# Knowledge Management in Virtual Organisations Using Mobile Agents

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## Abstract

This paper presents a conceptual framework for enhancing knowledge management (KM) processes in virtual organizations through the integration of mobile agents. With the growing digitization of workplaces and the proliferation of distributed teams, managing and leveraging knowledge efficiently has become critical. Mobile agents offer promising features such as autonomy, adaptability, and mobility, making them suitable for dynamic knowledge environments. The paper outlines the architecture of a multi-agent system for KM and discusses its potential impact on organizational performance. Emphasis is placed on the role of intelligent agents in collecting, filtering, and disseminating relevant knowledge across virtual settings. The proposed model aims to support decision-making, reduce information overload, and facilitate knowledge sharing among members of decentralized organizations.

Keywords: knowledge management; distributed knowledge; virtual environments; mobile agents; multi-agents system.

JEL Classification: O32; D83; Q56.

## Introduction

Knowledge represents a fundamental asset for any organization, highlighting the importance of effective strategies for acquiring, organizing, and distributing knowledge. Acquisition involves extracting knowledge from diverse sources, such as databases, repositories, and printed materials. Organization focuses on structuring and storing knowledge efficiently for easy retrieval and reuse. Distribution ensures that the right knowledge is delivered to the right person at the right time, enhancing its utility and strategic value. As emphasized by Chatterjee and Mousumi (2023), knowledge is a critical organizational resource whose effective management underpins success across various domains.

A widely recognized approach to support KM is through the development of an organizational memory - defined as a structured repository of essential knowledge and information within an organization. This memory enables knowledge sharing, reuse, and collaboration (Liotta et al., 2002; FIPA). Sharma (2021) argues that while the concept of information has long been a subject of epistemological discourse since the Greek Classical era, recent attention has shifted toward its practical role in organizational knowledge management, particularly through the development and implementation of Knowledge Management Systems (KMS) designed to support the creation, transfer, and application of knowledge within organizations.

Technological advancements, particularly in areas such as big data and cloud computing, have further expanded the capabilities of organizational memory systems, enhancing their effectiveness in capturing, storing, and leveraging valuable insights for organizational success (Brătianu, 2015). These developments enable faster knowledge access, scalability of storage, and improved traceability of knowledge flows.

The design of complex information systems, and their individual components, is heavily influenced by the explicit and implicit requirements and objectives of an organization. When these requirements are perceived to be relatively stable, it often guides the system design process can be structured and goal-oriented. However, as organizational needs evolve over time - due to internal growth, external market changes, or technology disruptions – there is a need for systems to be reevaluated and reengineered to maintain alignment with broader strategic goals. Periodic reevaluation and reengineering of these systems become necessary to ensure continued alignment with the knowledge management strategies, organization's goals and its environments (Ștefănescu & Ștefănescu, 2008). While infrequent changes can be accommodated through reengineering processes, the technological advancement and shifting business environments necessitate a flexible approach to system design that can readily adapt to evolving requirements and emerging challenges of virtual organisation.

In the context of knowledge management (KM), virtual environments provide collaborative platforms where employees can share knowledge, engage in discussions, and co-create knowledge assets - accessible anytime, from anywhere (Terentyeva et al., 2020). Virtual environments can serve as platforms for implementing KM systems, providing a digital space where employees can access, contribute to, and collaborate on knowledge resources from anywhere, at any time. KM systems typically include repositories, databases, and platforms for storing and accessing knowledge assets such as documents, best practices, lessons learned, and expertise. New forms of organisations are not so stable. Given the fluid nature of virtual organizations, their structural design tends to be more flexible, scalable, and responsive to external stimuli, unlike traditional, hierarchically rigid structures.

A virtual organization represents a dynamic and collaborative entity formed by a temporary alliance of enterprises, pooling their skills, core competencies, and resources to exploit on business opportunities. These joint endeavors heavily rely on computer networks and a distributed information systems structure to facilitate seamless communication and coordination among member entities. The characteristics of virtual organizational environments need the adoption of a multi-agent system architecture at the implementation level. In a multi-agent system, each agent operates autonomously, embodying the principles of decentralization and distributed decision-making. This flat architecture ensures that decisions made at the inter-enterprise level are swiftly distributed and integrated across all member organizations, down to the granular machine or cell level. To standardize and facilitate interoperability within multi-agent systems, frameworks like the Foundation for Intelligent Physical Agents (FIPA) provide essential guidelines and protocols for agent interaction and communication. Agents within this system act as proxies for their respective organizations, tasked with representing and advancing the objectives of both the individual entity and the overarching virtual organization. This dual commitment features the complexity of managing knowledge within such dynamic contexts, where information must be accessed, shared, and leveraged across disparate organizational boundaries.

