Resource Allocation Based on MAS Coordination

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Abstract

Resource allocation is a crucial type of decision making activities. Resource coordination is the process of intelligently allocating resources among different agents or goals. In this paper, a new MAS approach is proposed to study resource coordination, which breaks through the restriction of traditional optimization approach under dynamic context. Starting from BDI coordination reasoning, and utility to represent individual interesting of the resources' usage, utility based BDI resource coordination reasoning model is presented. Process of the utility calculation, reasoning and multi-agent interaction is described, and an evaluation and its result is given. These works may have great importance on management and DSS.
Keywords: MAS, Resource Allocation, Coordination Reasoning

I. Introduction

Resource Coordination is intelligent allocation of resources among individuals and their goals in social society [1], which makes individuals utilizing their resources more beneficially, so as to promote the achievement of individual and/or social goals. Usually, the requirement of coordination comes from the distribution and interdependencies of resources, entities and information [2]. In resource coordination, because of the resource constraints, individual plan is to be evaluated and refined, and it may be needed to acquire available resources from external environment, including other individuals.

As Hazelrigg [3] pointed out that decision making is unchangeable resource allocation, allocation of resources is an essential type of decision making activities, where resources include material, labor resource etc. Traditionally, such allocations may be modeled as mathematical programming problems, which are limited to precise model with constant number of variables and centralized computation not adapted to load balance and fault tolerance. As compared with this, MAS approach is proposed to study distributed solution of resource coordination, which not only overcomes aforementioned troubles, but supports group decision well. Especially in the dynamic context, MAS approach has advantages. This paper suggests a utility based BDI reasoning model and a multi-agent negotiation process to study MAS resource coordination, and evaluates it with a transportation problem.

II. MAS resource coordination

The problems that distributed resource coordination will face include, how individuals judge if they need resources or have unused resources, how they make up the resource shortage, how they choose the helper if there are several providing resources of the same type, and vice versa how the resource owners decide the priority of many requests.

How an individual determines its resources status is related to their plan and possession. Obviously, if one plans to use more resources than its possession, it will need help, and vice versa, it will provide help. Potentially, if there are plans one may enact with higher preference but without enough resources, it may choose an alternative with lower resource requirement and preference, or try to get more resources to carry the highly preferred plan to achieve more benefit.

There are three ways for individuals to coordinating resources. They may require unused resources from environment or others, ask for resources spared by others changing their plans, and choose an alternative plan with lower resource demand [1][4].

If there is not only one requester or provider, the other side will decide which one gets the deal. The decision may vary with different individual preference.

From above, the resource coordination process requires individual intelligence and social interaction. Modeling the resource coordination with MAS is a reasonable choice. First, social construction may be built on MAS, and mental state can be modeled by agent, such that design based on MAS is easy to be understood and applied. Second, since MAS is inherently distributed system, it is easy to be load-balanced and fault-tolerant. The last, MAS based design is applicable to dynamic, open environment, which is the most cases in the world.

In this paper, it is assumed that coordination focuses on interests and occurs during collaboration of self-interested rational individuals. Within that context, if individuals pursue their own profit despite others, they would hurt each others finally. The interests of participants are often not totally conflict, but complementary, which means that every one may get more profit from successful coordination. With well-designed social interaction rules to guide individuals behaving, they would support group goal by maximizing self interest.

Borrowed from economics, Pareto optimality may explain human rational behavior well. In this paper, it is used to guide rational choice of individual agents. Achievement of individuals' local goals depends on how much the resource requirement of its current plan is fulfilled. Since the priorities of these goals are not the same and alternative plans exist, different individuals have different preference on the same resources, which make it possible to coordinating the individuals' behavior.

Coordination strategies generally may be divided into four classes, namely negotiation, arbitration, voting and self modification, which are adapted to various contexts respectively [5]. Arbitration strategies assure available result within a short run, but the coordination outcome may be worse, while negotiation often results in a better outcome with more efforts. Voting has the problem of Arrow's Impossible Theorem [6]. Self modification considers the other participants as the same as outside environment, and coordinates the individual behavior by self adaptation, which means coordination without communication.

According to the above discussion, this paper focused on a combination approach of negotiation and arbitration by introducing a mediator during communication. See Figure 1, resource suppliers register to the mediator, who chooses the best supplier to answer when the requesters search for resources. Then the chosen supplier and the requester negotiate until agreement made.

III. Agent reasoning on resource coordination

There is another problem about resource coordination, which is how individuals reason on this coordinating process. In MAS (Multi Agent System), interaction between agents and coordination reasoning in agents is related to their mental state model. BDI framework, which is based on

Bratman's philosophy and developed by Cohen and Levesque [7], Rao and Georgeff [8], models rational individuals as agents, and represents their rationality with three terms, namely Belief, Desire and Intention.

