TOWARD AGENT ORIENTED SOFTWARE ENGINEERING FOR DISTRIBUTED SCHEDULING

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Abstract – Software engineers have derived a progressively better understanding of the complexity characteristics in software. It is now widely recognised that interaction is probably the most important single characteristic of complex software. Agent-based computing can be considered as a new general purpose paradigm for software development, which tends to radically influence the way a software system is conceived and developed, and which calls for new agent specific software engineering approaches. This paper addresses distributed manufacturing scheduling and describes an architecture following Agent Oriented Software Engineering (AOSE) guidelines trough specification defined by Ingenias methodology. This architecture is based on a Multi-Agent System (MAS) composed by a set of autonomous agents that cooperates in order to accomplish a good global solution.

Keywords: AOSE Paradigm, Distributed Scheduling, Multi-Agent Systems, Meta-Heuristics.

1. INTRODUCTION

A major challenge in the area of global market economy is the development of new techniques for solving real world scheduling problems. Indeed, any industrial organization can only be economically visible by maximizing customer services, maintaining efficient, low cost operations and minimizing total investment.

Traditional scheduling methods, encounter great difficulties when they are applied to some real-world situations. The interest in optimization algorithms for dynamic optimization problems is growing and a number of authors have proposed an even greater number of new approaches, the field lacks a general understanding as to suitable benchmark problems, fair comparisons and measurement of algorithm quality [1][2][7][14].

Current practices and newly observed trends lead to the development of new ways of thinking, managing and organizing in enterprises, where autonomy, decentralization and distribution are some of the challenges. In manufacturing, a new class of software architectures, and organizational models appeared to give form to the Distributed Manufacturing System concept [5].

Since the 1980s, software agents and multi-agent systems have grown into what is now one of the most active areas of research and development activity in computing generally. There are many reasons for the current intensity of interest, but certainly one of the most important is that the concept of an agent as an autonomous system, capable of interacting with other agents in order to satisfy its design objectives, is a natural one for software designers. Different proposals in the field of Agent Oriented Software Engineering (AOSE) try to integrate results from agent research with engineering practices, some from the perspective of agent theory, some as an evolution of object-oriented systems, other as task execution models, or from a knowledge-based systems approach.

In the recent years, the characteristics and expectations of software systems have changed dramatically having as result that a variety of new software engineering challenges have arisen [3][23][24].

In this work we have two main purposes, first the resolution of more realistic scheduling problems in the domain of manufacturing environments, known as Extended Job-Shop Scheduling Problems [15-16], combining Multi-Agent Systems (MAS) and Meta-Heuristics technologies. The second is to demonstrate that is important for MAS development the integration of Software Engineering concepts like the AOSE paradigm.

The proposed Team-based architecture is rather different from the ones found in the literature; as we try to implement a system where each agent (Machine Agent) is responsible to achieve a near optimal solution to schedule operations related with one specific machine

through Tabu Search or Genetic Algorithms. After local solutions are found, each Machine Agent is required to cooperate with other Machine Agents in order to achieve a global optimal schedule.

The remaining sections are organized as follows: Section 2 summarizes some related work and the research on the use of multi-agent technology for dynamic scheduling resolution. In Section 3 are introduced some terms and definitions like coordination, negotiation, cooperation in Multi Agent Systems. This section presents some Agent-Oriented Methodologies and describes some considerations regarding Software Architectures and Multi-Agent Systems. In section 4 the scheduling problem under consideration is defined. Section 5 presents the Team-Work based Model for Dynamic Manufacturing Scheduling and a proposal by Ingenias methodology. Finally, the paper presents some conclusions and puts forward some ideas for future work.

2. RELATED WORK

Dynamic scheduling is one that is receiving increasing attention amongst both researchers and practitioners. In spite of all previous contributions the scheduling problem still known to be NP-complete [2]. This fact incites researchers to explore new directions. Multi-Agent technology has been considered as an important approach for developing industrial distributed systems.

