Loki-Infect 3
A Portable Networked Agent Model for Designing Community-Level Containment Strategies

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Previous Work with Loki-Infect

- **Loki-Infect versions 1 and 2** have been used in a variety of infectious disease modeling studies:
  - **Glass et al. (2006):** determined the critical importance of children in influenza epidemic propagation. Closing schools and social distancing of children reduced infections by 90%.
  - **Davey et al. (2008):** evaluated thresholds for rescinding community mitigation strategies.
  - **Glass & Glass (2008):** surveyed children and teenagers found teens had most contacts that could serve as influenza transmission ‘backbone’.
  - **Davey & Glass (2008):** a systematic evaluation of feasible mitigation strategies at wide range of pandemic severities and found critical enablers of success—rapid, stringent, regional implementation with high compliance.
  - **Perlroth et al. (2009):** evaluated cost-effectiveness of mitigation strategies, finding that the addition of school closure to adult and child social distancing and antiviral treatment and prophylaxis is not cost-effective for viral strains with low infectivity (Ro 1.6 and below) and low case fatality rates (1% and below).
Objectives for Loki-Infect 3

- Loki-Infect 3 is a **desktop application** intended for use by **community-level** decision makers.

- It allows rapid construction of small-scale studies of emerging or hypothetical infectious diseases in their communities and evaluation of the potential effectiveness of various containment strategies.

- It was designed with an emphasis on modularity, portability, and ease of use.

- Our goal is to make this program freely available to community workers across the world.
Loki-Infect Graphical User Interface allows users to easily create a propagation network.

Welcome to the Loki Environment

- To get started click **File -> New -> Complete Simulation Environment**

- The **Community Parameters** tab is used to set up your community, the people in it and their connections.

- The **Infections** tab can be used to modify the parameters of the infection that will run through the community.

- The **Interventions** tab can be used to select and modify different interventions that will go into effect at specified times.

- For more information about the Loki Environment you can access the Wiki by clicking **Help -> Resources**

- If you hover your mouse over different text you can find more details about the specific parameters you can change.

- You can return to this view at any time by clicking **Help -> Getting Started**
A community is described by a set of **layers**, such as a family layer, a friend layer, or a classroom layer.

Each layer contains a number of **groups**, which represent, e.g., individual families, friendship groups, or classrooms.

A person is represented by a **node**, which can be a member of multiple different groups.
Users can begin with a blank community, building it from scratch to suit their needs...
Or users can begin with a predefined community that reflects basic contact networks for a model 10000-member community.
Individual cells can be edited to update the entire population, or only a portion of it.

<table>
<thead>
<tr>
<th>Network Group</th>
<th>Age Classes</th>
<th>Group Distribution</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Senior Households</td>
<td>Adults</td>
<td>Uniform Distribution</td>
<td>1</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Teens</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Senior Households</td>
<td>Seniors</td>
<td>Uniform Distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Members of a layer and how they're distributed in groups in the layer can be configured

<table>
<thead>
<tr>
<th>Network Group</th>
<th>Age Classes</th>
<th>Group Distribution</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
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<tr>
<td></td>
<td>Children</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Teens</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Senior Households</td>
<td>Seniors</td>
<td>Uniform Distribution</td>
<td>1</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Extended Families or ...</td>
<td>Seniors</td>
<td>Uniform Distribution</td>
<td>0</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Adults</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>8</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Teens</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>8</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>Exponential Distribution</td>
<td>0</td>
<td>8</td>
<td>4.0</td>
</tr>
<tr>
<td>Child Classes</td>
<td>Children</td>
<td>Uniform Distribution</td>
<td>20</td>
<td>35</td>
<td>27.5</td>
</tr>
</tbody>
</table>
Graphs of the distributions of groups upon constructing a given layer can be requested by clicking the appropriate icon.
Finally, for each layer in a community, the user provides an idealized network topology (and any parameters for that topology) for each group in the layer.

