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Classification and Review of Multi-Agents Systems in the Manufacturing Section

Georgios Andreadis[a]*, Paraskevi Klazoglou[b], Kyriaki Niotaki[b], Konstantin-Dionysios Bouzakis[a]

[a]*Mechanical Eng. Dept., Aristotle University of Thessaloniki, Thessaloniki 54124, Greece*
[b]*Department of Informatics, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece*

Abstract

Current technology and especially Artificial Intelligence effectively increase productivity and take cost out of operations in the Manufacturing sector. One of the main representatives of information technology in the industrial applications are agents. This paper suggests a way to a) categorize multi-agent systems according to the coordination mode among agents and b) classify agents that take action on them, depending on their functions It examines the main approaches of multi-agent architectures, according to their coordination way. The main coordination types are: a) centralized multi-agent coordination (or coordinator agents), in which one central agent undertakes the collection of partial plans from agents, combines them in a plan and solves possible conflicts and b) decentralized multi-agent coordination (or autonomous agents), in which agents are not controlled by a central agent although they communicate with each other for the creation of their plans and the solution of possible arguments. Although there are several aspects that we can consider in order to classify CAD, CAPP and CAM multi-agent systems, this review develops a classification scheme, based on interaction characteristics.

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Keywords: Agent; Multi-agent; Manufacturing; Cad/Cam; Design

1. Introduction

Modern technology is applied wherever is able to contribute in rapid growth and efficient manufacture. In modern enterprising environment, the manufacture industry plays an important role. Software, being an important

* Corresponding author. Tel.: +30-2310-996355; fax: +30-2310-996059.
E-mail address: andreadi@eng.auth.gr

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part of the used technology, has been rendered irreplaceable, since it accelerates and automates many complex processes. However, not only certain operations are not supported sufficiently, but also the possibilities that have been made available by modern technology are not being used in their full capabilities.

Agents technology is an autonomous scientific field with exceptional, last years, research activity [1, 2]. As every technology, they have a variety of special skills and that is why they are useful for distributed, unstructured and decentralized architectures that change usually and thus are complicated. The term "agent" [3, 4] concerns the meaning of autonomy which means self-activity for its objectives achievement. Agents interact, collaborate, coordinate and negotiate in a system that was designed and implemented as a multi-agent system. A multi-agent architecture is based on cooperative intelligent entities and has been developed for the integration of design, manufacturing and shop-floor control activities.

Aim of this paper is to review and classify multi-agents systems, used in the manufacturing section. It is structured as follows. Section 2 introduces reader to the categorization of multi-agent systems architectures and discusses the principles of centralized and decentralized architectures. Section 3 presents a classification of agents that belong to centralized systems into design and manufacturing stages. Respectively, section 4 classifies agents that belong to decentralized systems into design and manufacturing stages. Finally, section 5 summarizes the basic problems which might be solved by agents.

2. Classification of multi-agent systems architectures

This section demonstrates the main approaches of multi-agent architectures, according to their coordination way. The main coordination types are: a) centralized multi-agent coordination (or coordinator agents), in which one central agent undertakes the collection of partial plans from agents, combines them in a plan and solves possible conflicts and b) decentralized multi-agent coordination (or autonomous agents), in which agents are not controlled by a central agent although they communicate with each other for the creation of their plans and the solution of possible arguments.

Although there are several aspects that we can consider in order to classify CAD, CAPP and CAM multi-agent systems, this review develops a classification scheme, based on interaction characteristics, which has the following advantages:

- This categorization is easily applied as it depends on the existence, or not, of a coordinator agent. For instance, much multi-agent architecture includes facilitator or mediator agents and thus these systems are clearly centralized. In contrast, classification based on agent function is more ambiguous, as an agent may handle operations from several engineering stages.
- The communication among agents has played an increasingly important role in multi-agent architectures and is a key research area in multi-agent systems. Analysis of the interaction mode may highlight a variety of potential problems and suggest possible ways of resolution. Therefore, the specific classification focuses on agent coordination.

