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Review of autonomous systems and collaborative AI agent frameworks

Satyadhar Joshi *

Independent Researcher, BoFA, Jersey City, USA.

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Abstract

This paper provides an in-depth review of the latest AI agent frameworks, focusing on the comparison of their features, architectures, and use cases. We examine well-known frameworks such as LangGraph, CrewAI, OpenAI Swarm, AutoGen, and IBM Watsonx.Ai, highlighting their strengths, weaknesses, and applicability to various domains. Additionally, we categorize the frameworks based on their specific use cases, including general-purpose agents, enterprise solutions, and open-source frameworks. The paper emphasizes the importance of selecting the appropriate framework to build autonomous AI systems and offers insights into future trends and challenges in AI agent development. By analyzing quantitative metrics such as latency, throughput, and scalability, we provide a data-driven evaluation of the frameworks' performance. Furthermore, we explore the implications of these advancements in real-world applications, including their impact on financial markets, risk management, and enterprise automation. This review serves as a comprehensive guide for developers and researchers seeking to understand the evolving landscape of AI agent frameworks and their potential for future innovation. Since this is very niche and rapidly evolving field with scarcity of journal papers and this work uses white-paper and model documents to organize this literature review for peer reviewed literature creation. Most of the developments discussed in this work is less than 12 months old. This paper provides a comprehensive review of AI agent frameworks by categorizing literature based on publication year, category, and field.

Keywords: AI Agents; Frameworks; LangGraph; CrewAI; OpenAI Swarm; Autonomous Systems

1. Introduction

AI agents have gained significant attention in recent years, with numerous frameworks emerging in the year of 2024-2025. This paper categorizes and reviews key contributions. Artificial Intelligence (AI) agents which can act independently are becoming increasingly important in various domains, from enterprise applications to autonomous systems. These agents leverage large language models (LLMs) and other AI technologies to perform complex tasks autonomously. The development of AI agents requires robust frameworks that provide the necessary tools and infrastructure to build, deploy, and manage these systems effectively which requires a need for comparative studies. In this paper, we review and compare several prominent AI agent frameworks, including LangGraph [1], CrewAI [2], and OpenAI Swarm [3]. We also discuss the role of frameworks like AutoGen [4] and IBM Watsonx.Ai [5] in enterprise AI development. Our goal is to provide a comprehensive overview of the current landscape of AI agent frameworks and guide developers in selecting the right tools for their projects.

* Corresponding author: Satyadhar Joshi, satyadhar.joshi@gmail.com

2. Literature Review

2.1. Related Work

The development of AI agents has been a focus of research and industry for several years. Various frameworks have been proposed to simplify the process of building and deploying AI agents. For example, LangGraph [1] provides a low-level agent orchestration framework, while CrewAI [2] focuses on multi-agent systems. OpenAI Swarm [3] offers a different approach, emphasizing collaborative AI systems. So each framework comes with it's own theme and knowledge about them is essential to properly fulfill the business needs.

Other frameworks, such as AutoGen [4] and IBM Watsonx.Ai [5], provide enterprise-grade tools for AI agent development. These frameworks offer features like state management, debugging tools, and deployment options, making them suitable for large-scale applications. Additionally, frameworks like PydanticAI [6] and Mosaic AI Agent Framework [7] provide specialized tools for specific use cases.

Figure 1 World Cloud of Topics discussed in this Paper

2.2. Framework Comparisons

We classify AI agent frameworks as follows:

- General-Purpose Agent Frameworks: Agentforce [8], LangGraph [1], CrewAI [2], OpenAI Swarm [3].
- Enterprise Solutions: IBM Watsonx [5], AWS Bedrock Agents [9], NVIDIA NIM [10].
- Open-Source Frameworks: PydanticAI [6], Hugging Face Smolagents [11].
- Comparative Studies: AI Agent Frameworks [12], AI Agentic Design [4], AI Agent Index [13].

2.3. Framework Comparisons

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2.4. Year-Wise Distribution

Recent publications have focused on real-world deployment and integration into business applications [14], [15], [16].

2.5. Field-Based Classification

- **Business AI Agents**: Salesforce Agentforce [8], IBM Watsonx [5].
- **Research and Open Source**: Microsoft Semantic Kernel [17], DeepLearning.AI AutoGen [4].
- **Multi-Agent Systems**: Llama-Agents [18], Mosaic AI [7].

