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## Autonomous agent negotiation strategies in complex environments

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# Autonomous Agent Negotiation Strategies in Complex Environments

A thesis submitted in fulfillment of the  
requirements for the award of the degree

**Doctor of Philosophy**

from

UNIVERSITY OF WOLLONGONG

by

**Fenghui Ren**

School of Computer Science and Software Engineering  
April 2010

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by

Fenghui Ren

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*Dedicated to  
My family and friends*

# Declaration

This is to certify that the work reported in this thesis was done by the author, unless specified otherwise, and that no part of it has been submitted in a thesis to any other university or similar institution.

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Fenghui Ren  
April 30, 2010

# Abstract

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Autonomous agents are software agents that are self-contained, capable of making independent decisions, and taking actions to satisfy internal goals based upon their perceived environment. Agent negotiation is a means for autonomous agents to communicate and compromise to reach mutually beneficial agreements. By considering the complexity of negotiation environments, agent negotiation can be classified into three levels, which are the *Bilateral Negotiation Level*, the *Multilateral Negotiation Level*, and the *Multiple Related Negotiation Level*.

In the *Bilateral Negotiation Level*, negotiations are performed between only two agents. The challenges on this level are how to predict an opponent's negotiation behavior, and how to reach the optimal negotiation outcome when the negotiation environment becomes open and dynamic. The contribution of this thesis on this level is (1) to propose a regression-based approach to learn, analyze and predict the opponent negotiation behaviors in open and dynamic environments based on the historical records of the current negotiation; and (2) to propose a multi-issue negotiation approach to estimate the opponent's negotiation preference, and to search for the bi-beneficial negotiation outcome when the opponent changes its negotiation strategies dynamically.

In the *Multilateral Negotiation Level*, negotiations are performed among more than two agents. Agents need more efficient negotiation protocols, strategies and approaches to handle outside options as well as competitions. Especially when negotiation environments become open and dynamic, future possible upcoming outside options still need to be considered. The challenge in this level is how to guide agents to efficiently and effectively reach agreements in highly open and dynamic negotiation environments, such as e-marketplaces. The contribution of this thesis on this level is (1) to propose a negotiation partner selection approach to filter out unexpected negotiation opponents before a multilateral negotiation starts; (2) to extend

a market-driven strategy for multilateral single issue negotiation in dynamic environments by considering upcoming changes of the environment; and (3) to propose a market-based strategy for multilateral multi-issue negotiation by considering both markets situations and agents specifications.

In the *Multiple Related Negotiation Level*, several negotiations are processed together by agents in order to achieve a global goal. These negotiations are not absolutely independent, but some how related. In order to ensure the global goal can be efficiently achieved, factors such as the negotiation procedure, the success rate, and the expected utility for each of these related negotiations should be considered. The contribution of this thesis on this level is to introduce a Multi-Negotiation Network (MNN) and a Multi-Negotiation Influence Diagram (MNID) to search for the optimal policy to concurrently conduct the multiple related negotiation by considering both the joint success rate and the joint utility.



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# Publications

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The following is a list of my research papers that have been already published during my PhD study that ends with the completion of this thesis.

## Scholarly Book Chapters

- 1 **Fenghui Ren** and Minjie Zhang, Desire-Based Negotiation in Electronic Marketplaces. In *Post-Proceedings of the Second International Workshop on Agent-based Complex Automated Negotiations (ACAN09), Innovations of Agent-based Complex Automated Negotiations*, (accepted in Jan. 2010), in press.
- 2 John Fulcher, Minjie Zhang, Quan Bai and **Fenghui Ren**, Discovery of Telephone Call Patterns by the use of Intelligent Reasoning. In *K. Nakamatsu (Ed.), Handbook of Intelligent Reasoning*, World Scientific, (accepted in Oct. 2008).
- 3 Mingjie Zhang, Quan Bai, **Fenghui Ren** and John Fulcher, Chapter IV: Collaborative Agents for Complex Problem Solving. In *C. Mumford and L. Jain (Ed.), Computational Intelligence, Collaborative, Fusion and Emergence*, Springer, pp. 361-399, 2009.
- 4 Quan Bai, **Fenghui Ren**, Minjie Zhang and John Fulcher, Chapter 8: CPN-Based State Analysis and Prediction for Multi-Agent Scheduling and Planning. In *T. Ito, M. Zhang, V. Robu, S. Fatima and T. Matsuo (Ed.), Advances in Agent-Based Complex Automated Negotiation, Studies in Computational Intelligence*, Springer, Vol.233, pp. 161-176, 2009.
- 5 **Fenghui Ren** and Minjie Zhang, Chapter 12: The Prediction of Partners' Behaviors in Self-Interested Agents. In *M Yokoo, T. Ito, M. Zhang, J. Lee and T. Matsuo (Ed.), Electronic Commerce: Theory and Practice. Studies in Computational Intelligence*, Springer, Vol. 110, Springer, pp. 157-170, 2008.

