Modeling Influenza Pandemic Response Effectiveness in Canada

Zack Jacobson
ARAD Health
Canada

zack.jacobson@hc-sc.gc.ca

Ben Houston
Exocortex Technologies
Canada

ben@exocortex.org

1.0 INTRODUCTION

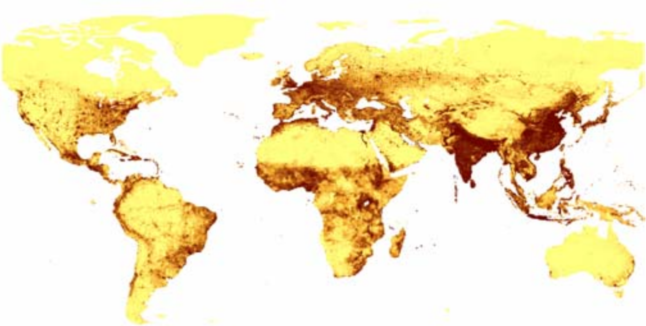
As the risk of a global influenza pandemic increases there is growing response preparedness efforts within Canada. One question that governmental decision makers have in this context is what is the most effective distribution of anti-virals, such as oral oseltamivir, within the population of first responders, health care workers, administrators and the general public in addition to what extent should the anti-virals be used as prophylactics. To provide an answer to this question, we have developed a Canada-wide influenza pandemic simulator and visualization system that allows for the modeling of various patterns of anti-viral distribution and use.

2.0 BACKGROUND

The seminal paper on modeling the effects anti-viral distribution and use in response to an influenza pandemic is that of [Ferguson *et. al.* 2005]. This paper focused on an indigenous outbreak of influenza from within Thailand and its eventual spread to neighboring countries within South East Asia.

We have presently presented a simple agent-based disease simulation model. This presentation represents the continued development of this on-going project.

3.0 ADAPTING TO CANADA



Unlike South East Asia, it is very unlikely that pandemic influenza will spontaneously develop internally. Rather, the entry into Canada of pandemic influenza is likely to occur at either Canada-US border crossings or at one of Canada's international airports. Also, unlike South East Asia, Canada has a different socioeconomic distribution, broader domestic travel routines in addition to having a significantly more geographically distributed population with relatively few major urban centers. These present modeling tasks not faced by [Ferguson *et. al.* 2005].

Jacobson, Z.; Houston, B. (2006) Modeling Influenza Pandemic Response Effectiveness in Canada. In *Visualising Network Information* (pp. 13-1 – 13-6). Meeting Proceedings RTO-MP-IST-063, Paper 13. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 DEC 2006	**N/A**	**-**

4. TITLE AND SUBTITLE	
Modeling Influenza Pandemic Response Effectiveness in Canada	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **ARAD Health Canada**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002067., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

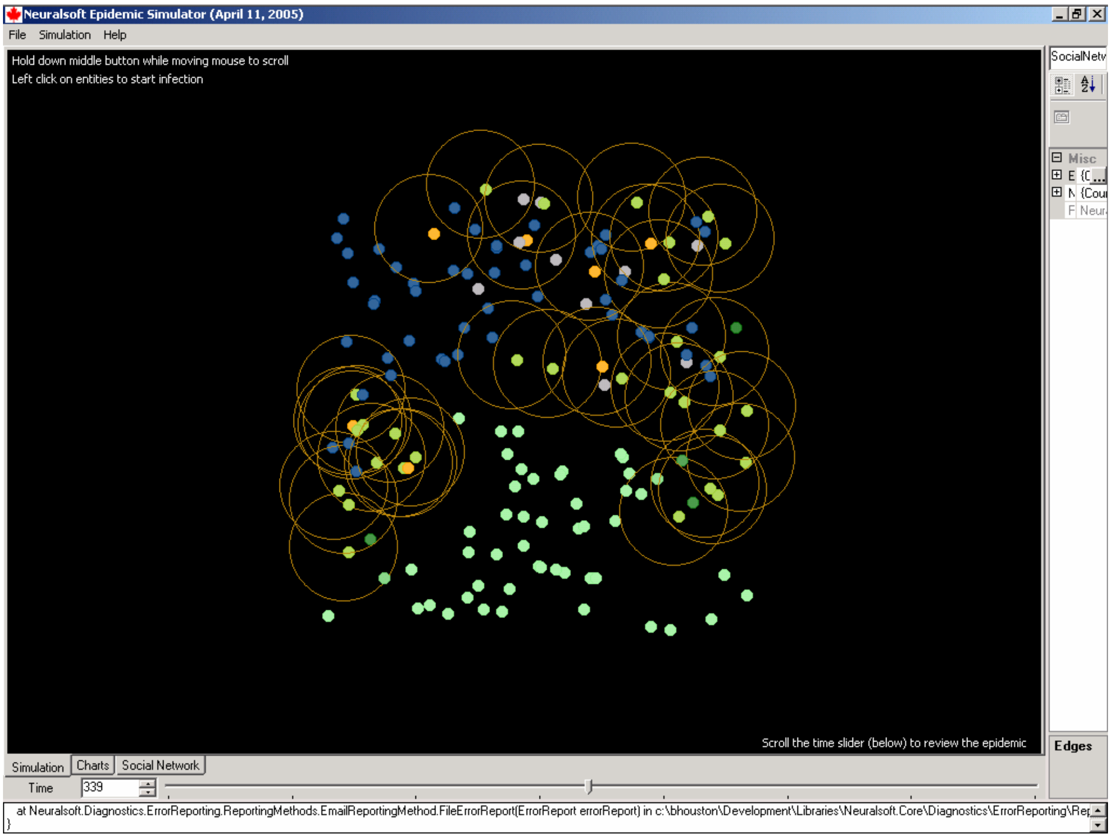
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**21**	