In [19] Shen and Norrie presented a state-of-the-art survey referencing a number of publications that attempted to solve distributed dynamic scheduling problems. According to these authors, there are two distinct approaches in the mentioned work. The first is based on an incremental search process that may involve backtracking. The second approach is based on systems in which an agent represents a single resource and is therefore responsible for scheduling that resource. Agents then negotiate with other agents in order to accomplish a feasible solution.

For further works developed on MAS for dynamic scheduling, see for example, [7][15].

The characteristics and expectations of software systems have changed dramatically in the last few years, with the result that a range of new software engineering challenges have arisen [3][23]. First, most software systems are concurrent and distributed, and are expected to interact with components and exploit services that are dynamically found in the network. Second, software systems are becoming "always-on" entities that cannot be stopped, restored, and maintained in the traditional way. Finally, current software systems tend to be open, because they exist in a dynamic operating environment where new components can join and existing components can leave the system on a continuous basis, and where the operating conditions themselves are likely to change in unpredictable ways.

From the literature we can conclude that Agent-based computing is a promising research approach for developing applications in complex domains. However, despite the great research effort [14][24][25], there still exist a number of challenges before making agent-based computing a widely accepted paradigm in software engineering practice. In order to realize an engineering change in agent oriented software engineering, it is necessary to turn agent oriented software abstractions into practical tools for facing the complexity of modern application areas.

3. MULTI-AGENT SYSTEMS

Agents and multi-agent systems (MAS) have recently emerged as a powerful technology to deal with the complexity of current Information and Communication Technologies environments. In this section we will describe some issues and considerations regarding the developing of the MAS following a software engineering perspective.

A. *Terms and Definitions*

The development of multi-agent systems requires powerful and effective modelling, architectures, methodologies, notation techniques, languages and frameworks. Agent-based computing can be considered as a new general purpose paradigm for software development, which tends to radically influence the way a software system is conceived and developed, and which calls for new, agent specific, software engineering approaches [23].

The main term of Multi-Agent based computing is an Agent. However the definition of the term Agent has not common consent. In the last few years most authors agreed that this definition depends on the domain where agents are used. In Ferber [10] is proposed a definition: "*An agent is a virtual or physical autonomous entity which performs a given task using information gleaned from its environment to act in a suitable manner so as to complete the task successfully. The agent should be able to adapt itself based on changes occurring in its environment, so that a change in circumstances will still yield the intended result*."

An agent can be generally viewed as a software entity with the some characteristics [21] like:

- Autonomy - where an agent has its own internal thread of execution, typically oriented to the achievement of a specific task, and it decides for itself what actions it should perform at what time.
- Situatedness - agents perform their actions while situated in a particular environment.
- Proactivity - in order to accomplish its design objectives in a dynamic and unpredictable environment the agent may need to act to ensure that its set goals are achieved and that new goals are opportunistically pursued whenever appropriate.
- Sociability - agents interact (cooperate, coordinate or negotiate) with one another, either to achieve a common objective or because this is necessary for them to achieve their own objectives.

A Multi-Agent System (MAS) can be defined as "*a system composed by population of autonomous agents,*

which cooperate with each other to reach common objectives, while simultaneously each agent pursues individual objectives" [10]. According to Russell and Norving [18] multi-agent systems "[...] *solve complex problems in a distributed fashion without the need for each agent to know about the whole problem being solved*".

We can see MAS like a society of agents that cooperates to work in the best way possible. With this we gain the ability of solve complex problems like dynamic and distributed scheduling. Considering the complexity inherent to the manufacturing systems, the dynamic scheduling is considered an excellent candidate for the application of agent-based technology. In many implementations of multi-agent systems for manufacturing scheduling, the agents model the resources of the system and the tasks scheduling is done in a distributed way by means of cooperation and coordination amongst agents [23]. There are also approaches that use a single agent for scheduling (centralized scheduling algorithm) that defines the schedules that the resource agents will execute [21][23]. When responding to disturbances, the distributed nature of multi-agent systems can also be a benefit to the rescheduling algorithm by involving only the agents directly affected, without disturbance to the rest of the community that can continue with their work.

