Intelligent Scheduling in Complex Dynamic Distributed Environments

Sankalp Khanna[a,b], Abdul Sattar[a], Anthony Maeder[b], Bela Stantic[a]

[a] *Institute for Integrated and Intelligent Systems, Griffith University, Australia.*
[b] *e-Health Research Centre / CSIRO ICT Centre, Australia.*

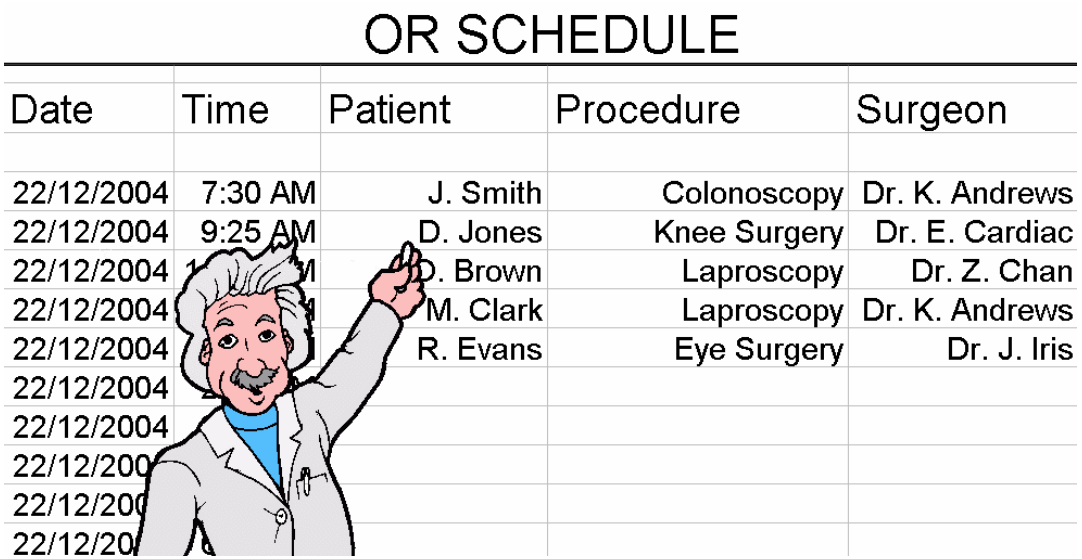
Motivation

"The scheduling problem is far from solved" [1]

"Most existing tools provide only a user-interface for manual roster generation and various facilities to check the validity of the prepared schedules" [2]

"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]

Scheduling



OR SCHEDULE

Date	Time	Patient	Procedure	Surgeon
22/12/2004	7:30 AM	J. Smith	Colonoscopy	Dr. K. Andrews
22/12/2004	9:25 AM	D. Jones	Knee Surgery	Dr. E. Cardiac
22/12/2004	1 M	D. Brown	Laproscopy	Dr. Z. Chan
22/12/2004	4	M. Clark	Laproscopy	Dr. K. Andrews
22/12/2004	1	R. Evans	Eye Surgery	Dr. J. Iris
22/12/2004				
22/12/2004				
22/12/200				
22/12/200				
22/12/20				

- *"Scheduling deals with the temporal assignment of activities to limited resources where a set of constraints has to be regarded" [4]*
- *"Scheduling problems are decidedly complex, combinatorial problems that are in general NP - hard" [5]*

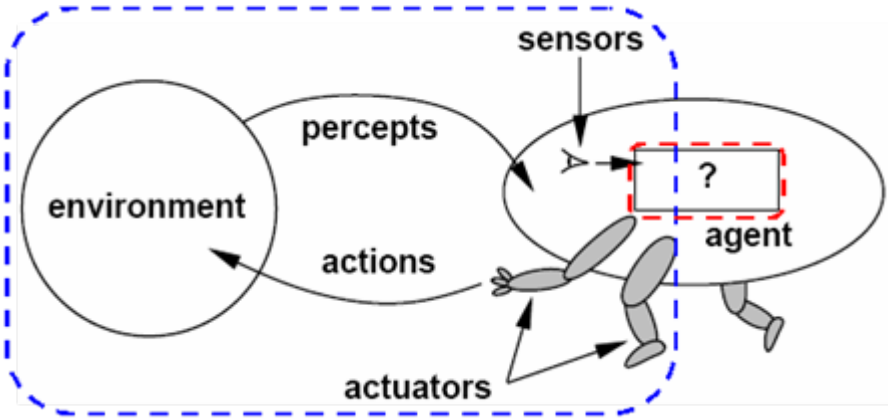
Scheduling for Complex Dynamic Distributed Environments

