COMPUTATIONAL ANALYSIS OF SOCIAL AND ORGANIZATIONAL SYSTEMS

Social Network Influences on Strategic Choices

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Computational Analysis of Social And Organizational Systems
Engineering and Public Policy

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Outline

- **Introduction**
  - Problem statement
  - Previous literature
- **Model**
  - Meta-Matrix Representation of conflict
  - Goal correspondence of actions
  - Structural influence on preferences
- **Simulation**
  - Decision choice
  - Model state updating
- **Validation strategy & Results**
- **Policy Implications**

Problem Statements

- Develop a scalable, computationally tractable method of representing conflict scenarios
- Allow a definition of conflict scenarios in which complimentary goals, non-zero sum games, and cooperative behavior can be modeled
- Describe a method in which beliefs about other actors and courses of action develop through the conflict and affect participants' actions
- Combine these into a simulation model able to make predictions about actor behavior in a conflict

Literature used in model development

- **Representation of conflict scenarios**
  - Based on the meta-matrix method of representing social networks developed by Krackhardt & Carley (1998)
  - Used previously by Louie, Carley, Kunz, & Levitt (2002) to represent tasks and group interaction in military tasks; used by Carley & Schreiber to describe design of C^3I teams (2002)
- **Goal correspondence of actions**
  - Uses a combination-word approach standard to social network methods (Wasserman & Faust 1994)
- **Belief propagation**
  - Uses structural influence theory (Friedkin, 1998 & 2002) to model the beliefs of various actors
  - Conditions actions taken by beliefs and feelings towards other actors.

Model Structure

- **Three primary elements**
  - Representation of conflict scenarios
  - Computing actor goals correspondence of actions
  - Computing action **(A-N)** preferences
- **Inputs**
  - Primitive relations
  - Scenario information
- **Outputs**
  - Actor-Action **(A-N)** probability matrix

Meta-Matrix Representation I

- **Network Entities:**
  - Actors (A)
  - Goals (G)
  - Resources (R)
  - Actions (N)
- **Weighting Relations:**
  - Stubbornness **(S)**
  - Volatility **(V)**
- **Primitive Relations:**
  - Influence **= $(A–A)^t_{Influence}$**
  - Preferences **= $(A–N)^t_{Preferences}$**
  - Goal weights **= (A–G)**
  - Resource support **= (G–R)**
  - Action effects **= (N–R)**