Mobile agents can be employed in knowledge management systems to gather, filter, and distribute knowledge resources based on user preferences or organizational needs. They can also facilitate knowledge discovery by autonomously searching for relevant information across diverse sources and bringing it back to the KM system or directly to users. The system analyses the user's query in order to establish which domains of the virtual organisation have the potential answer and send the query to each domain until he finds a domain that has the answer. Besides autonomy, reactivity, pro-activeness and social ability (Padovitz, Zaslavsky, & Loke, 2004), another software agent's property is mobility. Mobility refers to the ability of an agent for dynamically transferring its execution onto different sites (Olfati-Saber, 2006). This characteristic allows them to gather real-time data from various parts of a virtual organization, analyze it locally, and return results or initiate actions. Additionally, the cloning feature of mobile agents allows for parallel execution, increasing system efficiency and reducing latency.

To address the knowledge management challenges inherent in virtual organizational environments, we are developing a distributed knowledge management system utilizing mobile agents. These agents act as agile information brokers, capable of analyzing user queries, traversing multiple domains, and returning targeted, relevant knowledge. The system adapts dynamically to user preferences, organizational needs, and environmental changes, ensuring continuous and context-aware knowledge exchange. Exploiting the mobility and adaptability of these agents, the proposed system aims to promote continuous, context-aware knowledge exchange and collaboration, ultimately strengthening the adaptability and competitiveness of virtual enterprises.

Despite advancements in KM systems, limited research has explored the application of mobile agents specifically in the context of virtual organizations. This paper aims to bridge this gap by presenting a conceptual model that integrates mobile agent-based knowledge processing into the broader KM framework of distributed enterprises. In doing so, it offers a novel perspective on organizational adaptability and innovation in increasingly virtualized and interconnected business environments.

## 1. Literature Review

### Virtual Environments

The emergence of virtual environments has significantly transformed modern organizational practices, particularly following the disruptions caused by the COVID-19 pandemic. These environments have become not only a practical necessity but also a strategic asset, enabling organizations to maintain continuity, enhance productivity, and increase adaptability in uncertain conditions. Virtual environments offer organizations the means to achieve higher levels of efficiency and sustainability by transcending traditional limitations related to space, cost, and access to talent.

From a strategic standpoint, virtual environments contribute to organizational growth by facilitating either cost reduction or revenue enhancement - two fundamental levers for profitability. Firstly, virtual environments enable organizations to significantly reduce various human resource costs associated with traditional office setups. This includes savings on hiring costs, training expenses, and utilities such as energy and heating/air conditioning, as employees can work remotely from anywhere, eliminating the need for physical office spaces and the associated overhead. Secondly, leveraging virtual technologies allows organizations to extend their target market beyond geographical limitations. Unlike traditional modes of operation, where products and services are confined to specific regions, virtual environments enable businesses to reach a global audience, effectively expanding their market reach and potential customer base. Additionally, virtual environments promote knowledge and experience sharing across the organization by providing continuous communication and collaboration channels. Through centralized digital platforms and automated processes, organizations can streamline operations, optimize workflows, and maximize resource utilization, ultimately saving time and resources while enhancing overall productivity and competitiveness.

In addition, virtual platforms allow businesses to reach broader markets by removing geographic barriers. This global reach empowers organizations to expand their customer base and tap into emerging markets, boosting their competitive positioning. As noted by Priya (2013), modern virtual environments enhance internal and external user engagement by leveraging intuitive technologies that streamline communication and collaboration. These platforms facilitate continuous knowledge sharing and collaborative workflows across departments and organizational boundaries.

Virtual environments also support the centralization of data and process automation. This consolidation enables better decision-making, improved workflow efficiency, and optimized resource allocation. By enabling employees to interact with shared knowledge repositories and collaborative tools in real-time, organizations are better positioned to respond to market demands and changing operational requirements.

Aligning technology with knowledge management processes plays a pivotal role in enhancing organizational performance. Dornhöfer et al. (2020) argue that the strategic integration of IT capabilities enables virtual organizations to generate greater business value. When technological tools are designed to align with business objectives, organizations can experience improved financial outcomes and increased market competitiveness. Effective strategic planning ensures that IT investments contribute to key performance indicators and long-term goals.

Moreover, studies by Alavi & Leidner (2001) and Sabherwal & Becerra-Fernandez (2003) highlight that knowledge-based IT systems significantly improve knowledge sharing and decision-making effectiveness across organizational units. Similarly, the findings of Feng et al. (2022) emphasize that digital tools supporting knowledge acquisition and dissemination positively affect innovation performance. These perspectives underscore the importance of continuous investment in digital infrastructure tailored to the evolving knowledge management needs of virtual enterprises.

