Computational Modeling of Social and Organizational Systems

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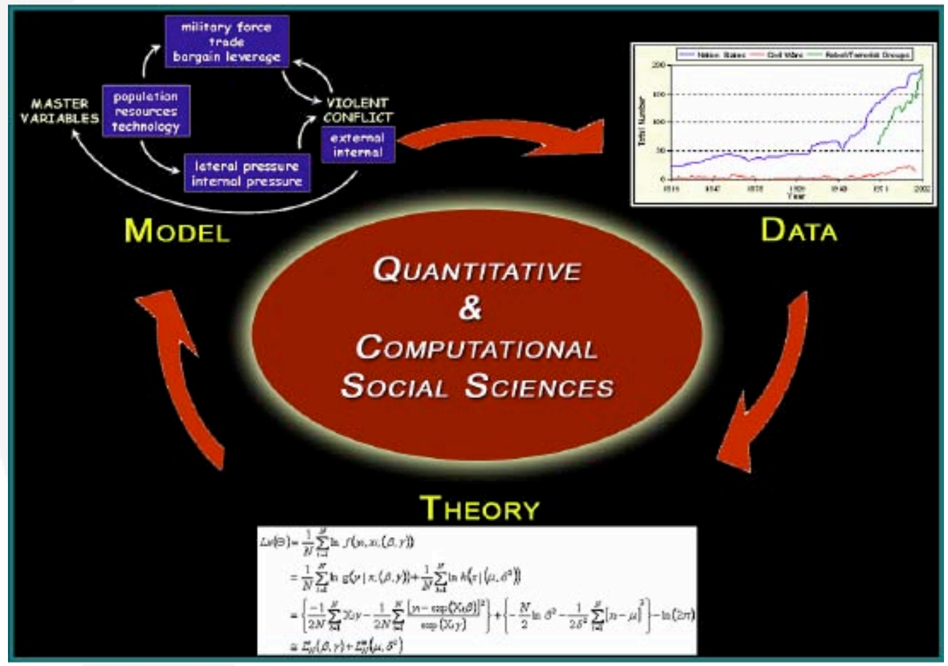


Source: Popp 2005

Agenda

	Session	Time
I.	Introduction to Computational Social Science	9:00 – 10:15
	Break	
II.	Hidden Markov Models	10:45 – 12:00
	Lunch	
III.	Social Network Analysis	1:00 – 2:15
	Break	
IV.	Agent-Based Simulation	2:45 – 4:00

A (Brief) Introduction To Computational Social Science

I. Introduction to Q/CSS

- **Brief Outline:**
  - Definition of Q/CSS
  - Brief Historical Perspective
  - Why Is It Important Now?
  - Examples of applications of Q/CSS

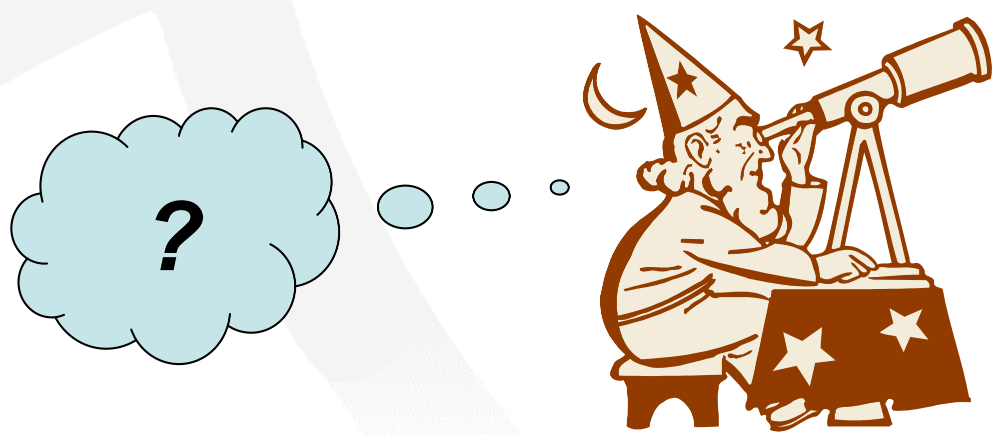
Assumption:
Social Sciences are structurally equivalent to Natural Sciences and so methodological propositions that apply to natural sciences are transferable

Takeaway:
Q/CSS is a viable "third leg" of the stool that complements theory and experimentation/field studies to elicit understanding and new concepts.

What is Q/CSS?

- ***Quantitative/Computational Social Science*** **(CSS) is about:**
  - developing integrated models of human, technical,and environmental systems
  - based on accepted principles in the social sciences (e.g., economics, anthropology, geography, political science, sociology, demography, ethnography, public policy, psychology, and their sub- and cross-disciplines, etc)
  - supported by mathematical and physical science principles
  - investigating and experimenting in situations where direct observations of human behavior are not possible or not ethical
  - developing new theory and insights that can be applied from the artificial to the natural world

- **Two Aspects:**
  - Methodological
  - Substantive



Substantive vs. Methodological

	Pure	Applied
Substantive	Basic theory-driven CSS research for understanding information processing and computation in real social systems	Uses extant methods applied to intervention-oriented, issue-specific CSS research
Methodological	CSS methods used in basic research: Simulation tools, Physical, Mathematical, and Medical principles	CSS methods as decision Tools for solving complex socio-technical problems

Source: C. Cioffi-Revilla

Why Is Q/CSS Important Now?

- Information and Risk are perennial issues with decision makers:
  - Without information, we cannot make rational decisions
  - Information about the future is usually imperfect and subject to uncertainty
- Risk is inherent in any decision process, e.g., the low probability of extreme events
- People still make decisions about risky situations
- Q/CSS models can assist in making such decisions, by shedding new light on uncertainty

Thus, we observe …

"God chose to give all the easy problems to the physicists."

—Michael Lave & Jim March, ***Introduction to Models in the Social Sciences***

Why Do We Model?

- To overcome *linear thinking*: We cannot understand how the various parts of the system interact and add up to the whole
- To discover the space of behaviors and cascading effects that real social systems can realize
- To foresee novel events that our mental models cannot even imagine
- To conduct virtual experiments on simulated social worlds on many scales

<u>In summary</u>, we model for three key reasons:

1. To gain insights into key variables and their causes and effects
2. To construct reasonable arguments as to why events can or cannot occur based on the model
3. To make qualitative or quantitative predictions about the future

Models, Models, …

- Descriptive, Prescriptive and Predictive Models
  - A model that attempts to describe the best or optimal solution of a system
    - **Provides insight**
    - **Perhaps create requirements**
    - **Actionable Options Evaluations**
  - The "what's best" & "what if" questions
  - Aid in selecting the best alternative solution for decision problems

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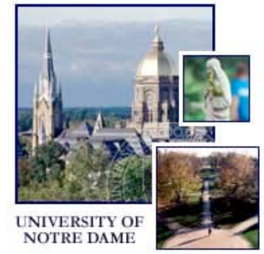
Cause and Effect

- **According to Hume, *causation* is a learnable habit of the mind:**
  - When we see that two things go together, we learn that one “causes” the other (but,… caution about spurious correlations)
  - When the flame burns us, we learn to keep away from it
- **In our everyday lives, we generally assume that people express rational behavior.**
  - Certainly, driving one’s car to work in Washington, D.C. is an example.
  - People react to changes in the world in a way that is in their best interests, privately
  - People generally learn cause and effect, and seek to optimize (Simon: “satisfice”) them for their own benefit
- **Simon’s principle: Social complexity is the result of (is caused by) the behavior of simple actors as they adapt to their complex environments**

What's The Problem?



- **Most pre-computational social science models are linear:**
  - Linearity is based on independence of elements
  - Linearity is a good modeling technique for simple systems
  - The linearity assumption implies that the whole is <u>equal</u> to the sum of its parts!
- **We know a lot about:**
  - Individuals (through surveys)
  - Aggregated as groups and populations
  - On a domain-specific basis
- **We know a lot less about interactions among individuals and groups:**
  - How social structures form; how protocols emerge and the interactions in large groups and among subgroups
  - How and why do group structures (and their protocols) change
  - What the content of interaction is: influence, power, imitation, exchange, association

BUT:

- Social science systems are not simple,….
- The whole may be greater (or lesser) than the sum of its parts!!
- Modeling the dynamics is (very) hard …

The Problem is Complexity!

- **Wicked problems have incomplete, contradictory, and changing requirements**
  - solutions to them are often difficult to recognize as such because of complex interdependencies.
- **Rittel and Webber (1973) stated that while attempting to solve a wicked problem, the solution of one of its aspects may reveal or create another, even more complex problems.**
- **Complexity—systems of systems—is among the factors that makes wicked problems so resistant to analysis and, more importantly, to resolution**
- **Wicked problems are adaptive, e.g., the (partial) solution changes the problem**
  - Is there a restatement of Heisenberg's Hypothesis here??

Wicked Problems

- **Characteristics (Ritchey 2005):**
  1. There is no definitive formulation of a wicked problem.
  2. Wicked problems have no stopping rule.
  3. Solutions to wicked problems are not true-or-false, but better or worse.
  4. There is no immediate and no ultimate test of a solution to a wicked problem.
  5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
  6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
  7. Every wicked problem is essentially unique.
  8. Every wicked problem can be considered to be a symptom of another problem.
  9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
  10. The planner has no right to be wrong (planners are liable for the consequences of the actions they generate).

Examples of Wicked Problems

- Global Warming
- War on terrorism
- Sprawl and Sustainable Development
- A National Healthcare System for the U.S.
- World Hunger
- Energy Crisis: When the Oil (Coal) Runs Out?
- Large-Scale Software Development
- Epidemic: Worldwide Explosion of Ebola/Marburg/…
- Emergent Systems

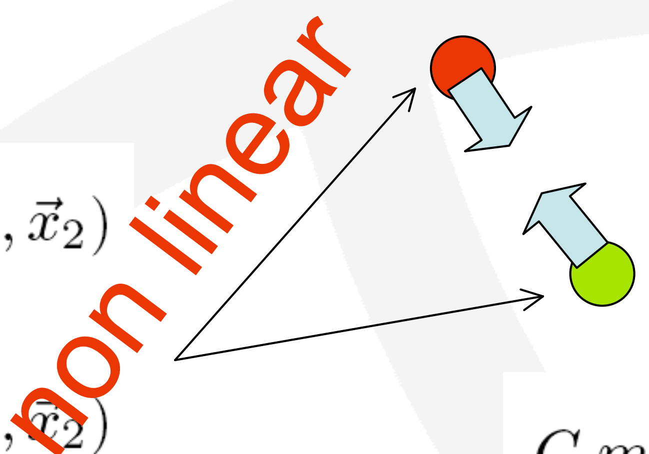
- And, your favorite social science problem here!!

What is Complexity?

- **Complex: consisting of interconnected or interdependent parts**
  - Not easy to understand or analyze
- **Simple systems: An oscillator, a pendulum, a spinning wheel, an orbiting planet**
- **Complex Systems: Government, an economy, families, the human body—physiological perspective, a person—psychosocial perspective, the brain, the ecosystem of the world**

$$\frac{d\vec{p}_1}{dt} = \vec{F}_{2/1}(\vec{x}_1, \vec{x}_2)$$

$$\frac{d\vec{p}_2}{dt} = \vec{F}_{1/2}(\vec{x}_1, \vec{x}_2)$$

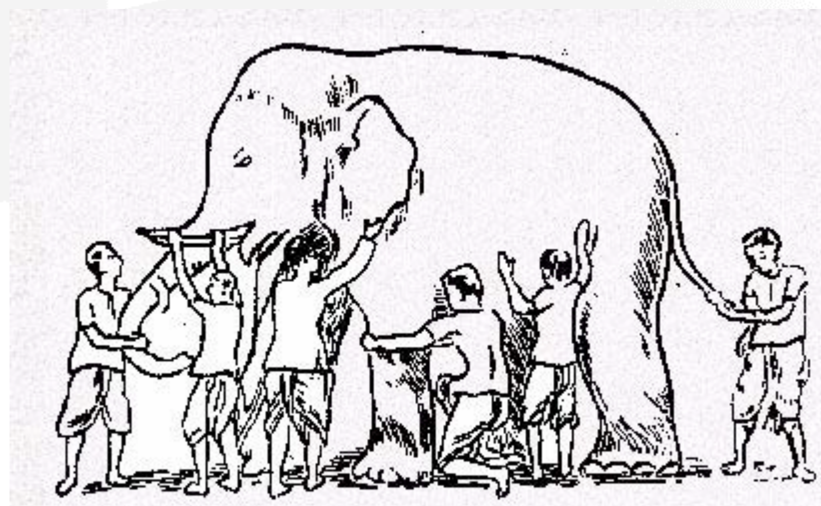


$$G\, m_1\, m_2 \frac{\vec{x}_2 - \vec{x}_1}{|\vec{x}_1 - \vec{x}_2|^3}$$

$$G\, m_1\, m_2 \frac{\vec{x}_1 - \vec{x}_2}{|\vec{x}_1 - \vec{x}_2|^3}$$

What is Complexity Theory?

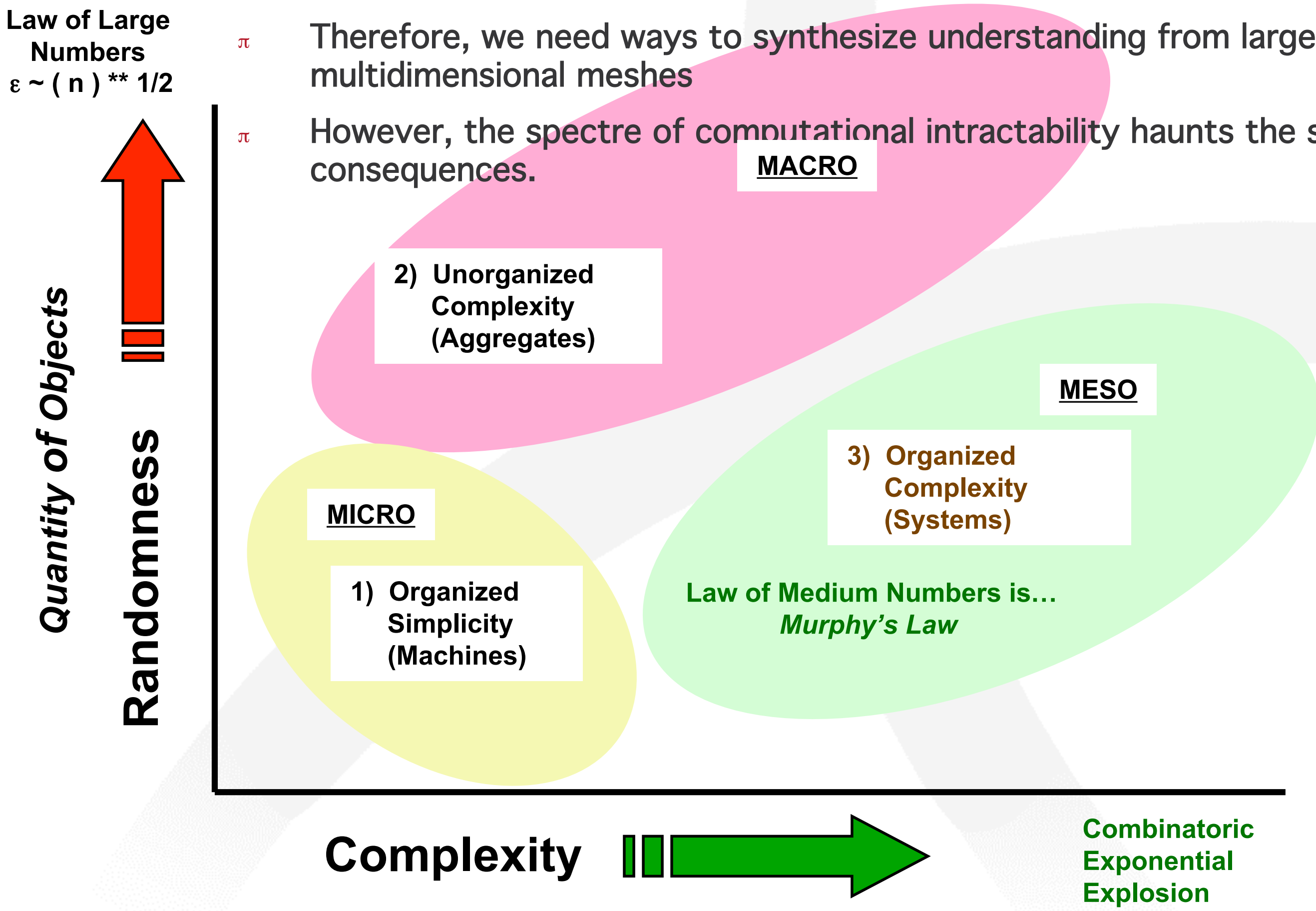
- *Complexity theory* is a scientific framework that explains how rules govern emergence and the constraints mediating self-organization and system dynamics.
- The science of complexity, is not a single body of theory, but rather is comprised of a collection of fields, including:
  - *Artificial Intelligence* (AI)
  - *Cognitive science*
  - *Ecology*
  - *Evolution*
  - *Game theory*
  - *Linguistics*
  - *Social science*
  - *Artificial Life*
  - *Computer science*
  - *Economics*
  - *Immunology*
  - *Philosophy*



… among others

Complexity Issues

- Complex behaviour originates from the operation of simple underlying rules (Simon's conjecture).
- But, sometimes, deducing behaviour from rules is not possible.
- There is no practical way to study the network of causality in detail.
- Therefore, we need ways to synthesize understanding from large state spaces and multidimensional meshes
- However, the spectre of computational intractability haunts the space between rules and consequences.



From: G.M. Weinberg, An Introduction to General Systems Thinking,
John Wiley & Sons, New York, 1975, p 18.

Assessing Types of Systems

Activity	Simple System	Complex System	Adaptive System
Number of States	A few possible states only (10s)	Many states (100s)	Unbounded (1000s and more)
Connectivity	Static Connections; unidirectional; no learning	Varying connections, but slowly changing; May learn	Dynamic connections; Local & global actions; Self-modifying
Behavioral Pattern	Predictable behavior w/ Reasonable Accuracy	Highly unpredictable, possibly chaotic behavior	Emergent behavior w/ Ability to adapt & learn
Typical Example	Heating & Air Conditioning TVs	Collapsing sand piles Tornadoes	Nation-states, Biological Systems Society & Culture
Computational State	Static; Statistical	Self-modifying in Parameters	Self-modifying in Control & Actions

Complex System Characteristics

- Tightly Coupled
  - ***"Everything influences everything else"***
  - ***"You can't just do one thing"***
- Dynamic
  - ***Change occurs at many time scales***
- Policy Resistant
  - ***Many obvious solutions to problems fail or actually worsen the situation***
- Counterintuitive
  - ***Cause and effect may be distant in time and space***
- Exhibit Tradeoffs
  - ***Long term behavior is often different from short term behavior***

Q/CSS Challenges

- ***Are Computational Models Predictive Under Uncertainty?***

- **In scientific computing, simulation credibility requires:**
  - The fidelity of a model's predictions to empirical data (verification)
  - The degree to which the model is robust under uncertainty
  - The accuracy of the model in predicting phenomena in regions where experiments haven't been conducted

- **Main tradeoffs:**
  - High fidelity models may be less robust to uncertainty
  - Models more robust under uncertainty may be less consistent in their predictions

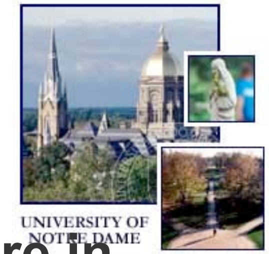
Q/CSS Challenges

- **Can we develop computation models as tools for a user community?**
- **Consider computational models as tools like a hammer or a screwdriver:**
  - Don’t need to know a lot about their construction to use them
- **Scientific models**
  - Require the user to know a lot about the guts before they can be used productively
  - Have complex structures where knowledge may be represented in multiple ways
  - Interpreting the model’s output in a decision environment w/ significant consequences requires considerable cognitive familiarity with the model *and* the domain

Q/CSS Challenges

- **Can we trust the output of computational models over human judgment?**
  – Models represent the current knowledge of a domain and problem space
  – Users may be wary of computational technologies that promise prediction, but whose workings they don't understand
  – Verification and validation require a considerable research investment in the code
- **Human judgment will always be an irreducible component of complex decision making**
  – Computational models will not eliminate this role (anytime soon)

When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.
—Arthur C. Clarke, Report on Planet Three



Q/CSS Challenges

- **Q/CSS is still an emerging discipline, but one that is mature in some areas**
- **Most systematic studies of human behavior that follow the scientific model of research have analyzed numbers:**
  - But, most human knowledge is represented in natural language in textual form
  - How to extract the relevant data in order to utilize it?
- **Are numerically-based simulations the best way of studying human behavior and interactions in different social milieu?**
- **How can we best exploit object-oriented modeling (OOM) and OOP (programming) simulation for modeling social systems and processes?**
- **Could OOM provide social science what the calculus provided physics?**

Q/CSS Models

Indicators & Warning **(I&W)**	**Indicators of warfare and potential conflict, based on quantitative Information found in open source statistical datasets.**
Dynamical Systems	**Differential or difference equations of low-dimensionality representing competing adversaries (including the *systems dynamics* approach).**
(Hidden) Markov Models	**Time-phased data is aggregated at fixed intervals with scaled values separate from the underlying events. A set of discrete states and associated probabiliities; data drives transitions between states.**
Events Data Analysis	**Based on abstracting and coding high-frequency streams of short-term interaction occurrences exchanged among adversaries.**
Econometric & Sociometric models	**Large-scale aggregate models of social actors, states or regions in the international systems**
Probabilistic Models	**Logistic regression, e.g., estimates the probability that a given variable will affect the expected outcome.**
Principal Components Analysis	**Dimensionality-reduction technique for extracting a low-dimensionality space from high-dimensional data**
Game Theoretic Models	**Based on the application of 2-person and n-person games to social situations with strategic interdependence.**

Q/CSS Models

Expected Utility Models	**Applications of Bayesian Decision Theory to individual or collective choices**
Control-theoretic Models	**Applying linear, non-linear, and optimal control theory principles to Interactions among social and political entities**
Survival Models	**Based on modeling the hazard rate or intensity function of a social process, which are capable of integrating stochastic and causal variables into unified models of social dynamics.**
Evolutionary Computation	**Applying a variety of evolutionary methods (e.g., genetic algorithms) To social simulation models**
State Transition Systems	**Based on modeling interactions among social and political entities as transitions between known states (including cellular automata/Petri nets)**
Graph & Network Theory	**Including artificial neural networks (ANNs) and Social Network Analysis (SNA)**
Agent-Based Simulations	**Applications of multi-agent systems to simulate human and social dynamics in complex environments**
Field Models	**Spatial models of human and social dynamics based on the effect of distance metrics on interactions**

