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A COOPERATIVE MULTI-AGENT SYSTEM FOR MODELING OF AUTHORING SYSTEM IN E-LEARNING

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Nowadays, development of application that supports cooperative works has attracted recent attention. Thus, several approaches and methods were proposed to reach this aim. In this context, we propose a new solution to the problem of collective work that presents a result of hybridization of several cooperative approaches, as follows: the non-communicative approach to minimizing the required time to perform a cooperative activity and conflict resolution approach based competency for improving the quality of cooperative works. Therefore, we propose a cooperation framework fault tolerant called CoMAS (Cooperative Multi-Agent System) brings preemption resources to cooperating agents (CA) in case of failure to prevent the blocking and ensure the survival of the system. Moreover, we study the case of cooperative authoring systems for e-learning to examine the behavior of our framework with a cooperative activity. Finally, our cooperation approach provides a generic and extensible solution that covers the whole cycle of a cooperation process.

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1 Introduction

Cooperation is one of the social behaviors occurring in a multi-agent system (MAS), this behavior is necessary when an agent cannot achieve its goals without the help of other agents. This is common even among primitive species, building a nest for example. The goals that often require cooperation are social goals; they ensure the survival of the group or species. Sometimes these are individual goals; an agent that helps another may expect help in return or to get paid work. An agent may need the help of another agent that has competence it has not, or because it needs help to complete the task (pushing too heavy object). Cooperation is not necessarily conscious, it can result from automatic behavior, such as construction of hives or termite mounds.

The focus of the research described in this paper, is the proposal of a new solution that supports cooperative activity in a multi-agent environment, this solution must satisfy two constraints, as follows: minimizing the time required to accomplish a collective work and improving its quality.

In order to satisfy the both constraints outlined above, we propose a new solution to the problem of cooperation in MAS; this solution is the result of hybridization of several approaches, as follows: non-communicative approach, competency-based approach and conflict resolution approach.

We adopt the non-communicative approach, which prohibited all forms of communication inter-CA in our architecture of cooperation to ensure the minimization of the time constraint. In addition, the competency-based approach is a pedagogical technique that uses skills in a field of design and development of an educational activity; it defines and cut in terms of acquisition of skills necessary to perform a task (Hodge, 2007). This approach fosters increased training, skill building, job satisfaction and other measurements and leads to improved hiring practices. Indeed, we adopt the teaching technique based competency in defining the skills of CA to increase the quality of service of cooperation in terms of specialization. Finally, we resolve every conflict in the society of CA by the metric of competence to ensure the constraint of the quality of cooperative works.

After giving an overview of related work on cooperation in MAS, we present in section 3, the general architecture of our cooperation approach. In section 4, we study the case of cooperative authoring systems for e-learning and we exhibit the sequence of steps in a cooperation process under our framework. In section 5, we examine the behavior of our framework against a cooperative activity. In section 6, we evaluate the performance of our cooperative approach compared to some existing approaches. Finally, we conclude this paper and describe future directions of our research.

2 Related work

Several studies on cooperation in MAS have been realized. Similarly, many subordinate concepts were identified as part of the cooperation, such as: communication, interaction, coordination and negotiation. Despite the diversity of these works, we note the lack of a universal definition of cooperation and its relationship with the subordinate concepts (Doran *et al.*, 1997). Lesser in (Lesser, 1999), for example, provides a personal view of the key application areas for cooperative MASs, the major intellectual problems in building such systems, the underlying principles governing their design, and the major directions and challenges for future developments in this field. In addition, Ferber in (Ferber, 1995), defines cooperation as a tool helping to solve problems of cooperation among agents. Indeed, it has no precise definition of cooperation, but rather a relationship between cooperation and pair: collaboration / coordination. This relationship, according to point of view of Jmaiel in (Jmaiel *et al.*, 2000), is due to the fact that Ferber, in his approach, starts with the concept of interaction instead of cooperation.

