Advanced Engineering Informatics xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei

An organizational approach to designing an intelligent knowledge-based system: Application to the decision-making process in design projects

Julien Girodon [a,*], Davy Monticolo [a], Eric Bonjour [a], Maggy Perrier [b]

[a] Laboratoire ERPI/ENSGSI, Université de Lorraine, 8 rue Bastien Lepage, 54000 Nancy, France
[b] Essilor International, 81 Boulevard Jean-Baptiste Oudry, 94046 Creteil, France

ARTICLE INFO

Article history:
Received 20 November 2014
Received in revised form 3 June 2015
Accepted 12 July 2015
Available online xxxx

Keywords:
Knowledge-based engineering
Organizational modelling
Multi-agent systems
Knowledge-based system

ABSTRACT

Knowledge-based engineering (KBE) approaches are designed to reduce the time and cost of product development by capturing, retaining and re-using design knowledge. They currently focus on repetitive design tasks where knowledge is considered as a static resource. However, knowledge is intrinsically linked to the organizations and people who use it. Thus, to be efficient, these knowledge-based systems (KBS) have to be able to take into account all the mechanisms of knowledge creation, sharing and evaluation made by the users. Using the agent paradigm, new knowledge-based systems can be designed in order to address this research issue. Indeed, the agents have social abilities and are able to achieve very complex tasks. These two features are necessary for making a knowledge-based system efficient. However, there still exists today a lack of approaches and methodologies to help design such applications. This paper presents DOCK, a methodology to design an intelligent knowledge-based system that aims to support the knowledge management process. In order to take into account all the mechanisms of knowledge generation, sharing and re-use, DOCK is based on the hypothesis that efficient modelling of human organizations, by highlighting their roles, collaborations, skills, goals and knowledge, will help the KBS designer to specify an adapted knowledge-based system. Finally, DOCK is implemented to design the SMA SNOTRA that is dedicated to supporting a decision-making process for design projects.

1. Introduction

Companies are engaged in continuous performance improvement processes to stay competitive in their core business. Performance improvement levers can be found at every level of the company and can be grouped in three main axes. The first axis has the purpose of defining how the performance of the products and the operational design processes can be improved. This area is well recognized and investigated by enterprises. It embeds methods and tools such as functional analysis, dependability, statistical process control or modelling and simulation. The second axis aims at improving the performance of organizational processes. This area embeds, for instance, all the methodologies and tools of project management, agile methodologies, system engineering, or quality management systems. Finally, the third axis deals with the improvement of human performance. It embeds all the elements dealing with the ways to better manage and valorize knowledge and competences. Nonaka and Takeuchi [1] have explained the importance of the process of capturing, developing, sharing, and using organizational knowledge and complexity to manage tacit and explicit knowledge. This paper focuses on the last axis in order to present a methodology to design a support system to enhance knowledge sharing. The research field of knowledge-based engineering (KBE) proposes many approaches that allow one to capture and re-use knowledge [2–7]. These approaches currently focus on repetitive design tasks where knowledge is considered as a resource. However, knowledge cannot be simply reduced to a static resource-based view because of its intrinsic nature. People interact together during meetings or workshops in a collaborative way to share their expertise and experiences in order to carry out a common objective. Thus, they generate organizational groups where the knowledge is created, shared, evaluated and updated [8]. In order to take this complexity into account, the KBE approaches need to rely on knowledge models having richer semantics and better traceability [9]. According to this statement, and contrary to other KBE approaches, an organizational approach makes it possible to highlight the mechanisms of knowledge sharing and evolution, rather than focusing on the formalization and the modelling of knowledge [10].

* Corresponding author. Tel.: +33 1 41 94 68 98, +33 6 99 06 66 53.
E-mail addresses: julien.girodon@univ-lorraine.fr, julien.girodon63@gmail.com (J. Girodon), davy.monticolo@univ-lorraine.fr (D. Monticolo), eric.bonjour@univ-lorraine.fr (E. Bonjour), perrierm@essilor.fr (M. Perrier).

http://dx.doi.org/10.1016/j.aei.2015.07.001
1474-0346/

Semiotic engineering [11] recommends that data, information and knowledge should be represented and exploited by using signs in the computer-based information system. Semiotic engineering gathers three domains: syntactic [12], semantic [13] and pragmatic [14]. In Semiotic theory, designers tell the users, through the system's interface, how they can, should, or must interact with the system in order to achieve a particular range of goals anticipated at design time [15]. However, this paper, does not aim to investigate the question of the one-shot messages sent from designers to users, but aims to propose a framework to efficiently take into account the users' organizational context in the early design steps. Thus only the semantic and pragmatic domains will be investigated in this paper.