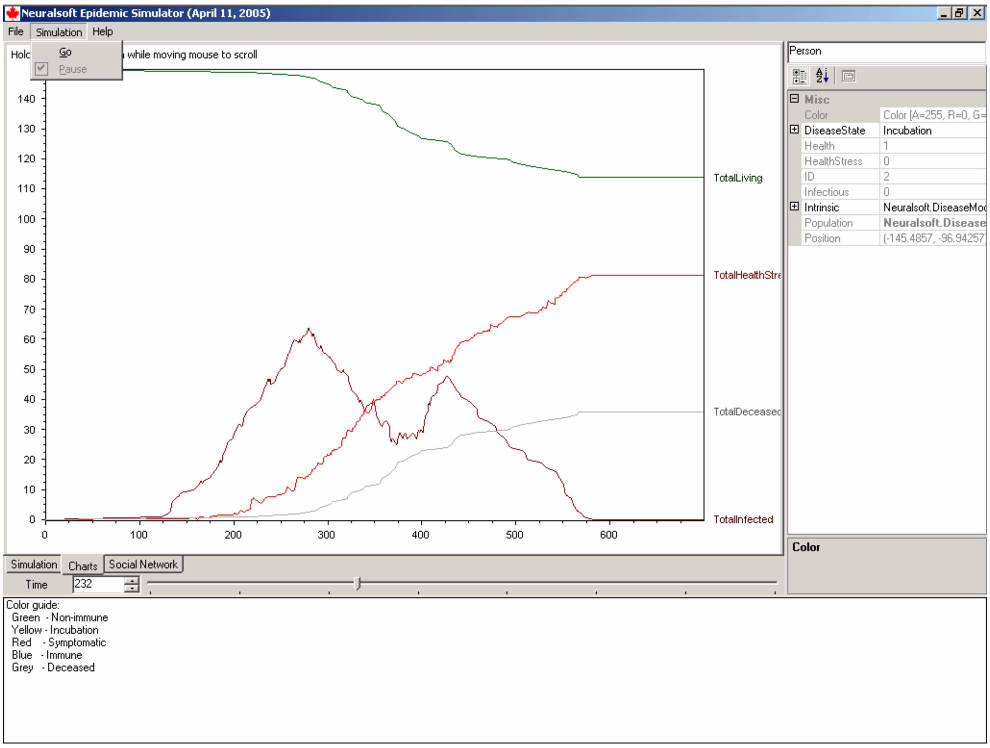
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

4.0 VISUALIZATION

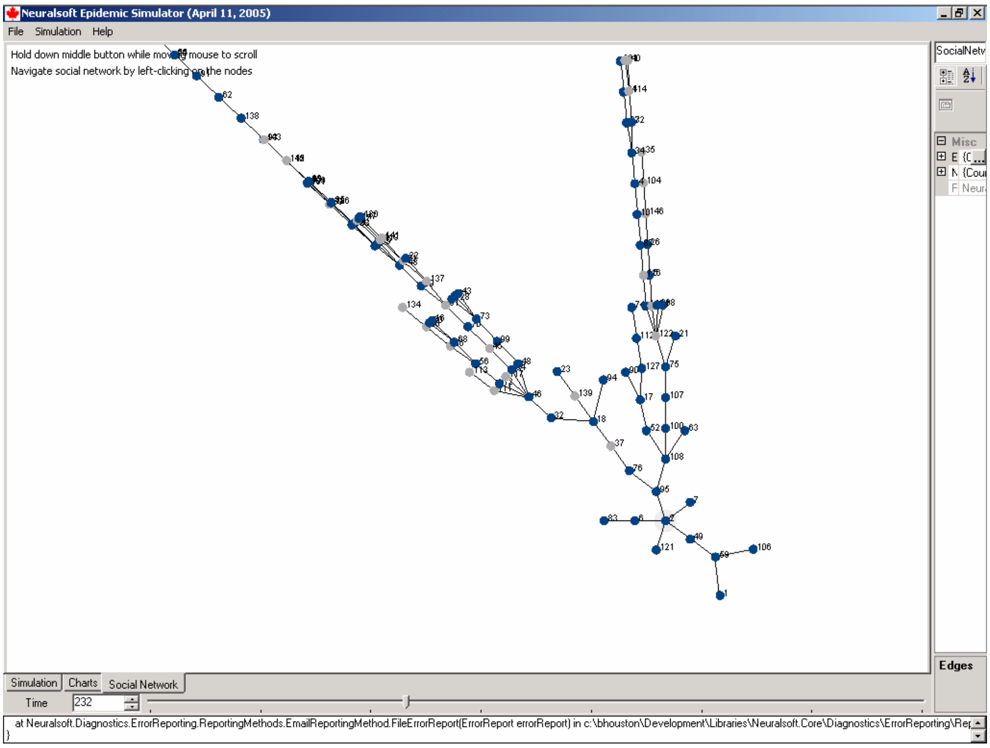
The end result of our simulation work is massive amounts of population, disease and response pattern data which represent the dynamics of the disease spread over time. We have developed a geographically-based visualization system that displays the incremental spread of the disease in tandem with the dynamic response in anti-viral usage and distribution.