What Follows …

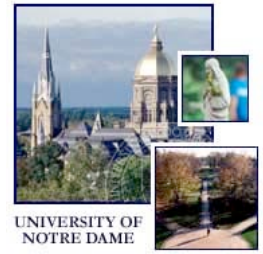
- **We present three sessions on applying different types of computational models to social and organizational systems**
  - Hidden Markov Models
  - Social network Analysis
  - Agent-Based Simulation

The Computational Social/Organizational Science Process

- Pick a (problem, issue or question) of interest to you
- If possible, observe real-world situations and collect data
- Understand the underlying theory
- Devise an experimental approach
- Built a model of the phenomena
- Experiment!!
- Interpret the results
- Write one or more quality paper(s)

This tutorial focuses on these two topics

Introduction - References



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HMM
Hidden Markov Models

History

- **Andrey Markov, 1856-1922**
  - Russian mathematician
  - Stochastic processes
    - Markov processes
    - Markov chains
    - Markov property
- **Leonard E. Baum, Ted Petri, et al., late 1960's**
  - Institute for Defense Analyses (IDA), Princeton, N.J.
  - Several papers in mathematical statistics
  - Hidden Markov Models
- **Speech recognition starting in the 1970's**
- **Biological sequence analysis starting in the 1980's**

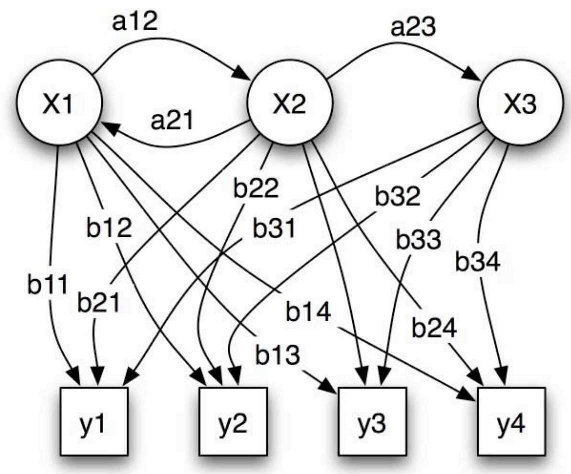
Andrey Markov

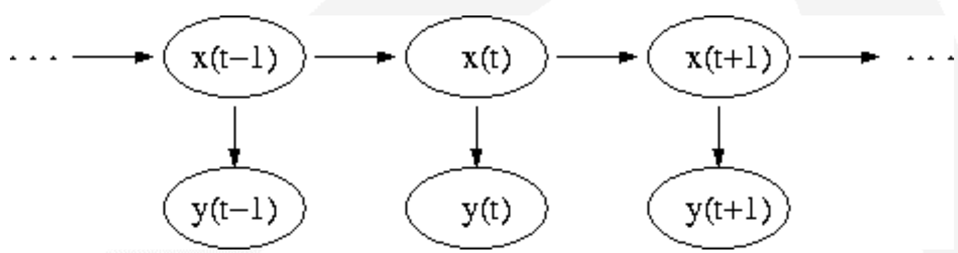
Mathematical Context

- Deterministic processes
- Stochastic processes (random processes)
- Markov process / Markov chain
- Markov property / memoryless property
- Examples
- Hidden Markov Model

Hidden Markov Model

- A Markov Model with unknown state parameters
- Parameters influenced by unknown state parameters <u>are</u> observable
- Forward-backward algorithm
- Viterbi algorithm
- Baum-Welch Algorithm

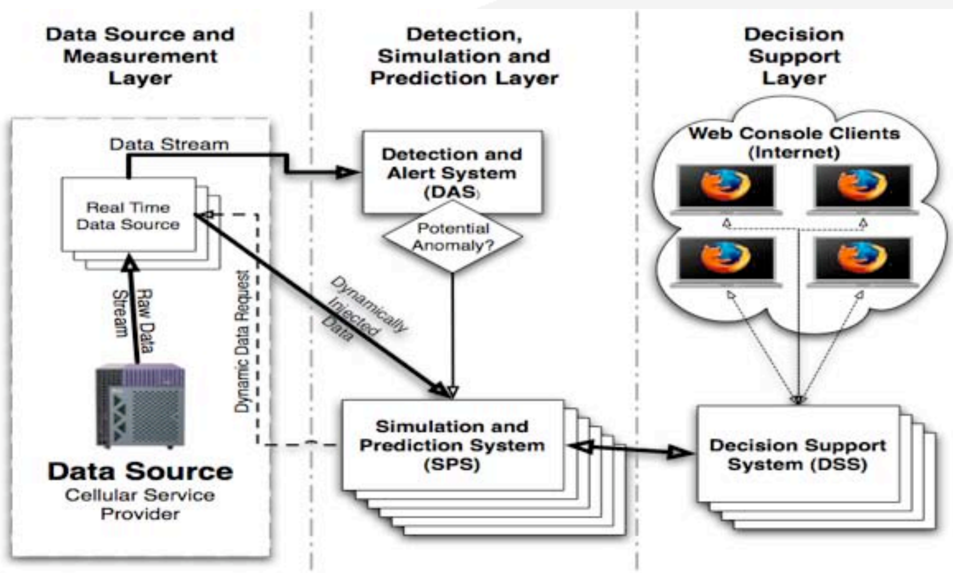




Probabilistic parameters of a hidden Markov model
x — states
y — possible observations
a — state transition probabilities
b — output probabilities

An Example Application: WIPER System

- Wireless Phone-based Emergency Response System
  - Supported in part by the National Science Foundation, the DDDAS Program, under Grant No. CNS-050312 (PI's: Barabasi, Madey)
- Functions
  - **Detect possible emergencies**
  - **Improve situational awareness during emergencies**
- Cell phone call activities reflect human behavior



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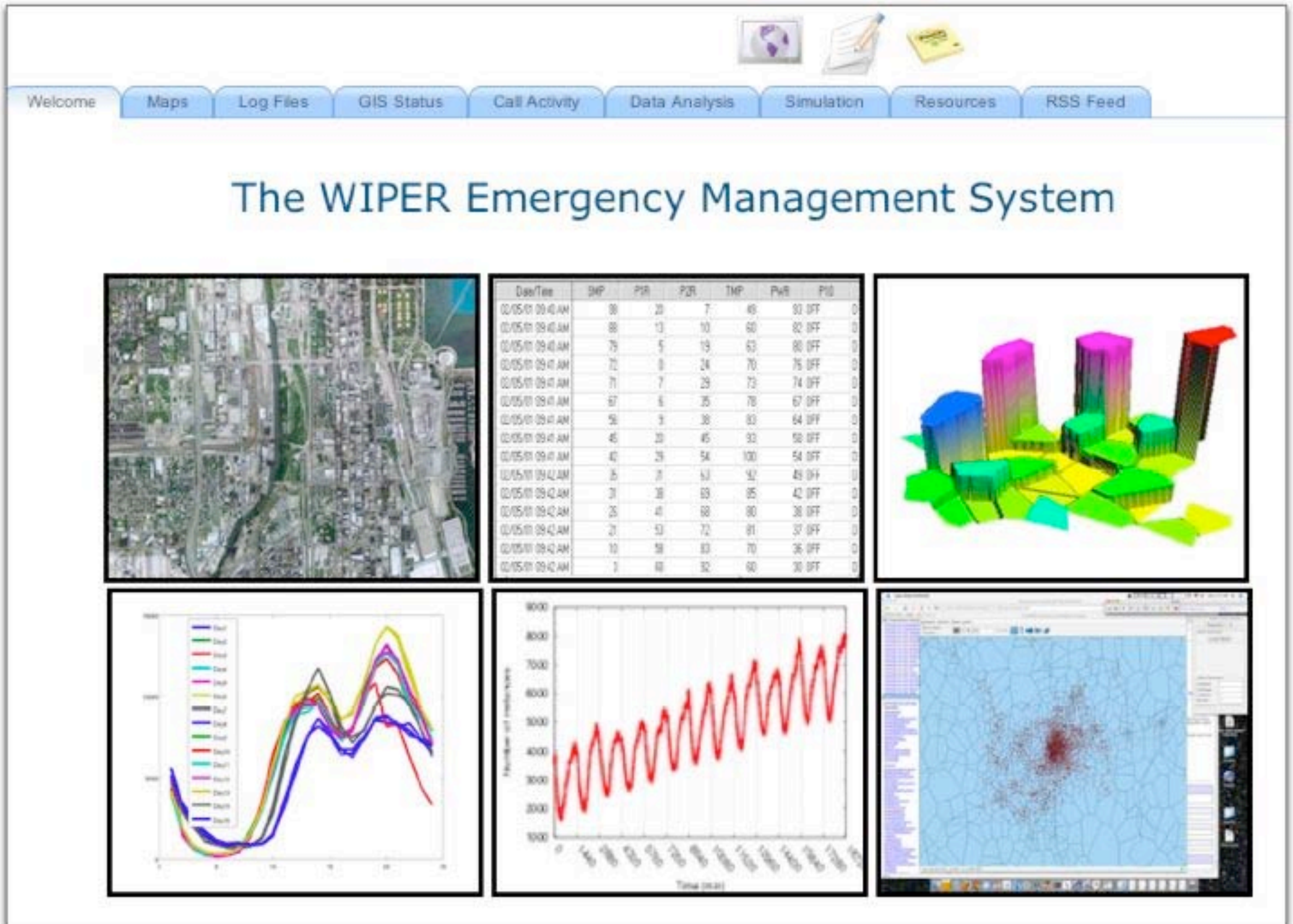
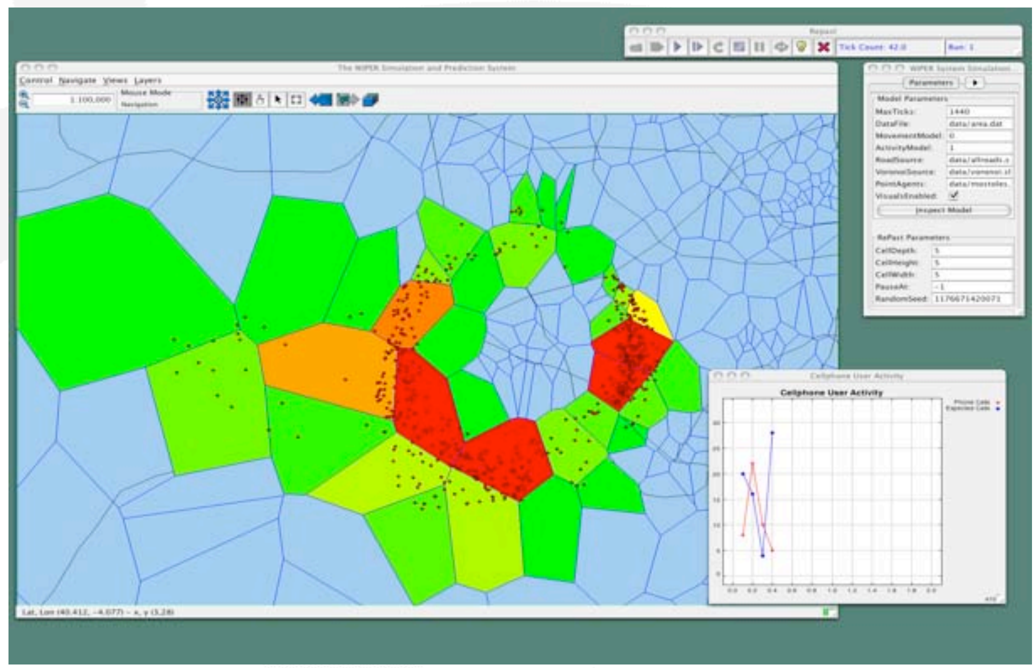
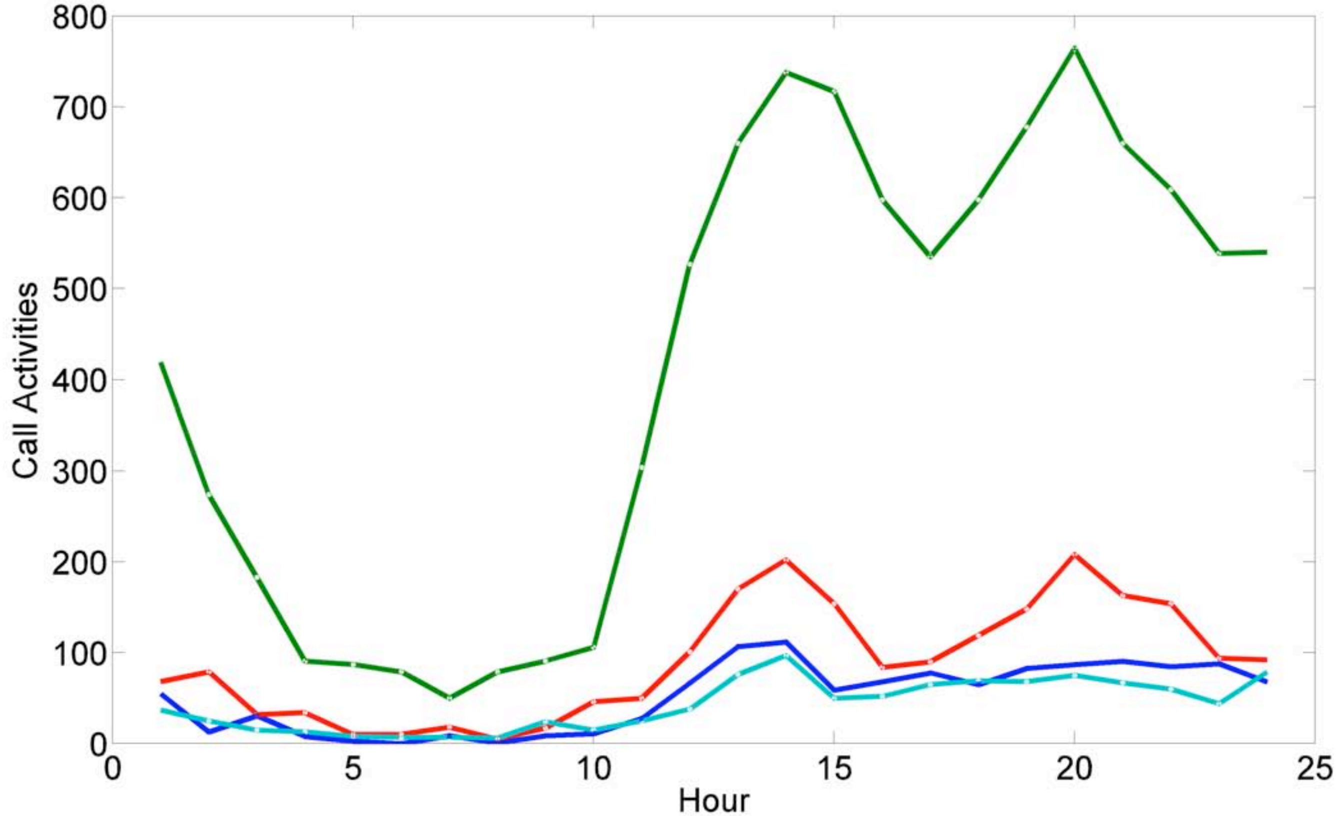


Data Characteristics

- Two cities:
  - Small city A:
    - **Population – 20,000 Towers – 4**
  - Large city B:
    - **Population – 200,000 Towers – 31**
- Time Period
  - Jan. 15 – Feb. 12, 2006
- HMM Analysis
- Agent-based modeling

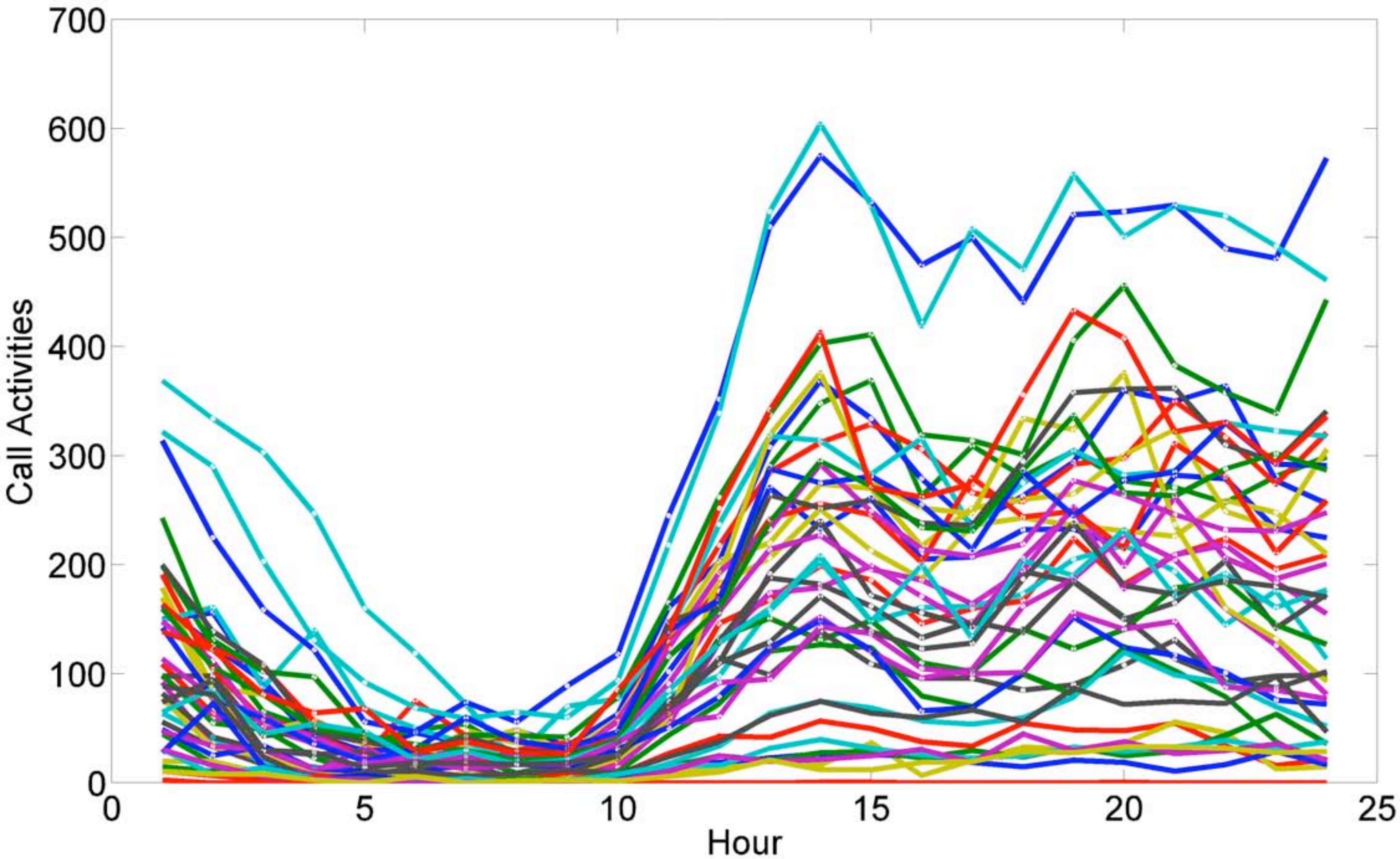


Tower Activity



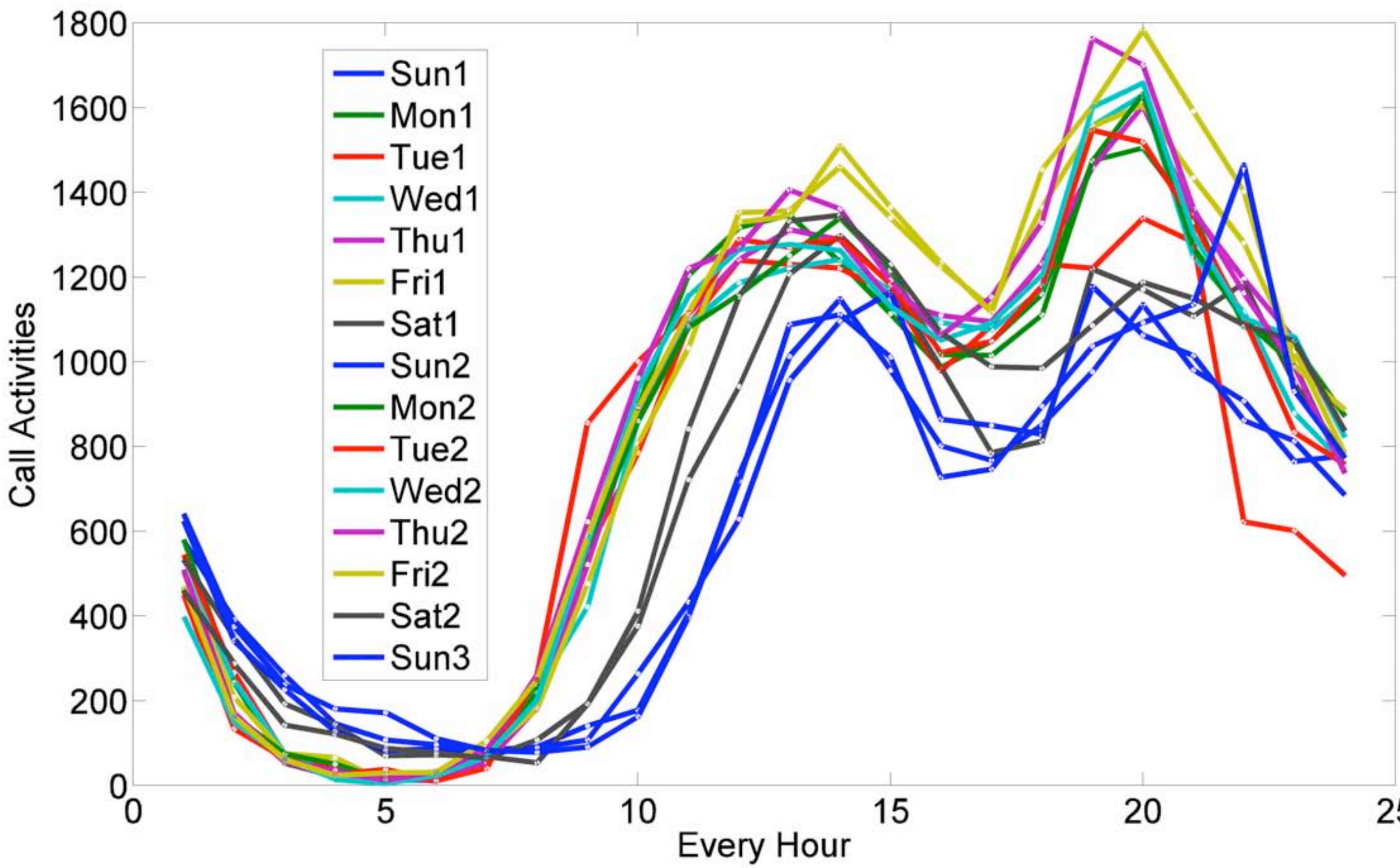
Small City (4 Towers)

