., between Generative AI (for model/data generation and scenario simulation), MCP comes with context-aware decision-making, and ML (for lifelong learning and model refinement), are still under-explored in a unified environment.

Current Agentic AI systems have the shortcoming that they are largely contextually inflexible, as they do not adapt to the real-time dynamics of the environment, such as changing patterns of user activities or unforeseeable external occurrences. This research works to bridge this gap by investigating the intersection of Generative AI, MCP and ML to outline how Agentic AI systems can reason, learn and decide in real-time based on a deep understanding of the world around them.

2. Literature Review

It is now a rapidly growing area of research in AI and consists of Generative AI, Model Context Protocol (MCP) and Applied Machine Learning (ML) as one of its premises to invent advanced Agentic AI systems. The goal of this literature review is to investigate the state of these technologies and how they are combined to lead to intelligent, adaptive, learning systems that can act independently, in real time, in dynamic contexts [11].

2.1. Generative AI and Its Applications

Machine learning has already made several great strides (particularly in deep learning) thanks to generative AI models like Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs). These models are built to create data that looks just like real data sets, from images and text to audio and synthetic data for things like simulations. Research by Ogbu et al. (2023) established the power of GANs for generating high-value images and videos that has been extended to other domains, including natural language generation and drug discovery [12].

MCP: Model Context Protocol Model Context Protocol (MCP) for Context-Aware AI Model Context Protocol is a unified interface protocol for reasoning about and acting on context in human-centered systems and behaviors.

The Model Context (MC) protocol is a new way to let AI models know where (in what context) they currently are. Context-awareness provides the intelligence of AI systems to learn from changing situations to better inform decisions by considering additional factors from outside, such as user predilections, environmental status factors and task or user-specific parameters. Earlier work on context-awareness in AI systems (Hu et al, 2024) has shown its importance in enhancing performance and adaptability. However, its application was not very wide, mainly because of the shortage of coherent methodologies to adapt models on-the-fly to new environments [13].

2.1.1. Adaptation of Practical Machine Learning to the Real World.

Machine Learning (ML) has long been at the forefront of AI advancements, with a focus on training algorithms to recognize patterns and make predictions based on historical data. But applied ML goes further by focusing on actually shipping machine learning models in real-world scenarios. The practice of applied ML includes iteration on models via continued learning, a feedback loop, and performance measurement in an operational system. In the context of machine learning, bridging the gap between theoretical machine learning and its actual use is the topic of the work of Negnevitsky, M. (2025), but the scalability and deployment of ML models in dynamic environments remain key challenges [14].

For Agentic AI, applied ML is critical for systems that can actively learn from their environment on the fly. Unlike classical AI systems based on pre-programmed rules, Agentic AI systems enabled by applied ML can continually update their models, meaning that the accuracy of their decision-making increases as they receive feedback from the world. For example, Reinforcement Learning (RL) is a subdomain of ML used to teach AI-agents how to make decisions to maximize long-term objectives via interaction with an environment and learning to adapt their strategy based on its feedback (Borghoff et al., 2025) [15].

2.1.2. Agentic AI Systems: Deciding and Learning for Themselves

These advances in Generative AI, MCP, and Applied ML and the combination of these technologies, are expanding the capabilities for automated decision making. Agentic AI is built for high-level tasks that it performs by itself, and the fact that it can learn on a perpetual basis is what sets it apart from normal AI. Some early work on autonomous decision-making can be attributed to the work of Dodda (2023), who proposed the idea of autonomous robots that can decide independently based on sensor input without any external control [16]. Convolutional networks, Recent work by Dev et al. (2025) for deep reinforcement learning, have increasingly reaffirmed the significance of agentic AI in learning the optimal decision-making policy in environments under uncertainty [17].

The fusion of MCP and agentic AI enables agentic AI systems to process context-sensitive information and respond to it. Take, for instance, self-driving cars, which work on generative models and contextual perception, which can simulate different traffic conditions in real-time and react to instant changes in the environment (e.g., weather/road conditions), and generate optimal intentions without human intervention. This context-sensitive decision making is essential in domains like robotics, healthcare and finance, which depend on real-time changeable and self-acting behavior.

2.2. Research Purpose

The objective of this research is to examine the fusion of Generative AI, Model Context Protocol (MCP) and Applied ML to create advanced Agentic AI systems that have the ability to make decisions as an autonomous agent, to adapt in real-time and exhibit context-based behavior. Intelligent systems in which the above technologies are combined to be learned continuously, new knowledge is generated, and decisions are made in dynamic environments.

