Computational Models for

Belief Revision, Group Decisions and Cultural Shifts

Whitman Richards (PI), M. I. T.
Computer Science and Artificial Intelligence Laboratory

MURI Objective: models that forecast patterns of behavior when social networks respond to external pressures.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Distribution A: Approved for public release; distribution unlimited.

The Team

Belief Structures:

Scott Atran, Univ. of Michigan & CNRS, Anthropology

Doug Medin, Northwestern University, Psychology

Analogical Reasoning:

Ken Forbus, Northwestern Univ., Computer Science and Education

Patrick Winston, MIT, Computer Science and Artificial Intelligence

Agents & Networks:

Jenna Bednar, Univ. of Michigan, Political Science & Public Policy

Scott Page, University of Michigan, Political Science & Complexity

Whitman Richards, MIT, Cognition and Artificial Intelligence

Joshua Tenebaum, MIT, Computation and Cognitive Science

Strategic Plans:

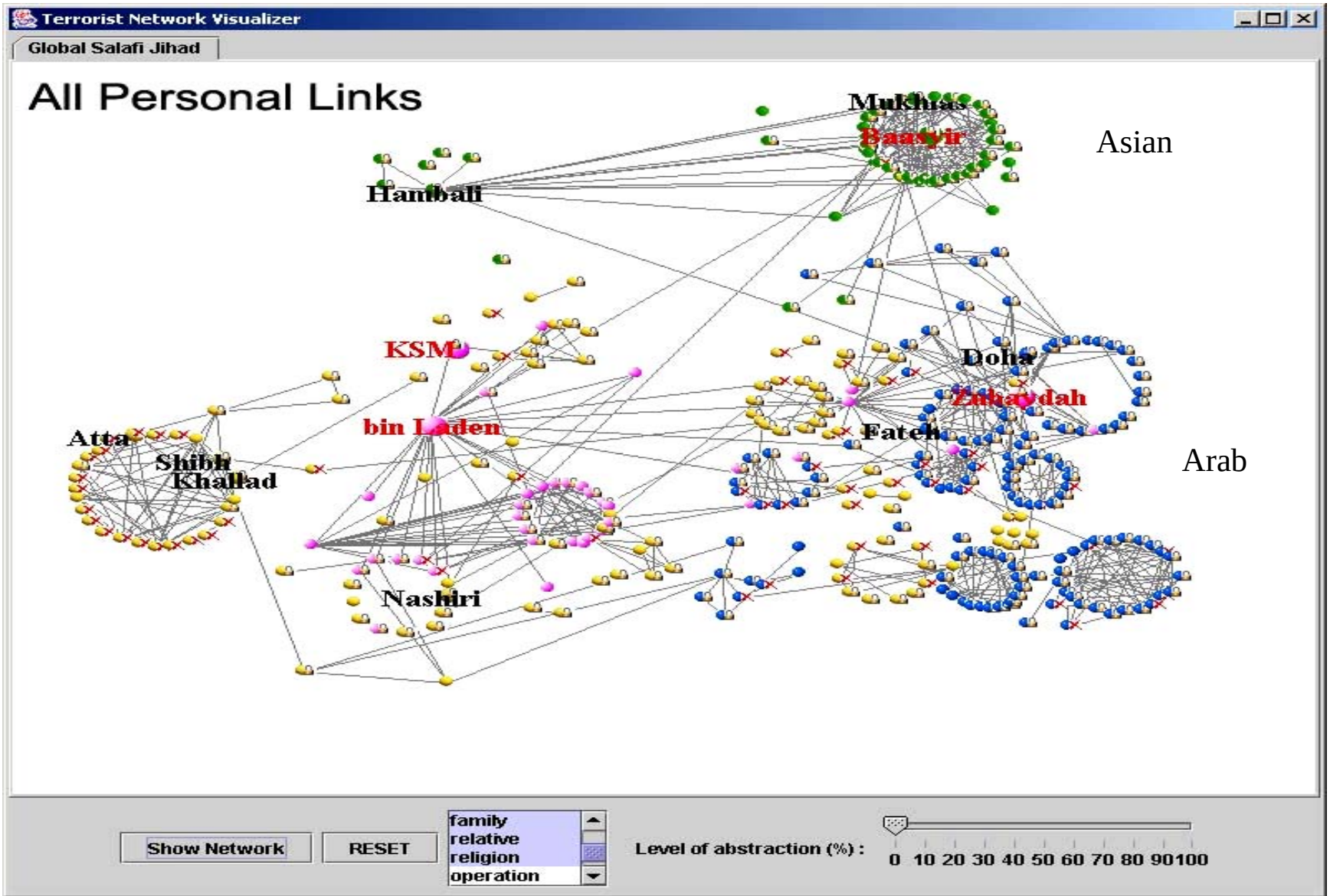
Brian Stankiewicz, Univ. of Texas, Austin, Expt'l Psychology

Avi Pfeffer, Harvard, Computer Science

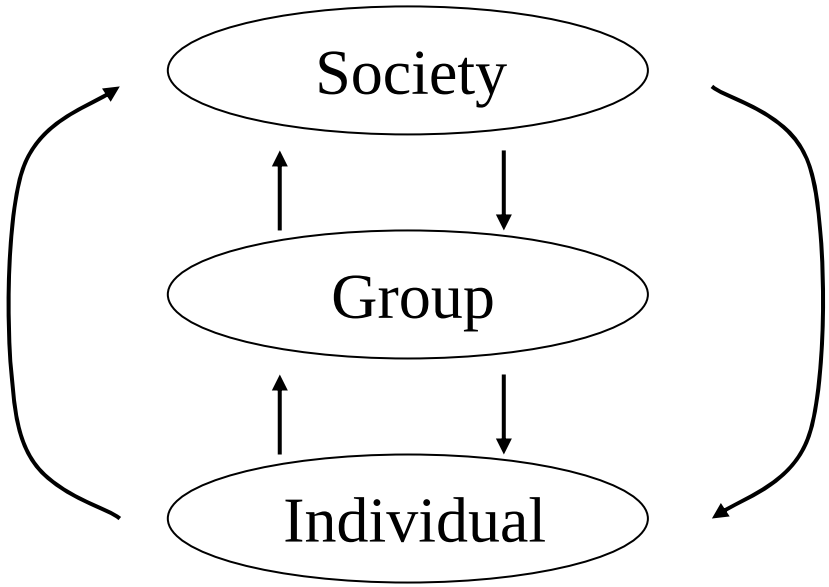
Consultant: Robert Axelrod, University of Michigan, Political Science

Atran

A Complex Network Structure

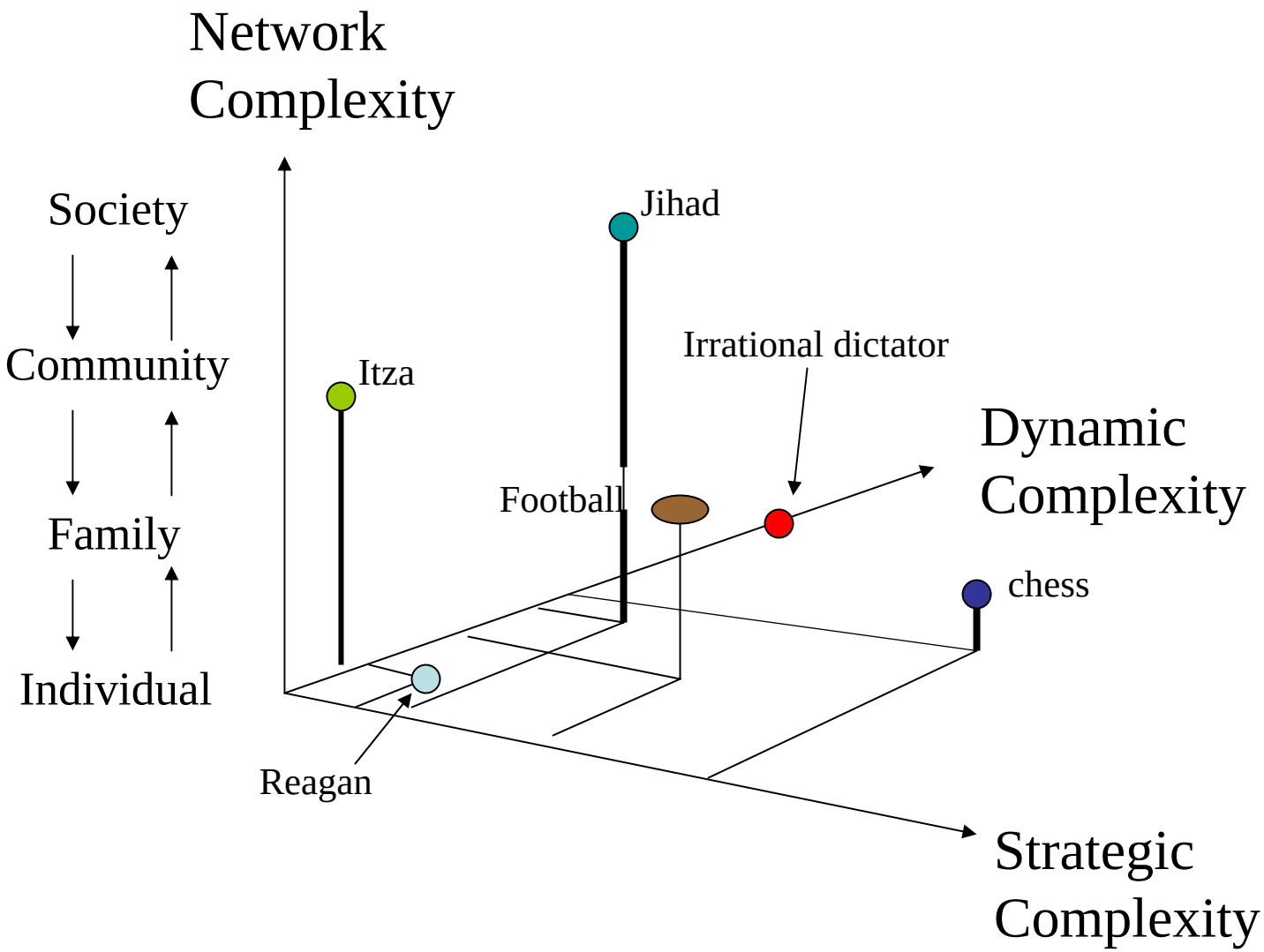


Levels of Study



Goals: (1) Understand interaction between levels and the dynamics of these interactions.
(2) At any level, how may a network be manipulated or shattered ? What actions follow applied external pressures?