Tower Activity



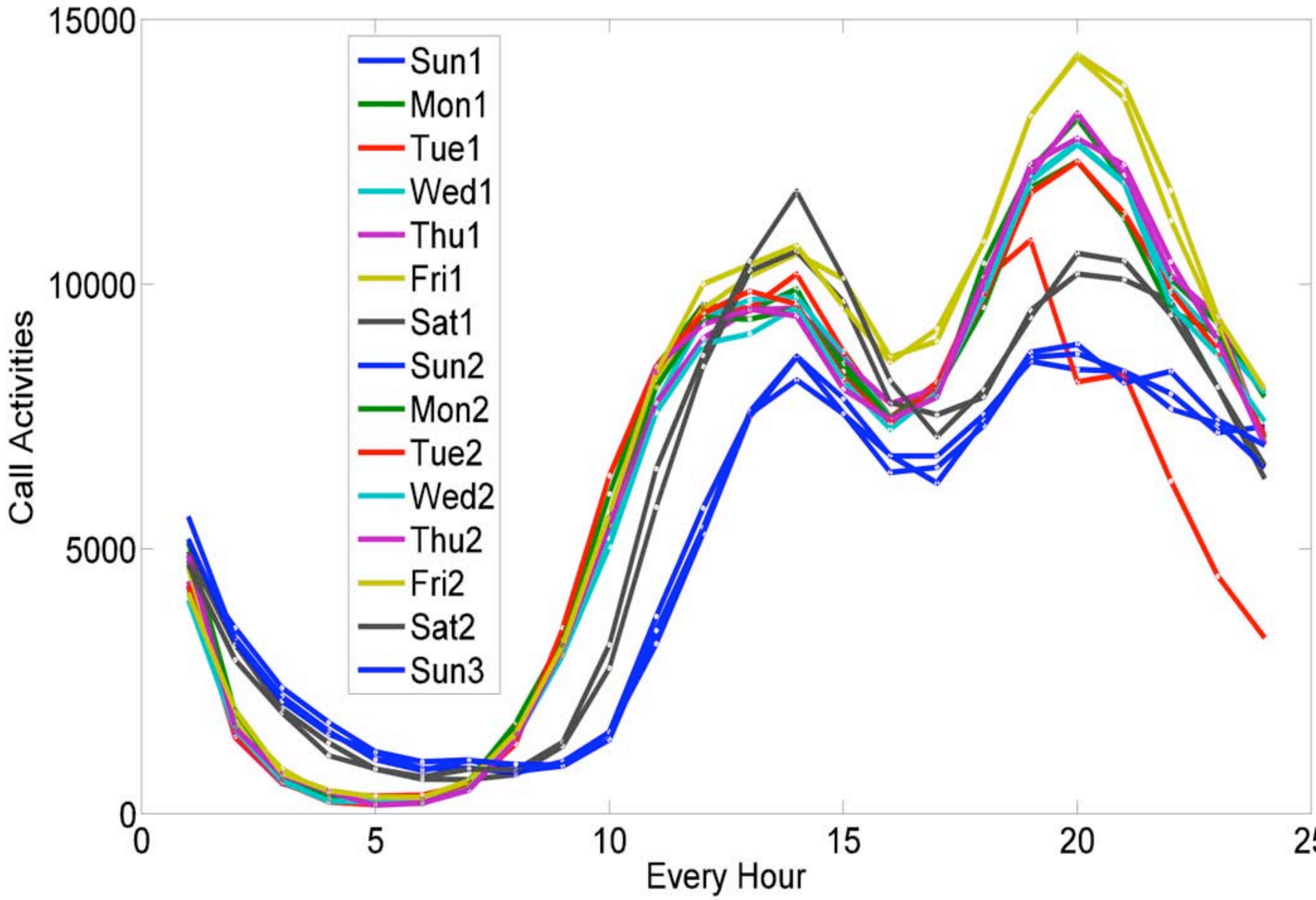
Large City (31 Towers)

15-Day Time Period Data



Small City

15-Day Time Period Data



Large City

Observations

- Overall call activity of a city are more uniform than a single tower
- Call activity for each day displays similar trend
- Call activity for each day of the week shares similar behavior

MMPP Modeling

$$N(t) = N_0(t) + N_A(t)$$

$N(t)$: **Observed Data**

$N_0(t)$: **Unobserved Data with normal behavior**

$N_A(t)$: **Unobserved Data with abnormal behavior**

Both $N_0(t)$ and $N_A(t)$ can be modulated as a Poisson Process.

Modeling Normal Data

- Poisson distribution

$$P(N;\lambda) = \frac{e^{-\lambda}\lambda^N}{N!} \qquad N = 0, 1, \ldots$$

- Rate Parameter: a function of time

$$\lambda \sim \lambda(t)$$

Adding Day/hour effects

$$\lambda(t) = \lambda_0 \, \delta_{d(t)} \, \eta_{d(t),h(t)}$$

$$d(t) \in [1, 2, ..., 7]$$

Associated with Monday, Tuesday … Sunday

$h(t)$ **: Time interval, such as minute, half hour, hour etc**

λ_0 **: Average rate of the Poisson process over one week**

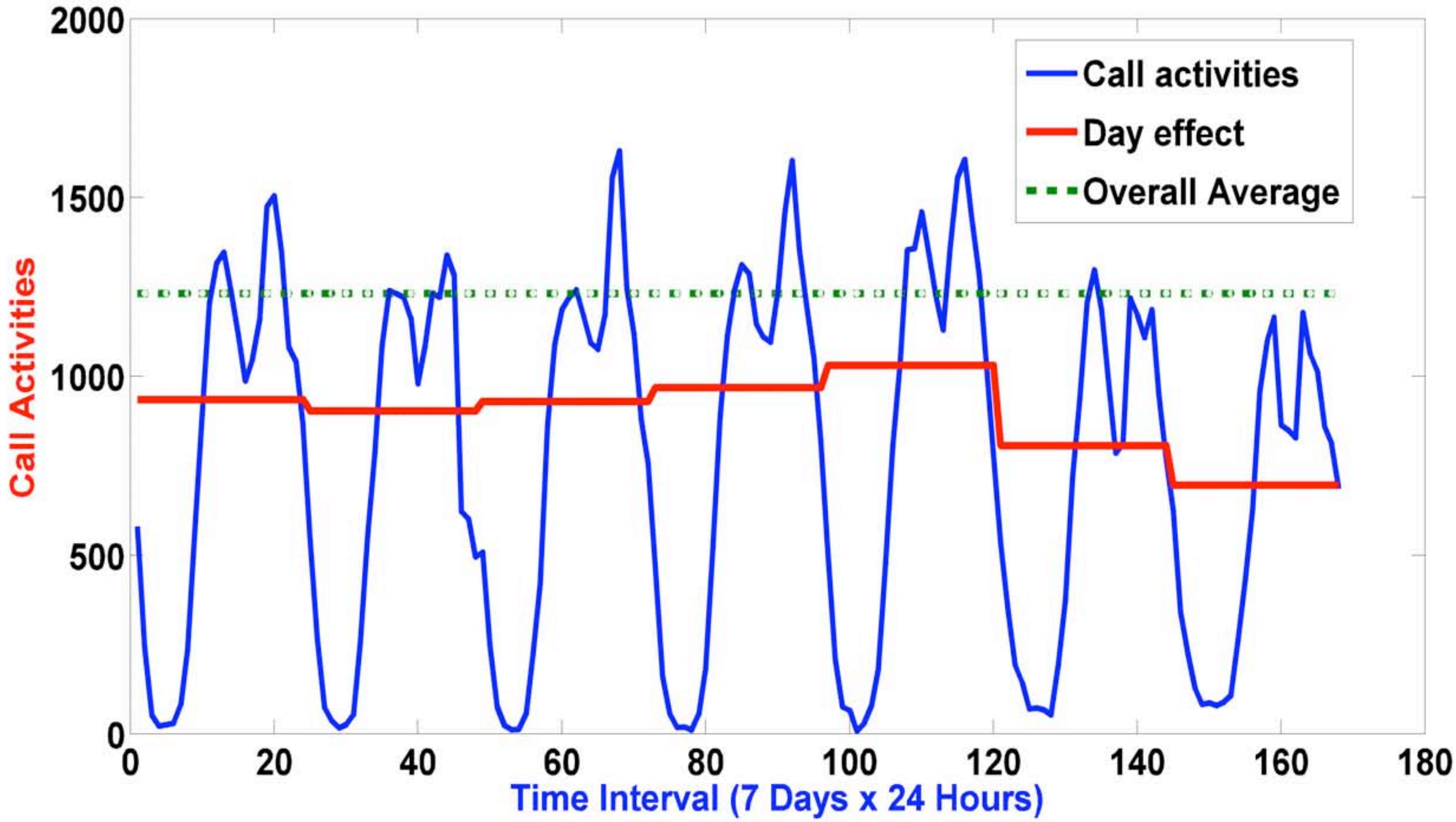
Requirements

$$\sum_{i=1}^{7} \delta_i = 7 \qquad \sum_{j=1}^{D} \eta_{i,j} = D, \ \forall i$$

δ_i : **Day effect, indicates the changes over the day of the week**

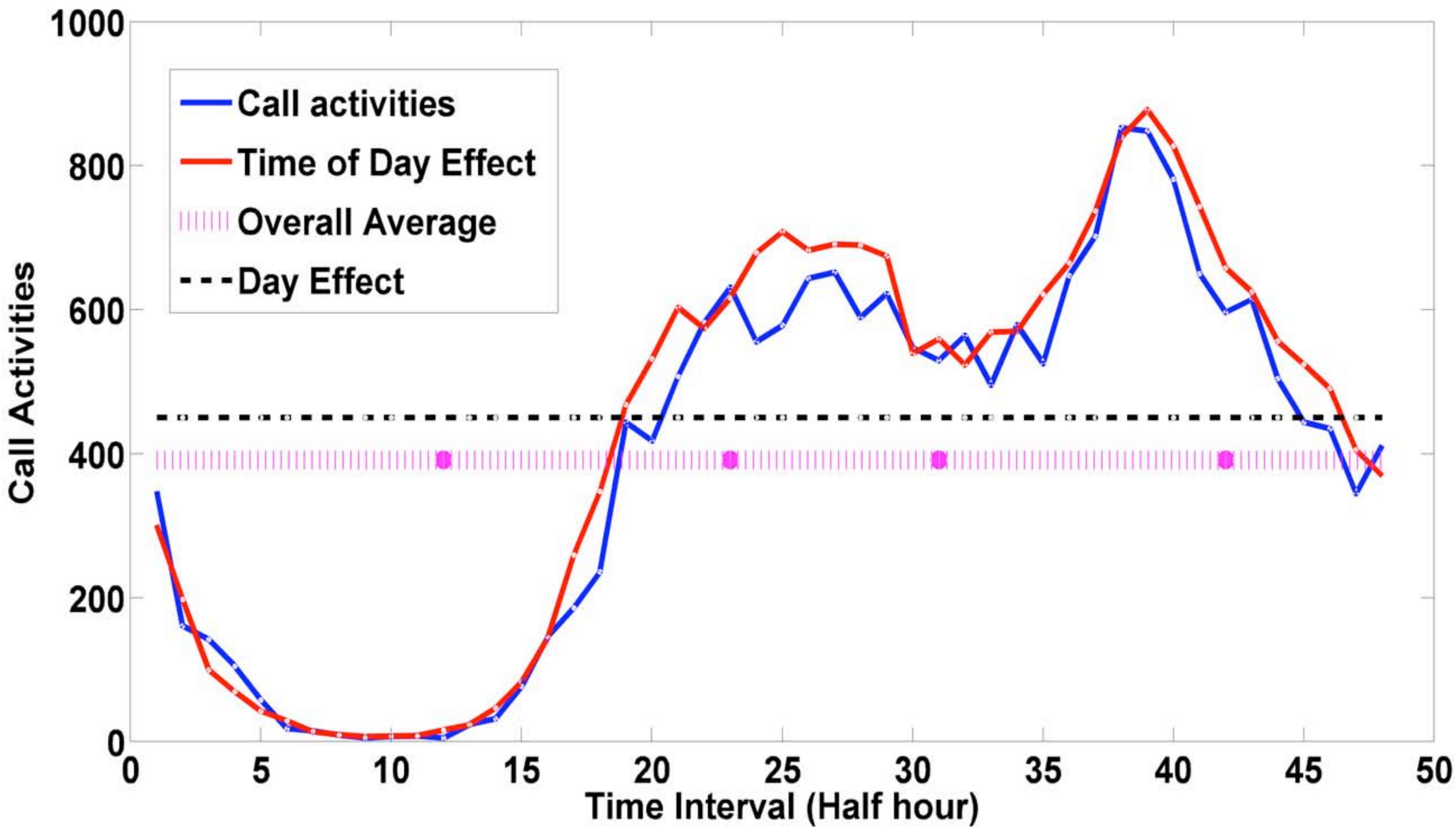
$\eta_{i,j}$: **Time of day effect, indicates the changes over the time period j on a given day of i**

Day Effect



Call activities
Day effect
Overall Average
Call Activities
Time Interval (7 Days x 24 Hours)
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
180

Time of Day Effect



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Prior Distributions for Parameters

$$\lambda_0 \sim \Gamma(\lambda; a^L, b^L)$$ $\Gamma(.)$ is the Gamma distribution

$$\frac{1}{7}[\delta_1, \delta_2, \ldots, \delta_7] \sim Dir(\alpha_1^d, \alpha_2^d, \ldots, \alpha_7^d,)$$

$$\frac{1}{D}[\eta_{i,1}, \eta_{i,2}, \ldots, \eta_{i,D}] \sim Dir(\alpha_1^h, \alpha_2^h, \ldots, \alpha_D^d)$$

$Dir(.)$ is a Dirichlet distribution

Modeling Anomalous Data

- $N_A(t)$ is also a Poisson process with rate $\lambda_A(t)$

- Markov process A(t) is used to determine the existence of anomalous events at time t

$$A(t) = \begin{cases} 1 & \text{an event is occuring at time t} \\ 0 & \text{otherwise} \end{cases}$$

Continued

- Transition probabilities matrix

$$M_A = \begin{pmatrix} 1 - A_0 & A_1 \\ A_0 & 1 - A_1 \end{pmatrix}$$

$$A_0 \sim \beta(A, a_0^A, b_0^A)$$

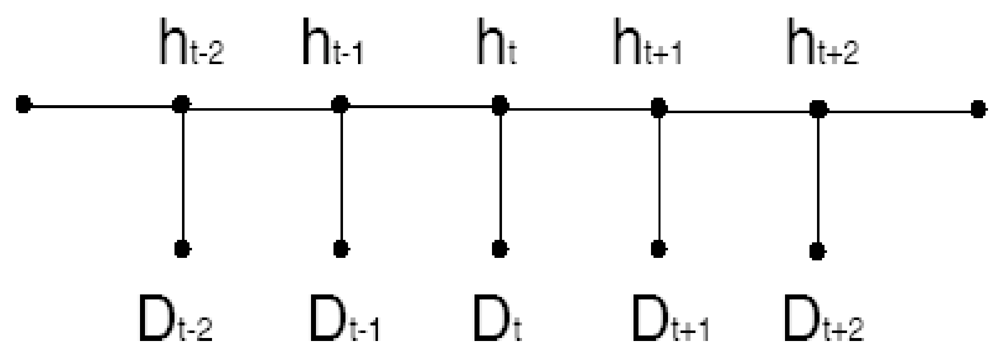
$$A_1 \sim \beta(A, a_1^A, b_1^A)$$

$$N_A(t) \sim \begin{cases} 0 & \mathrm{A(t) = 0} \\ P(N; \lambda_A(t)) & \mathrm{A(t) = 1} \end{cases}$$

MMPP ~ HMM

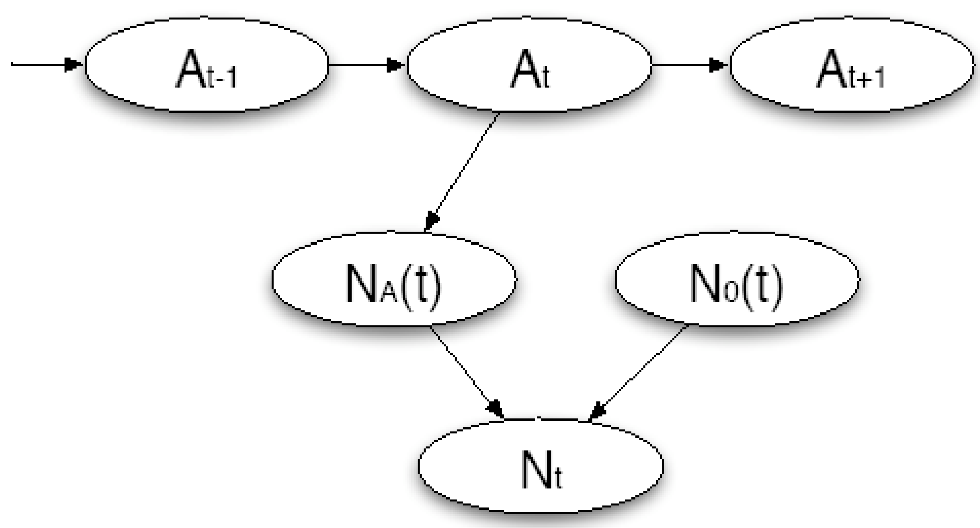
- Typical HMM

  (Hidden Markov Model)



- MMPP

  (Markov Modulated Poisson Process)



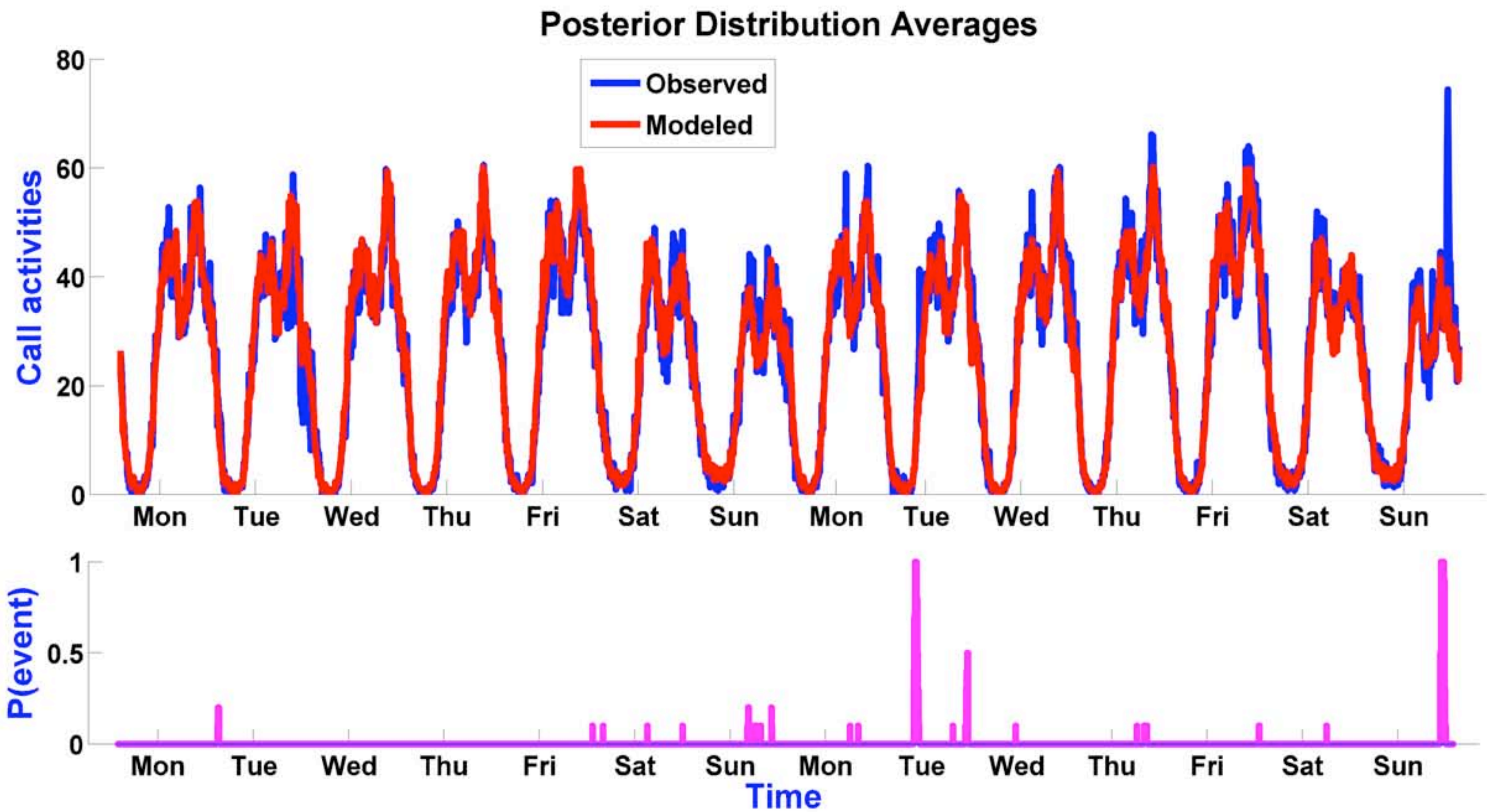
Apply MCMC

- Forward Recursion
  - **Calculate conditional distribution of P(A(t) | N(t))**
- Backward Recursion
  - **Draw sample of** $N_A(t)$ **and** $N_0(t)$
- Draw Transition Matrix from Complete Data