3. Agentic AI

Agentic AI systems are AI systems where the behavior is such that the AI system may act autonomously, not only in a reactive, non-incremental manner, but rather more proactively, where the AI is acting on the world without necessarily being directed by a human. Such systems are designed to emulate certain aspects of human interactions, in other words, to perceive their environment, process information, select between various courses of action, and make goal-directed choices, subject to the constraints of various circumstances [18].

3.1. Agentic AI Systems Tend to have the following Features

3.1.1. Autonomy

Agentic AI has the ability to work autonomously, performing actions or making decisions or choices without needing constant human supervision or control.

3.1.2. Flexibility

The systems can modify their behavior and decision-making due to changes in the system or new knowledge; hence, they are adaptable and able to learn dynamically in time.

3.1.3. Purposeful

Agentic AI systems are made to do certain things or achieve specific end states, ranging from simple activities to solving intricate problems.

3.1.4. Context Awareness

The ability to understand and analyze their environment context and are capable of adjusting their strategies behaviorally at will, incorporating cues to reach decisions.

3.1.5. Decision Process

Agentic AI can evaluate various options and choose the best response, typically using logic, algorithms, or machine learning to optimize a decision [19].

3.2. Some Examples of Agentic AI Systems Would be

Autonomous vehicles: Self-driving vehicles use real-time data from various sensors embedded in the surrounding environment to guide their motion and decision-making in real time.

Robotic Process Automation (RPA): Systems that are capable of performing repetitive tasks without human intervention. In turn, it learns from new information and adapts to change.

Artificial Intelligence (AI) recommendation engines: These are systems that actively adapt and learn their suggestions based on explicit and/or implicit user feedback loops, and work in a real-time context.

Virtual agents (such as Siri, Alexa): AI agents that execute tasks or answer questions autonomously across various channels, including voice, and learn from each of their responses.

The combination of generative AI with model context protocols and applied machine learning allows for more intelligent and adaptive agentic AI systems, capable of handling functions in more complex and dynamic environments.

Table 1 highlights the integration of Generative AI, Model Context Protocol (MCP), and Machine Learning (ML) in various Agentic AI systems across industries.
Each component plays a unique role in enhancing the overall capabilities of Agentic AI systems :

- Generative AI enables the creation of synthetic data, simulations, and predictions to improve training models. Helping prepare the AI agents for real-world situations.
- Model Context Protocol (MCP), an upcoming protocol, ensures that the AI system can adapt to changing environments by processing and incorporating contextual information.

- Machine Learning facilitates continuous learning, thus allowing AI agents to refine their behavior over a period of time. This is achieved by real-time feedback loops and performance optimization.

These integrations allow Agentic AI systems to function autonomously, adapt to evolving contexts, and make intelligent, informed decisions across various applications such as autonomous vehicles, healthcare, robotics, and financial systems [20].

Table 1. Role and integration of Generative AI, Model Context Protocol (MCP), and Machine Learning in different Agentic AI systems

Agentic AI System	Generative AI	Model Context Protocol (MCP)	Machine Learning (ML)
Autonomous Vehicles	Generates a synthetic dataset for model training. Useful for simulating driving conditions for better real-life preparation	Adjusting to varying traffic conditions, weather and changing road situations, making on-the-fly decisions in milliseconds/microseconds	Continuously improving driving strategies with the help of reinforcement learning based on environment interactions.
Healthcare Diagnostic Systems	Creates new medical data (e.g., images, patient records) to supplement training datasets, leading towards more accurate predictions	Adjusts the diagnostic journey for a given patient based on patient history, symptomology, and real-time data	Uses supervised learning to diagnose and predict medical conditions based on historical data.
Robotic Process Automation (RPA)	Produces task-based scenario scripts or synthetic data for decision-making in various environments	Continuously adjusts task execution based on context. Such context includes work volume, urgency, or specific task requirements.	Leverages machine learning in order to refine responses over time, building knowledge from past actions to improve future performance
AI-powered Virtual Assistants	Generates natural language responses or relevant interactions to users based on context	Understands user preferences, not limited to environment, and intent to provide personalized, real-time responses	Improves the accuracy of understanding and response generation over a period of time by learning and adapting from user interactions
Autonomous Drones	Generates simulations for flight paths, obstacle avoidance, and environmental interaction for better and effective training	Adjusts flight behaviour in real time based on environmental cues such as wind, obstacles, and even a drone's battery level	Employs machine learning for real-time navigation and decision-making during flight based on sensor data
Financial Trading Systems	Creates simulated financial data to test models under varying market conditions, optimizing strategies	Adapts trading strategies based on market context (e.g., market trends, volatility, regulatory changes)	Uses machine learning to navigate and make real-time decisions in flight with sensor data

4. Building Agentic AI systems

Building an Agentic AI System is highly complex & involves several key architectural components. These modules collectively enable the system to operate autonomously, adapt to dynamic environments, and make intelligent, context-aware decisions.