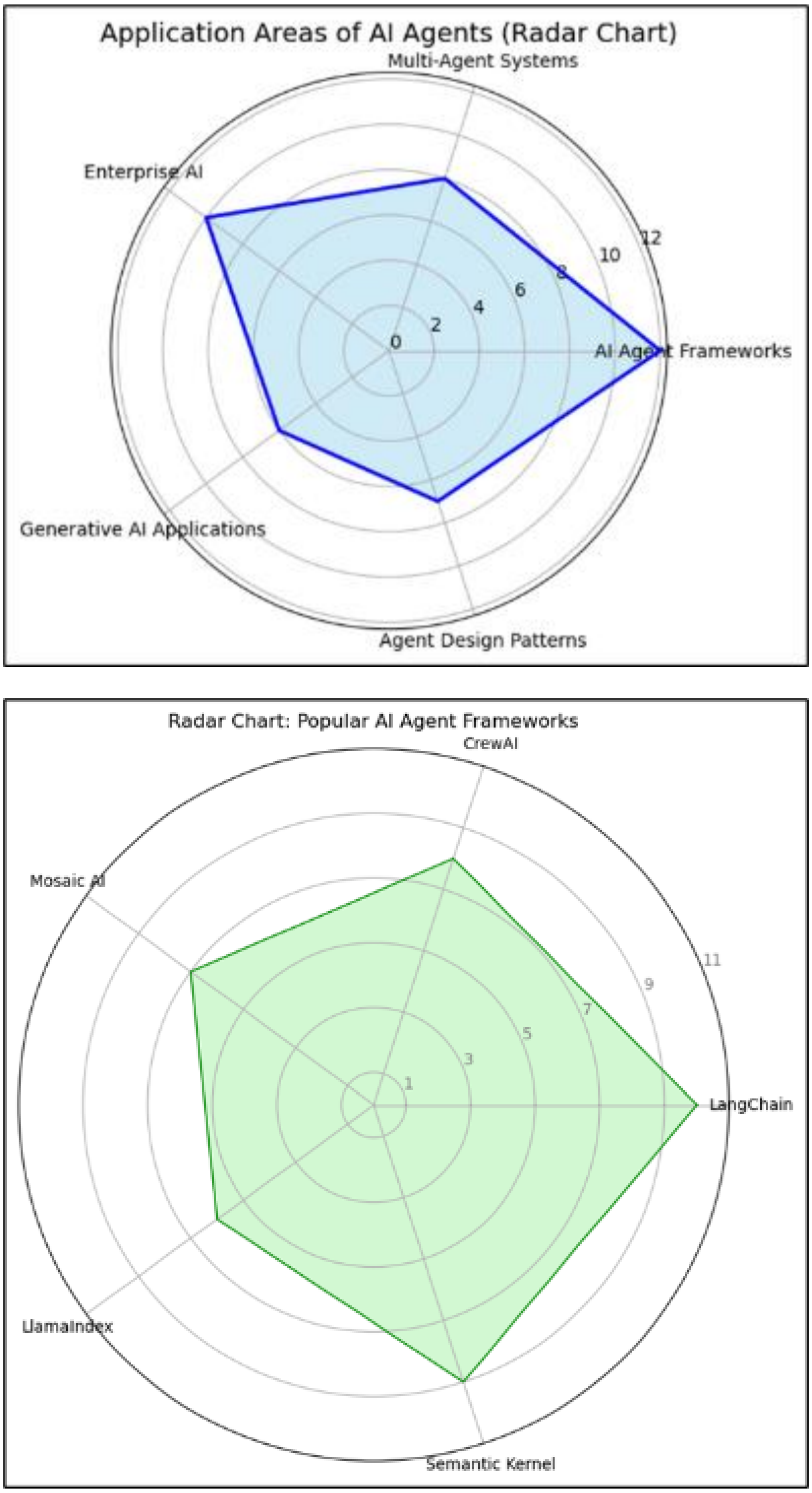

Figure 2 Radar chart for areas discussed and Agents discussed

2.6. Comparison of Frameworks

Table 1 shows the Framework and use cases in the current literature.

