Emergence of Convention through Social Learning

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Introduction

- Norms
- Conformity
- Norms as equilibrium

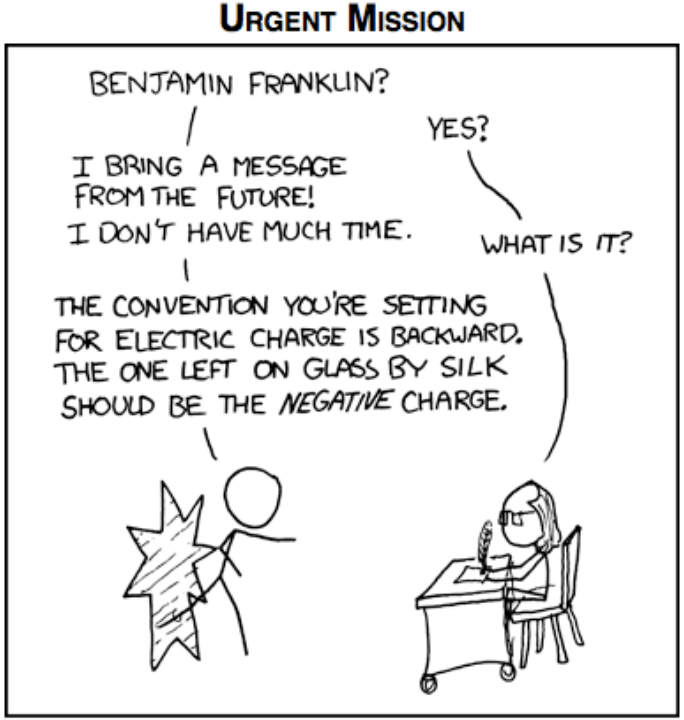
Norms

- What are norms?
- Self-enforcement
- Normative MAS:
  - “A multiagent system organized by means of mechanisms to represent, communicate, distribute, detect, create, modify, and enforce norms, and mechanisms to deliberate about norms and detect norm violation and fulfilment” - Boella et. al.

Kinds of Norms

- Conventional norms
- Essential norms

- Convention in unknown environments



Convention

- “We may define a convention as an equilibrium that everyone expects in interactions that have more than one equilibrium” - Young

- Convention as a 2-choice game
- Global vs. local knowledge
- Social Learning

MAS Today

- Logic / rule based enforcement
- Global knowledge is assumed
- Agents create their own ‘language’

Related Studies

- Proximity / stochastic based influence
- Evolution of Convention
- Highest cumulative reward
- Outlier agent strategies

Social Learning Framework

- How can we formally describe agents & environments to study social learning?

Rules of the Road Example

Agents must learn

1. Which side of the road to drive on
2. Who stops & who goes when two cars approach an intersection

Basic Concepts

- Conventions are implicit
  - Agents adopt personal stable behavior that can be seen as a convention at a macroscopic level
- Normal-form game used to represent social interaction between 2 agents
- All agents have same preference orderings
  - May have different payoff values, though

Basic Concepts cont.

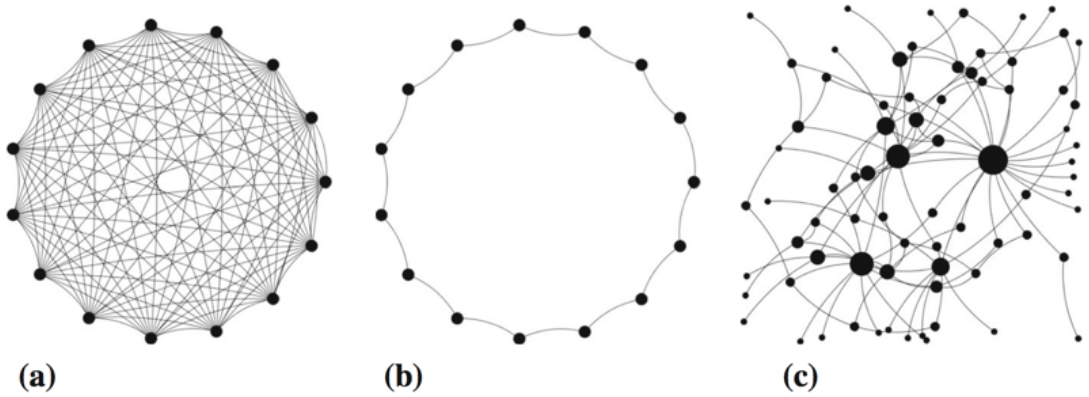
- Agents use one of several learning algorithms to adapt their behavior
  - Agents don’t need to all use the same strategy
- Fixed interaction topology constrains interactions
  - Agents can only interact with neighbors
- Interactions are private