In line with the current trends followed by the virtual businesses worldwide, we further advance an integrative framework that offers a wide understanding of using innovation to grow virtual environments for business of virtual organisations (Figure 1). Simultaneously, promising avenues for future research to enhance the adaptability of business to the Indistry 4.0 (Vogel-Heuser et al., 2020). Some practical advices concerning the key areas to focus on addressing the unique challenges the virtual business might face right now, becomes in fact a comprehensive 3 main-phases approach:

- Phase I: Assess the Environment, Performance, and Digital Maturity of the Organization. This phase involves a thorough evaluation of various aspects of the organization to identify strengths, weaknesses, opportunities, and threats. Key components include:
    - Market analysis to understand industry dynamics and trends;
    - Competitor analysis to benchmark against industry peers;
    - Evaluation of company performance metrics to identify areas for improvement;
    - SWOT analysis summarizing key business insights;
    - Assessment of the organization's digital maturity status using a predefined model.
- Phase II: Define & Communicate the Digital Transformation Strategy & Plan. Once the organizational landscape is assessed, the next step is to develop a clear digital transformation strategy and plan. This phase involves:
    - Setting targets for digital maturity based on desired outcomes.
    - Defining strategic objectives, assembling teams, and allocating budgets.
    - Identifying relevant technologies to support digital transformation goals.
    - Proposing initiatives to align with strategic objectives.
    - Developing business cases to justify investments.
    - Prioritizing digital transformation initiatives based on their impact and feasibility.
    - Creating a detailed transformation plan outlining timelines and responsibilities.
    - Establishing change management strategies and communication plans to facilitate smooth transitions.
- Phase III: Implement, Track & Manage Progress. In this phase, the focus shifts to executing the digital transformation plan and monitoring progress. Key activities include:
    - Establishing governance rules to guide decision-making and accountability.
    - Tracking key performance indicators (KPIs) to measure the effectiveness of digital initiatives.
    - Monitoring the status of each transformation initiative to ensure timely execution.
    - Assessing the progress of change management efforts and adjusting strategies as needed.
    - Evaluating the effectiveness of communication strategies in keeping stakeholders informed.
    - Capturing lessons learned throughout the transformation process to inform future initiatives.

Figure 1: Overview of three phases for key activities involved


Source: FIPA http://www.fipa.org

## Virtual Organizations

In the contemporary digital economy, organizations must be highly flexible and adaptable to succeed in an environment characterized by rapid technological change, shifting market dynamics, and increasing interconnectivity. From this need for agility, the concept of the virtual organization has emerged - a modern organizational model that transcends traditional, hierarchical business structures.

A virtual organization is typically defined as a temporary or semi-permanent network of independent enterprises, institutions, or individuals that collaborate through digital technologies to achieve a common strategic goal. These entities pool their core competencies, resources, and capabilities to respond rapidly to market opportunities while maintaining their legal and operational independence (Ulieru & Unland, 2004; Ni et al., 2020). Recent studies emphasize the growing role of virtual organizations in enabling agility, resilience, and innovation, especially in the context of global disruptions and rapid digital transformation (Bellis et al., 2022; Sarala et al., 2024). The collaboration is enabled through advanced communication technologies, cloud-based infrastructures, and distributed information systems, which provide the architecture for real-time knowledge exchange, autonomous decision-making, and coordinated action across organizational boundaries.

We distinguish four characteristics commune to all virtual organisations: purpose-driven, flexible organizational structure (Ni et al., 2020)., autonomy of members, temporal membership, detailed as follows:

a) All virtual organizations are created for specific reasons and they know exactly the goals and the objectives of their creation. The virtual organisation members have agreed on these goals and objectives.
b) The organizational structure of a virtual organization can change numerous times during the life of the virtual organization. From the outside, the shape of a virtual organization may change continuously, the virtual organisation may extend its original task, companies or people can leave the virtual organisation because their goals are no longer common to the virtual organisation goals. From the inside the virtual organisation has to deal with a permanent demand of restructuring processes.
c) All the members of the virtual organisation are all the time autonomous and independent as they join the virtual organisation intentionally. This means that each member keeps the responsibility for and the control of information concerning its part in the virtual organization.
d) Independent organisation may join or leave the virtual organisation at any time. Temporal means that the lifetime of a virtual organization is normally either explicitly or implicitly restricted; the virtual organization is dissolved when its overall goal has been achieved (Byrne,1993; Calegari et al., 2020).

Building upon the foundational characteristics, scholars such as Nami & Malekpour (2008) and Calegari et al. (2020) propose additional dimensions that define how virtual organizations operate in practice. Recent contributions further refine these dimensions by examining how digital ecosystems, platform-based collaboration, and AI-driven coordination shape virtual organizational behavior and governance structures in dynamic business contexts (Aulkemeier et al., 2019; Baumann & Wu, 2023; Faraj & Leonardi, 2022):

- Duration: This refers to the temporal aspect of the virtual organization, distinguishing between those formed for single business endeavors and long-term alliances.
- Topology: The structural arrangement within the virtual organization can vary between a dynamic, variable structure and a fixed one. Members of the organization may join or depart the alliance dynamically, requiring flexibility in the organizational structure.
- Participation: This aspect considers whether an organization engages in a single alliance or participates in multiple alliances concurrently. Members must be equipped to manage and align with the goals of all virtual organizations in which they are involved, necessitating adaptability and coordination across multiple fronts.
- Coordination: Virtual organizations may exhibit different coordination structures, ranging from star-like arrangements with a dominant member to democratic alliances or federations. In democratic setups, organizations cooperate on equal footing while preserving autonomy, although a coordinator may still be required to oversee organizational structure and operational principles.
- Visibility: This pertains to the level of visibility or transparency within the virtual organization's structure. Members may have access to varying levels of information, from only their immediate neighbors to a broader multi-level view of the organization's structure.