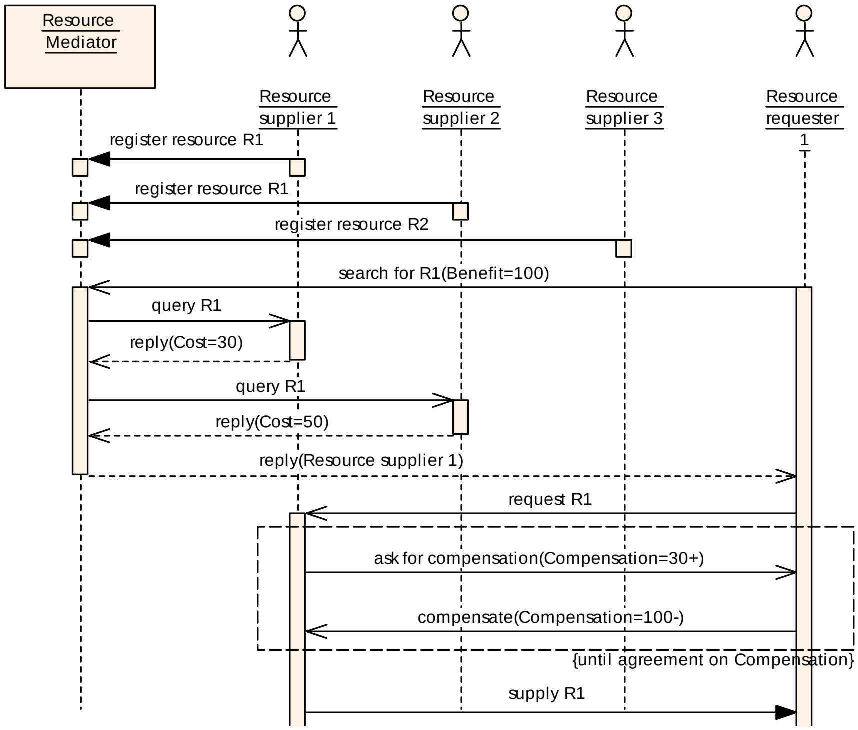

Figure 1

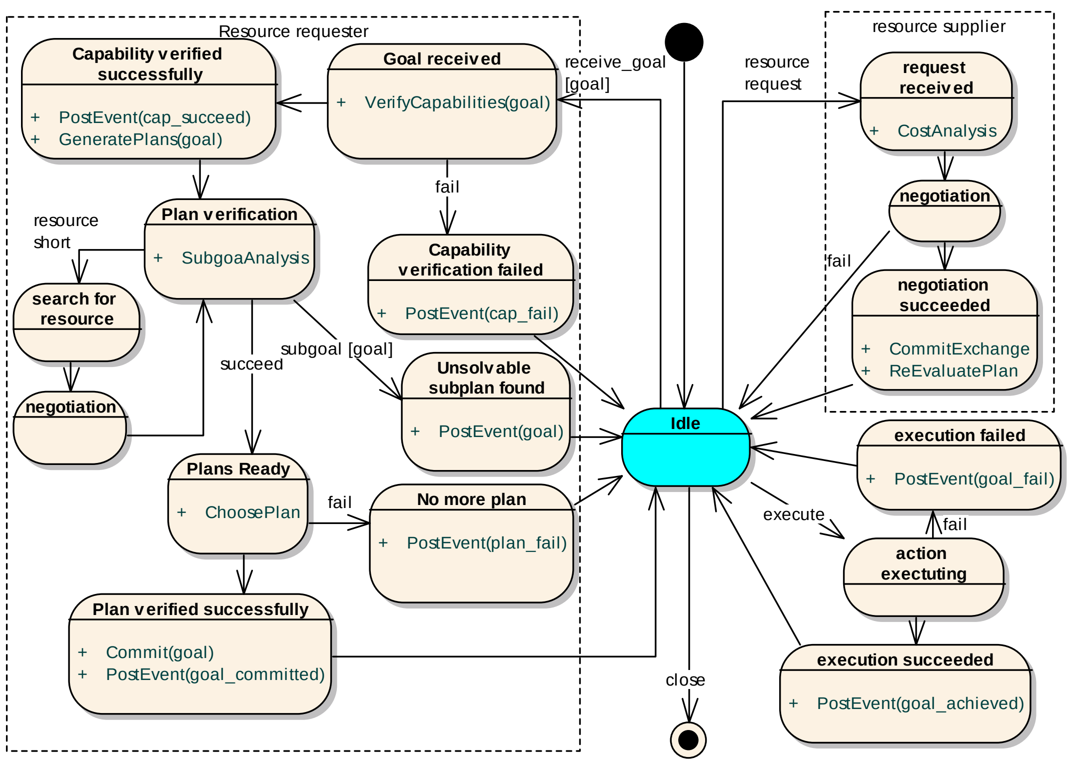

Figure 2

See Figure 2, coordination reasoning is focused on how desire is filtered and intension is chosen. Taking resource requester for example, the reasoning process is given as following.