MURI Scope


Network
Complexity
Society
Community
Family
Individual
Jihad
Itza
Irrational dictator
Dynamic
Complexity
Football
chess
Reagan
Strategic
Complexity

Multi-Level Influences

The Society: role of stories

Hypothesis: Cultural traditions are institutional constraints that shape and stabilize social networks.

Stories are powerful expressions of traditions and sacred values.

Who are the heros? The villains?

What are the challenges -- the obstacles to overcome?

What are the punishments or the rewards?

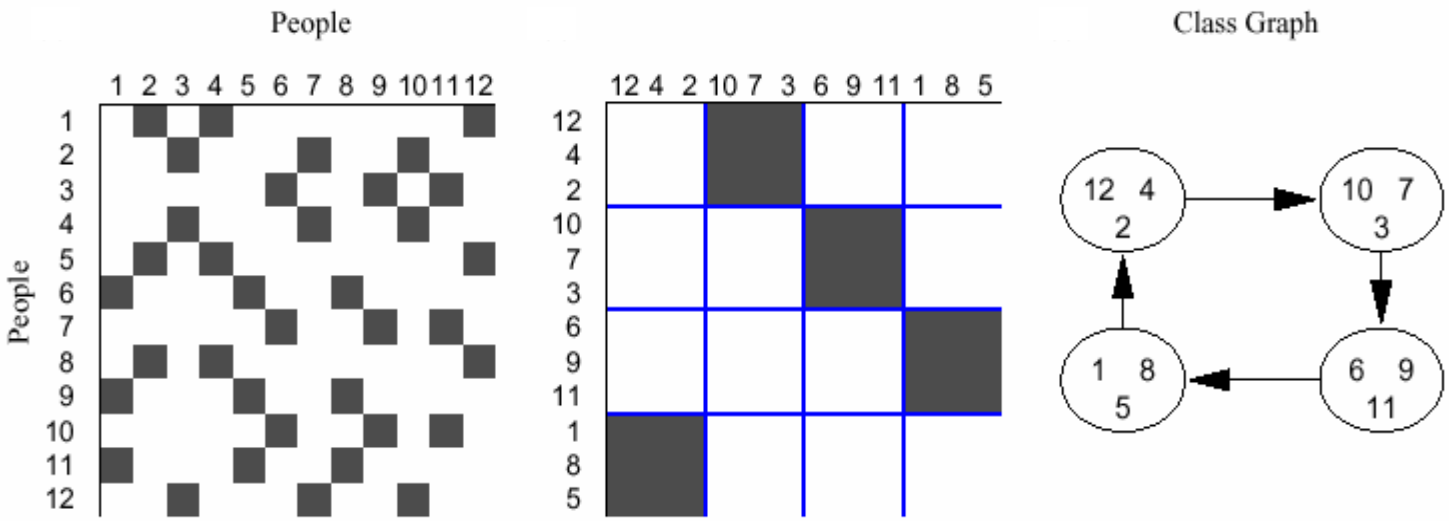
Objective: computational framework for stories {events, forces, beliefs…} [~ formalization of Campbell's a hero's journey.]

Forbus (NW): Winston & Finlayson (MIT): Kasturirangan(MIT/Bangalore):

Other Computational Models

Infinite Block Model: (MIT)	Uses Bayesian methods to recover network/graph structure from "noisy" relational data
Language for Networks of Influence Diagrams (NID): (Harvard)	A language for reasoning about the beliefs and rationality of agents' engaged in strategic decision-making
Qualitative Process Theory: (NW)	A framework for formalizing analogical and causal reasoning
Agent-Based Models: (UMich)	Specifically, models for the complex interaction of (seven) forces that generate cultural diversity

Network Structure (Static): An Infinite Block Model

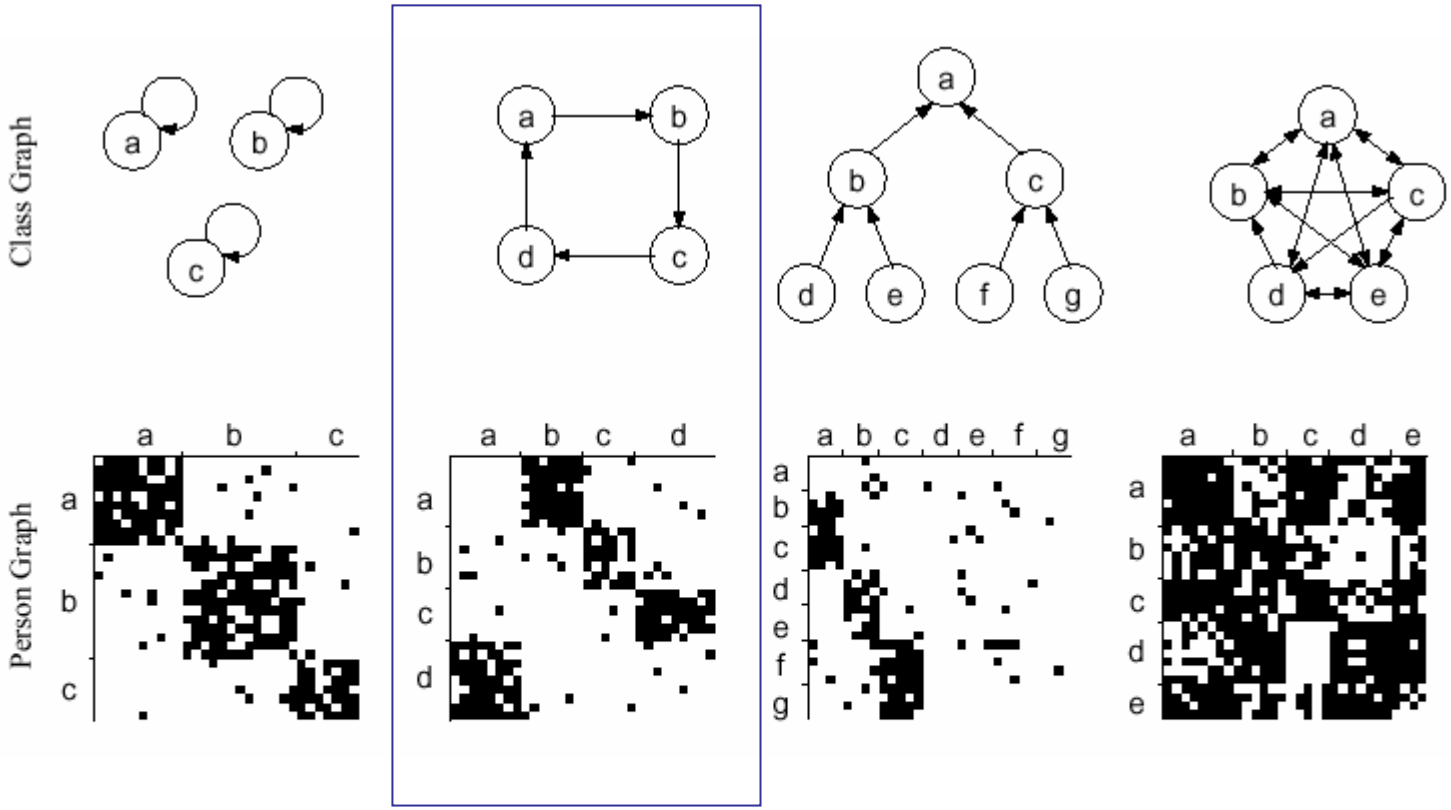


(a) (b) (c)

The procedure takes relations among people (a), calculates clusters and a class adjacency matrix (b), which then can be translated into a directed graph showing class relationships (c).