Anomaly Detection

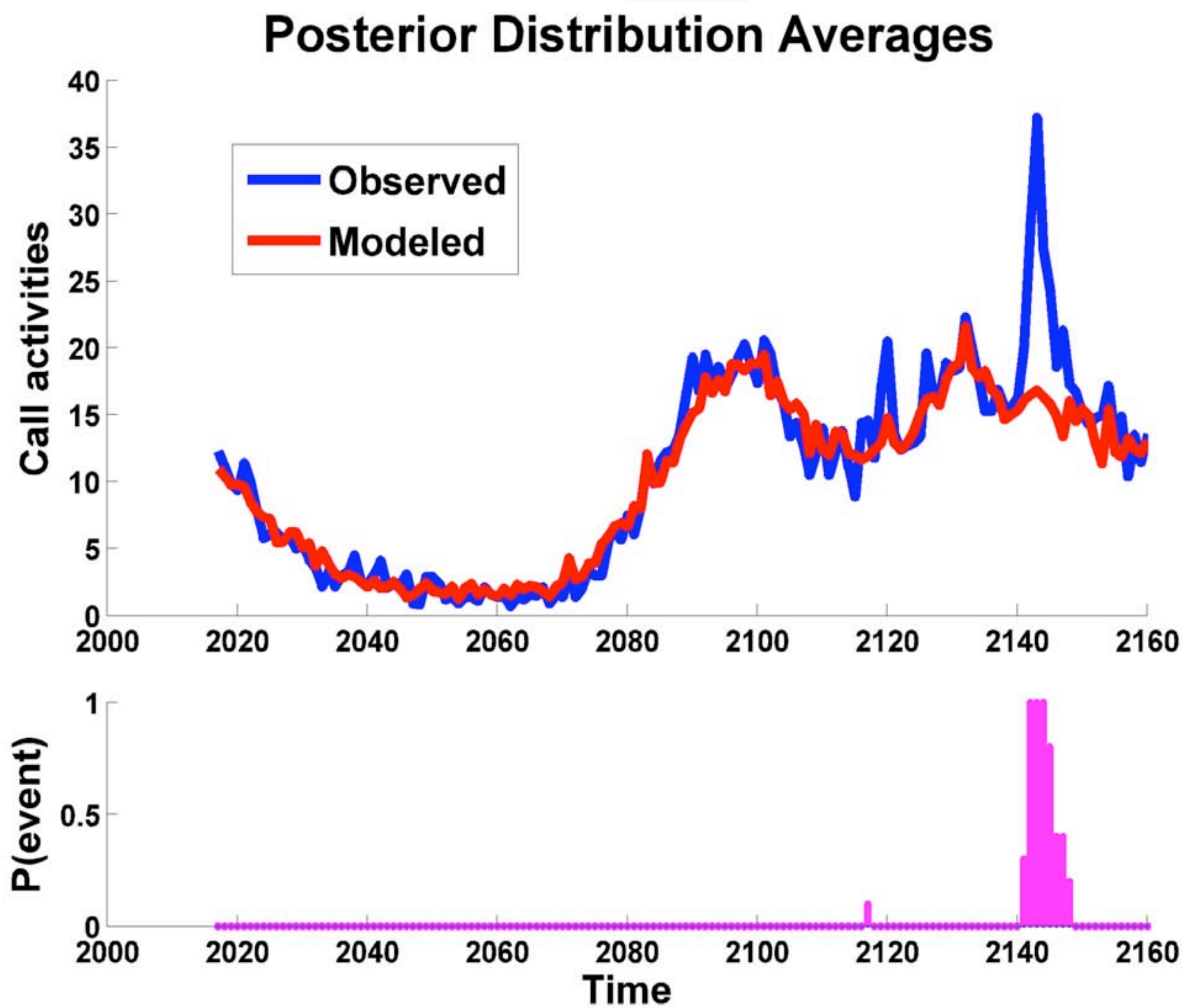
- Posterior probability of A(t) at each time t is an indicator of anomalies
- Apply MCMC algorithm:
  - **50 iterations**

Results



Posterior Distribution Averages
Observed
Modeled
Call activities
80
60
40
20
0
Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun
P(event)
1
0.5
0
Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun
Time

Continued

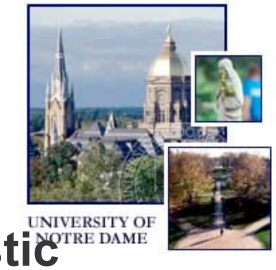

Posterior Distribution Averages
Observed
Modeled
Call activities
0
5
10
15
20
25
30
35
40
2000
2020
2040
2060
2080
2100
2120
2140
2160
P(event)
0
0.5
1
Time

Conclusions - WIPER Example

- Cell phone data reflects human activities on hourly, daily scale
- Hidden Markov Modeling provides a method of modeling call activity, and detecting anomalous events

Summary

- **Markov Modeling is a mature method for analysis of time series data**
  - Efficient algorithms
  - Software available
- **Popular applications**
  - Speech recognition
  - Machine translation
  - Vision
  - Cryptographic analysis
  - Bioinformatics
- **Potential new applications**
  - Social network analysis - temporal analysis
  - Organizational behavior
  - Consumer behavior
  - Intrusion and anomaly detection



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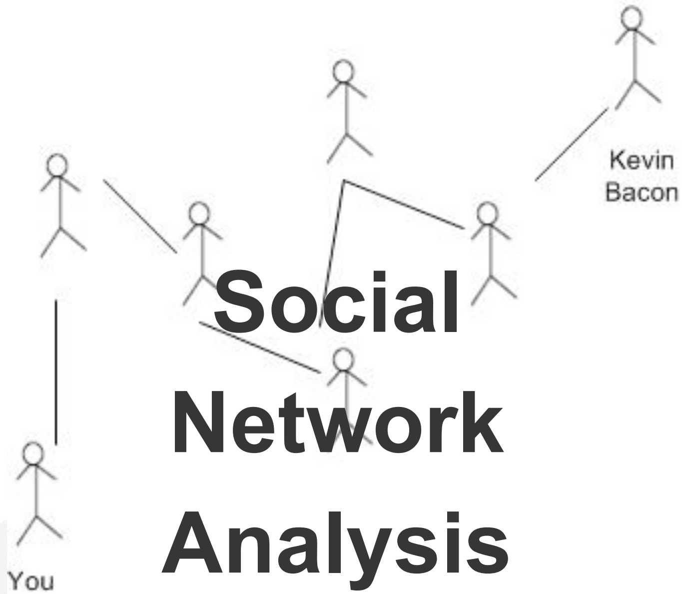
Social Network Analysis

Steven Strogatz



Duncan Watts

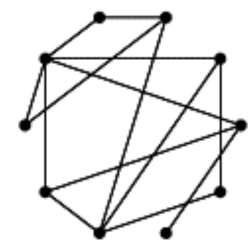
Stanley Milgram
"6 Degrees of Separation"

What is SNA?

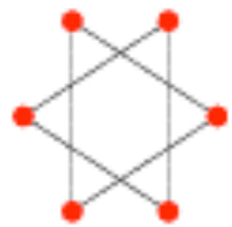
- A method based on formal graph theory that:
  - provides a set of techniques for analyzing the structure of networks
  - where the linkages between the nodes are well-defined social relations (e.g., cooperation, enmity, trade), including multiple 1-to-1 relations.
- Used extensively in sociology, anthropology, and psychology in the study of human social networks.
- Key Ideas:
  - Network nodes are people (groups), links are relationships (contacts)
  - Who is connected closely to whom (path length, clustering)?
  - Who is key in the network (centrality)?
  - Can we infer a large network structure from a very small amount of data (hidden networks, cells)?

SNA Characteristics

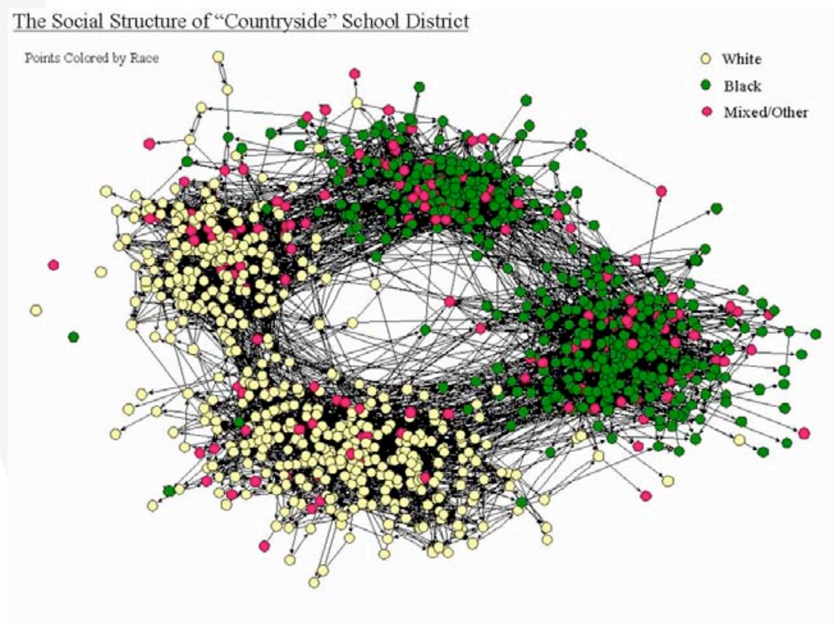
- Most empirical social networks are neither random …



- nor regular



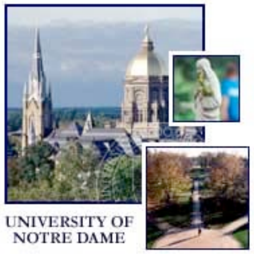
- but complex …
- Social network analysis is focused on uncovering the patterns of people's relationships (interconnectedness) and interactions
- Analysis can produce understanding as well as action



Source: James Moody, 2000

A Quick Review of Network Concepts - I

- **Node Properties:**
  - Fixed attributes
  - Variable attributes (size, beliefs, opinions, capacity, goals, etc)
  - Activation thresholds (critical fraction of neighbors in a particular state)
  - Network location (centrality)
- **Centrality:**
  - Distinguishes “insiders” from “outsiders”; measures the impact of removing a node (and, perhaps, isolating a sub-network)
  - *Degree*: number of links (to, from) a node.
  - *Closeness*
    - Takes into account not only node *k* degree but also the degree of *k's* neighbors.
    - The reciprocal of the sum of geodesics between a node and other nodes.
  - *Betweenness*: the number of geodesics that pass through a node



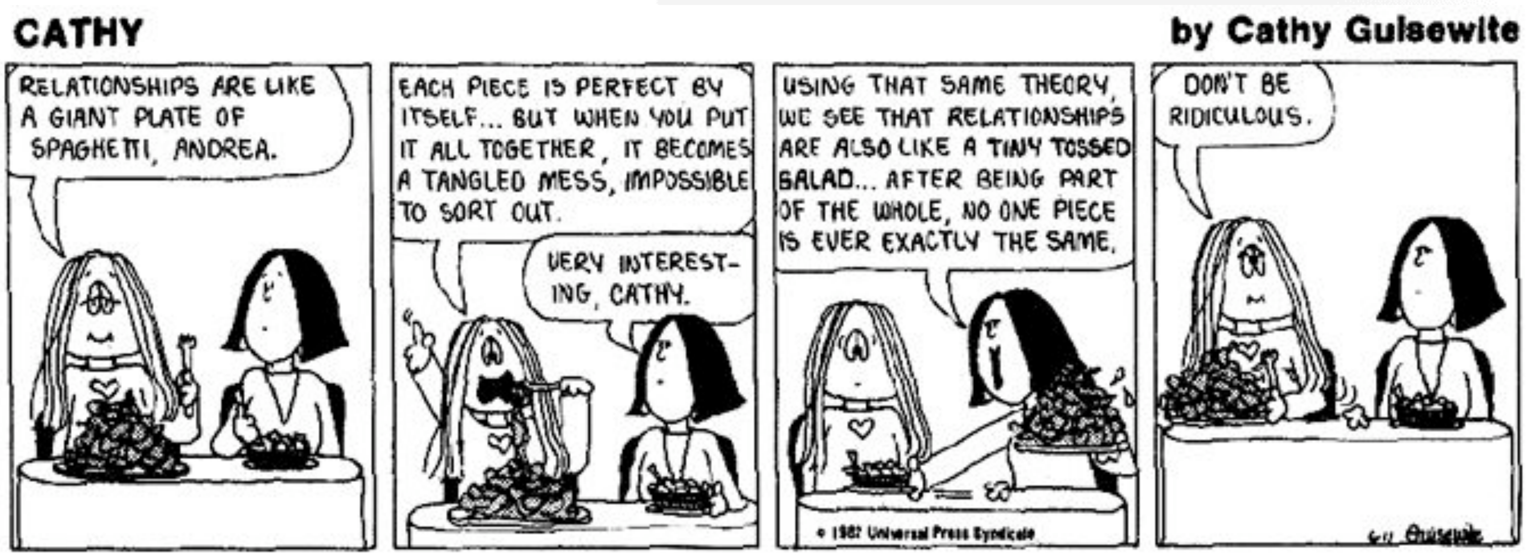
LOGOS Technologies

A Quick Review of Network Concepts - II

- **Edge: Direct link, tie, or “arc” connecting nodes**
  - **Symmetric, undirected (e.g. marriage, alliance, warfare)**
  - **Asymmetric, directed (e.g. employment, insurgency)**
  - **Strength, value (e.g. frequency of interaction, weight)**
  - **Valence (positive or negative influence on to node)**
- **Network Properties:**
  - *Connectivity* -- how easy is it to get from one node to another?
    - A graph is *connected* if every node is *reachable* from every other node
    - *Geodesic:* If one node is reachable from the other, what is the shortest path between them?
    - Kevin Bacon Game of 6 Degrees of Relationship, based on Stanley Milgram’s small-world discovery of six degrees of separation
  - *Mean geodesic*: the average path length over all pairs of connected nodes.
  - *Redundancy*: How many different paths connect each pair?
  - *Density*: the number of paths divided by number of possible paths

A Quick Review of Network Concepts - III

- **Network Properties:**
  – Clustering: Given a group of nodes, the number of links between the nodes in the group is greater than the sum of the number of links to nodes outside the group
- **See more slides in Appendix**



SNA – Basic Ideas

- People have interconnections with other people
  - These can be represented as a simple graph
- Patterns of relationships and interactions emerge from analyzing this graph
- Information flows along the edges of the graph that represent connectedness between two people
- To understand the interactions and structure, identify and follow the patterns
- Once we know the connectedness and the information flow, we can develop intervention mechanisms to create, destroy, reinforce or change the patterns

Where Can SNA Be Used?

- Organizational Psychology
- Epidemiology
- Homeland Security
- Social Engineering
- Analyzing connectivity through email
  - **ENRON Mail Database**
- Analyzing corporate interactions
  - **Trust in Virtual teams (Ahuja et al 2006)**
- Politics
  - **Political Contests and Elections**
  - **Analysis of Iranian Government (Deckro et al)**
- Intelligence Analysis
  - **Terrorism Relationships**

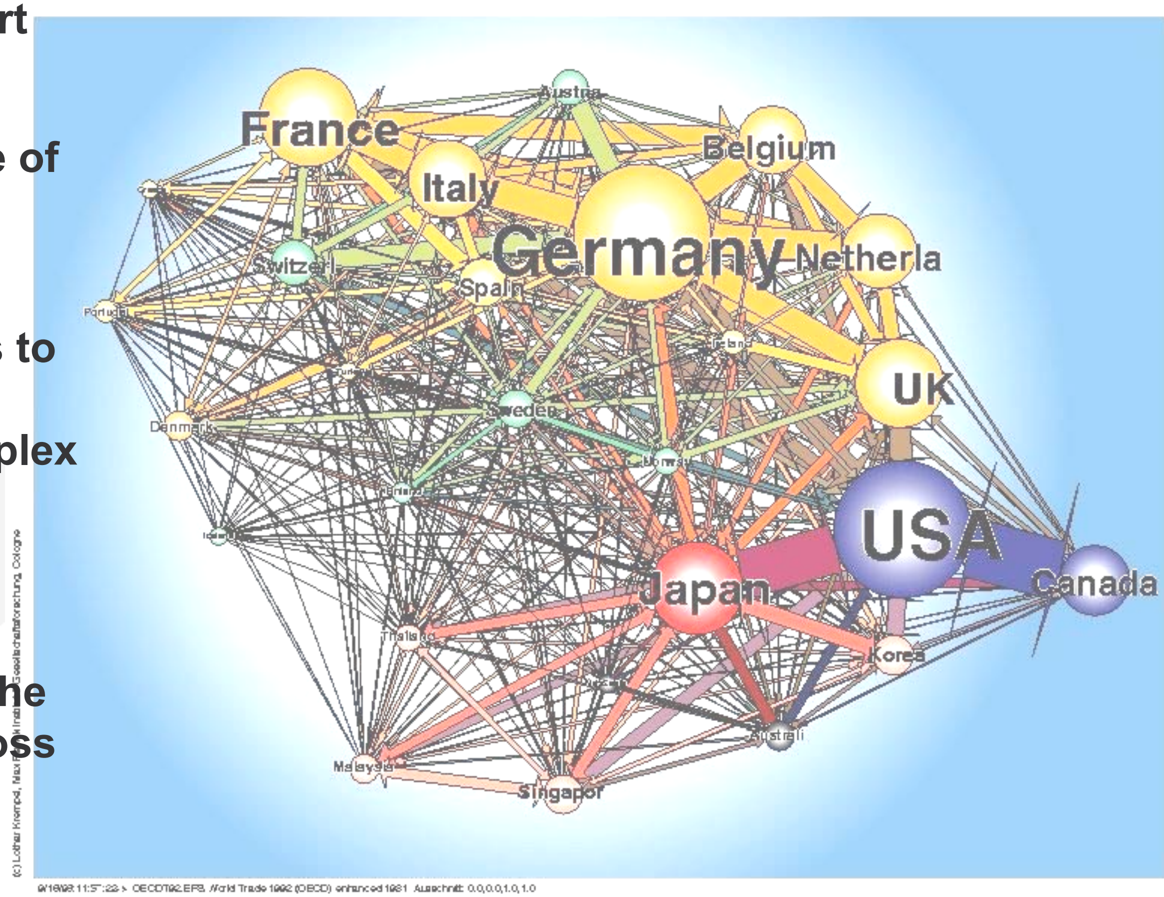
SNA & Organizational Modeling

- Identify personnel with vital knowledge and connections that may be targeted for retention/reward
- Increase innovation, productivity, and responsiveness of the organization by plugging “know-who” gaps
- Establish key knowledge roles in order to make smarter decisions about organizational changes
- After restructuring, mergers, or acquisitions, gain insight into challenges of knowledge transfer and integration across the melded organization

- *Example*: Developing an Enterprise System Architecture (see the EA minitrack)

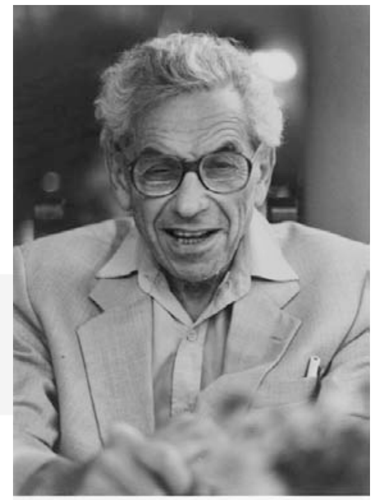
Social Network Analysis: Trade Analysis

- Examine the Foreign trade of countries based on the types of products they import/export
- Size of spheres is measure of trading volume
- Problem: Need better tools to visualize the linkages and navigate through this complex network
- Examine over time the fluctuations in the size of the spheres and the flows across the links



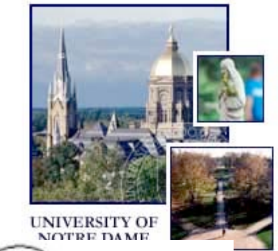
Social Network Analysis: Erdos Numbers

- **Explore Scientific Collaboration**
- **Erdos Numbers: http://www.oakland.edu/enp/**
  - Distance of an author to a collaboration with Paul Erdos (d. 1996)
  - Vertices: math and compsci researchers
  - Had 507 co-authors
- **Rules:**
  - If you co-authored a paper with Erdos, your Erdos number is 1
  - If you co-authored a paper with someone who authored a paper with Erdos, your number is 2
  - And, so on ….
- **How does one navigate in such a network?**
- **What does it tell us?**
  - Probably need to augment links with topics of papers
  - Add geolocations of co-authors
  - Low Erdos numbers are possessed by many Fields Medalists and Nobel Prize Laureates



Paul Erdős, the most prolific mathematician who ever lived, has no home and no job, but he has wandered the world for over fifty years, inspiring other mathematicians. From the documentary N is a Number: A Portrait of Paul Erdős © 1993 by George Csicsery

SNA: Iranian National Government

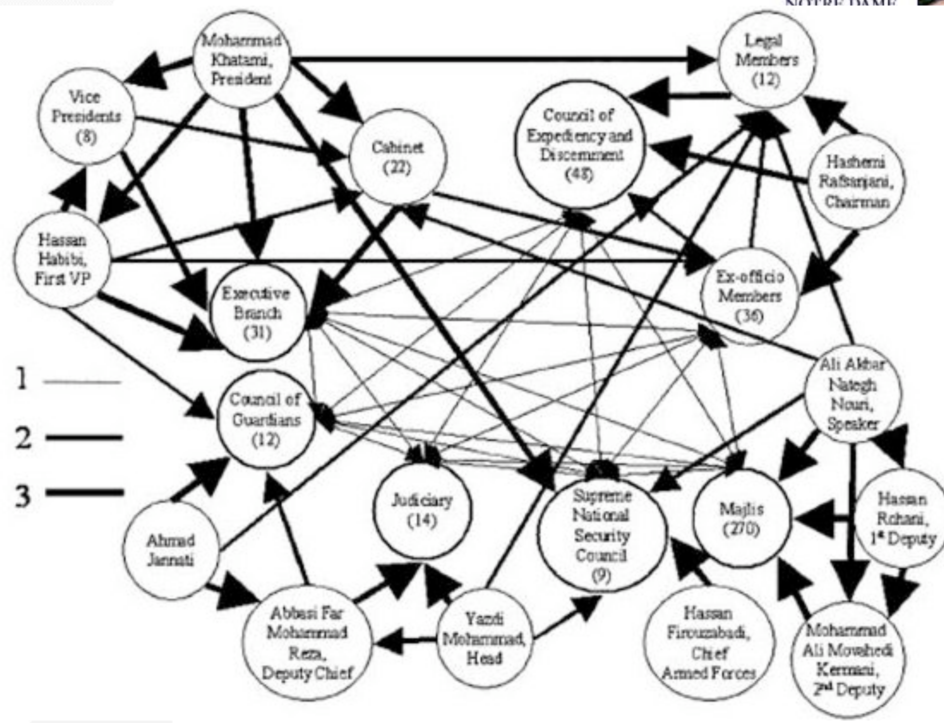


- **Social Closeness: a ratio reflecting the maximum potential one person or group (i) has on another person or group (j)**