The multi-agent system (MAS) paradigm is particularly well-suited to implementing virtual organizations. MAS technologies mirror the core features of virtual organizations: they are decentralized, adaptive, and capable of autonomous action within a networked structure. Each agent in a MAS represents an autonomous entity - analogous to a member of a virtual organization - that collaborates with other agents to achieve system-level goals. Recent research has highlighted the increasing relevance of MAS in digital enterprise settings, especially for managing distributed decision-making, ensuring task coordination, and optimizing performance in real-time across complex virtual ecosystems (Zhu et al., 2024; Smyth|OS[1], 2024; Rzevski, 2019).

The MAS-based approach developed in our research reflects the characteristics discussed above. Our system is designed around:

- Single-business focus (aligned with purpose-driven and project-specific goals),
- Variable topology (allowing structural flexibility),
- Multi-membership capability (agents can participate in multiple knowledge-sharing contexts),
- Democratic coordination (agents collaborate on equal terms),
- Multi-level visibility (agents operate with local knowledge and global coordination capabilities).

Integrating these principles into a distributed system architecture, our model supports dynamic, scalable, and intelligent knowledge exchange within and across virtual organizations—promoting adaptability, responsiveness, and innovation in complex environments.

## 2. Knowledge Management in Virtual Organization Using Multi-Agent Systems Approach

### Research Aim and Scope

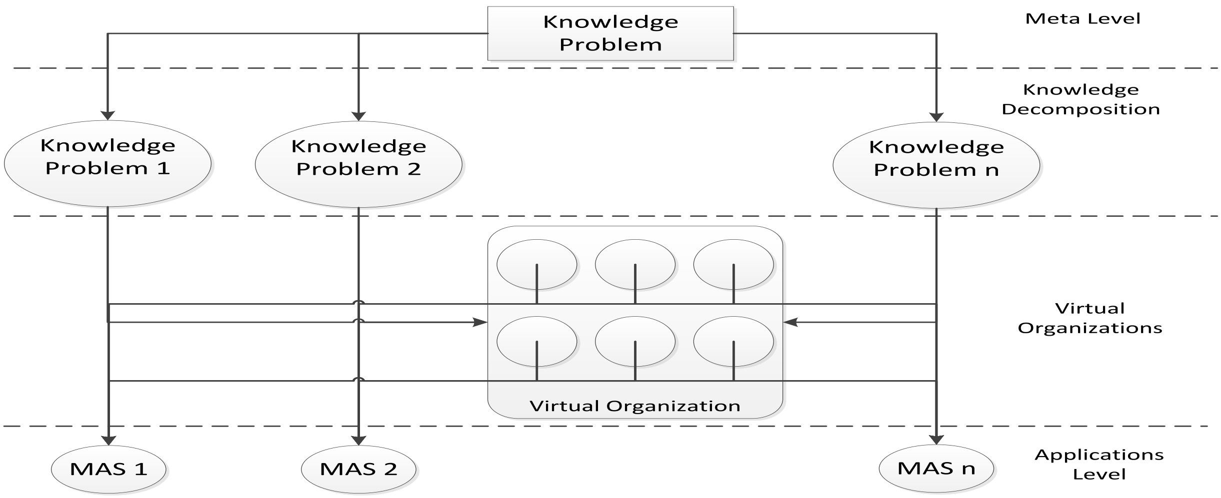
This study aims to explore how mobile agents, embedded within a Multi-Agent System (MAS) architecture, can optimize knowledge management (KM) processes in virtual organizations. Specifically, it investigates how autonomous, adaptable agents can support decentralized decision-making, dynamic collaboration, and real-time knowledge exchange across distributed environments. Integrating MAS with web services and interoperable standards such as FIPA, the proposed model seeks to advance current KM practices by addressing challenges related to scalability, agility, and communication in digital enterprise ecosystems.

In Figure 2, a complete description of the Multi-Agent Systems (MAS) architecture is provided, offering insight into its main components. However, in line with the purpose of this paper, our focus will be directed merely

[1] https://smythos.com/ai-agents/multi-agent-systems/multi-agent-systems-in-business-processes/

towards explaining the particularities of knowledge management within the Virtual Organization context, utilizing recent standards.

