SAND2011-8292C

Cognitive Science and Applications

POPULATION WIDE ATTITUDE DIFFUSION IN COMMUNITY STRUCTURED GRAPHS

Cognitive Science and Applications
Sandia National Laboratories

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November 4th, 2011

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Research Objective

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- How can we model population wide changes in behavior?
  - Linguistic behavior
  - Technology adoption (e.g., Smart Grid)
  - Violent actions etc.
  - Climate Change
- Building computational models that help in understanding population wide attitude change.

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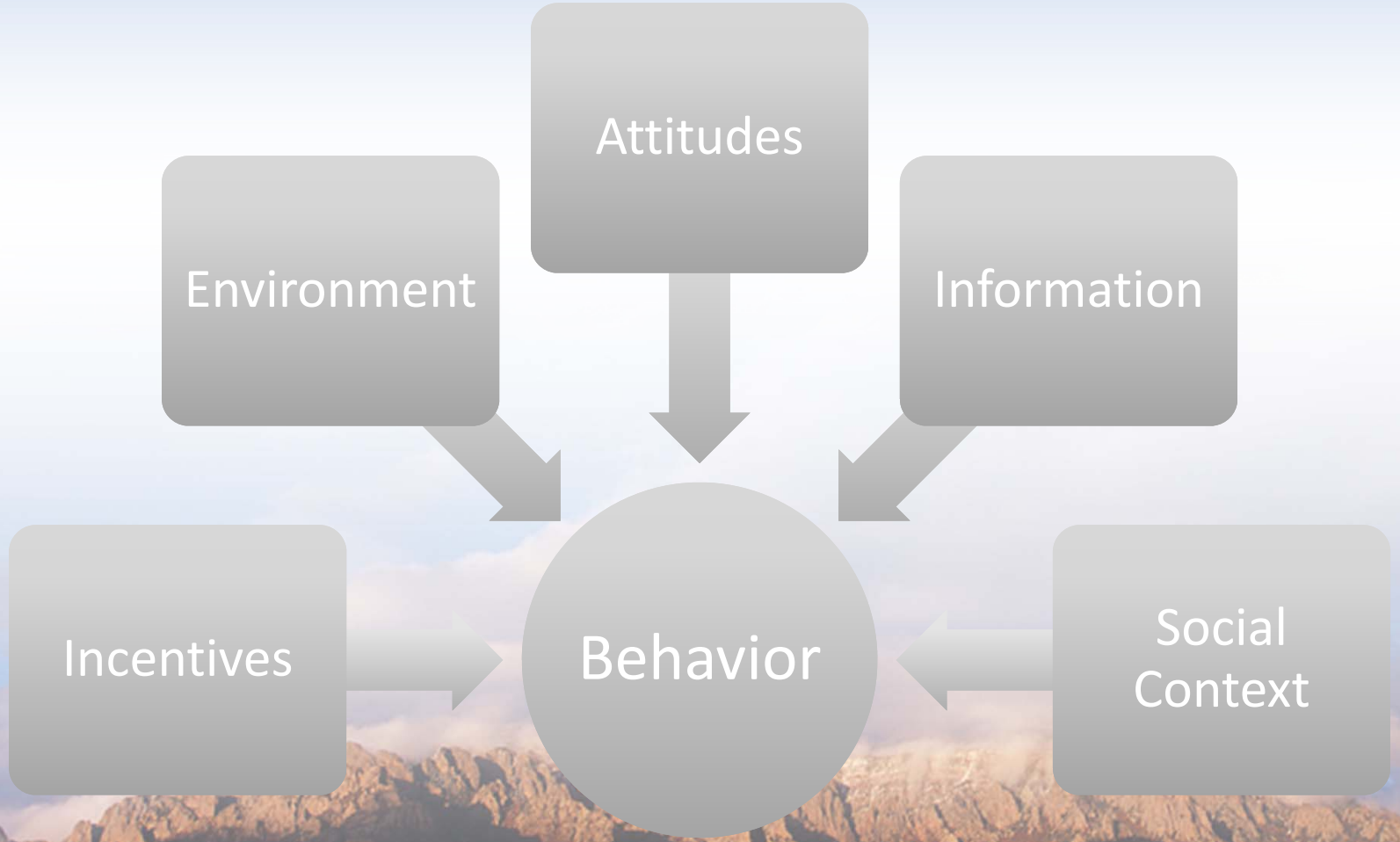
Factors in behavior change



Current Focus

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- Attitude change.
- Leads to behavior change, but that is out of scope right now.
- How can we model the diffusion of information and subsequent attitude change within a population?

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Attitude Definition

- "General, relatively enduring evaluation of an object" (Visser, 2003)
  - Object: Person, group, concept, issues
  - Valence: Positive or negative evaluation
  - Strength: Intensity of evaluation

Attitude properties

- **Continuous:** Attitudes can range from strongly negative to strongly positive.
- **Malleable:** Attitudes can change.
- **Linked:** Attitudes can influence each other

Factors in Attitude Change

- **Cognitive Effort:** Level of effort individuals place in evaluating arguments etc.
- **Social Network:** The impact of friends and family etc.

Drive for consistency

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- Cognitive Consistency Theories: Originated in the 1950's from work on Gestalt Psychology.
- Key idea: Maintain consistency among "elements of thought"
- Example:
  - "positive attitude towards environmentalism" == "positive attitude towards recycling"
  - "positive attitude towards environmentalism" != "positive attitude towards littering"

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Bi-directional Reasoning

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- Bidirectional reasoning
  - Evidence influences conclusion; conclusion influences belief in evidence.
  - "motivated reasoning" (Mooney, 2010)
  - Numerous studies from different domains:
    - Legal reasoning
    - Climate issues
    - Political affiliations

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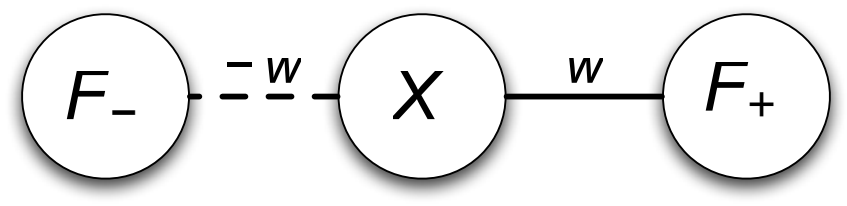
Parallel Constraint Satisfaction

- Nodes represent *concepts*: propositions, beliefs, information, traits, actions, goals.
- Links represent positive/negative influences between concepts: entailment, explanation, deduction, similarity, association.
- Nodes have a value (i.e. -1 … +1) and a valence (+/-)
- Attitude towards a concept is determined by the value and the valence of the concept:
  - Positive value = positive feeling.
  - Negative value = negative feeling.

Preliminary Experiment



- Two satisfying attitude structures:
  - F1=1, X=1, F2=-1
  - F1=-1,X=-1,F2=1

Three node

- X represents attitude to a particular object.
- F+ : Agents attitude towards positive information about X.
- F-: Agents attitude towards negative information about X.