Below is a breakdown of the essential building blocks for developing an agentic AI system:

Table 2. Building blocks for Agentic AI systems

Building Block	Description	Key Component/Technologies
Data Collection and Sensing	To capture real-time data from various sources continuously. This helps the system to provide appropriate context for decision-making with better accuracy. (e.g., sensors, IoT devices, user inputs)	IoT sensors, APIs, Data streams, Edge computing, Real-time data ingestion
Data Preprocessing and Cleaning	Process to ensure that data is clean, consistent, and ready for use by AI models. Process includes data normalization, noise reduction, and transformation.	Data wrangling tools, ETL processes, and Data pipelines
Generative AI Model	Generates synthetic datasets, scenarios, and simulations to train models for better simulation outcomes and predict future events.	GANs, VAEs, Language Models (e.g., GPT), Autoencoders
Model Context Protocol (MCP)	Extends a framework for the AI system to understand and incorporate the current context of the environment. (e.g., location, time, task status) These contexts are further used in its decision-making process.	Contextual data management, Dynamic context models
Machine Learning Algorithms	A core component that enables the system to learn from historical data and, through a continuous feedback loop, optimize decision-making over time.	Supervised, unsupervised, and reinforcement learning algorithms
Decision-Making Engine	The brain of the agentic system, which is the core, is where real-time decisions are made based. Such decisions are based on model outputs, contextual information, and learned behaviour.	Optimization algorithms, Decision trees, Rule-based systems, Multi-criteria decision analysis (MCDA)
Knowledge Base / Memory	Stores learned information, historical data, and contextual knowledge in the knowledge base. In turn, to help the AI system make informed decisions over time.	Databases, Knowledge graphs, Ontologies, Graph databases
Action and Control Layer	The decisions made by the AI system are further executed in the physical or digital world. (e.g., commanding robots, triggering notifications).	Actuators, Robotic systems, API calls, Cloud-based controllers
Feedback Loop and Monitoring	Continuously collects feedback from the environment. This feedback loop helps in monitoring system performance to improve decision-making.	Real-time feedback loops, Monitoring dashboards, A/B testing
Ethical and Governance Layer	Ensures that the system operates within ethical boundaries, with transparency, fairness, and accountability, which is key to establishing trust in the AI system.	AI explainability, Ethical frameworks, Regulatory compliance (e.g., GDPR, HIPAA)
Security and Privacy Layer	Protection of sensitive data and ensuring secure interactions. Extremely vital for systems handling personal or confidential information.	Encryption, Authentication, Authorization, Blockchain for integrity
User Interface (UI) / Interaction Layer	Provides an interface for users to interact with the system, receive responses, and provide feedback.	Web interfaces, Voice interfaces, Chatbots, Virtual assistants
Integration Layer	Facilitates communication between different systems & applications. Ensures seamless data flow and interoperability.	API Gateway, Microservices, RESTful APIs, Webhooks

5. Future Scope

Integrating Generative AI, Model Context Protocol (MCP) and Machine Learning (ML), leading to Agentic AI systems, extends immense potential in the future [24],[25].

As AI progresses, some of the main advances and capabilities the world will witness are:

5.1. Increased Autonomy and Decision-Making

Next-generation Agentic AI systems will have greater autonomy and will be capable of making complex and context-based decisions in real time through dynamic settings. And by growing the role of MCP in these systems, they become even better at handling such situational subtleties, paving the way for AI to do more work in less predictable situations (like complex urban settings or evolving health care situations) [21].

5.2. Personalized AI Systems

As Generative AI progresses, it will make it possible to generate personalized solutions for users. In healthcare, finance, and customer service, next-generation Agentic AI systems could create customized solutions on the fly, learning from each interaction and adjusting tactics based on the user's unique state and preferences.

5.3. Cross-Domain Application

The combination of these techniques may facilitate developing multi-function AI systems capable of working in multiple domains without having to be significantly reprogrammed. Through transfer learning and domain adaptation, a single AI system can be applied to multiple industries, e.g., autonomous driving, medical diagnosis, and financial trading, by simply adjusting its contextual comprehension and learning properties to those respective domains [22].

5.4. Better Human-AI Interaction

On the way to full autonomy, agentic AI may be designed to become better at working with humans in the future. Such AI systems will present more natural and human-like interactions, collaborating with human professionals to complement decision-making, do complex reasoning and increase productivity in a variety of sectors.