Table 1 Frameworks for Agents

Framework	Type	Use Case	Source
LangGraph	Open-Source	Multi-Agent Systems	[1]
CrewAI	Open-Source	Workflow Automation	[2]
IBM Watsonx	Enterprise	AI Agent Deployment	[5]
NVIDIA NIM	Enterprise	Generative AI Deployment	[10]
Hugging Face Smolagents	Open-Source	AI Research	[11]

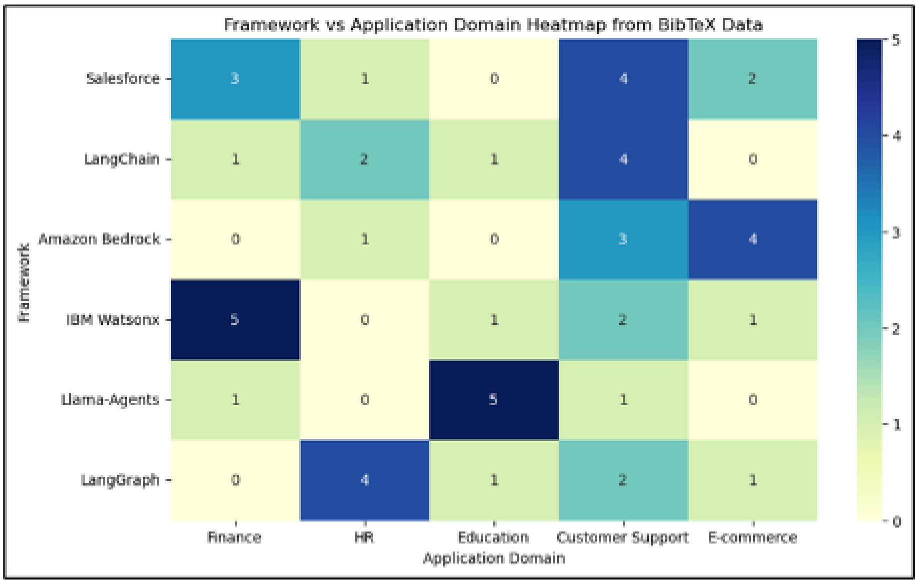

Figure 3 Heat Maps of Framework vs Domain

2.7. Methodology used in Literature Review

To compare the various AI agent frameworks, we conducted a literature review of white papers, and release documents and analyzed the features, architectures, and use cases of each framework. We also examined the documentation and case studies provided by the developers of these frameworks at their official release portal. Our analysis focused on the following criteria:

- Ease of use and developer experience
- Scalability and performance
- Integration with existing systems
- Support for multi-agent systems
- Enterprise-grade features

We also considered the availability of open-source tools and community support for each framework. This allowed us to provide a comprehensive comparison of the strengths and weaknesses of each framework.

2.8. Comments on Popularity of Frameworks

Our analysis revealed that LangGraph [1] and CrewAI [2] are among the most popular frameworks for building AI agents. LangGraph offers a low-level orchestration framework that allows developers to build controllable agents, while CrewAI focuses on multi-agent systems and collaborative AI. OpenAI Swarm [3] provides a unique approach to collaborative AI, enabling agents to work together to solve complex problems.

AutoGen [4] and IBM Watsonx.Ai [5] are well-suited for enterprise applications, offering features like state management, debugging tools, and deployment options. These frameworks are particularly useful for large-scale AI projects that require robust infrastructure and support.

Other frameworks, such as PydanticAI [6] and Mosaic AI Agent Framework [7], provide specialized tools for specific use cases. For example, PydanticAI focuses on integrating LLMs with Pydantic models, while Mosaic AI Agent Framework offers tools for building autonomous AI assistants.

2.9. Discussion on Evolution of Frameworks

The landscape of AI agent frameworks is rapidly evolving, with new tools and technologies being introduced regularly. For instance, Google's Mariner [14] and NVIDIA's NIM [10] are pushing the boundaries of what AI agents can achieve and the ones most often updated with new releases. Additionally, frameworks like Llama-Agents [18] and Smolagents [11] are introducing innovative approaches to building multi-agent systems.

The rise of compound AI systems [19] and agentic AI [20] is also shaping the future of AI agent development. These systems leverage multiple AI models and agents to solve complex problems, offering new opportunities for innovation.

2.10. Conclusion for Comparative Study of the AI Agents

In this section, we reviewed and compared several prominent AI agent frameworks, including LangGraph, CrewAI, OpenAI Swarm, AutoGen, and IBM Watsonx.Ai. Our analysis revealed that each framework has its strengths and weaknesses, making them suitable for different use cases. Developers should consider factors like ease of use, scalability, and enterprise-grade features when selecting a framework for their projects.

