Synthetic Environment for Analysis and Simulation

Towards theory-based Synthetic Environment for Computational Experimentation

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I am believer!!
Most models are right!!
Data is not the problem!!
Explosions rock central Baghdad, Police say
10 killed, 22 wounded in three blasts at sunset

BAGHDAD, Iraq (CNN) -- Three explosions near two hotels housing international journalists and contractors rocked Iraq's capital at sunset Monday, killing 10 people and wounding 22, Baghdad emergency police said.

Police said the three blasts were caused by suicide bombers using two car bombs and a cement truck, but journalists in one of the hotels said the first two explosions were rockets, followed by a car bomb. A statement from the coalition press office said the explosions were a combination of rockets and car bombs and that no coalition forces were injured.

Three bombers have staged a coordinated attack on a Baghdad hotel complex used by foreign journalists, killing at least 17 people and ending a lull in violence in front of the world's media. ... it exploded beside a US Bradley armoured vehicle on guard duty. ... The explosions were captured in television footage by cameras trained on the area after the first blast and perfectly placed for subsequent detonations. ... Two Sunni Arab provinces have returned resounding no votes on the charter.
Modeling Approach (Insurgency Example)

**Current Observations**
- Minority group activism
- Orgs involved
- Use of weapons
- Level of violence
- Impact on public opinion
- …

**Historical Observations**
- Minority group deprivation
- Expectations/outcome gap
- Org affect on perception
- Natural resources and conflict
- …

**How to model?**

**Published Data**
- Data Source 1
- Data Source 2
- …

**Theory**
- Deprivation
- Org Mobilization
- Rebel-greed
- Intl Linkages
- …

Combine when modeling

**Insurgency Model**

- Aggressor
- Defense

- Hypothesis 1
- Hypothesis 2
- …

**Synthetic Data**

- Vulnerability Index ???

**Validate synthetic results against observation**
Macro to Micro Challenge

Using Macro Level Theories to simulate Micro Level behavior leads to a lack of richness in diversity.

Micro to Macro Challenge

Using Micro Level Theories to make Macro Level observations leads to a gap in reality.
Issues in Computational Experimentation..

- High fidelity computational experimentation requires deep understanding of:
  - The underlying Science -- physical, social, computational, life sciences, humanities
  - The computational models
    - Mathematical equations
    - Equation free
    - Differential equations vs Difference equations
    - Baseball or basketball
  - Representation paradigms -- Common (?) Uniform (?) Diverse (?)
  - Presentations -- digital art (?) semantics (?) ontology (?) storytelling (?) entertaining (appeals to emotions)
  - Platform HPC (?) Peer-2-Peer (Xbox, PS 2/3, PDA)
  - Business models (?)
SEAS Modeling Approach

Bottom-up Approach

Advantages
- Validity of Emergent Behaviors
- Explanation at the individual behavior level
- Intervention at the individual level

Mathematical Models
- Validation
- Shapes of Curves

Nature does not Solve Equations

Actions

It all starts with an Agent

- An agent is defined by its:
  - Traits (demographics, nationalism, religion, etc.)
    - Social psychology
  - Sensors -- through media, social groups
    - Communications
  - Expectation and predisposition -- security, education, financial well-being, etc.
    - Hedonic psychology, economics
  - Perception -- to evaluate sensed information
    - Psychology, economics
  - Behaviors -- normal or transgressive
    - Sociology
  - Feeling and emotions -- normal or aroused
    - Psychology
  - Memory -- short term and long term
    - Computational neuroscience
Well-being

- WB is the cognitive process of evaluation of an individual's life or with the experience of emotions
- Understanding the individual within her/his socio-environmental context
- It is an integrative theory of human functioning

Diener, Suh, Lucas, & Smith, 1999; Kahneman, Diener, & Schwarz, 1999

Maintained Changes in Well being

Sheldon and Lyubomirsky, in Positive Psychology in Practice, 2004
Media Agenda Setting

Perception Filter
- Increasing coalition strength for Red
- Increasing coalition strength for Blue
- Red (D-) to COI
- Red (E-) to COI
- Red (D+ M+ E+) to COI
- Blue (D+ M+ E+) to Red
- Blue (D- M- E-) to Red
- Blue (D- M- E-) to COI
- Blue (D+ M+ E+) to COI

