Intelligent Systems in Healthcare: an Architecture proposal

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Abstract. Multi-Agent Systems has existed for decades and has focused on principles such as loose coupling, distribution, reactivity, and local state. Despite substantial tool and programming language research and development, industry adoption of these systems has been restricted, particularly in the healthcare arena. Artificial intelligence, on the other hand, entails developing computer systems that can execute tasks that normally require human intelligence, such as decision-making, problem-solving, and learning. The goal of this article is to develop and implement an architecture that includes multi-agent systems with microservices, leveraging the capabilities of both methodologies in order to harness the power of Artificial Intelligence in the healthcare industry. It assesses the proposed architecture's merits and downsides, as well as its relevance to various healthcare use cases and the influence on system scalability, adaptability, and maintainability. Indeed, the proposed architecture is capable of meeting the objectives while maintaining scalability, flexibility, and adaptability.

Keywords: Artificial Intelligence · Multi-Agent Systems · Microservices · Intelligent Healthcare

1 Introduction

Artificial Intelligence (AI) has been making significant contributions to the healthcare sector, especially in hospitals, where the complexity of healthcare systems necessitates advanced technologies to enhance patient outcomes. Multi-Agent Systems (MAS) are one of the AI technologies that are being utilized to support architecture in the instantiation of AI applications in hospitals. The inclusion of AI applications in this environment requires a solid structural backbone [1]. In this research, we aim to explore two of the main frameworks for the deployment of such applications, their comparison and how they can work in together to achieve scalability, modularity and robustness.

As a research field, MAS, has existed since the late 1980s. Since its inception, notions such as loose-coupling, distribution, reactivity and isolated (local) state have been core concepts [2]. While the notion of an agent has been widely researched and a large range of tools and programming languages developed, there has been little real adoption of these languages and tools within industry. AI refers to the development of computer systems that can perform tasks that usually require human intelligence, such as problem-solving, decision-making, and learning. These systems can be trained using machine learning algorithms that enable them to recognize patterns in data and make predictions or decisions based on that information.

Microservice architecture, on the other hand, is a software development approach that focuses on breaking down complex applications into smaller, modular services that can be developed, deployed, and scaled independently [3]. Each service runs its own processes and communicates with other services via lightweight protocols, allowing for greater flexibility, agility, and scalability [4]. Overall, these three concepts - AI, microservice architecture, and multi-agent systems - are all essential components of modern software development and have the potential to transform the healthcare industry by improving patient outcomes, reducing costs, and increasing efficiency.

In this paper, we will explore the use of microservice architecture and multi-agent systems for implementing AI in the healthcare field. Specifically, we will examine the benefits and drawbacks of the combined approach, its applicability to different healthcare use cases, and their impact on system scalability, flexibility, and maintainability. By analyzing these factors, we aim to provide insights into the usability of the now called Multi-Agent Microservices and whether its application in the healthcare sector can be of use.

2 Background

The goal of the background material presented here is to illustrate the fundamental ideas behind AI, Microservice architecture, and MAS, as well as how contemporary research has been able to use these ideas in both theoretical and practical contexts. AI has received a lot of interest recently in the healthcare sector due to its potential to enhance patient outcomes, save costs, and boost productivity. There are numerous methods for putting AI into practice as it develops, including multi-agent systems and microservice architecture.

2.1 Microservice Architecture

Smaller, modular services that can be created, deployed, and scaled independently are what is meant by the term "microservice architecture" in the context of software development. Greater flexibility, agility, and scalability are possible thanks to the fact that each microservice manages its own processes and communicates with other microservices using simple protocols. Building an application as a group of loosely coupled, independently deployable services is the fundamental concept behind microservices. This makes it simpler to develop, test, and deploy new features because developers can work on each service independently without affecting the rest of the application [5].

Greater flexibility and scalability are two of microservices' main advantages. It is simpler to add new functionality to the application without affecting the rest of the system because each microservice can be developed and deployed independently. Greater fault-tolerance is also made possible because a failure in one microservice does not always have an impact on the entire system. Additionally, microservices can be scaled horizontally by adding more instances of a specific service, making it easier to handle high traffic loads [6].

Microservice architecture does, however, present some difficulties. More coordination and communication between microservices are needed, as well as more infrastructure for fault tolerance, load balancing and service discovery. Additionally, it calls for a higher level of technical proficiency from developers, who must be knowledgeable of related technologies such as distributed systems, message queues, and others.

Generally speaking, microservice architecture offers a more modular and adaptable method of developing software, enabling greater agility and scalability. Its suitability depends on the particular use case and project requirements, but it has become increasingly well-liked in recent years as a means of developing large-scale, complex applications [7].