The main advantages of a Multi-Agent system are the abilities of coordination and cooperation in order to accomplish a common objective.

B. Coordination, Negotiation and Cooperation

The development of MAS must consider some important organizational issues, like Coordination, Negotiation and Cooperation. These kinds of issues perform an important role, because the set of autonomous agents can only act like MAS if they can communicate in a flexible and trustable way.

Coordination is defined in the literature like "the act of working like a group in an harmonious way"[12]. This means that autonomous agents must be an active part of the system despite of all their own goals. A coordinated system is needed in order to allow pursuit objectives independently of their individual or global.

Cooperation is the act of combining efforts in order to pursue common objectives that can not be reached individually. To allow this cooperation, autonomous agents must be gifted with a certain social ability that will allow interaction with other agents, trough a communication protocol [17][23].

Negotiation can be defined as the process in which at least two operators, a sender and a receiver, communicate across a communication protocol in order to accomplish an agreement.

MAS must implement a set of mechanisms that can differ with systems objectives. If autonomous agents are intended to work like a team, a cooperation mechanism should be considered, instead of that, if they are intended to pursue their own individual goals a negotiation mechanism is probably the best option to consider.

The above definitions are not absolute neither have not common consent, but in our opinion this can be considered a good way, because it allow a clarification in which mechanism is advised for what system.

4. AGENT-ORIENTED SOFTWARE METHODOLOGIES

Software agents and multi-agent systems have grown into what is now one of the most active areas of research and development activity in computing generally. There are many reasons for the current intensity of interest, but certainly one of the most important is that the concept of an agent as an autonomous system, capable of interacting with other agents in order to satisfy its design objectives, is a natural one for software designers.

Several methodologies for the analysis and design of MAS have been proposed in the literature, however only few of them focus on organizational abstractions.

MASE Methodology [20] provides guidelines for developing MAS based on a multi-step process. In analysis, the requirements are used to define use-cases and application goals and sub-goals, and eventually to identify the roles to be played by the agents and their interactions. In design, agent classes and agent interaction protocols are derived from the outcome of the analysis phase, leading to a complete architecture of the system.

MESSAGE methodology [4] exploits organizational abstractions that can be mapped into the abstractions identified by Gaia. In particular, MESSAGE defines an organization in terms of a structure, determining the roles to be played by the agents and their topological relations (i.e., the interactions occurring among them). In addition, in MESSAGE, an organization is also characterized by a control entity and by a workflow structure.

GAIA methodology described in Zambonelli [25] is an extension of the version described in Wooldridge et al. [22]. The first version of GAIA, provided a clear separation between the analysis and design phases. However, as already noted in this paper, it suffered from limitations caused by the incompleteness of its set of abstractions. The objective of the analysis phase in the first version of GAIA was to define a fully elaborated role model, derived from the system specification, together with an accurate description of the protocols in which the roles will be involved. This implicitly assumed that the overall organizational structure was known a priori (which is not always the case). In addition, by focusing exclusively on the role model, the analysis phase in the first version of GAIA failed to identify both the concept of global organizational rules (thus making it unsuitable for modelling open systems and for controlling the behaviour of self-interested agents) and the modelling of the environment (which is indeed important, as extensively discussed in this paper). The new version of GAIA overcomes these limitations.

The TROPOS methodology first proposed in [9], adopt the organizational metaphor and an emphasis on the explicitly study and identification of the organiza-

tional structure. TROPOS recognizes that the organizational structure is a primary dimension for the development of agent systems and that an appropriate choice of it is needed to meet both functional and non-functional requirements.

PASSI (Process for Agent Societies Specification and Implementation) [6] is a methodology to MAS developing, that integrates the definition of MAS philosophy, modelling and the orientation to objects using UML. This is composed by five models that address different visions and twelve steps during the development process (http://mozart.csai.unipa.it/passi/).