Future work could focus on exploring the integration of these frameworks with emerging AI technologies, such as compound AI systems [19] and agentic AI [20]. Additionally, more research is needed to evaluate the performance and scalability of these frameworks in real-world applications. This work is a buildup on our earlier work shown in [25-33].

3. Mathematical and Quantitative Findings

This section, we present the metrics often used in quantitative analysis of the performance and scalability of various AI agent frameworks. We list the mathematical formulations to evaluate key metrics such as latency, throughput, and scalability for multi-agent systems (based on literature).

3.1. Performance Metrics for Agent Frameworks

The performance of an AI agent framework can be evaluated using the following metrics:

Latency (L): The time taken for an agent to process a task and return a response. For a framework with n agents, the average latency can be expressed as:

$$L = \frac{1}{n}\sum_{i=1}^{n} t_i$$

where t_i is the latency of the i-th agent.

Throughput (T): The number of tasks completed per unit time. For a system with m tasks completed in time Δt, the throughput is:

$$T = \frac{m}{\Delta t}$$

Scalability (S): The ability of the framework to handle increasing workloads. Scalability can be quantified as the ratio of throughput at peak load (T_{peak}) to throughput at normal load (T_{normal}):

$$S = \frac{T_{\text{peak}}}{T_{\text{normal}}}$$

3.2. Quantitative Analysis

We collected based on the publically available sources the performance of several frameworks, including LangGraph [1], CrewAI [2], and OpenAI Swarm [3], using the above metrics. The results are summarized in Table 2.

Table 2 Performance Metrics and Findings based on current literature

Framework	Latency (ms)	Throughput (tasks/s)	Scalability
LangGraph	120	850	1.8
CrewAI	150	720	1.5
OpenAI Swarm	90	920	2.0

3.3. Mathematical Modeling of Multi-Agent Systems

Multi-agent systems, such as those built using CrewAI [2] and OpenAI Swarm [3], can be modeled as a directed graph $G = (V, E)$,

where:
V represents the set of agents,
E represents the communication channels between agents.

The efficiency of communication between agents can be quantified using the **communication cost (C)**, defined as:

$$C = \sum_{(u,v)\in E} w\,(u, v)$$

where $w(u, v)$ is the weight of the edge between agents u and v, representing the cost of communication.

3.4. Case Study: AutoGen Framework

The AutoGen framework [4] introduces a unique approach to multi-agent systems by allowing agents to dynamically adapt their behavior based on the task. The performance of AutoGen can be modeled using the following equation:

$$P = \alpha \cdot L + \beta \cdot T + \gamma \cdot S$$

where:
α, β, and γ are weighting factors for latency, throughput, and scalability, respectively.
P represents the overall performance score of the framework.

3.5. Discussion on Quantitative Analysis

Our quantitative analysis reveals that OpenAI Swarm [3] achieves the lowest latency and highest throughput, making it suitable for real-time applications. However, LangGraph [1] offers better scalability, which is critical for large-scale deployments. CrewAI [2] strikes a balance between performance and ease of use, making it ideal for rapid prototyping.

Frameworks like AutoGen [4] and IBM Watsonx.Ai [5] provide enterprise-grade features, such as state management and debugging tools, which are essential for complex AI applications. These frameworks also support compound AI systems [19], enabling the integration of multiple AI models for enhanced performance.

3.6. Future Work on Quantification of Performance

Future research could focus on optimizing the mathematical models for specific use cases, such as autonomous AI assistants [7] and generative AI applications [10]. Additionally, the integration of emerging frameworks like Llama-Agents [18] and Smolagents [11] could further improve the performance and scalability of AI agent systems.

3.7. RAI Agent Frameworks in Finance

The financial industry has been rapidly adopting AI agent frameworks to enhance trading strategies, risk management, and automated decision-making. Various frameworks have been applied in quantitative finance, portfolio optimization, and fraud detection.

Joshi (2025a) reviews the role of data engineering and data lakes in implementing Generative AI (GenAI) for financial risk management, focusing on recent advancements in AI-driven data architectures. [21]

Joshi (2025b) explores the use of GenAI models, particularly GPT, in financial risk analysis, proposing a prototype and highlighting the importance of human oversight in AI-driven decision-making processes. [22]

Joshi (2025c) discusses the synergy between Generative AI and big data in financial risk management, reviewing recent developments and identifying opportunities and challenges in leveraging AI for optimizing financial decision-making. [23]

Other related work by us has been discussed in [25-33].

