Understanding Norm Change: An Evolutionary Game-Theoretic Approach

Soham De
Department of Computer Science

Joint work with:
Dana S Nau (Department of Computer Science)
Michele J Gelfand (Department of Psychology)
SOCIAL NORMS

Human societies all around the world interact and accomplish different tasks by developing and maintaining social norms.

Examples:
- Walking on a specific side of the pavement
- Right of way while driving
- Shaking hands when meeting someone new
SOCIAL NORMS

Empirical studies show marked differences in the strength of social norms around the globe.

Tight Societies:
High norm-adherence. High punishment of norm deviations.
E.g. Indonesia

Loose Societies:
Weaker norms. More tolerance for deviations from norms.
E.g. Netherlands
Empirical studies show marked differences in the strength of social norms around the globe.

How do such norms emerge & change in different societies?

**Tight Societies:**
High norm-adherence. High punishment of norm deviations.
E.g. Indonesia

**Loose Societies:**
Weaker norms. More tolerance for deviations from norms.
E.g. Netherlands
WHY STUDY NORM CHANGE?

How do such norms emerge & change in different societies?

• How/when will a society become unstable?
• How can we predict a shift in norms?
• How likely are social uprisings and turmoil?
WHY STUDY NORM CHANGE?

How do such norms emerge & change in different societies?

• How/when will a society become unstable?
• How can we predict a shift in norms?
• How likely are social uprisings and turmoil?

First work to provide a model of how cultural differences affect norm change
EVOLUTIONARY GAME THEORY (EGT)

Application of game theory to evolving populations

Recently being used to model the evolution of cultural characteristics
EVOLUTIONARY GAME THEORY (EGT)

Application of game theory to evolving populations

Recently being used to model the evolution of cultural characteristics

Setting (for this talk):

- Large population structured on a network:
  - Individuals arranged on the nodes
  - Edges represent social connections
EVALUATIONARY GAME THEORY (EGT)

Application of game theory to evolving populations

Recently being used to model the evolution of cultural characteristics

Setting (for this talk):

- Large population structured on a network:
  - Individuals arranged on the nodes
  - Edges represent social connections

- Individuals interact with neighbors using a game

Game Strategies → Possible Behaviors
EVOLUTIONARY GAME THEORY (EGT)

Application of game theory to evolving populations

Recently being used to model the evolution of cultural characteristics

Setting (for this talk):

✧ Large population structured on a network:
  • Individuals arranged on the nodes
  • Edges represent social connections

✧ Individuals interact with neighbors using a game
  Game Strategies ➞ Possible Behaviors

✧ Individuals observe neighbors’ strategies and payoffs and imitate/learn from them
FRAMEWORK

Current Population

Interactions
(stage game)

Payoffs
(relative fitness)

Transmission
(evolutionary fitness)

Next Population
Each strategy used by some proportion of the population

- Current Population
- Interactions (stage game)
- Payoffs (relative fitness)
- Transmission (evolutionary fitness)
- Next Population
Each strategy used by some proportion of the population

Individuals interact with each of their neighbors using a 2-player game
FRAMEWORK

Each strategy used by some proportion of the population

Individuals interact with each of their neighbors using a 2-player game

Payoffs depend on both the individual’s strategy and neighbors’ strategies; Total payoff = sum of individual payoffs
FRAMEWORK

Current Population

Interactions (stage game)

Payoffs (relative fitness)

Transmission (evolutionary fitness)

Next Population

Each strategy used by some proportion of the population

Individuals interact with each of their neighbors using a 2-player game

Payoffs depend on both the individual’s strategy and neighbors’ strategies; Total payoff = sum of individual payoffs

Humans imitate others, learn from others; Successful strategies are more likely to be adopted by others (more on this later)
Each strategy used by some proportion of the population

Individuals interact with each of their neighbors using a 2-player game

Payoffs depend on both the individual’s strategy and neighbors’ strategies; Total payoff = sum of individual payoffs

Humans imitate others, learn from others; Successful strategies are more likely to be adopted by others (more on this later)
TRANSMISSION OF BEHAVIORS

Interpret game-theoretic payoffs as reproductive fitness

Fermi Rule

Each individual compares its payoff to a randomly chosen neighbor
TRANSMISSION OF BEHAVIORS

Interpret game-theoretic payoffs as reproductive fitness

Fermi Rule

Each individual compares its payoff to a randomly chosen neighbor
TRANSMISSION OF BEHAVIORS

Interpret game-theoretic payoffs as reproductive fitness

Fermi Rule

Each individual compares its payoff to a randomly chosen neighbor

Individual switches to neighbor’s strategy w.p. depending on the difference in payoffs:

\[ p = \frac{1}{1 + \exp(s(u_a - u_n))} \]

\[ u_a, u_n = \text{individual’s and neighbor’s payoffs} \]

\[ s \geq 0 \text{ is the selection strength} \]
Interpret game-theoretic payoffs as reproductive fitness

**Fermi Rule**

Each individual compares its payoff to a randomly chosen neighbor

Individual switches to neighbor’s strategy w.p. depending on the difference in payoffs:

\[ p = \frac{1}{1 + \exp(s(u_a - u_n))} \]