According to this hypothesis, the multi-agent systems (MAS) research field has proposed a metaphor of an organizational model in order to design and implement intelligent systems. Multi-agent systems working in a decentralized way are able to use distributed and incomplete sources of information and knowledge [16]. However, the existing methodologies to design and implement these systems are not knowledge base oriented, i.e. they do not take into account all the mechanisms of knowledge creation, sharing and evaluation made by the users. Thus based on these approaches, this paper presents DOCK, a methodology to design an intelligent knowledge-based system, which aims to support the knowledge management process and its implementation in the decision-making process throughout engineering projects. Section 2 presents a literature review of the methodologies to design a MAS as well as their adequacy regarding KBE applications. Section 3 presents DOCK, a new methodology to design an intelligent knowledge-based system using the agent paradigm. Section 4 presents the application of DOCK to the design of the intelligent knowledge-based system SNOTRA, which is dedicated to supporting a decision-making process for design projects. Finally, Section 5 contains a discussion and a comparative analysis of DOCK with the major existing approaches to design MAS.

2. Literature review concerning the MAS design

The design methodologies of MAS cover each step in the life cycle of an agent-oriented application [17]. These methodologies can be split into two main categories: agent-oriented approaches and organizational approaches [18]. In the former category, designers focus on the description of the agents' individual actions, whereas the latter category focuses on the description of the agents' organizations.

The aim of this article is to propose a MAS design approach that highlights the fact that knowledge should not be regarded as a subsidiary concept, but as a key element that allows the designers to structure the organization of agents and their interactions and goals. It is crucial to consider the concept of knowledge in its organizational environment when designing a knowledge-based system (KBS). This ensures that knowledge is managed as efficiently as possible. This literature review will compare the main existing organizational MAS design approaches in order to present their key elements and potential shortfalls when applied as a KBE approach.

2.1. Adequacy of MAS regarding organizational modelling and KBE applications

By analysing an organization, one can define how members of a society act and interact with one another. This is important as the effectiveness of an organization depends on several factors, including the coordination between the members and their ability to solve problems. Several published works focus on the effects of organizational structures on performances and knowledge sharing inside a group [19–22]. However, it is difficult to take these structures into account in standard KBE approaches because they currently deliver centralized systems [17].

To effectively model the dynamic aspect of the organizational environment, the agent paradigm can be used. Agents are, by definition, autonomous entities, proactive and capable of social interaction in dynamic environments [23]. They are thus able to handle this issue when they are considered as components of groups of agents that interact together in a system in order to fulfil common goals.

In addition, the increasing complexity of the MAS (number of entities, number of complex tasks to fulfil, dynamical environment, etc.) has led researchers to work on an individual point of view of the agents and their interactions. This research is dedicated to the specific field of agent organizations and has increased the flexibility of agent architectures [24–26]. In order to give a synthetic view of these works, Dignum and Meyer in [27] provide the following definition: "The agent organizations can be seen as sets of entities and their interactions, regulated by mechanisms of social order and created by autonomous actors to achieve a common goal." This definition helps to emphasize the social aspect of agent organizations. In addition, Boissier and Demazeau [28] assert that, "An organization of agents can be seen in a simple way as a set of constraints adopted by a group of agents with the aim of facilitating the achievement of their goals." From these two statements it is clear that, within an organization, agents must take into account the objectives of the group so that they have the ability to achieve their own goals. Guizzardi [29] proposes including the concept of knowledge within organizations: "An organization of agents is a community of knowledge sharing in which agents collaborate and exchange knowledge to carry out their activities." This definition is important because it highlights the effectiveness of knowledge sharing within organizations of agents.

As a result, knowledge-based engineering methodologies can provide good basics for MAS design so long as they make it possible to model the mechanisms of knowledge sharing within a community. There are currently two relevant approaches that address this topic in the KBE field: the MAS-CommonKADS approach [30] and the MASINA methodology [31], which is an extension of the former. These two approaches belong to the agent-oriented methodologies for designing MAS, because they focus on the description of process elements such as tasks and relationships by a collection of rules. Using a set of models, they guide the designers through a bottom-up analysis of the system from the agents' specifications to the organization's architecture description. Compared to the MAS-CommonKads approach, MASINA strengthens the communication between agents by modifying the meaning of the coordination and communication models of MAS-CommonKads and introducing a new model. But in order to efficiently cover the mechanisms of knowledge sharing through an organization, a top-down analysis of the system appears more suitable. Starting from the agents' organization description and moving to the agents' specifications enables one to identify the roles and interactions [32] that are crucial for describing knowledge sharing mechanisms.

According to the descriptions of the agents' organizations, Carley [33] explains that the analysis and the study of human organizations allow one to design computational models which can be used to enhance three perspectives in organizations: the structure, the information sharing, and the social cooperation. The agent paradigm, together with coordination, stigmergy, adaptivity and evolution, enables the development of knowledge engineering applications to enhance the performance of human organizations.

Please cite this article in press as: J. Girodon et al., An organizational approach to designing an intelligent knowledge-based system: Application to the decision-making process in design projects, Adv. Eng. Informat. (2015), http://dx.doi.org/10.1016/j.aei.2015.07.001