BioWar
A Scalable Multi-Agent Model for Biological and Chemical Incidents

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Center for Computational Analysis of Social and Organizational Systems
http://www.casos.cs.cmu.edu/
BioWar – Conceptualization
City Scale Multi-Agent Network Model of WMD Attacks

Comparative death rates due to Anthrax in Pittsburgh and San Diego

Movement of Smallpox infected agents in Pittsburgh

Deaths due to Anthrax
BioWar
Inputs and Outputs

- Realistic input
  - Census data, climate history,…
  - Varied by location
  - Scaleable
- Need-based outputs
  - Matched to real-world prototypes
    - Aggregate information
    - Imprecise
    - Useful for testing algorithms, training,…
  - Providing exact insights into simulation
    - Precise timings
    - Complete accuracy
    - Useful for “what-if” and effectiveness studies

Agents move in networks which influence what they do, where, with whom, what they know, what diseases they get, when, and how they respond to them.

Major difference in network and disease effects are based on race, gender and age.
BioWar Model

- Autonomous agents
  - Individual variation
  - Connected by social networks
- Scaleable architecture
  - Multithreaded execution
  - Scaleable population size
- Symptom driven ailment model
  - Disease spread and progression on a per-disease basis
  - Agents respond to perceived symptoms
  - Medical diagnosis response based on symptoms and tests
    - Diagnosis may be incorrect
    - Symptom profile is coded for likelihood and evoking strength
- Dynamic responses
  - Event or time based response injection during runs
  - Pre-scripted for batch runs or interactive
# Current City Models

<table>
<thead>
<tr>
<th>Location</th>
<th>Pittsburgh</th>
<th>San Diego</th>
<th>San Francisco</th>
<th>Hampton Roads Norfolk</th>
<th>Hampton</th>
<th>Washington DC+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POPULATION</strong></td>
<td>2,332,823</td>
<td>2,699,582</td>
<td>745,377</td>
<td>1,530,908</td>
<td>? 146,431</td>
<td>559,258</td>
</tr>
<tr>
<td><strong>LOCATIONS</strong></td>
<td>59,498</td>
<td>67,335</td>
<td>31,532</td>
<td>34,407</td>
<td>2,459</td>
<td>19,438</td>
</tr>
<tr>
<td>Clinics</td>
<td>2,032</td>
<td>1,917</td>
<td>783</td>
<td>905</td>
<td>78</td>
<td>632</td>
</tr>
<tr>
<td>Hospitals</td>
<td>50</td>
<td>33</td>
<td>14</td>
<td>19</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Pharmacies</td>
<td>479</td>
<td>274</td>
<td>123</td>
<td>199</td>
<td>16</td>
<td>92</td>
</tr>
<tr>
<td>Restaurants</td>
<td>4,383</td>
<td>4,886</td>
<td>2,862</td>
<td>2,504</td>
<td>203</td>
<td>1,476</td>
</tr>
<tr>
<td>Schools</td>
<td>645</td>
<td>112</td>
<td>541</td>
<td>346</td>
<td>34</td>
<td>147</td>
</tr>
<tr>
<td>Stadiums</td>
<td>200</td>
<td>143</td>
<td>33</td>
<td>97</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Stores</td>
<td>9,088</td>
<td>9,182</td>
<td>3,827</td>
<td>5,825</td>
<td>445</td>
<td>1,963</td>
</tr>
<tr>
<td>Theaters</td>
<td>551</td>
<td>516</td>
<td>294</td>
<td>307</td>
<td>25</td>
<td>134</td>
</tr>
<tr>
<td>Other Work</td>
<td>42,070</td>
<td>50,272</td>
<td>23,055</td>
<td>24,205</td>
<td>1,647</td>
<td>14,961</td>
</tr>
</tbody>
</table>

*Hampton City is a subset of the entire Hampton Roads/Norfolk metro area.

+Washington, DC is limited to the District of Columbia.

■ Need to revise these numbers based on simulation runs.
Ailments

• Diseases
  • Distribution of occurrence
    • Background – present more or less continuously in simulation
    • Outbreak – “bursts” due to natural events or attacks
  • Spread modes
    • Non-contagious – contracted from attacks, outbreaks and background
    • Contagious – as above, but also spread by agent to agent contacts
  • New diseases and variations possible
• Chemical agents
  • Types
    • Sarin – war agent
      • Actual events for comparison (Aum Shinrikyo, Japan)
      • Fairly well studied
    • Chlorine – industrial chemical
      • Used in large quantities commercially
      • Release may occur deliberately or accidentally
  • Spread by wind
    • Plume – for continuous releases
    • Puff – for burst releases
Current Diseases – Contagious