The next 2 paragraphs refer to centralized architectures aspect and analyze decentralized architectures or autonomous agents [6,7].

a) Centralized architectures: In centralized architectures an agent coordinator manages the other agents. Coordinator is an agent that manages other agents and directs information flow among the other agents. Each agent has to contact to the coordinator agent in order to communicate with each other. Moreover, we consider an architecture centralized whether there is also a central coordinator that handles coordinator's communication. The main representatives of agent coordinator are the Mediator and the Facilitator. In the rest of this paper, we call centralized a multi-agent system that owns a facilitator agent, a mediator or an agent that undertakes the management and the cooperation of the other agents.

a1) A facilitator is a program that coordinates the communication of agents. The facilitator provides a reliable level of communication in the network and is responsible of routing messages between agents, based on their content, and regulating the control of multi-agent activities. Agents interact via the facilitators (coordinators), who translate the tool - specific knowledge from and to a standard knowledge interchange language. In these systems, the communication and the coordination are accomplished among agents and facilitators or among facilitators but not directly via the agents.

a2) the mediator takes on low level decisions only for crucial situations. The mediator may include behaviors of mediation that may focus in high policies in order to break decisions deadlock. The actions of mediation are performance-directed behaviors. The mediator uses mechanisms of brokerage and recruitment for the achievement of communication in order to find relative agents for the establishment of collaborative subsystems. Lastly, the mediator's responsibilities involve message interpretation, tasks decomposition and the benefit of the treatment's time for each new subtask.

b) Decentralized architectures: According to [5] autonomous is an agent which concentrates the following attributes: (a) it is not controlled or directed of a software agent or person, (b) it can communicate/interact immediately with other agents in the system or in other systems, (c) it has knowledge for other agents and their environment and (d) it devotes its own plans and an associated total of motives.

Decentralized multi-agent architectures involve operations associated with preliminary design, manufacturing planning, distributed surface machining system, operation of a machine-tool and many other operations. Generally, classical planning and scheduling mechanisms have been substituted by task decomposition within a community of autonomous agents associated with their subtasks without a central control mechanism. Decentralized systems work on how a community of agents can make decisions and perform tasks within a manufacturing company or across companies and communication problems among agents with the lack of central control.

3. Centralized architectures or coordinator agents

In these systems central agents interlink dissimilar agents requesting communication channels, route messages among agents, control the multi-agent activities and monitor the executions. Generally, they are responsible for the coordination between agents. In the following paragraphs an overview of the existing coordinator agents and agents interact with them, will be presented [8, 9, 10]. As it is mentioned before agents interact through central agents, facilitators or mediators that translate tool-specific knowledge into and out of a standard knowledge interchange language. The sequence systems concentrate several central agents coordinating the communication among agents and characteristics of their interaction. The first system [11] deals with the application of Information Technology (IT) in order to develop the virtual enterprise within the area of Manufacturing Engineering. In this system the determinative agent is the Environment Manager, which coordinates the others (Fig. 1). These agents are design agent, geometric agent and feature agent that belong to design agents and are responsible geometric part representation, translation information between geometric part representation and the manufacturing features of the part agent describes the geometric and technological constraints. The machine agents select sequence and cluster the operations in order to obtain the process plan of the part. Finally the part agent dynamically updates and maintains the information and data converted into knowledge related to the part description.

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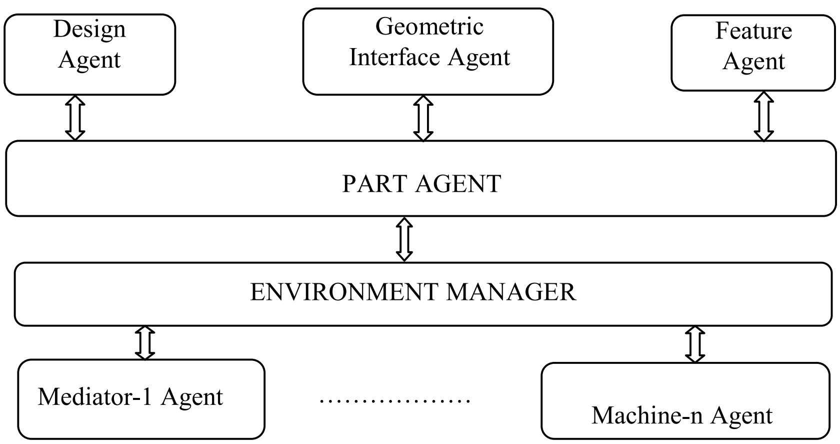

Fig. 1. Multi-agent architecture for manufacturing [11].