Issue Desires
- Political Stability
- Military Strength
- Economic Stability
- Social Stability

Infra Status
- Information Avail

Status of Media Infrastructure
- Government
- Censorship

Events
- Increasing coalition strength for Red
- Increasing coalition strength for Blue
- Red (D-) to COI
- Red (E-) to COI
- Red (D+ M+ E+) to COI
- Blue (D+ M+ E+) to Red
- Blue (D- M- E-) to Red
- Blue (D- M- E-) to COI
- Blue (D+ M+ E+) to COI

Issues
- DImE Agenda
- PMESII Agenda

Media Effect on Emotions

Response Intensity
- Denormalization in Positive Valance
- Media Tone

Sensitization to Negative Valance

Valence

Pro Government
Neutral
Anti-Government
Model Development Process

1. Requirements and Data
   - Scenario Definition
   - System Nodes
   - Action Sets

2. Theory and Research
   - Scenario-Specific Research
   - Documentation of WA Sources

3. Model Development
   - Translation of Theory to Model
   - Technical Requirements Definition
   - Integrate customer action sets and system nodes

4. Validation
   - Verification
   - Accreditation

5. Model Calibration
   - Iterative Process
   - Input Simulation Data
   - Run Model Tests
   - Evaluate Output Sets
   - Make Modifications

6. Model Implementation
   - Integration of Model and SEAS Engine

V&V Toolset – Model Bull Pen

- Place a model within a “canned” environment and test behavior
- Test correctness of implementation (verification)
- Ability to fix random seed
- Semantics are very important
  - Initial Conditions
  - Range of inputs
- Tools Required
  - Bull Pen configuration loader
  - Bull Pen driver
  - Data Collector
  - Data Visualizer
  - Statistical Analyzer

Analysis mode vs Wargame mode
V&V Toolset – Model Bull Pen

Custom scenario parsed from XML and constructed in run-time

Driver runs Scenario

Visualize scenario outputs

SEAS
VIS, NRT, and SimBridge
SEAS Virtual International System

Synthetic Environments for Analysis and Simulation (SEAS) is a Computational Experimentation Environment that is:

- Theoretically validated, behaviorally accurate, light weight virtual agents for detailed oriented behaviors
- Allows human in the loop experimentation for strategic interaction
- Detailed environment modeling for accurate interaction and situational context
- Emergent agent-environment interaction

.. By creating a synthetic environment consisting of nodes* from the Real World..

Nodes
- Citizen
- Organizations
- Institutions
- Infrastructure
- Media
- Governments

Theories
Open Source
Client's Databases:
- Historical
- Live
- Synthetic

Multiple Perspectives

*Any object of interest -- contains traits, behavior..
SEAS-VIS 2006 Capabilities
Multi-layer, Multi-Granularity, Effects Based

SEAS VIS is a representation of 40 countries with "validated" models (well accepted, published in peer-reviewed journals)

Represents
• Political Nodes
• Military Nodes
• Economic Nodes
• Social Nodes
• Information
• Infrastructure

• 100+ Named Organizations
• 150+ Named Leaders
• 1200+ Named Infrastructure Nodes
• 500+ Named media nodes

12 Million Active Agents

Rapidly Configurable Nodes, Emergent Network

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**PMESII: Political**

### Highlights
- Individual objectives of entities
- Objectives are dynamic
- Objectives might converge or diverge as the scenario unfolds
- Emergence of various alliances based on objectives

### Some Indicators
- **Institutionalization**
  - Regime durability
  - Fractionalization
  - Legitimacy
  - Bureaucratic quality
  - Regime’s responsiveness
- **Democratization**
  - Political and civil liberties
  - Freedom of the press

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**PMESII: Political**

### N-sided pre-conflict shaping
- Blue’s Strategic Objective
  - Regional
    - Prevent destabilization of countries
  - Country of Interest
    - Prevent state failure
    - Prosecute GWOT
    - Prevent spread of WMD
- Green’s Strategic Objectives
  - Maintain territorial Integrity
  - Restore order
  - Restore Effective Governance
- Red’s Strategic Objectives
  - Gain popular support
  - Gain international recognition
- CX and Organization Objectives
- Individual Objectives

