A Survey of Multi-Agent Systems for Optimization Problems

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***Abstract*—Optimization problems, such as resource allocation or scheduling, often involves different entities, such as departments or production units, which might have different constraints and objectives, but are interested in cooperating. In this presentation, we survey various scenarios and the solutions proposed in the literature for this kind of situations. We start from simple distributed constraint satisfaction problems, to move to more complex situations involving contract nets and Markov Decision Problems. Finally, we discuss various kinds of auctions and market mechanisms to solve this kind of problems using a timetabling problem as running example.**

I. Outline of the Presentation

Complex optimization problems are ubiquitous in the industrial context. They range from resource allocation, to machine scheduling, to logistics just to name some. In many cases, the overall problem involves different entities, such as departments or production units. The various entities, which have their crucial decisions to make in terms of assignments, might have different constraints and objectives. Nevertheless, they are normally interested in cooperating in order to obtain a global solution acceptable for all the entities involved. In addition, it is often the case that there are privacy issues involved among the entities, so that the possibility to share all the information is not a viable option.

In all these cases, it might be useful to resort to an architecture in which each decision maker is equipped with an agent-based software system. Each system should be able to solve complex optimization tasks, but also to interact and negotiate with the other systems for the achievement of common objectives or for the identification of actions that lead to mutual advantages.

In this presentation, we survey various scenarios and the solutions proposed in the literature for this kind of situations. We start from simple distributed constraint satisfaction problems, to move to more complex situations involving Contract Nets or Markov Decision Problems. Finally, we discuss various kinds of auctions and market mechanisms to solve this kind of problems.

We also discuss how optimization packages have to be modified in order to take care of the presence of uncertain resources that might be obtained from the other entities.

Special attention will be devoted to a running case, arising from a real-world problem, namely an educational timetabling problem. The *university course timetabling* (CTT) problem is one of the most studied educational timetabling problems and consists in scheduling a sequence of events or lectures of university courses in a prefixed period of time (typically a week), satisfying a set of various constraints on rooms and students.

We consider the timetabling problem for a set of university departments (or schools, or faculties) that have to schedule the courses of their curricula in a given term. Each department prepares its weekly schedule based on its endowment of rooms, and according to its own constraints, rules, and objectives. In general, a department is not willing to share its information with the other departments; therefore we assume that all input data are private for each department and thus inaccessible to the others.

On the other hand, whenever resources are usable for more departments, e.g., they are located in the same site, departments could benefit from sharing and/or exchanging their resources. Indeed, the resource endowment for each term is not always optimally suited to the needs of the departments, but rather based on political and historical matters. Moreover, normally there are no global objectives to be satisfied; therefore all departments exchange resources for their own selfish interest, although they have a moral impulse to be helpful with the other departments, whenever possible without loss.

We this specific timetabling setting, we discuss the possible general architectures for the system and we describe the tasks and the functionalities of each of the agents. Finally, we will discuss the trade-off between privacy and independence in the one side and effectiveness and efficiency on the other, for this type of distributed problems.