Dynamic Coalition Formation in Iterative Request For Proposal Environments

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1. Objective and Motivation

2. Theoretical Framework

3. Results on Model Analysis
   - Simple Environments
   - Environments with Farsighted Agents
   - Environments with Myopic Agents
   - Environments with Multiple Simultaneous Tasks

4. Conclusions
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4. Conclusions
Limitations on Automated Negotiation

- Negotiations of commodities
- Auction design
- Bundle negotiations
• Reverse Auction (RFQ)
• Contract Net (CNET)
• Request For Proposal (RFP)
Limitations on RFP Research Environments

- Limited to simple task allocation scenarios
- Dynamic aspects of negotiation are usually ignored
- Usually focuses on communicational aspects
- Consider individual bids instead of joint proposals
Coalition Formation

- **Coalition Formation organizational paradigm**
  - Solving optimization problem of each coalition
  - Dividing the value of the generated solution
  - Coalition structure generation

- **Dynamic Coalition formation**
  - Assuming a series of negotiation between agents
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Theoretical Framework

• Aspects to consider in the model
  • Dynamism
  • Amount of information
  • Heterogeneity
  • Topology
  • Simultaneity
The General Model

- **Tasks** \( T = \langle T^1, T^2, \ldots, T^k \rangle \)
- **Agents** \( \sigma_{il} = \langle \sigma_{i1}^1, \sigma_{i2}^2, \ldots, \sigma_{ik}^k \rangle \)
- **Coalitions** \( \sigma = \{ \sigma_1, \sigma_2, \ldots, \sigma_w \} \)
- **Aggregated skills** \( \hat{\sigma}_i = \langle \sigma_{i1}^1, \sigma_{i2}^2, \ldots, \sigma_{ik}^k \rangle \) \( \sigma_{i}^l = \max(\sigma_{ij}^l) : 1 \leq j \leq m \)
- **Quantitative value** \( \text{scr}(\sigma_x, T) = \sum_{j=0}^{k} (\sigma_{x}^j * T^j) \)
- **Rank** \( \text{rank}(\sigma_x, \sigma) \rightarrow \mathbb{R} \)
- **Payment** \( \text{pay}(\sigma_x, \sigma) = \begin{cases} Mx/2^{\text{rank}^*(\sigma_x, \sigma)-1}, & \text{if } \exists \sigma_y : \text{scr}(\sigma_x, T) \geq \text{scr}(\sigma_y, T) \\ Mx/2^{\text{rank}^*(\sigma_x, \sigma)-2}, & \text{if } (\forall y : y \neq x) : \text{scr}(\sigma_y, T) > \text{scr}(\sigma_x, T) \end{cases} \)
**Agents actions**

- **Stay**
- **Leave**
- **Leave - Join - [replace]**

\[
\psi_i = \langle (\sigma x, \phi_{xy}), \ldots, (\sigma w, \phi_{wz}) \rangle
\]
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03 Model Analysis

Simple Environments

- **Reduced Strategic Set**
  - Stay
  - Stay if all Stay
  - Stay if Win
  - Stay if Win-2
  - Leave
  - Random
• **System Performance in isolation**
• **Individual Performance in Mixed Populations**
Simple Environments

- Adapting using indicators

\[
\text{Leave}(X, Y, \Delta) = (Y - X) > \Delta
\]

- \[V_x^{t+1}(y) = \begin{cases} 
V_x^t(y) + R^+, & \text{if } V_x(y) + R^+ < \text{MaxValue} \\
V_x^t(y), & \text{if } V_x(y) + R^+ \geq \text{MaxValue} 
\end{cases} \]

- \[V_x^{t+1}(z \neq y) = \begin{cases} 
V_x^t(z) - (R^+/\text{(n - 1)}), & \text{if } V_x(y) + R^+ < \text{MaxValue} \\
V_x^t(z), & \forall z \text{ if } V_x(y) + R^+ \geq \text{MaxValue} 
\end{cases} \]

- LMA: Local Memory Agents
- GMA: Global Memory Agents
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Environments With Farsighted Agents

- **Tasks**
  \[ T = \langle T^1, T^2, \ldots, T^k \rangle \]

- **Agents**
  \[ \sigma_{il} = \langle \sigma_{i1}^1, \sigma_{i2}^2, \ldots, \sigma_{ik}^k \rangle \]

- **Coalitions**
  \[ \sigma = \{ \sigma_1, \sigma_2, \ldots, \sigma_w \} \]

- **Aggregated skills**
  \[ \hat{\sigma}_i = \langle \sigma_{i1}^1, \sigma_{i2}^2, \ldots, \sigma_{ik}^k \rangle \]

- **Quantitative value**
  \[ \text{scr}(\sigma_x, T) = \sum_{j=0}^{k} (\sigma_x^j \ast T^j) \]

- **Rank**
  \[ \text{rank}(\sigma_x, \sigma) \rightarrow \mathbb{R} \]