  $s_{ij} = a(s_{kl}), a > 0, i /= j, k /= l$

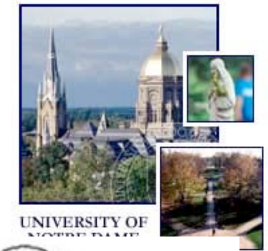
- **Assume primary membership 3x administrative membership**
- **Assume secondary group membership 2x as administrative membership**
- **Based on weighted membership, *Khatami* seems to have the greatest influence**
- **Represents strength in given organizational hierarchy**

Ref: Renfro and Deckro. 2001. A Social Network Analysis of the Iranian Government, 69th MORS Symposium



Source	Maximum Flow
Khatami	**17**
Rafsanjani	9
Nouri	15
Mohammad	9
Jannati	8
Firouzabadi	3

SNA: Iranian National Government



- Let x_{ij} = the flow of influence over

  the edge from i to j

  – Let s = influencer node; t = influenced node

- Maximize z – the maximum flow – subject to:

  $\Sigma_j x_{sj} - z = 0$

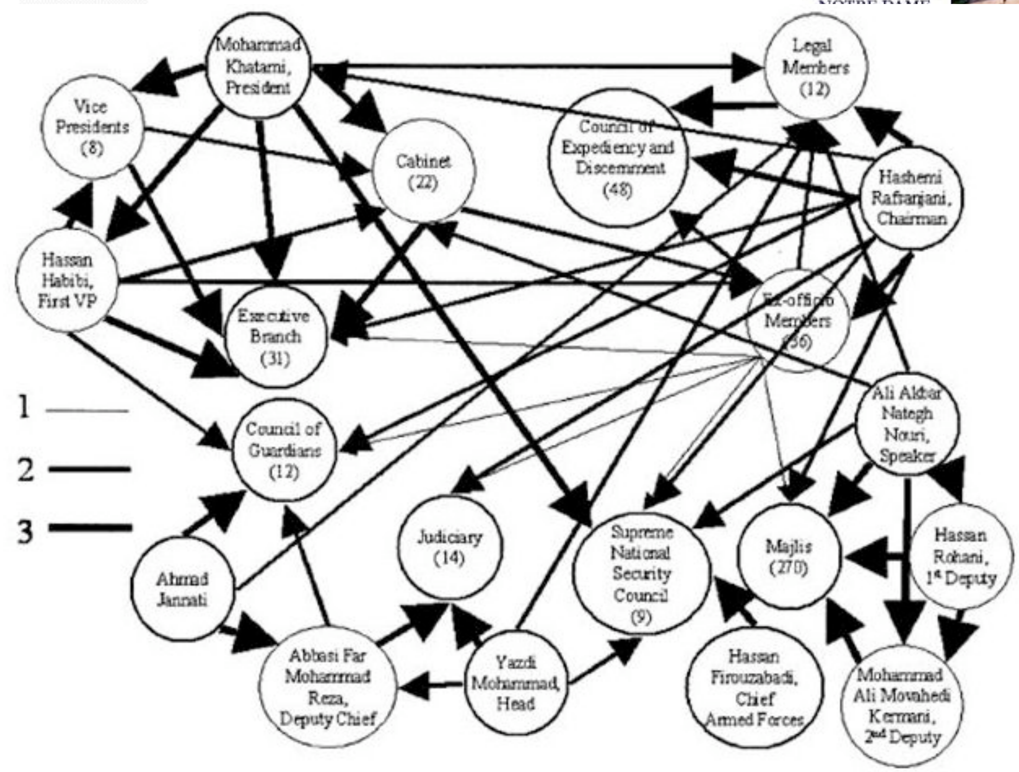
  $\Sigma_j x_{ij} - \Sigma_j x_{ji} = 0$ for all i

  $z - \Sigma_i x_{it} = 0$

  $0 <= x_{ij} <= s_{ij}$ for all i,j

- Assume importance of context, e.g., Rafsanjani was formerly President of Iran

- Rafsanjani has greater influence, so target him in any operation



Khatami	17
Rafsanjani	**21**
Nouri	15
Mohammad	9
Jannati	8
Firouzabadi	3

Methodology: Creating an SNA

- **Determine the boundaries of the social/organizational space**
  - A single unit of an organization or a small group of people
  - Several units of an organization
  - Establish an initial reachability value, e.g., how many extent links from each node will you consider
- **Determine the attributes and interactions that you will record**
  - What data about each node
  - What data about each interaction: type, frequency, duration, location, etc.
- **Develop a survey instrument**
  - A checklist for questions you want to individuals or interactions you want to observe in a group setting (such as a meeting)
- **Develop a schedule and a roadmap**
  - When will you (re-)interview selected individuals or observe meetings
  - Plan to update as the interviews/observations proceed

Methodology: Creating an SNA

- **Review Documentation (if any):**
  - Obtain and review the formal documentation for an organization or business unit
  - Use checklist(s) to fill in survey forms
  - Draw some initial graphs to get a rough idea of the formal network(s) and hierarchies
  - If allowed, review emails relating to projects; may get an idea of informal networks
- **Revise interview list based on rough draft of formal networks**
- **Develop interview questions**
- **Conduct interviews**
  - Distribution, Roles, trace rough formal network(s)
  - Schedule backup interviews to cross-check information

Methodology: Creating an SNA

- **Analyze Data:**
  - Create an adjacency matrix
  - Calculate measures

Distance: diameter of the network
Density: %-age of connections that exist out of total number possible
Centrality: measure of the extent to which the network is organized around a few people or nodes
Degree: # People connected to me – in my unit; all other units

	Sam	Jackie	Carol	Rob	Myrna
Sam					friendOf
Jackie					
Carol		employeeOf		spouseOf	friendOf
Rob	friendOf		spouseOf		
Myrna	friendOf				

	# People	Density	Distance	Centrality	Degree
Unit -1					
Unit-2					
Unit-3					

Methodology: Analyzing an SNA

- **Numerous Approaches:**
  - ERGM - Exponential Random Graph Models (Wasserman, Pattison, Robins, Snijders, et al)
  - Network Evolution – Actor oriented models (Snijders, Steglich)
  - Positional analysis – generalized block modeling (Batagelj)
  - Autocorrelation Models (Leenders)
  - Spectral analysis (Richards, Seary)
  - Multi-relational, multi-rater networks (Koehly, Corman)
  - Sampling, missing data (Wasserman, Butts)
- **Example: Monte Carlo techniques for Maximum Likelihood Estimation of ERGM:**
  - Simulate a distribution of random graphs from a starting set of parameter values and to refine these estimated parameter values by comparing the distribution of graphs with observed graph until parameter stabilizes.
  - But, Monte Carlo is computationally intensive
  - # Parameters to obtain a good distribution
  - Scalability: nodes, # relationships, complexity

Methodology: Modeling an SNA

- **A wide variety of tools:**
  - AGNA, GRADAP, NetDraw, Pajek, PGRAPH, et al
  - *Huisman, M. & Van Duijn, M. A. J. (2005). Software for Social Network Analysis. In P J. Carrington, J. Scott, & S. Wasserman (Editors), Models and Methods in Social Network Analysis (pp. 270-316). New York: Cambridge University Press*
- **Network Simulation:**
  - System Dynamics (VENSIM)
  - Agent-Based Simulation (Repast, MASON, SWARM, Madkit)
  - Computational Network Models (NetLOGO)
- **Issues:**
  - Reusable
  - Transparency
  - Multi-scale simulations
  - Analysis of simulation models on benchmark data to explain variance
  - Theoretical testing and empirical validation

Methodology: Visualizing an SNA

- **Visualization:**
  - An (animated) image of a network is easier to comprehend, search, and navigate through than a list of millions of (dynamically changing) node-node pairs
  - A major means to represent and communicate scientific results -- across scientific boundaries
- Example: Pajek (Batagelj), JUNG (Fisher)
- Issues:
  - Eye candy vs. effective, navigable visualizations
  - Visualization of data origin, provenance, accuracy, uncertainty as annotations
  - Tools for data analysis and visualization to help people make sense of very large, dynamically evolving datasets
  - Scalable, interactive/iterative specification of data analysis and data mappings
  - Visualization (see http://www.visualcomplexity.com/vc/)

Methodology: Maintaining an SNA

- **Challenge: Social networks change over time**
  - How to track – periodically – changes
  - How stable are relationships that are detected
- **Challenge: Resolve inconsistencies in information**
  - Conflicting Data
  - Assigning responsibility for sources; weighting reliability
- **Challenge: Expressing Dynamics**
  - (Human) Networks are self-organizing systems
  - How to reflect dynamics of interaction in social networks
  - Suggestions:
    - Use Petri nets
    - Use System Dynamics

SNA: Interventions for EA

- **Enterprise Architecting (EA) is the process of analyzing the IT operations of an organization**
  - We (Armour and Kaisler) use SNA approaches as an analysis tool
- **Some Interventions we have recommended:**
  - Structural: Introduce new personnel into specific roles to facilitate IT and business operations; relocate business or IT operations
  - Developmental: Accelerate adoption of new technology to facilitate exchange and processing of data; establish links between people and applications to get data where it is needed
  - Functional: Recommend changes in duties, operational responsibilities, etc to improve performance and information flow

π Ask yourself these questions (after Webster 2003):

Q1. Suppose you need *sugar* or something like that and the shops are closed, or you need a piece of equipment. Who would you ask to lend you these sort of things?

Q2. Suppose you need help with *jobs in or around the house,* for instance holding a ladder or moving furniture. Who would you ask for this kind of help?

Q3. Suppose you have problems with *filling informs,* for instance tax forms.

Who would you ask for help with such problems?

Q4. Most people from time to time *discuss important matters* with others. Looking back over the last six months, who are the people with whom you discussed matters important to you?

Q5. Suppose you need advice **with a *major change in your life,* for** instance changing **jobs or moving to** another area.

Who would **you ask for advice if such a major change occurred in your** life?

Q6. Suppose you have the *flu* and **must *stay*** *in bed* **for a couple of days. Who would you ask to take** care **of you or do some shopping?**

Q7. Suppose you need to *borrow a large sum of money.* Who would you ask?

Q8. Suppose you have serious *problems with your partner* which you cannot discuss with him or her.

With whom would you talk about **such problems?**

Q9. Suppose you are *feeling depressed* and you want to talk **to someone** about it.

With whom would you talk about **such problems?**

Q10. With whom do you *go out* once in a while, for instance shopping, going for a walk, going **to a** restaurant, **or to a movie?**

Q11. With whom do you have contact at least **once a month, by *visiting* each other for a chat, a cup of coffee, a drink, or a game of cards?**

Q12. Is there anybody ***else*** **who is *important* to you,** not mentioned **so far? Relatives, or co-workers who** are important **to you?**

SNA Principles

1. **Networks are often Invisible**
2. **People link with others who are Similar**
   - homophily matters
3. **People talk with those who are Physically Close**
   - proximity matters
4. **People who are Similar & Close form Clusters**
5. **Info quickly Spreads within Dense Clusters**
   - people in the same clique know the same info
6. **Information gets Trapped in Clusters**
7. **“Bridging Ties” assist information/knowledge Flow between Clusters**
   - “opinion leaders” have connections to multiple clusters
8. **Weak Ties are Surprisingly Strong**
   - acquaintances are important sources of novel information
9. **The Net nurtures weak ties**
   - explains why information travels much faster today
10. **Networks go across domains**
    - users and non-users talk about multiple product categories

SNA: Challenges

- **How do social networks explain large social phenomena such as:**
  - diffusion of ideas
  - Individual and group creativity
  - political movements and action
  - infectious diseases (AIDS, Avian flu) spread/epidemics
  - online retailing
  - mobilization to prepare, respond and recover from disasters?
- **What are the results of social networks?**
- **How do we interpret the results from social networks?**

Social Network Analysis: Challenges

- **How do social networks change over time?**
  - How do interaction patterns dynamically relate to structural position in the network?
  - Why do people sharing relationships tend to be similar?
  - Can one predict formation or break-up of communities?
- **What effect does {location, gender, race, … } have on social networks?**
  - What are the spatio-temporal distributions of interactions?
  - How do people serve as hubs and bridges between people and organizations?

Social Network Analysis: Challenges

- **Can be hard to observe relations. You can interview friends, but you cannot interview a friendship, so:**
  - measure and aggregate attributes of individuals.
  - model social life as correlations among individual attributes (e.g. age, race, gender, education, income)
- **Challenges for current tools and techniques:**
  - Accounting for missing or erroneous data
  - Modeling dynamic changes in network structure (diachronic change)
  - Modeling key flows, identify key players
  - Detecting vulnerabilities
  - Performing what-if analyses

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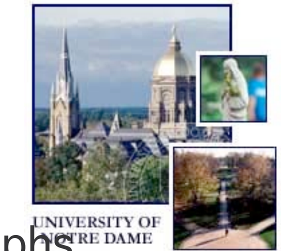

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Agent-Based Simulation

Simulation in the Social Sciences

Simulation is a <u>third way</u> of doing science, in contrast to both induction (statistics) and deduction (mathematics).

Like deduction, it starts with a set of explicit assumptions.

But unlike deduction, it does not prove theorems

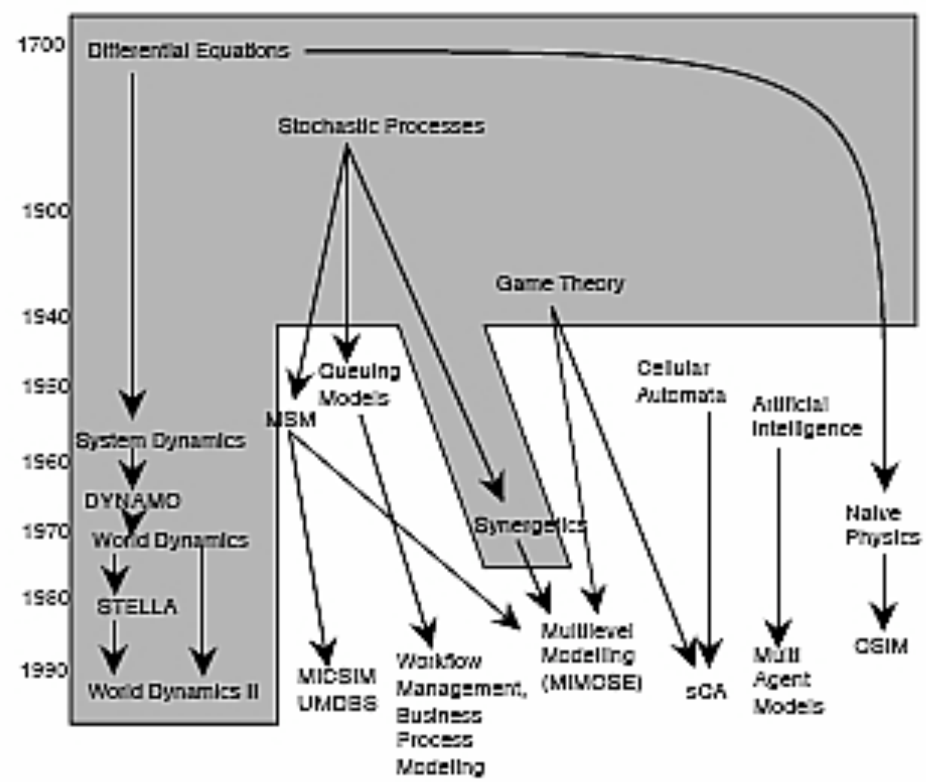
Instead, a simulation generates data that can be analyzed inductively.

Unlike typical induction, the simulated data comes from a <u>rigorously</u> specified set of rules rather than direct measurement of the real world.

While induction can be used to find patterns in data, and deduction can be used to find consequences of assumptions, simulation modeling can be used to <u>aid</u> intuition.

Robert Axelrod, 1997

Figure 1.2: The development of contemporary approaches to simulation in the social sciences (after Troitzsch 1997)



Why Simulation?

- Want to solve problems through strategy of "divide and conquer"
- Need to make *ceteris paribus* assumption
- But in complex systems this assumption breaks down
- Herbert Simon: Complex systems are composed of large numbers of parts that interact in a non-linear fashion
- Therefore, we need to study interactions explicitly

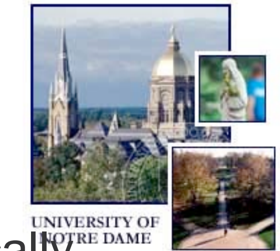
- Causal Theory: efficient history
- Cannot capture social forms in variables and equations
- Explain complex systems by deriving the mechanisms that generate them
- Feedback undermines this perspective
- Need to endogenize the actors and interactions
- Object-oriented design is a good way to agents

A *social form* is a configuration of social interactions and actors together with the structures in which they are embedded

What is Agent-Based Simulation?

- An *agent* is:
  - An individual with a set of characteristics or attributes
  - A set of rules governing agent behaviors or “decision-making” capability, protocols for communication
    - Respond to the environment
    - Interact with other agents in the system
- Agent-based modeling is a *computational methodology* that allows scientists to create, analyze, and experiment with artificial worlds populated by agents that interact in nontrivial ways and that constitute their own environment.
- An agent-based simulation (ABS) is one in which a collection of agents compete or collaborate or both to attain individual goals in pursuit of a social or organizational goal(s).
- A simulation based on software agents can support good science provided the design of the agents and the simulation environment are themselves based on good science.

Why ABS?



- **Aspects of the real world that we want to examine are** not physically accessible
  - **ABS takes place in an *artificial world***
- **Experimenting with the real system is prohibited due to** undesirable disturbances
- **Time scale of system behavior is** too small or too large **for observation**
- **The original system** does not exist **any more or does not exist yet**
- **Modeling is a** tool for understanding → **formalization of a hypothesis that otherwise would have remained very vague**
- Begins with object/agent behavior rules governing interactions**; aggregate** *observables "emerge"*
- **Natural** modularity follows the types of objects **(real world analog)**
- **Can** distinguish between physical space & interaction topology
- **Handles** large heterogeneity of objects
- **Behavioral** validation at both object and aggregate levels

ABS: Key Assumptions

- ***Agents interact with little or no central authority or direction*:**
  - Global patterns emerge from the bottom-up
  - "Self-organization" process (Kaufmann 1996)
- ***Agents are interdependent*:**
  - Agents influence others in response to influence they receive.
- ***Agents follow simple rules*:**
  - Global complexity does not necessarily reflect the cognitive complexity of individuals
  - Simon contended that human beings are quite simple.
  - "the apparent complexity of our behavior is largely a reflection of the complexity of the environment." (Simon 1998)
- ***Agents are adaptive and backward-looking.***
  - When interdependent agents are also adaptive, their interaction can generate a "complex adaptive system" (Holland 1995)
  - Agents adapt at two levels: individual and population (or group)
  - Individual learning alters the probability distribution of rules competing for attention.
  - Population learning alters the frequency distribution of agents competing for reproduction through processes of selection, imitation, and social influence.

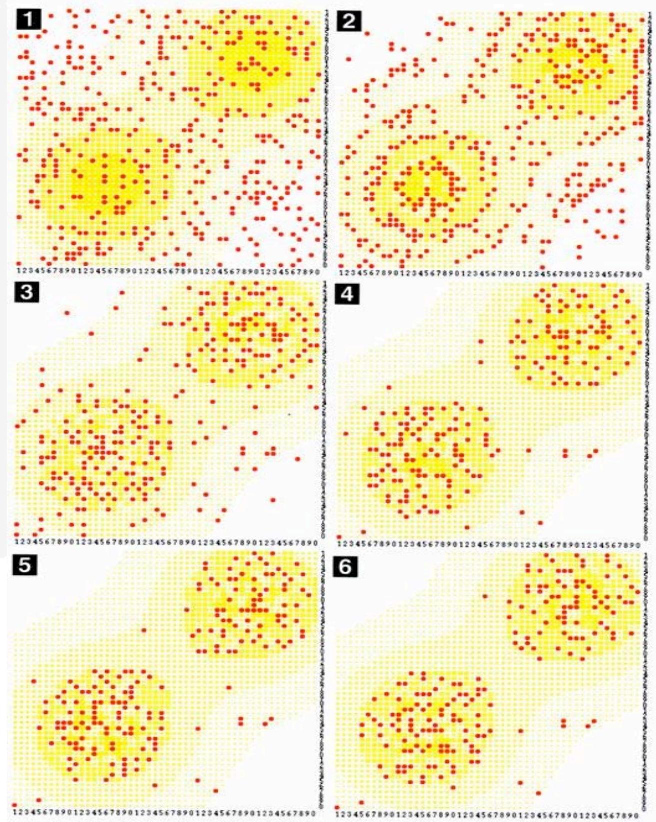
ABS Implementation

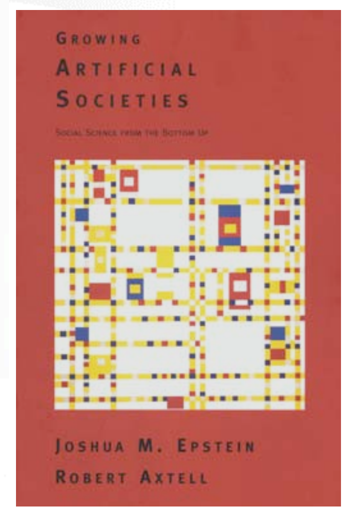
- The observed behavior is typically best described qualitatively and the reasons individuals give for their behavior is almost invariably qualitative as well.
- Validation of software agents as good representations of real individuals can be facilitated by:
  - having the agents perceive events specified by qualitative descriptions
  - maintaining the qualitative terms in processing those perceptions
  - acting in ways that can be described qualitatively
- A natural way to maintain this qualitative link between the language of actors and the language of the agents is to use production systems whereby:
  - the rule conditions describe the perceptions by the agents
  - processing is governed by some inference engine
  - the actions are specified by the consequents of the rules
- There are many logics that can facilitate this representation, but few are known to social scientists.

