Design and Implementation of a GIS-Based Simulation for Emergency Response and Crisis Management

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Outline

- WIPER Simulation
- Movement Models
- Application of GIS
- Simulation Tools
- Conclusions

Wireless Phone Based Emergency Response System (WIPER)

- Laboratory prototype: Proof-of-Concept
  - DDDAS – NSF – Dynamic Data Driven Application Systems
- Monitors a real-time stream of cell phone activity
- Evaluates crises using Agent-Based Models
- Presents results and guidance for emergency responders

Problem Domain

Disasters, crises, emergencies, civil disorders, humanitarian relief efforts, transportation disruptions, … events involving large numbers of people.

- Natural origins: hurricanes, tornados, earthquakes, tsunami, snow storms, floods, volcanoes, epidemics, …
- Human origins: terrorists attacks, political unrest, civil unrest/disorder, industrial accidents, transportation accidents, …

Emergency Response Management

Problems

- Communication
- Co-ordination
- Situation Awareness (SA)
- Sharing SA

Information Needs

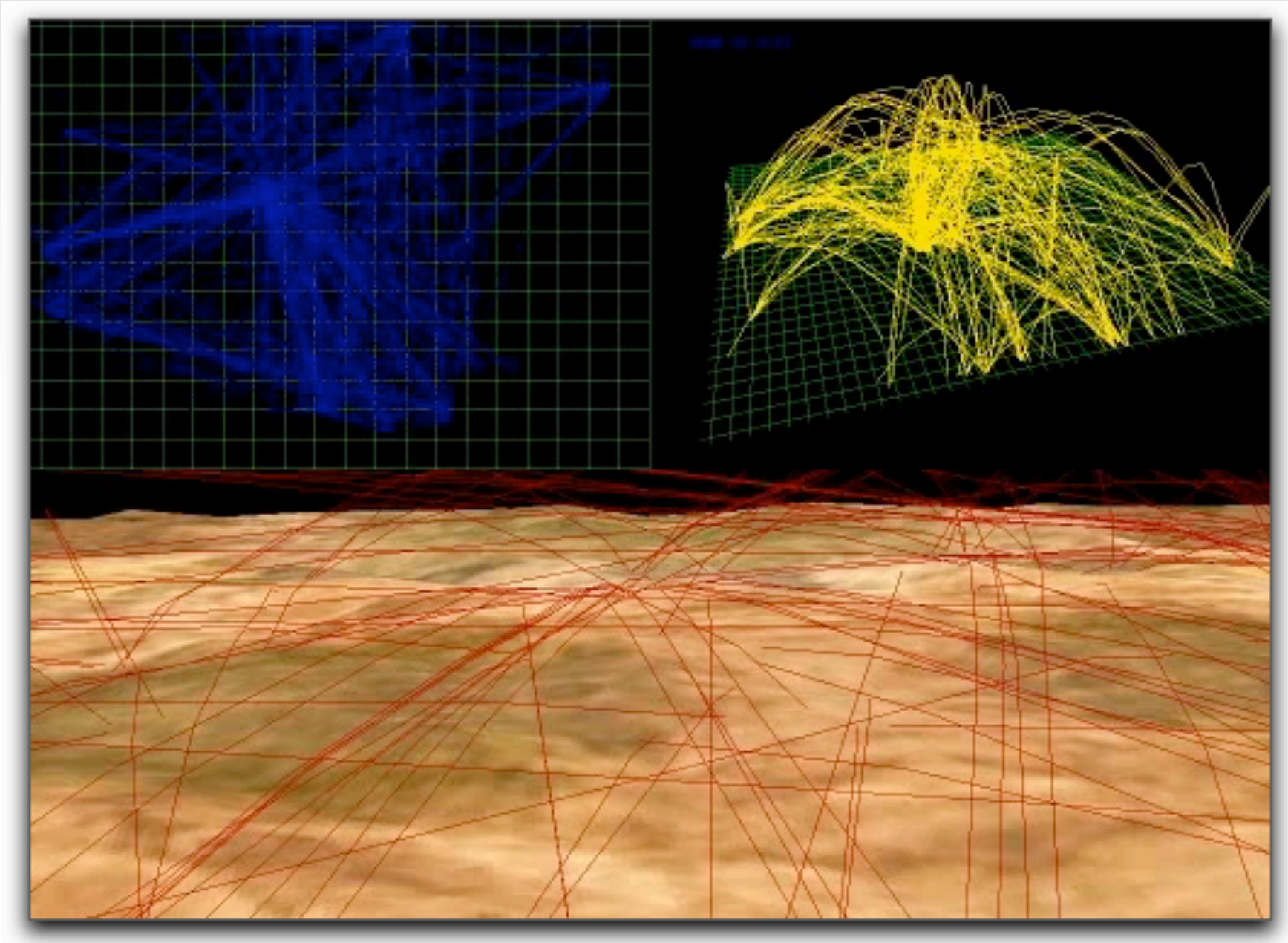
- Alerts - Has something happened?
- Location - Where, extent?
- Numbers - How many people?
- Movement - Stationary, moving?
- What is nature of the event?
- How should we respond?