Supported topologies include:

- Scale-Free (Barabási)
- Random (Erdős–Rényi)
- Small-World (Strogatz)
- Ring
- Bipartite
- Cycles of Cliques

The resulting community is a network of networks, where each node is a member of multiple different sub-networks.
Example group topology: idealized cycle of cliques
scale-free network over a population of 1000
Network colored by age classes

Same network colored by node degree

The entire network structure for a community can be exported to the GraphML format.
Models of Contagion

- Loki-Infect 3 allows the user to simulate different or multiple contagions on the same social network.
- Currently we have implemented an influenza model developed by Davey et al. between 2006 and 2009 within the context of Loki-Infect 3.
- We are also currently working with Danilo Scepanovic of MIT to implement an alternative manifestation of influenza that is more biologically realistic.
- Loki-Infect 3 is also being adapted to model the spread of opinions and behaviors along social networks.
Davey et al. Influenza Manifestation

- In the influenza manifestation by Davey et al., each edge in the social network represents a potential contact between two people with an associated contact **frequency**, **duration**, and **intensity**.

- Individuals progress through a probabilistic state machine, either remaining susceptible, or becoming infectious and later recovering or dying from the infection. The infection spreads through individual contact.
Davey et al. Influenza Manifestation

- This influenza model has a small, yet descriptive, parameter set, which can be configured though the GUI and used to represent a number of influenza manifestations.
Different models for spreading an infection can be selected, and details for that model displayed and editable

<table>
<thead>
<tr>
<th>Name of infection:</th>
<th>Basic Influenza</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection model:</td>
<td>Davey Influenza</td>
</tr>
<tr>
<td>Base Infectivity:</td>
<td>0.19</td>
</tr>
<tr>
<td>Prob. Symptomatic:</td>
<td>0.5</td>
</tr>
<tr>
<td>Prob. Stay at Home:</td>
<td>0.8</td>
</tr>
<tr>
<td>Mortality:</td>
<td>0.02</td>
</tr>
<tr>
<td>IDF:</td>
<td>1.0</td>
</tr>
<tr>
<td>Relative Infectivities:</td>
<td>Seniors</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

A simulation can begin with a distribution of people chosen from the population to be initially infected
Interventions

- There are two primary categories of interventions: **case-based** and **network-based**.

- Network-based interventions, such as school closures and social distancing, take effect immediately for all relevant nodes.
- Case-based interventions include actions such as antiviral treatment and prophylaxis, which reduce a node’s infectivity and susceptibility for the duration of antiviral administration.

- Case-based interventions apply only to new cases that emerge.

<table>
<thead>
<tr>
<th>Name:</th>
<th>antiviral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention:</td>
<td>Antiviral</td>
</tr>
<tr>
<td>Entry State:</td>
<td>inf.sympathome1</td>
</tr>
<tr>
<td>Exit State:</td>
<td></td>
</tr>
<tr>
<td>Start Cases:</td>
<td>10</td>
</tr>
<tr>
<td>Stop Cases:</td>
<td>0</td>
</tr>
<tr>
<td>Entry Probabilities:</td>
<td>Group</td>
</tr>
<tr>
<td>everyone</td>
<td></td>
</tr>
<tr>
<td>Prophylaxis groups:</td>
<td>Group</td>
</tr>
<tr>
<td>Senior Households</td>
<td></td>
</tr>
</tbody>
</table>
In the simulate window, you can perform multiple runs, and filter the data you wish to view.
Data can be averaged, and dumped to file.
Example: The Effect of School Closures on Disease Propagation

![Graph showing the effect of school closures on disease propagation. The graph indicates the population infected over time with different scenarios.](image)
Extensions

- Investigation of the spread of correlated diseases and opinions.
- Investigation of the spread of multiple competitive and non-competitive strains of influenza, including strains that are resistant to neuraminidase inhibitors.
- Used for cost-effectiveness evaluation of mitigation strategies.
- Implementation of a mechanism to retrieve census data based upon GIS coordinates and construct characteristic communities.
Demos

Come see me for demos or if you’re interested in beta testing
Distribution and Release

- We intend to publicly release Loki-Infect 3 along with its source code under a free license in the summer of 2011.
Questions?
Additional slides
Representation of a Community

- To construct a layer in the community, we begin by randomly sampling the user-provided distributions to produce new distributions.

- We then use these distributions as constraints in a linear least squares problem, which we solve using a weighted non-negative least squares algorithm.

- We then use a hill-climbing approach to produce a solution that satisfies all necessary constraints (e.g., we must guarantee that the sum of all members in all groups is consistent with the demographics of the population).

- Repeatedly applying this approach to all layers produces a new random community that necessarily satisfies all hard constraints and roughly approximates all soft constraints.