The adaptation of behavior is the subject of several studies, for example, the authors in (Boussebough *et al.*, 2010; Dutta *et al.*, 2006) proposed models of cooperation based on the adaptation of the behavior of agents to combine their individual competence. In (Abchiche, 2012), the author proposed a model of cooperation in an adaptive MAS method for distributed heterogeneous reasoning model for cooperation, integration to perform a distributed integration to dynamically build and adaptively scenarios that lead to a collective resolution for the same problem. The investigations carried out in (Wooldridge *et al.*, 1995) on cooperation are simply interested in defining notations and formalisms that enable rigorous specification in MAS. This work does not directly consider cooperation, but they defined concepts related to the notion of cooperation such as the concepts of agent, goal, commitment, agreement without defining their relations. In (Kobayashi *et al.*, 2012), the authors proposed an intelligent learning system using attention degree to emerge a cooperative behavior in MAS.

Finally, in (Kobayashi *et al.*, *op. cit.*), the authors define an agent as an entity that appears to be the subject of beliefs, desires, etc., which has properties such as autonomy, social ability, reactivity and pro-activity. In addition, the authors in (Kendall *et al.*, 1998) provided a list of attributes and consider an agent to be autonomous, social, reactive and proactive. They structure an agent into seven layers, namely: mobility, translation, collaboration, action, reasoning, beliefs and sensory. The process of creating an agent is to develop the different layers and their integrations.

From this panoramic study of various works related cooperation in MAS, we note the absence of a genuine recognition of the characteristics of cooperative activity in MAS; these features helped us to solve completely this social activity. Therefore, we define a cooperating agent (CA) as (software or hardware) that operates in an environment (possibly, contains other agents), that has the skills and resources to perform individual tasks and to cooperate with other agents to achieve a common goal. This common goal is achieved through the realization of partial goals. According to this vision of CA, we can extract three essential characteristics of an agent, i.e. the competence, resources and goals. In our opinion, competences and goals are closely related to an agent, while resources are considered as tools to achieve these partial goals.

3 General architecture of our cooperation approach

In this section, we present the proposed architecture of cooperation based MAS. Our approach adopts two main actors: the society of CA and CoMAS framework. We introduce the concept of the *state vector* of CA to facilitate the task of management of cooperative activity carried out by our framework. The following figure shows the proposed architecture of cooperation.

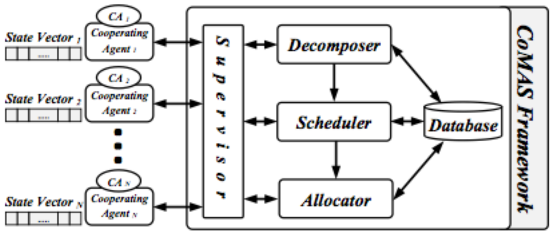


Fig. 1 - Proposed cooperation architecture

3.1 Cooperating agent (CA)

We find that the engagement of an agent in a cooperative activity is directed by their competences. For this aim, we propose the inclusion of a *state vector* in the conceptual specification of CA to explicitly declare these skills. This *state vector* comports: field for the name of agent, field of current activity state (0: passive, 1: active), field for number of competences and set of fields for declaring these competences. Formally, we propose the following definition of a state vector of the CA:

$$\overrightarrow{S_{CAi}} \overset{def}{=} (Nam_{CA}, SA, Nbr_{comp}, \{C_j\})$$

The passive state of a CA means that its free of all commitments and pending allocation of a task, therefore, the active state means that CA is carrying out a task and it does not wait for another allowance.

3.2 CoMAS framework

Our cooperation framework includes three essential modules, namely: decomposers, scheduler and allocator. In addition, a database and a supervisor that coordinates agent's work.

3.2.1 Decomposer

The main task of this module is to decompose the cooperation that is the global goal (G_G) of MAS to a set of elementary sub-problems that constituents partial goals (P_G) of CA. We note:

$$G_G \overset{def}{=} \{P_{G1}, ..., P_{Gm} \mid P_G \in PG, m \geq 1\}$$

Where, PG is the set of partial goals.

