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Bounded optimization of resource allocation among multiple agents using an organizational decision model

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Abstract

Multi-agent System (MAS) can be used to dispose bounded optimization problems with dynamically changing resources because its autonomous distributed management model aspect is fitted to dealing with such external disturbances. One of the problems in multi-agent optimizations is that it is difficult to rigorously define the optimization criteria with respect to the global optimization in advance. Rather, it may depend much on more situated factors such as temporal availability of resources and coexistence of current conflicts, conflicts among what has been already scheduled and what is to be scheduled. In this paper, an organizational model called Garbage Can Model (GCM) is introduced. In GCM, through its three decision-making strategies and the fluidities of problems and resources, solutions made by an individual agent are concerned with several agents that are co-existing in the environment. The problems allocated to each agent are solved not only by an agent's own efforts, but also by the change of problem solving status of other agents. Our simulation experiment shows that GCM is a preferred framework for multi-agent optimization problems in dealing with the above difficulties.

Keywords: Garbage can model (GCM); Multi-agent system (MAS); Conflict; Bounded optimization; Decision mode

1. Introduction

An optimization problem is a computational problem in which the objective is to find the best of all possible solutions for some problems with the given resources. Such kind of optimization is called as 'bounded optimization/optimality' ([1]). Bounded optimization configuration is an equilibrium point of the forces that tend to maximize the quality of decisions, minimize the time to make those decisions, and maximize the speed of adaptation to the environment ([2]). To accommodate these forces, we should incorporate a variety of representations of functions, ranging from a fully declarative, decision-theoretic model to fully complied condition-action rules and procedures with finite calculation. In some problems with bounded resources and multiple optimal goals, the best solution cannot be found easily. It much depends on the temporal available resources and the relationships of goals. In recent years, many researchers argue that multi-agent optimization is one of the approaches of dealing with such difficulty ([3,4,14]).

Most of MASs is decentralized systems composed of autonomous agents. The autonomous distributed organizational model makes that MAS is suitable for some bounded optimization problems with dynamically bounded resources and multiple goals, in which the optimization is carried out under the resource allowance (i.e. bounded rationality), and global optimization criteria are divided into several local objectives that will be achieved by each unit (i.e. *agent*). The global criteria are achieved through agents' individual optimizations and the negotiations among them. Generally, there are three kinds of crucial problems when applying MAS to such a multi-goals optimization problem: the unpredicted temporal available resources in each optimization stage; the competitions among agents and the re-allocations of problems and resources for the changing of the environment.

In this paper, we adopt an organizational model named *Garbage Can Model* (GCM) [12] to multi-agent

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optimization. In GCM, the problems and resources to be optimized are thrown into several garbage cans (i.e. choice opportunities) in a time series. When the problems and resources in a garbage can satisfy some pre-defined criteria (e.g. the garbage can is full-filled), the can will be dumped (i.e. be thrown away of the current environment). The optimization systems are composed of un-dumped garbage cans, among which the problems and resources are able to be re-allocated (i.e. shifted from one can to another) according to some decision-making strategies (i.e. organizational norm). This model allocates temporal resources dynamically and efficiently, not only because it provides many opportunities when problems and resources are being thrown into the system, but also because it provides lots of fluidities for the problems and resources which have been allocated to garbage cans. Furthermore, agents' competitions for the bounded resources are relaxed through the decision-making strategies in GCM.

This paper focuses on how to deal with the optimizations among autonomous agents in resource-bounded environment. It is organized as follows: in Section 2 we discuss the decision problems in MAS multi-agent system. Then one of organizational models—GCM is introduced in Section 3. Through an example we explain how to apply GCM to a multi-agent optimization system in Section 4. After that, by comparing the result of this new system to original MAS optimization system, we show the advantage when GCM is applied to a multi-agent scheduling problem. In the Section 6, we summarize the whole paper and talk about our future work.

2. Multi-agent optimization problem

A multi-agent system is a dynamic system composed of autonomous agents. It is a decentralized management system in which there is no any super-agent or system controller. The system functions rely on each agent's functions. *Multi-agent optimization* is an optimal methodology in which the global optimization criteria are divided into several local optimization goals. Each agent in the MAS is only concerned about a local optimization goal. The global optimization is achieved through a combination of these local optimizations. This kind of methodology is suitable for those complicate problems in which there are too many *constraints* or *goals* to define a global optimization criterion clearly and exhaustively in advance.

In multi-agent optimization, an agent is an independent optimizing unit and it achieves its local goal individually. It communicates with other agents only when its optimization process cannot be carried on without others' collaborations. In such a *loosely coupled* optimization system [13], there are some crucial problems to be considered.

First, to predict temporal available resources in every stage of bounded optimization is one of the eargest difficulties in multi-agent optimization. MAS is not a closed system, but is an open system that continuously interacts with its outside world. The participants, resources as well as problems of a MAS are changed from time to time. For a MAS designer, it is difficult to predict the withdrawal/appearance of agents, the occurrence and production of problems/resources in advance. In addition, each agent in a MAS takes actions and consumes resources independently and dispersedly. The resources available in the system in a certain situation are difficult to predict in advance because agent's resource-consuming activities are idiopathic and irregular.

Second, agents sometimes interfere and conflict with each other in a MAS. Most of such conflicts belong to resource competitions, which are usually caused by agents' various implementations seeking for an identical goal. In a MAS without coordination and collaborations, agents are usually concerned about how to achieve their local goals in their own implementations even if they have an identical global goal. When two agents want to make use of an identical resource simultaneously, a conflict will occur.

Another difficulty in multi-agent optimization is that solutions cannot be generated before all the problems and resources are available to the optimization system. In a traditional multi-agent optimization system, solutions are generated only when all the problems and resources are known to the optimization system. In such system, the optimization is carried on among all the problems/resources and tries to find the best solution for these problems and resources. Such strategy has some the disadvantage not only because it is difficult to find the best solution for all the problems/resources in some optimization problems (e.g. NP-hard problem), but also because it cannot be used in real time bounded optimization problems, in which the problems and resources are delivered and allocated into the optimization system in a time series. In the latter case, it is impossible to know all the information about the problems and resources before all of them have entered into the system. Therefore, there is no solution generated before all the problems and resources are known. But on the other hand, real world problems do need an *anytime algorithm*—a bounded optimization algorithm that generates some solutions under partial available problems and resources in order to satisfy real time requirements.

3. Garbage can model

3.1. Overview of original GCM

GCM was originally introduced in a field of organization theory for explaining organized anarchies It is a kind of descriptive model that is most appropriate for modeling the tasks in organizations descriptively where the technologies are not clear, the involvement of participants fluctuates in the given amount of time and effort, and choices are sometimes inconsistent and not well defined ([5,6]).