AGENT BASED INTERFACES – LITERATURE REVIEW

Tanmy Somkuwar – 23210112

Gangaram Siddam – 22210014

Poornima Bhatia - 23210073

Ananyaa Verma - 23510010

Problem statement:

In today's digital landscape, many user interfaces lack the sophistication and adaptability required to deliver personalized and contextually relevant interactions. Traditional interfaces often rely on static designs and predefined interactions, which can lead to limited user engagement and hinder task performance. To overcome these challenges and improve user experience, there is a growing interest in the development of Agent-based Interfaces (ABI).
Agent-based Interfaces (ABI) utilize intelligent agents to dynamically adjust and personalize interactions based on various factors such as user preferences, needs, and contextual cues. The core objective of this project is to design and implement ABI that leverage intelligent agents to offer personalized, adaptive, and context-aware user experiences across a range of digital applications and platforms.

For example, consider a smart personal assistant application that employs ABI. Instead of presenting a fixed set of options or responses, the interface utilizes intelligent agents to analyze user input, understand preferences, and anticipate needs. If a user frequently requests weather updates in the morning, the ABI could proactively provide this information without the user explicitly asking for it. Furthermore, if the user's location changes, the interface adapts accordingly to provide relevant updates tailored to the new context.
Another example could be an e-commerce platform that employs ABI to enhance user engagement and streamline the shopping experience. By analysing past purchases, browsing history, and user interactions, the interface can dynamically recommend products that align with the user's preferences and interests. Additionally, the ABI can adjust the layout and presentation of product listings based on the device being used, ensuring an optimal shopping experience across desktop, mobile, and tablet devices.

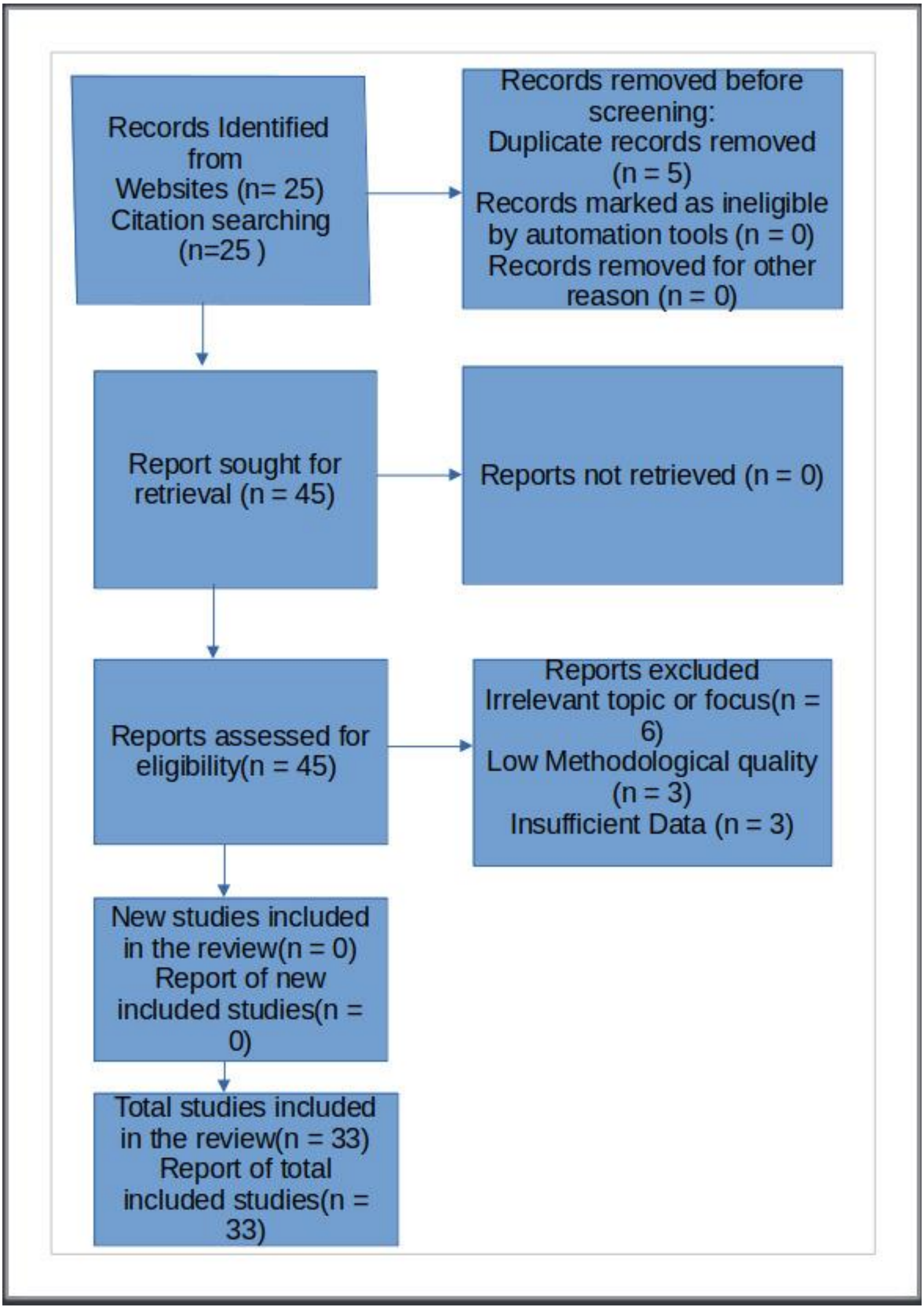
Agent-based Interfaces (ABI) offer a promising solution to the limitations of traditional user interfaces by leveraging intelligent agents to personalize interactions, adapt to user needs, and enhance overall user experience. Through the integration of machine learning, natural language processing, and other AI techniques, ABI aim to optimize user interaction and facilitate seamless task performance in diverse digital environments.

