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Validation of an Agent-Based Civil Violence Model

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Validation of an Agent-based Civil Violence Model

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• Validation: ascertains whether or not a model represents and correctly reproduces behaviors of the intended real-world system

• Required by some agencies

• Agent-based model (ABM) validation:
  – Is the process of ABM validation different than that for any other model?
  – Defense-related validation work:
    • Appleget, et.al, “Irregular Warfare Model Validation Best Practices Guide”
    • USMC “Agent-Based Simulation Verification, Validation, and Accreditation Framework Study”
Model Validation

Conceptual Validation
• Establishes credibility of model
  – Underlying theories
  – Structure, logic
  – Sufficiently accurate for intended purpose
  – Includes submodel(s)
• Must be well-documented

Operational Validation
• Establishes that output behavior has accuracy required for model’s intended purpose

• Techniques vary – depend on system of interest (observable) and approach (subjective/objective); include statistical comparison, face validation (SME), docking, etc.
Agent-Based Model Validation

Conceptual Validation

- Establishes credibility of model
  - Underlying theories
  - Structure, logic
  - Sufficiently accurate for intended purpose
  - Includes submodel(s)
- Must be well-documented
- Must include the rules by which agents behave & operate

Operational Validation

- Establishes that output behavior has accuracy required for model’s intended purpose
- Techniques vary – depend on system of interest (observable) and approach (subjective/objective); include statistical comparison, face validation (SME), docking, etc.
• Dynamic interaction between competing sides over contested political space.

• Theories include
  – Leites & Wolf, “Rebellion and Authority: An analytic essay on insurgent conflicts” (Insurgency analyzed as a system)
  – Kuran, “Sparks and prairie fires: A theory of unanticipated political revolution” (Preference Falsification)
  – McCormick, “Revolutionary origins and conditional mobilization” (Expected Cost)
  – Epstein, “Modeling civil violence: An agent-based computational approach” (Legitimacy, Hardship, Repression)
Two Conceptual Models

• Epstein’s Civil Violence agent-based model (ABM) implementation, with extensions
  – A member of the general population considers grievance, government (il-) legitimacy, “momentum”, risk aversion in the determination of whether or not to rebel

• S-I-R-S Ordinary Differential Equation (ODE) model
  – Likens insurgency spread to that of an infectious disease
Civil Violence Model Agent Specification

- Members of fixed (no births/deaths) population may be:
  - Inactive (not rebelling)
  - Actively rebelling
  - Jailed
  - Moving (randomly) to open space (Moore neighborhood) within “vision”
  - At end of jail term, agents return to population as inactive

- Political grievance a function of hardship and regime illegitimacy

- Agents decide to rebel based on:
  - Risk aversion
  - Hardship
  - Government illegitimacy
  - Arrest probability
  - Some threshold value

Two Types of Agents
State (“Cop”)
General Population
• Number of state agents ("cops") specified and fixed
• Move randomly (Moore neighborhood)
• Can arrest active agents within some "vision" radius
  – Arrested agent’s jail time is random, up to some max
  – Jailed agent location frozen
  – Freed agent re-enters as inactive agent
Agent Rules

- If \((G - N) > T\), become active (join rebellion); otherwise remain inactive.
  - \(G = H(1 - L)\)
  - \(N = R(1 - \exp[-k(C/A)\nu])\)
  - \(H\) and \(R\) are assigned from \(U[0, 1]\)
  - \(T\) is a threshold value, \(\nu\) is the agent “vision” radius, and \(k\) is a constant, each user prescribed

- Cop arrest rule: each turn, arrest one active agent chosen randomly from those within cop “vision” radius
Many published works consider insurgency growth as the spread of an infectious disease

- Inactive - or Susceptible (S) - agents interact and can become part of insurgency, thereby Infected (I)
- Infected agents can be Removed (R); e.g. jail
- After serving jail term, agents revert back to Susceptible
- Insurgency spreads from S to I to R, then back to S
- Assume fixed population (no births, deaths)

Yields a system of ordinary differential equations (ODEs)
\[
\frac{dS}{dt} = -\beta SI + \nu R \\
\frac{dI}{dt} = \beta SI - \gamma I \\
\frac{dR}{dt} = \gamma I - \nu R
\]

With initial conditions:
\[S(0) = S_0; \quad I(0) = 1; \quad R(0) = 0\]
Solution Trajectories

Stable equilibrium condition in first quadrant (only meaningful quadrant)

Implications

– Revolutionary ideas persist
– Herd immunity can be achieved due to indoctrination/repression
Solution Trajectories

Slight oscillation, equilibrium conditions attained

- Susceptible Population
- Currently Arrested
- Actively Rebelling

Graph with lines indicating trajectory changes over time.
Civil Violence ABM Implementation

NETLOGO implementation (Initial Setup)

User Interface Screen
NETLOGO implementation (65 Time Steps)
Slight oscillation, equilibrium conditions attained
Civil Violence ABM & S-I-R-S Model Result

“Docking” results of two models is a means toward establishing operational validity.
Additional ABM Results

ABM results
- not attainable from the ODE model
- observed behavior - riots

Punctuated Equilibrium
ABM results

- not attainable from the ODE model
- observed behavior - revolutionary war

Agent vision 10
Cop vision 1

Average active agents ≈ 6
"Sparks and Prairie Fires"

A Spark set off a sudden rebellion

Equilibrium shift = Revolution!

New equilibrium: average active Agents ≈ 120

Mechanism: Threshold is a function Of agent vision radius
Further establishing operational (face) validity

“When Do Institutions Suddenly Collapse? Zones of Knowledge and the Likelihood of Political Cascades”

– Ian Lustick, Dan Miodownik

• Considers “zones of knowledge”, small worlds (flash mobs)
• Neighborhood size – akin to “vision” radius
• Cascades and threshold behaviors related
Further establishing operational (statistical) validity

“Empirical Performance of a Decentralized Civil Violence Model”
– Klemens, Epstein, Hammond, Raifman

• Examines Hardship, Legitimacy, Repression
• Draws from Political Instability Task Force data set
• Findings:
  - model’s explanatory power supported at high significance
  - results robust across a variety of statistical instruments
• Stressing other insurgency theories through ABM implementation.
  – Kuran: agent preference falsification
  – McCormick: effect of insurgent violence on agent expectation
• Validation ‘best practices’
Questions?
Comments?