Formal Notation

- Social interaction: < N, Ar, Ac, (Gi) i∈N >
- N: number of agents
- Ar(c): Actions available to the row/column agent
- Gi: Payoff for each agent based on the actions taken

Network Topologies

A. Fully connected networks
B. One dimensional lattice with neighborhood size *k*
C. Scale free networks



Interaction Protocol

Input: N: set of agents
$\mathcal{G} \subseteq N \times N$: symmetric relation modeling neighbours
for *a fixed number of epoch* **do**
$A \leftarrow N$ //Initialize the available agents with the entire population
repeat
randomly select an agent from the available agents: $i \in A$;
randomly select a neighbor of i that is available: $j \in A \cup \{j \mid (i, j) \in \mathcal{G}\}$;
remove i and j from the set of available agents: $A = A \setminus \{i, j\}$;
With probability $\frac{1}{2}$ draw $(p_{row}, p_{col}) = (i, j)$, else draw $(p_{row}, p_{col}) = (j, i)$;
let p_{row} to select an action r in $\mathcal{A}_r$;
let p_{col} to select an action c in $\mathcal{A}_c$;
send the joint action (r, c) to both p_{row} and p_{col} for policy update;
until *no pair of agents is available:* $\nexists (i, j) \in A^2 \mid (i, j) \in \mathcal{G}$;

What is a convention?

- For all pairs of agents (i, j), there is an equilibrium (ri, cj) for (Gi, G′j) and there is an equilibrium (rj, ci) for (G′j, Gi)
  where G′j is the transpose of Gi
- All pairs of agents follow the same pure strategy in a given role


Not this


No convention

Convention Emergence

- A convention has emerged when the convention strategy is played by 95% of the population on a given iteration

Implicit Learning

- Agent goal is **not** to discover convention
- Goal is to maximize its expected utility
  - Researcher’s goal is to see if convention will emerge and agents will implicitly follow it

Learning Algorithms

1. Fictitious Play
    a. Agent keeps frequency count of opponents' moves, assumes opponents play the mixed strategy represented by that distribution
2. Q-Learning
3. Win or Learn Fast-Policy Hill Climbing
    a. Quickly adapt when losing, but be cautious when winning

Results

Convention Experimentation

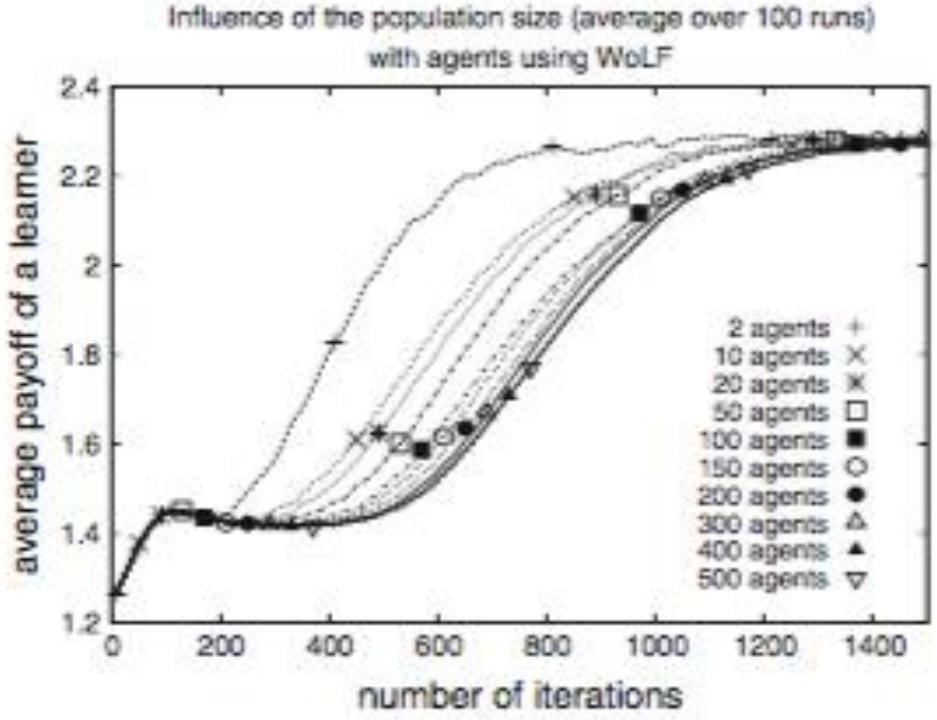
This research focuses on:

- game type
- number of actions
- number of interactions
- learning algorithm used
- presence of non-learning agents

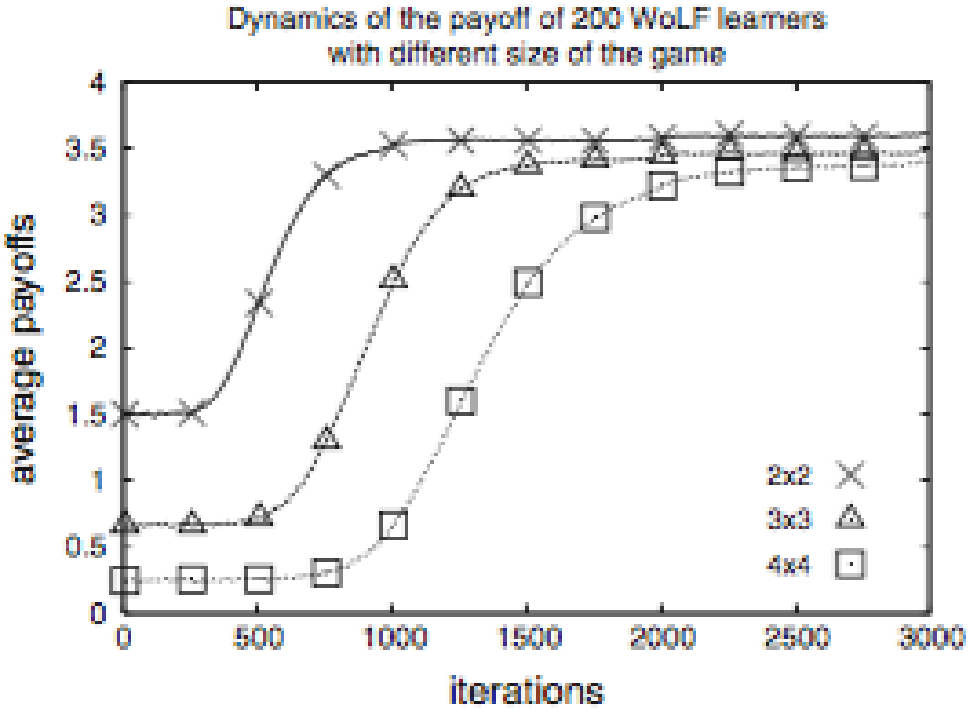
Social Constructs

- Social Dilemma
  - cars at an intersection
- Cooperation Game
  - which side of the road to drive on