Impression Formation (IMP) model

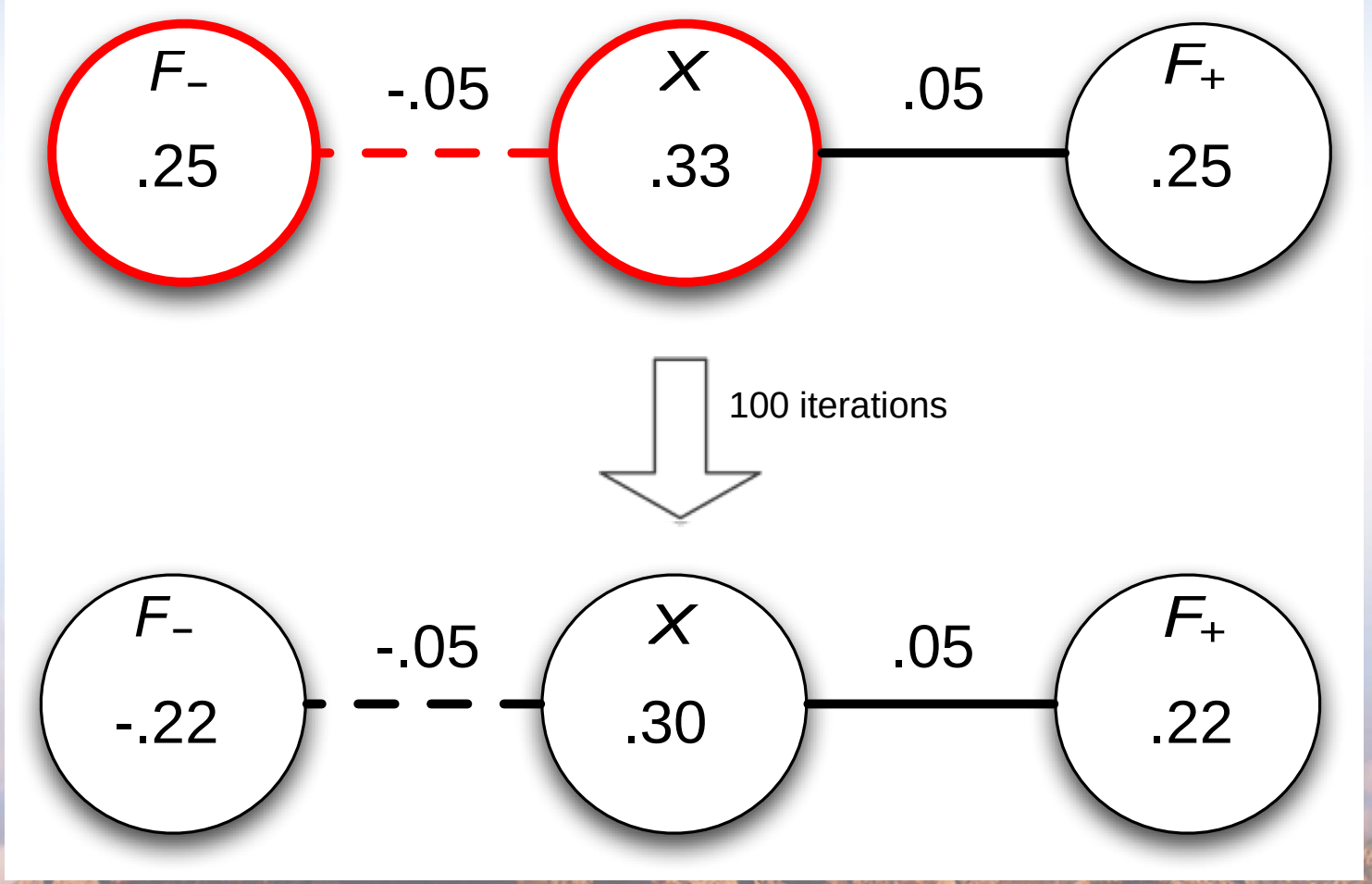
$$a_j(t+1) = a_j(t)(1-d) + \begin{cases} net_j(\max - a_j(t)) & \text{if } net_j > 0 \\ net_j(a_j(t) - \min) & \text{if } net_j \leq 0 \end{cases} \quad (1)$$

where:

$$net_j = \sum_i w_{ij} a_i(t) \quad (2)$$

From: (Kunda and Thagard, 1996)

Example Dynamics



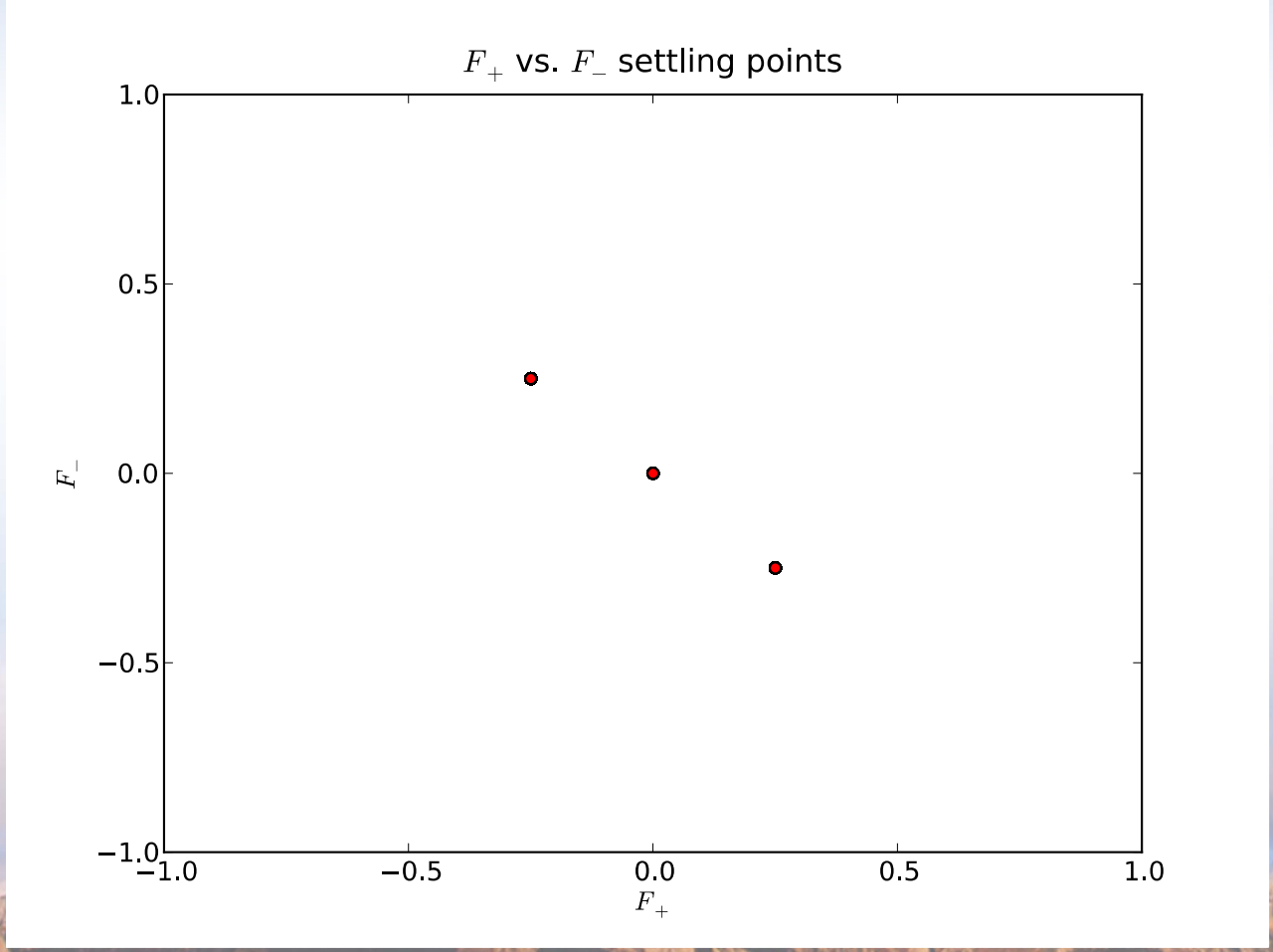
Key aspects

- Cognitive Effort.
- Bidirectional reasoning.