In a process planning method for assembly lines based on collaborative system, a central agent manages the mediator agent which transfers messages and controls each application agent and mediates their conflicts in case that their results does not coincide with each other and with Planner Interface which provides an interaction between process planners and the process planning [12]. Fig. 2 shows agents hierarchy and process planners' functions in assembly process planning system. Coordinator, negotiator and process planners' agents are associated with databases, management and coordination. Specifically the coordinator transfers information generated during process planning to appropriate agents. The result of a process planner is transferred to the coordinator and it transfers the result to other agents, negotiator provides supporting facilities for negotiation between two agents and process planning agents start negotiation when they begin communicating their goals, and finish when all of them agree to a specified decision.

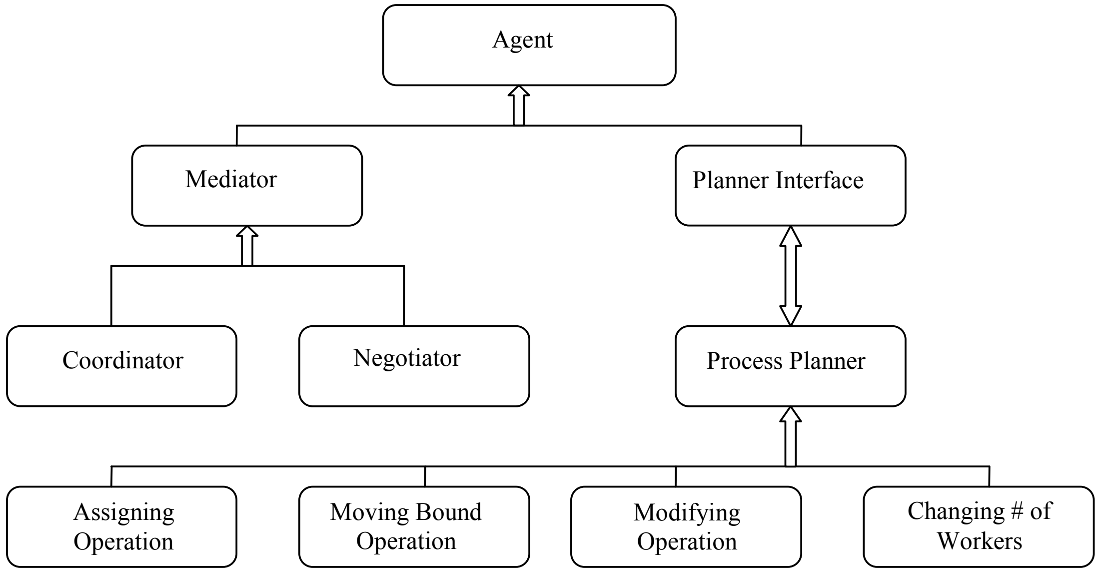

Fig. 2. Hierarchy of process planning agents [12].

Another agent that is responsible for central control is the alliance agent that coordinates (Fig. 3) agents regarding to their execution states, thus balancing the load of each agent [13]. The alliance agent maintains a register information table and takes charge of tasks coordination and execution monitoring of agents. This agent acts in a model that is based on multi-agent system (MAS), supports distributed design and analyzes the factors that affect the manufacturing, assembly and cost of the product. In this system there are also CAD agents that get the information of the evaluation agent through querying the alliance agent and DFx agents which have their own reasoning mechanism and corresponding rule bases, join and quit MAS through registering and unregistering at the alliance agent. Thus Knowledge maintenance agents that express the evaluation knowledge by the hybrid of object-oriented approach and production-rule facilitate the organization of evaluation rules and accelerating the selection of rules when reasoning.