Intelligent agents

An “agent” is an independent program or entity that interacts with its environment by perceiving its surroundings via sensors, then acting through actuators or effectors
Agents use their actuators to run through a cycle of perception, thought, and action. Examples of agents in general terms include:
Software, Human and Robotic agents.
Intelligent agents in AI are autonomous entities that act upon an environment using sensors

and actuators to achieve their goals. In addition, intelligent agents may learn from the environment to achieve those goals [26].

PRISMA Guidelines:



Literature Review:

There is a long-standing debate over the role that intelligent agents should play and how much autonomy they should be given in user-centric systems such as intelligent environments and other pervasive computing technologies. Matthew Ball et al conducted an online survey to assess people's opinions of the use of autonomy in intelligent environments with the options, Fully autonomous-agent driven, Semi-autonomous (with high autonomy), Semi-autonomous (with low autonomy),Fully end-user driven. Results turned out that majority of the users wanted a Semi-autonomous (with high autonomy) agent driven interface which results in minimising user cognitive load [1].

Wei Liu et al. developed an intelligent sales-agent interface prototype for B2C online shop. Where they developed an agent which guides the customer throughout the shopping. this prototype stimulate an scenario of online order a book, the purpose to design this prototype is to give customer an easy way to communicate with the online retail store, to reach that requirement, an human to human way is easier and more flexible to customers. Since conversations begin, the intelligent agent helps customer with their shopping until to the end. During the buying process, agent can send the useful links automatically, talk to customer naturally and friendly, also, can bargain with customers [2].

Muntean et al proposed an approach based on the use of agent technology and big data concept in order to improve the process time of Map-Reduce programming model where agent used key- value concept to filter out and search the records in the data bases which turned out to be 1.7x faster compared to traditional Map-Reduced technique. They proposed two levels of Hadoop Map-Reduce improvement. First, we improved the execution time of Map-Reduce, by integrating the algorithm in intelligent agent and by running the agents simultaneously on multiple databases. Second, they enhanced each Map-Reduce algorithm with a Regex System in order to help it to perform faster and to return clear results [3].