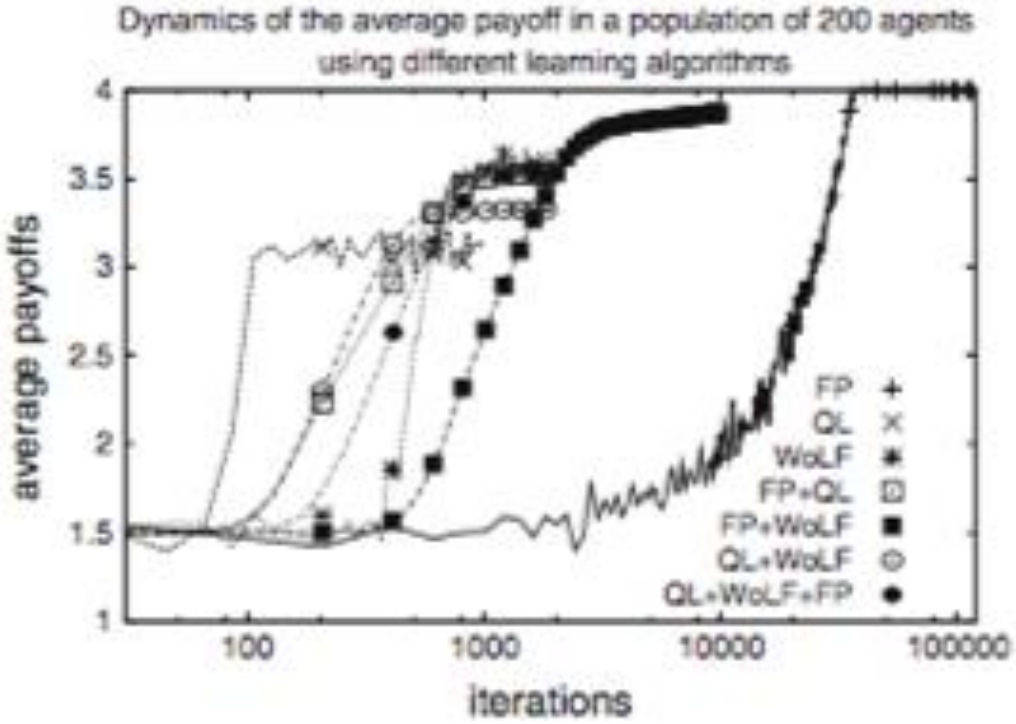
Population Size



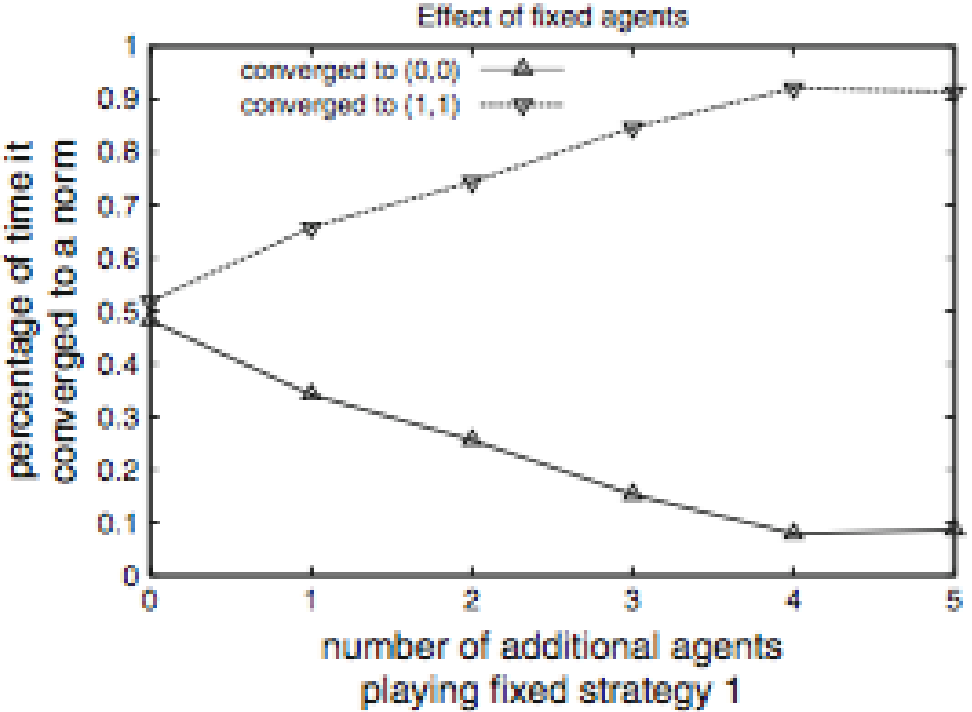
Number of Actions



Learning Algorithm

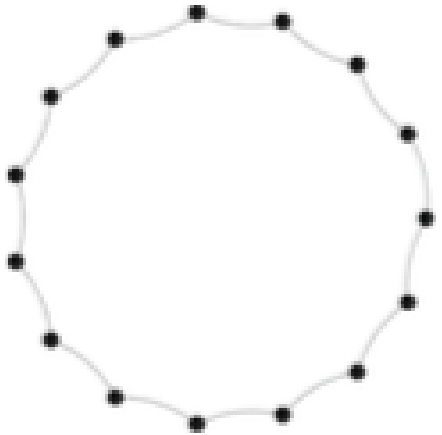


Fixed Agents



Social Networks

- Agents could only interact with neighbors
- Large neighborhoods reduced convergence time
- Small neighborhoods increased likelihood of sub-conventions