3.2.2 Scheduler

The CA must have the skills and the resources to achieve his goals, skills constitutes a structural part of CA but resources are considered as the tools offered by MAS or other CA. In addition, the dependence of resource to partial goals of CA leads us to order the execution of these goals according to the availability of these resources. To do this, the scheduler generates a precedence query (PQ) for each partial goal by specifying the required competence and the set of partial goals that must be completed to constitute the required resources.

$$PQ_i \overset{def}{=} P_{Gi} \; need \; C_x \; pred\{P_{Gj}\} \text{Where } j \geq 0$$

3.2.3 Allocator

As its name suggests, this module ensures the allocation of PG to CA, this operation is based on the criteria of required competence. To pay for this optimization problem, the allocator adopts a strategy which is similar to an election process to select a candidate CA, this strategy is summarized in the following steps:

1. Selection of unoccupied agent (actual state is passive) from CA society;
2. Featuring of CA who have the required competence from selection outlined in first step;
3. Choosing the CA with the least amount of skills from selection outlined in second step.

In the proposed allocation policy, we solve the conflict by adopting a selection technique based on the choice of the agent with the least amount of competence to preserve relevant for purposes other agents to increase expectancy of the system and avoid the deadlock.

3.2.4 Supervisor

Fault tolerance is one of the criteria for quality of service (QoS) introduced by our cooperation framework to ensure the proper functioning of the latter. We adopt the supervisor module to ensure control of CA during the execution of PG in the event of malfunction or failure of one of these agents, the intake supervisor preemption of resources and partial goal on the agent in question and cause a new allocation. Thus, this module coordinates the work of the various components of the framework of a share, and manages communications between the framework and the society of CA on the other.

3.2.5 Database

The exchange of data and intermediate results between the different components of the framework are the main missions of our database.

4 CoMAS-AS: Cooperative authoring system for e-learning

In this section of paper, we illustrate the operating function of our cooperation framework with an example. So, we choose the example of cooperative authoring system for e-learning. This kind of systems offers a supportive work environment to the authors who are distributed geographically remote to develop their educational content in a cooperative manner. The metric of the QoS is provided by the proposed authoring system in terms of time and scientific quality of educational content because it's based on CoMAS framework. The following figure shows the client / server architecture of proposed cooperative authoring system named CoMAS-AS (Cooperative Multi-Agent System for Authoring System).

The proposed architecture is based on two main actors: cooperating author on the client side and our cooperation framework on the server side. The proposed system promotes the submission of cooperative activities to every cooperative entity connected to the system. In this context, we define the process of cooperation under our framework in three consecutive phases, namely: goals, resources and competences.

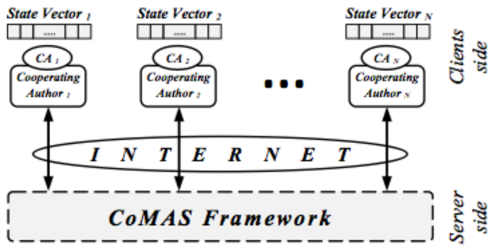


Fig. 2 - CoMAS-AS: Authoring System based CoMAS framework.

The following figure shows the sequence of steps in a cooperation process.

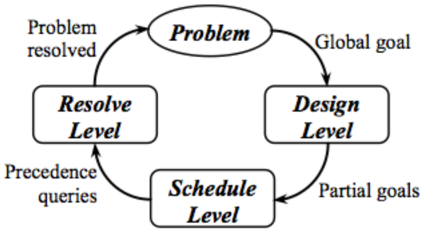


Fig. 3 - Cooperation process.

Firstly, in design level, we decompose the global goal which introduces the topic of cooperation to a non-empty set of partial goals that will be resolved by the society of CA. In schedule level, for each partial goal identified above, we generate using the scheduler modulates a precedence query which includes the identity of the required competence and a list of resources to solve the partial goal. We seek the resources that are data or results of executions obtained from other partial goals. Finally, in resolve level, we define an affordable goal is a partial goal which has all the resources necessary for its implementation. For this, the allocator acts on precedence query to identify an affordable goal, and then makes a series of changes on the allocation matrix to select a candidate CA for solving this partial goal.