Figure 2: Knowledge management architecture in context of virtual organization using multi-agent systems




Source: FIPA http://www.fipa.org

The MAS architecture serves as a robust agent framework, advancing interoperability both within and across diverse agent-based applications. Some of the most recent Multi-Agent Systems (MAS) implementations that predominantly leverage Java and Internet-relevant technologies include: JADE (Java Agent DEvelopment Framework) a popular open-source framework for developing agent-based applications in Java, JACK (Java Agent Construction Kit) – offers a range of features for designing and implementing intelligent agents, including support for communication, coordination, and negotiation, JaCaMo (Jason, Cartago, and Moise) - provides developers with a flexible and powerful platform for building complex multi-agent systems, Cartago (an agent-oriented programming language), Repast Symphony used in research and education for modeling complex systems and studying emergent behaviors, NetLogo that supports the development of complex simulations. These implementations influence Java's versatility, platform independence, and extensive ecosystem of libraries and tools, making them well-suited for developing robust and scalable multi-agent systems in diverse domains. Additionally, they often integrate easily with Internet-relevant technologies such as XML, SMTP, and web services to facilitate communication, data exchange, and interoperability in distributed environments.

The general architecture of knowledge management proposed in context of virtual organization using multi-agent systems are presented in Figure 2. Agents act as knowledge brokers that receive user queries, traverse organizational nodes, and retrieve relevant data. Autonomy, reactivity, proactiveness, and mobility are key agent characteristics (Padovitz, Zaslavsky, & Loke, 2004). Mobility, in particular, refers to the agent's ability to migrate across platforms to access distributed data (Olfati-Saber, 2006).

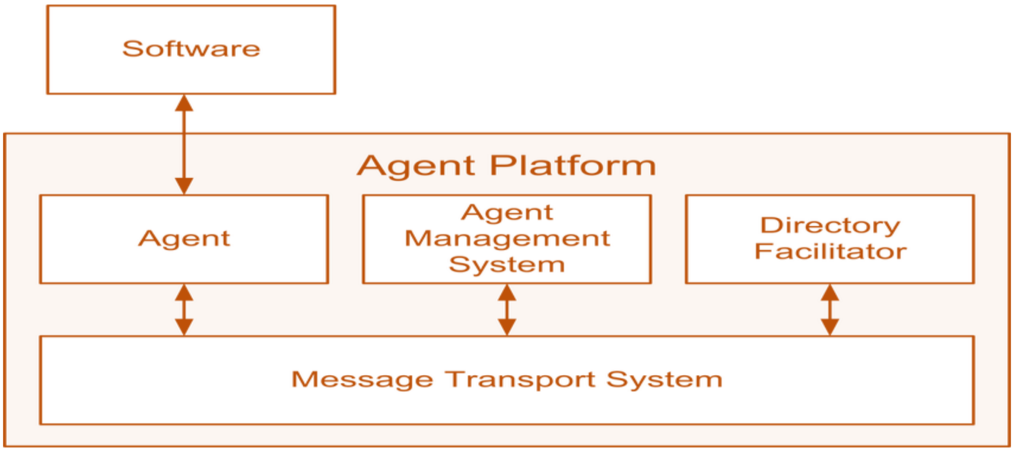
In instances where a partner fails to meet expectations - such as timely delivery or competitive bidding - MAS are empowered to initiate the replacement of the underperforming partner with a more suitable counterpart. This decision-making process, coupled with subsequent negotiations, is seamlessly orchestrated by the multi-agent systems, ensuring the smooth operation and efficacy of the collaborative endeavor. Moreover, security standards have an essential role in facilitating inter-platform accessibility at this juncture. By marked a delicate balance between autonomy and cooperative forces, robust security measures enable collaborative entities within the cluster to access each other's services while safeguarding sensitive information and maintaining confidentiality. This equilibrium ensures a fair and transparent operational environment favourable to productive collaboration and sustained success.

Popîrlan & Ştefănescu (2011) proposed in previous research, a multi-agent approach for managing knowledge within virtual organisations, leveraging the capabilities of multi-agent systems (MAS) to autonomously adapt to changes in the environment using JADE for knowledge management, emphasizing agent characteristics, functionalities, communication, cooperation, and coordination. Furthers, (Ștefănescu & Ștefănescu, 2013) attempted an intelligent agents' approach to support the management decision-making process in virtual organizations, leveraging autonomous software entities to assist managers in various aspects of decision-making within the virtual environment focusing on gather data from various sources within the virtual organization, including databases, online repositories, and external sources.

A main requirement to implement the proposed architecture with software agents is to ensure inter-enterprise/inter-node/inter-platform communication among the participants in the collaboration. The Foundation for Intelligent Physical Agents (FIPA) has already definined robust communication protocols and standards. Through initiatives like Agent cities[2], FIPA has established the groundwork for enterprises to operate as nodes within a collaborative network of agent-based systems. Each enterprise within this network is tasked with developing software that operates on FIPA-compliant agent platforms. Adhering to these standards, enterprises ensure that their agents can effectively communicate with counterparts on diverse platforms and access a wide array of services offered by other participants. This interoperability advances the creation of innovative, value-added services within the collaborative cluster, driving collective efficiency and productivity.

Moreover, FIPA's framework enables enterprises to establish dynamic and adaptive connections, allowing agents to interact, exchange information, and coordinate activities. In Figure 3 is presented the agent management reference model[3] as base of the virtual organisation architecture.