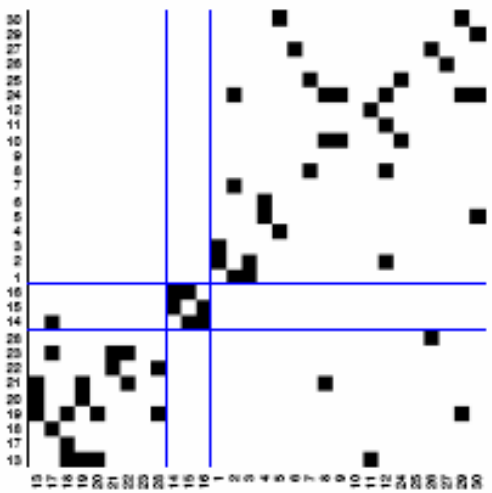
Maximizes coherence, minimizes number of blocks

J. Tenenbaum and C. Kemp, MIT

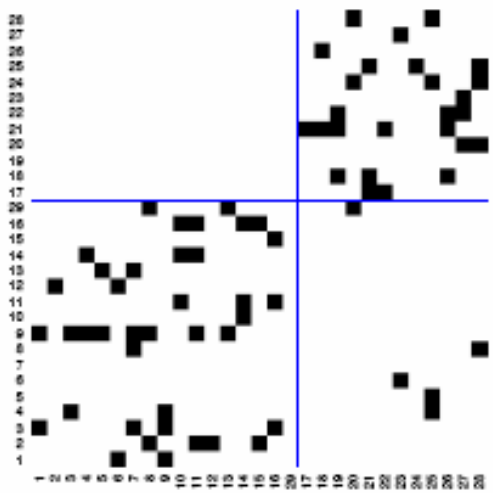


Block Model Adjacency Matrices (30x30) and Associated Graphical Models

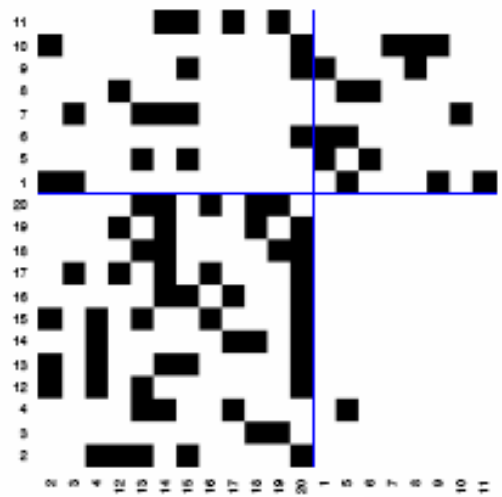
Snapshots of three Community Networks



Itza

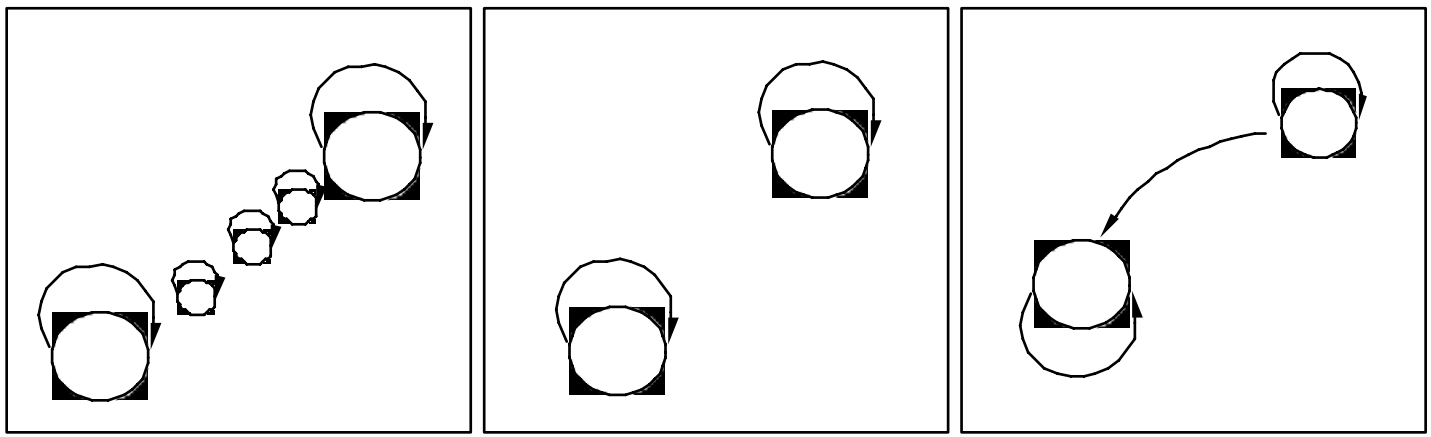


Ladino



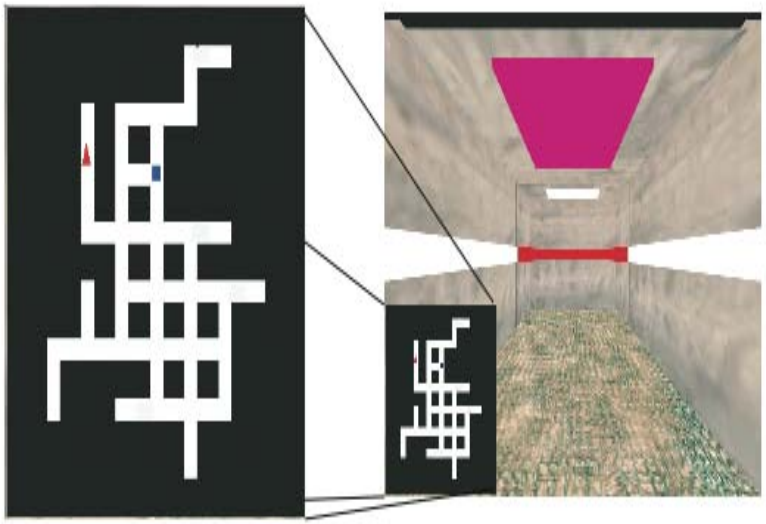
Qeqchi

Figure 1: Social networks (asymmetric) sorted according to the classes found by the IRM



C. Kemp (MIT), D. Medin (NW) & S. Atran (UMich)

Strategic Complexity



Non-Strategic Task

Given view of corridors ahead, estimate your location in maze.
Then choose best set of moves to reach target as quickly as possible.
Probabilistic because location uncertain

B. Stankiewicz, University of Texas, Austin
K. Gal & A. Pfeffer, Harvard

Capture the Flag

Block

Flank

Blocking Corridor costs me a move, but costs 3 moves for you.

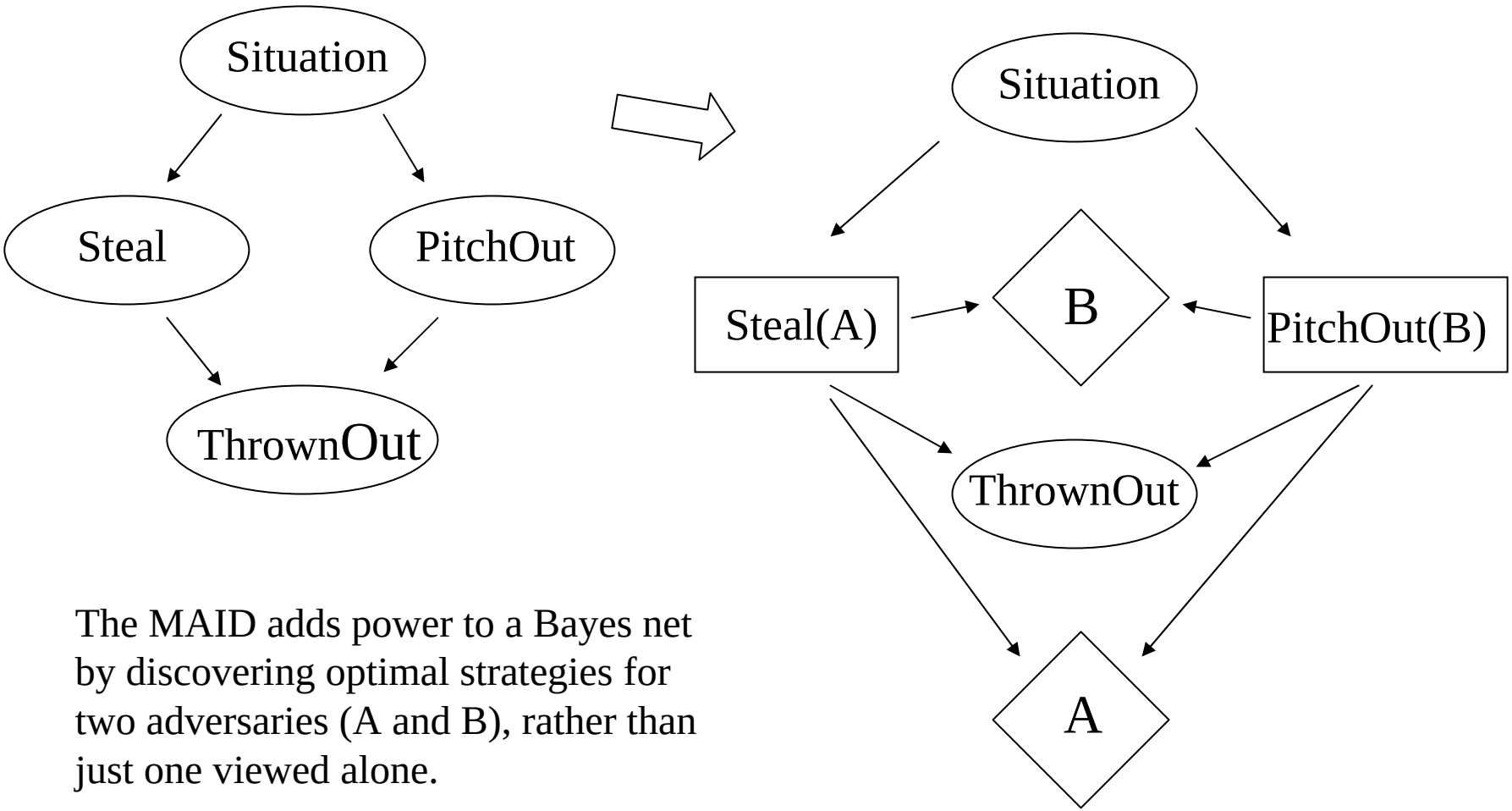
Flanking costs me two moves

Strategic Task

- What is the opponent's intended route to your flag?
- When should you exercise your block?
- When should you guess a flank will out-maneuver an anticipated block?