Applying CAs to Social Sciences

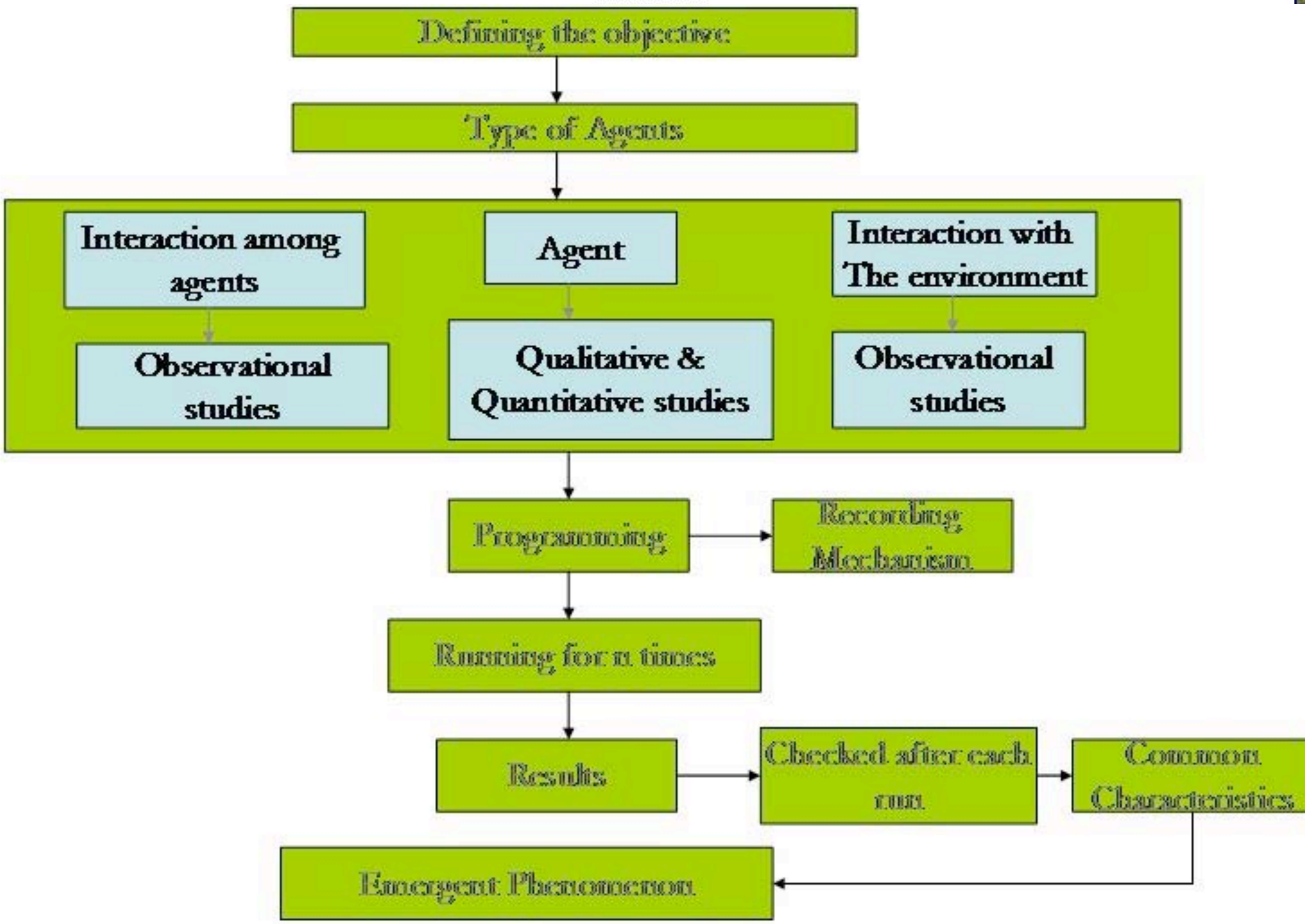
- **Sugarscape (Epstein & Axtell)**
  – Goal: Explain social and economic behaviors at large scale based on individual behaviors.
- **Agent rules:**
  – *Life, Death, Disease*
  – *Trade: Sugar, Spice*
  – *Wealth*
  – *Sex, Reproduction*
  – *Culture*
  – *Conflict, War*
  – *Externalities: Pollution*
- ***A Classic Example (ca.1990s)***

Animation II-2. Societal Evolution under Rules ({G_1}, {**M**}) from a Random Initial Distribution of Agents





Agent-Based Model Development

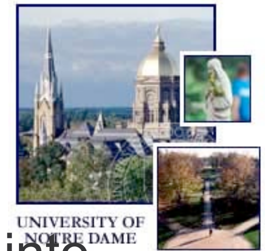


Ref: Kilicay, N. “Emergent Phenomena and Human Social Systems”, web.umr.edu/~sesl/Presentations%5Ckilicay-sesl.ppt

Designing Agent-Based Simulations

- ***Conceptualization***:
  - **Formalize the first description of the problem**
  - *UML use cases provide an easy way to document the major problem space elements*
- ***Analysis***: Develop a detailed requirements specification by *delimitation* to distinguish the agent-based system from the external non-agent system
- ***Decomposition:*** Partition the system based on the geographical, logical and knowledge distribution
- ***Validation***: Determine correctness with respect to previous definitions and other models.

Designing Agent-Based Simulations



- ***Design***: Conduct *application design; decompose fucntionality* into submodules
  - *architecture design* through selection of a multi-agent architecture and determining the infrastructure based on the applied network, used knowledge and the coordination
  - *platform design*, addressing the needed software and hardware - the basis for this phase is mainly the expertise model and the task model.
- ***Coding and testing***: performed on an individual agent basis.
- ***Integration***: Integrating the different individual agents, any support mechanisms, and testing of the multiagent system.
- ***Operation and maintenance***: apply to real problems

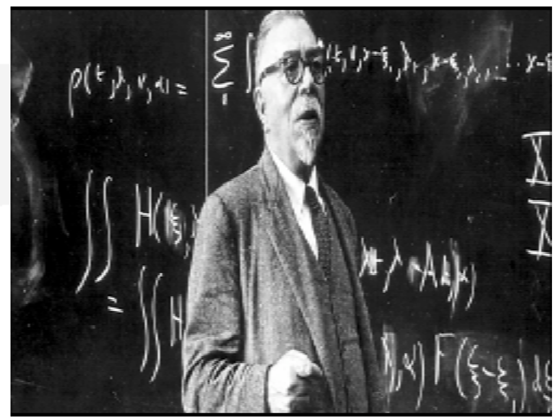
Types of Models To Construct

- **Organization Model: environments for agents**
  - Perform actions that are aggregate within the simulation
  - Specifies context: must ground in the 'real world" to be acceptable to users
- **Agent Model: descriptions of individual actors and their abilities**
  - Attribute- and Operation-based
  - Operations are functions the agent can perform
- **Task Model: descriptions of actions to be performed by agents or organizations**
  - Develop a task hierarchy; maybe a many-rooted tree
  - Topmost elements are objectives of the simulation
  - What is important is how the agents achieve the objectives rather than the objectives themselves (since they are already specified)
  - Allow for a certain amount of serendipity

"Boids"

Types of Models To Construct

- **Communication Model: describes the interactions between agents, organizations and the external world**
  - Specifies the protocols of information exchange: types of messages, content, conditions, etc.
  - The basic system interaction is embedded in the communication model
  - Think of the protocol as a set of transactions:
    - A gives B
    - Then (sometimes) B gives A
    - B may not respond directly to A's last transaction, but changes the subject
  - How do people communicate in the real world?
  - Agents communicate with organizations as well

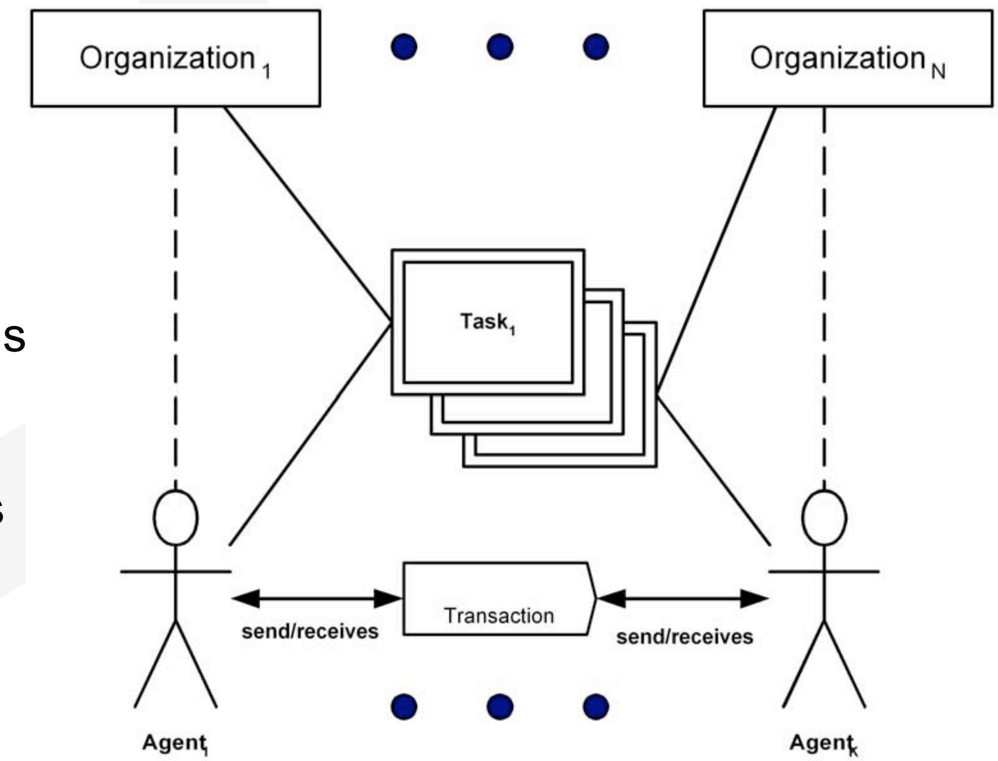


Norbert Wiener, Cybernetics

- **Question: How would you model a standing ovation?**

Model Relationships

- Behavior-oriented Agent Models
  - Modeling = Describing agent behavior
- Goal-oriented Agent Models
  - Modeling = Identifying goals and let the agents plan…



Problem: East Coast Evacuation

- **Assume an asteroid is going to strike somewhere off the East Coast in 1 week**
  - Will generate a wall of water over 30 feet high
  - Inundate the coastline into Richmond, Va (for example)
- **How do we determine how best to evacuate the East Coast**
- **How would you use ABS to model the behavior of (groups of) people?**

STRADS

- **Strategic Automated Discovery System (Oresky, Lenat, Clarkson, and Kaisler 1991)**
  - Based on work pioneered by Lenat in AM and Eurisko
  - A knowledge-based simulation system for generating and analyzing alternative scenarios in geopolitical military situations
- **Basic Idea:**
  - Given an event, STRADS simulates the responses of various actors (countries, leaders, NGOs, etc.) in the context specified by the particular scenario.
  - These responses, in turn, generate new events, which cause the process to repeat.
  - STRADS continues until no new events have been created.
- **STRADS aided analysts by generating plausible scenarios**
  - Analysts often knew likely outcomes, but did not know what sequence(s) of events would lead to a specific outcome
  - Sometimes, unlikely outcomes, even surprising ones, could arise from the proper mix of factors
  - By varying the initial assumptions (boundary conditions), an analyst can (possibly) generate many different scenarios and, thus, explore the problem space

Why STRADS?

- **Human Limitations:**
  - “Mirror-Imaging”: Analysts reflect own perspectives when analyzing other countries actions

    When making deals with Iran, it was a mistaken belief that it would make them feel indebted to us, rather than viewing it from their perspective of Koran-sanctioned cheating and stealing and lying to infidels
  - Assuming “Past is Prologue” in dissimilar situations

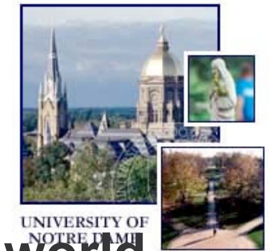
    Treating the Mayaguez incident as similar to the Pueblo, just because both ships had Spanish-sounding names and were hijacked.
  - Mindset: Perceiving what you expect rather than what actually is happening

    During overthrow of the Shah of Iran by Shi’ite fundamentalists, it was unexpected that a grass roots religious upheaval would succeed in a country with a powerful secret police and disciplined, well-armed military. But, the Shah was unwilling to use force to defend his position.

Motivation

- **Al Clarkson, Towards Effective Strategic Analysis, Westview Press, Colorado Springs, CO 1981**
  - Strategic analysis is a rigorous cognitive process by which possible crucial realities of the future are first imagined and then modeled systematically to delineate their conditions, dynamics, and possible outcomes, every effort being made to achieve realism and verisimilitude; with various inferential strategies procedurally employed to develop comparative probabilities; with the models and probabilities continuously reviewed and modified appropriately on the basis of new data; with *post mortems* conducted systematically to measure performance and to stimulate learning; and the entire process oriented towards decision making and policy formulation.
- **Goal: Overcome Mindset**
  - The tendency to perceive what you expect to happen rather than what actually happened

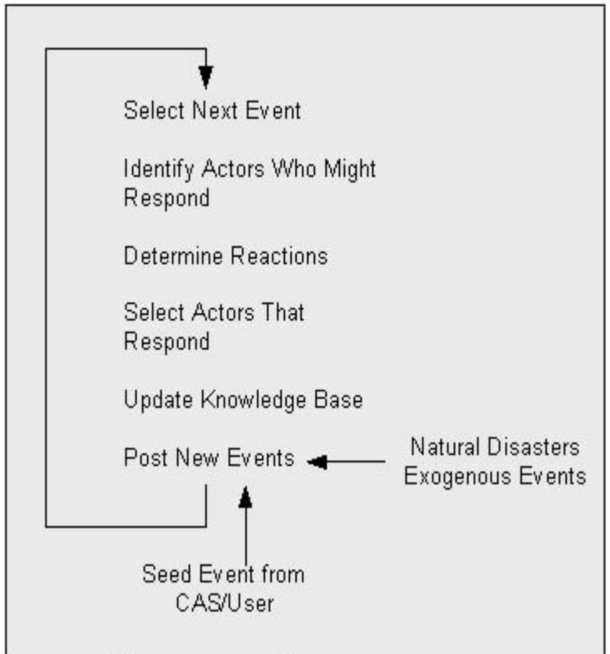
STRADS Implementation



- **Symbolically represented extensive knowledge about the world**
  - Political, cultural, economic, military, etc…
- **Represented actual and/or imagined problems through scripts and events**
  - Scrips associated with event types, actors, and activities
- **Produced numerous scenarios to explore strategic possibilities using a heuristics-guided program**
- **Conduct experiments based on user-defined parameters to examine possible outcomes**
  - Actors behavior determined by scripts, observance of events, and perceptions of other actor's behaviors

STRADS Overview

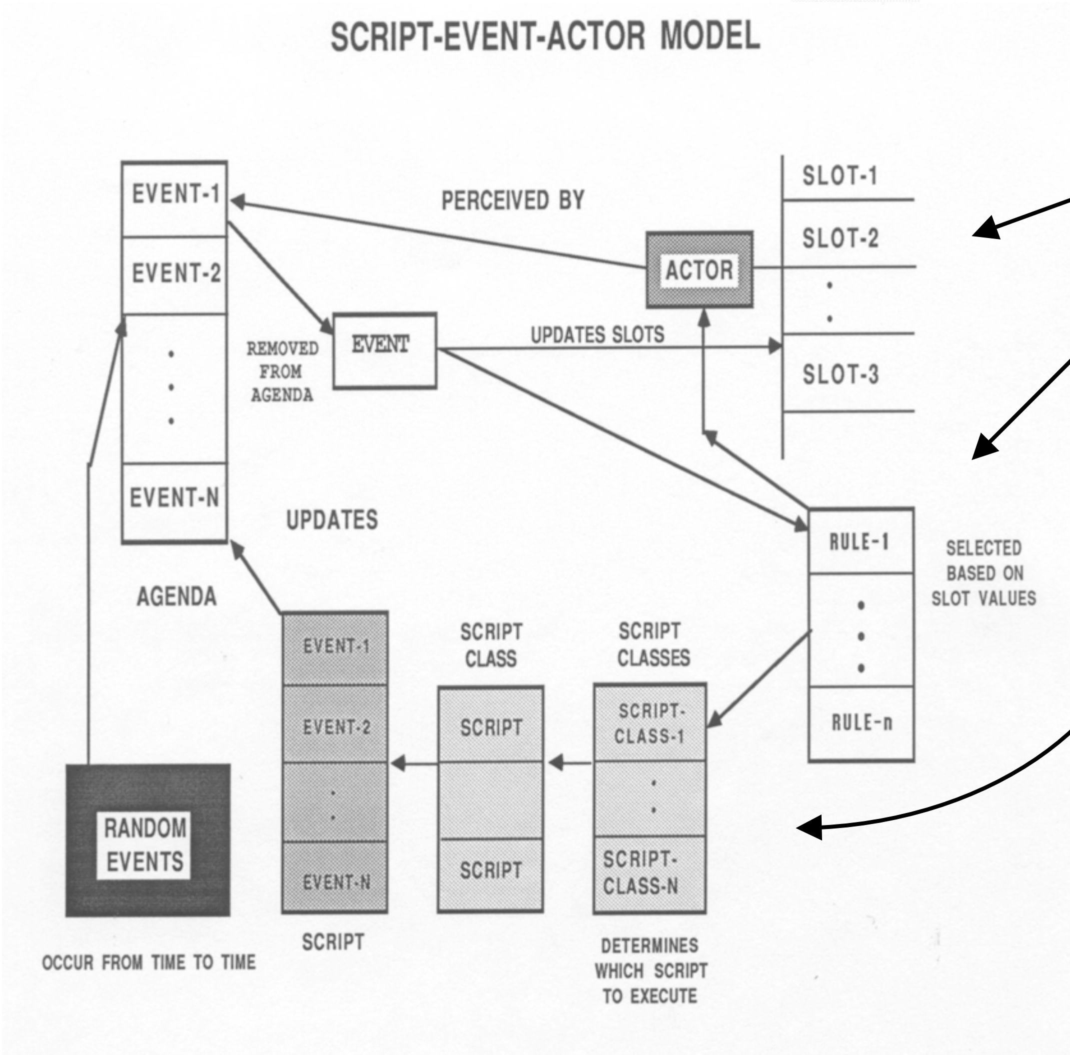
Simulation Conceptual Flow



Actors	Events	Rules	Scripts	Scenarios
USA North Korea Red Cross United Nations Iraq Taliban M. al Sadr Etc.	Terrorist Attack Announcements Military Ops Food Riots Assassination National Election Typhoon Etc.	Performers of an Event May React Allies to Performers Make Announcement Interested Parties May Respond To Event Etc	Host Actor Responds By Trying Terrorists: - Capture Terrorists -Try terrorists -Announce Verdict -Carry Out Sentence	Scenario: - Taliban attacks US Citizens -Afghani Police Capture Terrorists -Afghanistan Tries Terrorists -Afghanistan Announces Guilty Verdict -Afghanistan Executes Terrorists -Taliban Retaliates Against US

- Actor-based Simulation
  - Actors dynamically make decisions based on perceived events and belief models
  - Rule-based decision-making
- Discrete Simulation
- Belief System Modeling
- "What-If" Subsimulation Capability
- Scenario-Driven
- Self Modification Based on Learning from Interactions with other Actors (Future)

STRAD Script-Event-Actor Model



- An Actor perceives events occurring in the simulation
- Based on values of Actor slots, an appropriate Script is selected for the Actor to execute by the Rules
- The Script determines the number of and type of responses the Actor may give
- Responses cause new Events to be added to the simulation agenda
- Random natural events can be inserted into the event queue (typhoons, death of a leader, famine, etc…)

STRADS: Partial Actor Definition

LIBYA:

SubActors: (Libyans LibyanRebelGroups LibyaGovernment)

ElementOf: (ActorsAlliedToUSSR ThoseThatPlaceThemselvesAboveTheLaw AfricanStates EconomicallyDepressedNations RadicalActors)

DiplomingWith:
ActualValue: (USSR PLO Cyprus Jordan SouthYemen Iraq ...)
CurrentValue: (USSR PLO Cyprus Jordan SouthYemen Iraq ...)
GoalValue: (= (USSR ArabActors USA UnitedKingdom Austria ...))
ImportanceOfGoalValue: Important
OtherActorsGoals: ((WesternActors (= Libya DiplomingWith) IMportant)
(USSR (= (Israel)) Important)
(ArabActors (= (Israel)) Important))

EconomicEnemies:
ActualValue: (USA Israel)
CurrentValue: (USA Israel)
GoalValue: (= (Israel))
ImportanceOfGoalValue: VeryImportant
OtherActorsGoals: ((WesternActors (= (None) Important)
(USSR (= (Israel)) Important)
(ArabActors (= (Israel)) Important)

Each is an independent actor

Member of groups organized by affinity or attributes

Several hundred slots describe actors

Values of slots are complex structures to support the belief system:
- *ActualValue – the present value*
- *CurrentValue – what the actor believes the value to be*
- *GoalValue – what the actor wants the value to be*
- *ImportanceOfGoalValue – how important it is to the actor that the goal value be achieved*
- *OtherActorsGoals – what other actors want the value to be and how important it is to the to achieve that value*

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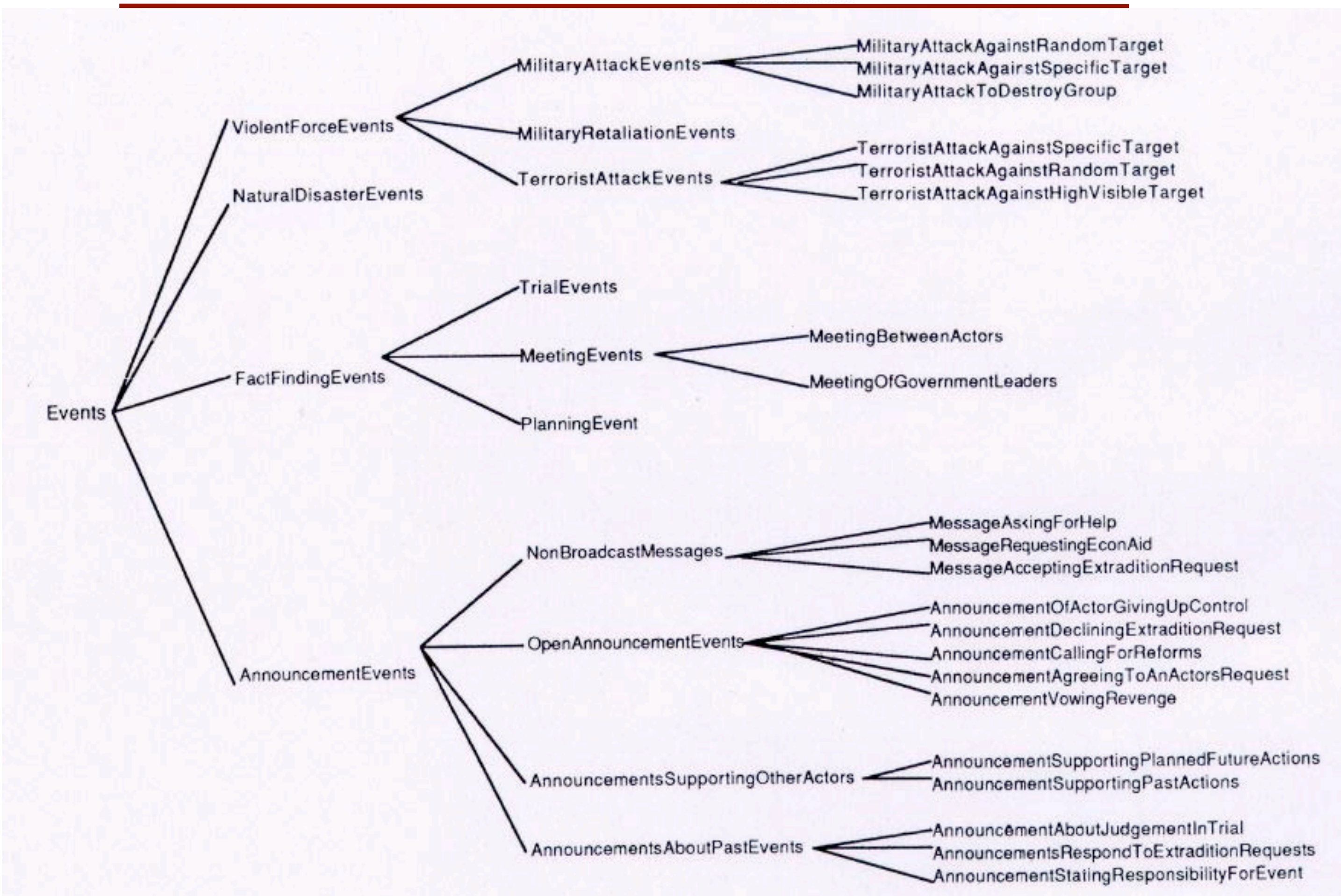
STRADS Events



An event corresponds to an action that occurred in the world at a particular time and place.