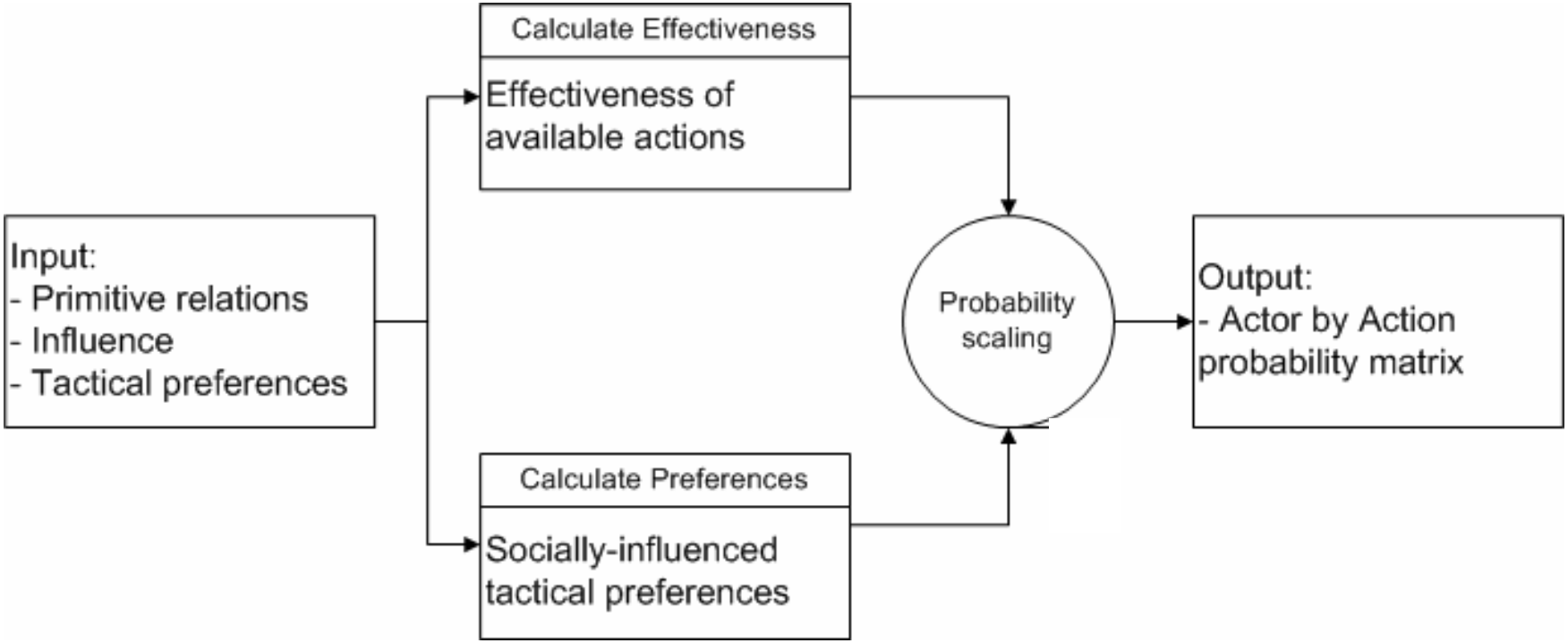
Meta-Matrix Representation II

Primitive Relations

	Actors	Goals	Resources	Actions
Actors	Influence, Hostility	Goal weights	Controlled Resources	Action probabilities
Goals			Resource requirements	
Resources	Prior actions			
Actions			Effects of actions	

Deriving probabilities of actions

Flow Diagram



'Effectiveness' Matrix

- Indicates how much various actions support decision maker goals
- Calculated as a matrix multiplication of the input network primitives, constrained between 0 and 1; given by:

$$(A\text{-}N)_{Goal=}(A\text{-}G)(G\text{-}R)(R\text{-}N)$$

- Individual elements given by:

$$goal_{ij} = \max\left(\sum_{l}\left[\left(\sum_{k}(A-G)_{ik}(G-R)_{kl}\right)(R-N)_{lj}\right],0\right)$$

for *i* actors, *j* actions, *k* goals, and *l* resources.

'Preferences' Matrix I

- Represents decision makers' preferences or preparation for certain courses of action
- A weighted average of learned and initial preferences at each time period in a conflict

Influence=$(A\text{-}A)^{t}_{influence}$

S=diagonal matrix of Influence$^{1}_{ii}$ – corresponds to "self-influence"

$$Pref^{t} = (A\text{-}A)^{t}_{Preference} = (Pref)^{t-1}(Influence)^{1}(I\text{-}S) + (Pref)^{1}\,S$$

Indicates ability to be influenced by other actors' beliefs.

Indicates "stubbornness", or tendency to go by own initial beliefs

‘Preferences’ Matrix II

- **Individual elements of the A-N preference matrix indicate the cardinal ranked preferences for various actions**
- **Individual values given by:**

$$pref_{ij}^{t} = (1 - S_{ii}) \sum_{j} \left(Influence_{ik}^{t-1} \times pref_{kj}^{t-1} \right) + (S_{ii}) pref_{ij}^{1}$$

for $i = k$ actors and j actions.

Combined and Scaled Probability Matrix

- **$(A\text{-}N)^t_{prob} = P^t$ Indicates the relative probabilities that actors will choose one of the actions available to them at time period *t***
- **Calculated by a nonstandard matrix operation:**

$$P_{ij}^{t} = \frac{\left(goal_{ij} \times pref_{ij}^{t}\right)}{\left(\sum_{j} goal_{ij} \times pref_{ij}^{t}\right)}$$