NID: adds power to Bayes net by discovering optimal strategies for both players

Multi-Agent Influence Diagram (MAID)



The MAID adds power to a Bayes net by discovering optimal strategies for two adversaries (A and B), rather than just one viewed alone.

A. Pfeffer & Y. Gal, Harvard

I know that you know I know that……

Strategies and Path Dependence

S. Page and J. Bednar, Univ. Michigan

Given: $S = \{s_1, s_2, s_3, s_4, \ldots\ldots s_n\}$, $A = (a_1, a_2, a_3.)$

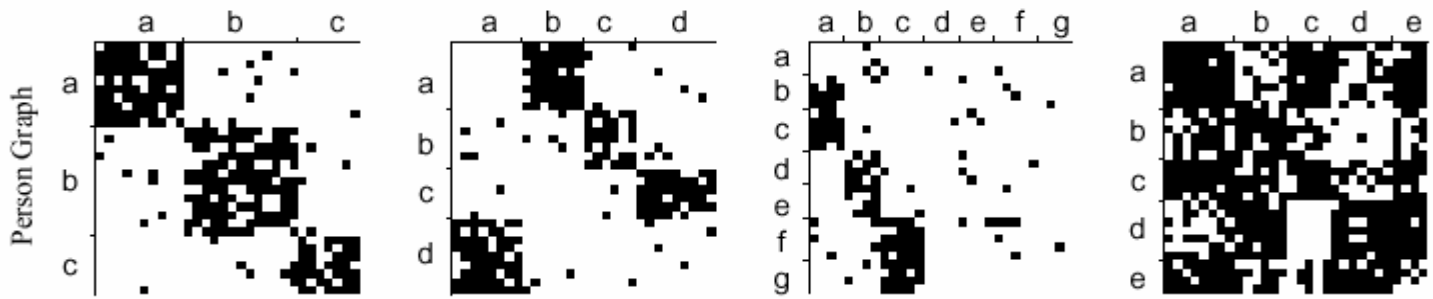
If: a_1 plays s_i then s_k in response to a_2's strategy shift,

What will a_1 play when a_2 again shifts strategy?

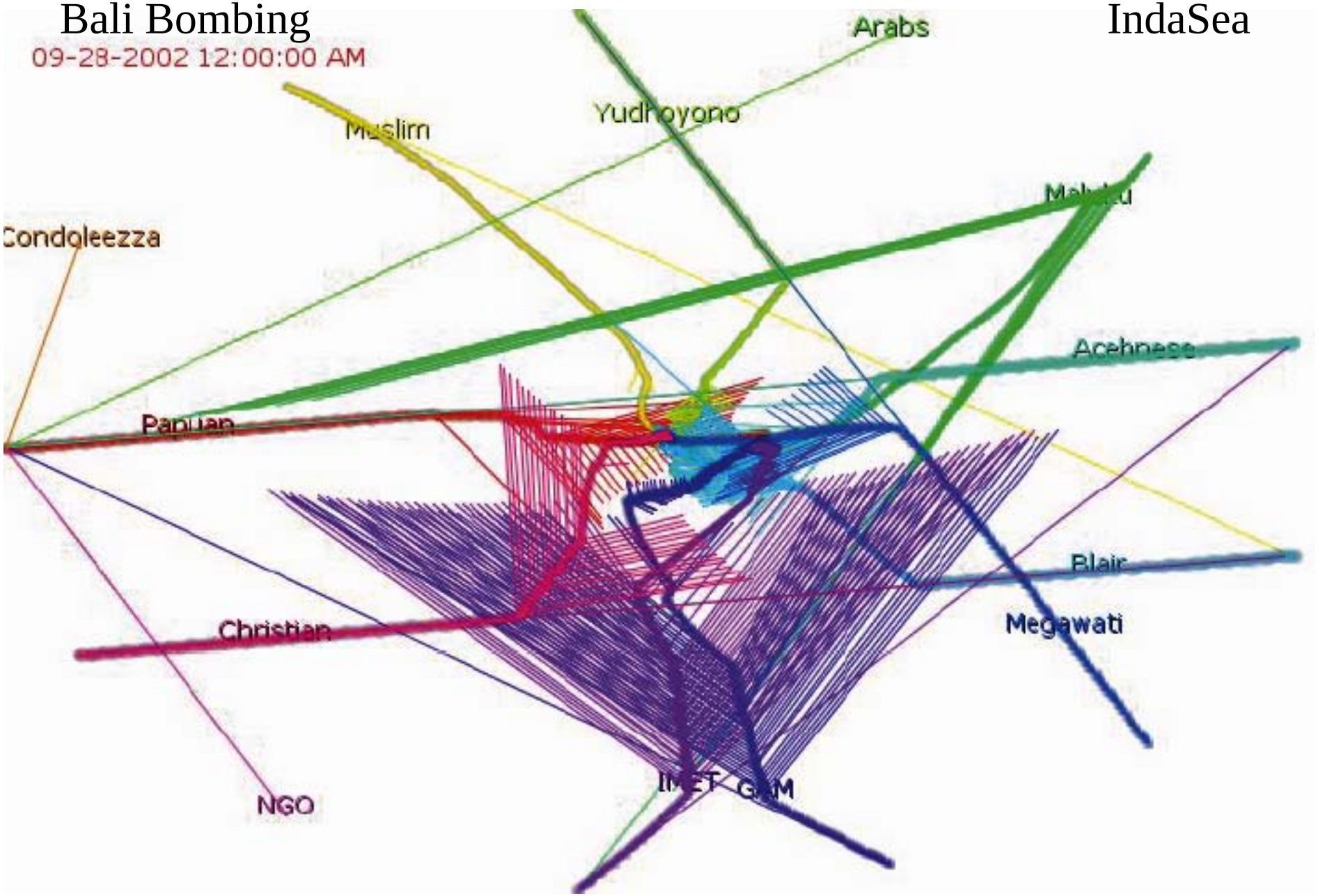
Dynamic Complexity

Objective: to characterize the changes and stabilities of networks.

What is the temperature or entropy of a network's structure?