### Some Indicators
- Dependence
- Border disputes
- Resource disputes
- Terrorism
- Trade restrictions
**PMESII: Military**

**Highlights**
- Military Institutions, Leaders and Infrastructure as distinct entities
- Soldiers and other combatants as extension to citizens
- Strategic Will to Fight modeled at Institution Level
- Operation Will to Fight modeled at Organization Level
- Tactical Will to Fight modeled at Soldier Level

**Some Indicators**
- Degree of political control over military organizations
- Nature of populations support for the military factions
- Scope of violence against the civilian population

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**PMESII: Economy/Infrastructure**

**Salient Features:**
- Conformity with economic theory
- Demand driven
- Bilateral trade
  - Close/open economy
  - Greater international dependence
- Black market effects
- Greater government influence
- Realistic monetary values for all components
- Adaptive and emergent

The new SEAS-VIS synthetic economy
PMESII: Society

Highlights
• Emergent social networks
  • Religious, Ethnic and other
  • Strength of each network changes
  • Networks are information sources
• Social and Religious Organizations
• Ethnic and Religious Unrest
• Terrorism Propagation

Some Indicators
• Wealth distribution
• Ethnic Identity
• Extremism
• Xenophobia
• Nationalism
• Terrorism

PMESII: Information

Multiple Sources of Information
• Organizations
• Media
• Social Network
• Leaders
• Direct sensing

Perception and Agenda Setting
• Entities perceives information based on certain preconceptions
• Entities report information in the agenda setting model based on individual objectives
Courses of Action Analysis

Effects Based Operation

- **E**: Observe the achievement level of each Effect over the past 10 days
- **N**: Select node to act upon to increase the achievement of an effect
- **A**: Select one or more actions to impose on the node to achieve this effect
- **R**: Set the amount of resources to utilize for this action over 10 day period
Dynamic Ontology Development - N-sided view

- Effect’s trend over time
- Estimated contribution of Top 10 action/node combinations on the Effect
- Effect under Investigation

Shared Reality Model:

- Shared Reality Engine
- Red Actions
- Blue Actions
- Green Actions
- CX Actions
3-D models for buildings and City blocks
Developing algorithms for agents to navigate through building and city blocks

A* Algorithm

Artificial Physics Algorithm

Capitol Building Evacuation
Capitol Building Evacuation

Mixed Reality for Concept Development, Testing, Training -- Real Muscatatuck Building virtual placed On Purdue Campus
Theories: Can we observe them?

- **Deprivation Theory**: examines the range of discriminations and disparities that is experienced by minority groups as contributing factors of rebellion inequity (Gurr 1970, 2000; Schmid 1983; Harmon 2000; Krueger and Maleckova 2002; Duckitt et al. 2002; Post, Sprinzak and Denny 2003; Besancon 2005)

- **Rebel-Resource Theory**: states that depended extensively on natural resources for capital generations were more prone to civil violence (Collier and Hoeffler 2004; Fearon 2004; Weinstein 2005; Regan and Norton 2005; Humphreys 2005; Lujala et al. 2005)

- **Organizational Mobilization Theory**: action and activism is a result of the mobilizational capacity of groups and organizations. (Tilly 1978; Tarrow 1994; Lichbach 1998).

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Data Source (examples)

- **Groups and Conflict**
  - http://garnet.acns.fsu.edu/~whmoore/M@R.HTM
  - http://news.bbc.co.uk/2/hi/asia-pacific/3391689.stm
  - http://news.bbc.co.uk/1/hi/australia/9937499.stm
  - http://news.bbc.co.uk/1/hi/world/australia_pacific/3815909.stm
  - http://news.bbc.co.uk/2/hi/australia_pacific/3815909.stm
  - http://www.internationalviewpoint.org/article.php3?id_article=321

- **Political Systems/ Regime Type**
  - Polity IV data set
    - http://garnet.acns.fsu.edu/~phensel/polity4.html
    - http://garnet.acns.fsu.edu/~phensel/itlpoll.html

- **Political and Civil Liberties**
  - Freedom of the Press 2005: Draft Country Reports
    - www.freedomhouse.org

