University of Ottawa
School of Information Technology and Engineering

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

Vladimir Hinić, vhinic@ieee.org
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, Γ)

$\mathcal{A}$ - 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 $perf$

Γ - the set of satisfaction thresholds representing aspiration levels of agents

Concepts

- Definitions:

C_n - capacity of provider $\mathcal{R}_n$

D - distributions of agents over providers

D_Γ - acceptable distribution,
every agent receives a satisfaction above their threshold

$\mathcal{E}(D)$ - entropy of a distribution D

$$\mathcal{E}(D) = \sum_N max\left(0, \mid \mathcal{A}_n \mid - C_n\right)$$

K_{move} - number of agents that can move to a different provider

K_{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_{move} has a beneficial effect on the entropy of the system:

  $$\mathcal{E}(D^{d+1}) \in [max(0, \mathcal{E}(D^d) - K^d_{move}),\ \mathcal{E}(D^d) + K^d_{move}]$$

- Considering an environment where $C_n = K/N$, the number of agents inclined to move K_{wm} is in the range:

  $$K_{wm} \in [S(D) + \mathrm{K/N}, S(D)\,(\mathrm{K/N} + 1)]$$

- Lower bound N^* for the stable system with D_Γ
  - Zone I $\mathrm{N} < N^*$
  - Zone II $\mathrm{N} \geq N^*$

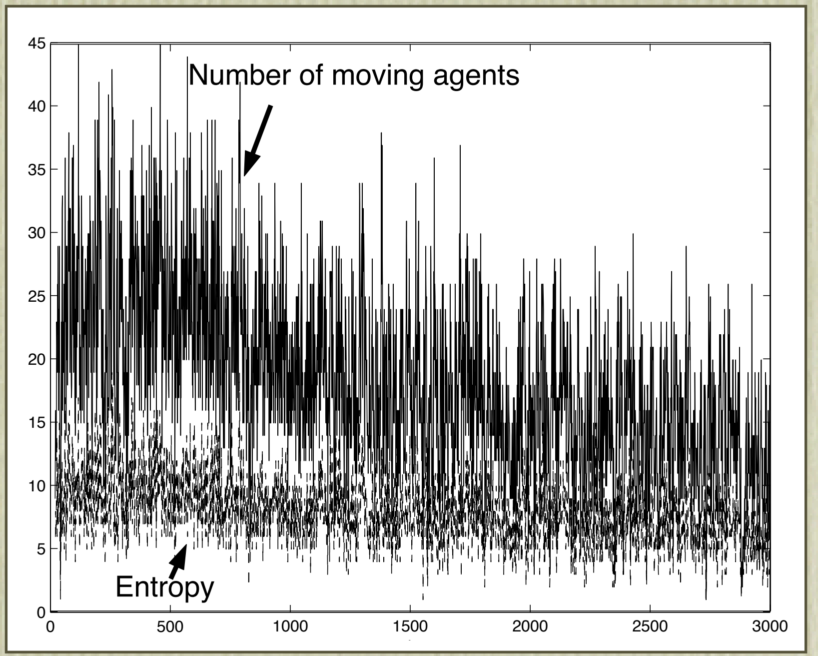
System Convergence

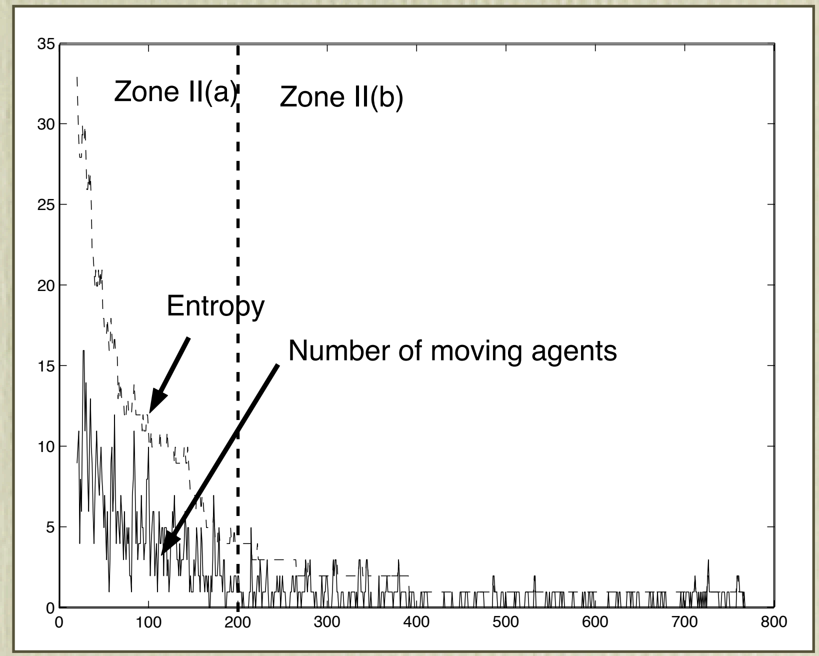
- Inertia of the system
  - An inverse function of the number of agents moving
- Influence of inertia
  - The more agents move, the more unstable the system becomes
  - System stability is important for the convergence
- Exploration
  - Agents have to move to different providers in order to learn about 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