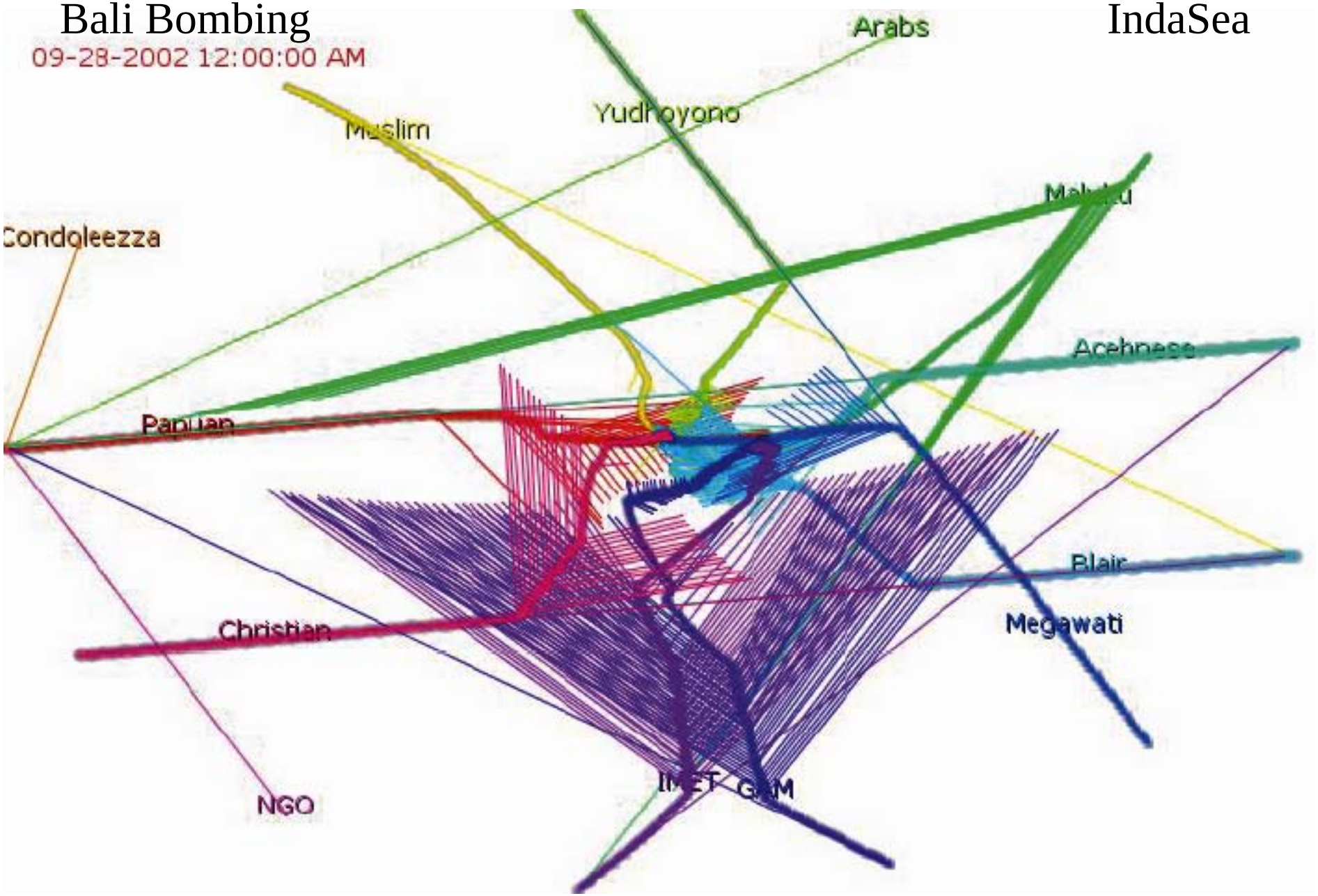
30 x 30 edge adjacency matrices

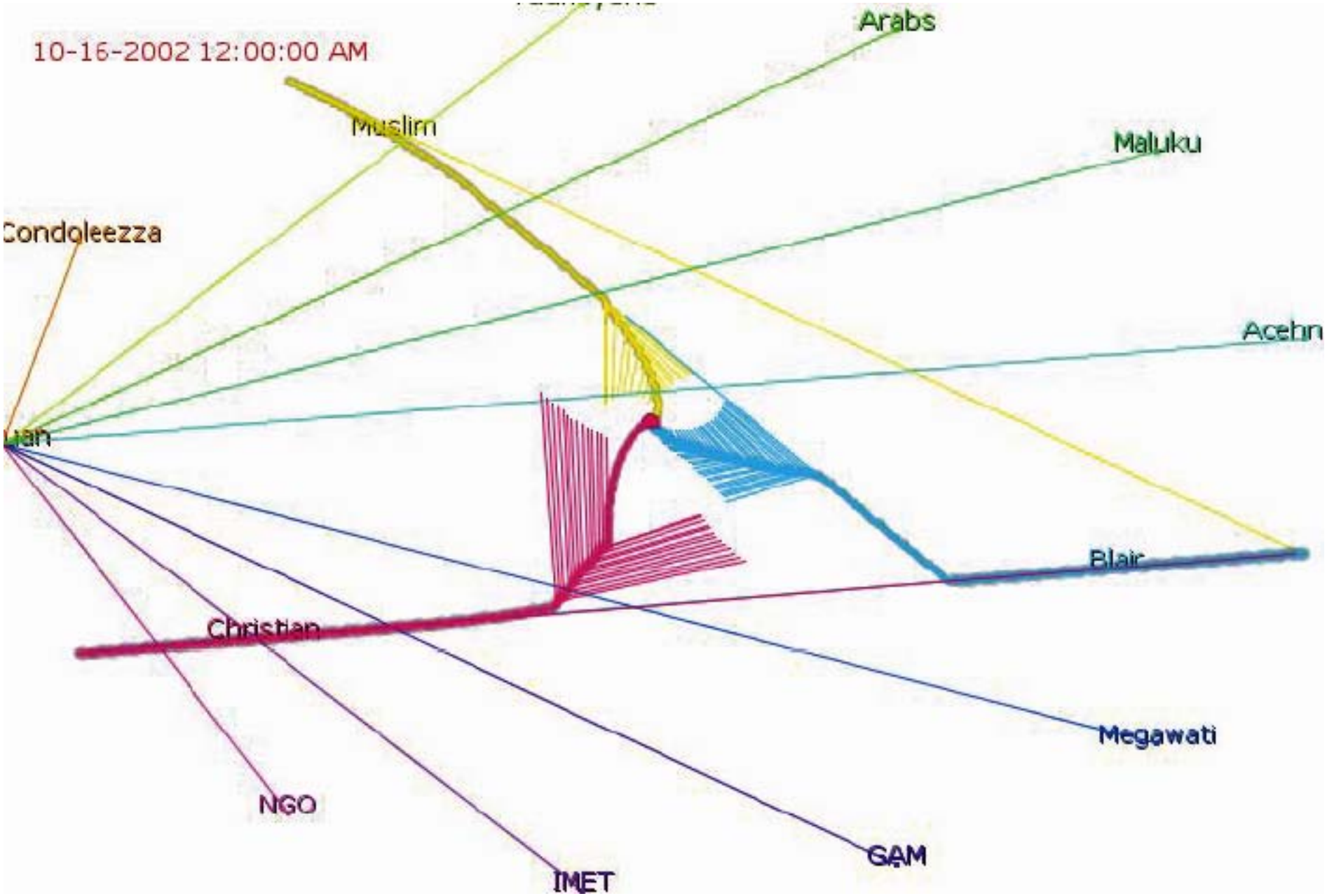


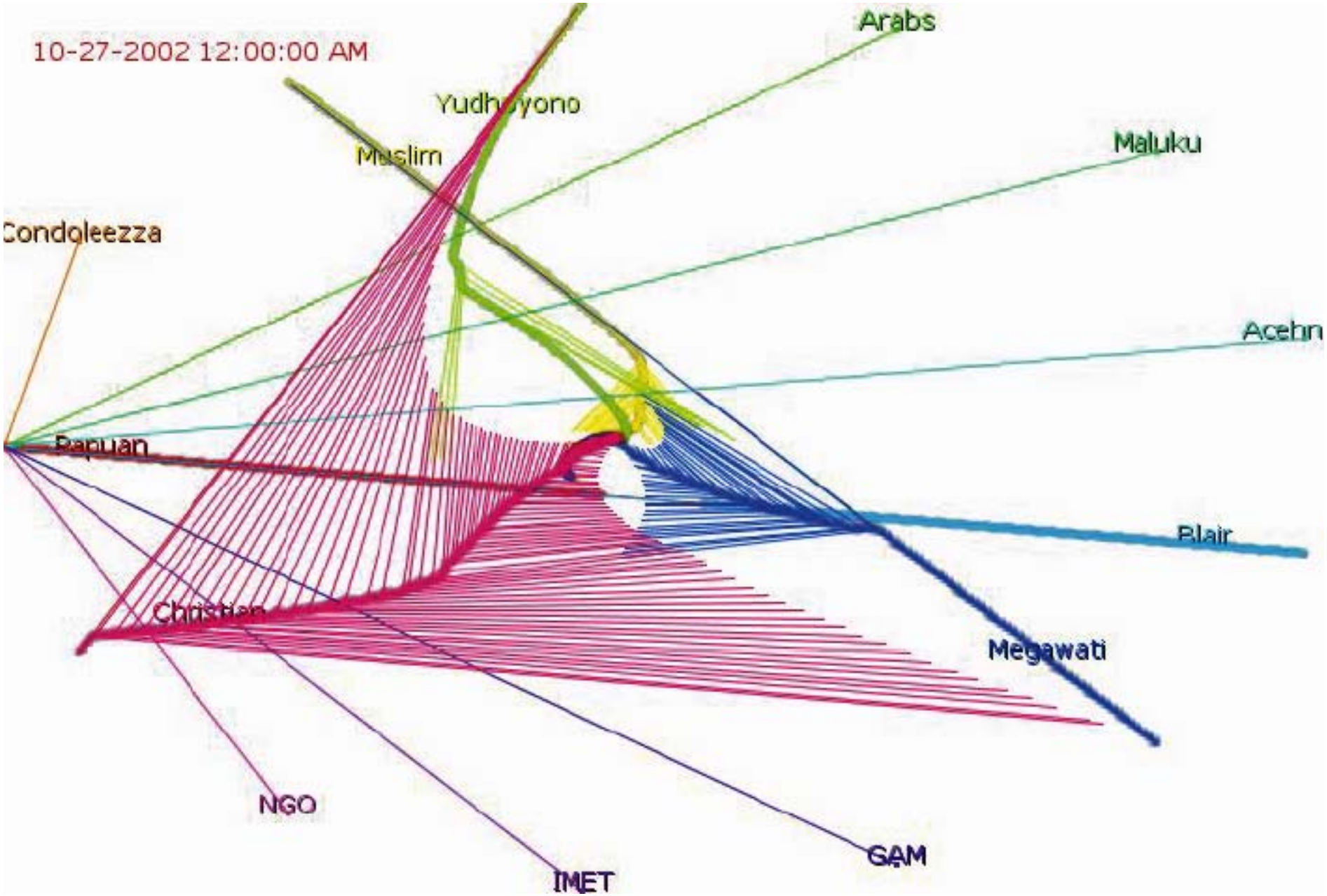
Influence Map: A Representation for Tracking changes in Cultural Stances

Bali Bombing

IndaSea




10-16-2002 12:00:00 AM
Arabs
Muslim
Maluku
Condoleezza
Acehn
Blair
Christian
Megawati
NGO
GAM
IMET


10-27-2002 12:00:00 AM
Arabs
Yudhoyono
Muslim
Maluku
Condoleezza
Acehn
Papuan
Blair
Christian
Megawati
NGO
GAM
IMET

“Kick-off”