Problems with current systems [6] :

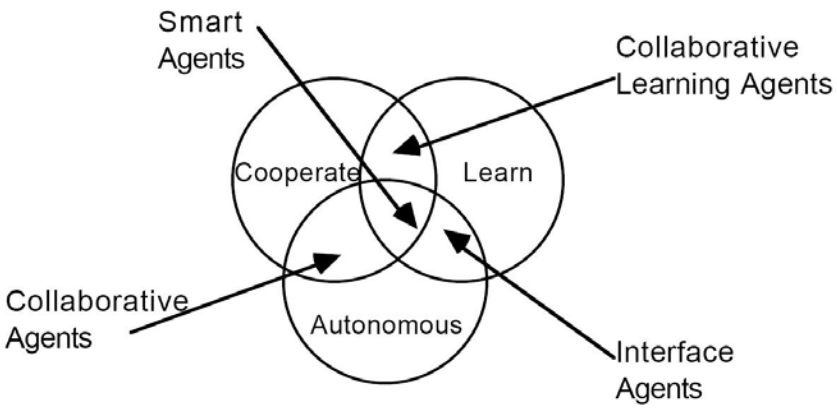
- Do not react well to dynamic environments
- Do not react well to time
- Leave difficult scheduling decisions up to the user of the system
- Are expressively limited – not good for modelling complex system requirements

A complex scheduling environment is one which has a large number of variables, a large number of constraints between them, and multiple, often conflicting, scheduling goals

Understanding Agents



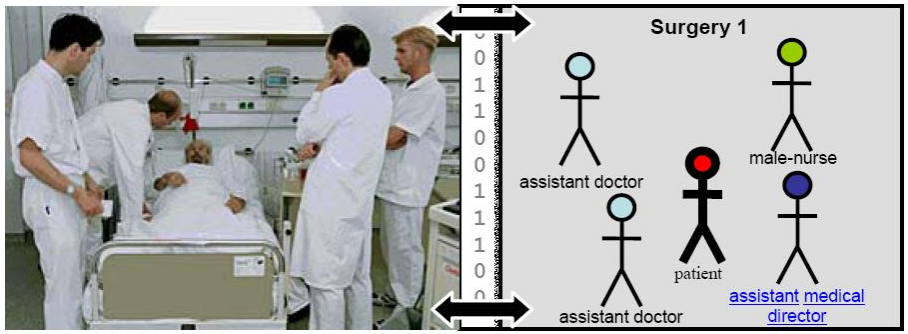
An Agent and its Environment [7]



Nwana's Smart Agent [8]

"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" [9]

Multi Agent Systems

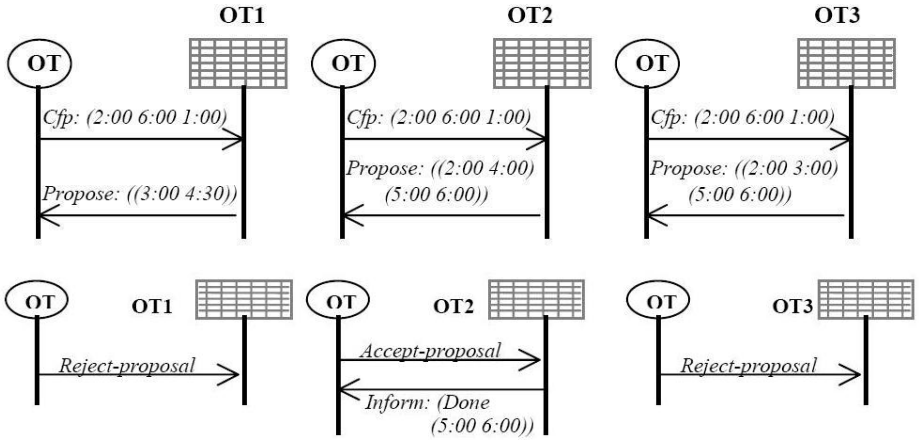


Physical World **Logical World**

Using Agents to Model the Physical World [10]