INGENIAS is an agent oriented software engineering methodology for Multi-Agent Systems development. It combines agent research results with concepts and methods established in MESSAGE/UML. The result is a development process in the line of conventional software engineering processes, like object oriented software development paradigm or structured paradigm. INGENIAS defines deliverables and default activities to help in planning effort along a project. INGENIAS also provides with tools that facilitate the production of these deliverables (http://grasia.fdi.ucm.es/ingenias/).

The described methodologies have different proposals to model agents and MAS, however they share some characteristics. All of them model agents like an autonomous entities and addresses the interaction between agents in an agent society. A comparative study can be found in [13].

MESSAGE, MaSE, PASSI and Ingenias are more adaptable to industrial scenarios, because they are evolutions of UML that is a common standard in this kind of environments.

Research in the area of agent-oriented software engineering has expanded significantly in the past few years. Several groups have started addressing the problem of modelling agent systems with appropriate abstractions and defining methodologies for MAS development [13][24][25].

Traditional object-based computing promotes a perspective of software components as functional or service-oriented entities that directly influences the way that software systems are architected.

Usually, the global design relies on a rather static architecture that derives from the decomposition and modularisation of the functionalities and data required by the system to achieve its global goals and on the definition of their inter-dependencies [24].

5. Problem Definition

Most real-world multi-operation scheduling problems can be described as dynamic and extended versions of the classic or basic Job-Shop scheduling combinatorial optimization problem. The general Job-Shop Scheduling Problem (JSSP) can be generally described as a decision-making process on the allocation of a limited set of resources over time to perform a set of tasks or jobs. Most real-world multi-operation scheduling problems can be depicted as dynamic as already described before. In this work we consider several extensions and additional constraints to the classic JSSP, namely: the existence of different job release dates; the existence of different job due dates; the possibility of job priorities; machines that can process more than one operation in the same job (recirculation); the existence of alternative machines; precedence constraints among operations of different jobs (as quite often, mainly in discrete manufacturing, products are made of several components that can be seen as different jobs whose manufacture must be coordinated); the existence of operations of the same job, on different parts and components, processed simultaneously on different machines, followed by components assembly operations (which characterizes the Extended Job-Shop Scheduling Problem (EJSSP)[15-16]).

Moreover, in practice, scheduling environment tend to be dynamic, i.e. new jobs arrive at unpredictable intervals, machines breakdown, jobs are cancelled and due dates and processing times change frequently.

6. Multi-Agent System for Distributed Manufacturing Scheduling with Genetic Algorithms and Tabu Search

This section describes the architecture proposed for dynamic and distributed scheduling and proposes a methodology trough Ingenias for its specification.

A. MASDScheGATS Architecture

Distributed environment approaches are important in order to improve scheduling systems flexibility and capacity to react to unpredictable events. It is accepted that new generations of manufacturing facilities, with increasing specialization and integration, add more problematic challenges to scheduling systems. For that reason, issues like robustness, regeneration capacities and efficiency are currently critical elements in the design of manufacturing scheduling system and encouraged the development of new architectures and solutions, leveraging the MAS research results. The work described in this paper is a system where a community of distributed, autonomous and often conflicting behaviours, cooperating and asynchronously communicating machines tries to solve scheduling problems. A global system behaviour can emerge with requested abilities of reactivity and flexibility to accomplish all the external perturbations.

The main purpose of MASDScheGATS (Multi Agent System for Distributed Manufacturing Scheduling with Genetic Algorithms and Tabu Search) is to create a Multi-Agent system where each agent represents a resource (Machine Agents) in a Manufacturing System. Each Machine Agent is able to find an optimal or near optimal local solution trough Genetic Algorithms or Tabu Search meta-heuristics, to change/adapt the parameters of the basic algorithm according to the current situation or even to switch from one algorithm to another.