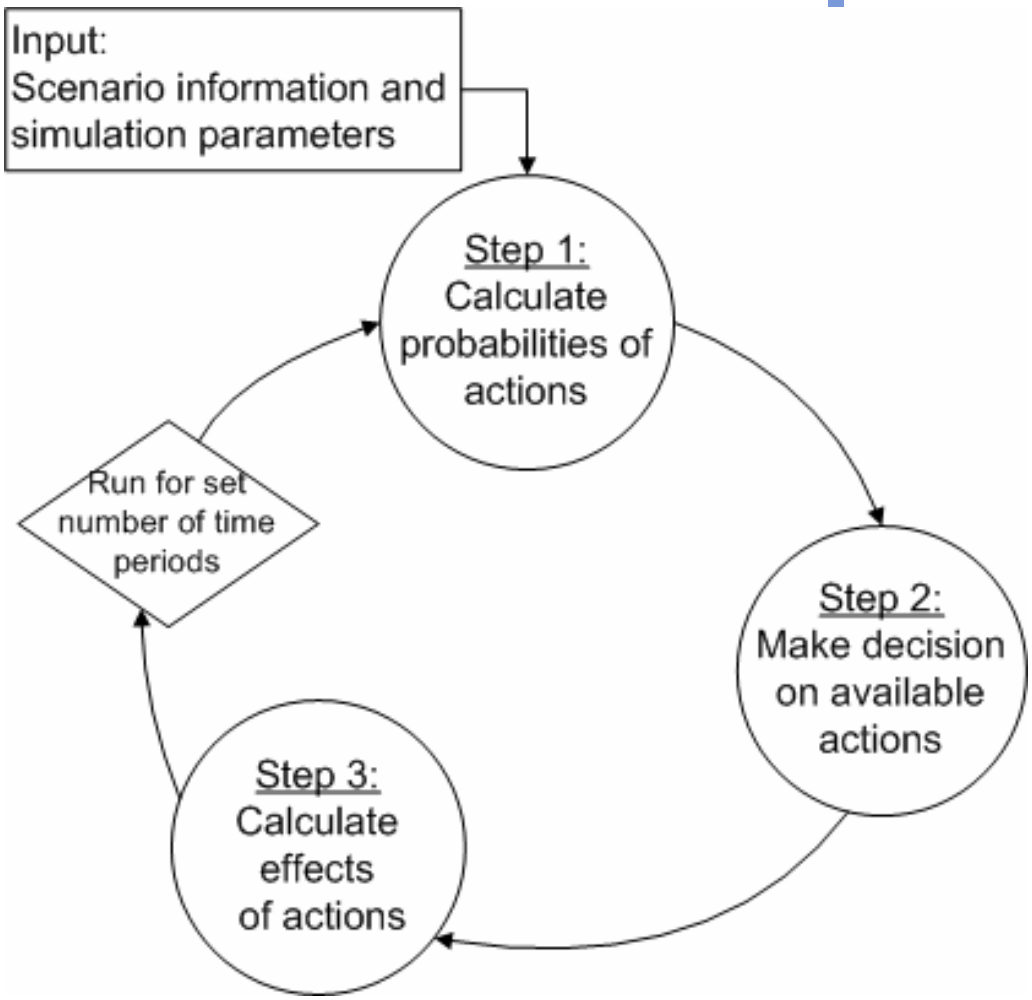
for *i* actors and *j* actions

- **Such that** $\sum_{j} goal_{ij} \neq 0$ **and** $\sum_{j} pref_{ij}^{t} \neq 0$ **; else** $P^t_{ij} = 0$

Simulation

The model, as written, is particularly suited to simulation, since it describes time-dynamic behavior among multiple agents. 2 concepts must be added, however:

- **Decision model**
- **Calculation of action effects.**



Decision model

- **Since the model itself generates probabilities of action over time, the decision model does not require significant additions**
- **Instead, decision model focuses on actor resource requirements for actions.**
  - Rescales actions the actor can't afford as probability zero
  - Normalizes remaining actions on probability scale 0 to 1
  - If actor can't afford anything, determines that actor will take no action.

Simulation state updating

- **Resource effects:**
  - Calculates **(R-A)^t,** or the resource effects of the action taken by each actor that turn.
  - Adds the row sum of each resource to the available resource levels.
- **Influence effects**
  - Calculates the changes to the **A-A Influence** matrix based on the actions taken each turn **(R-A)^t.** Given by**:**