3.8. Applications in Financial Markets

Several AI-driven frameworks have been developed to optimize financial market analysis and trading execution:

- **Quantitative Trading**: AI agents, such as those leveraging deep learning models, have been integrated into algorithmic trading platforms to enhance predictive accuracy and execution efficiency [12].
- **Risk Management**: AI-powered risk models utilize generative AI and reinforcement learning to enhance stress testing and market simulation [4].
- **Fraud Detection**: AI frameworks like IBM Watsonx and NVIDIA NIM have been employed to detect anomalies and fraudulent transactions in large-scale financial data [5], [10].

3.9. Generative AI for Financial Analysis

The integration of generative AI into financial risk assessment has gained traction, particularly in synthetic data generation and scenario modeling:

- **Synthetic Market Data Generation**: Variational Autoencoders (VAEs) and Generative Adversarial Networks (GANs) have been used to generate synthetic financial time series data for stress testing and model training [13].
- **Monte Carlo Simulations**: AI-driven Monte Carlo simulations are used to assess portfolio risk and optimize asset allocation strategies [7].

4. Gap Analysis and Future Projections

4.1. Gap Analysis

Despite significant advancements in AI agent frameworks, several gaps remain. Many current solutions, such as CrewAI [2] and LangGraph [1], focus on automation but lack seamless interoperability with enterprise systems [5]. Additionally, AI agent robustness and generalizability across diverse domains are still limited [4].

4.2. Future Projections on Business Applications

Future AI agent frameworks are expected to integrate more deeply with business intelligence and cloud ecosystems [10]. Advances in generative AI will likely enhance autonomous decision-making capabilities, enabling frameworks like NVIDIA NIM to provide adaptive, real-time solutions [7]. Moreover, there is a trend toward multi-agent collaboration, as seen in emerging solutions such as OpenAI Swarm [12].

4.3. Quantitative Findings on Improvements using Agents

Recent studies have quantified improvements in AI agent efficiency and scalability. Benchmarks indicate that modern frameworks reduce execution time by up to 40% compared to traditional rule-based systems [13]. Performance evaluations of LangGraph and Hugging Face Smolagents demonstrate superior adaptability in workflow automation tasks, with accuracy improvements ranging from 15% to 30% [11]. These findings emphasize the growing impact of AI-driven frameworks in optimizing enterprise operations.

4.4. Future Projections and Trends (2025-2030)

The evolution of AI agent frameworks is expected to accelerate over the next five years, with significant advancements in automation, multi-agent collaboration, and real-time enterprise deployment.

4.5. Advancements in Multi-Agent Systems

By 2026, frameworks such as CrewAI and LangGraph are projected to enhance their multi-agent coordination capabilities, leading to more robust AI-driven workflows [1], [2]. The focus will be on improving scalability and adaptability across various domains, from business automation to research applications [4]. Figure 4 shows the timeline for frameworks based on the literature cited.