A technologies are like smart helpers that are crucial in learning and using case-based reasoning. They're like the backbone of a brainy system. This system can be flexible and adaptable, learning and changing based on what it encounters. Kaswan et al. Proposed a way to build smart systems that can handle complicated situations. It's like giving these systems a solid foundation to operate in tricky environments. This structure is flexible because it can learn and change based on what it knows. The paper talks about using smart agents that learn from data to pick the best suppliers. It also discusses how these agents can work with case-based reasoning, which is like looking at past experiences to solve problems [4].

Liu et al discussed the various applications of intelligent agents in library systems which enhances the user experiences in several ways [5].
Mozgai et al developed mHealth based on Apple smart watch. This app monitors the users by taking the from API then makes the user to go through some cognitive questions

Introduced a novel mHealth application with an agent-based interface designed to collect multimodal data with passive sensors native to popular wearables (e.g., Apple Watch) as well as through user self-report. This mHealth application delivers personalized and adaptive multimedia content via smartphone application specifically tailored to the user in the interdependent domains of physical, cognitive, and emotional health via novel adaptive logic-based algorithms while employing behavior change techniques. It also makes user go through some breathing techniques and some sort of meditation to make user feel relaxed [6].

Tomášek et al introduced a multi-agent system that embodies a distributed computational approach. It outlines a software architecture that views distributed locations as representations of the system's distributed computational aspects, with various software agents representing different functional components. The interactions among these agents within the system are deemed crucial, particularly in applications such as e-commerce, where understanding consumer buying behavior is fundamental. The paper proposes a model utilizing a general multi-agent system to explore its capabilities in depicting consumer buying behavior [7].

Vidmanov et al explored the use of machine learning techniques for enhancing user interfaces within mobile ecosystems. Specifically, they focused on testing adaptive interfaces by framing them as stochastic sequential decision problems. They introduced the application of multi-agent model-based reinforcement learning for planning adaptation strategies. Notably, it's the first to apply reinforcement learning to mobile adaptive user interfaces. Their work suggests various adaptation options, including altering element representations and defining transition functions for Markov decision processes models. It introduces a new approach named MARLMUI (Multi-Agent Reinforcement Learning Mobile User Interface) [8].
Kim et al conducted a Study on text-based and voice-based dialogue interfaces for human-computer interactions in a blocks world and explored various kinds of problems in respective interfaces. They found out that for the text-based interface, grammatical errors and/or spelling mistakes were the main cause of communication issues. For the voice-based interface, speech recognition error and pauses between utterances as well as transcription failures led to communication issues [9].

Javier et al work introduces a non-invasive Adaptive Brain Machine Interface (BMI) designed to discern four mental tasks. By incorporating Software Agents (SA), it enables adaptive strategies for robust BMI implementations. The SA monitors features to aid in the adaptive process, while the user's engagement state facilitates feedback between the BMI and the environment. Performance is evaluated using Silhouette's width as a metric for the active learning process. Results demonstrate that the system achieves high accuracy (75%) in task classification [10].

The WIC Australia Centre, in collaboration with the Australian Defence Science and Technology Organization (DSTO), has directed its focus towards tackling defense and security challenges through intelligent agent technologies. This collaboration suggests an exploration of applications such as surveillance, decision-making support, and information analysis to address complex issues in the realm of defense and security. Concurrently, working closely with Agent Oriented Software Pty. Ltd (AOS), the developer of JACK Intelligent Agent Software, underscores the center's commitment to advancing agent-based software solutions. The problems addressed in this context likely revolve around enhancing the efficiency, adaptability, and intelligence of software systems through innovative agent-based approaches [11].

In recent times, software agents have transitioned from merely facilitating tasks to becoming decision-makers in managing complex, real-time systems like logistics enterprises. Emergent behavior, which arises from the coordination of individual agents and leads to global outcomes, has become a significant aspect of these systems. As agents gain more autonomy and responsibility, understanding the impact of emergent behavior on system performance and stability has become crucial. In industries such as transportation planning and logistics coordination, emergent behavior is a major concern for potential users of agent technology. To effectively apply agent technology in such fields, it's important to study emergent behavior and its implications thoroughly. Zhengping et al reviews existing research on emergent behavior, discusses its challenges and impact on applications, and proposes future research directions in understanding and managing agent emergent behavior [12].