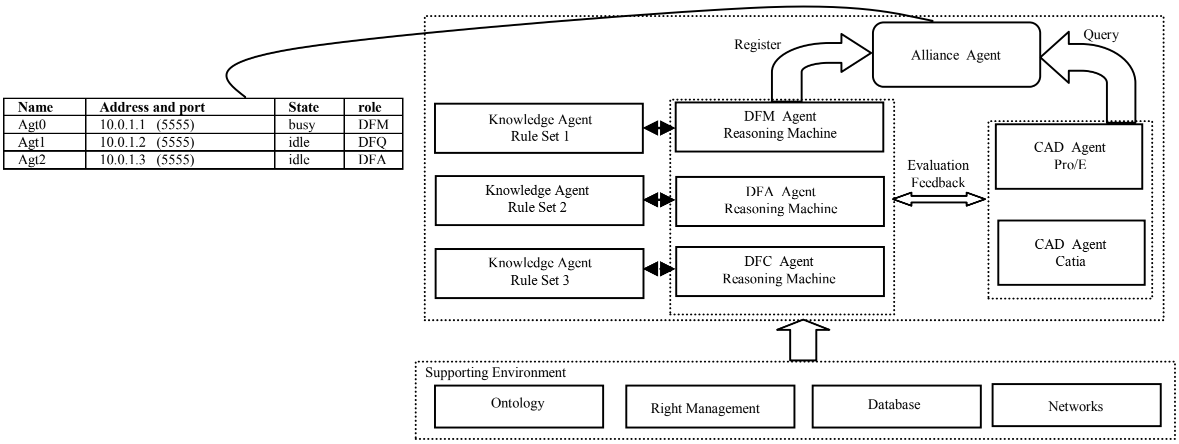

Fig. 3. DFx architecture [13].

This system [14] provides a new design methodology known as A-Design, which combines aspects of multi-objective optimization, multi-agent systems and automated design synthesis. As it is obvious by the Fig. 4, a simple hierarchy exists where one set of agents, known as manager-agents, invokes the operations of the other agent classes: the maker- and modification-agents. The manager-agents analyze the designs created by these agents and provide feedback about how to improve the design process according to the user's preferences. Throughout the iterative process and interaction of agent types, the manager agents make decisions about which designs are better, and how agents should be grouped, penalized or rewarded for their design contributions. An other class of agents known as maker-agents, have two responsibilities: create design alternatives based on the problem description and re-build designs returned by the modification agents. The maker-agents are currently composed of the configuration-agents and instantiation-agents while the modification-agents are comprised of the fragment-agents. The modification-agents are active at the end of the evaluation phase of the process to take design states and improve them based on how they were evaluated. Initially, all makerand modification-agents have the same population, and the manager-agents randomly invoke these agents until all design tasks for the given iteration are accomplished. In this system there are also two design agents, configuration-Agents(C-AGENTS) and fragment-Agents (F-AGENTS) which have the ability to take the user-defined inputs and outputs and choose components to fulfil the functionality of the design problem, choose a design to be modified, and remove embodiments from the design.

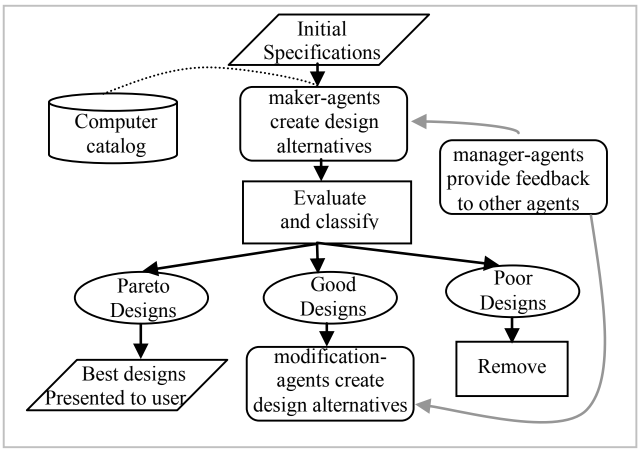

Fig. 4. Electromechanical flow chart A-Design [14].

4. Decentralized multi-agent systems

Contrary to centralized systems, agents that are described in the sequence architectures are decentralized [15, 16, 17]. Agent technology has been considered as an important approach for developing industrial distributed systems and in large business networks, software tools, databases, and knowledge bases are usually distributed. An agent is a distributed computing entity and possesses an independent thread of execution control. It communicates with other agents through asynchronous messages, facilitating parallel and distributed computing. In the following paragraphs an overview of some distributed multi-agent activities will be presented.

There are many decentralized multi agent systems that belong to this category.

There are many researches and projects that examine the use of agent technology in manufacturing section. Likewise, many agents have been proposed and developed in such systems. As we mentioned before, agents can enable operations integration. In the project [18] agents are used and aim to the integration of preliminary design with manufacturing planning software systems. In this work, a multi-agent platform for concurrent design and process planning activity integration is examined. The system's structure is represented in Fig. 5.