5 Experimentation

In order to know the operating function of the proposed authoring system, we propose that the society of cooperating authors has eight (8) authors who have five (5) competences at most for each. In this context, we find that the size of the state vector of the cooperating authors is equal to 8 (field for the name of author +field current state of the author + field for number of competences of author + maximum number of competences).

We also find that the dimensions of the allocation matrix is 8 rows and 8 columns (number of lines equal to the number of cooperating authors and number of columns equal to the size of the state vector). In this context, we suppose the allocation matrix contains the following values:

$$\overrightarrow{AM} = \begin{bmatrix} 1 & 0 & 5 & 1 & 2 & 3 & 4 & 5 \\ 2 & 1 & 3 & 1 & 3 & 5 & 0 & 0 \\ 3 & 0 & 3 & 2 & 3 & 5 & 0 & 0 \\ 4 & 0 & 1 & 5 & 0 & 0 & 0 & 0 \\ 5 & 1 & 2 & 1 & 5 & 0 & 0 & 0 \\ 6 & 0 & 1 & 2 & 0 & 0 & 0 & 0 \\ 7 & 0 & 4 & 1 & 2 & 3 & 5 & 0 \\ 8 & 0 & 2 & 1 & 3 & 0 & 0 & 0 \end{bmatrix}$$

Now, we assume that a cooperative activity has occurred in our framework, the cooperation process is as follows:

5.1 Designing phase

First, the authoring system must select cooperating author to decompose the cooperative activity to a set of sub-problems (partial goals). To do this, the decomposer evokes a request of selection to the allocator to choose one of the cooperating authors divide this cooperative activity (assume that the competency of decomposition is C5). The allocator makes a series of changes on the allocation matrix to identify the cooperating author decomposers, namely:

- Elimination of active cooperating authors;

$$\overrightarrow{AM} = \begin{bmatrix} 1 & 0 & 5 & 1 & 2 & 3 & 4 & 5 \\ 3 & 0 & 3 & 2 & 3 & 5 & 0 & 0 \\ 4 & 0 & 1 & 5 & 0 & 0 & 0 & 0 \\ 6 & 0 & 1 & 2 & 0 & 0 & 0 & 0 \\ 7 & 0 & 4 & 1 & 2 & 3 & 5 & 0 \\ 8 & 0 & 2 & 1 & 3 & 0 & 0 & 0 \end{bmatrix}$$

- Featured authors who have the competency of decomposition (C5);

$$\overrightarrow{AM} = \begin{bmatrix} 3 & 0 & 3 & 2 & 3 & 5 & 0 & 0 \\ 4 & 0 & 1 & 5 & 0 & 0 & 0 & 0 \\ 7 & 0 & 4 & 1 & 2 & 3 & 5 & 0 \\ 8 & 0 & 2 & 1 & 3 & 0 & 0 & 0 \end{bmatrix}$$

- Selecting the cooperating author with the minimum number of skills, in our case it is the author number 4.

- Finally, the supervisor update the state vector to active (value = 1):

$$\overrightarrow{S_{CA4}} = (4,1,1,5,0,0,0,0)$$

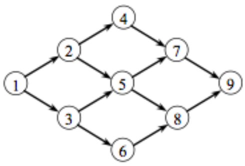
Once the cooperating author accomplished their decomposition activity, the allocator must restore this passive state. We assume that the decomposer author has defined 9 sub-problems (partial goals).

5.2 Scheduling phase

Secondly, the scheduler proceeds in a similar manner as the decomposer to select the scheduler author. It is assumed that the scheduler author generates the following precedence queries:

```
PG1 Need C2 Pred {};
PG2 Need C4 Pred {PG1};
PG3 Need C1 Pred {PG1};
PG4 Need C5 Pred {PG2};
PG5 Need C3 Pred {PG2, PG3};
PG6 Need C2 Pred {PG3};
PG7 Need C1 Pred {PG4, PG5};
PG8 Need C3 Pred {PG5, PG6};
PG9 Need C5 Pred {PG7, PG8}.
```

(a)



(b)

Fig. 4 - (a) Initial precedence queries, and (b) these dependence graph

5.3 Resolving phase

Finally, the allocator examines affordable goals, to do this; it selects the partial goals with an empty set of predecessors, in our case the first partial goal (PG1) with the required competence (C2). Then the allocator proceeds in a similar manner as decomposer or scheduler to identify the CA allocator.