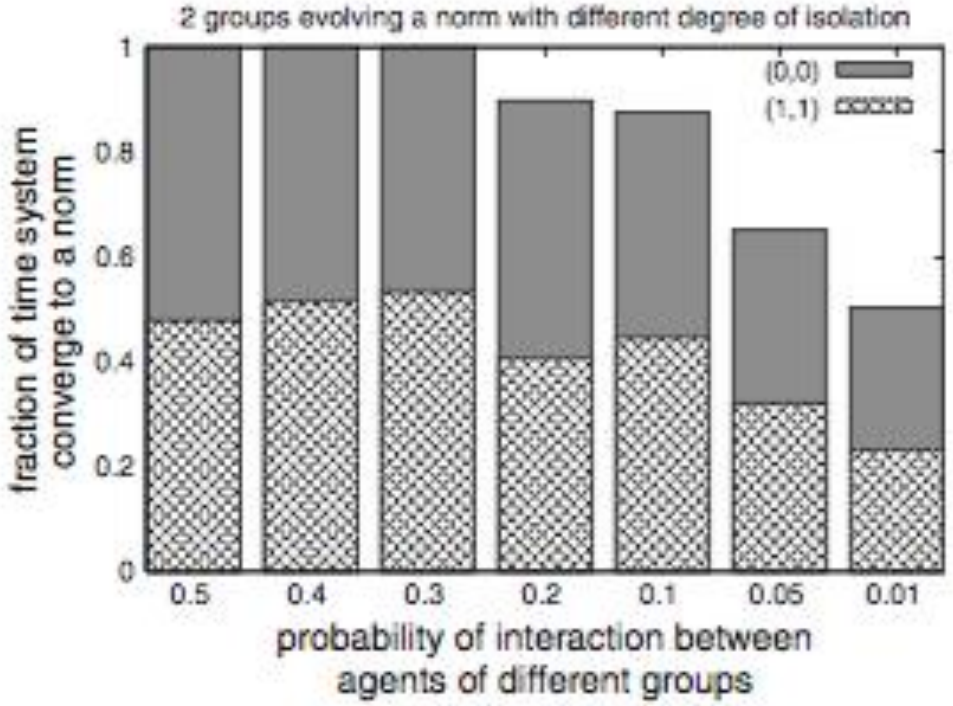


one-dimensional network used

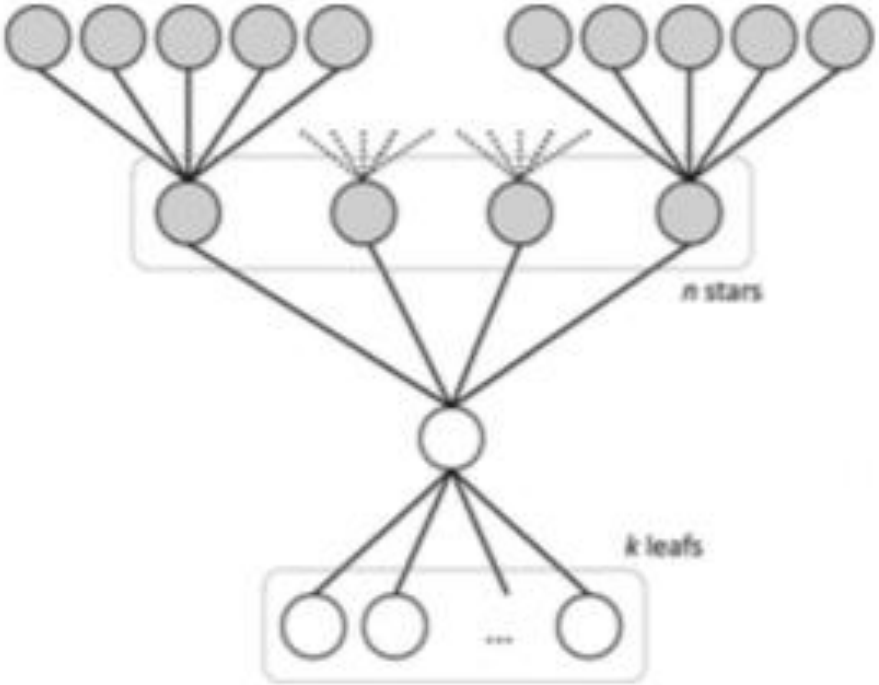
Emergent Sub-Conventions

- When agents in distant parts of a network interact infrequently sub conventions are likely to emerge.
- Sub-conventions can be stable.

Isolated Sub-population



Scale Free Networks



In conclusion

- Conventions can emerge through a bottom up approach
- These conventions help us solve social dilemmas and cooperate
- Sub-conventions can emerge and be stable depending on the structure of the graph

Questions?