N	*NR*	*RT*	*RD*
200	*2206.529*	*1578.863*	*1867.706*
100	*624.588*	*454.510*	*558.078*
40	*167.647*	*3002.059*	*n/a*
20	*3624.647*	*n/a*	*n/a*
10	*3879.471*	*n/a*	*n/a*

Average number of iterations to reach convergence

Experiment 1 - Observations

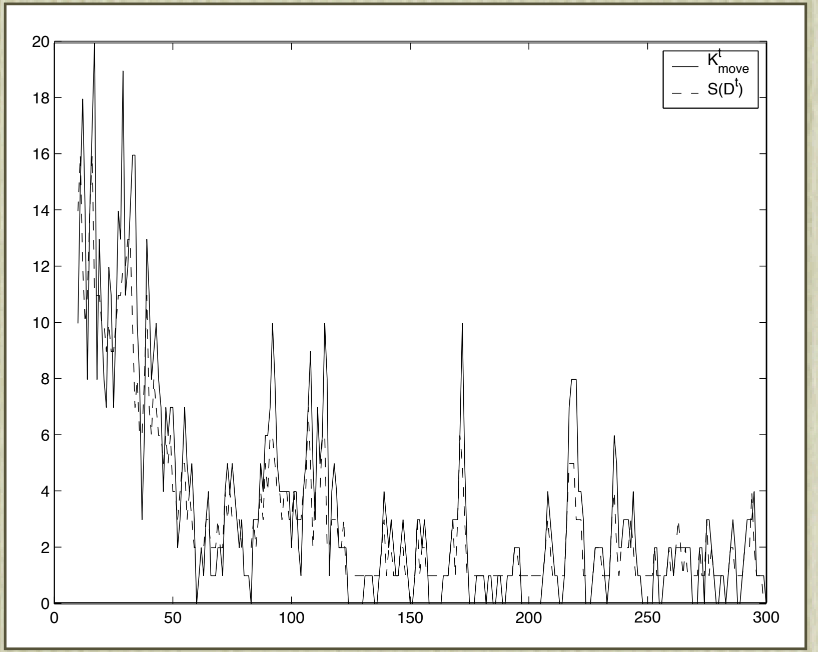
- Direct:
  - Results confirm prediction of lower bound N^*
  - Performance in Zone II is better than in Zone I
  - In Zone II, RT is faster than RD, which is faster than NR
  - NR is more robust for a larger range of environments
- Derived:

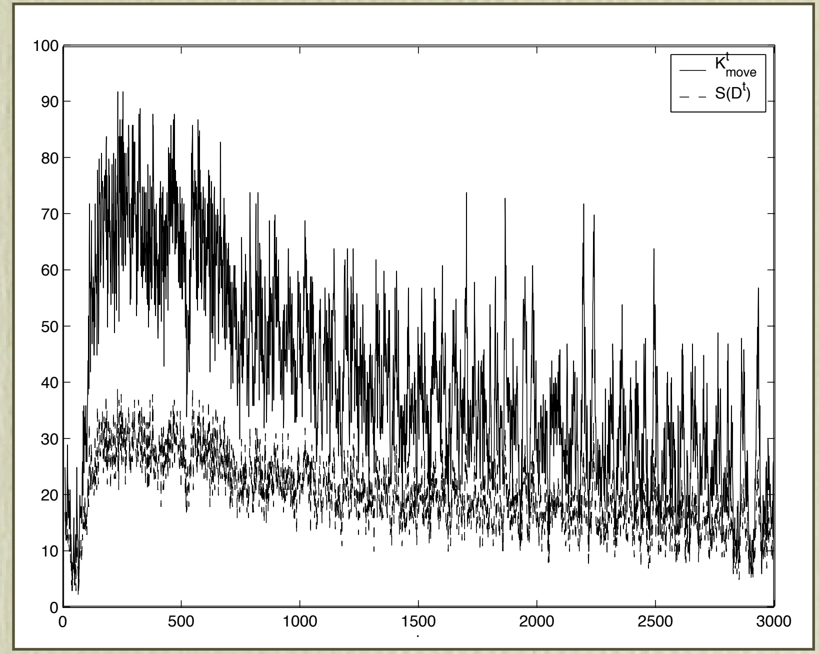
  While the use of referrals from truthful agents can speed up system convergence to satisfactory distributions, such knowledge sharing can also increase system entropy and slow down convergence with a relatively small number of providers in the environment

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^d_{move} and $S(D^d)$ for *NR* (left) and *RT* (right) for $N = 40$

Experiment 2 - Results

# providers with capacity:		NR	RT	RD
20	2			
1	90	1059.608	834.137	1028.177
50	50	300.235	229.882	271.725

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 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

- T. Candale & S. Sen, "Effect of referrals on convergence to satisficing distributions," In AAMAS '05 Proceedings, pp. 347-354, ACM Press, NY, 2005
- G. Weiss (ed.), "Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence," The MIT Press, Cambridge, Massachusetts, 2001
- H. A. Simon, "Rational Decision-Making in Business Organizations, " Nobel Memorial Lecture, 8 December, 1978
- Wikipedia, the Free Encyclopedia, http://en.wikipedia.org