Previous work showed a SARS-like disease outbreak on a featureless plane, the outbreak profile and the social network of infection:

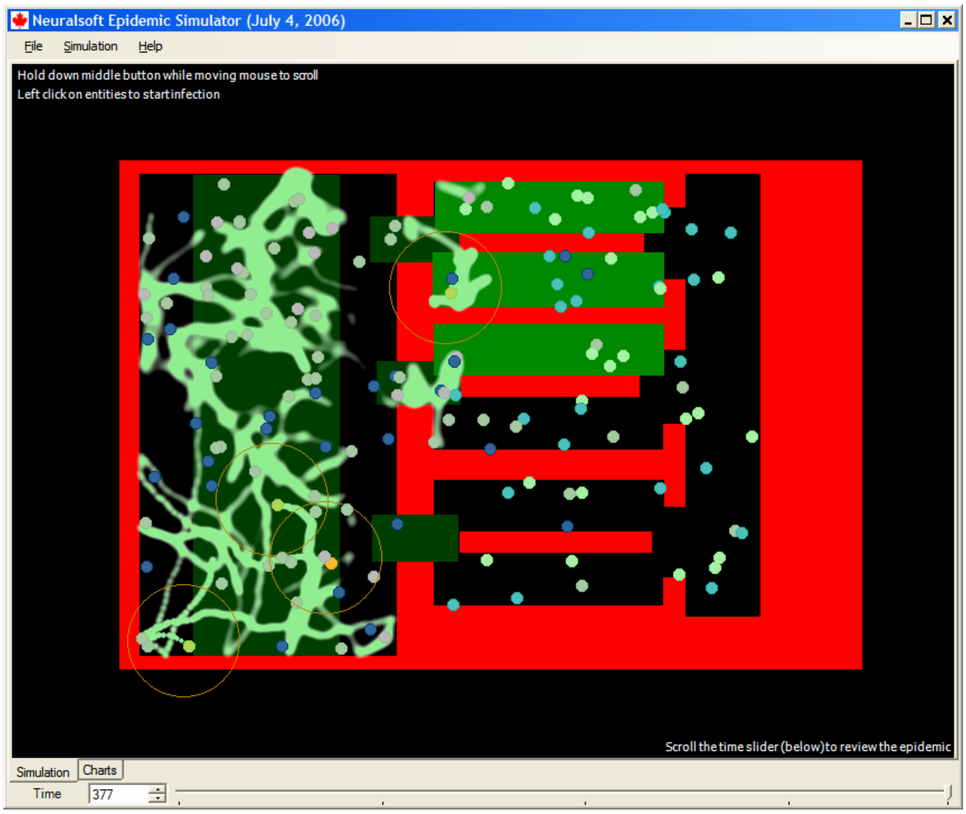




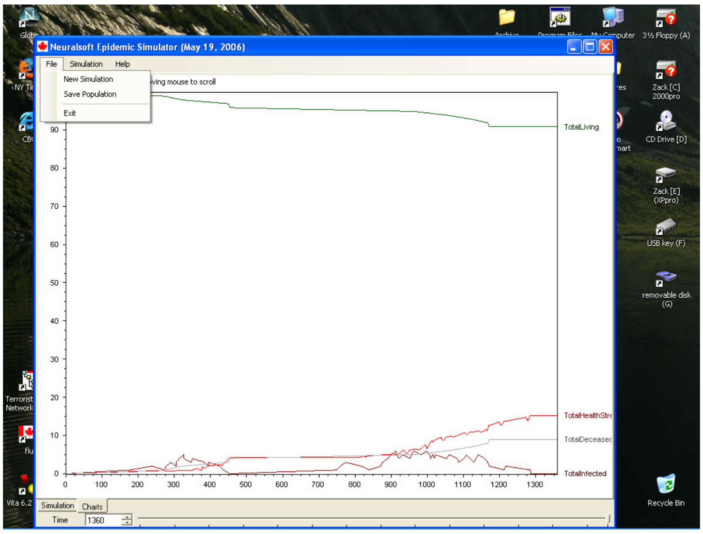
Notice the two-lobed outbreak, similar to SARS in Toronto. Our simulations show that this is a surprisingly frequent finding in the course of generic outbreaks, due to the chaotic nature of events.