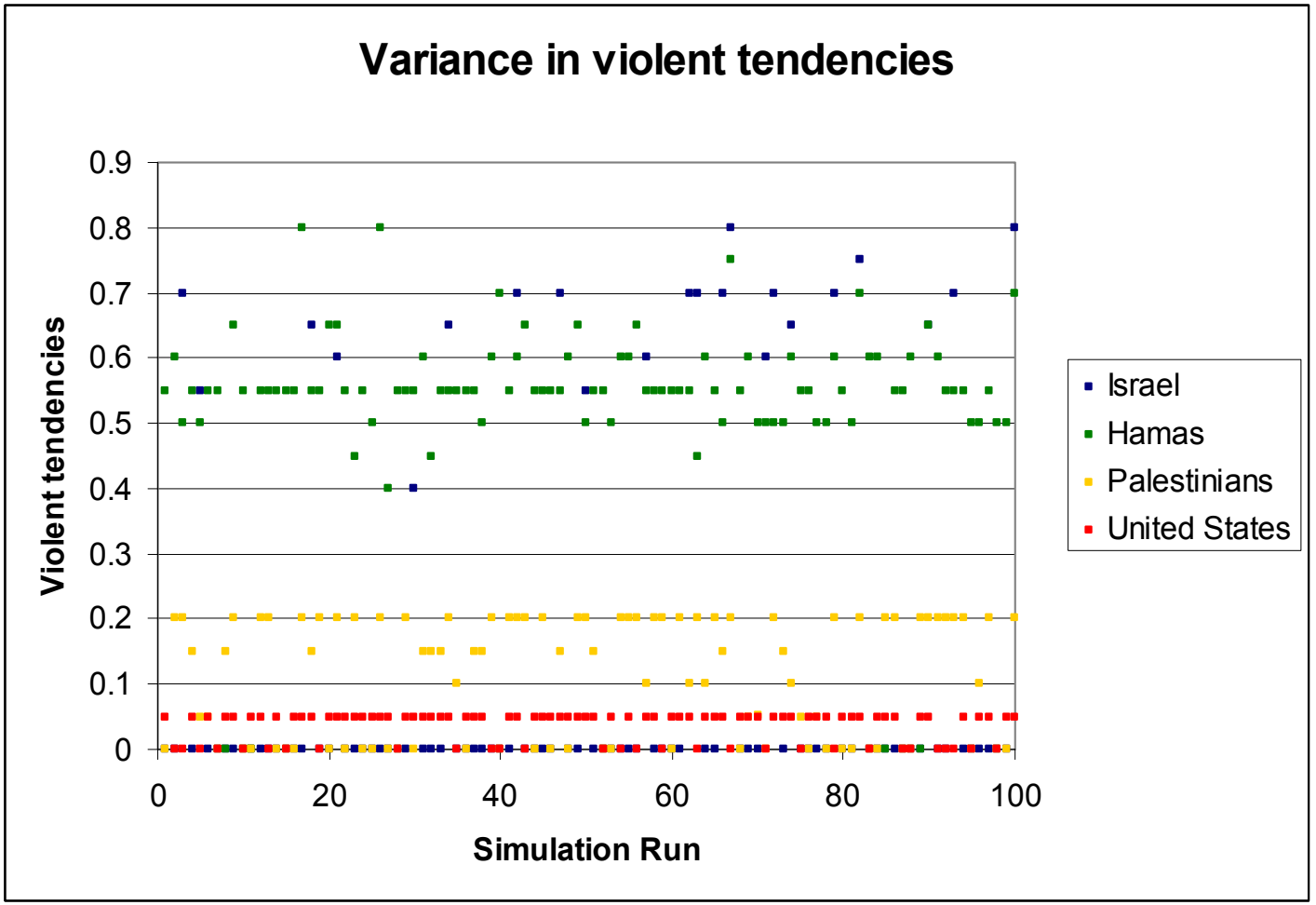
(A-A)$^t_{influencechange}$ = ΔInfluence^t = (A-G)(G-R)(R-A)^t((R-A)^t)'(G-R)'(A-G)'

  - Such that **Influence^t = Influence^{t-1} + (V)(ΔInfluence)$^{t-1}$**
  - **(V)** is an **A-A** weight indicating an actor's tendency to change influences

