Multi-agent Dynamical Systems with Reinforcement Learning

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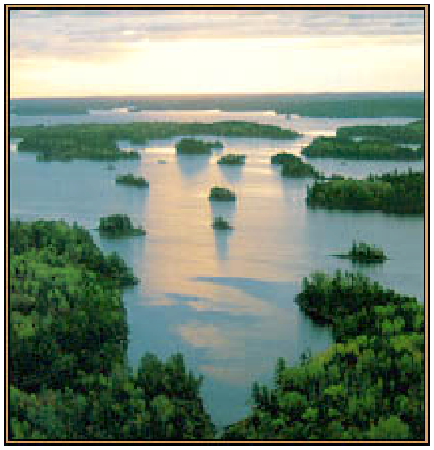
The Problem:



In the World: Ducks, Food, and 10,000 Lakes

- Robots and Blocks

In the Abstract: Dynamical Reconstruction = Learning

- Types of Information Captured in Particular Learning Constructions

- Long Term Versus Short Term Reconstruction

- Practical Training - Is the Most General Always the Most Representative or Easiest to Train

The World: Basic Components of a Reinforcement Learning Scheme

- Agent: the learner and action/decision maker (duck)
- Environment: everything that the agent interacts with, including all other agents in the population (other ducks + ponds)
- Action: an action taken by an agent, chosen from the set of all possible actions posed by the environment (selection of a pond)
- Rewards: a set of values, including positive, negative, and zero values, that an agent receives upon each action taken (a full or empty duck belly)
- Population: the set of all agents in the collective environment (all the ducks)

Multi-Agent Systems with Replicator Equations

"Memory versus Sensory Input"

$$\frac{\dot{x}_i^n}{x_i^n} = \beta_n[R_i^n - \sum_{j=1}^{M} x_j^n R_j^n] + \alpha_n I(x_i^n) \qquad (1)$$

Variables

- $n = 1, ..., N$ indexes the agents in the population
- $i = 1, ..., M$ indexes the choices(actions) possible by each agent
- R_i^n is the reward (punishment) agent n receives for choosing action i
- α_n is the memory constant for agent n (controls memory decay)
- β_n is the learning constant for agent n
- x_i^n is the probability of agent n choosing action i
- $I(x_i^n) = \sum_{j=1}^{M} x_j^n \log(\frac{x_j^n}{x_i^n})$

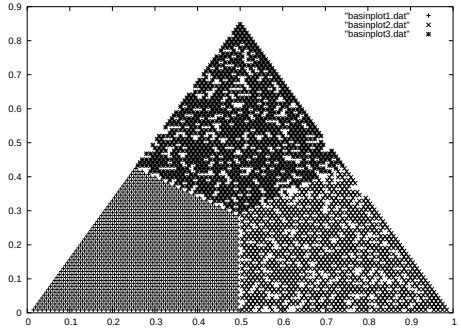
Multiple Agent Servicing Multiple Tasks

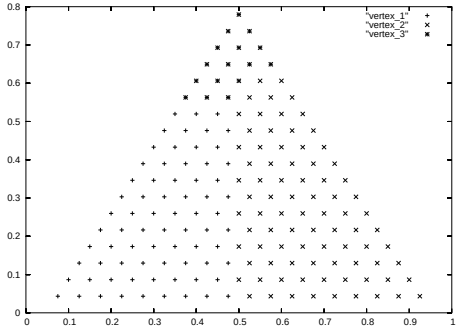
Three Schemes:

- Lone Ranger: $R_i^n(t) = (x_i^n - \gamma)$ $(\gamma = \frac{1}{M})$
  - Ignore All Other Agents
  - Ignore Sites "Unknown" Sites
- Fashion Agent: $R_i^n(t) = (x_i^n - \frac{1}{N-1}\sum_{k=1,k\neq i}^{M} x_k^n)$
  - Follow (or Act Contrary) to the Crowd
  - Ignore Sites "Unknown" Sites
- Fashion Agent with a Conscience: $R_i^n(t) = [\sigma_i - v_i^n(t)][x_i^n(t) - \sigma_i]$ ($\sigma_i =$ desired service rate for site i)
  - Avoid Overpopulated Locations
  - "All Seeing"

Two Preliminary Results

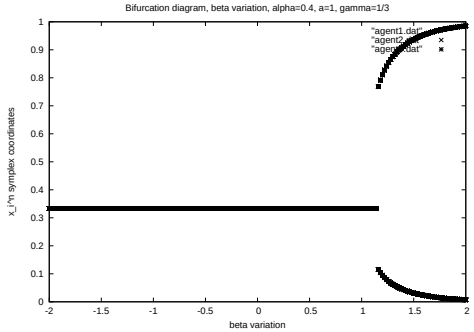
Basins of Attraction

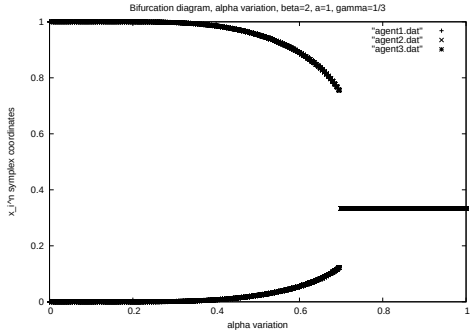




Basin of Attraction Figures with 3 Sites Lone Ranger (left) and Fashion (right)

Memory versus Sensory Input





Bifurcation diagrams for β ($\alpha = 0.4$, $a = 1$, $\gamma = 1/3$) and α ($\beta = 2$, $\gamma = 1/3$), 3 agents, 4 sites

Final Remarks

Why Do You Care?

Framework for Understanding Group Dynamics

Geometrical Understanding of Learning Schemes

A New Framework for Interpretation of Learning Dynamics

Future Directions

Time Dependent Service Rates (σ)

Introduction of Spatial Dependence

Other Reward Schemes

Bifurcation Theory (Center Manifold Analysis)

Hopes and Dreams

Introduction of More Complicated Agents

- Understand Differences and Similarities Between Representations
- Allow for a Better Understanding of Information Storage