2.2 Multi-Agent Systems

MAS are a class of AI systems that employs a number of intelligent agents working together to accomplish a single objective [8]. Each agent is a software entity with the ability to perceive its surroundings, think through its actions, and interact with other agents to plan out their actions [9]. The fundamental idea behind MAS is to represent complex systems as a group of autonomous agents that communicate with one another and their surroundings. In the creation of a multi-agent system, a certain group of high level abstractions should be successfully utilized. For example, agents are autonomous entities with independent spheres of control that are positioned in environments and engage in social interaction. These agents are capable of observation and utilisation of their surroundings and resources. The interactions between agents and other resources are defined functionalities which can be limited and further defined by organizational rules [10].

There are, however, some difficulties with MAS as well. When there are competing objectives or worldviews, it can be complicated and challenging to coordinate the actions of several actors. Additionally, developers need to have a greater degree of competence because MAS demand them to be knowledgeable about technologies like distributed systems, agent-based modeling, and other relevant fields [11].

Overall, MAS provide an effective method for simulating complex systems and enhancing their behavior. Its appropriateness depends on the particular use case and project objectives, but it has drawn a lot of attention recently as a way to boost coordination and efficiency across a number of industries [12].

2.3 Artificial Intelligence in Healthcare

Artificial intelligence is a sub-field of computer science that focuses on the creation of intelligent robots capable of conducting tasks that normally require human intellect, such as sensing, reasoning, learning, decision making, and natural language processing [13]. Large volumes of data inputs and outputs are used by these algorithms to identify patterns and effectively "learn" in order to teach the computer to make autonomous suggestions or conclusions [14]. Overall, artificial intelligence has the potential to alter numerous sectors, including healthcare, by giving intelligent assistance with decision making, diagnosis, and treatment.

Examples of intelligent AI applications in healthcare span across different fields. [15] reviewed different Machine Learning algorithms applied for the diagnosis of chronic diseases from 2015 until 2019. While the issue does not target a specific type or group of chronic diseases, researchers were able to deduce the best models for prediction over an entire subset of disorders.

Another interest of AI in healthcare is its application in Medical Imaging processing and symptom detection. Both [16] and [17] proposed Deep Learning frameworks for the prediction of and analysis of different medical images.

3 Proposed Architecture

Multi-agent systems involve the development of intelligent software agents that can interact with each other to achieve a common goal [18]. Each agent is capable of autonomous decision-making and can communicate with other agents to exchange information and coordinate actions [19]. Microservices, on the other hand, involve breaking down a large application into smaller, modular services that can be developed and deployed independently. Each microservice focuses on a specific functionality, and communicates with other microservices through standardized interfaces. Modern large-scale software development practices use microservices. They have clearly proven their potential as a tool for developing systems at scale, despite not being an all-encompassing answer [20]. The case study presented hereby, relies on two different proposed applications which employ AI models in order to achieve their goals. Figure 1 aims to explain how different context specific applications can make use of their own structure of a group of microservices which activate intelligent agents in order to preform their specific tasks.

By combining these two approaches, it is possible to develop intelligent software systems that consist of multiple autonomous agents that interact with each other through well-defined APIs. Each agent can represent a specific functionality or service, and can communicate with other agents to exchange information and coordinate actions [6]. This architecture allows for the exposure of Intelligent Agents' capabilities through RESTful APIs, with an impact on how MAS

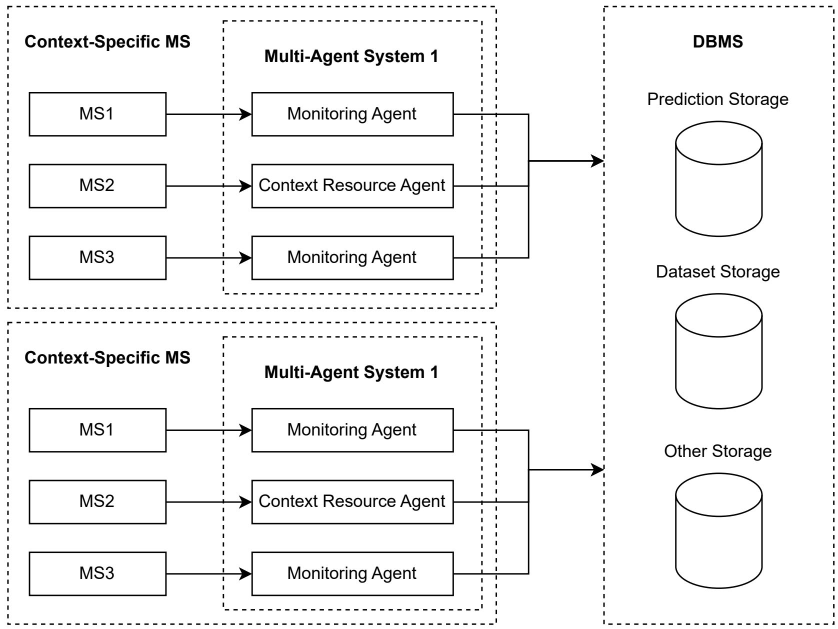

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Fig. 1. Proposed architecture comprised of Microservices and Multi-Agent Systems

are viewed and implemented, making it easier to incorporate agile development techniques and modify how agents are accessed and utilized, resulting in systems that are quicker and more intelligent [21].

