Exploring Human Dynamics in Critical Infrastructures:

An Agent-based Simulation of Stress in Hospital Surge

Alexis Morris,
Faculty of Computer Science, UNB Fredericton

Motivation:

Is it possible to predict systemic failures in critical infrastructures that are due to human factors?

Critical infrastructures are complex, socio-technical systems that involve a coordinated mix of people, technologies, and organizations. These ensembles have a unified objective; to protect important assets, predict and prevent losses, and promote a stable operation of a system. Such systems comprise a social and a technical subsystem which are interdependent and inter-organizational networks of human-to-human, human-to-technology, connections. These are directed at a high level by policy makers, decision-makers, and translate to decisions of groups, and their use of technologies.

The problem is that such systems are prone to failure due to indirect consequences of decisions, flaws in organizational policy, and a poor understanding of the complexity of the holistic inter-dependencies within and among organizations.

The way of improving is to understand both social and technological aspects that cause global system failures. The technological systems are typically well defined, and well researched problems. The human problems, however, are less clearly understood. Hence the research question**: How can one use the techniques of simulation, both agent based, and system dynamic, in order to predict failures due to human dynamics and organizational policies?**

Methodology:

- Understanding how to represent non-discrete, and "fuzzy concepts" in simulations of human factors.
- Defining a taxonomy of important human factors in critical situations, eg. stress, trust, culture, personality, and emotion.
- Defining a particular case study and base simulation environment.
- Enhancing agents with interesting human factor models.
- Analyzing behaviours over time and in different contexts.
- Modelling policies and important facets of several critical infrastructures (hospitals, police stations, fire stations, etc).
- Assessment of results and policies that predict system failure.
- Understanding the benefits of holistic simulation using top-down, and bottom up methods (namely Agent-based, and System Dynamics techniques).

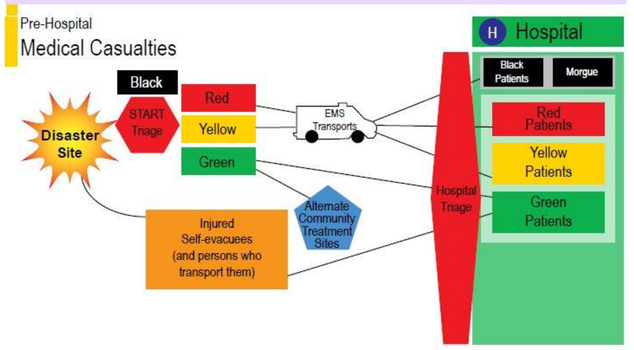
Experiment 1: Stress in Hospital Surge

- Medical support systems are a first responder in crisis situations. As such, it is common that these systems face massive overloads when the number of casualties is high and they are near a disaster site. Hospital surge capacity is often a function of the number of beds available, incoming patients, current patients, and staff available. We want to model the psychological factor of stress on these individuals in different configurations, with a focus on victim arrivals, nurses, doctors, technicians, and resources. It should be possible to concretize this notion, and measure it against surge capacity.

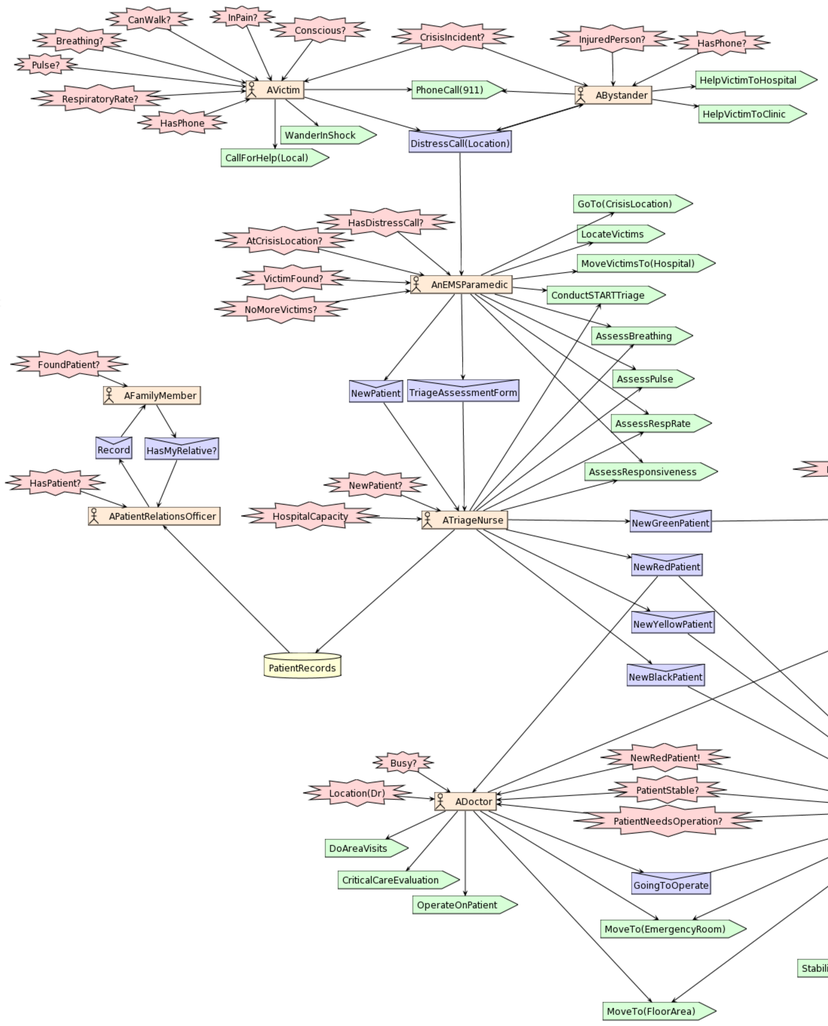
We intend to model this scenario using NASA's Brahms agent platform. Stress modeling makes use of Hobfoll's Conservation of resources as a starting point. This will eventually be explored as a system dynamics model, of rates, levels, and feedback loops.

Hospital Surge Scenario:

- First responders in a crisis are trained in categorizing casualty illnesses through a process known as triage. Below triage sorts victims into four classes for eventual treatment and discharge.



From: "Surge, Sort, Support: Disaster Behavioural Health for Healthcare Professionals Textbook" DEEPCenter, University of Miami. 2006



Agent Design: System Overview

- The basic agent based simulation design is shown here, minus an appropriate stress model.
- Agents, their percepts, activities, and message communication are shown.

After implementation the numbers of victims and different configurations of hospital workers will be instantiated, allowing for understanding surge capacity, patient distress, and worker burnout.

Discussion:

Medical informatics is an immediately relevant domain for studying human dynamics in critical systems. Results should show that failures due to stress, and burnout can be measured, and predicted. This could lead to describing policies and better configurations of work environments. Future work will involve the merger of this hospital simulation scenario with others in an inter-dependent critical infrastructure.

Adaptive Risk Management Laboratory

Prof. Mihaela Ulieru
Canada Research Chair
Director ARM Laboratory

UNIVERSITY OF NEW BRUNSWICK
UNB