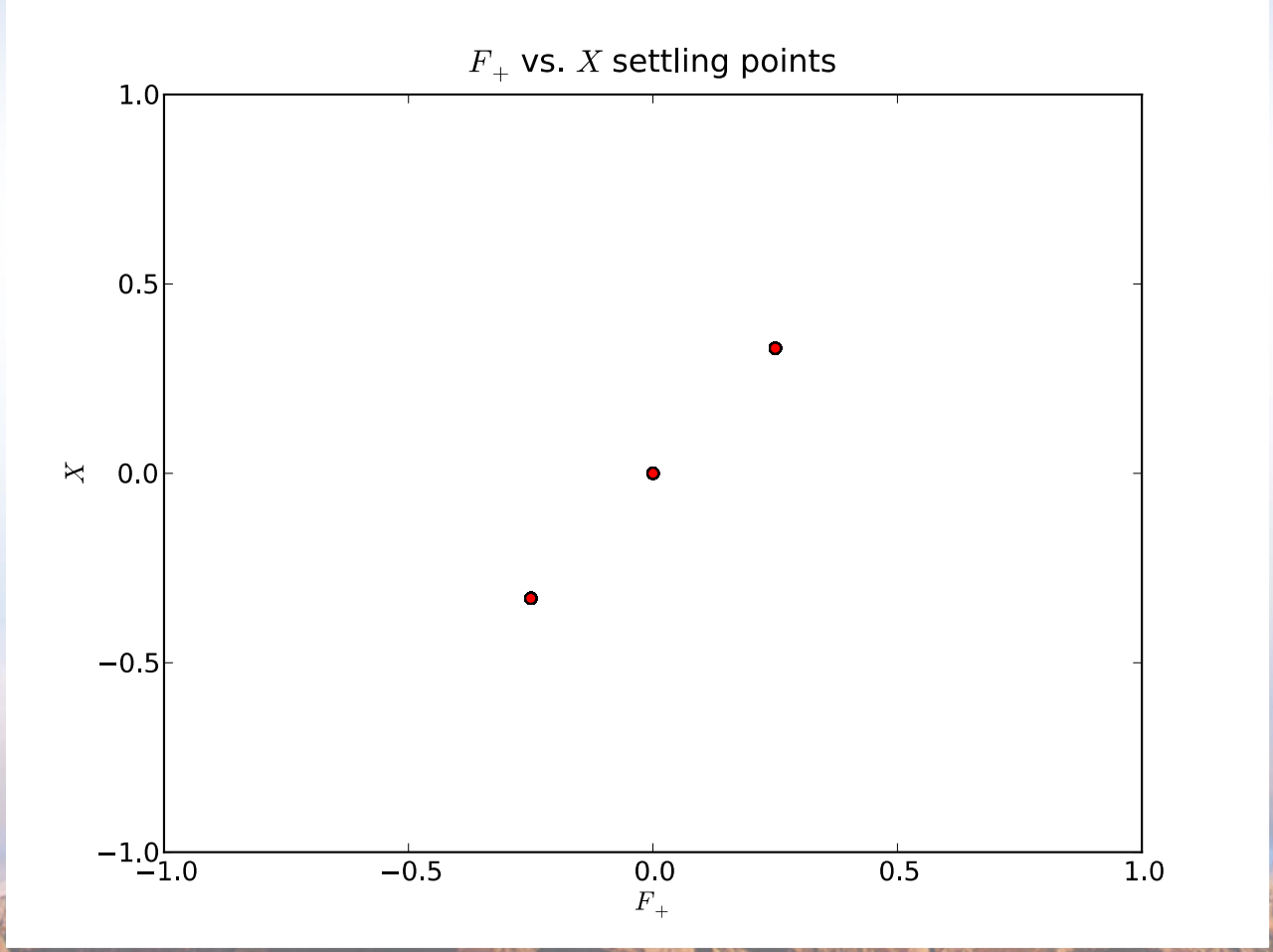
Cognitive Effort

- Cognitive effort captured by the *number* of iterations of the update Eq.
- Higher cognitive effort – more iterations.
- Lower cognitive effort – fewer iterations.