Bacterial Pharyngitis Acute Non Streptococcal  
Non Gonococcal  
Botulism  
Bubonic Plague  
Campylobacter Enteritis  
Cutaneous Atypical Mycobacterial Infection  
Encephalitis Acute Viral  
Giardiasis Intestinal  
Gram Negative Pneumonia Non Klebsiella  
Hepatitis A Acute  
Herpes Simplex Encephalitis  
Immunice Deficiency Syndrome Acquired (Aids)  
Infectious Mononucleosis  
Influenza  
Influenza Pneumonia  
Malaria  
Meningococcal Meningitis  
Mycoplasma Pneumonia  
Plague Meningitis  
Plague Pneumonia  
Pneumococcal Pneumonia  
Pulmonary Legionellosis  
Salmonella Enterocolitis Non Typhi  
Schistosomiasis Systemic Shigellosis  
Staphylococcal Pneumonia  
Staphylococcal Scarlet Fever  
Toxic Shock Syndrome  
Streptococcal Pharyngitis Acute  
Streptococcus Pyogenes Pneumonia  
Syphilis Primary  
Smallpox  
Tuberculosis Chronic Pulmonary  
Tuberculosis Disseminated  
Varicella Pneumonia  
Viral Gastroenteritis  
Viral Pharyngitis Acute Non Herpetic

Actually, this list was carried across from the Ver. 1.5 presentation and needs to be checked.
Current Diseases – Noncontagious

Anthrax, Cutaneous
Anthrax, Inhalational
Angina Pectoris
Anxiety Neurosis
Arteriolar Nephrosclerosis Benign Essential Hypertension
Arteriosclerotic Heart Disease
Bronchial Asthma
Bronchitis Chronic Simple
Brucellosis
Cardiogenic Shock Acute
Chronic Fatigue Syndrome
Depression
Diabetes Mellitus
Disseminated Intravascular Coagulation

Fibromyalgia Syndrome
Heat Exhaustion
Hypertensive Heart Disease
Hypovolemic Shock
Myocardial Infarction Acute
Obsessive Compulsive Neurosis
Pulmonary Emphysema
Somatization Disorder Hysteria
Staphylococcal Gastroenteritis Food Poisoning Tension Headache
Tularemia
Tularemia Menigitis

Actually, this list was carried across from the Ver. 1.5 presentation and needs to be checked.
Interventions

- Interventions change simulator state during the run
- Currently two types supported
  - Attacks – inject chemical or diseases “incidents”
    - Time triggered
    - May utilize any chemical agent or disease
  - Responses – dynamically change simulator state
    - Event triggered
    - Allow policy decisions to be simulated
- Additional “quasi-interventions” mechanisms available
  - Support simulation of naturally occurring diseases
    - Outbreaks – model periodic events (e.g. flu)
    - Background – model “steady state” diseases (e.g. heart disease)
  - Sensible defaults provided, but user may modify
Responses

• Dynamically change simulator state based on events
  • Medical interventions: vaccinate, prophylaxis
  • Public health responses: quarantine, isolate, evacuate, shelter in place
  • Simulator control: pause simulation, activate/deactivate locations
• May be invoked automatically or manually.
• Rule based, with the general form:
  \[\text{<trigger>} \ [\text{<delay>}] \ \text{<target>} \ \text{<response>}\]
  \[\text{on(<trigger>) [wait (<delay>)]} \ \text{for(<target>) do(<response>)};\]
• Example: On May 13, order agents to shelter in place for 24 hours.
  \[\text{on(5/13) for(agent all) do(shelter\_in\_place for(1d))};\]
Wind Model

• Attack agents (chemical and disease) are wind dispersed
  • Wind models utilize location specific climatic information
  • Weather is randomized, but matches historical profiles for modeled cities

• Several wind models are provided, optimized for ailment type and release duration
  • Gaussian Puff
    • Puff-A – suspended particles (e.g. anthrax spore dispersal).
    • Puff-B – molecular transport (burst dispersal of chemicals)
  • Gaussian Plume
    • Plume-A – molecular transport (continuous release of chemicals)
where

C - concentration of pollutant;
Q – fixed mass of poisoning material;
u – air velocity;
H – height of puff release;
x, y, z – distance from the release;
$\sigma_x, \sigma_y, \sigma_z$ - standard deviations along the axis
Generic disease model can be enhanced for specific diseases.

Smallpox example

- Incubation and infectious periods well-studied.
- Considered a significant biological threat.
Smallpox Infections: SIR vs. BioWar
Smallpox Death: SIR vs. BioWar
10) Attack On Hampton Roads

“Impact of small/medium/large anthrax or smallpox attack on Hampton Roads (100% population) outputs to plot number infected, number who die, number first-responders infected, number first responders who die, number military infected number military who die.” (KMC)

Will do this later.
11) Performance Specs - From Eric

“Time for a single run generating 6 months of data (or whatever length it was that Eric ran) for some city using a single processor machine, and for same city using a 4 processor machine - note use the data here Eric generated a few months ago - no need to do new runs for this.” (KMC)

Deferred first draft to Eric.
Planned Functionality Enhancements

• Simplify emergent threats modeling (e.g. Avian Flu)
• More realistically model medical capacities
  • Standard capacity – set limitations by treatment type.
  • Surge capacity – hospital in extraordinary circumstances
    • Regular hospitals
    • Temporary facilities
• Add first responders interaction with the injured and ill
• Expand interventions
  • Allocation of critical supplies
  • More models of public health interventions
• Model extraordinary agent behavior
  • High threat/stress levels
  • Panic
Acknowledgements

- This is final slide, it repeats the original logo
- Feel free to stick sponsor logos at the bottom or along the side, we need to standardize on one