The next figure is taken from our current pandemic flu model, in a fictitious hospital floor. Green are susceptible, yellow are infected, recovered are blue and grey are dead. The disease spreads through the air [yellow circles] and through residue on surfaces [green traces].



Following is the course of the disease. Due to the spread of the influenza-like disease by pathogen residue, the social network of who infected whom is less significant.



We have active projects to make this modeling more realistic, modeling two Toronto area hospitals in order to forecast resource allocation needs. However we intend now to use the simpler models to show regional and broader expected results, and to begin to answer practical questions in general, concerning vaccination, antiviral use, effects to be expected from isolation and quarantine, and other questions of immediate use to policy makers; our experience is, the simple stochastic models are of great use in that manner.

5.0 REFERENCE

Ferguson, Neal *et alii* . "Strategies for containing an emerging influenza pandemic in Southeast Asia" *Nature*, 2005. Available online at:
http://www.nature.com/nature/journal/v437/n7056/full/nature04017.html

Modeling Influenza Pandemic Response Effectiveness in Canada

Ben Houston

Zack Jacobson

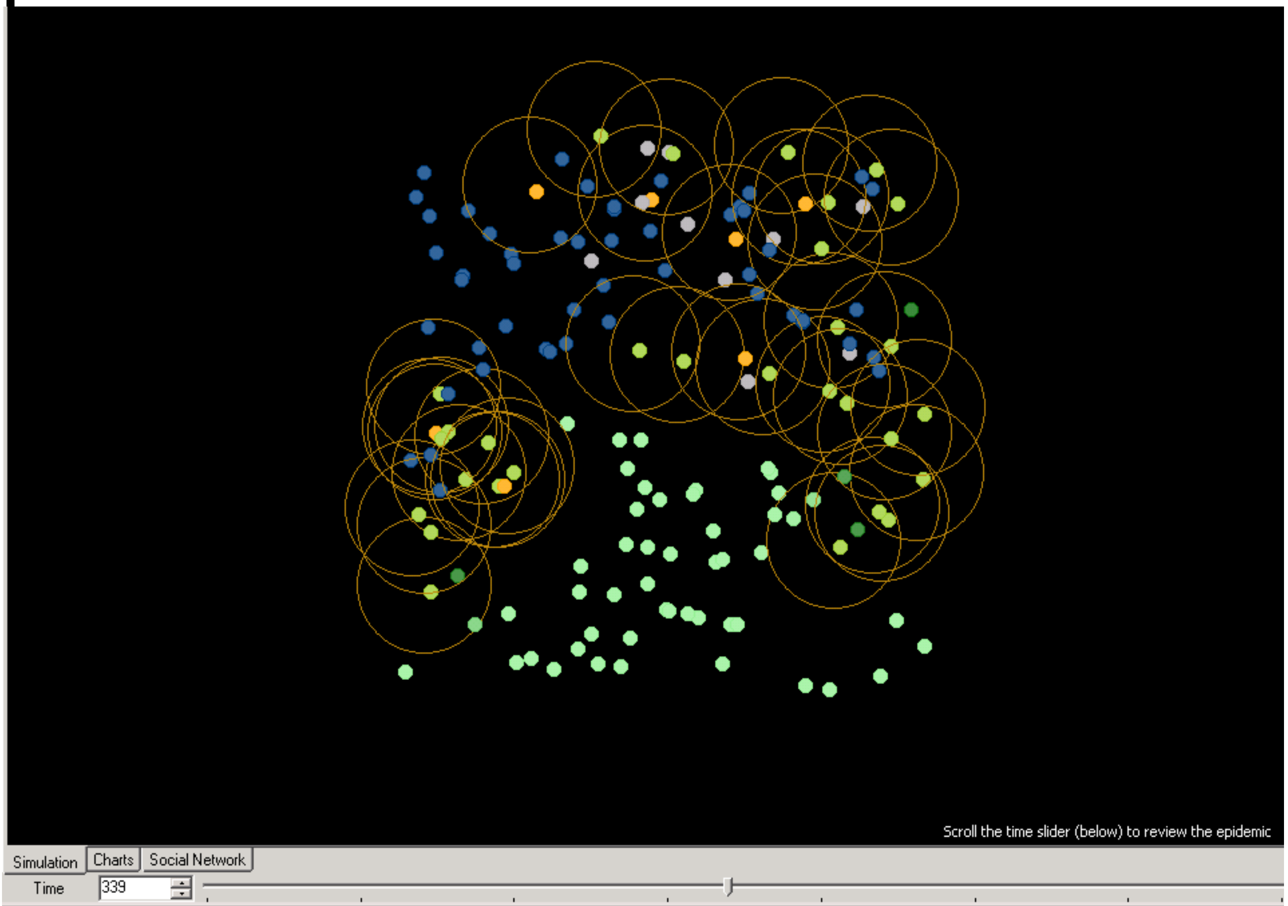
NATO Workshop
Copenhagen
October, 2006

Initial disease outbreak model

- Dynamic
- Stochastic
- Interactive use
  - much faster than real time
- Graphic
- Easy to use
- <u>Easy to understand</u>!
- What-if & sensitivity analyses