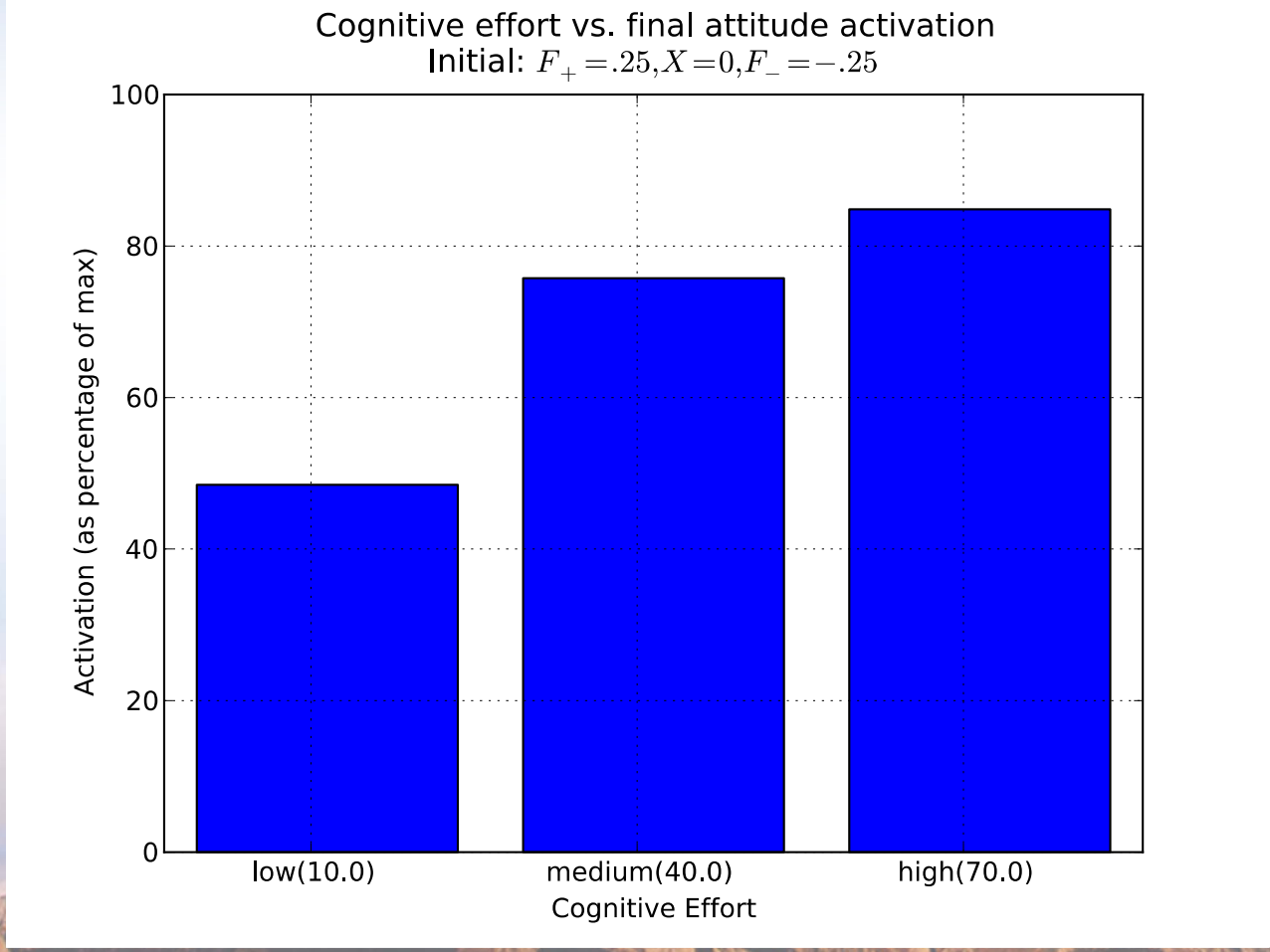
Settling Points
F+ vs. F-



Settling Points
F+ vs. X



Non-linear increase in attitude strength



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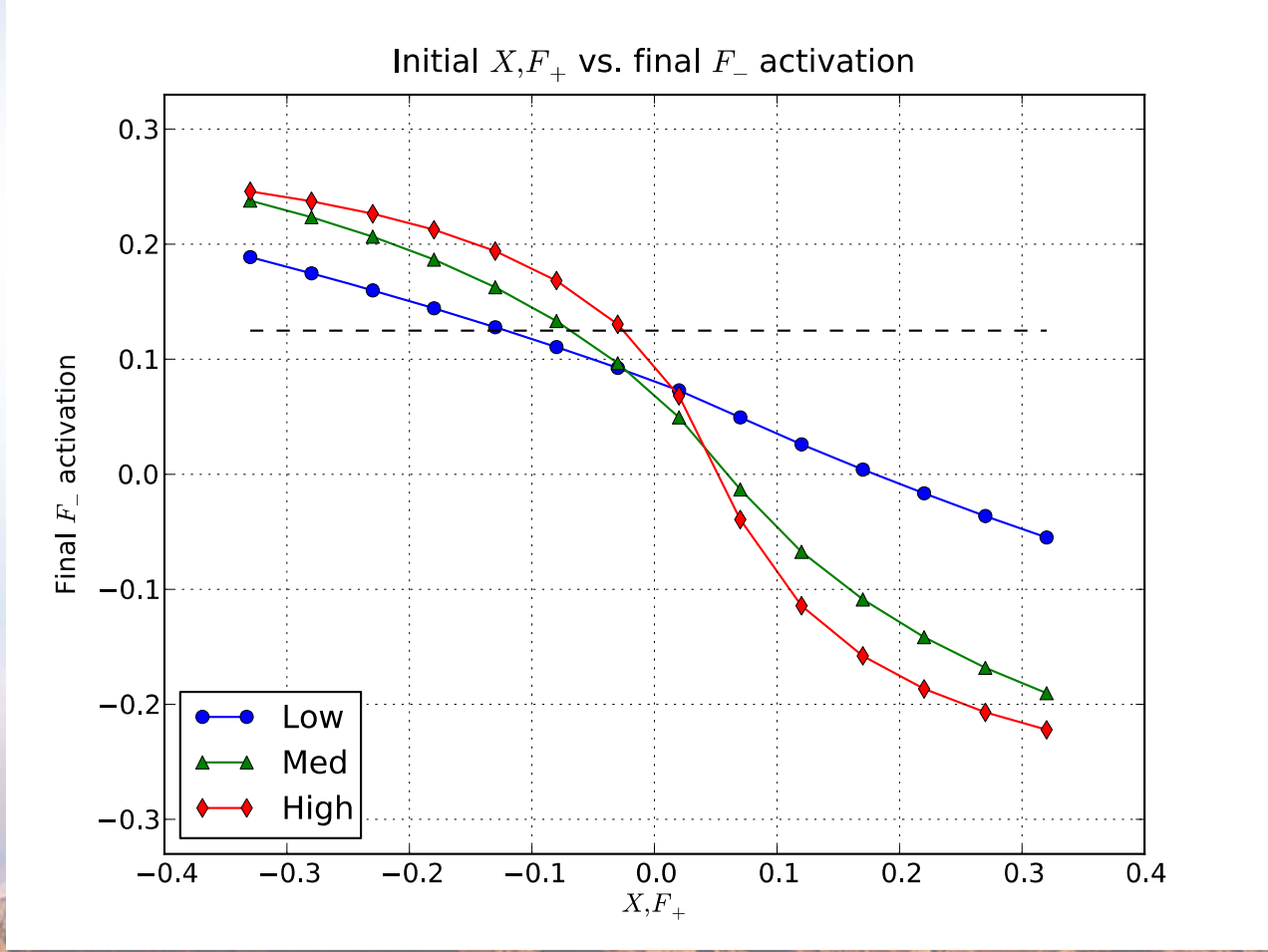
Bi-directional change

- Eqs. (1) and (2) clearly show the impact of X on F- and F+.
- What is the exact impact?
- Vary X,F+ from -.125 to .125
- Set F-=.125