"A multi-agent system is a system that consists of a number of agents, which interact with each other, typically by exchanging messages through some computer network infrastructure" [11]

"The central problem of multi-agent systems is how to achieve coordinated action among agents in a way yielding problem solving capabilities that exceed those of any individual agent" [12]



The Contract Net Protocol at Work [13]

Distributed Constraint Satisfaction [DisCSP]

DisCSPs offer an excellent framework for modelling and solving complex distributed problems

A DisCSP [14] consists of :

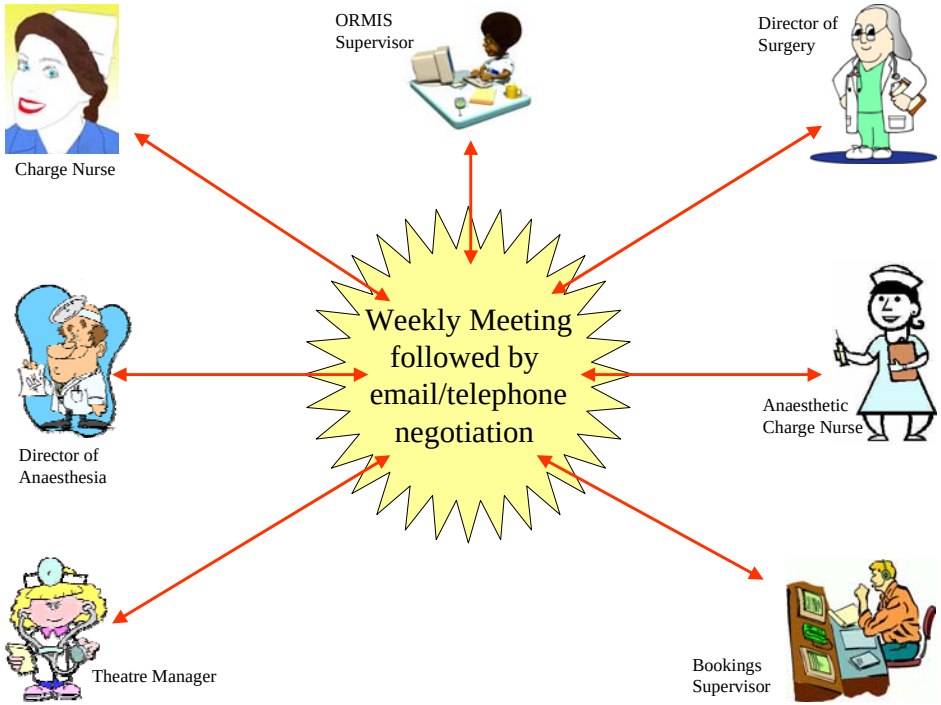
- A finite ordered set of Agents $A = \{A1,A2,A3,\ldots,An \mid n \in Z+\}$
- For each Agent there exists :
  - A finite ordered set of variables $V = \{V1,V2,V3,\ldots,Vn \mid n \in Z+\}$
  - A finite and discrete domain set $D = \{D1,D2,D3,\ldots,Dn\}$
  - An intra-agent constraint set $C = \{C1,C2,\ldots,Cm\}$, $m \in Z+$
  - An inter-agent constraint set $IC=\{IC1,IC2,\ldots,Icm\}$, $m \in Z+$
  - An ordered solution set $S = \{v1,v2,v3,\ldots, vn \mid vi \in Di, \forall i \in [1,m]\}$
- The solution set of the DisCSP is the set of solution sets of each agent

Most current DisCSP efforts at modelling real world complexity however suffer from several limitations