## Refereed Journal Articles

- 6 **Fenghui Ren**, Minjie Zhang and Kwang Mong Sim, Adaptive Conceding Strategies for Automated Trading Agents in Dynamic, Open Markets. *Decision Support Systems*, Elsevier, Vol. 46, No. 3, pp. 704-716, 2009.
- 7 Quan Bai, **Fenghui Ren**, Minjie Zhang and John Fulcher, CPN-Based State Analysis and Prediction for Multi-Agent Scheduling and Planning. In *Multi-agent and Grid Systems, International Transactions on Systems Science and Applications*, (accepted in Dec. 2009), in press.
- 8 **Fenghui Ren**, Minjie Zhang and John Fulcher, Expectation on Behaviour of Trading Agent in Negotiation in Electronic Marketplace. *Web Intelligence and Agent Systems: An International Journal*, (accepted in Nov. 2009), in press.
- 9 **Fenghui Ren** and Minjie Zhang, Prediction of Partners Behaviors in Agent Negotiation under Open and Dynamic Environments. In *International Transactions on Systems Science and Applications*, Vol 4, No. 2, pp. 295-304, 2008.
- 10 **Fenghui Ren** and Minjie Zhang, Partners Selection in Multi-Agent Systems by Using Linear and Non-linear Approaches. In *Transactions on Computational Sciences I*, pp. 37-60, 2008.
- 11 **Fenghui Ren**, Minjie Zhang and Jun Yan, An Extended Dual Concern Model for Partner Selection in Multi-agent Systems. In *System and Information Sciences Notes*, Vol 1, No. 2, pp. 153-158, 2007.

## Refereed Conference Papers

- 12 **Fenghui Ren**, Minjie Zhang, Chunyan Miao and Zhiqi Shen, A Market-Based Multi-Issue Negotiation Model Considering Multiple Preferences in Dynamic E-Marketplaces. In *Proceedings of the 12th International Conference on Principles of Practice in Multi-Agent Systems (PRIMA09)*, pp. 1-16, 2009. (**Best Student Paper Award**)
- 13 **Fenghui Ren** and Minjie Zhang, Optimal Multi-Issue Negotiation in Open and Dynamic Environments. In *PRICAI2008: Trends in Artificial Intelligence, Lecture Notes in Artificial Intelligence, LNAI 5351*, pp. 321-332, 2008.

- 14 **Fenghui Ren**, Kwang Mong Sim and Minjie Zhang, Market-Driven Agents with Uncertain and Dynamic Outside Options. In *Proceedings of the Sixth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS07)*, Honolulu, US, pp. 721-723, 2007.
- 15 **Fenghui Ren** and Minjie Zhang, Prediction Partners' Behaviours in Negotiation by Using Regression Analysis. In *Proceedings of the Second International Conference on Knowledge Science, Engineering and Management, Lecture Notes in Artificial Intelligence, LNAI 4798*, Springer, pp. 165-179, 2007, (**Runner-up, Best Student Paper Award**).
- 16 **Fenghui Ren**, Minjie Zhang and Quan Bai, A Fuzzy-Based Approach for Partner Selection in Multi-Agent Systems. In *Proceedings of the Sixth IEEE/ACIS International Conference on Computer and Information Science*, Melbourne, Australia, pp. 457-462, 2007.
- 17 Quan Bai, Minjie Zhang and **Fenghui Ren**, A Colored Petri Net Based Approach for Flexible Agent Interactions. In *Proceedings of the Fourth IEEE International Conference in IT and Application*, Harbin, China, pp. 186-191, 2007.
- 18 **Fenghui Ren** and Minjie Zhang, Prediction of Partners' Behaviors in Agent Negotiation under Open and Dynamic Environments. In *Proceedings of 2007 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology Workshops*, pp. 379-382, 2007.

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