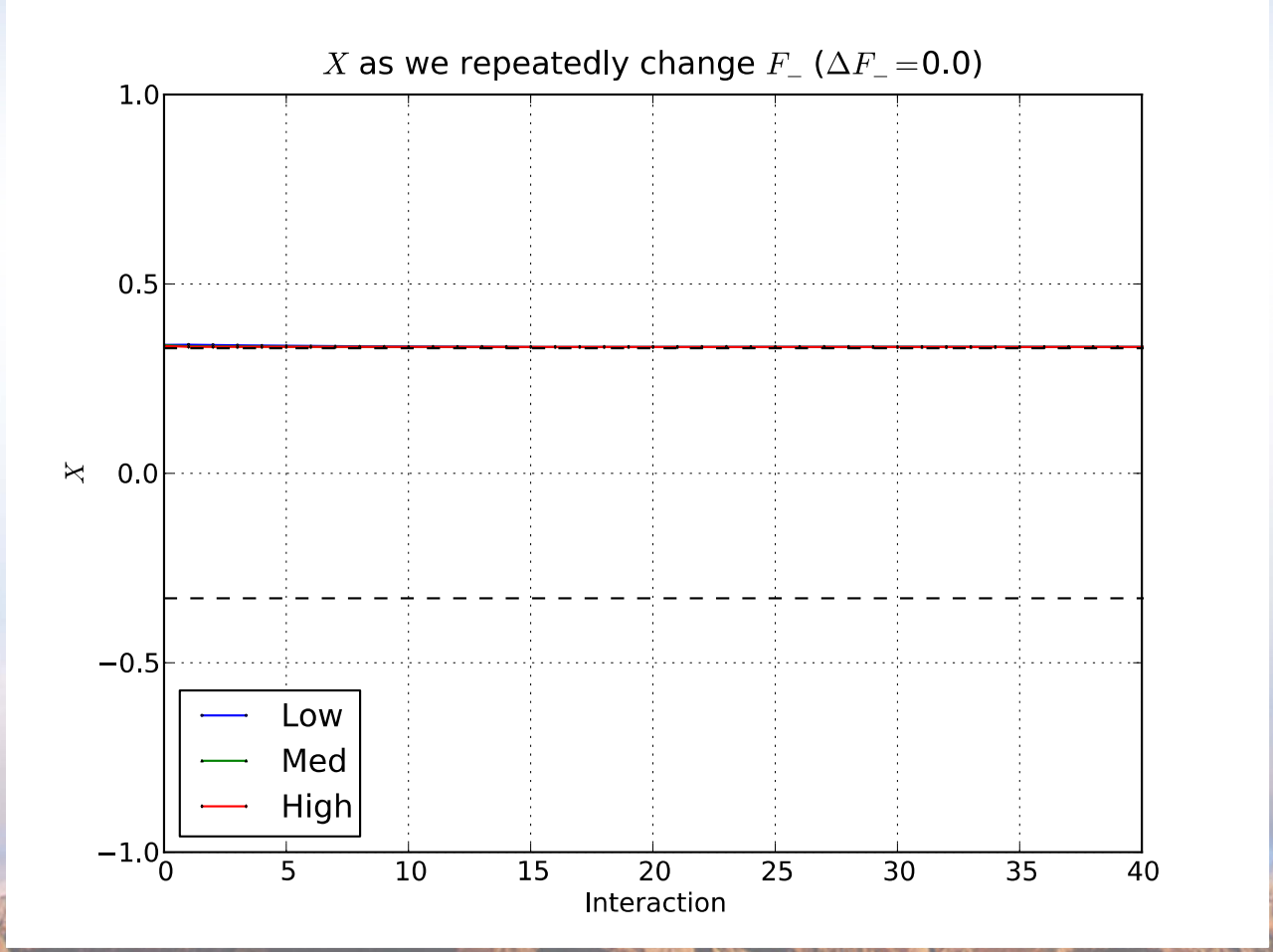
Bi-Directional Change



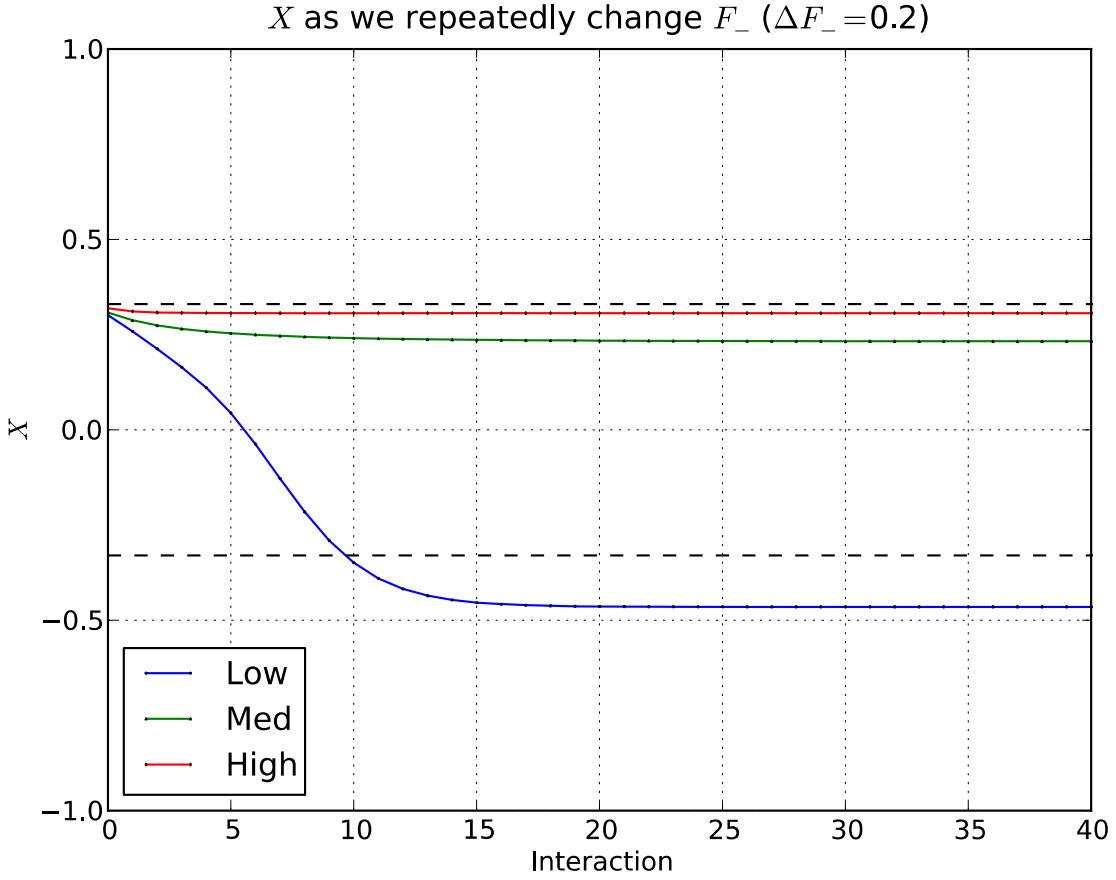
Attitude change

- How many *interaction* till a positive attitude turns into a negative attitude?
- Start with a positive attitude agents <.25, .33, -.25>
- Increase F- by fixed amount each turn.
- Run update eqs.
- How many turns till change?

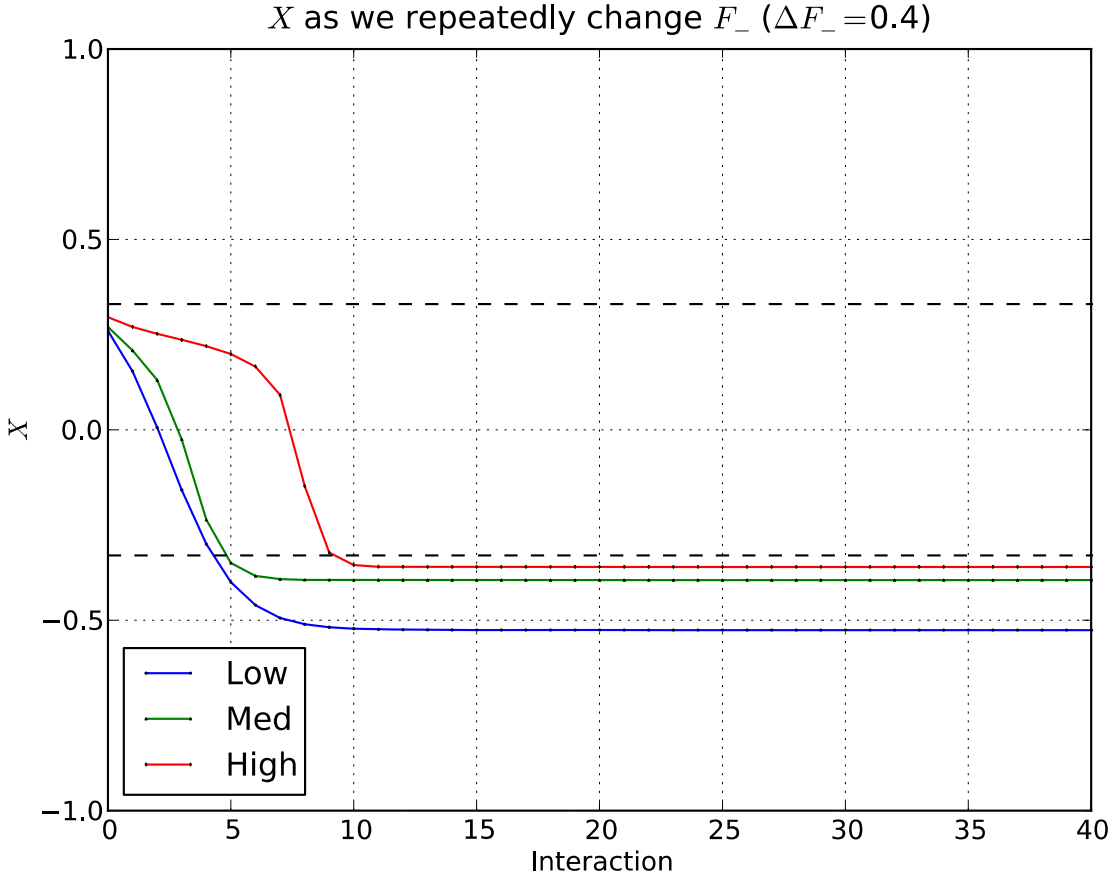
\Delta F- = 0.0


X as we repeatedly change $F_{\_}$ ($\Delta F_{\_}$=0.0)
1.0
0.5
0.0
−0.5
−1.0
X
0
5
10
15
20
25
30
35
40
Interaction
Low
Med
High

\Delta F- = .2


X as we repeatedly change $F_{\_}$ ($\Delta F_{\_}$=0.2)
1.0
0.5
0.0
−0.5
−1.0
X
0
5
10
15
20
25
30
35
40
Interaction
Low
Med
High

\Delta F- = .4


X as we repeatedly change $F_{\_}$ ($\Delta F_{\_}$=0.4)
1.0
0.5
0.0
−0.5
−1.0
X
0
5
10
15
20
25
30
35
40
Interaction
Low
Med
High

A Socio-Cognitive Model

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- So we have attitudes and information within individual, how do we capture social influence?
- Use a social network to capture the topology of interactions between individuals.