Once the CA accomplished their partial goal, the supervisor must restore this passive state and clears the precedence query of completed partial goal (PG1) and these appearances in the predecessors of the other partial goals.

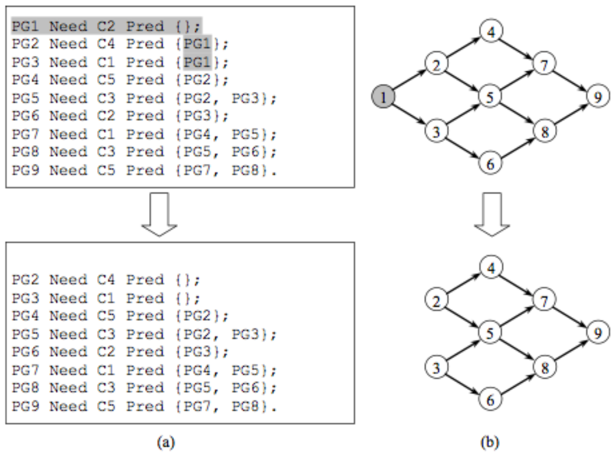


Fig. 5 - Transformation of PQ after resolve of PG1, and (b) these dependence graph

The allocator respites the same procedure until the shortage precedence queries that indicates the completion of cooperative activity.

6 Evaluation

In this section, we examine the performance of our cooperative approach compared to some existing approaches in order to evaluate the lost time due to cooperation. In this context, we define three main reasons that may cause the losses of time in a cooperative activity, namely: acquisition time, selection time and waiting time.

- **Acquisition time**: is the time that separates between the moments of begin of our cooperation activity and the time when our partial goal becomes affordable (has all the resources necessary for their fulfillment).
- **Selection time**: is the time that separates between the moment when our partial goal becomes affordable (has all the resources necessary for their fulfillment) and the time of their allocation to a cooperating agent.
- **Waiting time**: is the separated time between the allocation moment of the partial goal and the moment of starting its resolution by a cooperating agent because of a pending task accomplishment.

We want to evaluate the performances of cooperative approaches, we suppose that the time of treatment of all the partial goals is the same (*10T*) and the negotiation time of CA is equal to (*1T*).

The data and the table that are depicted bellow represent the results of the process of cooperative approaches using the example of authors explained above.

Table 1
COMPARISON OF COOPERATION APPROACHES

Task (Comptence)	Call for bids Approach				Negotiation Approach				Our Approach			
	NSA	AT	ST	WT	NSA	AT	ST	WT	NSA	AT	ST	WT
GP1 (C2)	6	00	01	00	6	00	07	00	6	00	01	00
GP2 (C3)	1	10	01	00	8	10	07	00	8	10	01	00
GP3 (C2)	3	11	01	00	6	11	07	00	6	11	01	00
GP4 (C3)	1	21	01	00	8	21	07	00	8	21	01	00
GP5 (C1)	7	22	01	00	2	22	07	00	2	22	01	00
GP6 (C4)	1	23	01	08	1	23	07	00	1	23	01	00
GP7 (C3)	8	41	01	00	8	33	07	00	8	33	01	00
GP8 (C1)	7	42	01	00	7	34	07	00	7	34	01	00
GP9 (C5)	4	52	01	00	4	44	07	00	4	44	01	00

NSA: Number of Selected Agent; AT: Acquisition Time;
ST: Selection Time; WT: waiting time

We define the achievement time of partial goals as the sum of times: acquisition, selection, waiting and treatment. The following figure shows the performance of cooperative approaches studied in terms of minimizing the time lost in a cooperative activity.