Disease outbreak model

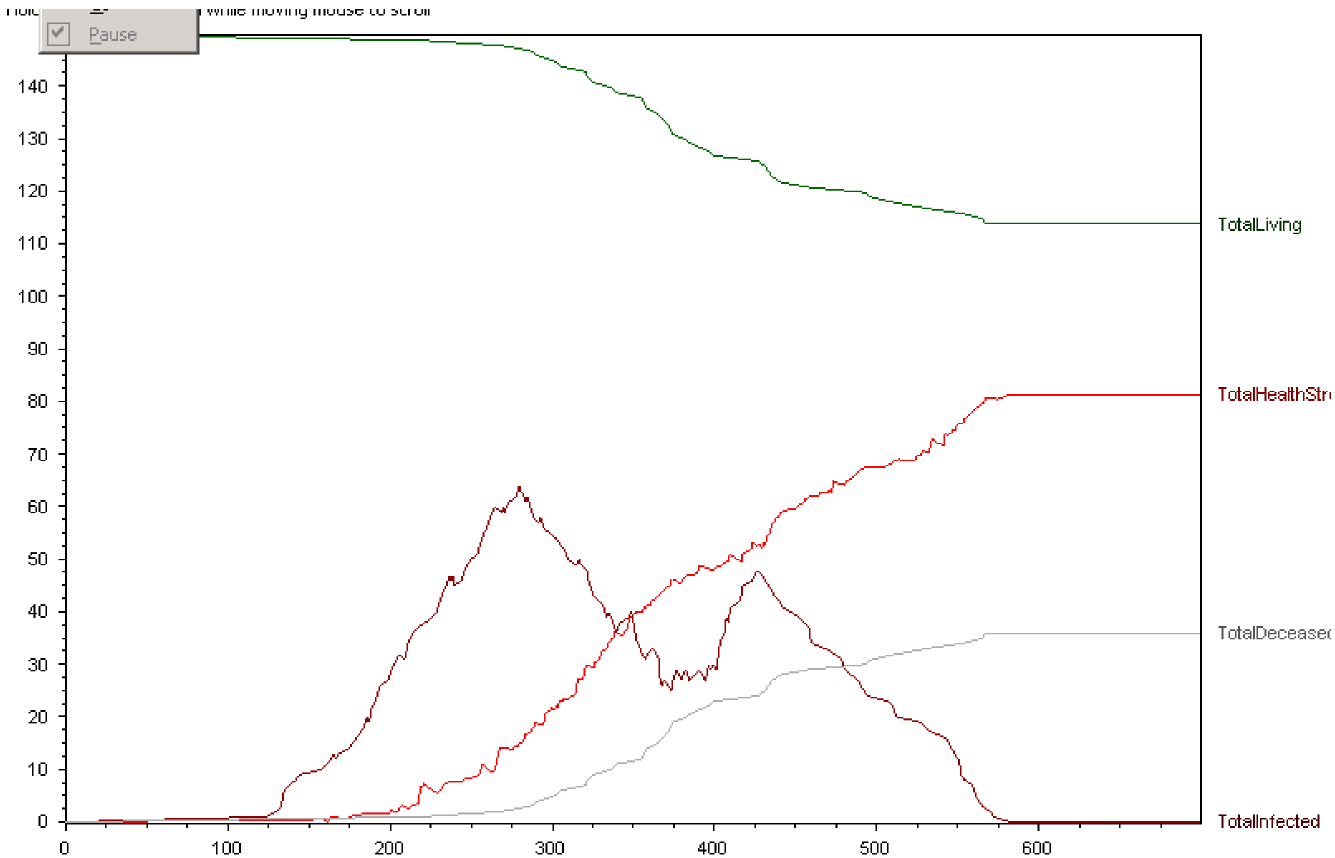
individual level



The original interactive spatial disease simulator interface. The time-slider is located at the bottom.