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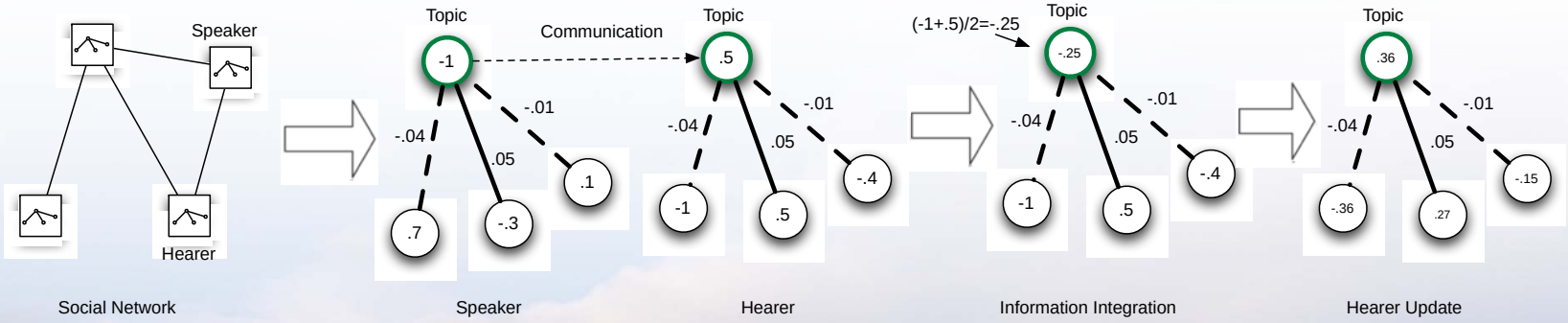
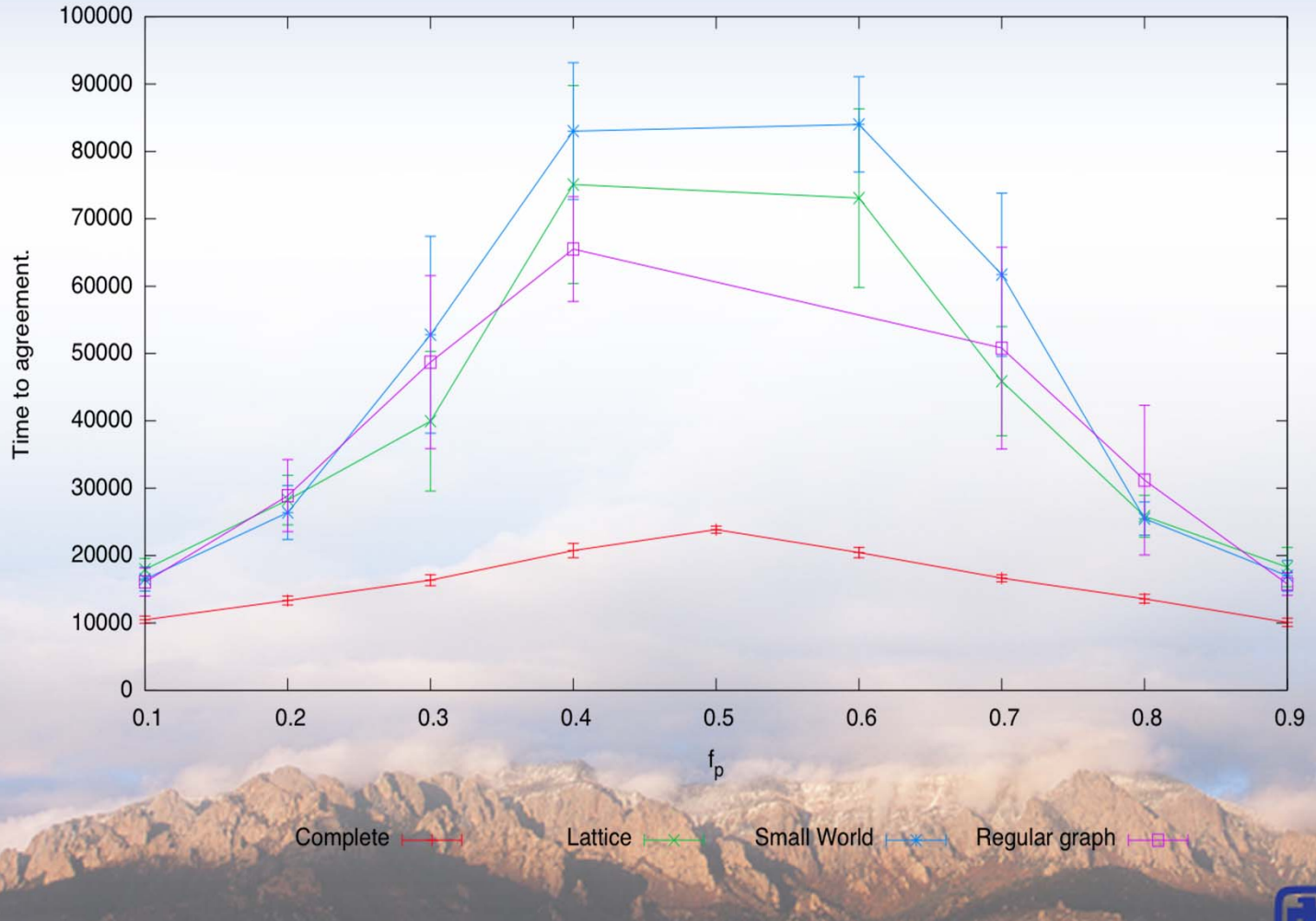
Socio-Cognitive Model



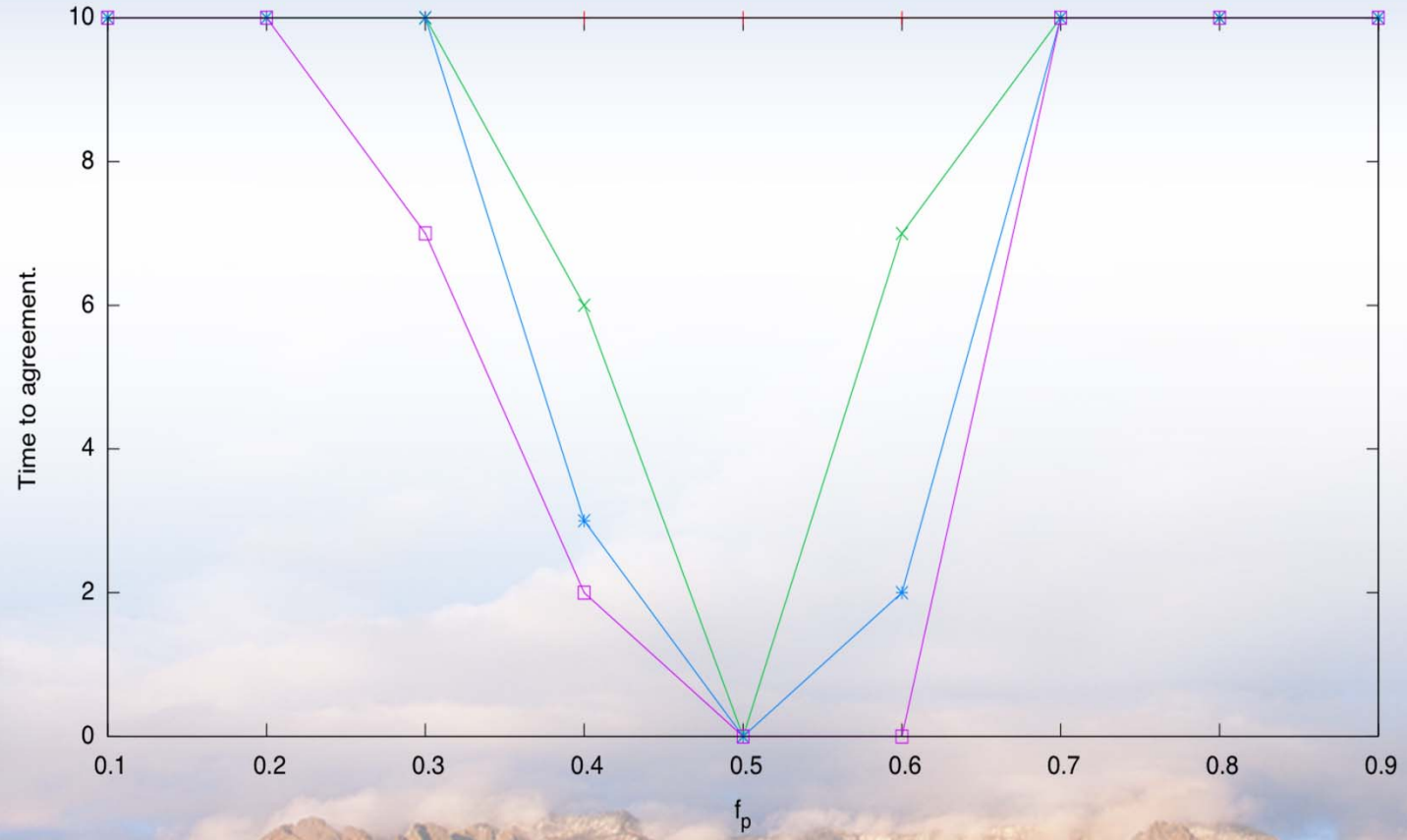
Experiment

- Preliminary experiment: What happens when two differing populations meet?
- Simple cognitive network.
- Initialize f_p fraction of population with positive state.
- Low cognitive effort (using different measurement of effort in these experiments).
- Execute turn dynamics.
- Dependent variables:
  - Does the system reach consensus?
  - How long till consensus?
  - On what state is agreement reached?