- **Ethnic, Linguistic, and Religious Minorities**
  - http://garnet.acns.fsu.edu/~phensel/data.html
  - Minorities at Risk
    - http://garnet.acns.fsu.edu/~whmoore/M@R.HTM
    - http://www.joshuaproject.net/peoptry.php
Demographics

Citizens

- Religion
  - Shia
  - Sunni
  - Other

- Ethnicity
  - Javanese
  - Acehnese
  - Sundanese
  - Batak
  - Minangakabau
  - Banjarese
  - Bantanese
  - Madurese
  - Buginese
  - Betawi
  - Chinese
  - Malay
  - Other

- Income
- Public Opinion
- Well Being

Income Distribution
- Rich
- Middle
- Poor

Basic Needs
- Health
- Education
- Financial
- Political
- Social
- Religious
- Security
- FOM

Population
Indonesia – 240 million

“Named” Leaders/Organizations

Indonesia
- Yusuf Kalla (VP)
- Megawati Sukarnoputri
- Hamzah Haz
- Husan di Tiro
- Hashim Mujadi
- Amien Rais
- Abu Bakar Bashiyir
  (Leader of MMI)
- Susilo Yudhoyono (P)

Indonesia
- Golkar
- PDI P
- PPP
- GAM
- NU
- Muhamadiya
- Jemmah Islamiyah
- MMI
- Democrat Party

Leaders

Orgs

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Media/Economic Sectors

Indonesia
Jakarta Post
Indonesia Times
Jaringan Islam Liberal
Sinar Harapan
Voice of Islam
Radio Republik Indonesia
Televisi Republik Indonesia

Oil
Gas
Power
Education
Financial Services
Agriculture
Water
Manufacturing
Military Industrial
Transportation
Telecommunication
Government Services
Labor
Capital

Media

Sector

Broadcast Capability
Opinion
Agenda

Infrastructure

Schematic of a VIS Configuration

TARGET ACTION AT SPECIFIC NODES

GOVERNMENT

MEDIA

Newswire
Red Spin
Blue Spin

Actions

Node

Node

Node

Node

ORGANIZATIONS

Citizen

MEDIA

Newswire
Red Spin
Blue Spin

Actions

Node

Node

Node

LEADERS

Status/Operational Level

Roads and Bridges
Communication Lines
Oil and Gas
Sea Ports
Financial
Public Utilities
Health Services
Security

Node

Node

Node

Node
Insurgency Indicator

- Insurgency Indicator, \( S = \frac{\text{total number of mobilized citizens}}{\text{total population}} \)
- Intention to Rebel, \( I = f \{\text{grievance, risk propensity}\} \)
- Grievance, \( G = f \{\text{subjective well-being; legitimacy}\} \)
- Subjective Well-being, \( W = f \{\text{basic needs, political needs, financial needs, security needs, religious needs, educational needs, health needs, and freedom of movement needs}\} \)
- Legitimacy, \( L = f \{\text{Government actions; media, organization & leader attitudes}\} \)
- Risk Propensity, \( R = f \{\text{media, organization & leader actions}\} \)

Scenario

A. Pre-Tsunami: Calibrate experimental scenario for Aceh, Indonesia
   - pre-existing active secessionist movement led by GAM and its leader Hasan Di Tiro
B. Immediate aftermath of Tsunami: Insert our best approximation of response to the calamity by the local government and the international community
C. Post-Tsunami Recovery: Local Government and International Aid
D. Intermediate aftermath of Tsunami: Indonesian Government actions
E. Local Government permits greater freedom to citizen and media while interdicting organizations
F. Prediction of the outcome of government policies on insurgency indicator.
Media, Organizations’, & Leaders’ Attitude

Region B

Region C + D

Region E + F

Media

Organizations

Leaders

Attitude towards Government
Attitude towards the Rebel

SEAS Summary

- Robust, scalable, extensible engine to support a variety of experimentation domains
- Persistent experimentation environment
- Repository of organizational memories through play books
- Plurality of thoughts
- An approach to bridge micro-macro divide
- Complete transparency of data, algorithms, and assumptions
- User configurable and extensible
- Multiple courses of action analysis with time travel capability