The user interface is a crucial component of application software. Currently, there is significant interest in integrating intelligent agents into user interface design. This paper [13] presents a method for constructing user interfaces using the Model-ViewController (MVC) model Agent. It explains the design pattern and development approach for user interfaces based on agents in an information retrieval system.

This paper [14] introduces an approach to generate subject-oriented process models dynamically based on the cognitive models used by agents during ad-hoc interactions in business processes. It employs the function-behaviour-structure (FBS) model, mapping it onto subject-oriented business process management (S-BPM) concepts. Ad-hoc processes, supported by agents adapting autonomously to changing environments, are acknowledged for dealing with unpredictable situations. However, individual agent deviations may impact global business process goals. The paper proposes capturing these deviations for analysis, potentially rejecting or incorporating them into future process models.

Nafea et al discussed the concept of intelligent agents, defining them as programs that gather information or perform services without human intervention, often referred to as bots. These agents exhibit capabilities like acting, sensing, understanding, reasoning, and learning. The design of an intelligent agent involves specifying its task environment, type, number, and how it accesses tasks in the environment. Task specification includes considering the state and action spaces in the environment and addressing problems related to describing these spaces and training the agent. The enhancement in agent design focuses on making them intelligent to save resources, reduce workload, and aid security forces in overcoming obstacles, especially in dealing with spatial data. The text emphasizes the importance of heuristic search techniques and highlights the challenges faced by untrained agents in searching for objects, proposing the use of software models for problem-solving in dangerous environments. The ultimate goal is to create an intelligent agent that can independently understand, interact with, and navigate a dynamic environment, avoiding obstacles without user intervention. The text concludes by discussing the significance of considering various dimensions of task environments and suggests exploring more complex and stochastic environments for future work [15].

The concept of an Intelligent Space involves a physical environment equipped with distributed sensory intelligence, including sensors like cameras and microphones, as well as actuators such as displays, speakers, manipulators, and mobile robots. These intelligent agents within the space possess computational capabilities and can communicate with each other through computer networks. The agents autonomously cooperate, providing both physical and informational support to the inhabitants of the space. The goal is to create a highly intelligent environment where agents operate collectively, responding intuitively to human needs [16].

The role of an intelligent agent is to autonomously gather information or perform services without direct human intervention. These agents possess key capabilities such as acting, sensing, understanding, reasoning, and learning. They are designed to tackle a range of problems, from simple to complex, with a focus on minimizing the need for extensive humanengineered knowledge. The design process involves specifying the task environment, identifying the state and action spaces within that environment, and developing algorithms or utilizing existing ones to train the agent to perform its tasks effectively [17].

The agent facilitates communication by providing a structured framework for interaction between users and agent systems through multiple communication modes. The multi-agent structure allows seamless communication regardless of the physical location of users or their respective agents. It acts as an intermediary that can handle different communication channels, enabling users to interact with their agents efficiently.
In practical applications, such as the e-mail monitoring system and the Web-based event monitoring system described in the paper, the agent plays a crucial role in managing and processing information. For the e-mail monitoring system, the agent keeps track of a user's e-mails, providing a means for users to stay connected with their communication even when away from the office. In the Web-based event monitoring system, the agent scans the internet for specific events, like weather alerts, and communicates relevant information to the user [18].

This paper [19] introduces the concept of Intelligent Space for assisting disabled or blind individuals in crowded environments like train stations or airports. The Intelligent Space utilizes distributed sensory intelligence and actuators, including mobile haptic interfaces and guiding mobile robots. The main contribution lies in presenting a fuzzy-neuro mathematical model for describing the obstacle avoidance behavior (walking habit) of moving objects, particularly humans, within a confined space monitored by the Intelligent Space. The paper discusses the adaptability of this method, crucial for successful operation in dynamic environments, and presents a vector field-based approach for handling adaptability. The research aims to enhance the capabilities of assisting devices for blind individuals, utilizing the Intelligent Space's ability to sense and track moving objects, such as guiding robots, to help navigate crowded areas and avoid obstacles. The presented mathematical model provides a flexible and easy-to-train background for applications like collision avoidance.