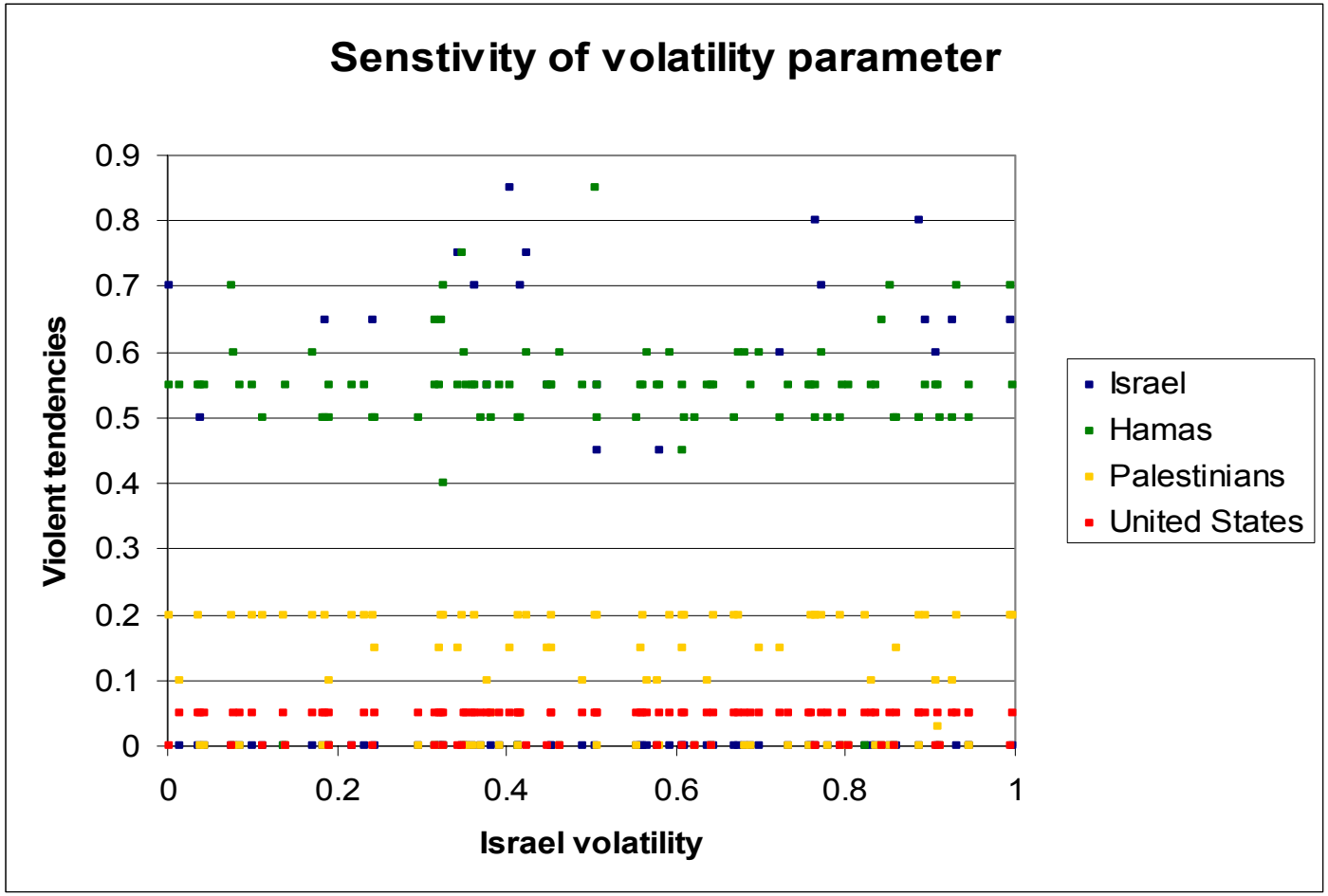
Validation

- Validation through Complex Organizational Reasoning Simulation (CORES), in development with Aptima, Inc. and CASOS.
- Validated through coding historical data sets into CORES and comparing simulated results with historical events
- CORES adds a hostility model; which further weights action probabilities by how a social propagation of 'hostility' beliefs.

Sample results I



Sample results II



Policy Implications

- Meta-Matrix approach allows for the representation of various conflict scenarios and decision making algorithms in terms of the same variables
- Allows for the representation and prediction of social consequences of hostile or positive actions; of distinct use to intelligence analysis in low-intensity conflict or deterrence theory
- Can be used to simulate policy problems or conflicts with a large number of actors, multiple payoffs, and incentives for or 'evolution of' cooperation

- Questions

Supplementary materials

- CORES Demonstration for Second Intifada data set
- Outputs
- Sample input matrices
- Convergence of hostile tendencies

Outputs

Default

- Action Probability Matrix output for each time period
- Influence matrix output
- Actions taken summary