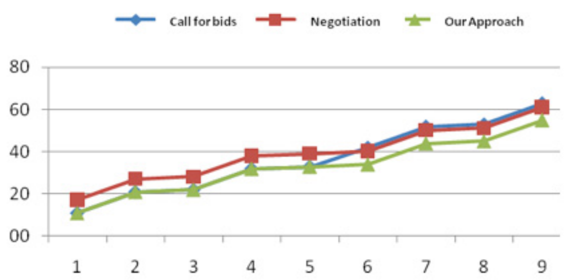


Fig. 6 - Performance of cooperative approaches studied

6.1 Approach based on call for bids

The principal challenge of this collaborative approach is the considerable losses due to the waiting time because it affects the task of cooperation to the first applicant agent that may generate system crash situations. The following figure shows the time to the problem of waiting in the approach based on the call for bids.

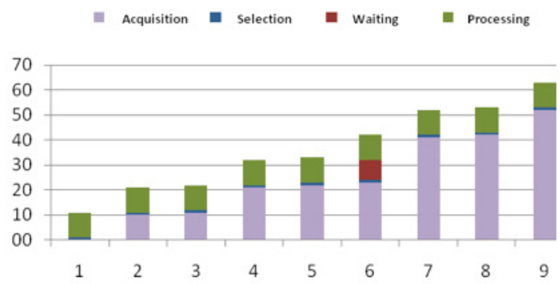


Fig. 7 - Problem of waiting time in call for bids approach

6.2 Approach based on the negotiation

The problem of waiting time is taken into account in this cooperative approach because it is based on the exploration of the quality of cooperating agents, but we find considerable time losses on the selection time because in the environment of n cooperative agents, we need (n-1) negotiations.The following figure shows the selection time problem in the approach based on negotiation.

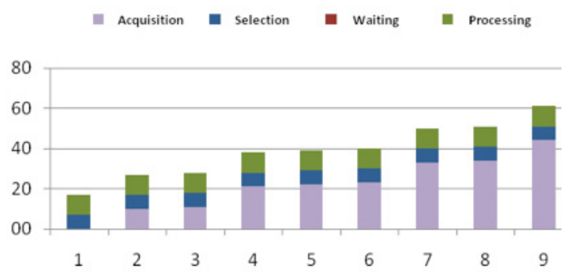


Fig. 8 - Problem of selection time in negotiation approach

6.3 Our approach

Our cooperative approach deals with the loss of time indicated previously, we minimize the selection time using non-communicative approach which forbids all the forms of communication between agents. In addition, we minimize the waiting time using a selection technique based on the choice of the agent that has the low number of competences in order to preserve the more competent agents for other goals, thus it rises the functionality of the system and helps to avoid the deadlock situation.

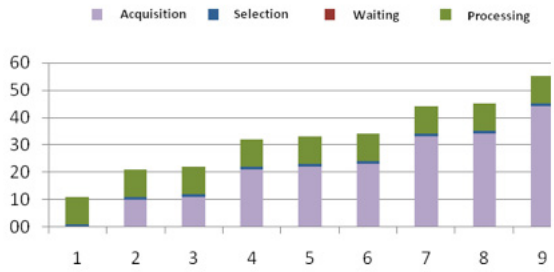


Fig. 9. Efficiency of cooperation in our approach

Discussion and Conclusion

Pragmatically, the constraint of minimizing the time required for solving a problem and the improvement of the quality of the results of solving the latter is being the essential motivations of the intervention of several agents in a cooperative activity. Indeed, several approaches have been developed in the context of the modeling of this social activity.

We proposed in this paper a new solution for modeling cooperative behavior in MAS. This solution has a result of hybridization of several approaches as follows: the non-communicative approach to minimizing the time and conflict resolution approach based competency for quality improvement. In this context, we proposed a framework for cooperation fault tolerant called CoMAS brings preemption resources to CA in case of failure to prevent blockage and ensures the survival of the system. In addition, we studied the case of cooperative authoring systems in e-learning to examine the behavior of our framework to face a cooperative activity.

Finally, a detailed selection policy for conflict resolution in the allocation of CA is considered as a future work.

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