Complex Systems Approaches for Better Understanding Of Health Behavior And Outcomes

Policy impacts on individual behavior and population health

Potential emergent system states (e.g., smoking prevalence, obesity) due to individual behavior and influences (incentives, warnings, education, ads)

SnapDragon for near-term policy effects

Population dynamic models (agent-based/dynamical systems) for population health impacts

SnapDragon uses software agents to represent a population of individuals with an initial Opinion and a Tolerance

At each time step, agents adjust their opinion based on opinions of neighboring agents, messaging and their own tolerance

Agent behavior is a function of their opinion

Population dynamics model: agent-based version simulates life span and health states for individuals (more than 300M agents for U.S.), and dynamical systems version simulates mean behavior of aggregate sub-populations by various demographics combinations (more than 1M sub-populations for U.S.)

- demographics of the entire U.S. population (by age, gender, and smoking status)
- health behavior (e.g., smoking, quit smoking, dual use)
- births, immigration, and deaths
- health state

SUMMARY

- SnapDragon - near-term changes in health behavior due to interventions and innovations
- Population models - population health and mortality dynamics due to changes in population, behaviors and healthcare.
- Applied to tobacco control policy, healthcare planning, and obesity interventions
Rapid and Efficient Disaster Recovery

Sandia’s resilience modeling and analysis capabilities

- Leverage multidisciplinary foundation
- Provide quantitative basis for assessment and design
- Identify optimal recovery and adaptation strategies
- Inform cost-benefit decisions for resilience design and investment

SUMMARY

- Sandia’s infrastructure modeling capabilities enables performance-based resilience analysis.
- Sandia’s suite of capabilities enable quantitative, science-informed decision-making for resilience issues.

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Complex system's non-linear, emergent behaviors are difficult to predict and control.

Models that are similar in structure and behavior of complex systems are key to improving understanding and for experiments.

Multiple, competing theories can be modeled and compared.

Modeling for understanding can improve interventions.

No single test is sufficient for CS model validation.

SUMMARY

- Defense in depth required for models used to design policy
- CS models are most useful for exploring conditions that have not existed previously
- Validation provides bounded confidence

Model Validation Activities:
- Parameter assessment
- Model behavior assessment
  - Basic-behaviors reproduction
  - Endogenous behavior-reproduction
  - Boundary adequacy
  - Hypothesis testing
- Uncertainty analysis
  - Behavior sensitivity analysis
  - Policy sensitivity analysis
- Forecasting/Behavior prediction
- History matching
- Analog behavior matching
- Peer review
Rapid and Efficient Disaster Recovery

Exceptional service in the national interest

Individuals Interact in Multiple Social Networks

Modeling and analysis processes that account for the dynamics of human-technical-natural systems

- Explicitly represent and account for uncertainties
- Explicitly represent and account for risk reduction strategies
- Comparative analysis to identify solutions that are robust to uncertainty
- Decision maker confidence in the analysis and ability to implement the engineered solution
- Evaluation and improvement

Epidemiological Model (Modified SEIR)

- Transition Probabilities
  - \( p_D = 0.5 \)
  - \( p_I = 0.5 \)
  - \( p_M = 0 \)

- Infectious symptomatic
  - Mean duration 1.5 days
  - IR for first 0.5 day, then reduced to 0.375 for final day

- Infectious asymptomatic
  - Mean duration 2 days
  - IR 0.25

- Dead

SUMMARY

- The best-performing intervention strategies include school closure early in the outbreak
- Child and teen social distancing is the next most important component (with school closure it reduces mean to 124 cases and the standard deviation to 14)
Water and energy are critical and interdependent resources. Their availability directly or indirectly touches every other sector. Managing these resources requires understanding the dynamics, uncertainty, and complexity.

**SUMMARY**

- CS approach represents dynamics of climate, population, economics, policy, and other events.
- Explicit representation of uncertainty and decision feedback are key.
- Used to assess:
  - Water stress impact on power generation and transmission expansion
  - Near-term risk of climate uncertainty
  - Conflicting and competing interests and values and compromises
  - Risk mitigation options and system resiliency