Effect of referrals on convergence to satisficing distributions

Presentation based on paper:
T. Candale & S. Sen, “Effect of referrals on convergence to satisficing distributions,”
In AAMAS '05 Proceedings, pp. 347-354, ACM Press, NY, 2005

Software Agents (ELG6113), Fall Term 2005, Dr. Babak Esfandiari

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November 22, 2005
Motivation

- Provide a framework where agents locate high-quality service providers by using referrals from peer agents.

- Develop strategies by which a system of autonomous agents can quickly reach a stable configuration where all agents are satisfied with their choice of current providers.
Problem

- Location of high quality services
  - Unlimited resources assumed
  - The cost of referral is generally assumed to be negligible
  - Higher rate:
    - indirect measure of a good quality of service
    - no decrease in response time

- Load balancing
  - Limited resources
  - The cost of referral is typically non-negligible
  - Higher rate:
    - indirect measure of a poor quality of service
    - decrease in response time
Possible Approaches

• Maximize
  • Maximizing the agent’s utility function
  • Myopic, self-interested behavior, can lead to poor performance of the individual and system-wide instability

• Optimize
  • Maximizing the overall system utility function
  • A complex problem and a large area of research

• Satisficing
  • Maximizing overall system utility function while introducing a satisfaction threshold (accepting imprecision)
Satisfice

• “The word satisfice was coined by Herbert Simon in 1957. Simon says that people are only ‘rational enough’, and in fact relax their rationality when it is no longer required. This is called bounded rationality.” - Wikipedia

• “Boundedly rational agents experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information” - Herbert Simon
Concepts

- **Environment** \( (\mathcal{A}, \mathcal{R}, f, perf, L, S, \Gamma) \)
  
  \( \mathcal{A} \) - set of \( K \) agents
  
  \( \mathcal{R} \) - set of \( N \) providers
  
  \( f \) - intrinsic performance (quality) of a provider
  
  \( L \) - load function for the agent
  
  \( perf \) - provided performance of a provider given a load \( L \)
  
  \( S \) - satisfaction function of agents given a \( perf \)
  
  \( \Gamma \) - the set of satisfaction thresholds representing aspiration levels of agents
**Concepts**

- **Definitions:**
  - $C_n$ - capacity of provider $R_n$
  - $D$ - distributions of agents over providers
  - $D_{\Gamma}$ - acceptable distribution, every agent receives a satisfaction above their threshold
  - $\mathcal{E}(D)$ - entropy of a distribution $D$
    \[ \mathcal{E}(D) = \sum_{N} \max (0, | A_n | - C_n) \]
  - $K_{\text{move}}$ - number of agents that can move to a different provider
  - $K_{\text{wm}}$ - number of agents inclined to move (not satisfied)
Concepts

Referral based provider selection:

- NR - Agents that find the provider without referrals, using only their own experience.
- RT - Agents may help each other by giving referrals. Agents are assumed to be helpful (referring only the best providers in their estimate). They are also assumed to be truthful.
- RD - Same as RT, except the agents are not truthful. They refer to the same provider but alter the true estimation.
Propositions

• Reducing $K_{\text{move}}$ has a beneficial effect on the entropy of the system:

$$\varepsilon(D^{d+1}) \in \left[ \max(0, \varepsilon(D^d) - K^d_{\text{move}}), \varepsilon(D^d) + K^d_{\text{move}} \right]$$

• Considering an environment where $C_n = K/N$, the number of agents inclined to move $K^d_{\text{wm}}$ is in the range:

$$K^d_{\text{wm}} \in \left[ S(D) + K/N, S(D) (K/N + 1) \right]$$

• Lower bound $N^*$ for the stable system with $D_G$
  • Zone I $N < N^*$
  • Zone II $N \geq N^*$
System Convergence

- Inertia of the system
  - An inverse function of the number of agents moving

- Influence of inertia
  - The more agents move, the more unstable the system becomes
  - System stability is important for the convergence

- Exploration
  - Agents have to move to different providers in order to learn about the quality of service
Experiment 1 - Assumptions

- Uniform provider capacities
- 200 agents with a satisfaction threshold of 0.7
- Each day (iteration cycle) an agent is assigned a task with a load of 1
Experiment 1 - Results

Examples of evolution of $K^d_{move}$ and $\mathcal{E}(D^d)$ in Zones I (left) and II (right)
## Experiment 1 - Results

<table>
<thead>
<tr>
<th>N</th>
<th>NR</th>
<th>RT</th>
<th>RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>2206.529</td>
<td>1578.863</td>
<td>1867.706</td>
</tr>
<tr>
<td>100</td>
<td>624.588</td>
<td>454.510</td>
<td>558.078</td>
</tr>
<tr>
<td>40</td>
<td>167.647</td>
<td>3002.059</td>
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<tr>
<td>20</td>
<td>3624.647</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>10</td>
<td>3879.471</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Average number of iterations to reach convergence
Experiment 1 - Observations

• Direct:
  - Results confirm prediction of lower bound $N^*$
  - Performance in Zone II is better than in Zone I
  - In Zone II, RT is faster than RD, which is faster than NR
  - NR is more robust for a larger range of environments

• Derived:
  While the use of referrals from truthful agents can speed up system convergence to satisfactory distributions, such knowledge sharing can also increase system entropy and slow down convergence with a relatively small number of providers in the environment
Experiment 2 - Assumptions

- Non-uniform provider capacities
- 200 agents with a satisfaction threshold of 0.7
- Each day (iteration cycle) an agent is assigned a task with a load of 1
Experiment 2 - Results

\[ K_{\text{move}}^d \quad \text{and} \quad S(D^d) \quad \text{for NR (left) and RT (right) for } N = 40 \]
## Experiment 2 - Results

<table>
<thead>
<tr>
<th># providers with capacity:</th>
<th>NR</th>
<th>RT</th>
<th>RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td>2059.608</td>
<td>834.137</td>
</tr>
<tr>
<td>1</td>
<td>300.235</td>
<td>229.882</td>
<td>271.725</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Average number of iterations to reach convergence
Experiment 2 - Observations

- As in the previous experiment, convergence of NR is slower than that of RD, which is slower than that of RT.
- When the number of providers with high capacity is increased, all strategies perform better.
Summary

• Conclusions
  • Referrals might incur a long-term cost by referring their preferred providers (Zone I); Faster convergence when using referrals to help satisfy other agents (Zone II)
  • The relationship between entropy and the number of moving agents are key characteristics underlying system convergence
  • Exploration should be limited to improve convergence rate

• Further research:
  • Agents learning about the entropy of the system and applying different strategies
  • Modeling capacities below $K/N$ (under-served)
  • Modeling agent and provider starvation effects
References


