AGENTS IN TIMETABLING PROBLEMS

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Abstract

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Introduction

In an accompanying contribution, the authors describe the distributed architecture of a timetabling system for a large hierarchical organisation. It is suggested there that the decision support within this system could best be build on the multi agent paradigm. In this presentation, we investigate the role that negotiating agents can play in such a timetabling system. We differentiate between fine grained and coarse grained levels within a distributed timetabling system. At both levels, conflicting expectations and constraints may be resolved by collaboration between agents.
We consider published negotiation schemes and investigate their applicability. We stress the importance of the overall behaviour of such a system. In particular, we describe a number of criteria that the system is expected to fulfil. We then raise the question in what sense a particular negotiation scheme guarantees that these criteria will be met. Finally we formulate possibilities for future research.

1. Problem

In another presentation at this conference, the authors describe an architecture of a timetabling system for a large hierarchical organisation [Adriaen et al., 2003]. The timetabling problem herein considered is the task to build rosters for personnel working in more or less loosely interacting units (e.g. departments in a university) which are hierarchically organised, i.e. units are organised in super-units from the individual workers up to the highest level. Decisions taken at a specific level of the hierarchy become more abstract and less detailed as the level goes up. The system described in the above mentioned contribution matches these organisational characteristics by defining a set of actions and assigning appropriate access rights within the hierarchical structure. One can argue that such a system has typical characteristics of a distributed system since the decision taking in its components is largely autonomous on the local details with relatively limited interaction at a higher level. Furthermore, these components will very often be really distributed due to geographical separation, or to other practical issues. Another example of such a system can be found in a paper by M. Carter on timetabling at the university of Waterloo [Carter, 2000]. From this it follows that a distributed software architecture will adequately describe this problem. Decision support in distributed systems with autonomous, asynchronous components can be modelled by a multi-agent system. We will investigate possible benefits of this paradigm in a timetabling context. Timetabling has been extensively studied at the unit level where people, or more generally resources, intensely interact with each other [Di Gaspero and Schaerf, 2002]. The main focus of this research has rightly been the modelling of the constraints and the algorithmic sophistication needed to resolve them.

At this level, to our knowledge, little research has been performed on the efficiency of multi-agent systems for optimisation [Dowsland et al., 2002]. At this fine grained level, a multi-agent based algorithm may profit from the availability of several CPU's. As argued above, timetabling becomes intrinsically distributed when taken above the level of the individual unit. From the point of view of the algorithm developer as well as from the system point of view, information is not shared among the units in every possible detail. Even at the detailed level, resources do not share all information. In a school timetabling system, e.g., teachers may have reasons and motivations which they do not want to make public.
Trivially, the system has to fulfil requirements and developers must keep concerns of potential users in mind.Requirements for timetabling systems typically involve the compliance to hard and soft constraints arising from the actual work that has to be done, and the work regulations that have been agreed upon. But the concerns of the potential users typically go further. There will always be a sensitivity for fairness in the system. The superior wants to be fair to his employees, and the employees have to be convinced that work has been distributed on a fair basis. A related issue is efficiency, demanding the right job to be

given to the right person. As a last example of this class, we mention continuity. Timetable adaptations should cause as little disturbance as possible.
Another class of concerns has to do with the timely performance of the systems. The negotiation process cannot last for ever and at the due time, a reasonable decision has to be taken. The negotiation process should not interfere with efficient resource utilisation [Schilloea et al., 2002]. In some cases, response requirements are such that at any time a decision must be available in case the users ask for it.
While some of these additional concerns can be defined as soft constraints, they very often are of a different, more global nature. What we propose here is to consider them as system properties, which at best should follow from the way the decision making proceeds.
This problem certainly bears strong resemblances to the distributed scheduling problem in e.g. a production environment. Experience from this domain will be valuable in the present context. As can be seen from the following short overview, multi-agent systems for scheduling have been intensively studied. In the pioneering work of [Shaw and Whinston, 1983] on agents in flexible manufacturing systems for scheduling and factory control, a manufacturing cell could sub-contract work to other cells through a bidding mechanism. The Yams system [Parunak, 1987] assigned an agent to each node in a control hierarchy. He uses the Contract Net Protocol (CNP) [Smith, 1980]. [Ouelhadj et al., 2000] described a multi-agent architecture for dynamic scheduling representing resources by agents, responsible for scheduling the resources. They have no control over each other and cooperate using the CNP. The CNP has been extended by [Sandholm and Lesser, 1999] to self-interested agents by attaching commitments to the negotiation protocol. Time-guarantee protocols were developed by [Lee et al., 2000]. The combination with dispatching rules was studied by [Kouis et al., 1997]. [Shen et al., 2000] combined CNP with the mediation mechanism for scheduling/rescheduling of flexible manufacturing systems. [Ramos and Sousa, 1999] proposed a holonic architecture for scheduling in manufacturing systems. Tasks and resources are represented by holons. CNP is used for the scheduling/rescheduling of tasks.

2. Model

Need for agents in distributed timetabling

As mentioned before, agents provide a model for distributed timetabling. The distribution arises from the presence of separated, autonomous components which do not communicate about every detail, but do exchange more coarse grained information. Decisions must be based on incomplete information. It will typically use expressions of interest and degrees of agreement obtained from individual agents. Between real world operators, better decisions are obtained through a negotiation process in which all partners actively research better solutions and ways to alleviate other partner's problems. Autonomous agents eventually negotiating on behalf of the operators they represent, obviously model this situation well.

Negotiation schemes

Published negotiation schemes have investigated coalition formation and contract negotiation, mostly in an e-commerce setting [Sandholm, 2000]. Some schemes use a global utility function to define global goals [Stirling et al., 2002]. Game theory plays a central role in evaluating these schemes [Parsons et al., 2002]. Preference of one scheme above another is influenced by its practical applicability to the timetabling domain. In addition, the degree to which they can guarantee to meet the more global requirements mentioned above must play an important role. Here we may bear on experience from other domains. As mentioned above, goals as continuity, fairness, efficiency are not easily quantified. A global utility function would need an explicit measure of these properties in order to consider them as a global goal. In [De Causmaecker et al., 2000] e.g., the authors investigated a measure of sympathy for trying to balance exchanges over time. The alternative approach of installing supervising agents to guard these concerns violates scalability and contradicts the basic principles of a distributed system. Instead, it must be a goal of the design to let these properties emerge automatically from the negotiation. Independently of the internal machinery of the system, the achievement of the concerns should be measured for the system as a whole. When done automatically, these measurements may be used as a feedback to the agents in order to influence their behaviour. To implement this idea involves designing measures for the concerns, and a mechanism for the agents to take the feedback into account while negotiating.

3. Conclusion

In the final paper we will present models for each of the above mentioned problems/processes. Specifically, we will investigate the possibility to make the achievement of the concerns implicit through the use of an appropriate negotiation scheme.

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