The sequence diagram in Figure 2, an explanation is drawn on how the exposure of the intelligent agents' capabilities through the microservice architecture can aid in scabalility, responsiveness and overall better organization in the services provided. In the diagram, the User, through a provided Graphical User Interface can request different actions in the same application context through different microservices, thus reducing server overload and obtaining better performance. On another note, this architecture can help with better load-balancing on the more utlized microservices without the need for the entire system to be replicated and run in parallel.

Overall, the combination of multi-agent systems and microservices can lead to more intelligent and modular software applications that are better suited to handle complex and dynamic environments.

4 Discussion

The fusion between MAS and Microservices has been growing in interest among the academic community, with different applications in mind [22]. MAMS is a term that arises from the belief that organizations combine outward-facing

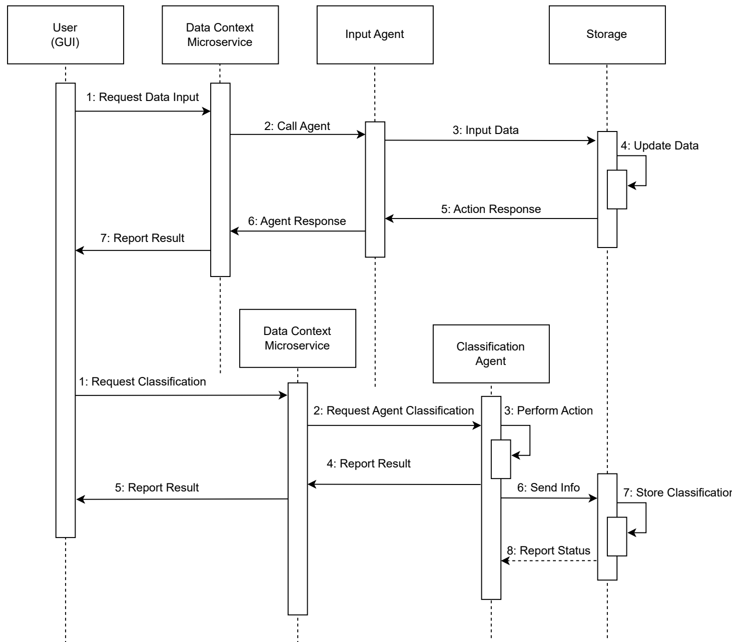

Fig. 2. Sequence Diagram for the Architecture

customer service agents while concealing internal worker agents. The most significant benefit of this technology is that it is now feasible to create packaged components that use agent-level reasoning as common practice [23]. The architecture allows for the deployment of decentralized Multi-Agent Systems, while also enabling easier exposure to the Intelligent Agents' actions.

In order to analyze the prospected architecture, some pros and cons of its utilization need to be taken into consideration:

- In terms of scalability, the microservice architecture offers the possibility to independently boost a desired service's responsiveness, through replication or changes in memory allocation.
- The architecture can leverage both MAS and MS for flexibility and modularity. Agent-Service combinations can easily be altered without affecting the rest of the system. Also, MAS stands out for its capacity in modeling complex systems and the integration or modification of Microservices and Agents can be performed seamlessly [24].
- Decentralizing services facilitates the fault tolerance and high availability. With the autonomous nature of MAS, the coupling of MS and IA allows its independent work without the need for centralized control in distribution.

It is also important to review the drawbacks of implementing the proposed architecture. These are more development centered but still impose some difficulties to deployment.

- Generally speaking, the MS architecture relies on additional resources to run and this may affect the need for scalability options if/when resources are limited.
- Both MAS and MS are applied in complex systems and the modularity should require additional security constraints to ensure system access control.
- It is crucial to give the Healthcare Information System architecture the ability to support communication across various, otherwise isolated systems, avoiding their centralization and dispersion of End-to-End connections [25]. The integration of MS relies on stability of its communication and interoperation protocols.

5 Conclusions

In this paper, we discuss the importance and applicability of the Microservice Architecture, and the possibility of combination with Multi Agent Systems for the deployment of intelligent applications in the healthcare scope.

A Multi-Agent Microservice architecture proves to be an appropriate methodology for developing intelligent healthcare systems. We may achieve great scalability, flexibility, and modularity by breaking down the system into separate agents, each accountable for a certain job. Furthermore, by combining this architecture with various AI models, we can create a system that can learn from data, reason, and make intelligent decisions. However, there are some drawbacks to using this architecture, such as complexity, integration, overhead and security. As a result, before using this design in a healthcare system, it is critical to carefully weigh the benefits and cons. Overall, we think that a Multi-Agent Microservices architecture has the potential to transform healthcare by delivering tailored and intelligent healthcare services. Additionally, the importance of a solid architecture when combined with rapidly growing AI models will allow for faster and more reliable versioning of production ready applications, without compromise in uptime. The proposed Multi-Agent Microservice architecture will also benefit from intrinsic decentralized architecture advantages, especially in terms of application access in downtime situations.

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