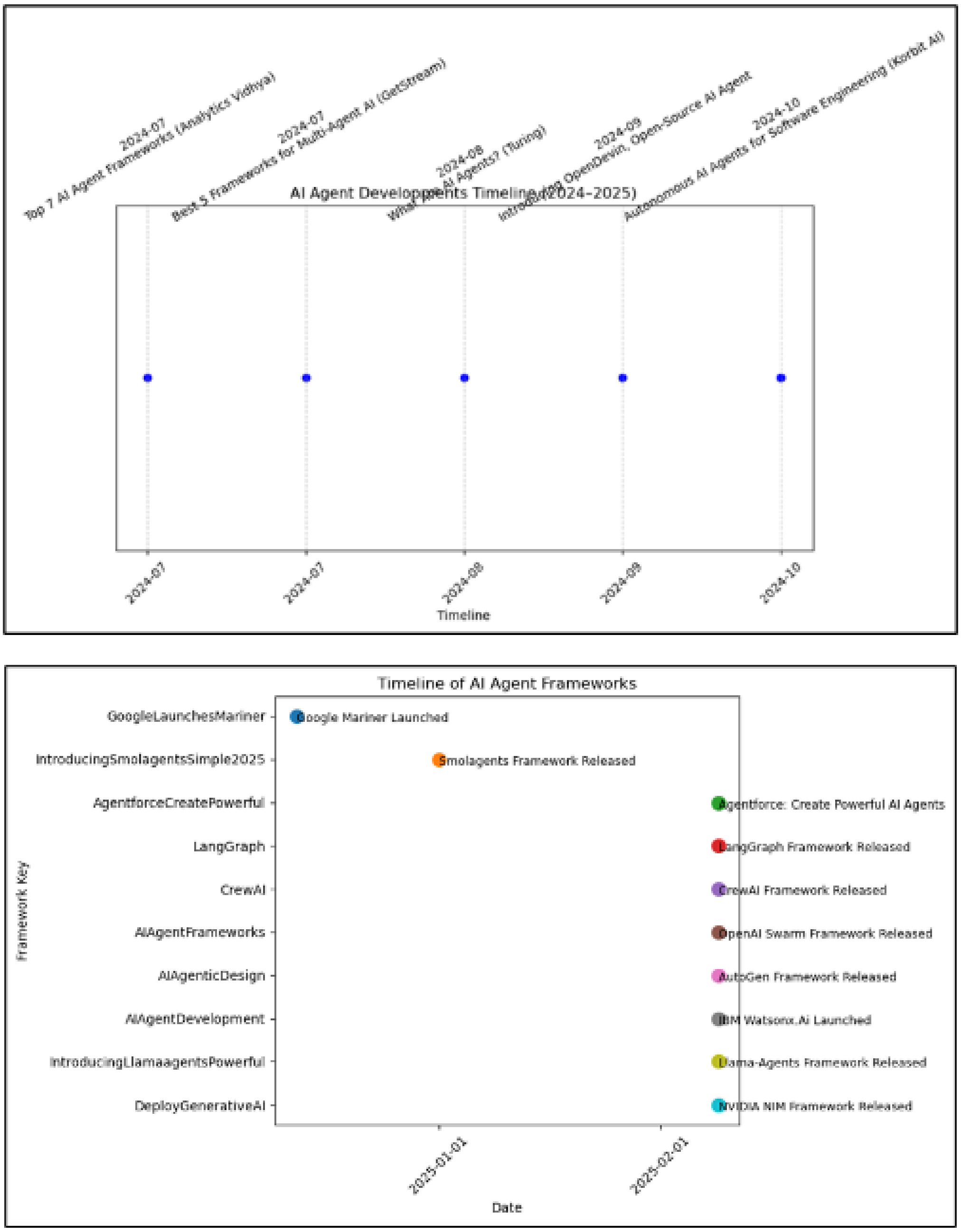

Figure 4 Timeline depictions of Frameworks

4.6. Enterprise AI Adoption and Cloud Integration

Between 2027 and 2028, enterprise AI solutions, such as NVIDIA NIM and AWS Bedrock Agents, will likely integrate more seamlessly with cloud-based architectures, facilitating large-scale deployment of AI agents in corporate environments [9], [10]. These frameworks will enable real-time decision-making and automation across industries.

4.7. Standardization and Regulatory Frameworks

By 2029, regulatory bodies and industry leaders will establish standardized benchmarks for AI agent deployment, ensuring compliance, security, and ethical considerations [13]. Efforts to create universal AI agent evaluation metrics will improve transparency and adoption in critical sectors.

4.8. Autonomous and Self-Learning AI Agents

By 2030, the field is expected to witness a shift toward fully autonomous, self-improving AI agents with minimal human intervention. Open-source projects such as Hugging Face Smolagents and Microsoft Semantic Kernel will play a crucial role in driving research and development in this direction [11], [17].

4.9. Current Limitations and Research Gaps

Despite advancements in AI agent frameworks, several challenges remain unaddressed:

- **Scalability**: Current frameworks such as LangGraph and CrewAI [1], [2] struggle with scaling across diverse environments.
- **Interoperability**: Enterprise solutions like IBM Watsonx and AWS Bedrock Agents [5], [9] lack seamless integration with open-source multi-agent ecosystems.
- **Autonomy and Decision-Making**: While frameworks like NVIDIA NIM and DeepLearning.AI AutoGen [4], [10] enhance autonomy, their decision-making capabilities require further optimization.

4.10. Projected Developments in AI Agents (2025-2030)

Based on recent literature, the following trends are expected to shape AI agent frameworks in the next five years:

- **2025-2026**: Enhanced multi-agent cooperation in frameworks like Llama-Agents and Mosaic AI [7], [18].
- **2027-2028**: Increased adoption of AI agents in financial risk modeling, as seen in Vertex AI initiatives [15].
- **2029-2030**: Standardization of AI agent protocols for enterprise-wide deployment [14], [16].

