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Assessing Organizational Effectiveness of Cooperative Agents

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Abstract

This paper investigates the effect of agents coalitional strategy on their effectiveness using an evaluation approach that causes no alteration of the global system's performance. Cooperation process is thus considered during the execution of a Multiagent System (MAS) in order to collect all necessary data for the evaluation phase. A structural analysis is then led to set instant and global assessments of the agents management and output. The observation and evaluation tools are implemented using aspect-oriented programming. We prove through experiments that they do not alter the global performance of the system regarding execution time and reached scores. The approach could then be validated as an objective evaluator of the system by judging real organizational capabilities of its agents in achieving their goals.

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1. Introduction

Cooperative Multiagent Systems (MASs) are widely used for solving complex problems. By grouping their respective competences, agents usually become more efficient in achieving their goals. Different cooperative strategies may then be adopted, depending on the agents' organization¹. For instance, coalition-based cooperation is commonly used. Such structures allow agents to dynamically combine their respective skills and resources to execute the system's goals. However, cooperation processes need supplementary processing time in order to organize agents' groups. MAS partitioning into coalitions may then be additive, super-additive or sub-additive depending on the benefit it may have on agents' society². It may then negatively impact the system's performance. For all these reasons we need to assess the agents good repartition among coalitions and study at the same time its effect on the global performance. In fact, such an aspect plays a major role in defining the degree of MAS functional adequacy, i.e. its ability to meet the goals for which it has been designed.

Our tools have to evaluate the studied MAS without any performance deterioration. Otherwise, if we consume too much CPU time for instance, the system will have less allocated time in every iteration which will inevitably affect the efficiency of its agents in tasks execution. Their behavior may then be influenced by observation and evaluation processes and give different results from the case where they are not observed. We had then to deal with the following

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issue: How to validate the aforementioned evaluation process as a performance non-altering tool that gives an accurate overview of the real capabilities of the agents' society? We intend, through this work, to implement observation tools that do not overload agents, and thus maintain a performance level similar to the default one, i.e. the one corresponding to the unobserved system.

This paper is organized as follows. Section 2 is dedicated to the presentation of related work. The evaluation approach and its different tools are presented within section 3. Section 4 consists of an empirical study that presents results of the approach application and investigates the impact of the observation and evaluation processes on the studied system's performance. Section 5 summarizes the main ideas of our contribution.

2. Related Work

Agents evolving in dynamic environments have been evaluated according to different criteria. Works interested in such a problematic may be divided into three main categories³. In the first one, MASs were evaluated according to their intrinsic characteristics, such as computational complexity, decentralization and communication⁴. In the second category, they were assessed regarding functioning aspects such as robustness and performance⁵. In the last one, their design methodology was focused on in order to assess systems' architectures and organizations⁶ for instance.

Our work aims at gathering different aspects in order to have a better explanation of MAS performance. Therefore, we studied multiple works in the literature that consider the problem of MAS evaluation, such as⁴ where the conversational aspect was evaluated using graph theory. In⁵ the communication aspect was considered too by analyzing agents conversations in order to assess the functional adequacy of the MAS. Other works were interested in evaluating MAS organizations such as⁶ where the graph theory was used too in order to set performance indicators inspired from that theory and make an analogy with the agents organization for the interpretation of such metrics. In⁷ authors treated the problem of evaluating agents' efficiency after using different grouping techniques: grouping by type of agent, speciality or workflow. The considered platform⁸ for our evaluation approach proposes assessment techniques of the coalitions formed during an execution. A constraint is raised whenever the number of agents within a coalition exceeds the required one. Such a technique does not consider the totality of the formed coalitions and presents thus a limited evaluation approach. The aforementioned works suggest interesting approaches in assessing agents organizations by considering multiple aspects that interfere in defining the global performance. We try to consider in our approach further aspects of agents organization and establish a causal relationship between them.

In order to be correctly evaluated, the MAS has to be observed during its execution. Observation tools, called *probes*, are classified in⁹ into three main categories: software, hardware and hybrid probes. We are interested in using the first category of probes, i.e. software ones. In fact, such a tool is hardware-independent and may easily be adapted to the considered system, as it considers its business logic level. Many works in the literature used software probes for different purposes. We are interested in using aspects as software tools for implementing our approach. In⁵ aspects were used for evaluating agents' conversations by collecting exchanged messages and semantically analyzing them. Authors in¹⁰ used aspect-based observation for evaluating communications as well as in⁴. In¹¹ and¹², observation was used for explaining agents reasoning. These works do not assess the impact of such observation tools on the system's performance, which is a must if we aim at establishing an objective evaluation technique.

3. Evaluation Approach

We start in this section by positioning our work and presenting its main contributions. Then we describe the different steps of our evaluation approach.

3.1. Our work positioning

We try through this work to combine two fundamental aspects defining MAS performance. Organization of the agents' society and its effect on the global performance of the system were studied to deduce a causal relationship between the two aspects. Our main contribution consists in giving an evaluation approach that is based on the use of a generic mathematical model associated to coalition-based cooperation in multiagent systems by grouping two fundamental aspects of the agents' society: organizational and functional aspects. The first one considers the coalitional

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