A STRADS event describes who was involved; what action was performed; how the action was performed; when, where, and why it took place; and who knows and believes the event took place.

STRADS Event Example - I

Chronology of events:

Egypt Cant Pay Loans And Requests Emergency Aid
Announcement is: (EgyptGovernment AnnouncesTheyHave EconomicProblems)
(EgyptGovernment RequestsEconomicAidFrom (USAGovernment WorldBank))

Rules That Execute:

IfExpectedByPerformerThenSelectEvent
TargetsOfAnEventMightReact
PerformersOfAnEventMightReact
HostActorofAnEventMightReact
RequesteeOfAnEconomicAidRequestMightReact
RespondToAnEconomicAidRequest
IfMaxDepthForRecursionThenDecideQuickly

Scripts Used to Create Events:

ResponseToAnEconomicAidRequest —— E
- RespondByDenyingActorsRequest
- **RespondByRequestingAMeeting**
- DelayResponseToEconomicAidRequest

Events Created and Added to Queue:

(15-Jul-87 09:00:00 EgyptCantPayLoansAndRequestsEmergencyAid)
(15-Jul-87 15:58:00 WorldBankDelaysResponseToEvent:EgyptCantPayLoansAndRequestsEmergencyAid)
(15-Jul-87 22:50:00 USAGovernmentRequestsAMeetingBetweenUSAGovernmentAndEgyptGovernment)
(23-Jul-87 19:16:00 USAGovernmentAndEgyptGovernmentMeetInEgypt)

STRADS Event Example - II

Chronology of events:

Egypt Cant Pay Loans And Requests Emergency Aid
Announcement is: (EgyptGovernment AnnouncesTheyHave EconomicProblems)
(EgyptGovernment RequestsEconomicAidFrom (USAGovernment WorldBank))

World Bank Delays Response to Event: Egypt Cant Pay Loans And Requests Emergency Aid

USAGovernment Requests AMeeting Between USAGovernment And Egypt Government
Announcement is: (USAGovernment RequestsAMeetingWith EgyptGovernment)
(FutureAction USAGovernmentAndEgyptGovernmentMeetInEgypt)

Rules That Execute:

PerformersOfAnEventMightReact
HostActorOfAnEventMightReact
IfExpectedByPerformerThenSelectEvent
TargetsOfAnEventMightReact
RequesteeOfAMeetingRequestMightReact
RespondToAMeetingRequest
IfMaxDepthForRecursionThenDecideQuickly

Same rules!

Scripts Used to Create Events:

Different Script

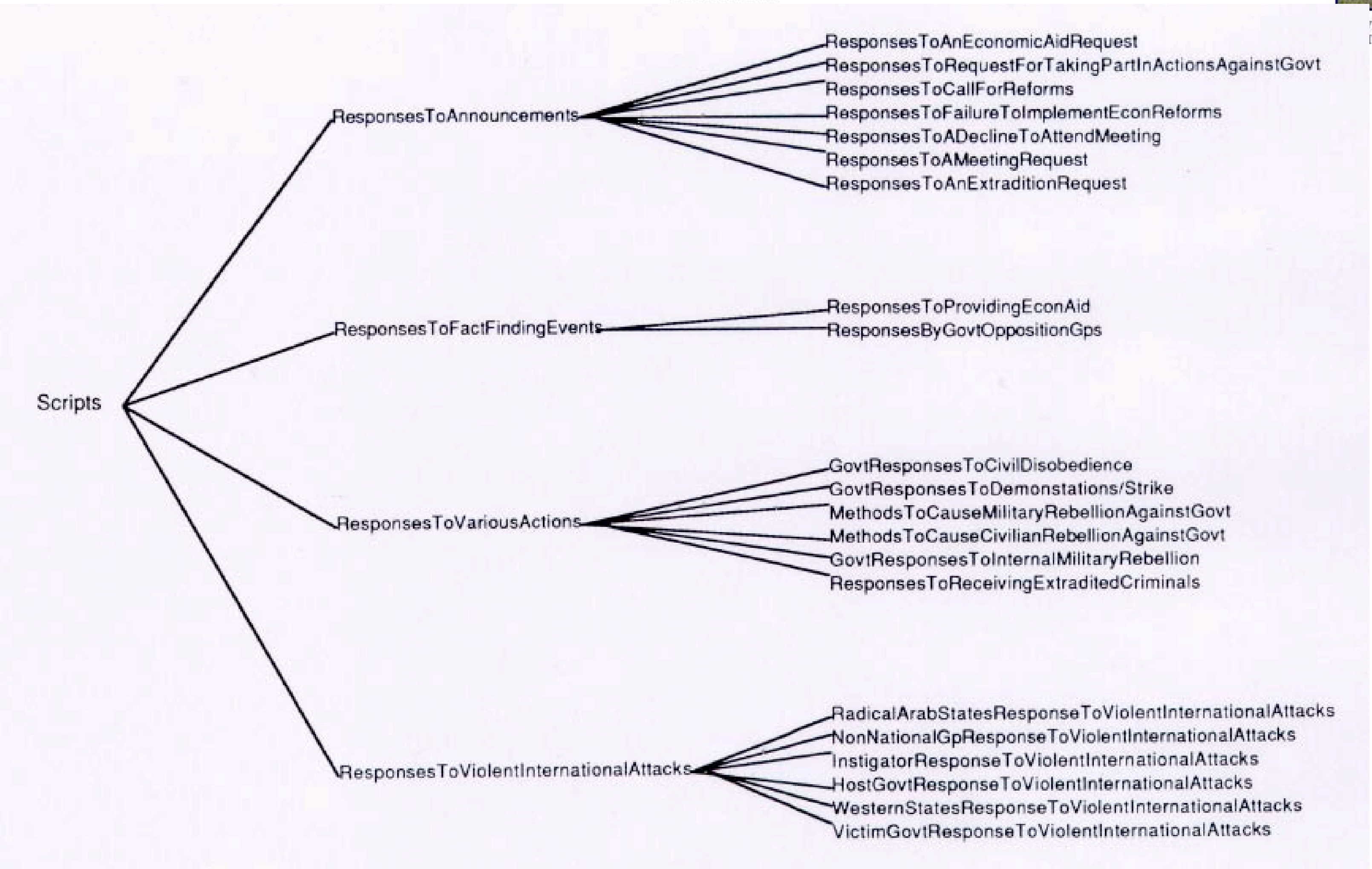
ResponsesToAMeetingRequest —— E
- RespondBySuggestingANewMeeting
- RespondByNotAgreeingToAttendMeeting
- DelayResponseToMeetingRequest
- **RespondByAgreeingToAttendMeeting**

Different Events

Events Created and Added to Queue:

(15-Jul-87 22:50:00 USAGovernmentRequestsAMeetingBetweenUSAGovernmentAndEgyptGovernment)
(16-Jul-87 02:10:00 EgyptGovernmentSendsMessageThatTheyWillAttendMeeting)
(23-Jul-87 19:16:00 USAGovernmentAndEgyptGovernmentMeetInEgypt)
(23-Jul-87 20:14:00 WorldBankAndEgyptGovernmentMeetInEgypt)

Script Hierarchy

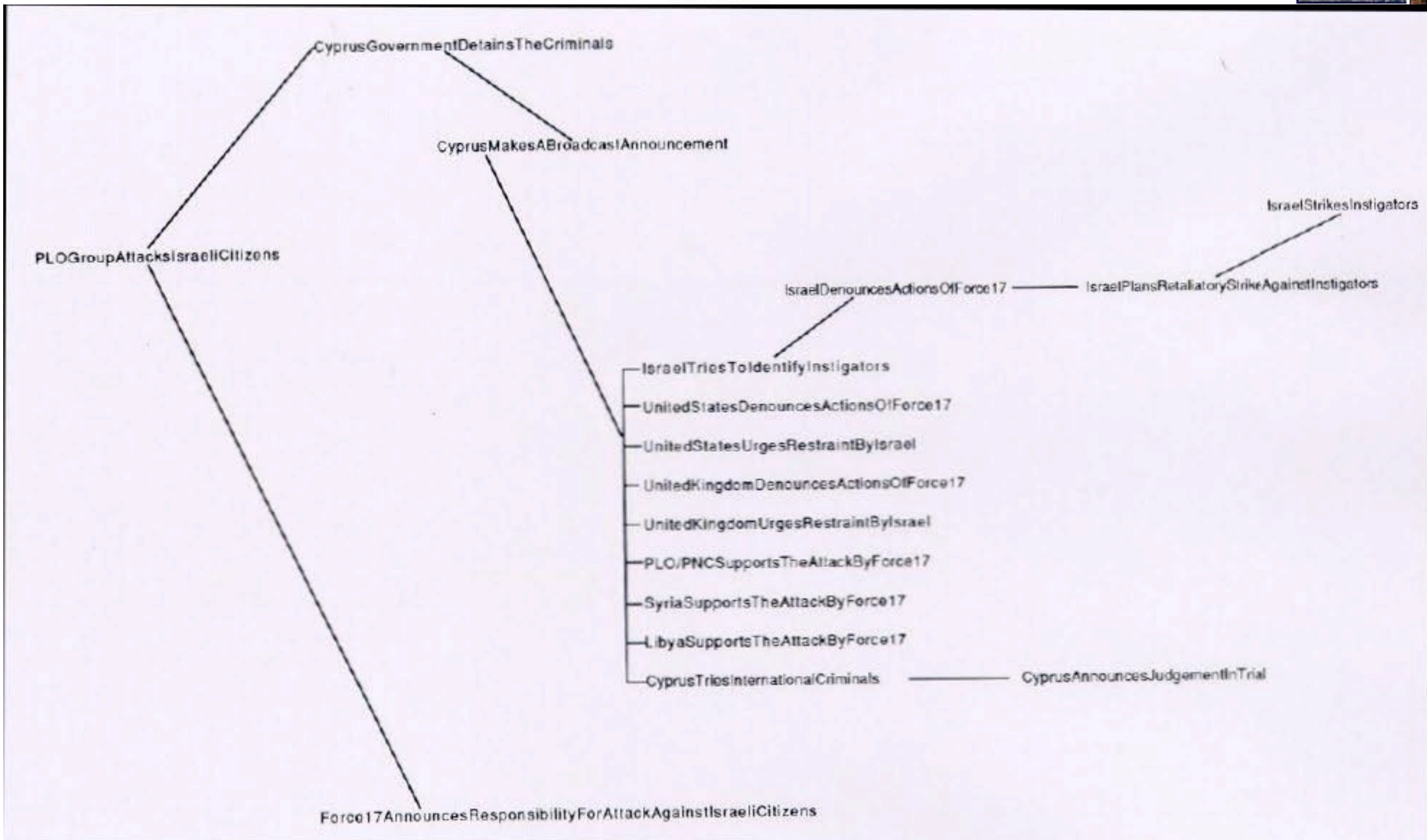


A script represents a set of options about how an actor might act in a particular situation.

Script Example (Lisp)

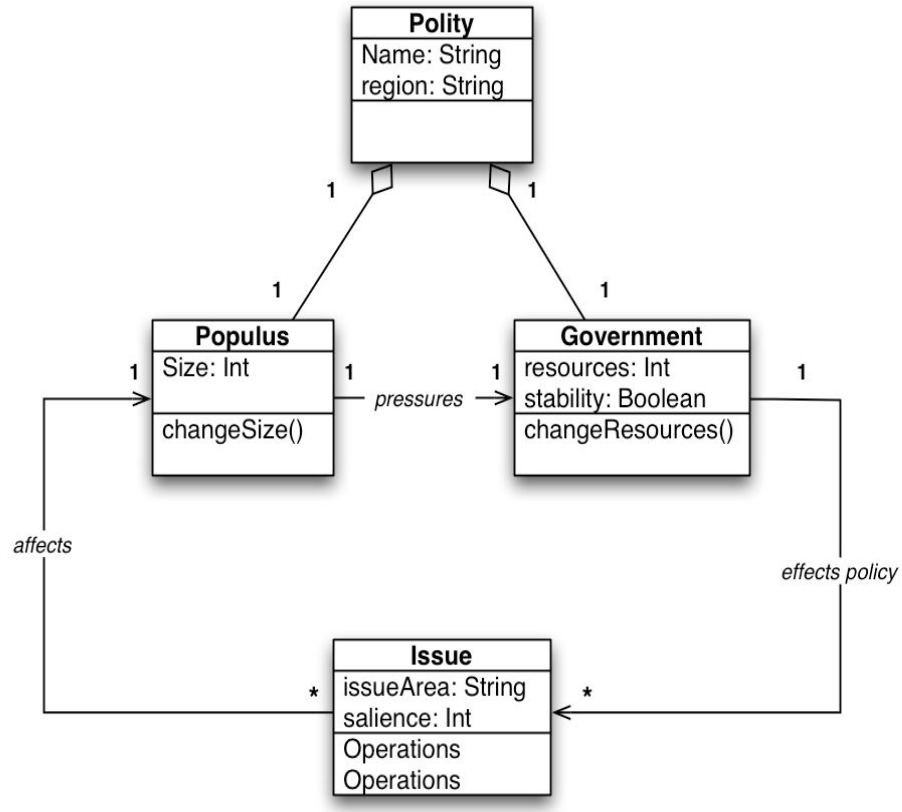

```
(defscript 'VictimGovtResponseToAttackByUsingLegalSystem
  'CreationDate "15-Jul-86 17:03:10"
  'English '(Government believes that support of military retaliations is
           lacking and therefore a strike would do more harm than good.
           Government will try using its legal system instead.)
  'QuickSelect 'VictimGovtUseLegalSystemFn
  'ScriptEvents '((InSequence IdentifyResponsibleGroupInAnEvent)
                (InCombination AnnouncementAssigningResponsibilityForAnEvent
                        AnnouncementDenouncingPastActionsOfOthers)
                (InParallel MessageRequestingExtraditionOfInstigatorParty
                       AnnouncementRequestingExtraditionOfInstigatorParty))
  'ScriptBindings '((setq actor1 instigators))
  'Isa '(VictimGovtResponseToViolentInternationalAttacks)
  'Parts '(IdentifyResponsibleGroupInAnEvent
        MessageRequestingExtraditionOfInstigatorParty
        AnnouncementRequestingExtraditionOfInstigatorParty
        AnnouncementDenouncingPastActionsOfOthers
        AnnouncementAssigningResponsibilityForAnEvent))
```

Scenario Example



Why "ABS" Will Help Advance Social Science Knowledge

- Most interesting sociopolitical systems are only *partially* understood (e.g., we know something about agent attributes and behaviors); and
- Known empirical social patterns can be used for assessing *fitness* of an evolved model*.*
- [1] and [2] *may* provide sufficient conditions for discovering more complete *and* insightful knowledge on complex social systems.



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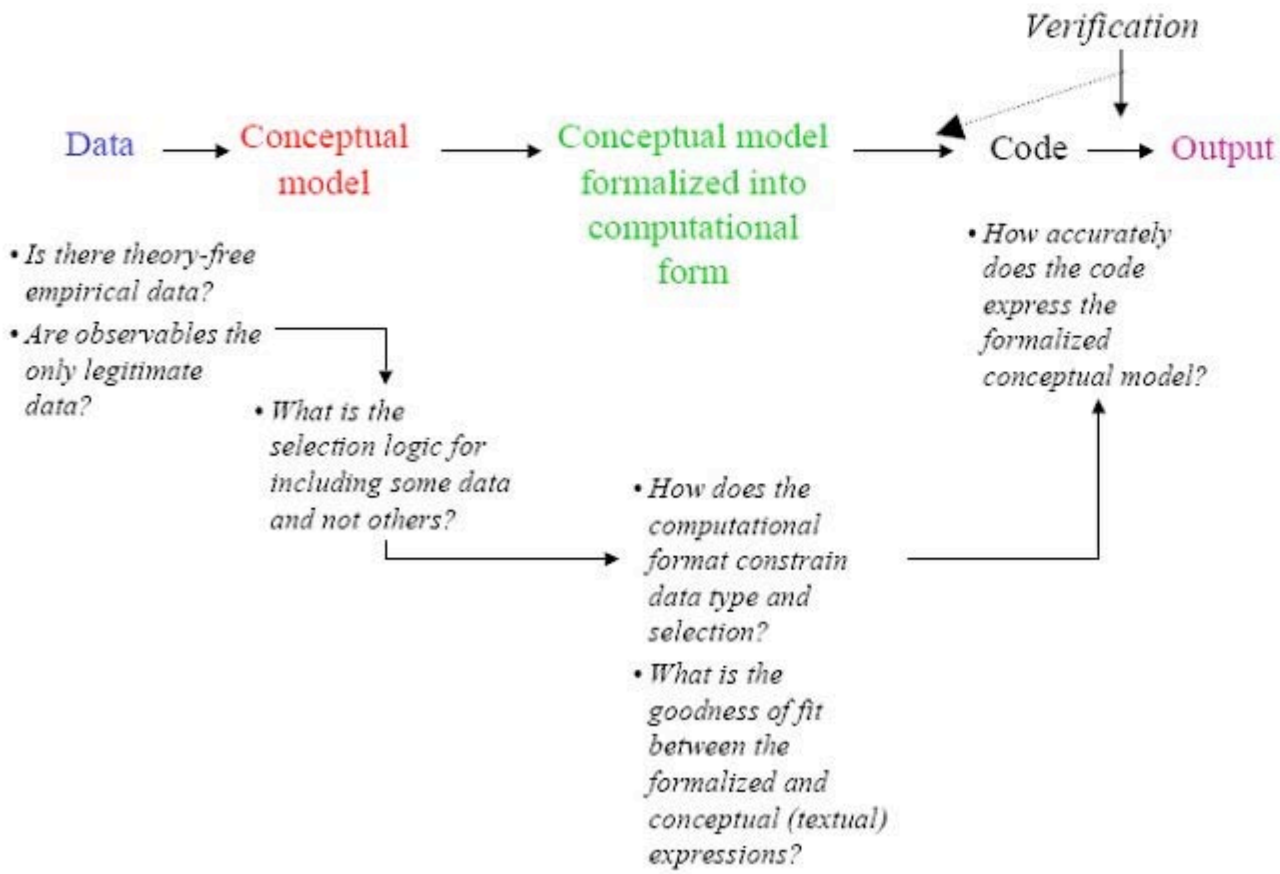
ABS: Validation & Verification

- **Validation is one of the most critical challenges**
  - What constitutes a validated model? Validated theory?
  - Is there social science theory in the model?
  - Has the theory been validated in the way it is used?
  - Are theories (multi-scale) used together appropriately? Conflicting? Gaps?
  - Do the theory implementations allow for empirical model validation?
- **Validation Resources**
  - Scientific validation philosophy, literature
  - Social science theory validation
  - Traditional model validation (for decision support)
  - Agent-based model validation: examples, literature
  - Human/social behavior representation and validation

ABS: Validation & Verification

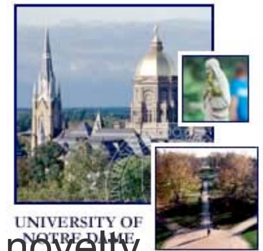


Ref: Turnley, J.G. 2005. Validation Issues in Computational Social Simulation, Galisteo Consulting Group, Inc.

A Methodology for ABS

- **Combines:**
  - Social Network Analysis
  - Systems Dynamics
- **Use Social network Analysis to identify the actors in the problem space**
  - Model the static relationships of the actors (people, groups, organizations)
  - Identify and associate attributes and factors
  - Understand the environmental actors, e.g., those not simulated
- **Use System Dynamics to model the dynamic interactions among actors based on attributes**
  - Formal (trade, diplomacy, tourism, etc…)
  - Informal (trust, advice, respect, information, etc …)

"Outside In" Modeling



By far the most common way to deal with something new is by trying to relate the novelty to what is familiar…: we think in terms of analogies and metaphors.

The **only feasible way of coming to grips with really radical novelty** is orthogonal to the common way of understanding: it **consists in consciously trying not to relate the phenomenon to what is familiar from one's accidental past, but approach it with a blank mind and *to appreciate it for its internal structure*.**

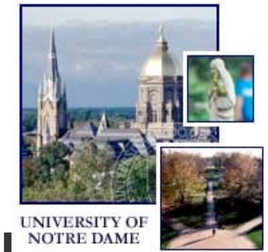
The latter way of understanding is far less popular that the former one, as it requires hard thinking. (And as Bertrand Russell has pointed out, "Many people would sooner die than think—in fact they do.") It is beyond the abilities of those—and **they form the majority—for whom continuous evolution is the only paradigm of history: unable to cope with discontinuity, they cannot see it and will deny it when faced with it**."