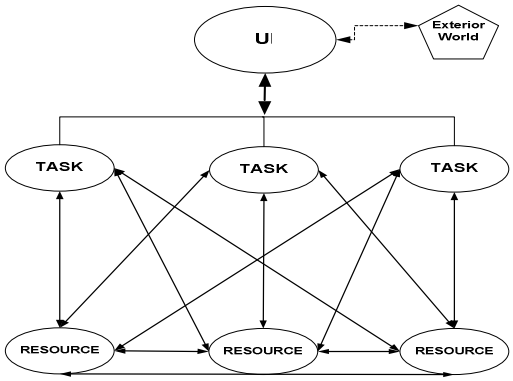

Figure 2 - MASDScheGATS System Architecture

In our case the dynamic scheduling problem is decomposed into a series of Single Machine Scheduling Problems (SMSP)[15-16]. The Machine Agents obtain local solutions and cooperate in order to overcome inter-agent constraints and achieve a global schedule.

Agents agree to work together in order to solve a problem that is shared by all agents in the team. Such approach allows for the resolution of large-scale problems that a single agent would not be able to solve. Moreover, Team-based architecture has the ability to meet global constraints given the capability that agents possess to act in concert. As we shall see later, this characteristic is critical for the problem treated in this work.

The proposed architecture (Figure 2) is based on three different types of agents. In order to allow a seamless communication with the user, a User Interface Agent is implemented. This agent, apart from being responsible for the user interface, will generate the necessary Task Agents dynamically according to the number of tasks that comprise the scheduling problem and assign each task to the respective Task Agent.

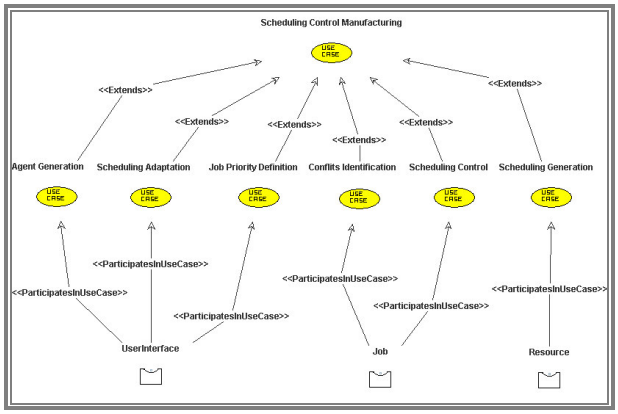

Figure 3 – Use Case Diagram for MASDScheGATS

Task Agent will process the necessary information regarding the task. That is to say that this agent will be responsible for the generation of the earliest and latest processing times, the verification of feasible schedules and identification of constraint conflicts on each task and the decision on which Machine Agent is responsible for solving a specific conflict. Finally, the Machine Agent is responsible for the scheduling of the operations that require processing in the machine supervised by the agent. This agent will implement meta-heuristic and local search procedures in order to find best possible operation schedules and will communicate those solutions to the Task Agent for later feasibility check (Figure 3).

B. Proposal methodology trough Ingenias

The development cycle that is proposed by INGENIAS (http://grasia.fdi.ucm.es/ingenias/) methodology sees MAS like a computational representation of a set of models. Each of these models has a partial view of the system: definition of the autonomous agents that compose the system, interaction between agents, system organization, domain, tasks and objectives.

In order to specify how must be these models, the definition of meta-models is needed. One meta-model is a representation of all types of entities that can exist in a model, their relations and application restrictions.

The meta-models used in this methodology are an evolution of MESSAGE methodology work [4].

This methodology uses five different kinds of meta-models that describe the correspondent diagrams:

1. Organization meta-model: defines groups of agents, system functionality and restrictions to agent's behaviour. Is equivalent to system architecture in MAS. The important value for these models is the definition of workflows.