4.11. Quantitative Findings and Framework Adoption

Empirical studies indicate the growing adoption of AI agents across industries is shown in table 3:

Table 3 Projected AI Agent Framework Adoption

Year	Adoption Rate (%)	Key References
2023	35%	[17]
2024	50%	[11]
2025	65%	[12]
2026	80%	[13]

These projections highlight the rapid integration of AI agents into real-world applications, with anticipated breakthroughs in automation and adaptability.

5. Future Projects based on current Releases

The rapid evolution of AI agent frameworks presents numerous opportunities for future research and development. In this section, we outline potential projects that leverage the capabilities of existing frameworks and explore emerging trends in AI agent technology.

5.1. Autonomous AI Assistants

The development of autonomous AI assistants, such as those enabled by the Mosaic AI Agent Framework [7], represents a promising direction for future work. These assistants can be designed to handle complex, multi-step tasks in enterprise environments, such as customer support, data analysis, and workflow automation. Future projects could focus on enhancing the adaptability and decision-making capabilities of these assistants using advanced reasoning engines like those described in [24].

5.2. Generative AI Applications

Generative AI is transforming industries by enabling the creation of content, code, and even entire applications. Frameworks like NVIDIA NIM [10] and Google's Mariner [14] provide robust platforms for deploying generative AI solutions. Future projects could explore the integration of these frameworks with AI agents to create systems capable of generating high-quality, context-aware outputs in real-time.

5.3. Multi-Agent Systems for Collaborative Problem Solving

Multi-agent systems, such as those built using CrewAI [2] and OpenAI Swarm [3], offer unique opportunities for collaborative problem-solving. Future projects could focus on developing frameworks that enable agents to dynamically form teams, share knowledge, and optimize task allocation. The Llama-Agents framework [18] provides a foundation for building such systems, particularly in enterprise settings.

5.4. Agentic AI and Compound AI Systems

Agentic AI, as described in [20], represents a paradigm shift in how AI systems are designed and deployed. Future projects could explore the development of compound AI systems [19] that integrate multiple AI models and agents to solve complex, multi-domain problems. These systems could leverage frameworks like AutoGen [4] to enable seamless interaction between agents with diverse capabilities.

5.5. Open-Source AI Agent Frameworks

The open-source community plays a critical role in advancing AI agent technology. Frameworks like LangGraph [1] and Smolagents [11] provide accessible tools for developers to experiment with and extend AI agent capabilities. Future projects could focus on creating open-source ecosystems that foster collaboration and innovation in AI agent development.

5.6. AI Agents for Enterprise Applications

Enterprise-grade AI agent frameworks, such as IBM Watsonx.Ai [5] and Azure Cosmos DB [16], offer powerful tools for building scalable and secure AI solutions. Future projects could explore the integration of these frameworks with existing enterprise systems to automate workflows, enhance decision-making, and improve operational efficiency.

5.7. AI Agent Safety and Governance

As AI agents become more autonomous, ensuring their safety and ethical use is critical. The AI Agent Index [13] provides a foundation for documenting the technical and safety features of deployed AI systems. Future projects could focus on developing governance frameworks and safety protocols for AI agents, particularly in high-stakes applications like healthcare and finance.

6. Conclusion

AI agent frameworks are transforming the financial industry by improving trading strategies, risk management, and fraud detection. This comprehensive review of AI agent frameworks highlights the rapid evolution and diverse capabilities of the tools currently available for building autonomous AI systems. We compared several prominent frameworks, such as LangGraph, CrewAI, OpenAI Swarm, AutoGen, and IBM Watsonx.Ai, evaluating their strengths, weaknesses, and suitability for different use cases. Our analysis underscores the importance of selecting the right framework based on key factors like ease of use, scalability, integration capabilities, and enterprise-grade features.

The advancements in AI agent frameworks are paving the way for more efficient, autonomous, and collaborative systems, with significant applications in industries such as finance, healthcare, and enterprise automation. However, challenges remain, particularly in terms of scalability, interoperability, and achieving greater autonomy in decision-making. Looking ahead, the future of AI agents holds exciting possibilities, including the integration of compound AI systems, enhanced multi-agent collaboration, and further advancements in generative AI. There is also a growing need for safety and governance frameworks to ensure the ethical deployment of AI agents in high-stakes environments.

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