When: 27 January 2006

Where: MIT, Cambridge, Ma

Contact: wrichards@mit.edu

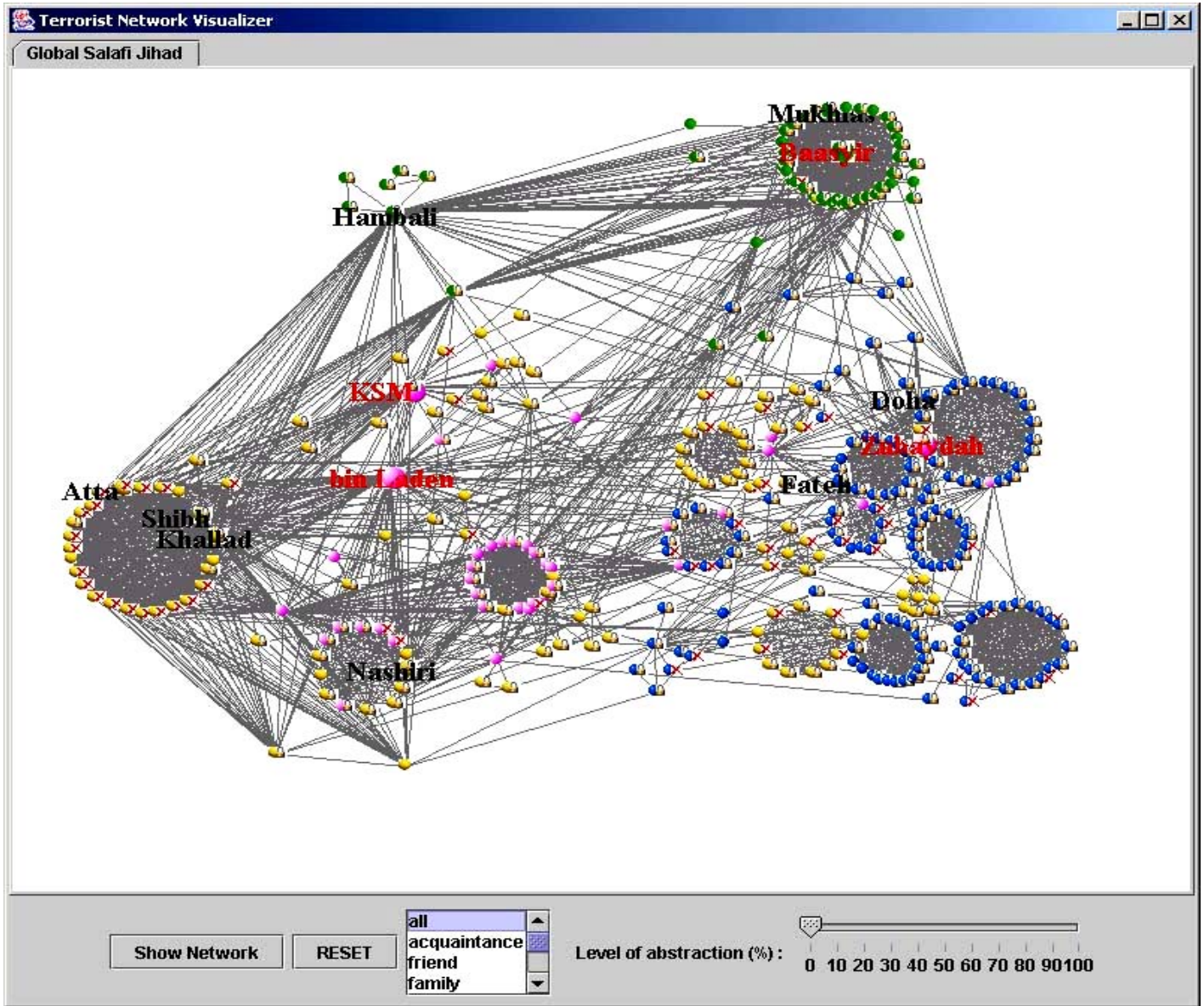
The Approach

Identify key variables in social networks that can be manipulated to revise beliefs. [Field studies & Lab Expt's.]

Develop insights into how trust and belief revision can impact the effectiveness of group decision-making.

Model how social networks may be shattered or made to cohere thru cultural shifts or external pressures.

A Complex Network Structure



Clumps

- Central Staff
- Core Arab
- Southeast Asian
- Maghreb Arab

Node Size

- Leader
- Lieutenant
- Other people

Fate

- Dead
- Captured

Deliverables (highlights only)

The Team: at least one integrated, computational model for one cultural context showing the dynamics of the interactions across the individual, group, and cultural levels. Lays groundwork for future models in other contexts. (Feb 08)

Collaborations:

Medin/Atran/Tenebaum: Agent-network model applied to decision-making outcomes gathered from Ladino & Itza' Maya field studies, and studies of terrorist organizations.

Page/Richards/Bednar: Show how information uncertainty or mis-information might fracture a network; explore role of institutional constraints on network stability.

Pfeffer/Stankiewicz/Tenebaum: Develop models and conduct experiments to test models for inferring goal-plans and action-planning personalities & styles.

Forbus/Winston/Medin: Two or three sets of culturally defining stories keyed to historical heroes. Algorithms for using analogical inference to model beliefs and reactions of agents to events that can be mapped into the story structure.

Individual Projects (partial list):

Pfeffer: Build a probabilistic mixture model of behavior in a strategic decision-making setting (Colored Trails.)

Tenenbaum: A program that discovers the structural principles underlying a network of interacting agents, using Bayesian inference and a probabilistic generative model for social networks. Extension of program to predict flow of beliefs in the network, and how belief changes revises network structure.

Page & Bednar: Models that link institutional to cognitive structures, especially with regard to how institutional factors influence cooperative behavior, expectations, and trust.

Richards: Graphical models for belief structures and decision-making, showing when excessive variety in individual beliefs leads to group fracture, and the formation of competitive subgroups.

Stankiewicz: Roles of leaders and followers in strategic decision-making of adversarial teams in a navigation competition, using a VR microworld.

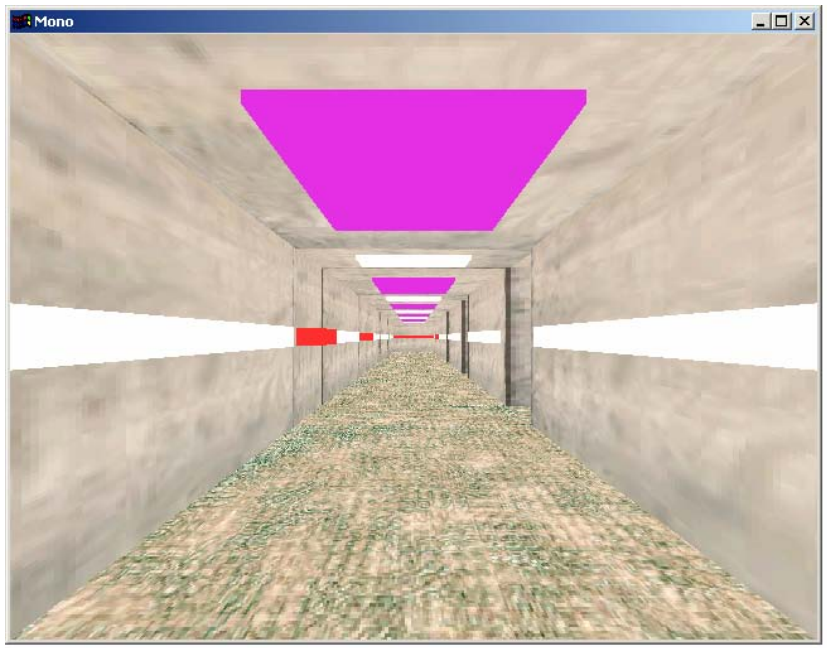
Medin & Atran: Additional field studies of belief systems, categorizations, and reasoning schemas in Guatemalian or Wisconsin tribal societies, as well as cultural effects on the development of terrorist networks.

Significance

The models provide the analyst with tools for predicting patterns of belief revision when social networks are subject to internal or external pressures.

Our models will give the decision-maker new tools for evaluating the consequences of various strategies and courses of adversarial actions taken both within and between cultures.

Adversary Behavior



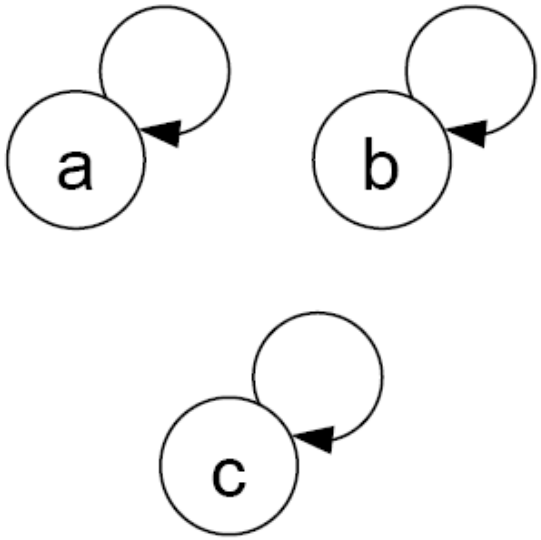
- Virtual indoor buildings
- Subjects working to reach goal while preventing adversary from reaching goal.
- Visually sparse:
  - Allows for computational modeling
  - Generates uncertainty