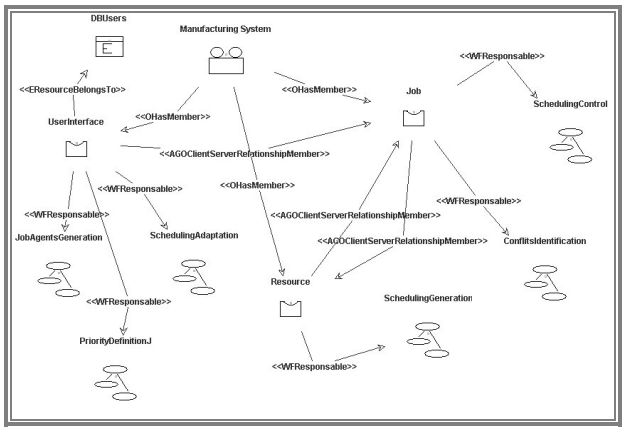

Figure 4 - Organization meta-model

2. Interaction meta-model: details how agents coordinate and communicates among them. The definition of systems interaction allows identifying dependencies among components.

3. Agent meta-model: describes agents, excluding interactions with other agents, and the mental states that they have in their life cycle. This meta-model is centred in agent functionality and in is control drawing. It gives information about the responsibilities or tasks that an agent is able to perform.

4. Tasks and Objectives meta-model: is used to attach an agent mental state to the task that executes. Is used to collect MAS motivations, to define the identified actions in organization, interaction or agents models, and like it assigns actions.

5. Environment meta-model: Defines everything that is present is the environment and the way in that each agent understands it. Is main function is identify all environment elements and define a relation with the other entities.

It seems a promising tool for the generic modelling of the system. We have noted that this approach has particular drawbacks for the specification of negotiation mechanism and for self-parameterization behaviour of the agents.

7. CONCLUSIONS AND FUTURE WORK

The Team-Work based architecture for distributed scheduling that we propose in this paper seems to be a good way to solve real world scheduling problems, because a good global solution may emerge from a set of autonomous agents that cooperates to a communication mechanism to accomplish a common goal. Coordination seems to be the edge in MAS, because it is not possible for all autonomous agents to work together in a effective way if even one intervenient in the system is not like an active part of the system. In our opinion depending of MAS objectives, agents can cooperate in two distinct ways like cooperation if the global goal is considered more important that all the individual ones. If an agent pursues first an individual goal instead of the global, the system probably must incorporate a negotiation mechanism to improve system performance.

We consider that the AOSE paradigm can perform an important role when a MAS in being developed, because with this definition it becomes easier to find problems observing global system structure. When a structure problem is discovered is the middle of systems implementation, most of the times it signifies an important lost of time.

Work still to be done in the MASDScheGATS system includes the testing of the system and negotiation mechanisms under dynamic environments subject to several random perturbations.

The proposed AOSE approach needs to be refined in order to support dynamic environments with unexpected disruptions that can not be strictly considered in the modelling because they can happen without any specific warning. Despite of this, in our opinion this kind of work can be very significant in order to turn MAS development a structured process that doesn't go from modelling to implementation without any intermediate test and validation.

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REFERENCES

[1] Aytug, H., Lawley, M.A., McKay, K., Mohan, S.& Uzsoy, Reha (2005). Executing production schedules in the face of uncertainties: A review and some future directions. European Journal of Operational Research .Volume 16 (1). 86- 110.

[2] Blazewicz, J., Ecker, K. H., Pesch, E., Smith, G. Weglarz, J.(2001). Scheduling Computer and Manufacturing Processes. Springer. 2nd edition. New York.

[3] Bresciani, P., Perini,A., Giorgini, P., Giunchiglia, F., and Mylopoulos, J. (2001). A knowledge level software engineering methodology for agent oriented programming. In Proc. of the 5th Int.Conf.on Autonomous Agents, pp 648–655. ACM Press, Montreal .

[4] Caire, G.; Leal, F.; Chainho, P.; Evans, R.; Gomez, J.; Garijo, F.; Juan Pavon, G.; Kearney, P.; Stark, J.; Massonet, P. (2001). Agent Oriented Analysis using MESSAGE/UML. In Proceedings of the 2nd International Workshop on Agent-oriented Software Engineering (AOSE 2001), Montreal.