Case Study … PA Hospital, Brisbane

Scheduling Elective Surgery at the PA Hospital

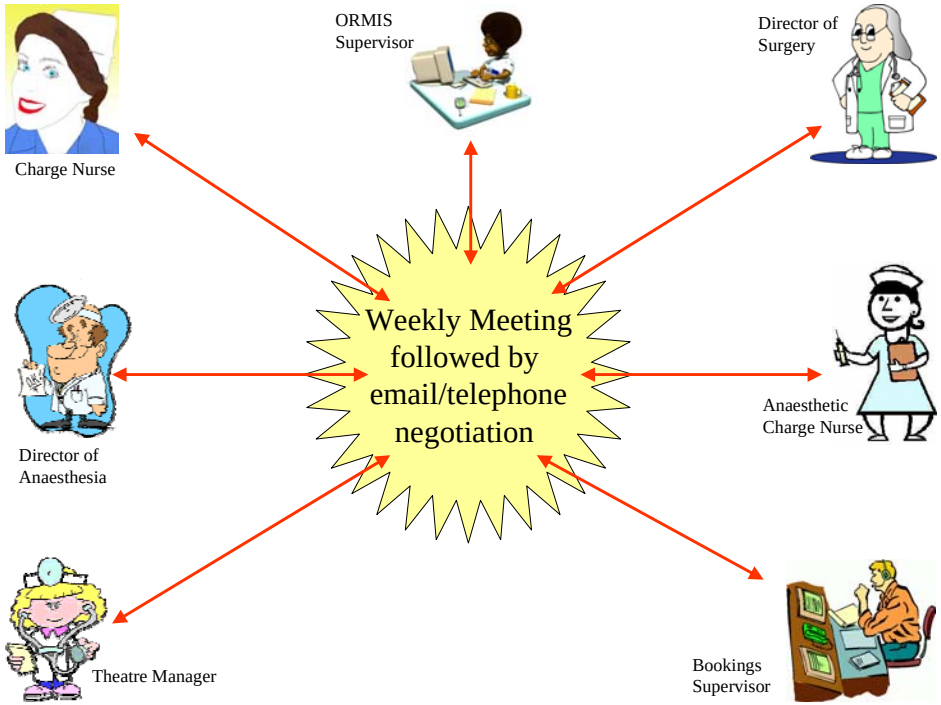
- There are 21 theatres dedicated to Elective Surgery at the PA Hospital
- The Bookings department books patients into the ORMIS system after discussions with surgical teams
- The updated Theatre schedule is posted online everyday at 3pm
- Each Department schedules its own staff/resources while maintaining the requirements of the Theatre schedule
- Every Thursday, the heads of the various departments get together to discuss and coordinate their schedules for the coming week



Case Study … PA Hospital, Brisbane

Scheduling Elective Surgery at the PA Hospital

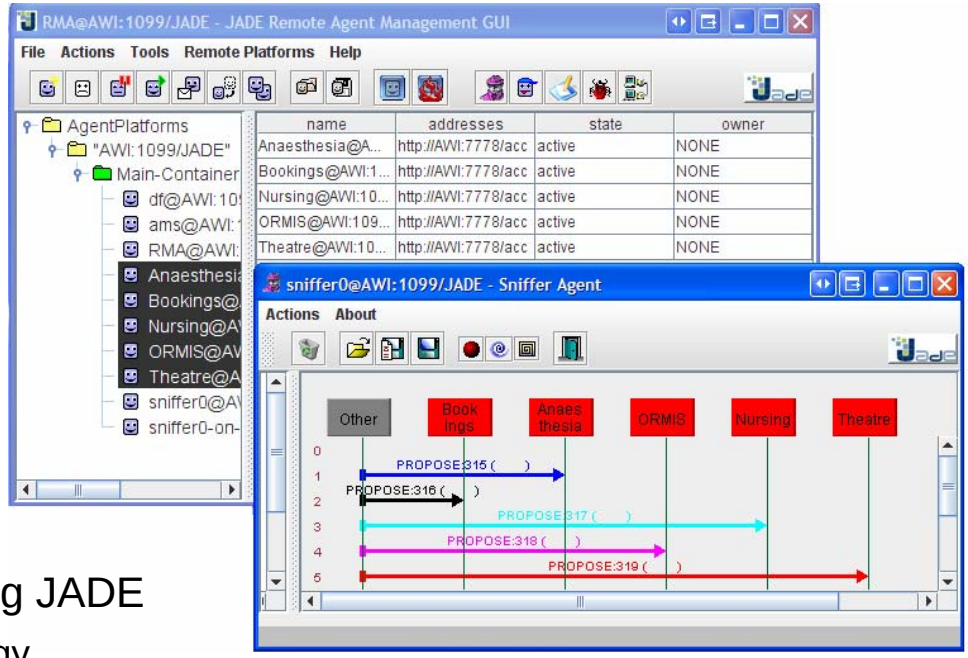
- During the scheduling meeting, conflicts between schedules are manually resolved. At this point, the theatre bookings list is typically 70%~80% complete
- After Thursday, all readjustments and conflicts are resolved on a case-by-case basis using email, phone or in-person communication
- If a conflict cannot be resolved in time, it may lead to the creation of a bad or compromised schedule
- Temporary absence of the domain expert from the scheduling process may also lead to a bad or compromised schedule