Disease outbreak model

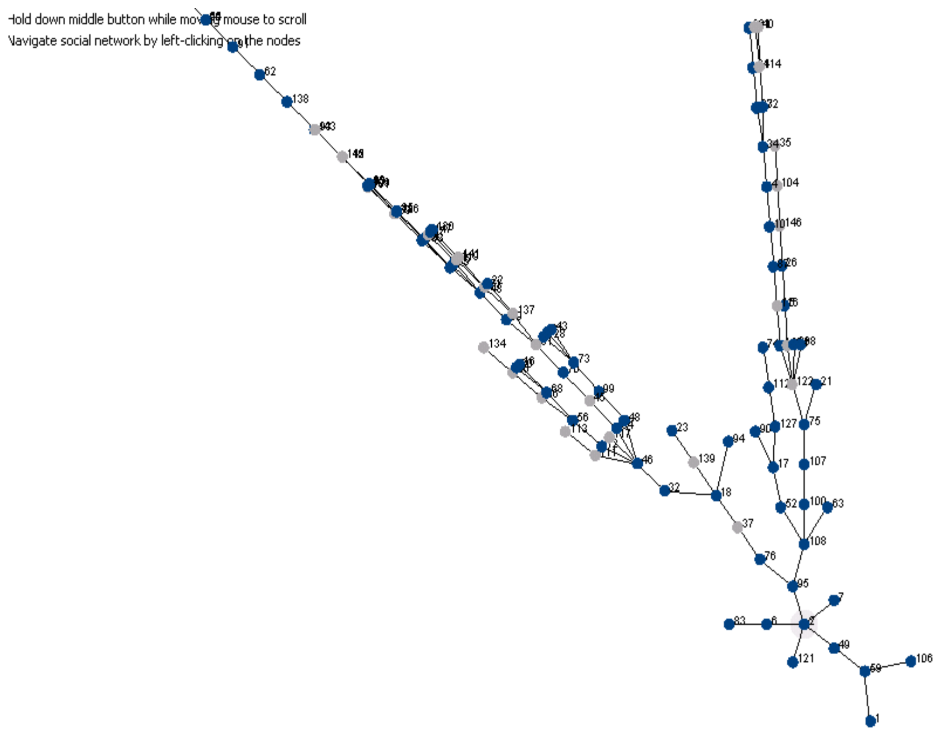
epidemic curves



A chart of the disease progression during a simulation run in terms of its affect on the population.

Disease outbreak model

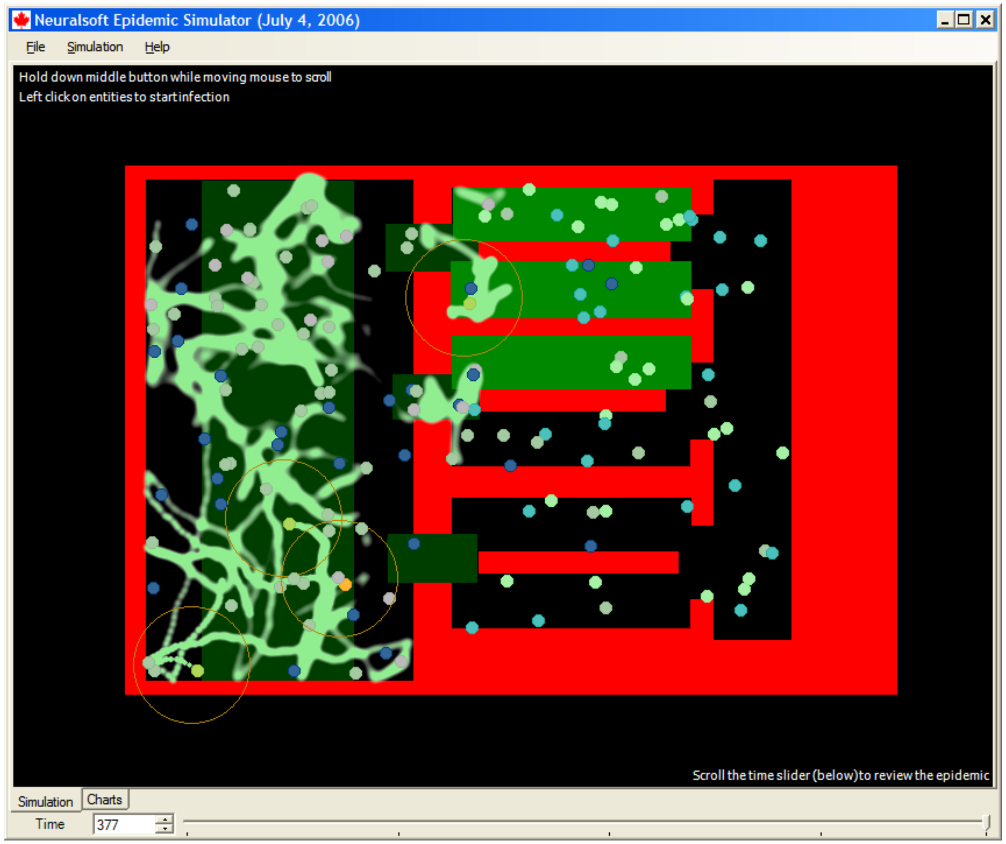
social network [who infected whom]



The resulting person-to-person disease transmission graph from a simulation run.