- **Payment**
  \[
  \text{pay}(\sigma_x, \sigma) = \begin{cases} 
    \frac{Mx}{2^{\text{rank}(\sigma_x, \theta) - 1}}, & \text{if } \exists \sigma_y : \text{scr}(\sigma_x, T) \geq \text{scr}(\sigma_y, T) \\
    \frac{Mx}{2^{\text{rank}(\sigma_y, \sigma) - 2}}, & \text{if } (\forall y : y \neq x) : \text{scr}(\sigma_y, T) > \text{src}(\sigma_x, T) 
  \end{cases}
\]
Theoretical Framework

Environments With Farsighted Agents

- **Tasks** \( T = \langle T^1, T^2, \ldots, T^k \rangle \)
- **Agents** \( \sigma_{i,l} = \langle \sigma_{i,l}^1, \sigma_{i,l}^2, \ldots, \sigma_{i,l}^k \rangle \)
- **Coalitions** \( \sigma = \{ \sigma_1, \sigma_2, \ldots, \sigma_w \} \)
- **Aggregated skills** \( \hat{\sigma}_i = \langle \sigma_{i,1}^i, \sigma_{i,2}^i, \ldots, \sigma_{i,k}^i \rangle \)
  \( \sigma_i^l = \max(\sigma_{ij}^l) : 1 \leq j \leq m \)
- **Quantitative value** \( \text{scr}(\sigma_x, T) = \sum_{j=0}^{k} (\sigma_x^j \times T^j) \) Score Maximizing
- **Rank** \( \text{rank}(\sigma_x, \sigma) \rightarrow \mathbb{R} \)
- **Payment**
  \[ \text{pay}(\sigma_x, \sigma) = \begin{cases} 
  \text{Mx}/2^{\text{rank}(\sigma_x, \sigma) - 1}, & \text{if } \exists \sigma_y : \text{scr}(\sigma_x, T) \geq \text{scr}(\sigma_y, T) \\
  \text{Mx}/2^{\text{rank}(\sigma_x, \sigma) - 2}, & \text{if } (\forall y : y \neq x) : \text{scr}(\sigma_y, T) > \text{scr}(\sigma_x, T) 
\end{cases} \]
Environments With Farsighted Agents

- **Tasks**
  \[ T = \langle T^1, T^2, \ldots, T^k \rangle \]

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  \[ \hat{\sigma}_i = \langle \sigma_{i1}^1, \sigma_{i2}^2, \ldots, \sigma_{ik}^k \rangle \]
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  \frac{Mx}{2^{\text{rank}^\ast(\sigma_x, \sigma) - 2}}, & \text{if } (\forall y : y \neq x) : \text{scr}(\sigma_y, T) > \text{scr}(\sigma_x, T)
  \end{cases} \]
• **Stability Analysis**

• Leading Coalition never reduces its value
• **Equilibrium Analysis**

• Optimal Leading coalition (if coalition size is not limited)
• **Equilibrium Analysis**

• Score Maximizing population converges to an equilibrium
• **Equilibrium Analysis**

• Stability is lost when requirements change
• **Equilibrium Analysis**

• Payoff maximizing systems are suboptimal and unstable
Environments With Farsighted Agents

- **Strategies Comparison**
  - Payoff maximizing systems are suboptimal and unstable
  - Correlation between performance difference and task competitiveness requirements
• **Strategies Comparison**

• **Endogamic Collaboration Structures**
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4. Conclusions
• Different Levels
• Different Levels
Environments With Myopic Agents

- Different Levels
- **Different Levels**

  ![Socially Farsighted](image1) ![Socially Myopic](image2)
Environments With Myopic Agents

- Different Levels

Socially Farsighted

Socially Myopic
03 Model Analysis

Environments With Myopic Agents

- **Different Levels**

Socially Farsighted

\[ SN_I = (V, E) \]

Socially Myopic

\[ SN_{\sigma_{ij}} = V \]
• **Effect of social network topologies in performance and individuals in key regions**

• **Agent Competitiveness**
  - Competitive
  - Versatile

• **Social Networks placement**
  - Degree Centrality
  - Betweenness Centrality
Experiments With Myopic Agents

- Effect of social network topologies in performance and individuals in key regions

![Graph showing social network topologies and suboptimality degree](image)

\[
Sc(\sigma) = \sum_{\text{rank}=0}^{p} (\text{scr}(\sigma_{\text{rank}}, T) \times 1/2^{\text{rank}})
\]

\[
\text{Sub} = Sc(\sigma^+) - Sc(\sigma)
\]
Effect of social network topologies in performance and individuals in key regions

HAD Metric

\[ \text{HAD}(\sigma_{xy}, \sigma_{xj}) \rightarrow N \]
\[ (\text{HAD}(\sigma_{xy}, \sigma_{xj}) = 1) \Leftrightarrow ((\sigma_{xj}, \sigma_{xj}) \in E) \]
\[ \text{HAD}(\sigma_{xy}, \sigma_{xk}) = 1 + d_{\text{HAD}}(\sigma_{xj}, \sigma_{xk}) \]
Environments With Myopic Agents

- Effect of social network topologies in performance and individuals in key regions
- Degree centrality
• Different Levels