Task

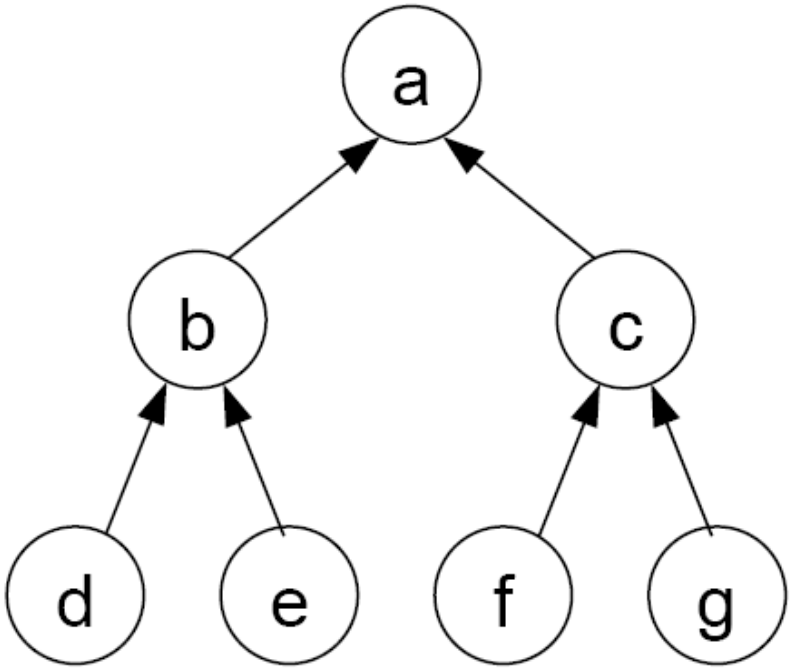
- Indoor virtual environment
  - Goal is to reach enemies position
  - Prevent enemy from reaching your position
- Actions
  - Move
  - Place barriers
- Model optimal behavior
  - Partially observable markov decision process

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

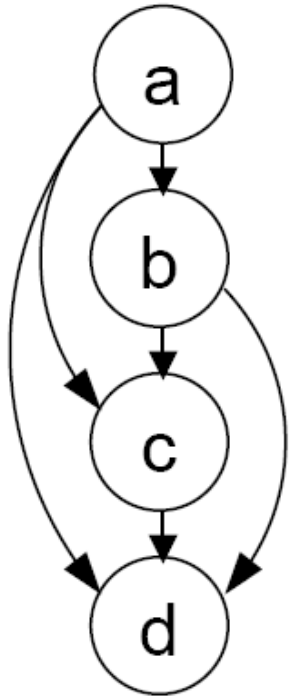
Types of Networks recovered by Block Model



Social groups



Hierarchical

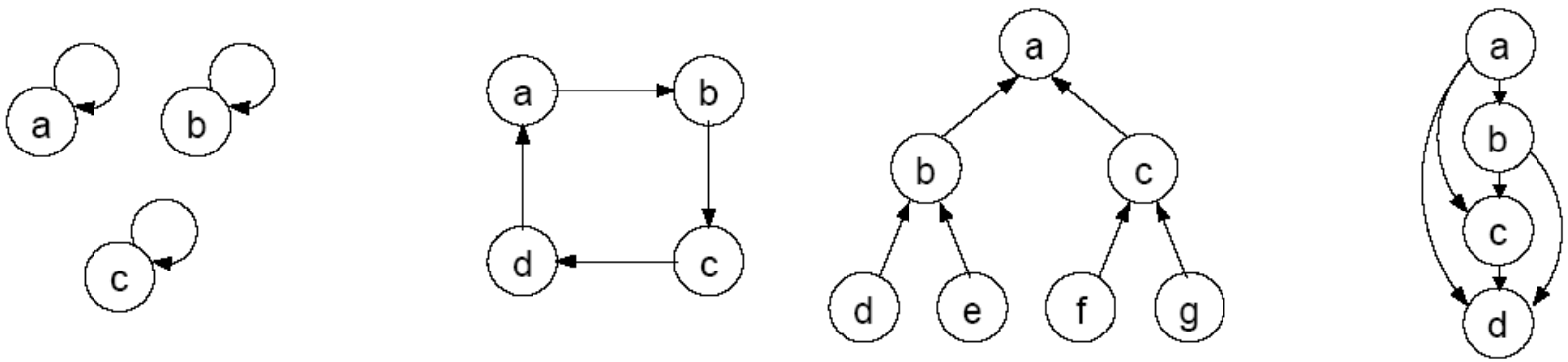


Dominance

Graph Type

Community | Ring | Tree | Dominance hierarchy

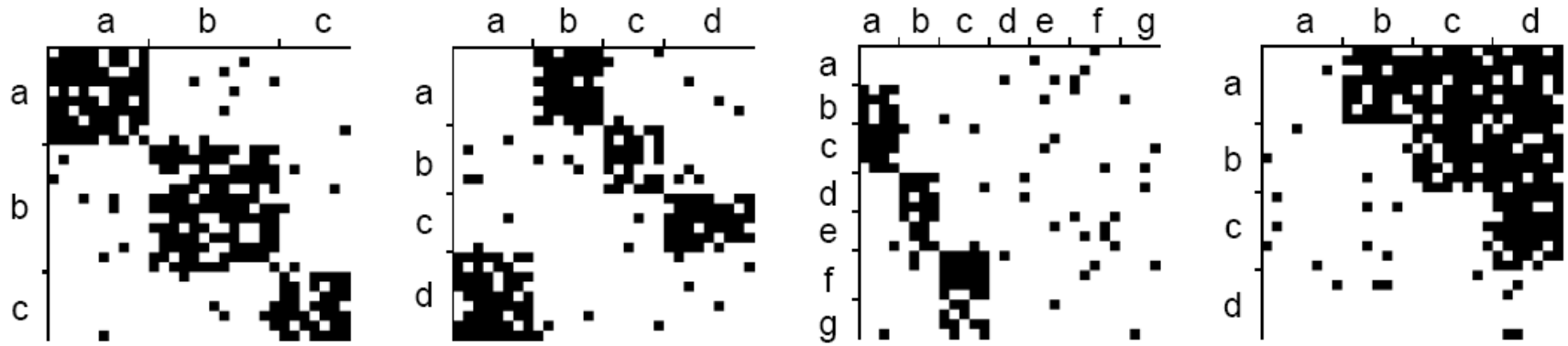
Class Graph



Eta

	a	b	c
a	0.9	0.1	0.1
b	0.1	0.9	0.1
c	0.1	0.1	0.9

Object Graph



The Approach

1. Choose a set of data on relations and beliefs in different social contexts by Jul 05 (e.g. the Ladino & Itza' Mayan, as well as several other kinship or relational data bases)

2. Apply two or more computational models to reveal the inherent structure of those networks by Jan 06.

3. Consolidate data on how institutional factors influence beliefs and trust in social networks by Jan 06

4. Preliminary Model of effects of institutional factors on belief dynamics and network structure by Jun 06.

5. Preliminary data on adversarial group interactions (VR environment and a strategic game) by Sep 05.

6. First models for adversarial group interactions by Jan 06.

7. Explore sensitivity of types of networks to fracture by Jan 06.

Hmm… all this is not clear….! Or organized well.

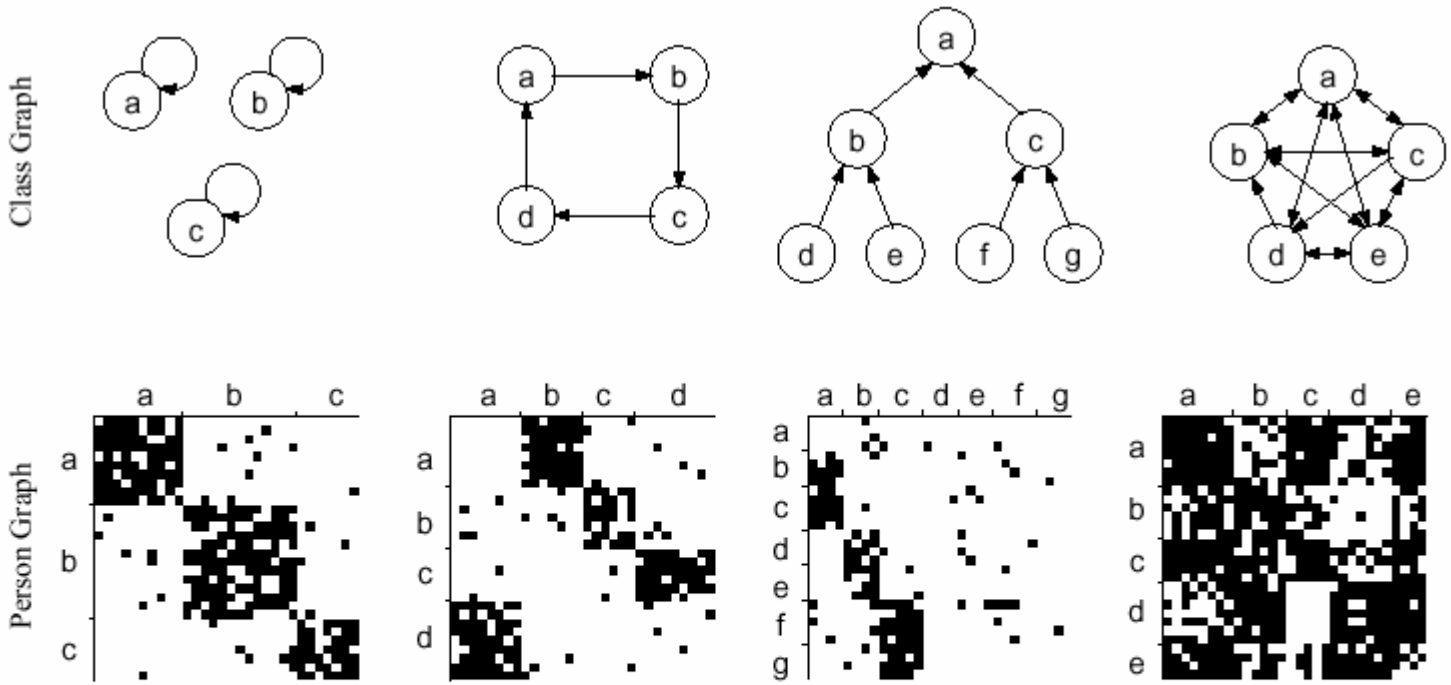


Figure 2: Bottom row: adjacency matrices representing relations in four domains, each with thirty people. The people are sorted into classes (indicated by labels a through g). Top row: class graphs corresponding to the people graphs below. Only the edges in the class graph with large weights are shown. The leftmost class graph, for example, indicates a case where people in one class tend to link only to other people in the same class.