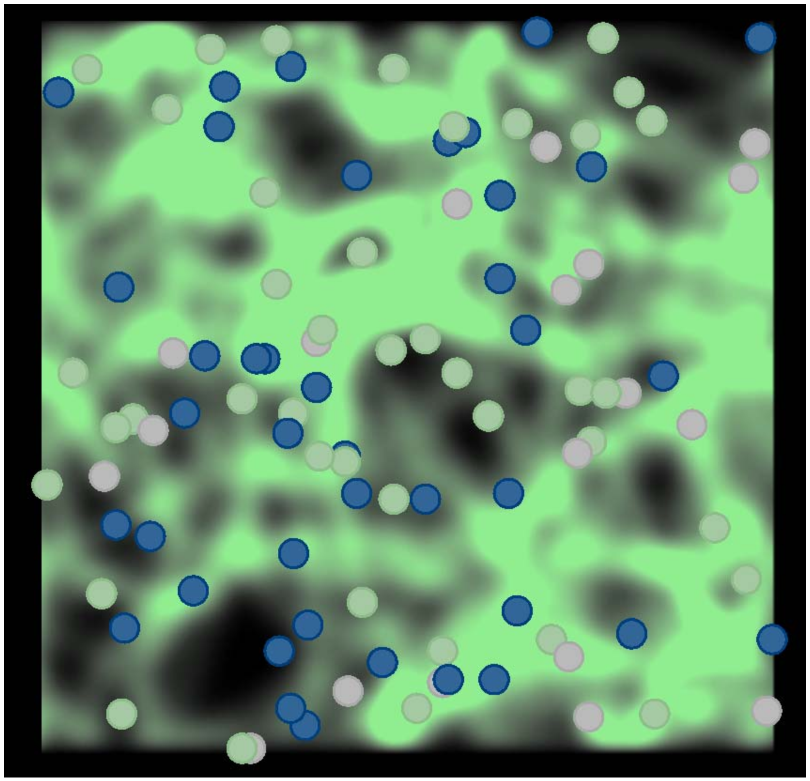
Environmental features

- Arbitrary boundaries: walls, rooms, hallways, doors.
- Regions of reduced movement: models sedentary behavior.



Walls (red) and regions of reduced mobility (green) significantly affect disease transmission.

Pathogen modeling



massive pathogen deposits within a small densely populated space.

- Pathogen is now explicitly released from infectious individuals and spreads via diffusion.
- Vaccine effectiveness and the percentage of population pre-vaccinated can now be set.
- Caveat: the pathogen deposit model precludes the extraction of simple person-to-person disease transmission graphs.

Available demonstrations

- Effect of anti-viral drugs.
- Pathogen deposit model.
- Vaccine and pre-vaccination effects

Two running simulations

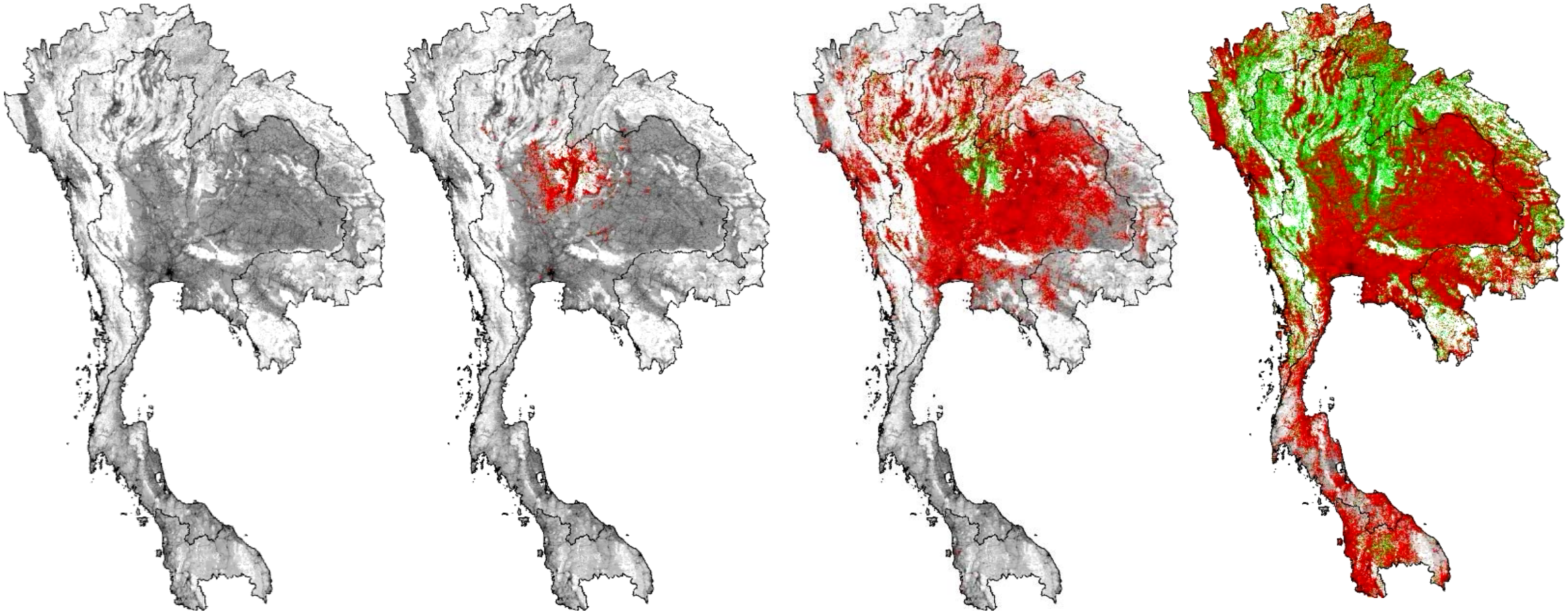
- SARS like outbreak
  - In a featureless space
- Flu like outbreak
  - In a structured space
    - Hospital ward or
    - Nursing home or
    - Poultry barn

The 80% solution

- Ability to model government response policies and resources.
  - Localized quarantines.
  - Localized school and workplace closures.
  - Localized vaccination strategies.
  - Border closures, and travel restrictions.
- Use for Health Canada

