Gryphon: A Hybrid Agent-Based Modeling and Simulation Platform for Infectious Diseases

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Quantum Leap Innovations
Agenda

- Overview of infectious disease modeling
- Gryphon modeling and simulation technologies
- Validation studies
- Conclusion
Overview of Infectious Disease Modeling

• Compartmental models by sets of differential equations
  – Susceptible-infectious-recovered (SIR) or susceptible-exposed-infectious-recovered (SEIR) models

Examples:
FluAid, FluSurge (CDC, Atlanta, GA)
DoDIM (QLHS)
Overview of Infectious Disease Modeling

• Highly complex individual-based models
  – Represent daily activities and connections of individuals via transmission networks
  – Often resorts to supercomputers and makes it impractical for quick what-if analyses of interventions or treatments under different conditions.

Examples:

EpiSims (NIH/MIDAS, LANL, NM)
EpiCast (NIH/MIDAS, LANL, NM)
CIP-DSS (NIH/MIDAS, LANL, NM)
1. Compartmental models by sets of differential equations
2. Highly complex individual-based models
3. **Gryphon**: Hybrid agent-based modeling and Simulation
Hybrid Agent-Based Modeling

• Based on groups, not individuals
  – Behaviors of groups are modeled by rules (Behaviors)
  – Populations are decomposed into primary, secondary groups (Decomposition)

• Groups move among different locations and mix with each other at each location (Distribution)
  – The groups for mixing at a location are determined by the behaviors of different groups, not a migration matrix in Structured Population-SEIR (Mixing)
Benefits of a Top-Down Approach

- Multi-scale modeling and simulation
  - State, county, age groups (top-down approach)
  - The level of abstraction for each group can be configured
Benefits of a Top-Down Approach

- Real-time data-driven modeling & simulation
  - CDC surveillance data, e.g. ILNet (state → age groups)
  - Google FluTrend data (state → county)
Gryphon Platform Features

- **Situational Awareness**
- **Contingency Planning**
- **Common Operational Picture**

**Hybrid agent-based modeling**
- Rules/differential equations
- Continuous/discrete time
- Behaviors/interactions of agents

**Interactive what-if analysis**
- Enabling what-if analysis of interventions or treatments under different conditions

**Generalized visualization framework**
- 2D/3D GIS visualization
- Data analysis of multiple runs data over time
Success Stories of the Gryphon Platform

- Supported by ONR since 2007
- Cobra Gold’08 (PACOM), 2008 spring
- Cyclone Nargis in Myanmar (PACOM), 2008 summer
- Swine Flu (NORTHCOM and CDC), 2009 spring
- Multi-user multi-scale M&S platform (DE HHS), 2010 spring
Gryphon Application for Swine Flu

Disease Simulation for the US Northern Command Area of Responsibility
(USNORTHCOM AOR)

United States, Mexico, and Canada
Data and Methods for Validation Studies

• **Discrete time stochastic SEIR model for mixing**

• The timeline of SARS outbreak in Hong Kong and other Asian countries can be described as follows
  – February 15, 2003: Official report of a 33-year male and a 9 year old son in Hong Kong with Avian influenza (H5N1).
  – March 12, 2003: First global alert about atypical pneumonia in Vietnam and Hong Kong was issued by World Health Organization (WHO).
  – March 15, 2003: Second global alert about name of SARS and case definition was issued by WHO.

• The travel data sets are generated from the International Air Transport Association (IATA) (http://www.iata.org) database, which contains the number of available sets between any two given countries.

• The country data sets, including population, latitude and longitude for each country, are generated from the website (http://www.geonames.org).
The estimated pairwise value of $R_0$ for Hong Kong is consistent with Wallinga and Teunis’s work by assuming an exponential increase in the number of cases over time.

Wallinga, J., Teunis, P.: Different epidemic curves for severe acute respiratory syndrome reveal similar impacts of control measures. American Journal of Epidemiology 160(6) (2004) 509–516
Results for non-Local Transmission Dynamics

• The predicated total case number for non-local disease transmission is close to the one given in Hufnagel’s PNAS paper in 2004, in which Hufnagel et al. used a continuous-time stochastic SEIR model.

Hufnagel, L., Brockmann, D., Geisel, T.: Forecast and control of epidemics in a globalized world. PNAS 101(42) (2004) 14124–15129
Conclusion

Gryphon: A scalable, flexible and interactive simulation platform

Future Work

Optimization of pharmaceutical and non-pharmaceutical interventions for infectious diseases

Pharmaceutical interventions
– Allocation of Antiviral and Vaccines at state and county levels

Non-Pharmaceutical interventions
– Isolation, quarantine, and school closure
– Assessing the benefits of these strategies weighted against the cascading consequences that may arise from their use

Modeling complex and adaptive behaviors of populations