Farsighted Social Environments

Myopic Social Environments
Different Levels

Farsighted Social Environments

Myopic Social Environments
Environments With Myopic Agents

- **Social Adaptation Mechanisms**
  - Which events trigger adaptation?
  - Which agents are reinforced?
  - What is the reinforcement value applied?

\[
PL_{\sigma_{wz}} = \langle \sigma_{ab}, \sigma_{cd}, \ldots, \sigma_{xy} >
\]

\[
PL_{\sigma_{wz}}(x) \cdot Reinf \rightarrow \mathbb{R}
\]
• Social Adaptation Mechanisms
  • R - Random
  • K - Progressive
  • M - Selective
  • P - Selective with control
- **Social Adaptation Mechanisms**

- **P - Selective With Control**

\[ P^I = \text{sort}(P, PL) \]

*comment: Sort the partners by decreasing order of reinforcement in the priority list*

\[ \text{CounterReinf} = 0 \]

*for each* \( p \in P^I \)

\[
\begin{align*}
\text{cr} &= p.\text{Reinf} + R \\
\text{if } \text{cr} &\leq PL(\alpha).\text{Reinf} \\
\text{then } p.\text{Reinf} &= p.\text{Reinf} + R \\
\text{do } \begin{cases} \\
\text{if } \text{CounterReinf} < \text{MaxReinf} \\
\text{else } \begin{cases} \\
\text{then } p.\text{Reinf} &= p.\text{Reinf} + R \\
\text{CounterReinf} &= \text{CounterReinf} + 1 \\
\end{cases} \\
\end{cases}
\end{align*}
\]
Environments With Myopic Agents

- Social Adaptation Mechanisms
- Performance Comparison
Environments With Myopic Agents

- Social Adaptation Mechanisms
- Social Network Analysis

![Graphs showing trends in average distance and clustering coefficient over runs for different models.](image)
Environments With Myopic Agents

- Social Adaptation Mechanisms
- Social Network Analysis
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Environments With Multiple Simultaneous Tasks

- Farsighted Social Environments
- Myopic Static Social Environments
- Myopic Dynamic Social Environments
- Multiple Simultaneous Request Environments
Environments With Multiple Simultaneous Tasks

- **Intra Market Strategy**
  - Score Maximizing

- **Inter Market Strategy**
  - S - Score
  - R - Ranking
  - RSz - Ranking + Size
• **Stability Analysis**
  
  • S, R. Converge
  
  • RSz. Does not necessarily converge
Performance Comparison Between Strategies

Variables studied
- Strategies
- Requests similarities
- Social network density
• **Performance Comparison Between Strategies**

• **Connection effect**

(g) S, NI , Minimal  
(h) R, NI , Minimal  
(i) RSz, NI , Minimal
03 Model Analysis

Environments With Multiple Simultaneous Tasks

- Performance Comparison Between Strategies
- Strategy effect

(a) S, NI, Farsighted
(b) R, NI, Farsighted
(c) RSz, NI, Farsighted
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General Conclusions

- It is possible to negotiate complex tasks using an iterative RFP protocol and a coalition formation mechanism.

- Agents can effectively negotiate complex tasks under the basis of incomplete data and incomplete social sight.

- Social structures can be considered in large scale negotiation models, for being exploited by effective adaptation mechanism.
Future Work

- Continuous negotiation instead of episodic
- Overlapping coalitions
- Dynamic capabilities
- Idiosyncratic choices
- Complete characterization of multiple market environments
- Application of the model to solve problems
Thank you for your attention.
Environments With Myopic Agents

(a) Social network

(b) Initial partition
Environments With Myopic Agents

(a) Social network

(b) Initial partition

(c) A5 joins A4’s coalition
Environments With Myopic Agents

(a) Social network
(b) Initial partition
(c) A5 joins A4’s coalition
(d) A3 joins A4’s coalition
Environments With Myopic Agents

(a) Social network
(b) Initial partition
(c) A5 joins A4’s coalition
(d) A3 joins A4’s coalition
(e) A1 joins A2’s coalition
(f) A6 joins A2’s coalition
(g) A2 joins A3’s coalition
Environments With Myopic Agents

(a) Social network
(b) Initial partition
(c) A5 joins A4’s coalition
(d) A3 joins A4’s coalition
(e) A1 joins A2’s coalition
(f) A6 joins A2’s coalition
(g) A2 joins A3’s coalition
(h) social net & coalitions
Publications


• MERIDA-CAMPOS, C., AND WILLMOTT, S. Stable coalitions under different demand conditions in iterative request for proposal environments. International Transactions on Systems Science and Applications 4, 2 (2008), 194–204.

Conclusions

Contributions

• An iterated RFP market type protocol that lets agents create coalitions dynamically to address complex tasks

• A social network based model to capture agent information limitations in RFP and coalition formation systems

• A successful adaptive strategy for agents to participate in large scale markets

• Graph based analysis techniques to analyze coalition formation model outcomes

• A metric on the exploitation of a social network that measures the historical average degree

• An application of the studied model in the context of Future Internet Networks