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Intelligent Scheduling in Complex Dynamic Distributed Environments

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Abstract

The complexity and changeability of interacting factors affecting scheduling in a distributed environment demands a very flexible and dynamic solution, in order to achieve a high level of utilisation and cater for many different competing priorities. A typical example of the problem domain can be found in elective surgery scheduling where efficient scheduling is critical to ensure optimum utilisation of the public health system. Current approaches have however failed to offer an efficient solution. The task of making complex resource allocation decisions is still left up to the operators of the system.

We propose a multi-agent approach to modelling distributed environments that employs distributed constraint satisfaction for intelligent scheduling. The proposed model is based on a case study of elective surgery scheduling at the Princess Alexandra Hospital in Brisbane, Australia.

Keywords:

allocation of resources, distributed systems

Introduction

Scheduling in a complex, dynamic environment is an open research problem. The problem is compounded further in the case of a distributed environment where each unit is working at optimising its own resources. In this situation, several units, and thus several schedules, need to be optimised simultaneously to ensure proper utilisation of resources.

While scheduling has been a long studied problem in Artificial Intelligence, no concrete intelligent solutions exist for real-world complex scheduling problems. The core of the problem lies in the inability of current systems to effectively model the inherent distributed structure and distributed decision-making of real-world scheduling environments. What is needed is an intelligent flexible methodology that can adapt itself to the problem at hand, instead of modifying or scaling down the problem to suit its structure. What is also needed is a series of real-world benchmarks to aid proper experimental analysis of current and future methods [1][2].

The hospital elective surgery scheduling problem is chosen as the foundation for building this study as it is an inherently distributed and complex real world problem and begs for an urgent solution. As at 1 January 2007, 35,058 Queenslanders were waiting for elective surgery. Of these, 29% had waited longer than a clinically desirable time [3].

Elective surgery at the PA Hospital

The Princess Alexandra hospital in Brisbane offers 21 operating theaters that can be utilised by various departments for emergency and elective surgery. For the process of scheduling, the theatre schedule is divided into AM and PM slots of 3.5 hours each. These slots are allocated to various doctors, departments, trauma or emergency.

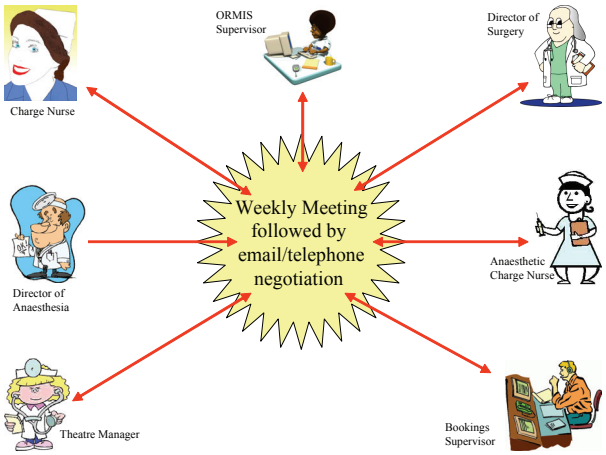

Figure 1- Current scheduling model at PA Hospital

Each department connected with the surgery (i.e. allocating staff or other resources to the surgery) carries out their individual scheduling activity. As elective procedures are booked into the ORMIS[1] (Operating Room Management Information System) system by the bookings department, they become visible to each of the other departments and any rescheduling required because of the nature or demand of the booking is carried out.

Every Thursday, the managers of the different departments meet and review bookings for the week ahead. Each session is discussed and if any of the managers has a problem, they bring it to everyone's notice and a solution is worked out by negotiation. Unexpected emergencies, variation in patients' health state, sudden perturbations in staffing and surgeon availability etc. lead to further changes being

1 http://www.isoftplc.com/corporate/products/2593.asp

required often. However, all changes made to the system after this meeting are dealt with individually by the departments, and resolved on a case-by-case basis using conventional communication such as telephone and emails, or even by face-to-face meetings. In keeping with the dynamics of the domain, the schedule needs to be updated quickly and efficiently. This is often not possible, because of the delays in communicating with the different departments to make the change, and leads to the adoption of an easy but inefficient solution resulting in a bad or compromised schedule.

Methods

Recent advances in the fields of Distributed Constraint Satisfaction (DisCSP) [4] and Multi Agent Technology offer powerful tools including autonomous, intelligent agents for solving complex distributed problems efficiently. "Autonomous agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed" [5]. An intelligent agent also possesses the capability to act without explicit user intervention and to learn and self correct itself. Given the decentralized and highly dynamic nature of hospital decision making, an intelligent agent based approach is a promising paradigm for modelling the environment. Using the DisCSP formalism further provides promising structured and reusable techniques to model complex and distributed problem domains efficiently and to handle the dynamics of the environment.

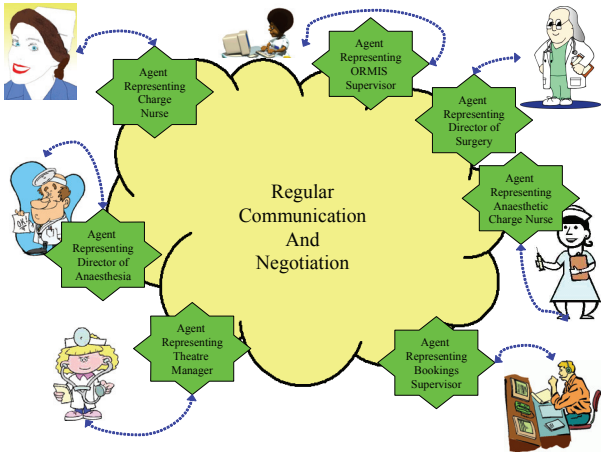

Figure 2- Proposed scheduling model

We are currently developing a methodology where intelligent agents trained with the medical constraints, preferences, priorities etc. of the administrators would carry out scheduling for their respective departments. They would also collaborate with each other to resolve conflicts and align themselves. As changes affect the system, the agents would automatically negotiate to realign themselves. It is proposed that the methodology will allow each unit(agent) to solve their local problem using independent algorithms and then negotiate with each other to maintain global requirements. By translating negotiation requests and strategies to constraints, it will also allow multiple negotiation strategies to be applied within the framework. The system as a whole would be intelligent – learning and self-correcting from user feedback.

We are also building a prototype application using JADE[2] (Java Agent DEvelopment Framework) as a proof of concept and to perform an experimental evaluation of the proposed methodology and its component algorithms. Scheduling process information and data from the case study is being used to construct problems for analysis. These problems, along with the performance data collected, will be used to create suitable benchmarks to further assist evaluation and aid future research.

Conclusion

An approach to intelligent scheduling in complex distributed environments is presented. The proposed method effectively models the distributed domain and uses DisCSP techniques to solve the scheduling problem. We are currently designing efficient scheduling algorithms and an implementation of the concept based on this case study in scheduling elective surgery.

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2 http://jade.tilab.com