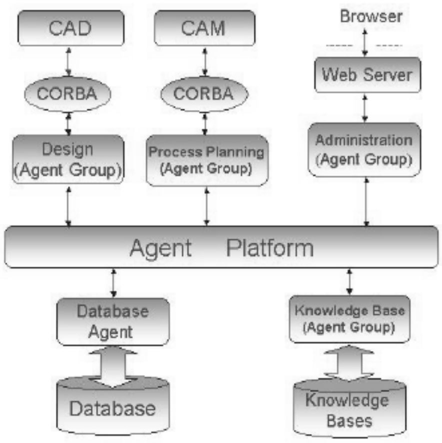

Fig. 5. Multi-agent platform [18].

Briefly, we can describe system's structure. The design agent group consists of agents that take care of functional, embodiment and detailed design. As sequence, the design agents belong to design stage. Another agent group, the process planning agent, consists of agents that provide functions such as process selection, resource selection and detailed process planning. These agents belong to process planning section. The remaining agents (web agents, XML agents and knowledge base agents) belong to the following category: agents associated with databases, knowledge bases, coordination, management and graphical user interface. The last three agents belong to a group named as administration agent group. The web agent provides users the ability to interact with agents' beginning and stop. The XML agent offers access to databases' information displayed in the appropriate form via web browsers administration agent group is not visible in Fig. 5. Moreover, the knowledge base agents include a knowledge base handling agent and a mathematical tool handling agent. As Fig. 5 shows, the database agent interacts with a respective database in order to supply other agents with data, such as NC programs and fixture information.

Rzevski G., except for the project associated with multi- agent mechatronic system, in its works has examined subjects such as the operation of a machine-tool [19] and the operation of an autonomous vehicle with distributed intelligence designed to service a factory cell. These systems consist of the following agents: performance, maintenance, scheduling, book-keeping and navigation agent. Their interaction is obvious in Fig. 6. Their tasks are almost similar in these systems and the reader can search more information [20]. Taking notice of their operation, they belong to manufacturing stage.

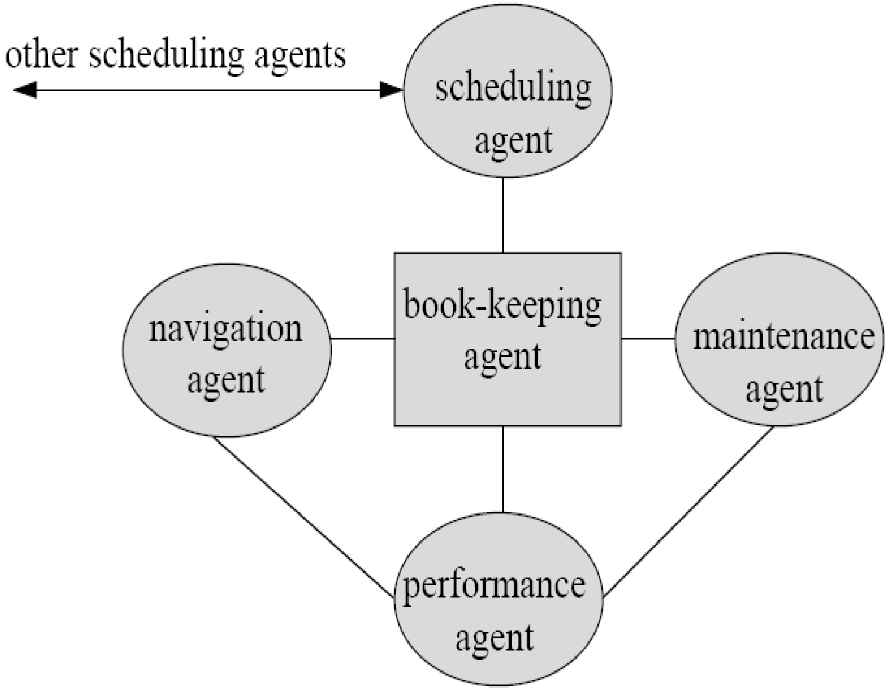

Fig. 6. Agents in a machine-tool and an autonomous vehicle [20].