a) Receive goal or goals, which arise from communication, perception and reasoning process, or given beforehand.
b) Verify the capabilities, search for available plans to achieve the goal.
c) Search for short resources, to fulfill the requirement to enact a plan.
d) Negotiate on the short resources with supplier, and update Belief database with the negotiation result.
e) Choose the most preferred plan.

Due to the resources exchange, there must be changes of interest among both sides, which makes analysis of interest change inside agent significant. It is usually cost-benefit analysis or cost-effectiveness analysis, named utility analysis here.

IV. Utility analysis

The agent's preference on resource is denoted by utility, which is defined as the difference between expected benefit and cost in the following. This section discusses about utility analysis on resource coordination.

In centralized computation, resource allocation may be modeled as mathematical programming. However, in distributed resource coordination, the allocation depends on the judgment of every individuals and interaction between each others. Usually the costs and benefits of the tasks that agents perform or will perform are different, which makes the one without enough resources may have stronger demand on the resources than the others. Obviously, if the local preferences are consistent with global objective and local goal are to be achieved to the best of agents' abilities, global coordination will be assured. Here to the best of agents' abilities means there is as little limitation of the resources on each agent's plan as possible.

The preference of an agent is dependent on its belief and goal. This paper assumes collaborative context, individual agents' goals are considered to be consistent or partially conflict. The differences of their interests may be reduced by introducing interaction rules and exchange of pay-offs. For example, if resource exchange occurs between two agents, the receiver must compensate the supplier for the loss of its resources.

Here is an evaluation example designed referring to the air campaign problem of Cox et al [1]. A certain transportation company gets paid by delivering goods. It comprises of several subordinate cargo agents with its vehicles. They are independent in interests and contribute to the parent company. Such the agents may consider only their own interests despite others, which may hurt each others. From the stand of the company, all the agents' achievement should be increasing and avoid inner conflicts.

Suppose there are two agents, who need to deliver $n_i \ (i=1,2)$ trucks of goods respectively and have R_i vehicles available now. According to the contract, if goods are delivered in time, the agent will get Pay_i , else the payment will be reduced by $Penalty_i$. Cancellation and long time postponement is not allowed. It is also assumed that the cargo must set off right now, which means the agents may not wait for more available vehicles. So the utility comes with Benefit-Cost analysis.

$$Benefit_i = Pay_i \tag{1}$$

$$Cost_i = Penalty_i + Fee_i \tag{2}$$

$$Utility_i = Pay_i - Penalty_i - Fee_i \tag{3}$$

The penalty is defined as a linear function of the delay ratio of goods P_i and a constant penalty rate $Rate_i$, namely $Penalty_i = Pay_i \times Rate_i \times P_i$. The delivering cost Fee_i , including fuel expense etc, is nearly constant within a delivering task and has little influence on decision. So it may be ignored, and the utility becomes

$$Utility_i = Pay_i - Penalty_i \tag{4}$$

If there are enough vehicles, agent would deliver the goods in time. But in the case of vehicle shortage, the delivering task would not be completed in time unless others share their vehicles for rent. If agent α_1 gets vehicles from agent α_2, α_1 will pay $Compensation_{1,2}$ to α_2. The $Compensation_{1,2}$ increases cost of α_1 and benefit of α_2, as Table 1.

Each agent decides whether to exchange resources based on $\Delta Utility$. The exchange will occur if and only if both get more utilities.

$\alpha_1 \leftarrow \alpha_2$	$R_2 > 1$	$R_2 = 1$
$\Delta Utility_1$	$Pay_1 \times Rate_1 \times \frac{1}{n_1} - Compensation_{1,2}$	$Pay_1 \times \left(1 - Rate_1 \times \frac{n_1 - 1}{n_1}\right) - Compensation_{1,2}$
$\Delta Utility_2$	$Compensation_{1,2} - Pay_2 \times Rate_2 \times \frac{1}{n_2}$	$Compensation_{1,2} - Pay_2 \times \left(1 - Rate_2 \times \frac{n_2 - 1}{n_2}\right)$