Current State of the Project

We are currently developing a methodology that can :

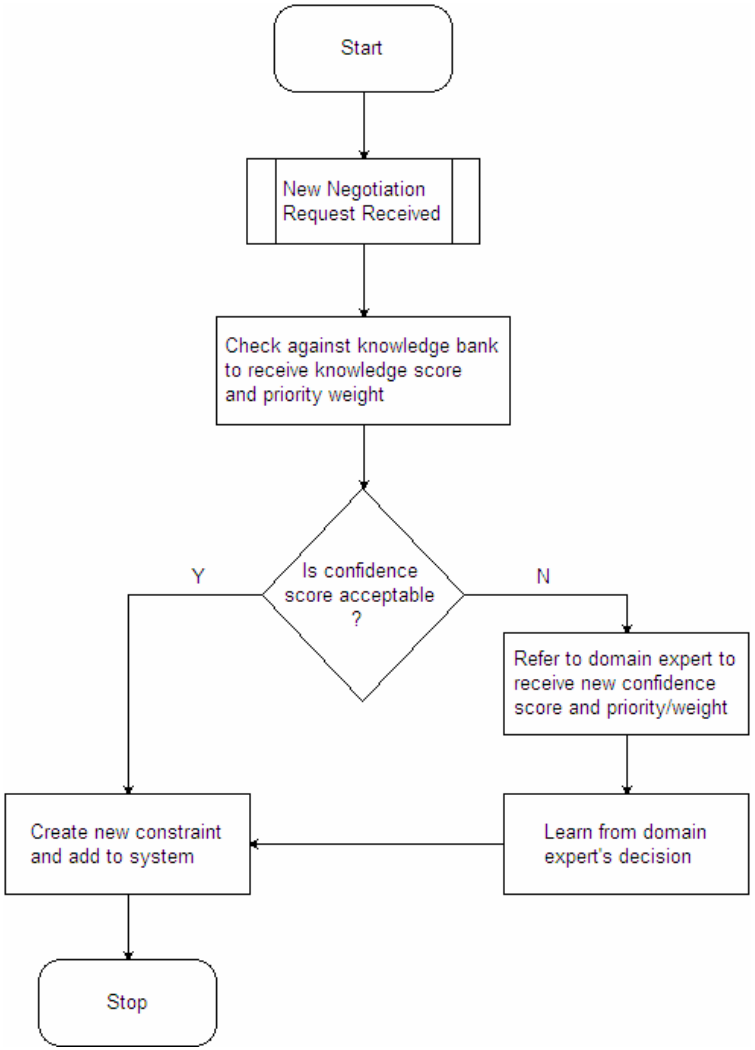
- Handle the inherent complexity
- Incorporate complex negotiation
- Select the solver based on problem characteristics
- Incorporate intelligent decision making
- Learn from user feedback & the decision making process