Software agents could improve the information flow and the decision-making processes within a company and among collaborative companies in a supply chain. Thus, a software agent-enabled process integration framework for manufacturing and supply chain management has been developed [21].

This manufacturing application contains two agents associated with databases and management: service-provider agent and company agent. The service provider agent provides secure data storage facilities for the company agents. Furthermore, it notifies the company agents about events that they might be interested in, for instance, a new manufacturing order or a change of a schedule. The company agents control these events. If any abnormality occurs, they send alarms to the responsible users in the companies so that they can take necessary actions. Process planning agent, tool selection agent, process parameter optimization agent machine tool control agent are also included in the system and control the machining tools providing a GUI for a user as an access to the multi-agent system.

A company network consists of many servers and Personal Computers (Fig. 7) Servers include firewall servers, Web servers, and agent container servers. A GUI to agents is displayed on Web browsers in Personal Computers. Agents are in several agent containers on servers, connected by a local area network. The company LAN is connected to the Internet via a firewall within a firewall server. The agent platform is located in a central server that is assessable through the Internet. The major functions of the agent platform include managing an agent joining in, logging out, and message exchange. Communication between the agent platform, which may contain the main agent container, and agent containers located in companies, is secured by using the Secure Socket Layer connection.

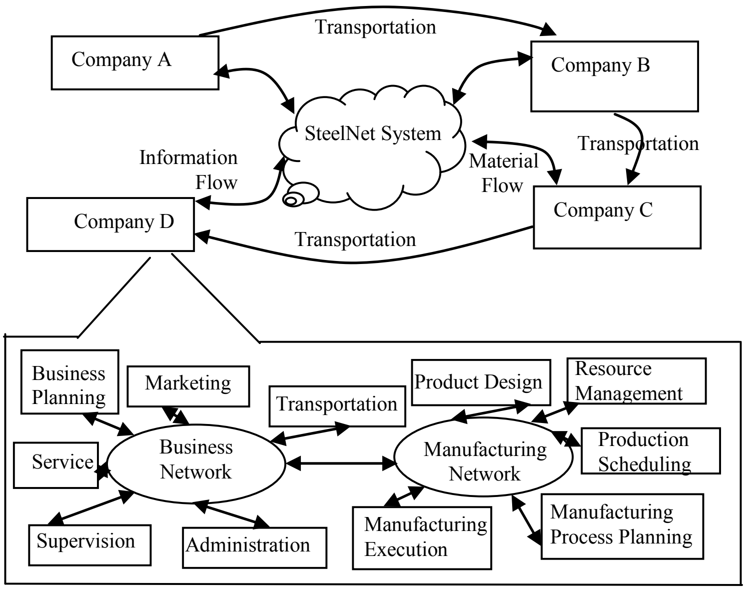

Fig. 7. Business and manufacturing network [21].

5. Conclusion

The use of agents in engineering leads us to the following conclusions:

- The existence of a similar agent in several systems, which is used for similar operations, is common. Both design agent and service provider agent belong to this category [22, 23, 24].
- There are agents with common actions but different names in several systems. For example, facilitator and blackboard agent facilitate communication operations. In reverse, there are agents with the same name but different functions. It should be highlighted that some agents take their name from their systems (for example, DFx agent belongs to DFx system that supports distributed design).
- The existence of an agent in a centralized system does not exclude its operation at a decentralized architecture. For example, design agent operates both at centralized and decentralized systems. Exceptions are coordinator agents that are used in centralized systems only.
- The design stage includes fewer agents than manufacturing stage [25, 26, 27, 28, 29]. This is predictable since the design of mechanical parts is not so much automated and also, design data are incomplete, ambiguous and unorganized.
- Several multi-agent systems are characterized by agents' hierarchy, since some agents have more profits and responsibilities in a system. For example, mediator agent in an assembly process planning framework assigns business tasks to process planners and mediates complications when their results do not coincide. So, it is responsible for other agents that belong to lower levels
- Scientific society focuses to communication and coordination issues, routing and exchanging messages. The communication means for knowledge sharing technology for software interoperability are FIPA ACL, KQML and CORBA.
- Important issues that have to be more developed are network security, data integrity and private data modification. As far as the security, there are cipher techniques and certification authorities that provide secure communication and data transfer among entities [30, 31].

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