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Survey paper

Analysis of interaction dynamics in collaborative and distributed design process

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ABSTRACT

This paper proposes a computational interaction analysis approach for extraction of emergent patterns and organization structures during collaborative and distributed design process based on its emergent state-problems. A better source of information on both collaborative and distributed design process as a time-based activity and the agent–agent interactions during the design process will allow design researchers to develop richer models of designing which in turn will provide the basis for a better understanding of collaborative and distributed design process and developing intelligent tools to support this process. Therefore, the proposed approach consists of discerning from the real interactions the different state-problems characterizing the mentioned process. The modelling of interactions corresponding to state-problems, permitted to observe the emergent patterns of collaborative and distributed design process: micro-groups and pivot agent. The collaborative and distributed design process is characterized by the new micro-group formation on the one hand, and by their evolution in the time on the other. Based on the properties of interaction, the approach has discerned three types of cooperation: complete, bilateral and quasi null. Results from some real collaborative and distributed design process, allow us to observe certain properties related to micro-groups, such as self-organization, dynamics and self-similarity. Self-organization results from interaction among adaptive human agents. It is an emergent structuration in response to non-linear collaborative and distributed design process. Dynamics results from the variation of micro-groups formation and the collaborative and distributed design process seems to articulate around one or several pivot agents. Self-similarity results from the similar emergent pattern in every discussion. This research served as core for developments of multi-agents system ISIAD (Intelligent System for Interactions Analysis in Design).

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1. Introduction

Within collaborative and distributed design process, large quantities of information and knowledge are widely distributed

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across multiple agents, which may be human, artificial or both. According to Baya et al. [1] human designer agents spend 80% of their times to generate and to search for their data on the one hand, and 93% of their times to evaluate the information to a no-quantitative level of abstraction on the other. During the design process, agents are continually engaged to perform design tasks, requiring these large quantities of information and knowledge. Tasks require agents to interact. Interacting during design process indicates that the agents may be affected by the other agents in pursuing their goals and executing their tasks. Interactions take place by carrying out an action that modifies the state of the design problem.

The interactions are not only necessary, but they form really collaborative and distributed design process and they exert a great influence on the development of the final product. The interactions between different agents permit to confront and to integrate their various and domain dependent points of view. Furthermore, the complexity of the collaborative and distributed design process is defined by interaction with its forms: communication, cooperation and coordination. Agents communicate in order to achieve better theirs goals or those of the system where they exist. Communication enables agents to coordinate their actions and behaviour [2]. The purpose of coordination is to achieve or avoid states of affairs being considered as desirable or undesirable by one or several agents. To coordinate their goals and tasks, agents have to explicitly take into consideration the dependencies among their activities. Cooperation is as a form of interaction in which agents work together and draw on the broad collection of their knowledge and capabilities to achieve a common goal. Through these forms of interactions agents are able to select useful information, make sense of it and store useful selections for future use [3].

Understanding of progress and advancement of the collaborative and distributed design process is important, not only for observing interactions between the different constituent elements of this system, but also for analyzing, formalizing, modelling and exploiting interactions, particularly with regard to the understanding of the dynamics of the collaborative and distributed design process. A better source of information on both designing as a time-based activity and the agent–agent interactions during the design process will allow design researchers to develop richer models of designing which in turn will provide the basis for a better understanding of collaborative and distributed design process and developing intelligent tools to support this process [4–6]. Then, the problem consists in analyzing and modelling the real interactions during the collaborative and distributed design process. The attempt is to understand dynamics of distributed design process interactions, which acquires, manipulates, and create information through the joint, interlocked activities of different agents and automated information technologies.

The goal of our research presented in this paper, consists in discerning, from the real interactions, the different state-problems characterizing the dynamics of the collaborative and distributed design process on one side, and the relative dynamics of agents organization to this one on the other. Computational analysis is used to develop a better understanding of the interactions, the nature of organization, the emergent patterns and structures of organization during collaborative and distributed design process. Mathematical and computational methods are used to study both human and automated organization as computational entities [7]. Theoretical computational models [8–10] as well as experimental and empirically based models [11] can provide computationally plausible accounts of organizational activity. In this context, interactions during collaborative and distributed design process can be viewed as inherently computational because many of their activities transform information from one form to another, and because design organizational activity is information and knowledge driven. In the frame of our research, the experiences of GRACC (Group of Research on the Cooperative Conception activity) with human agents are used as a situation of observation.

In the first section of this paper we put in evidence the dynamic of states of collaborative and distributed design process during interactions between agents. The approach used for extraction of these states and its relative design problem, called state-problems, is presented. In the second section, the interaction analysis approach is developed to extract the emergent patterns and structures of organization during collaborative and distributed design process. This part of our research is based on the interactions through the communication between human agents during the synchronous scenes of the collaborative and distributed design process. Finally, in the last section, the results of this research are presented.

2. Dynamic of the state-problems emergence

2.1. Analysis entities

Collaborative and distributed design is a complex process [12,13]. This complexity results from the conjugation of a great number of heterogeneous data (discipline, agents, organization and methods) interacting with each other. Within collaborative and distributed design process, large quantities of information and knowledge are widely distributed across multiple agents. This distribution affects group information sharing and processing as well as the concurrent information analysis. Information sharing between agents is strongly related to the perception of the ways in which multidisciplinary teams exploit the shared and organized comprehension [14,15], as well as the mental representation of the knowledge related to the problems of design process [16–19]. Developing shared meaning requires achieving a mutually accepted and understood lexicology, schema or language in which to communicate, despite background differences of the team agents [20]. In design teams, agents must communicate their thoughts verbally. The verbal communication, or verbalization of thoughts, offers us a direct path to the state of the design process and its relative problem, that we call the state-problem. Collaborative and distributed design experiences show that the majority of agent problems (related to their points of view, design criteria, evaluation, etc.) appear through their verbalizations. For that reason, we consider a message as being a form of the representation of domain knowledge. It can be characterized by a set of syntactic elements (for example, $<verb>$ and $<name>$), with a specific semantics to a domain of knowledge. The category of these elements is called analysis entities. For instance, some analysis entities related to a design object, from a design experience, are represented in Table 1 [6].

2.2. Identification of state-problems

During collaborative and distributed design process, each discipline is represented by an agent and has some specific responsibilities in design. Thus, every agent A_k ($k = 1,\ldots,q$) is allowed to be an expert in a certain domain of knowledge, noted k and called reference register. During collaborative and distributed design process the agents interact. We note Int_i, $i = 1,\ldots,n$, the ith interaction, with n the number of interactions. In the most elementary form, an interaction Int_i of the agent A_k, in the instant t, is characterized by one or several emitted messages. Every interaction is filtered by means of analysis entities. The filtered interaction Int_i is called enriched interaction. It is noted Int'_i. The