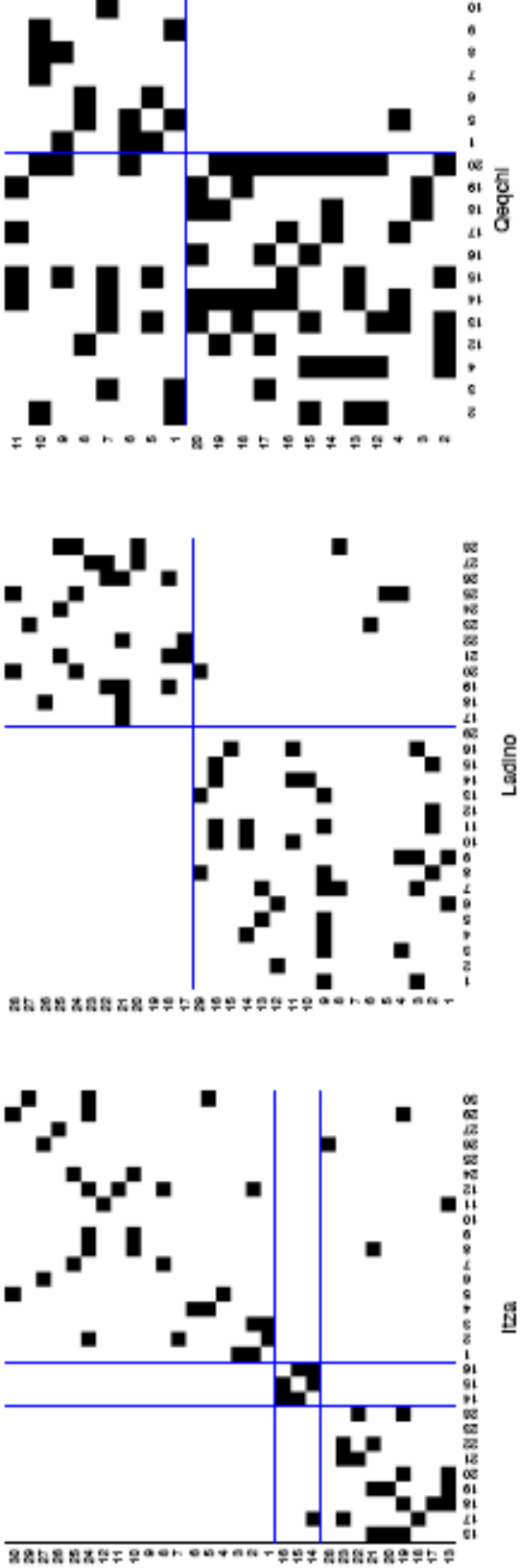


Figure 1: Social networks (asymmetric) sorted according to the classes found by the IRM

Key Assumptions

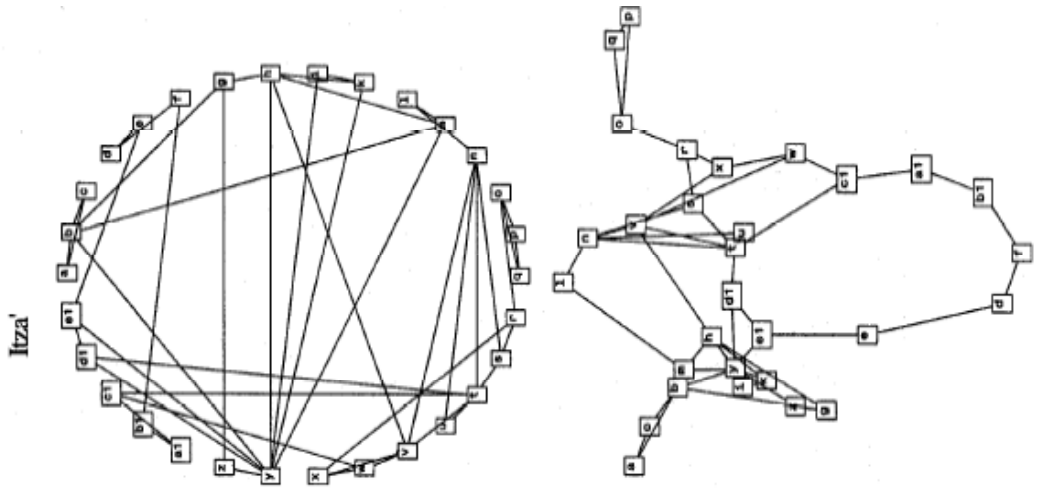
Behavior is rational when viewed in the proper cultural context.

Belief systems and their dynamics can be modeled by causal-like forces that strengthen or weaken social network structure.

Social Networks can be modeled in terms of the social roles of the participants, cultural norms and their sacred values.

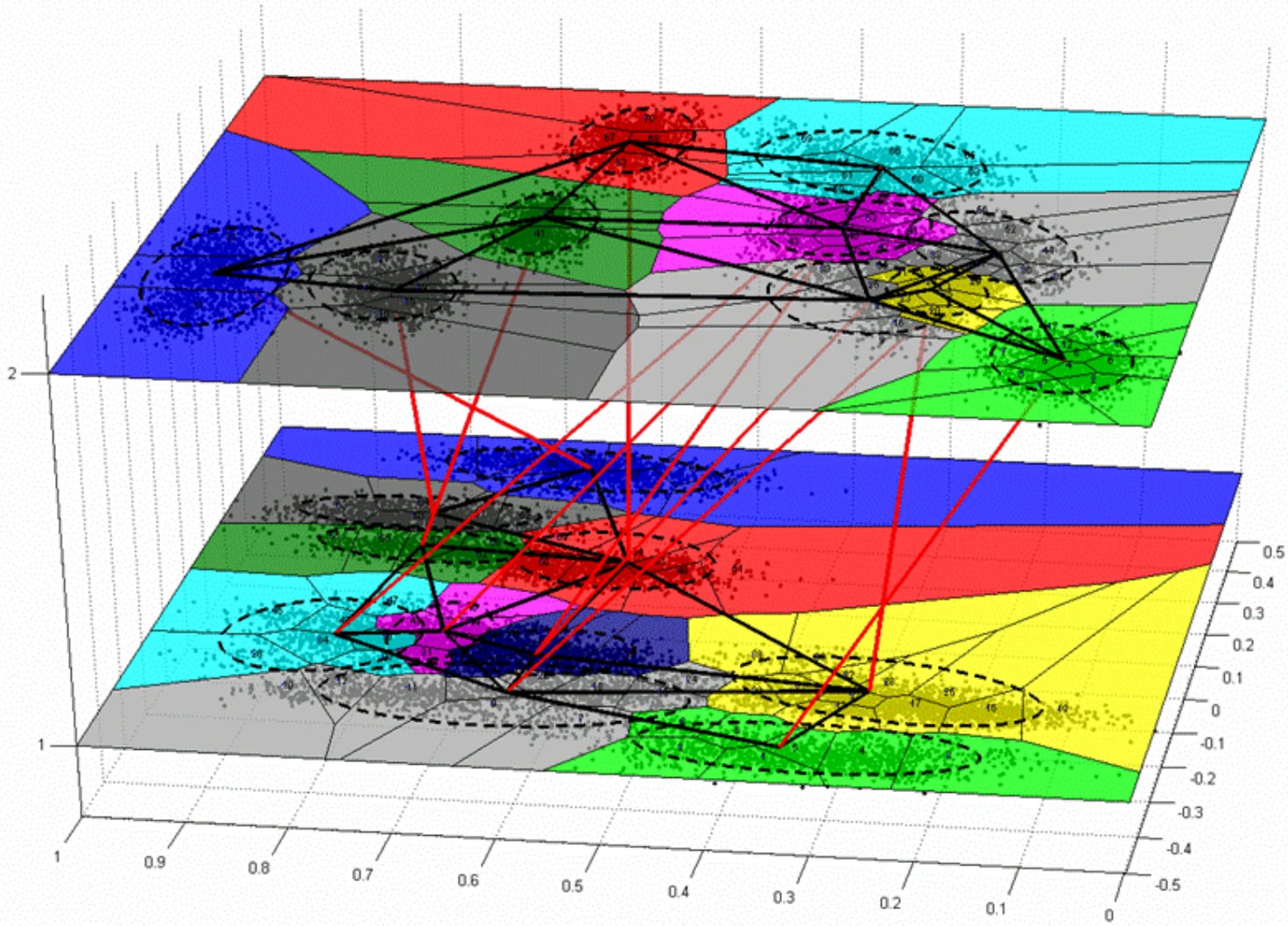
Models for Belief Revision must address three levels: the individual, the group, and the institutional norms of the society.

Field Studies: Determining the role of Culture and Belief systems on the form of social networks.



Itza' social network represented as a circle graph and an MDS map.

D. Medin & S. Atran, Northwestern Univ. and University of Michigan


2
1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5