Last run

- Action Probability Matrix output for each time period
- Influence matrix output
- Actions taken summary

Sample input matrices

Primitive Relations

Whole input doc	Actors	Goals	Resources	Actions
Actors	Influence	Goal weights	Controlled Resources	Action probabilities
Goals			Resource requirements	
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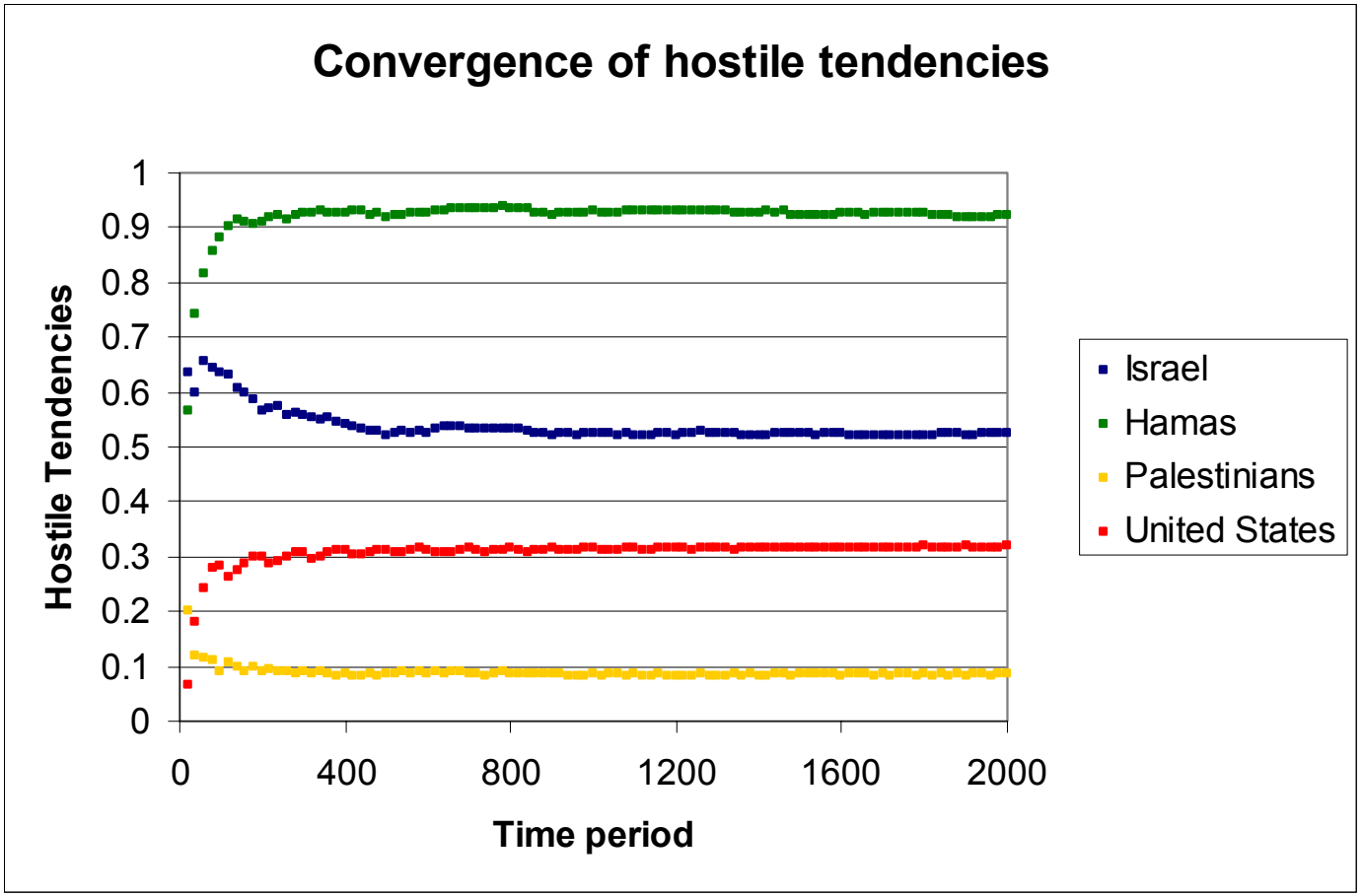
Convergence analysis I



Convergence analysis II