\( u_a, u_n \) = individual’s and neighbor’s payoffs
\( s \geq 0 \) is the selection strength
TRANSMISSION OF BEHAVIORS

Interpret game-theoretic payoffs as reproductive fitness

Fermi Rule

Each individual compares its payoff to a randomly chosen neighbor

Individual switches to neighbor’s strategy w.p. depending on the difference in payoffs:

\[ p = \frac{1}{1 + \exp(s(u_a - u_n))} \]

Proportion of agents using a strategy shrinks/grows depending on how well it performs (in terms of payoffs)
Individuals don’t always learn from neighbors

Sometimes, they try out a completely new behavior to see how it does
Individuals don’t always learn from neighbors

Sometimes, they try out a completely new behavior to see how it does

Modeled by modifying the Fermi Rule:

Let $S = \{\text{all available strategies}\}$

At each step, each agent chooses a strategy $s$ at random from $S$ with a small probability $\mu$

• regardless of whether strategy $s$ is currently successful
• regardless of whether any agent is currently using strategy $s$
WHAT CAN THIS ACCOMPLISH?

• Human interactions are very complicated
  EGT models use highly simplified abstractions

• Designed to capture only the essential nature of the interactions

• Can’t give exact numeric predictions of what would happen in real life
WHAT CAN THIS ACCOMPLISH?

• Human interactions are very complicated
  EGT models use highly simplified abstractions

• Designed to capture only the essential nature of the interactions

• Can’t give exact numeric predictions of what would happen in real life

But…

• It can provide explanations of the underlying dynamics

• Establish support for causal relationships and identify trends

• Evolution of human culture over time virtually impossible to study in lab settings or field studies. EGT can help out!
STUDYING NORM CHANGE IN TIGHT & LOOSE SOCIETIES

Denote possible norms as actions in a game

How do we set up tightness/looseness as a game-theoretic model?
STUDYING NORM CHANGE IN TIGHT & LOOSE SOCIETIES

Denote possible norms as actions in a game

How do we set up tightness/looseness as a game-theoretic model?

Use a closely-related concept:

Need For Coordination
STUDYING NORM CHANGE IN TIGHT & LOOSE SOCIETIES

Denote possible norms as actions in a game

How do we set up tightness/looseness as a game-theoretic model?

Use a closely-related concept:

Need For Coordination

Tight societies:
High need for coordination
Payoffs depend much more on strategies of neighbors

Loose societies:
Low need for coordination
Individualistic agents. Payoffs depend less on neighbors.
STUDYING NORM CHANGE IN TIGHT & LOOSE SOCIETIES

Tight societies: High need for coordination

Loose societies: Low need for coordination
Loose societies:
Low need for coordination

Tight societies:
High need for coordination

Game-theoretic model of
need for coordination

STUDYING NORM CHANGE IN TIGHT & LOOSE SOCIETIES
STUDYING NORM CHANGE IN TIGHT & LOOSE SOCIETIES

Tight societies: High need for coordination

Loose societies: Low need for coordination

Game-theoretic model of need for coordination

Study how the need for coordination affects norm change in societies
### PROPOSED MODEL

Assume two possible norms denoted by $A$ and $B$

<table>
<thead>
<tr>
<th>$M_c$</th>
<th>$A$</th>
<th>$B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>$a,a$</td>
<td>$0,0$</td>
</tr>
<tr>
<td>$B$</td>
<td>$0,0$</td>
<td>$b,b$</td>
</tr>
</tbody>
</table>

**Extreme Tight Society**

<table>
<thead>
<tr>
<th>$M_f$</th>
<th>$A$</th>
<th>$B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>$a,a$</td>
<td>$a,b$</td>
</tr>
<tr>
<td>$B$</td>
<td>$b,a$</td>
<td>$b,b$</td>
</tr>
</tbody>
</table>

**Exteme Loose Society**

**Coordination Game**

**Fixed-Payoff Game**
PROPOSED MODEL

Assume two possible norms denoted by A and B

<table>
<thead>
<tr>
<th>( M_c )</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>( a, a )</td>
<td>0, 0</td>
</tr>
<tr>
<td>B</td>
<td>0, 0</td>
<td>( b, b )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( M_f )</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>( a, a )</td>
<td>( a, b )</td>
</tr>
<tr>
<td>B</td>
<td>( b, a )</td>
<td>( b, b )</td>
</tr>
</tbody>
</table>

Coordination Game

Fixed-Payoff Game

\[ M = c \, M_c + (1-c) \, M_f \]
**PROPOSED MODEL**

Assume two possible norms denoted by A and B

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extreme Tight Society</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_c$</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>A</td>
<td>$a,a$</td>
<td>0,0</td>
</tr>
<tr>
<td>B</td>
<td>0,0</td>
<td>$b,b$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extreme Loose Society</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_f$</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>A</td>
<td>$a,a$</td>
<td>$a,b$</td>
</tr>
<tr>
<td>B</td>
<td>$b,a$</td>
<td>$b,b$</td>
</tr>
</tbody>
</table>

**Coordination Game**

$$M = c M_c + (1-c) M_f$$

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$a$</td>
<td>$(1-c) a$</td>
</tr>
<tr>
<td>B</td>
<td>$(1-c) b$</td>
<td>$b$</td>
</tr>
</tbody>
</table>

c denotes the level of tightness
HOW TO STUDY NORM CHANGE?