[5] Committee on Visionary Manufacturing Challenges(1999). Visionary Manufacturing Challenges for 2020. National Research Council. National Academic Press.

[6] Cossentino, M.; Potts, C. (2002). PASSI: a Process for Specifying and Implementing Multi-Agent Systems Using UML.

[7] Cowling, P. & Johansson, M. (2002). Real time information for effective dynamic scheduling. European Journal of Operational Research,139 (2). 230-244.

[8] De Maria, Beatriz.(2005).Usando uma abordagem MDA no desenvolvimento de sistemas multi-agente. Tese de Mestrado, Pontificia Universidade Catolica do Rio de Janeiro,(in portuguese).

[9] DeLoach, S. (1999). Multiagent Systems Engineering: A Methodology And Language for Designing Agent Systems, Agent-Oriented Information Systems (AOIS 1999).

[10]Ferber, J. (1995). Les Sístemes multi-agents: versune intelligence collective. Interedition.

[11]Horling, B., Lesser, V. (2005). A Survey of Multi-Agent Organizational Paradigms, University of Massachusets.

[12] Jennings N. R.(1996). Coordination Techniques for Distributed Artificial Intelligence , in Foundations of Distributed Artificial Intelligence(eds. G. M. P. O'Hare and N. R. Jennings), Wiley, 187-210.

[13] Lindoso, Alisson. (2006). "Uma Metodologia baseada em Ontologias para a Engenharia de Aplicações Multiagente". Tese de Mestrado, Universidade Federal do Maranhão, Brasil.

[14]Lind , Jurgen (1999). A Process Model for the Design of Multi-Agent Systems, Research Report TM- 99-03, German Research Center for AI (DFKI).

[15]Madureira, Ana M. (2003). Meta-Heuristics Application to Scheduling in Dynamic Environments of Discrete Manufacturing. PhD Dissertation. University of Minho, Portugal(in portuguese).

[16] Madureira, Ana, Ramos, Carlos & Silva, Sílvio (2004). Toward Dynamic Scheduling Through Evolutionary Computing. WSEAS Transactions on Systems. Issue 4. Volume 3. 1596-1604.

[17] Mao, Xinjub; Yu, Eric (2004). "Organizacional and Social Concepts in Agent Oriented Software Engineering". AOSE2004, New York, USA, pages 1-15.

[18] Russel, S. and Norvig, P. (2003). Artificial Intelligence: A Modern Approach, Prentice Hall/Pearson Education Intern.: Englewood Cliffs (NJ), (2nd Ed).

[19] Shen, W. and Norrie, D. (1999). Agent-based systems for intelligent manufacturing: a state of the art survey, Int. J. Knowl. Inform. Syst., vol. 1, no. 2, pp. 129– 156.

[20] Wood, M., DeLoach, S. A., and Sparkman, C. (2001). Multiagent system engineering. International Journal of Software Engineering and Knowledge Engineering, 11(3):231–258.

[21] Wooldridge, M. (2002). An Introduction to Multiagent Systems, John Wiley and Sons.

[22] Wooldridge, M.; Jennings, N. R.; Kinny, D.b(2000). The Gaia Methodology for Agent-Oriented Analisys and Design, Journal of Autonomous Agents and Multi- Agent Systems 15.

[23] Wooldridge, M.J. e Jennings, N. R. (1994). Agent Theories, Architectures, and Languages: A Survey". Workshop on Agent Theories, Architectures and Languages, 11th European Conf. on Artificial Intelligence, Amsterdam, The Netherlands.

[24] Zambonelli, F. and Parunak, H.V.D.(2004). Toward a change of paradigm in computer science and software engineering: A synthesis, Knowl. Eng. Rev., 18.

[25] Zambonelli, F.; Jennings, N.; Wooldridge, M. (2003). Developing Multiagent Systems: The Gaia Methodology, ACM Transactions on Software Engineering and Methodology Vol. 12(3):317–370.