The paper [20] uses a multimodal interface for sketch interpretation that relies on a multi-agent architecture. The design of the interpretation engine and the different agents is based on a user-centered approach, where efficiency is defined in terms of user satisfaction. Several graphical agents have been implemented for recognizing basic graphical objects (e.g., lines, circles, etc.) and more complex elements (e.g., hatches, stairs, captions, etc.) in architectural design. Additionally, vocal agents have been developed to recognize spoken annotations (e.g., dimensions) and interface commands. The potential interest of the proposed system has been demonstrated through realistic evaluations with professional users.

In the paper, challenges related to creating middleware for ubiquitous and context-aware computing are outlined, including the need to balance transparency and context-awareness and the requirement for a certain degree of autonomy. Techniques for successfully confronting these challenges are highlighted. Accordingly, the design and implementation of a middleware infrastructure for ubiquitous computing services are presented, facilitating the development of such services and allowing the service developer to focus on the service logic rather than the middleware implementation. Mechanisms for controlling sensors and actuators, dynamically registering and invoking resources and infrastructure elements, and modeling composite contextual information are provided by this infrastructure. [21]

While knowledge discovery in databases (KDD) involves several steps, like data pre-processing, data mining, and post-data mining, there's no one-size-fits-all solution in data mining. Different algorithms and techniques exist for each step, but none are universally suitable for every domain and dataset. This paper introduces a hybrid framework for finding patterns in databases or multiple databases. The framework brings together various techniques within an agent-based architecture. Experiments show that integrating different KDD techniques into this framework allows them to work together effectively when needed. Although this approach doesn't make individual KDD techniques perform better, it creates flexible and robust data-mining systems with emergent behaviors. [22]

Building information modeling is only beginning to incorporate human factors, although buildings are sites where humans and technologies interact with globally significant consequences. Some buildings fail to perform as their designers intended, partly because users cannot correctly operate the building, and some occupants behave differently than designers expect. Innovative buildings, e.g., green buildings, are particularly susceptible to usability problems. A framework for prospectively measuring the usability of designs before buildings are constructed is presented in this paper, while there is still time to improve the design. The framework, implemented as an agent-based computer simulation model, tests how well buildings are likely to perform, given realistic occupants. [23]

This paper introduces a non-invasive Adaptive Brain Machine Interface (BMI) to discriminate between four mental tasks. Including a Software Agent (SA) allows tracking features to contribute to an adaptive process while the user's engagement state provides feedback between the BMI and the environment. Performance is measured using the Silhouette's width, demonstrating that the implemented system achieves high accuracy (75%) in classification. [24]

The popularity of Voice User Interfaces (VUIs) is rapidly rising in consumer markets, resulting in a surge of applications across various industries. However, interface designers, primarily trained in Graphical User Interface (GUI) usability, face challenges in adapting to the unique design and usability requirements of VUIs. This paper explores the extent to which current educational resources prepare designers for VUI design challenges through a review of HCI curricula at top international departments. Findings reveal a lack of comprehensive VUI design training in HCI education. The paper advocates for updating HCI curricula to incorporate VUI design and developing VUI-specific educational materials to address this gap. [25]

Nicholas Hanssens[27] et al. proposes the Intelligent Room project which aims to construct an Intelligent Environment (IE) where technology seamlessly integrates into daily life, enhancing interactions and activities in business settings. This is done through software agents that facilitate interactions between different software components, from basic light control to complex applications. They emphasize on transparent, context-based reactions to user behavior, automatic resource allocation, and stable cross-space collaboration. Context-awareness, driven by tools like Metaglue and Hyperglue, plays a crucial role, alongside speech recognition infrastructure and context representation through computer vision. A comprehensive approach to building intelligent environments, leveraging advanced technologies and applications to enhance user experiences and interactions within the environment.

