Integrating Self-organisation into Dynamic Coalition Formation

(Extended Abstract)

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ABSTRACT

In some real systems, e.g., sensor networks, individual agents will often need to form coalitions to accomplish complex tasks. Due to communication or computation constrains, it is infeasible for agents to directly interact with all other peers to form coalitions. Most current coalition formation works, however, overlooked this aspect. Those works usually did not provide an explicitly modeled agent network or assumed agents in a fully connected network, where an agent can communicate with all other agents. Thus, to alleviate this problem, it is necessary to provide a neighbourhood system within which agents can directly interact only with their neighbours. Towards this end, in this paper, we propose a dynamic coalition formation mechanism, incorporated with self-organisation, in a structured agent network. Based on self-organisation principles, this mechanism enables agents to dynamically adjust their degrees of involvement in different coalitions and to join new coalitions at any time.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence

General Terms

Algorithms

Keywords

Coalition Formation, Self-organisation

1. INTRODUCTION

In many applications of multi-agent systems, agents will need to dynamically join together in a coalition to complete a complex task which none of them can complete independently. Recently, many efforts have been done on coalition formation and have achieved very great results. There is a common assumption in these studies that the agent network underlying structure is either not explicitly modeled or the network structure is based on some regular structures, e.g., a fully connected network or a hierarchical network. However, in many real circumstances, particularly in large and distributed environments, it is infeasible for each individual agent to consider all the other agents to form coalitions due to time, communication and computation constrains [4]. One approach to overcome this limitation is to impose some sort of network structure on the agents and require that agents can directly communicate only with their neighbours when forming coalitions. Gaston and desJardins [2, 3], and Glinton et al. [4] made many efforts in this way. The common limitation in [2, 3, 4] is that an agent can join only one coalition and once a coalition is formed for a task, the coalition is fixed and agents cannot leave the coalition, until the task is finished. Against this background, in this paper, our research concentrates on designing a dynamic coalition formation mechanism in a structured agent network, where each agent has only a limited view about its neighbours in the environment and makes decisions based only on this view. In addition, we integrate self-organisation notion into coalition formation which enables agents to dynamically adjust their degrees of involvement in different coalitions and to join new coalitions, via negotiation, at any time if necessary. In that case, agents have more autonomy and flexibility when they execute tasks.

Appears in: *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2012)*, Conitzer, Winikoff, Padgham, and van der Hoek (eds.), 4-8 June 2012, Valencia, Spain.

2. COALITION FORMATION

In the agent network, agents make decisions based only on local information about the system, and the decision making process of agents is autonomous without external control. Hence, we define a set $P = \{P_1, ..., P_n\}$. P is defined as a *partition* of the *Compatible Relation* R, where $\langle a_i, a_j \rangle \in R$ if and only if a_j is a neighbour of a_i. Accordingly, it can be obtained that $\bigcup_{1\leq i\leq n} P_i = R$ and $\forall P_i, P_j \in P : i \neq j \Rightarrow P_i \cap P_j = \emptyset$. The set P can be generated by using **Algorithm 1**.

Algorithm 1: Create a partition P on relation R
begin:
(1) **for each** a_i, $a_i \in A$, in sequential order
(2) **if** $\exists a_j \in A : \langle a_i, a_j \rangle \in R$ **then**
(3) $P_i \leftarrow P_i \cup \{\langle a_i, a_j \rangle\}$;
end

The coalition formation mechanism is illustrated in **Algorithm 2** as follows.

Algorithm 2: Coalition Formation Mechanism
begin:
(1)**Call Algorithm 1** to generate *P*;
(2)**for each** θ_i, $\theta_i \in \Theta$, in sequential order /*θ_i is a subtask of Θ*/
(3) randomly select an *IDLE* agent, $a_i \in A$, as *Initiator*;

(4) $State(a_i) \leftarrow BUSY$;
(5) **while** $t < DL(\theta_i)$ **do** * t is the real time * \
(6) **for each** $a_j \in A : \langle a_i, a_j \rangle \in P_i$
(7) **if** $\exists r^l_{\theta_i} \in R(\theta_i) : r^l_{\theta_i} = r_{a_j}$
and $r^l_{\theta_i}$ is unsatisfied **then**
(8) **Negotiate**(a_i, a_j);
(9) **end if**
(10) **end for**
(11) **if** $\forall r^l_{\theta_i} \in R(\theta_i) : r^l_{\theta_i}$ is satisfied **then**
(12) **break**;
(13) **else**
(14) **select** a_k as *Mediator* based on the number of a_k's neighbours, where $\langle a_i, a_k \rangle \in P_i$
(15) $State(a_k) \leftarrow BUSY$;
(16) $P_i \leftarrow P_i \circ P_k$;
(17) **end if**
(18) **end while**
(19) **end for**
end

2.1 The Negotiation Protocol

In order to operate the coalition formation mechanism, we need another important component, i.e., a negotiation protocol. The coalition formation problem can be modeled as a negotiation process between an *Initiator* and a *Participant*, where an *Initiator* acts as a *buyer* and a *Participant* plays as a *seller*. The negotiation focuses on a single issue, i.e., the degree of involvement of a *Participant* into a coalition which is being formed by an *Initiator*. Some constrains are listed as follows, with which each agent should comply.