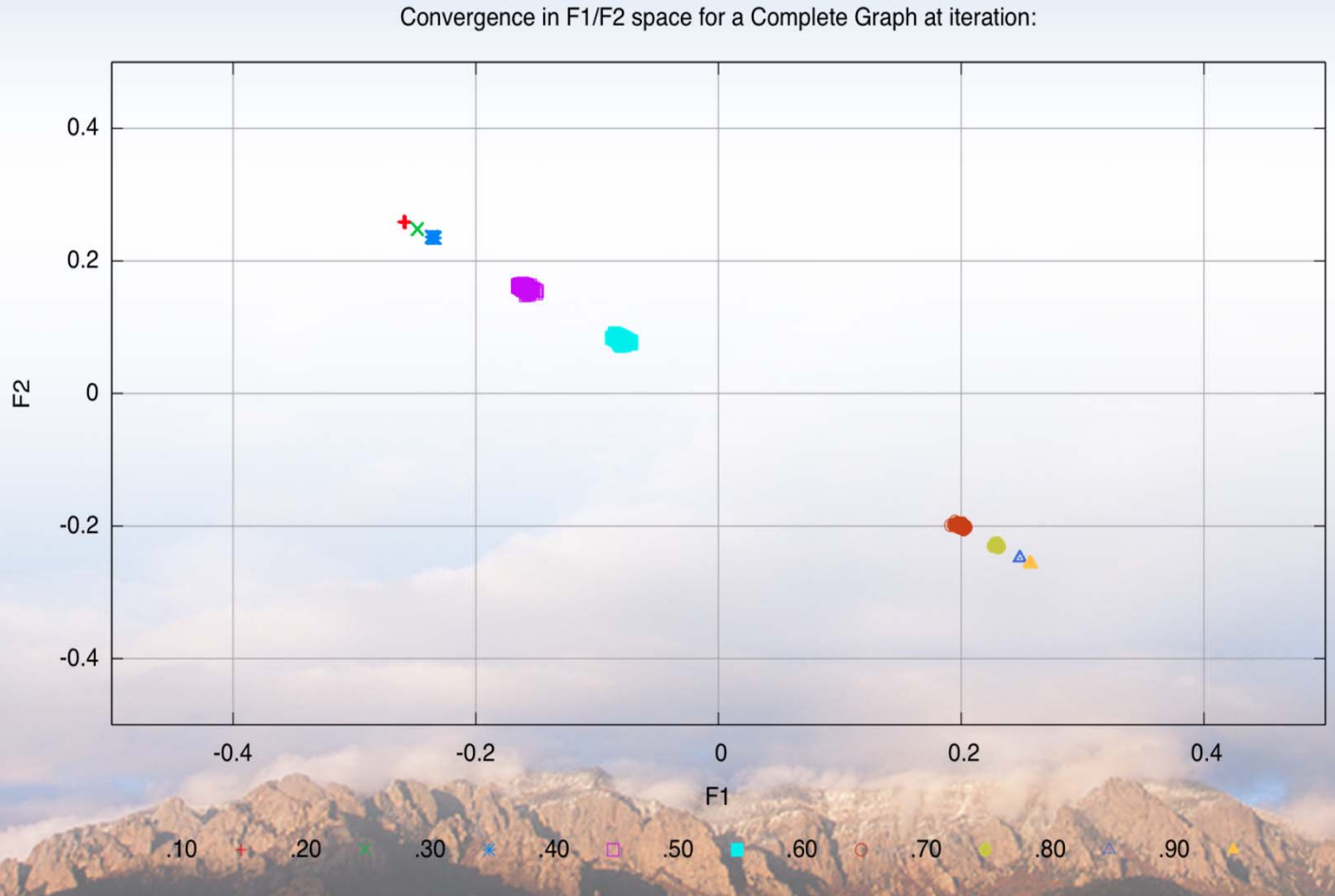
Agreement time vs. initial distribution of attitudes



Number of runs that reached agreement vs. initial distribution of attitudes.



F1/F2 space for a complete graph.



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Initial Distribution Impacts Final Attitude

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- Each group are the states of all agents at the end of a single run.
- Color indicates the initial distribution (f_p) of attitudes.
  - e.g, 0.1: 10% of initial population with F1=1,X=1,F2=-1
- Linear relationship between f_p and final state for a complete graph
- Nonlinear – polarizing effect for lattice graphs.

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F1/F2 space for a lattice graph

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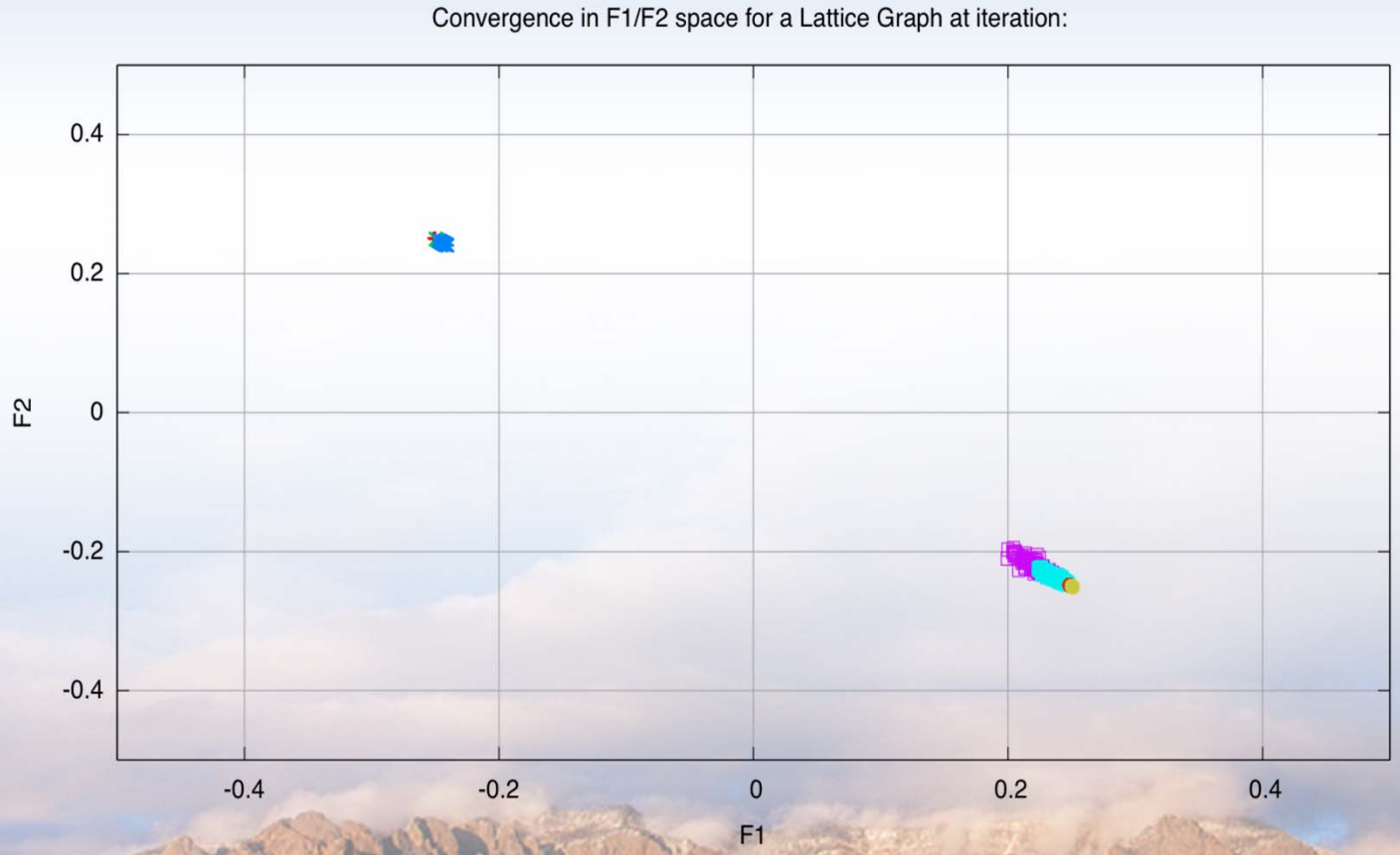