Kawamura[28] et al. addresses the challenges in human-robot interaction, particularly when limited sensory feedback is available from remote robots. The authors present an innovative agent-based adaptive UI architecture designed for mixed-initiative interaction, aiming to enhance communication of critical information between humans and robots. The proposed framework employs a multi-agent system for adaptability across various mobile robot platforms. The authors present an innovative agent-based adaptive UI architecture designed for interaction, aiming to enhance communication of mission-critical information between humans and robots. The framework has an adaptive user interface (UI) providing a platform for developing various agents that control robots and user interface components (UICs). Such components permit the human and the robot to communicate mission relevant information.

Omar J. Lopez[29] et al. research operates within the realm of distributed control systems applied to reconfigurable manufacturing systems. The focus is on detailing an interface facilitating interaction between two integral layers within an embedded controller endowed with networked capabilities: the high level control (HLC) and the low level control (LLC). The HLC, denoted as coordination control, employs software agents as its operational units, while the LLC, recognized as logic control, encompasses software applications manifested as algorithms encapsulated within functional blocks. This work is dedicated to elucidating the structure and communication dynamics between these two layers, providing insights into their roles and functionalities within the broader context of reconfigurable manufacturing systems.

Balaji, P. G.[30] et al. study delves into the realm of multi-agent systems, a dynamic field in distributed artificial intelligence, showcasing their significance in addressing intricate real-world challenges. The study particularly focuses on their application in optimizing traffic signal control within a simulated urban network in Singapore. Two distinct multi-agent architectures are explored, revealing their superiority over traditional pre-timed and current signal control methods. Key features of agent-based systems, such as autonomy, responsiveness, and social behavior, are outlined, underlining their advantages in contrast to rigid distributed problem-solving approaches. The paper employs two traffic signal control architectures, a hierarchical model, and a Simultaneous Perturbation Stochastic Approximation-based Neural Network (SPSA-NN) model, each with unique decision-making approaches and computational complexities.In a pretend road network in Singapore's main business area, the study showed that multi-agent signal control, especially the GFMAS model, works better when there's a lot of traffic or unexpected events. This suggests that using multi-agent systems could really improve how traffic signals are managed in the real world, helping with problems like changing traffic patterns and issues with communication in the usual control methods.

Douglas B.[31] proposes an Open Agent Architecture (OAA) system as a versatile framework, enabling intelligent, cooperative, and distributed agent-based applications with multimodal user interfaces. These interfaces support spoken language, handwriting, and gestures, adapting to user preferences and the environment, particularly on low-powered devices like PDAs. The OAA emphasizes flexibility, allowing mix-and-match of agents for rapid prototyping and promoting reuse across applications. The paper details the multimodal interface, the role of the User Interface (UI) Agent, and the use of a Modality Coordination (MC) agent for rich interactions between natural language and gestures. OAA's attributes include openness, distribution, extensibility, mobility, and collaboration. The Facilitator Agent enhances efficiency by managing agent interactions and facilitating complex tasks. Applications, including an office assistant, tourist information system, and emergency response system, demonstrate OAA's adaptability and effectiveness, emphasizing multimodal interfaces and collaborative agent functionalities. While acknowledging potential limitations, such as the Facilitator agent's bottleneck in high-volume interactions, the paper underscores OAA's contribution to creating sophisticated systems through its unique focus on multimodal user interfaces for diverse applications.

Kuderna-Iulian, et al.[32] presents the development of a smart house platform using the TAOM4E methodology and the JADE-platform with the Jadex-extension. A mobile application, Jade-Leap, is implemented for remote monitoring. The system incorporates a central ontology for context representation and supports behavior changes based on user affective feedback. The paper highlights challenges related to ontologies in agent communication, sensor integration, and affective sensing. Experimental results demonstrate the effective functioning of the system, showcasing its novelty in integrating a multi-agent system, an ontology-based mixed environment representation and reasoning engine, and a rule-based model of user affective feedback.