Figure 3: Agent Management Reference Model




Source: FIPA http://www.fipa.org

Virtual organisation is flexible and self-organizing structure in part because they are created using multi-agents' development mechanisms. The current FIPA specifications lack coverage of elements specific to the web-centric paradigm, particularly in domains like financial services. This gap may pose implementation challenges, but these issues can be effectively addressed using FIPA-OS, an extension that caters to e-business aspects. Within virtual organizations, mobile agents play an important role in streamlining various processes such as information gathering, order evaluation, decision-making, negotiation, order placement, and payment processing. Architectural challenges can be mitigated by leveraging technologies like CORBA, Java RMI, and XML, which facilitate communication, interoperability, and data exchange. Furthermore, security, performance, and fault tolerance within virtual organizations can be addressed through careful architectural design.

Another challenge in virtual organization formalization is optimizing the configuration of part organizations to maximize impact. To tackle this, an initiating agent takes charge of the formation process. This agent may rely

[2] http://www.agentcities.org/
[3] http://www.fipa.org/docs/input/f-in-00024/f-in-00024.html

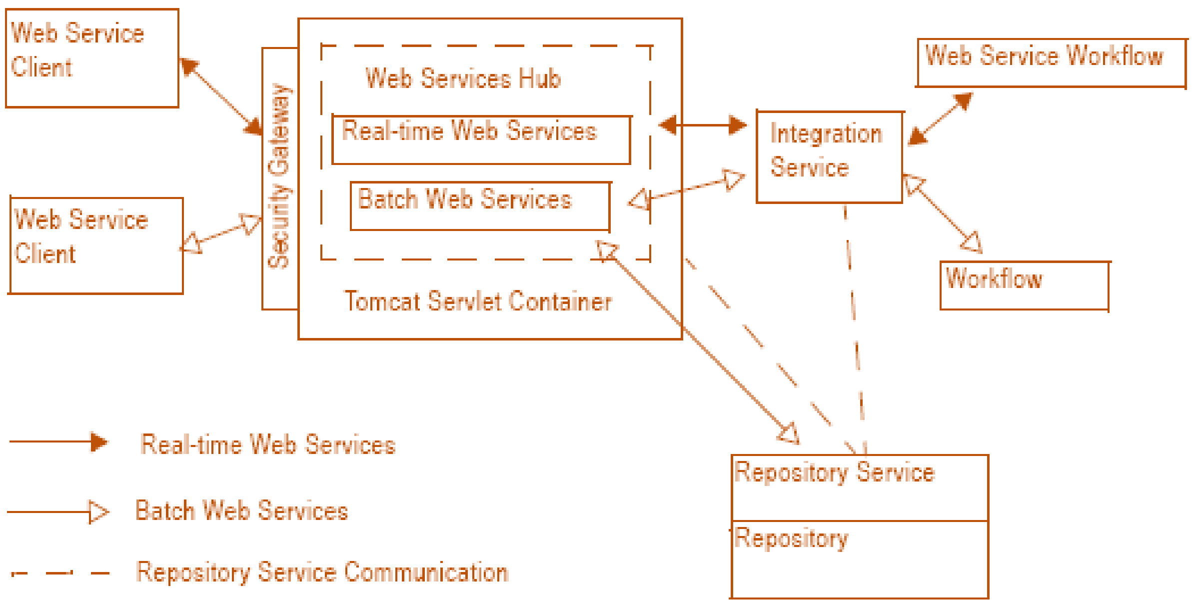
solely on internal knowledge to directly engage potential partners or utilize external knowledge sources. While the former grants full control over the process, the latter involves relinquishing some control. Leveraging web services, with their standardized XML messaging and platform-agnostic compatibility, offers a compelling solution for dissemination and problem-solving within virtual organizations. Connecting web services and intermediary agents, organizations can effectively navigate partner selection and collaboration challenges, enhancing the overall functioning of virtual organizational ecosystems.

Web services architectures are referred for virtual organisations because they are modular Internet applications that can be easily used on the web and that execute a specific business task. These services are based on XML standards and their architectures are based on standards for messages transfer. These services are well defined and can be easily integrated in other applications in order to create complex processes. Web services are suitable for agents' systems due to their functionality.

In the case of web services, each component assumes a distinct role within a layered architecture. First, there's the service provider, tasked with implementing specific services and making them accessible over the internet. Then, there's the service requestor, representing any consumer of web services, and finally, the service registry, serving as a central repository where agents can both publish and discover services.

Agents within this framework can take on dual roles as service providers and/or service requestors. When faced with complex tasks, an agent has several options for finding suitable partners. It may directly engage with one or more web service registries to locate compatible services, or alternatively, it could opt to interact with a mediator agent. This mediator agent possesses knowledge about service registries and the services they offer, enabling more efficient navigation of available services and facilitating collaborations to address complicated tasks.

Figure 4: Web services architectures for virtual organisations




Source: Informatica Documentation (https://docs.informatica.com)

Web services themselves are characterized by layered architectures, encompassing service transport for message delivery, XML messaging for encoding messages, service description defining the public interface, and service discovery enabling generic search and providing comprehensive interface descriptions.