Edsger W. Dijkstra, Mathematicians & Computing Scientists: The Cultural Gap, ABACUS, vol. 4 no. 4, Summer 1987.

ABS: Challenges

- **How can we use agent-based simulations to fulfill the role played by telescopes, for example, in the natural sciences?**
  - Computational Social Science must be recognized as a valid experimental method, just as it is in the natural sciences.
  - But, agent design must not be constrained by unvalidated theory, e.g., we must be able to explore unlikely theories about situations when existing theories don't seem to fit
- **What Kinds of Models Can Existing Social Science Theory Reasonably be Expected to Support?**
  - What 'social reality' is the model representing?
- **What is the basis for agent rationality:**
  - Search (utility, determinism, closed)
  - Choice (values, non-determinism, open)

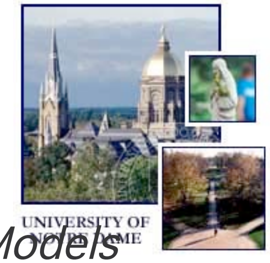
ABS: Challenges



- **How do we represent collective behavior of (multiple) goal-seeking groups?**
  - ABS has largely focused on individual agent behaviors, whether they represent people or groups of people
  - Formation of higher-order social structures as a beginning, not an end of experiments!
- **Self-Adaptation and Self-Learning of Agents**
  - Which precedes?
  - Need for long-term, continuous modeling environments and models
- **Real-Time, Real-World Focused Simulations**
  - Driving data derived from real-world events rather than hypothesized data
- **Scaling**
  - How to evolve from a few hundreds to a few 10,000s of agents
  - Is this realistic?

Agent-Based Simulation Toolkits

- Repast: http://repast.sourceforge.net/
- SWARM: http://www.swarm.org/wiki/Main_Page
- NetLogo: http://ccl.northwestern.edu/netlogo/
- MASON: http://cs.gmu.edu/~eclab/projects/mason/
- Madkit: http://www.madkit.org/



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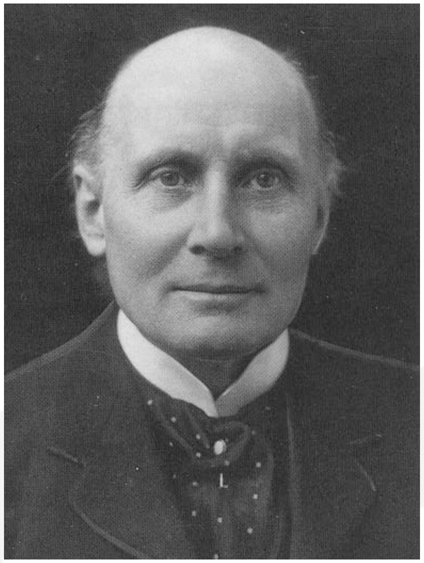
A Final Word!

Alfred North Whitehead



We have a tendency to mistake our models for reality, especially when they are good models.

Thank You

Additional Information

Q/CSS Organizations – A Sampler

- **George Mason University:**
  - Center for Social Complexity, Krasnow Institute
  - Professor Claudio Cioffi-Revilla, Director
  - http://socialcomplexity.gmu.edu/
- **Carnegie Mellon University**
  - Computational Analysis of Social and Organizational Systems
  - Professor Kathleen Carley, Director
  - http://www.casos.cs.cmu.edu
- **Brookings Institution**
  - Center on Social and Economic Dynamics
  - Dr. Joshua Epstein, Director
  - http://www.brook.edu/es/dynamics
- **The Santa Fe Institute**
  - http://www.santafe.edu/
  - Dr. Geoffrey West, President
- **University of Michigan**
  - Center for the Study of Complex Systems
  - Professor Carl P. Simon, Director
  - http://www.cscs.umich.edu/

Top Textbooks and Journals in Computational Social Science

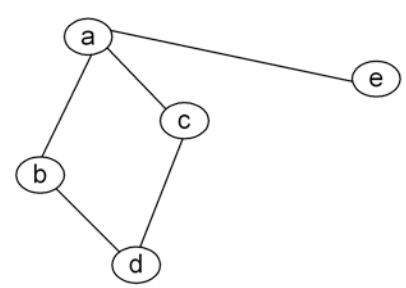
- Nigel Gilbert & Klaus Troitzsch. 2005. *Simulation for the Social Scientist*. Second edition ed. Buckingham and Philadelphia: Open University Press.
- Charles S. Taber & Richard J. Timpone. 1996. *Computational Modeling*. Thousand Oaks, London and New Dehli: Sage Publications.
- *JASSS Journal of Artificial Societies and Social Simulation (online)*
- *SSCR Social Science Computer Review (Sage)*

Social Network Analysis

Additional Material

Graph Theory Primer - I

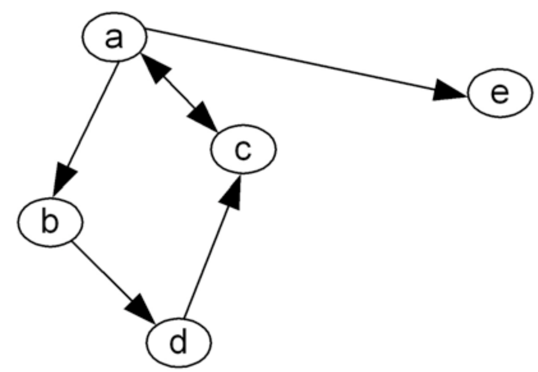
- **Social network data consists of binary social relations, of which there are many kinds (role-based, affective, cognitive, flows, etc.)**
  - Mathematically, social networks can be represented as graphs or matrices.
- **A *graph* is defined as a set of nodes and a set of lines that connect the nodes, written mathematically as G=(V,E) or G(V,E).**
- **The *nodes* in a graph represent persons (or animals, organizations, cities, countries, etc) and the *edges* (lines) represent relationships among them.**
  - The line between persons a and b is represented mathematically like this: (a,b).
  - The graph here contains these edges: (a,b), (a,e), (b,d), (a,c), and (d,c).
  - A *subgraph* of a graph is a subset of its points together with all the lines connecting members of the subset. (subgraph = {a, b,c,d})

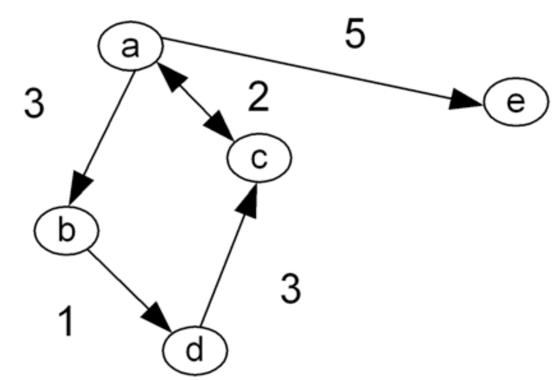


- **The degree of a point is defined as the number of lines incident upon that node. degree(a) = 3**

Graph Theory Primer - II

- If a node has degree 0 it is called an *isolate*.
- In a *directed graph*, the edges have direction (indicated by arrow heads)
- If a line connects two points, they are said to be "*adjacent*".
- The two points connected by a line are called *endpoints*.
  - An edge that originates or terminates at a given point is "*incident*" upon that point.
  - Two edges that share a point are also said to be *incident*.
- A *weighted graph* has values assigned to the edges.





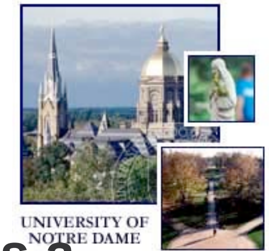
Graph Theory Primer - III

- **In a directed graph, a point has both indegree and outdegree:**
  - The *outdegree* is the number of arcs from that point to other points.
  - The *indegree* is the number of arcs coming in to the point from other points.
- **A *path* is an alternating sequence of points and lines, beginning at a point and ending at a point, and which does not visit any point more than once.**
  - Two paths are point-disjoint if they don't share any nodes.
  - Two paths are edge-disjoint if they don't share any edges.
  - A walk is a path with no restriction on the number of times a point can be visited.
  - A cycle is a path except that it starts and ends at the same point.
  - The *length of a path* is defined as the number of edges in it.
  - The shortest path between two points is called a *geodesic*.

SNA: Centrality

- **Centrality:**
  - A stratification measure
  - How to measure "power"
- **Does success depend on local or distal connections?**
- **Does success depend on the power/centrality of other actors/vertices to which a focal vertex is connected?**
- **Do resources “flow through” intermediary nodes, so that indirect relationships become proxies for direct ones?**
- **Or is centrality more in the way of an indicator of exchange opportunities/bargaining power?**
- **What are the “rules of the game” as regards the activation of multiple relationships?**

SNA: Centrality



- ***Degree Centrality*: number of distinct relationships or links a node has**
  - $C_D(i) = \Sigma x_{ij}; j = 1,N$ and $i /= j$
  - $\underline{C_D(i)} = C_D(i)/(N-1)$ normalized value
  - Differentiate by "in" and "out" connections based on which way power & influence flow
- ***Betweenness Centrality*: measures control or broker ability of a node**
  - Assume this "process" is efficient because it occurs along geodesic paths
  - Maximum "betweenness" is for an intermediary node in a star network
- ***Closeness*: who can reach others via few intermediaries are relatively independent/autonomous of others**
  - Intermediaries serve as attenuators and filters

SNA: Centrality

- **"Eigenvector" centrality:**
  - There exist multiple central nodes in the network
  - The centrality of a vertex depends on having strong ties to other central vertices
  - "Status" rises through strong affiliations with high-status others
  - Compute: $e_i = f(\Sigma\ r_{ij}e_j;\ j = 1, N)$ where e_i is the eigenvector centrality measure and r_{ij} is the strength of the relationship between i and j (sometimes thought of as j's dependence on i)
- **What else can we measure?**
  - Lots of different measures
  - Weighted, directional graphs to measure "flow of influence"
  - Borgatti/Everett partition networks into "core" and "periphery" graphs connected by key nodes

SNA Websites

- International Network for Social Network Analysis http://www.insna.org/
- Valdis Krebs, http://www.orgnet.com/
- Analytic technologies, http://www.analytictech.com/
- Networks/Pajek, http://vlado.fmf.uni-lj.si/pub/networks/pajek/default.htm

Agent-Based Simulation

Additional Material

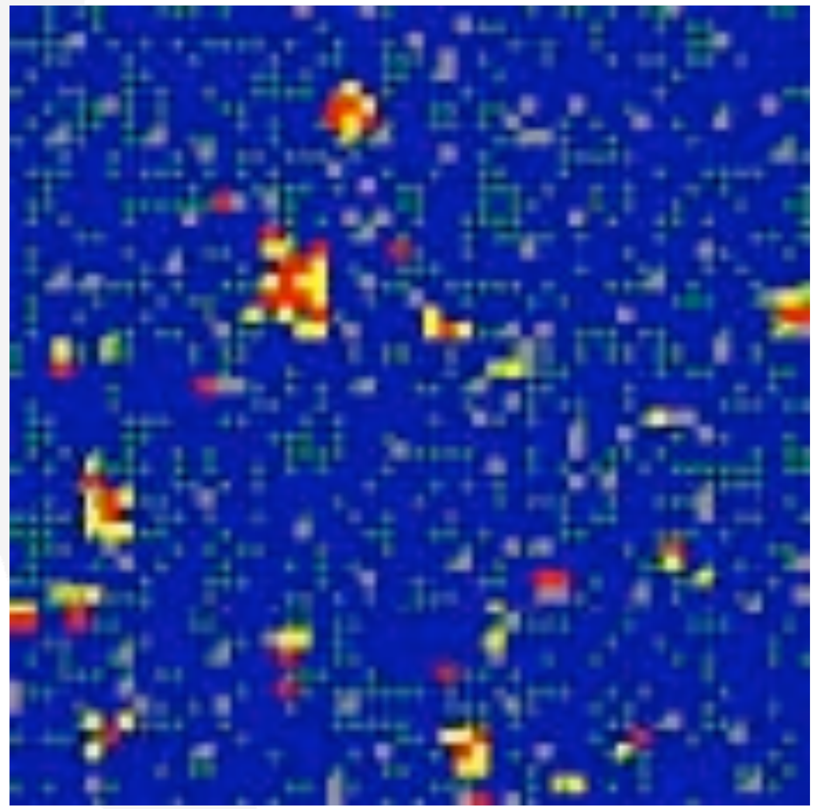
The MASON toolkit

- **MASON (Multi-Agent Simulator of Networks and Neighborhoods) is a**
  - general-purpose,
  - single-process,
  - discrete-event simulation library for building diverse multiagent models across
  - the social and computational sciences (AI, robotics),
  - ranging from 3D continuous models,
  - to social complexity networks,
  - to discretized foraging algorithms based on evolutionary computation (EC)

- **Design principles:**
  - *intersection* (not union) of needs
  - “additive” approach
  - divorced visualization
  - Checkpointing
  - EC

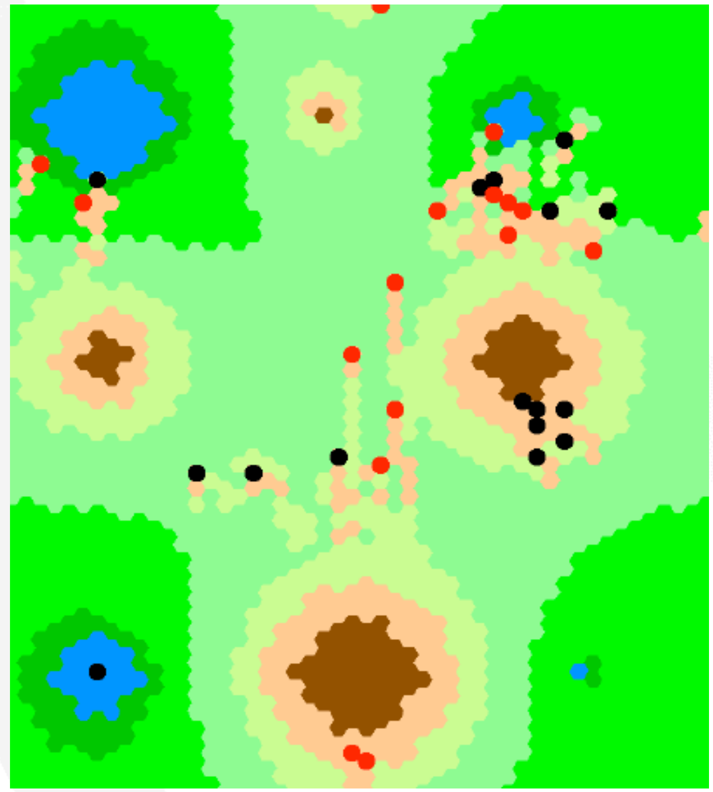
MASON Application Models

- **HeatBugs (MT)**
  - Classic, 3D, HexaBugs
- **Conway's Life**
- **Schelling's segregation**
- **Agent foraging**
  - Static & moving food
- **Virals**
  - Anthrax, cybersecurity
- **Wetlands**
  - Agent 05, CollInt IV



MASON “Wetlands” Model

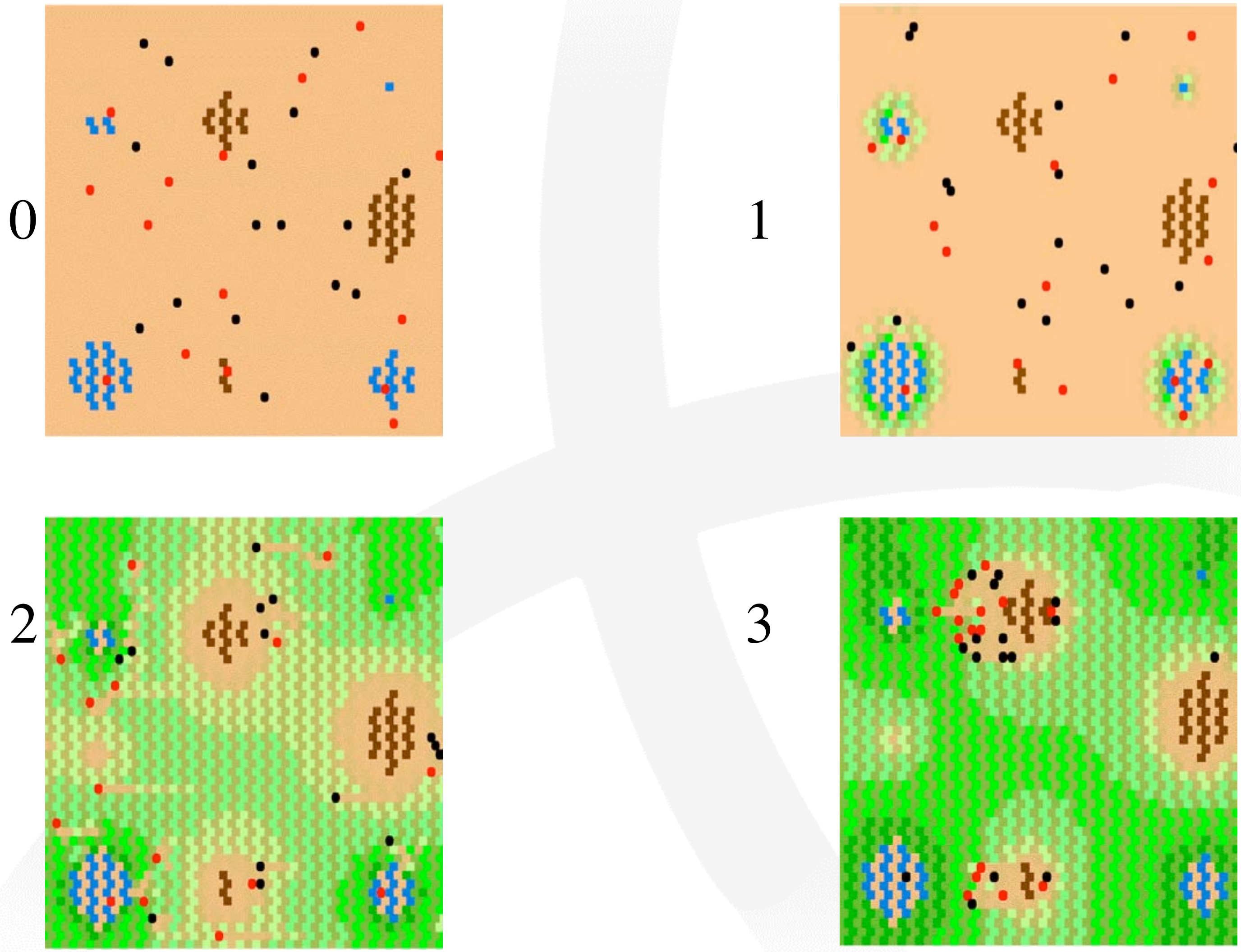
- **STATICS (“ontology”):**
  - Artificial world classes
    - Group-level social agents
    - Physical environment
  - Physical environment *layers*
    - Landscape of hex cells
      - Food distribution (green)
      - Shelter sites (brown)
    - Weather (rain)
    - Real world: simple ecotope
  - Heterogeneous social agents
    - Groups, not individuals
    - Two cultures: Atis (red) and Etis (black) each *with same social memory structure.*



MASON "Wetlands"

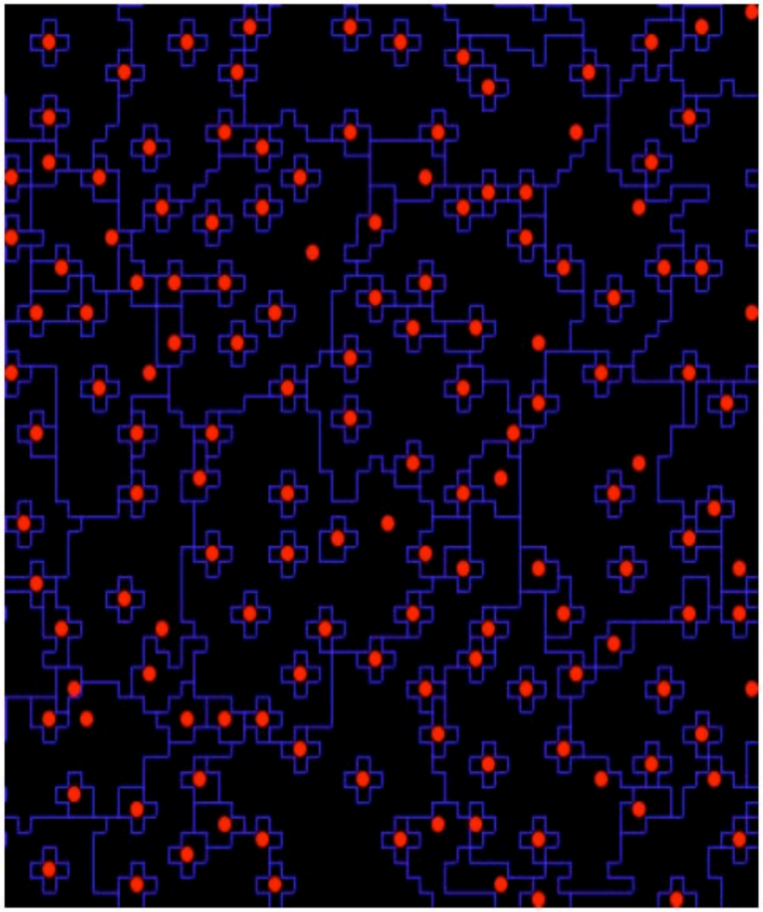
- **DYNAMICS:**
  1. Rain (blue) occurs constantly, causing food (green) to grow.
  2. Agents move seeking food, which consumes energy and makes them wet.
  3. IF an agent gets too wet it will seek shelter (brown sites) until dry enough to go out to eat again again.
  4. Agents share information (or "mind-read"?) on food and shelter location *only* with agents of same culture that they encounter nearby.
  5. There is *no* rule to behave collectively.

Observed Wetlands regimes



Examples of MASON models (open-source)

InterHex.MASON
- Model of an international system with incomplete knowledge and (eventually) EC



***Modeling tools are only as good as what they can actually model (Kline's thesis)*: What ABMs Simulators (Swarm, Ascape, RePast, MASON et al.) can model:**

- Climate
- 2D and 3D environments and neighborhoods
- Decision-making
- Memory
- Deception
- Leadership
- Strategic choice
- Trade
- Accumulation of wealth
- Networks
- Flocking
- Migration
- Foraging
- Agriculture
- Land-use patterns
- Warfare
- International war
- Peacekeeping
- Civil violence
- Colonization
- Urbanization
- Alliance dynamics
- Collective action