Rocco, et al.[33] proposes the architecture suggests integrating a Cloud on GRID architecture with a mobile agent platform.The cloud paradigm, introduced in 2005 with Amazon Elastic Compute Cloud (EC2), has led to the development of various related technologies. In the academic realm, particularly in High-Performance Computing (HPC), cloud computing and the GRID model are often seen as competing approaches. To leverage the potential of existing computational GRIDs in innovative ways, there is a proposal to integrate these two paradigms. The challenge lies in selecting the appropriate programming paradigm, given the multitude of existing approaches. This paper suggests integrating a Cloud on GRID architecture with a mobile agent platform. The proposed architecture provides virtual clusters with complete administrative control for end-users, utilizing an existing GRID architecture and its security infrastructure. The mobile agent platform dynamically adds and configures services on virtual clusters. The presented experience demonstrates that the mobile agent paradigm effectively aligns with the dynamic properties of the Cloud paradigm, making it a suitable choice for developing applications and services that can dynamically adapt to virtualized environments.

Nealon[34] et al. addresses the challenges associated with deploying agent-based systems in healthcare. It begins by highlighting the unique characteristics of healthcare problems and asserts that multi-agent systems offer a suitable approach for addressing challenges inherent in such scenarios. To support this claim, the paper presents examples of successful applications of agent-based systems in medical domains. Additionally, the paper explores various research directions that need attention before the successful deployment of multi-agent systems in real healthcare settings. The conclusion emphasizes the growing significance of multi-agent systems in healthcare domains, emphasizing their pivotal role in modeling, designing, and constructing complex and distributed healthcare software systems.

References:

[1] Ball, Matthew, and Vic Callaghan. "Introducing intelligent environments, agents and autonomy to users." *2011 Seventh International Conference on Intelligent Environments*. IEEE, 2011.

[2] Liu, Wei, and Nansheng Liu. "An intelligent sales-agent interface prototype for B2C online shop." *2011 International Conference on Computer Science and Service System (CSSS)*. IEEE, 2011.

[3] Muntean, Maria Viorela, and Raul Boldea. "Intelligent agents based improved map-reduce method for multiple databases." *2016 8th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*. IEEE, 2016.

[4] Kaswan, Kuldeep Singh, Jagjit Singh Dhatterwal, and Anupam Balyan. "Intelligent agents based integration of machine learning and case base reasoning system." *2022 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)*. IEEE, 2022.

[5] Liu, Guoying. "The application of intelligent agents in libraries: a survey." *Program* 45.1 (2011): 78-97.

[6] Mozgai, Sharon, Arno Hartholt, and Albert" Skip Rizzo. "An adaptive agent-based interface for personalized health interventions." *Proceedings of the 25th International Conference on Intelligent User Interfaces Companion*. 2020.

[7] Tomášek, M., and J. Trelová. "An e-commerce applications based on the multi-agent system." *2012 IEEE 10th International Conference on Emerging eLearning Technologies and Applications (ICETA)*. IEEE, 2012.

[8] Vidmanov, Dmitry A., and Alexander N. Alfimtsev. "MARLMUI: Multi-Agent Reinforcement Learning Approach in Mobile Adaptive User Interface." *2023 5th International Youth Conference on Radio Electronics, Electrical and Power Engineering (REEPE)*. Vol. 5. IEEE, 2023.

[9] Kim, Sujeong, et al. "Study on text-based and voice-based dialogue interfaces for human-computer interactions in a blocks world." *Proceedings of the 8th International Conference on Human-Agent Interaction*. 2020.

[10] Castillo-Garcia, Javier, et al. "Active learning for adaptive brain machine interface based on Software Agent." *2015 23rd Mediterranean Conference on Control and Automation (MED)*. IEEE, 2015.

[11] Tweedale, Jeffrey, and Nihkil Ichalkaranje. "Intelligent agents and their applications." *International Conference on Knowledge-Based and Intelligent Information and Engineering Systems*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2006.

[12] Li, Zhengping, Cheng Hwee Sim, and Malcolm Yoke Hean Low. "A survey of emergent behavior and its impacts in agent-based systems." *2006 4th IEEE international conference on industrial informatics*. IEEE, 2006.

[13] Li, Yan. "Intelligent user interface design based on agent technology." *2009 WRI World Congress on Software Engineering*. Vol. 1. IEEE, 2009.

[14] Kannengiesser, Udo, et al. "Generating subject-oriented process models from ad-hoc interactions of cognitive agents." *2014 IEEE/WIC/ACM International Joint Conferences on Web Intelligence (WI) and Intelligent Agent Technologies (IAT)*. Vol. 3. IEEE, 2014.