While agents can directly access web services due to standardized access protocols, the use of mediator agents offers certain advantages. Mediators can store valuable information about the success of agent clusters in performing collaborative tasks and the performance of individual service providers. Drawing from a broad range of experiences, mediators can better assess agent performance and establish highly successful clusters for complex tasks. However, reliance on mediators may compromise agent autonomy and entail additional fees for mediator services.

Considering their characteristics and architectural aspects, agent technology and web services synergize effectively. Agents can offer services, compose complex services, manage Internet dynamics, and optimize workflows of complex services, forming a symbiotic relationship that enhances overall efficiency and effectiveness.

## 3. Objectives and Collaborative Problem-Solving Strategies in Virtual Organizations

An agent can represent any organisation that is a part of the virtual organisation, and so virtual organisation consists in a lot of agents that are negotiating and that cooperate in order to solve complex problems. In the virtual organisation we assume there is an agent that takes initiative and that tries to find other agents in order to solve a problem. This task can be done either by the initiator agent or it can use a mediator agent.

When the formation process relies solely on a mediator agent, implementation is streamlined as only this agent requires the specialized capabilities for the task. However, if other agents possess mediator abilities, implementation costs escalate significantly. In complex problem-solving scenarios, agents may form groups to address challenges beyond the capacity of a single agent. This often occurs in global inter-enterprise collaborations or within large enterprises where multiple departments vie to solve tasks, necessitating the selection of suitable agents.

Within a multi-agent system, agents are interconnected directly due to their autonomy, enabling peer-to-peer messaging or non-directed broadcasts to contact known agents. Agents must maintain awareness of their peers and their respective capabilities for potential collaboration, storing this information in personal agent directories.

A key aspect of the virtual organization is the decomposition of system goals into structured phases, aiming to maximize overall profit. Agents collaborate to select and execute plans tailored to achieve both system goals and output goals, with planning processes prioritizing the former. This iterative planning involves evaluating alternative actions to identify the most appropriate ones aligned with system goals. So, the virtual organisation has in fact two goals: the output goal and the system goal. In (Stowell & Cooray, 2016) the system goal stands for the plan goal that is to be achieved, that is the problem that has to be solved, and the output goal describes the real purpose of the organizational unit, which often means profit maximization. In this case agents from the virtual organisation must consider both goals. The solution for this situation is to create agents that are capable of intentional problem solving. The ideal situation is when the agents achieve both system goal and output goal. Because there are two goals to be achieved then the planning process must have to phases, but taken in consideration the fact that the system goal is the one with a higher importance then the virtual organisation agents must concentrate to solve this goal and, in consequence the planning process must concentrate on this goal. The classical planning process concentrates mostly on the realisation of the output goal. Starting from the idea that the system goal is the one with a higher importance then from the planning actions must be chosen the ones that concentrate on this goal. The choice of the action is made rational by agents from the virtual organisation that takes control over the planning procedure. This means that whenever the planning process has to make a choice among alternative products the planning process will determine the one from which it assumes that is the most appropriate one with respect to the system goals. The planning process determines all the relevant plans, and then chose the one that is goes to the system goal in the best way possible. The choice is not so easy to be done because the agents must execute a complex search in the set of plans/alternatives.

## 4. Discussions and Further Research

MAS technologies have been successfully applied in various real-world scenarios, underscoring their practical viability. For instance, in distributed software development projects and virtual teams, agents coordinate task assignments, monitor repositories, and automate version control processes. In the logistics sector, MAS has been utilized to manage transportation networks, allowing agents to reroute deliveries in real time based on traffic data or delays, as seen in pilot projects by companies such as DHL. In cloud computing, agents optimize resource allocation across virtual machines, supporting scalability and fault tolerance. Similarly, MAS frameworks are used in electronic marketplaces, where agents autonomously negotiate prices and match buyers with sellers. These examples confirm the adaptability and usefulness of MAS in dynamic, distributed environments - reinforcing its relevance in the proposed knowledge management system.

As research continues to explore the complexities of multi-agent architectures and their integration with web services, further enhancements in knowledge management within virtual organizations are anticipated. Future research can explore strategies for optimizing collaboration within virtual organizations, focusing on enhancing synergy and coordination among member entities to achieve organizational goals efficiently. Also, addressing security and privacy concerns within MAS frameworks is imperative, along with exploring the integration of emerging technologies like artificial intelligence, blockchain, Internet of Things (IoT) within MAS offering new insights into enhancing knowledge management and decision-making processes in virtual environments. Dynamic problem-solving mechanisms within MAS can improve adaptability to evolving challenges, while investigating interoperability standards can focus on designing agile decision-making frameworks to address complex problems efficiently.