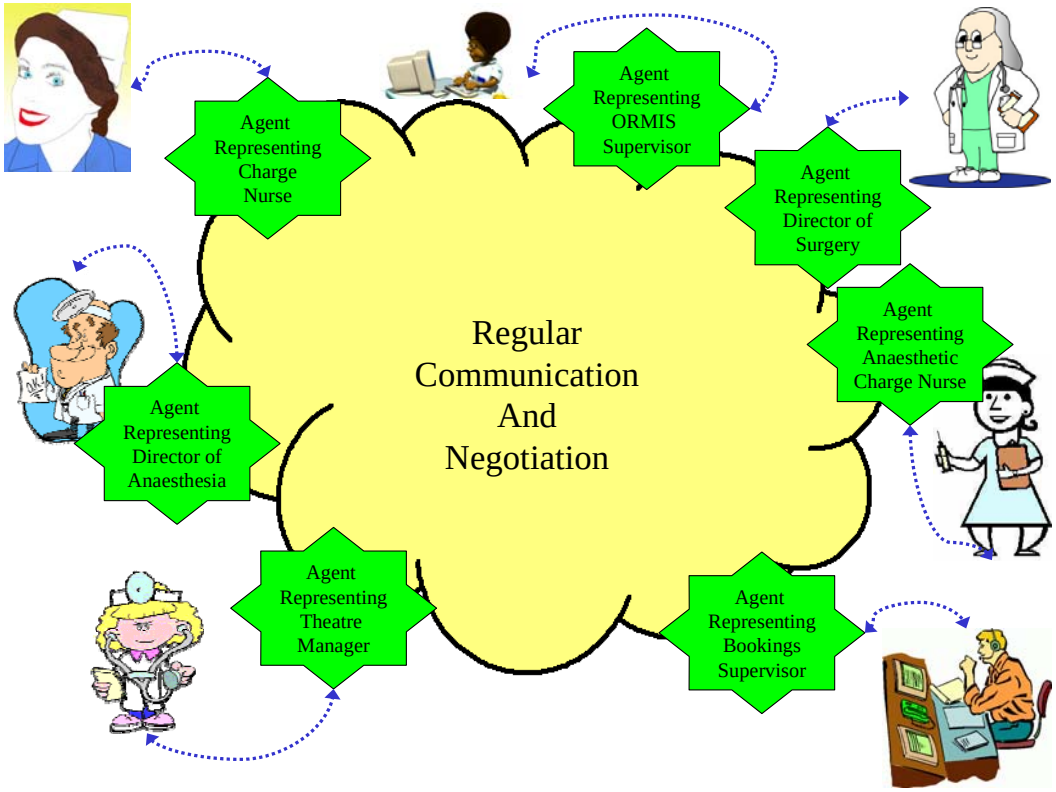


We are also building a prototype system using JADE

- **To Demonstrate :** The developed methodology
- **To Evaluate :** Performance of the methodology
- **To Establish :** Benchmarks that aid future research

Improving Scheduling at the PA Hospital





References

[1] Smith SF. Is Scheduling a Solved Problem? In Petrovic S, Burke E, Kendall G and Gendreau M, eds. Scheduling Theory and Applications: Selected Papers from a International, Multi-disciplinary Conference: Kluwer, 2005; pp. 3-17.

[2] Panchenko A. Preference-based scheduling of operation theatres [Master's thesis]. RWTH Aachen, Germany, 2005 June.

[3] Queensland Health. Elective Surgery Waiting List Report as at 1 January 2007 [online]. 2007 [cited 2007 Feb 28], Available from http://www.health.qld.gov.au/surgical_access/html/reports.asp.

[4] Sauer J. Knowledge-Based Systems in Scheduling. In Leondes CT, ed. Knowledge-Based Systems: Techniques and Applications, Academic Press, San Diego, 2000;4:1293-1325.

[5] Fromherz MPJ. Constraint-based scheduling. American Control Conference (ACC 2001), Arlington, VA, 2001 June.

[6] Prieditis A, Dalal M, and Arcilla A. Simulation-based real-time resource allocation for hospital workflows. International Conference on Health Sciences Simulation, 2004.

[7] Cardoso HL. Integrating JADE and Jess [online]. 2007 March [cited 2007 May 31]. Available from http://jade.tilab.com/doc/tutorials/jade-jess/jade_jess.html.

[8] Nwana HS. Software agents: An overview. Knowledge Engineering Review, 1996;11(3):205-244.

[9] Maes P. Artificial life meets entertainment: lifelike autonomous agents. Communications of the ACM, 1995;38(11):108-114.

[10] Muller G, Eymann T, Nopper N, and Seuken S. Emika system: architecture and prototypic realization. In IEEE International Conference on Systems, Man and Cybernetics, 2004; pp. 5621-5626.

[11] Wooldridge M. Introduction to Multiagent Systems. John Wiley & Sons, Inc., New York, NY, USA. 2002.

[12] Sauer J, and Appelrath H.-J. Scheduling the supply chain by teams of agents. In HICSS '03: Proceedings of the 36th Annual Hawaii International Conference on System Sciences, 2003.

[13] Moreno A, Valls A, and Bocio J. Management of hospital teams for organ transplants using multi-agent systems. In AIME '01: Proceedings of the 8th Conference on AI in Medicine in Europe, London, UK, Springer-Verlag, 2001; pp. 374-383.

[14] Yokoo M, Durfee EH, Ishida T, and Kuwabara K. Distributed constraint satisfaction for formalizing distributed problem solving. In International Conference on Distributed Computing Systems, 1992; pp. 614-621.