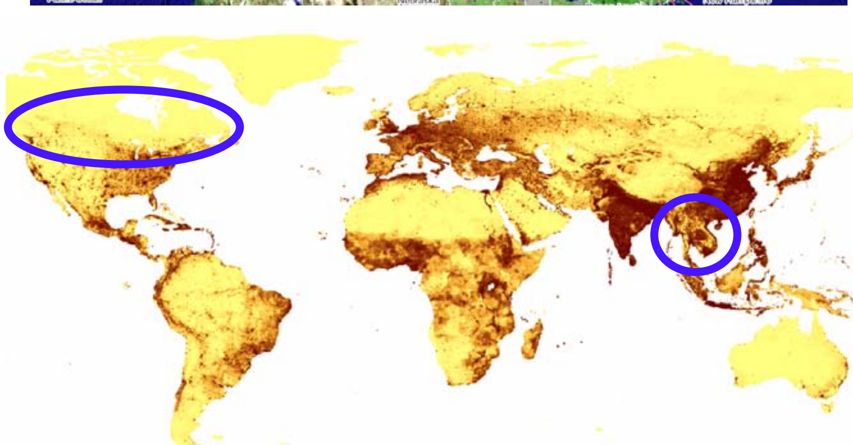
Next stage

Taking inspiration from Ferguson et al. (2005) “Strategies for containing an emerging influenza pandemic in Southeast Asia” *Nature*, 2005
http://www.nature.com/nature/journal/v437/n7056/full/nature04017.html



The simulated geographic spread of influenza in southeast Asia (from Ferguson et al 2005)

Main differences



Landscan population density estimate from ORNL

- Expand geography as far as Canadian population & geography.
  - Quite unlike Southeast Asia
- Population demographics [and behavior] can be derived from StatCan data and from SARS experience.
- Pandemic flu is likely to enter Canada at an international border or airport rather than appear from within.

Modeling Canada’s peculiarities

Attributes of Population

- Density per geographic region.
- Age distributions per geographic region.

Environment

- Households.
- Workplaces.
- Education system: schools, colleges and universities.

Place Attributes

- Within-group age distribution
- Group size distribution

Travel span

- Intra-city travel: distance between households, workplaces and educational institutes.
- Inter-city travel.
- International travel: border crossings, airports.

Travel Attributes

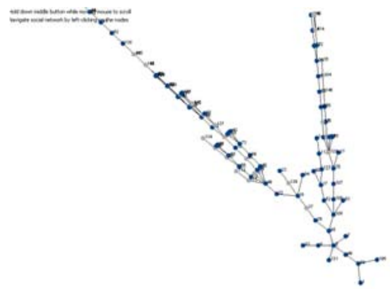
to model mass transit disease spread.

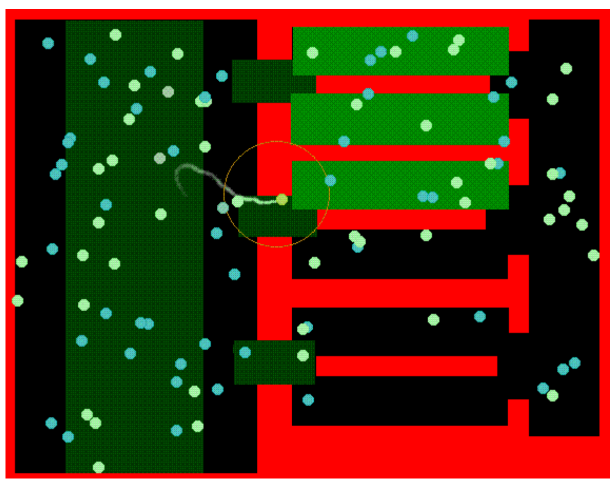
- Frequency, distance of travel.
- Inflow / outflow.

Architectural changes

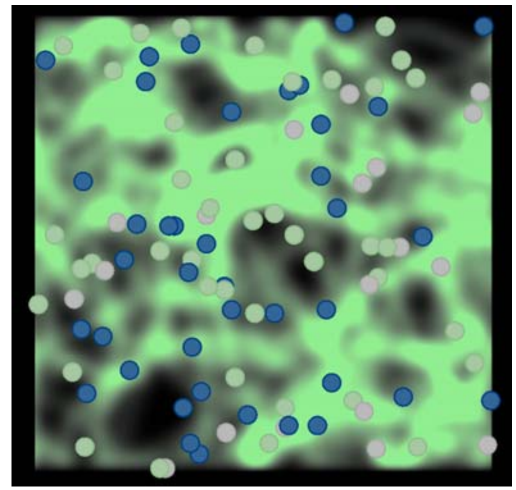
- Discard interactive simulation to allow an increase in the realism of the simulation (which will be achieved via a new non-real-time standalone simulator).
- The current application will be split into a simulator and a viewer.
- Multiple concurrent simulations will allow for robust sensitivity analysis.
- Targeting both city, provincial and country-scale simulations.

Questions and Comments?





Walls (red) and regions of reduced mobility (green) significantly affect disease transmission.



massive pathogen deposits within a small densely populated space.