Using this model, how do we study norm change in societies?
HOW TO STUDY NORM CHANGE?

Using this model, how do we study norm change in societies?

We look at two key aspects of norm change:

- **Cultural Inertia:** amount of resistance of a society to changing a norm

- **Exploration Rate:** how willing are agents to try out new behaviors at random
CULTURAL INERTIA

Setting:
CULTURAL INERTIA

Setting:

• Individuals arranged on the nodes of a grid
CULTURAL INERTIA

Setting:

• Individuals arranged on the nodes of a grid
• Initially, norm $B$ has a higher payoff than $A$ ($b > a$), with majority of the population playing $B$
CULTURAL INERTIA

Setting:

- Individuals arranged on the nodes of a grid
- Initially, norm $B$ has a higher payoff than $A$ ($b > a$), with majority of the population playing $B$
- After some time, **structural shock**: represents a catastrophic incident in a society, where suddenly there is abrupt change in the payoffs for actions $A$ and $B$.
  
Payoff of $A$ increases over $B$ ($a > b$)
CULTURAL INERTIA

Setting:

- Individuals arranged on the nodes of a grid
- Initially, norm B has a higher payoff than A ($b > a$), with majority of the population playing B
- After some time, structural shock: represents a catastrophic incident in a society, where suddenly there is abrupt change in the payoffs for actions A and B.
  Payoff of A increases over B ($a > b$)

How does a tight/loose society react?
CULTURAL INERTIA

- **Tight**
- **Intermediate**
- **Loose**
CULTURAL INERTIA

![Graph showing cultural inertia with structural shock]

- **Tight**
- **Intermediate**
- **Loose**
CULTURAL INERTIA

- **No Change**
- **Eventual Change**
- **Fast Change**

**Structural Shock**

- **Tight**
- **Intermediate**
- **Loose**
CULTURAL INERTIA

Higher needs for coordination (tighter societies) → Higher cultural inertia
EXPLORATION RATES

In all past work, exploration rate is kept constant

Why study exploration rates?

• How likely is an agent to learn socially?
• How fast are norms adopted in a population?
EXPLORATION RATES

In all past work, exploration rate is kept constant

Why study exploration rates?

• How likely is an agent to learn socially?
• How fast are norms adopted in a population?

To study how tightness/looseness affects exploration:

Let exploration rates evolve as part of agent’s strategy

Study evolution in a changing environment using regular structural shocks
EXPLORATION RATES

In all past work, exploration rate is kept constant

Why study exploration rates?

• How likely is an agent to learn socially?
• How fast are norms adopted in a population?

To study how tightness/looseness affects exploration:

Let exploration rates evolve as part of agent’s strategy

Study evolution in a changing environment using regular structural shocks

In a static environment, no exploration is always better in the long run
Same experiment with agents on a grid using Fermi Rule

Now we introduce structural shocks at regular intervals of 75 generations

Agents can choose an exploration rate from the set \{0.0, 0.1, 0.2, 0.3, 0.4, 0.5\} as part of their strategy
Same experiment with agents on a grid using Fermi Rule

Now we introduce structural shocks at regular intervals of 75 generations

Agents can choose an exploration rate from the set \{0.0, 0.1, 0.2, 0.3, 0.4, 0.5\} as part of their strategy
EVOLVING EXPLORATION RATES

Agents can choose an exploration from the set \{0.0, 0.1, 0.2, 0.3, 0.4, 0.5\} as part of their strategy.

Higher needs for coordination (tighter societies) → Lower exploration rates
CONTRIBUTIONS
Main Results:
Societies with higher needs for coordination (tighter societies) have:
  • Higher cultural inertia
  • Lower exploration rates
Using EGT model, we establish direct causal relationships
CONTRIBUTIONS

✦ Main Results:
Societies with higher needs for coordination (tighter societies) have:
  • Higher cultural inertia
  • Lower exploration rates
Using EGT model, we establish direct causal relationships

✦ Main qualitative findings robust to a wide range of parameter values
Please check paper for more details and theoretical justifications
CONTRIBUTIONS

✦ Main Results:
Societies with higher needs for coordination (tighter societies) have:
  • Higher cultural inertia
  • Lower exploration rates
Using EGT model, we establish direct causal relationships

✦ Main qualitative findings robust to a wide range of parameter values
Please check paper for more details and theoretical justifications

✦ Broader Takeaway:
Previous work have not accounted for the substantial societal differences in how individuals interact and influence each other.
Incorporating concepts from the social and behavioral sciences, and modeling them using game theory can lead to better insights!
THANKS!

Feel free to get in touch!


email: sohamde@cs.umd.edu
website: https://cs.umd.edu/~sohamde/

Soham De
Dana S Nau
Michele J Gelfand