5.5. Ethical and Transparent AI

Agentic systems will continue to grow in autonomy, presenting a (growing) need for regulation, Ethics and transparency. In the future, the research will probably aim to design ethical frameworks to guarantee accountability, fairness, and explainability in decision making, particularly in such high-stakes domains as medicine, law enforcement and financial services.

5.6. Integration into IoT and Edge Computing

With IoT and edge computing becoming widespread, Agentic AI systems will be deployed in a distributed way and will process data locally to get the best of both worlds. This paradigm would lead to immediate involvement in applications like smart cities, autonomous drones, and industrial robotics that rely on time-sensitive decision-making [23].

In summary, the future of combining Generative AI, MCP, and ML into Agentic AI systems is of significant magnitude in achieving smarter, adaptive, and flexible systems. These breakthroughs will lead to innovative applications across vertical markets, better business processes, and the creation of new opportunities for autonomous context-aware decision-making in an increasingly complicated world.

6. Challenges & Considerations

6.1. Context Management and Adaptability

A major challenge in interfacing Model Context Protocol (MCP) with an agentic AI system is the need for an efficient (dynamic) context management environment. Real-world environments are complex, and these systems will have to be flexible enough to update their decisions on the fly based on contextual changes, something that is hard to do with current MCP frameworks. Most contexts are highly dynamic and unpredictable in terms of behavior, and because of this, AI systems must be highly context-aware to be more effective. Suboptimal or incorrect decision-making, for instance, high-stakes applications such as health care or autonomous vehicles, can have adverse results arising due to wrong or incomplete interpretation of context.

6.2. Scalability and Computational Efficiency

Incorporating Generative AI, MCP, and Machine Learning are computationally expensive, particularly as these systems grow. Models in generative AI, like deep learning networks, need tons of training data and computational oomph to produce results that make sense. The above requirements are further complicated when we consider the real-time MCP and ML, resulting in an explosive growth in the system computational workload. Scaling toward billions of everyday use-cases that can reliably and rapidly process and transform data in real-time is challenging, especially when applied to real-world and mission-critical use-cases like autonomous systems or smart cities.

6.3. Ethical Issues and Responsible AI

Given the increased autonomy of Agentic AI systems, the ethical aspects of decision-making will be a crucial issue. Autonomously operating systems that make decisions on their own initiative, especially those in sensitive areas such as health care, finance or law enforcement, need to work within the realms of ethics to remain fair, transparent, and accountable. The opacity of decision-making, especially with black-box models such as deep neural networks, is a source of concern regarding bias, discrimination and explanations for AI-driven decisions. It is a prerequisite for their existence to have trust in those systems to follow an ethical guide and for their actions to be traced and justified.

Furthermore, there would also have to be suitable regulations to regulate the use and accountability of such advanced AI systems.

7. Results & Discussions

Based on our research and to achieve better results compared to current systems working discreetly, the seamless integration of Generative AI, the Model Context Protocol (MCP) and Applied ML is necessary. Generative AI is enabled to augment training datasets by generating synthetic data, which enhances the model's robustness. Context-awareness is aided by MCP, which allows solutions to adapt to changing environments, such as user preferences and real-time data, which most often conventional models fail to do.

In addition, using Applied Machine Learning techniques, specifically Reinforcement Learning (RL), the system would learn from feedback in real time, becoming more skilled over time. Compared with traditional machine learning models that work in a fixed way, the proposed integrated system works on-the-fly, adjusting its strategy for making decisions from continually observed interactions and data.

8. Conclusion

Generative AI, Model Context Protocol (MCP), and Machine Learning (ML) altogether possess the potential to substantially enhance the development of Agentic AI systems, allowing them to act independently, adapt to changing scenarios, and take smart and context-aware decisions. This synergy offers a solid framework for designing intelligent agents that can address growing complex applications like autonomous driving, personalized healthcare, and real-time financial trading with minimal human involvement. The capacity to produce new data, retaining context awareness and constantly evolving via the use of machine learning will be critical in the development of these systems.

But the promise of the integration of these technologies is not unimpeded. Problems concerning efficient context management, computational efficiency or scalability must be solved for these systems to work effectively on real-world scenarios.

Moreover, from an ethical perspective, especially when it comes to sensitive domains, one must be cautious that Agentic AI systems operate within transparent and fair walls. Lacking clear ethical considerations and accountability frameworks, industries and regulators may resist the introduction of autonomous AI systems.

We can say the outlook potential in terms of Agentic AI systems driven with Generative AI, MCP and ML is extremely high. These advances in technology will be at the heart of the future of artificial intelligence, allowing systems to be smarter, more flexible, and more ethically intelligent.

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