1. An agent, except *Initiator*, can dynamically join multiple coalitions with different degrees of involvement.
2. Temporary agreements can be canceled by either *Initiator*s or *Participant*s without paying penalty.
3. Both *Initiator*s and *Participant*s cannot cancel final agreements, but *Participant*s can adapt the degrees of involvement in their joined coalitions by paying penalty to *Initiator*s and *Participant*s can join other coalitions if necessary.
4. The degree of involvement of an *Initiator* in its initiated coalition is postulated to be 1 and cannot be adapted.

The negotiation protocol employed in this paper extends the alternating offers protocol [5] by allowing an agent to make multiple agreements with other agents and to cancel temporary agreements without paying penalty. Rubinstein's protocol [5] has been widely used for bilateral bargaining, e.g., An et al. [1]. Other more complex negotiation protocols may be also available for our problem, but based on our investigation, Rubinstein's protocol is enough for our problem and it is easy to implement.

There are some possible actions of *buyer* (*Initiator*) and *seller* (*Participant*) agents.

• $offer[o]$, where o is *buyer*'s offer to a *seller*. An offer is determined by four factors, which are the pressure of deadline, the payment of the resource paid by the *buyer* to the *seller*, the duration of using the resource, and the demand/supply ratio of the *buyer*'s required resource.

• $accept[o]$. When a *seller* receives an offer o, it can accept the offer which results in a temporary agreement made with the *buyer*.

• $counter\_offer[o']$. If a *seller* is not happy with an offer o, it can send back a counter-offer o' for its available resource. A counter-offer o' is determined by three aspects, which include the current state of the *seller*, e.g., whether it has joined other coalitions and the degrees of involvement into those coalitions, the payment received by the *seller* from the *buyer*, and the demand/supply ratio of the *seller*'s available resource.

• $cancel[o]$. After a temporary agreement is achieved by a *buyer* and a *seller*, any one of them can cancel the agreement without paying penalty. A final agreement, however, cannot be canceled by either of a *buyer* or a *seller*.

The negotiation protocol, displayed in Line 8 of **Algorithm 2**, is shown in **Algorithm 3** as follows.

Algorithm 3: Negotiate(a_i, a_j)
* a_i is the *buyer* and a_j is the *seller* * \
begin:
while $t <$predefined period **do** * t is the real time * \
a_i generates an offer o to a_j;
if a_j accepts o **then**
$\mathcal{A}^{\mathcal{T}}(a_i) \leftarrow \mathcal{A}^{\mathcal{T}}(a_i) \cup \{o\}$;
$\mathcal{A}^{\mathcal{T}}(a_j) \leftarrow \mathcal{A}^{\mathcal{T}}(a_j) \cup \{o\}$;
$State(a_j) \leftarrow BUSY$;
return;
else
a_j generates a counter-offer o' to a_i;
if a_i accepts o' **then**
$\mathcal{A}^{\mathcal{T}}(a_i) \leftarrow \mathcal{A}^{\mathcal{T}}(a_i) \cup \{o'\}$;
$\mathcal{A}^{\mathcal{T}}(a_j) \leftarrow \mathcal{A}^{\mathcal{T}}(a_j) \cup \{o'\}$;
$State(a_j) \leftarrow BUSY$;
return;
else
continue;
end if
end if
end while
end

3. CONCLUSION

This paper provided a self-organisation based dynamic coalition formation mechanism which enables agents to dynamically adjust their degrees of involvement in different coalitions to achieve efficient task allocation. This mechanism considers the existence of an underlying network structure and integrates the self-organisation concept. To realise the self-organisation concept, a negotiation protocol is employed. This research can be exploited for completing shared tasks in many distributed systems where resources are distributed and agents are highly autonomous, such as distributed agent-based grid systems, service-oriented computing and distributed sensor networks.

4. REFERENCES

[1] B. An, V. Lesser, D. Irwin, and M. Zink. Automated negotiation with decommitment for dynamic resource allocation in cloud computing. In *AAMAS'10*, pages 981–988, Toronto, Canada, May 2010.

[2] M. E. Gaston and M. desJardins. Agent-organized networks for dynamic team formation. In *AAMAS'05*, pages 230–237, Utrecht, Netherlands, Jul. 2005.

[3] M. E. Gaston and M. desJardins. The effect of network structure on dynamic team formation in multi-agent systems. *Computational Intelligence*, 24(2):122–157, 2008.

[4] R. Glinton, K. Sycara, and P. Scerri. Agent organized networks redux. In *AAAI'08*, pages 83–88, 2008.

[5] A. Rubinstein. Prefect equilibrium in a bargaining model. *Econometrica*, 50(1):97–109, 1982.