[15] Nafea, Ibtehal. "An Intelligent Agent Model and a Simulation for a Given Task in a Specific Environment." *2018 1st International Conference on Computer Applications & Information Security (ICCAIS)*. IEEE, 2018.

[16] Hashimoto, H., and P. T. Szemes. "Ubiquitous haptic interface in intelligent space." *SICE 2003 Annual Conference (IEEE Cat. No. 03TH8734)*. Vol. 1. IEEE, 2003.

[17] Ciocîrlan, Alexandra, et al. "Improved Performance of the Autonomous Mobile Robot Vectors by New Intelligent Control Interfaces." *2021 23rd International Conference on Control Systems and Computer Science (CSCS)*. IEEE, 2021.

[18] Kamel, Ahmed. "A Multi-modal User Interface for Agent Assistant Systems." *2009 Second International Conferences on Advances in Computer-Human Interactions*. IEEE, 2009.

[19] Szemes, Peter Tamas, et al. "Guiding assistant for disabled in intelligent urban environment." *Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003)(Cat. No. 03CH37453)*. Vol. 3. IEEE, 2003.

[20] *Azar, Sleiman, et al. "An agent-based multimodal interface for sketch interpretation." 2006 IEEE Workshop on Multimedia Signal Processing. IEEE, 2006.*

[21] *Soldatos, John, et al. "Agent-based middleware infrastructure for autonomous context-aware ubiquitous computing services." Computer Communications 30.3 (2007): 577-591.*

[22] *Zhang, Zili, Chengqi Zhang, and Shichao Zhang. "An agent-based hybrid framework for database mining." Applied Artificial Intelligence 17.5-6 (2003): 383-398.*

[23] *Andrews, Clinton J., et al. "Designing buildings for real occupants: An agent-based approach." IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans 41.6 (2011): 1077-1091.*

[24] *Castillo-Garcia, Javier, et al. "Active learning for adaptive brain-machine interface based on Software Agent." 2015 23rd Mediterranean Conference on Control and Automation (MED). IEEE, 2015.*

[25] *Murad, Christine, and Cosmin Munteanu. "Designing voice interfaces: Back to the (curriculum) basics." Proceedings of the 2020 chi conference on human factors in computing systems. 2020.*

[26] Exploring Intelligent Agents in Artificial Intelligence, By John Terra, https://www.simplilearn.com/what-is-intelligent-agent-in-ai-types-function-article

[27] Hanssens, Nicholas, et al. "Building Agent-Based Intelligent Workspaces." *International Conference on Internet Computing*. Vol. 7. 2002.

[28] Kawamura, Kazuhiko, et al. "An agent-based architecture for an adaptive human-robot interface." *36th Annual Hawaii International Conference on System Sciences, 2003. Proceedings of the*. IEEE, 2003.

[29] Orozco, Omar J. Lopez, and Jose L. Martinez Lastra. "A real-time interface for agent-based control." *2007 International Symposium on Industrial Embedded Systems*. IEEE, 2007.

[30] Balaji, P. G., and Dipti Srinivasan. "Multi-agent system in urban traffic signal control." *IEEE Computational Intelligence Magazine* 5.4 (2010): 43-51.

[31] Moran, Douglas B., et al. "Multimodal user interfaces in the Open Agent Architecture." *Proceedings of the 2nd international conference on Intelligent user interfaces*. 1997.

[32] Benta, Kuderna-Iulian, et al. "Agent based smart house platform with affective control." *Proceedings of the 2009 Euro American Conference on Telematics and Information Systems: New Opportunities to increase Digital Citizenship*. 2009.

[33] Aversa, Rocco, et al. "Cloud agency: A mobile agent based cloud system." *2010 international conference on complex, intelligent and software intensive systems*. IEEE, 2010.

[34] Nealon, John, and Antonio Moreno. "Agent-based applications in health care." *Applications of software agent technology in the healthcare domain*. Basel: Birkhäuser Basel, 2003. 3-18.