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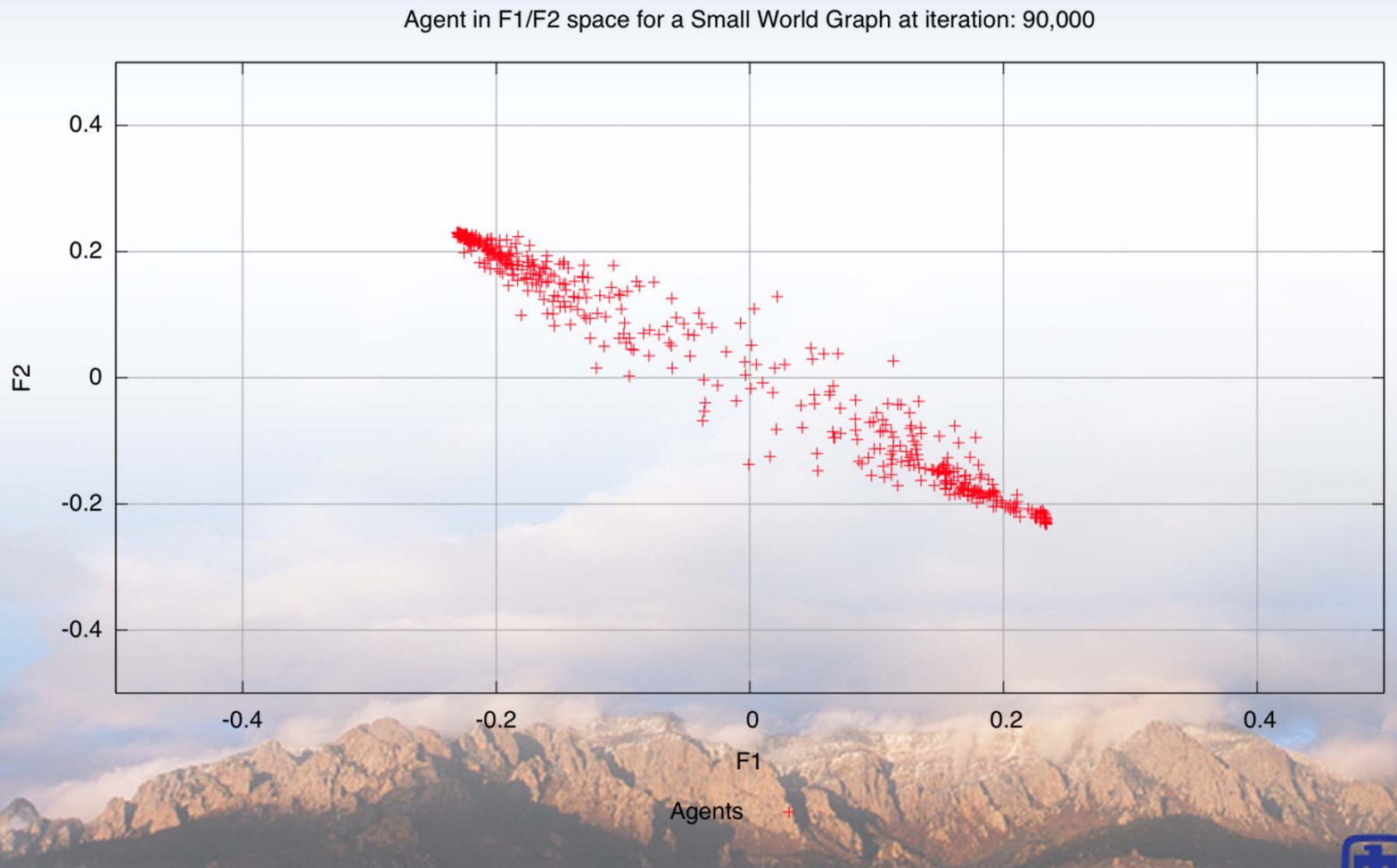
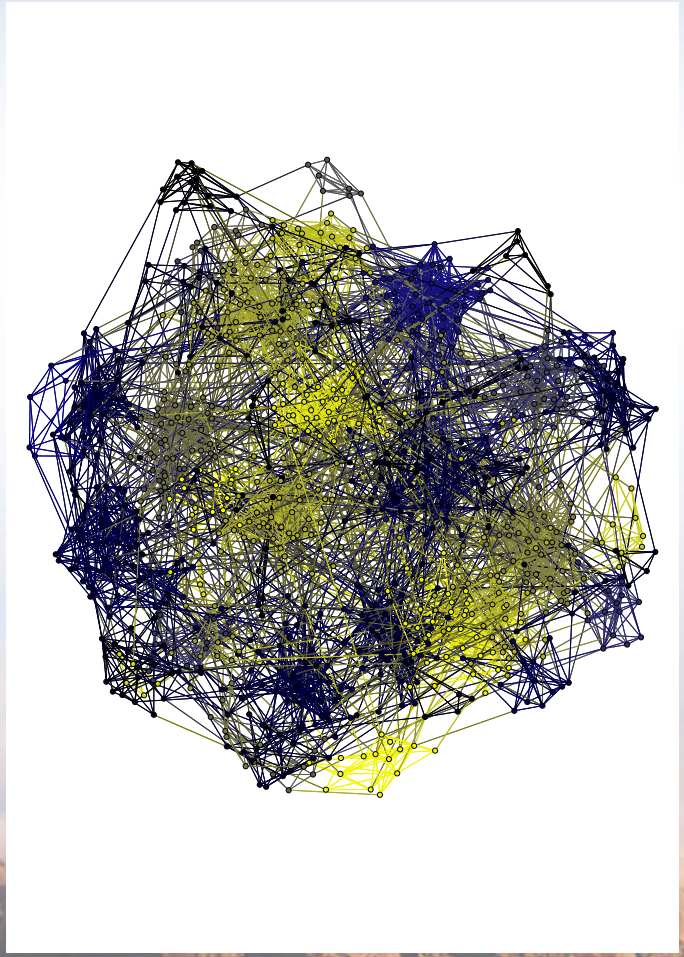
Non converging run for SW networks



Current Experiments

- Focus on *community structured* social networks.
- Groups of nodes with many links, vs. others with fewer links.

Example Community Graph



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Influence Maximization

- Suppose we have all nodes start with negative opinion.
- We can set m nodes to have positive opinion.
- Which m nodes should we pick to have a positive attitude diffuse through a population?

Related Work

- Well studied problem for *Independent Cascade* model
  - Progressive: Agent is positive, always stays positive.
  - For each positive neighbor, node has probability p of switching to negative
  - Occurs only once per neighbor.
- Approximation algorithm found.
- Heuristics like degree-based etc. work reasonably well.

Key Difference

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- Non-Progressive: Attitudes can change valence and strength.
  - Positive agents can be overwhelmed quickly and turn negative.
- Not a problem in the independent cascade models (since positive agents can never turn back to negative).

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Hypothesis: Positive structures

- Hypothesis: Assign positive agents to sub-graph structures rather than individual agents.
- Have “supporting” positive interaction between positive agents.
- Example structure: k-clique.

Doesn't yet work…

The End

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References

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