In case of a virtual organisation, agents decompose system goals in phases that can be structured as follows: obtain as much profit as possible using some specific products; obtain as much profit as possible from each problem; obtain as much profit as possible in period of time. The decomposition levels go from the simplest to the most complex goal in order to achieve the system goal (maximize profit). The planning process must consider the fact that the system gives a higher priority to some products or services in order to obtain the system goal, so it will apply the specific decomposition or use the specific product whenever possible for a given problem. All the plans are generated for a specific problem and the planning process must select the ones that are more profitable (the system goal is to maximize the profit).

Agents within a multi-agent system collaborate by sharing their services to collectively solve complex problems, either in full or in part. They negotiate and coordinate their output goals flexibly, ensuring the autonomy of each component. Agents are general problem solvers, capable of decomposing problems and assigning sub-problems to other agents through negotiation processes (Baltzersen, 2021). Information retrieval in virtual organizations mirrors distributed problem-solving systems, with multi-agent systems integrating supplementary capabilities. While distributed problem-solving systems start immediately and efficiently incorporate organizational knowledge, multi-agent systems derive and negotiate such information, yielding superior results.

Agents assign sub-problems to other agents, and because of the independency of agents the assignation process is based on the negotiation process. The negotiation process can be realized by a negotiation scheme, which has a flexible behaviour like distributed problem-solving systems (Yeoh and Yokoo, 2012). The multi-agent system excels in creating tailored product or service bundles by adeptly coordinating the output objectives of collaborating agents. This advances a demand-centric cooperation framework characterized by a network of client-contractor relationships. Such a structure mirrors the iterative problem breakdown process employed, facilitating coordination and efficient task execution within the system. (Rousset et al. 2014) conducted a comprehensive survey on parallel and distributed multi-agent systems a thorough examination of existing platforms and their functionalities.

The information retrieval in the virtual organisation is so inherit from distributed problems systems. We conclude that the multi-agents system has commune points with distributed problem solving systems, but supplements are integrated in multi-agents system. Problem solution within distributed problem-solving systems can start immediately and can be performed efficiently since organizational knowledge can be incorporated (Durfee, 2001). A multi-agents system has to derive such information. If we compare the results obtained with a multi-agents system and the results obtained with distributed problem solving systems, we observe better results with multi-agents system and so this field of agents is in extension.

## Conclusions

The significance of knowledge management (KM) in organizational success cannot be overstated, encompassing the acquisition, organization, and distribution of knowledge resources. Establishing an organizational memory facilitates access to valuable knowledge, enhancing individual and collective tasks. Virtual environments have emerged as key drivers of organizational productivity, offering advantages such as cost reduction, market expansion, enhanced flexibility, and improved knowledge sharing across organizations, particularly amid the global shift towards remote work catalyzed by recent events. Leveraging multi-agent systems (MAS) enhances knowledge management within virtual organizations by autonomous agents operating in flat architectures, facilitate effective coordination and communication in dynamic virtual environments. Their mobility and autonomy enable efficient knowledge retrieval and dissemination, contributing to enhanced organizational adaptability.

This paper has introduced a multi-agent system tailored to manage knowledge within virtual organizations, leveraging mobile agents in conjunction with e-business frameworks. The system offers a distributed approach to knowledge management, enabling the storage and retrieval of valuable insights from virtual entities. Each agent within the system possesses knowledge of other agents' characteristics, crucial for achieving organizational objectives. Architectures that enable seamless information sharing through message passing technologies are pivotal for enhancing knowledge management capabilities. Additionally, mechanisms ensuring consistency within the multi-agent system contribute to its effectiveness and reliability.

As researches continues to explore the complexities of multi-agent architectures and their integration with web services, further enhancements in knowledge management within virtual organizations are anticipated.

Future research can explore into strategies for optimizing collaboration within virtual organizations, focusing on enhancing synergy and coordination among member entities to achieve organizational goals efficiently. Also, addressing security and privacy concerns within MAS frameworks is imperative, along with exploring the integration of emerging technologies like artificial intelligence, blockchain, Internet of Things (IoT) within MAS offering new insights into enhancing knowledge management and decision-making processes in virtual environments. Dynamic problem-solving mechanisms within MAS can improve adaptability to evolving challenges, while investigating interoperability standards can focus on designing agile decision-making frameworks to address complex problems efficiently.

Additionally, exploring human-AI collaboration in knowledge management can provide important perceptions into optimizing the interaction between human workers and autonomous agents within virtual organizations, thereby fostering a symbiotic relationship for organizational success.

## Credit Authors/hip Contribution Statement

Nicola-Gavrilă, L. was responsible for the conceptualization and development of the research idea, as well as the design of the methodological framework. Popîrlan, C.I. handled software development, data processing, and the visualization of results. Both authors contributed significantly to the technical implementation and formal analysis of the study, particularly in designing and integrating mobile agent-based solutions within virtual organizational environments.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. It is noted that Nicola-Gavrilă, L., the Founding Editor, and Popirlan, C.I., the Editor-in-Chief, are co-authors of this paper. However, this affiliation did not influence the editorial decision-making process. The manuscript was subject to independent peer review handled by a qualified editorial team member with no competing interests.

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