Table 1

V. An example

According to above discussion, an evaluation is given in this section. There are 10 agents $Agent_i\,(i = 1,2,\ldots,10)$, each of whom has a random number R_j of available vehicles, and the total number of vehicles $TR = \sum R_i$ varies between 10 and 50. Each vehicle is supposed to be same on their capacity, and load unit goods. The amount of goods each agent needs to deliver n_i is a random integer between [1, 5], so the total task range from 10 to 50. The payments and the penalty constant $Rate_i$ of all tasks is set to 100 and 50% respectively. Observe the utility of each agent before and after coordination, compare

a) 1) The total utility of system in different resource context $\sum_{i=1}^{10} Utility_i^{TR} \quad (TR = 1,2,\ldots 50)$,

b) 2) Accumulated utility of each agent $\sum_{TR=1}^{50} Utility_i^{TR} \quad (i = 1,2,\ldots,10)$.

VI. Discussion

Resource coordination is an important kind of decision making activities. This paper studies it with MAS method, which is load-balanced, fault-tolerant, dynamic and easy to be understood. The evaluation result shows this method is effective on multi participants' resource allocation.

The negotiation strategy with mediator is introduced in this paper, which may be practicable within peer-to-peer coordination. But in real world, because of the variety of organization, the coordination strategies may be different. The dynamic selection of coordination strategies needs to be studied. Barber et al [9] and Excelente-Toledo et al [10] give us good basis. Moreover, role based design is applied in this paper. However the role modal is much simple, with only resource supplier and requester. Barber et al [9] present literatures on this problem. A hierarchical organization modal and strategy selection mechanism will be introduced into our work soon.

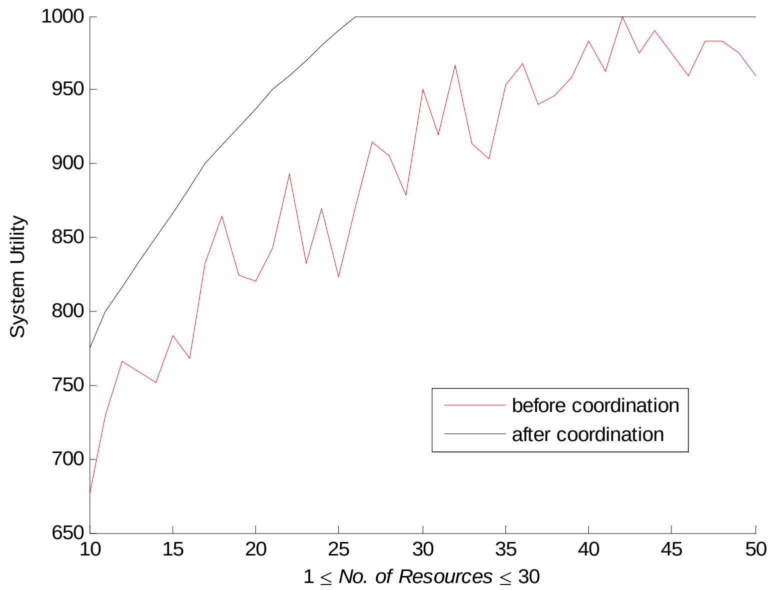

Figure 3

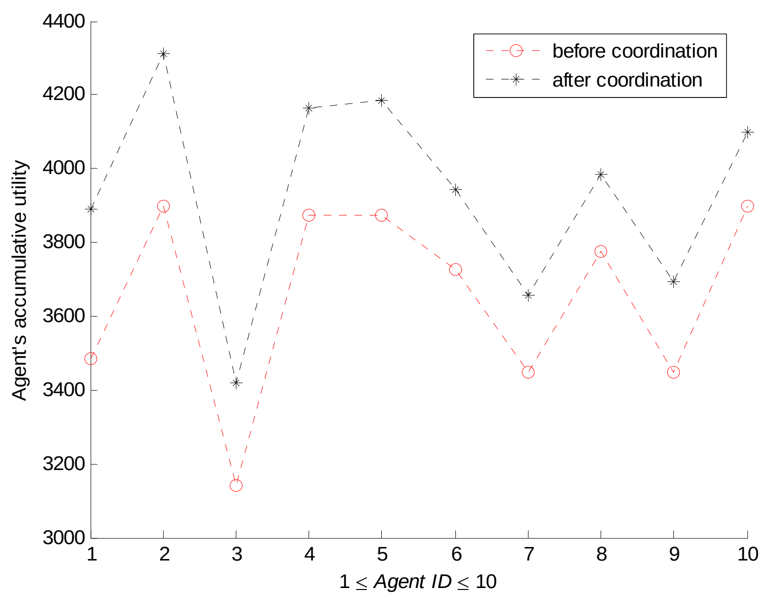

Figure 4

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