Enhanced Situational Awareness: Calling activity and cell phone locations can help with these information needs

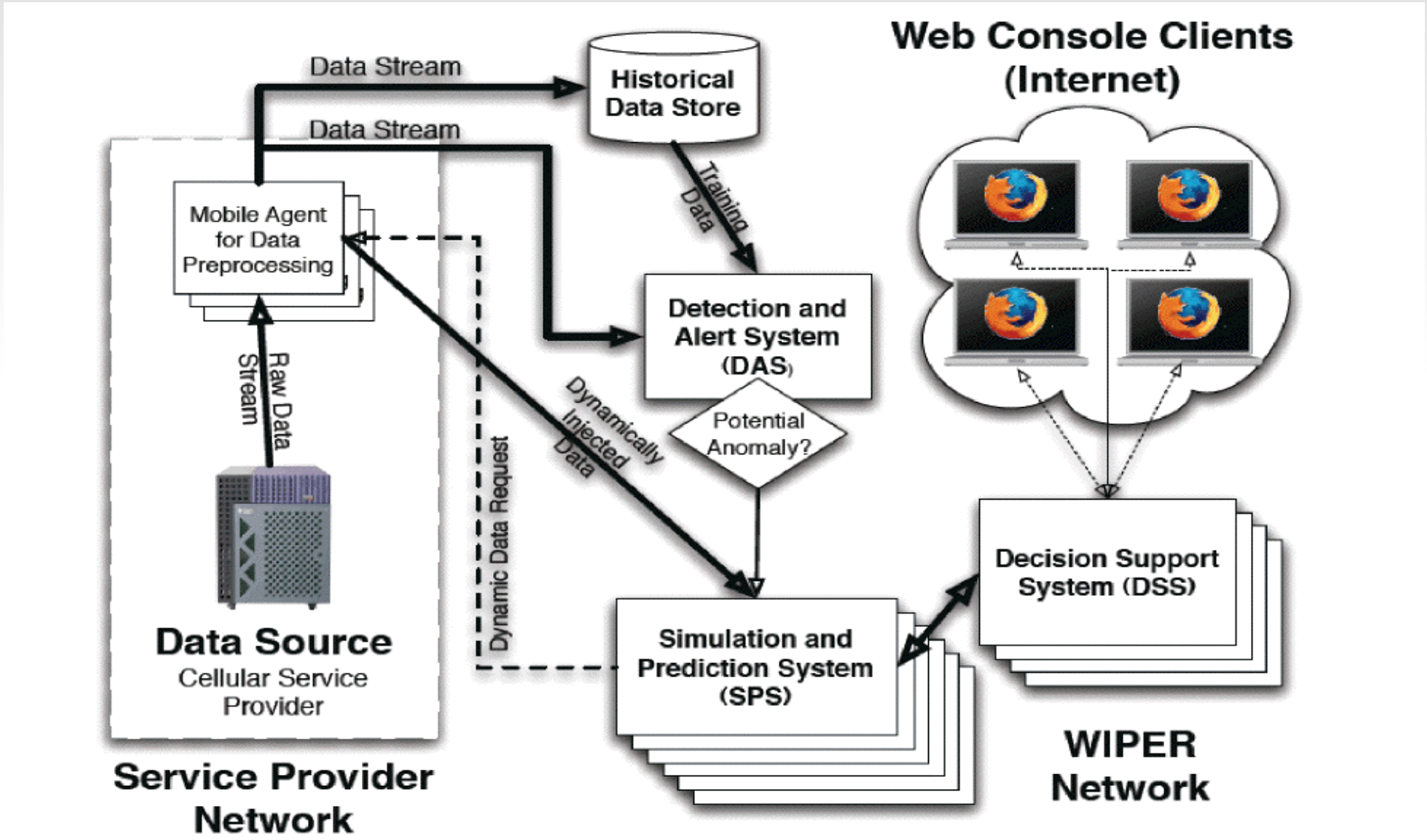
Cell Phone User Activity

Hurricane Evacuation

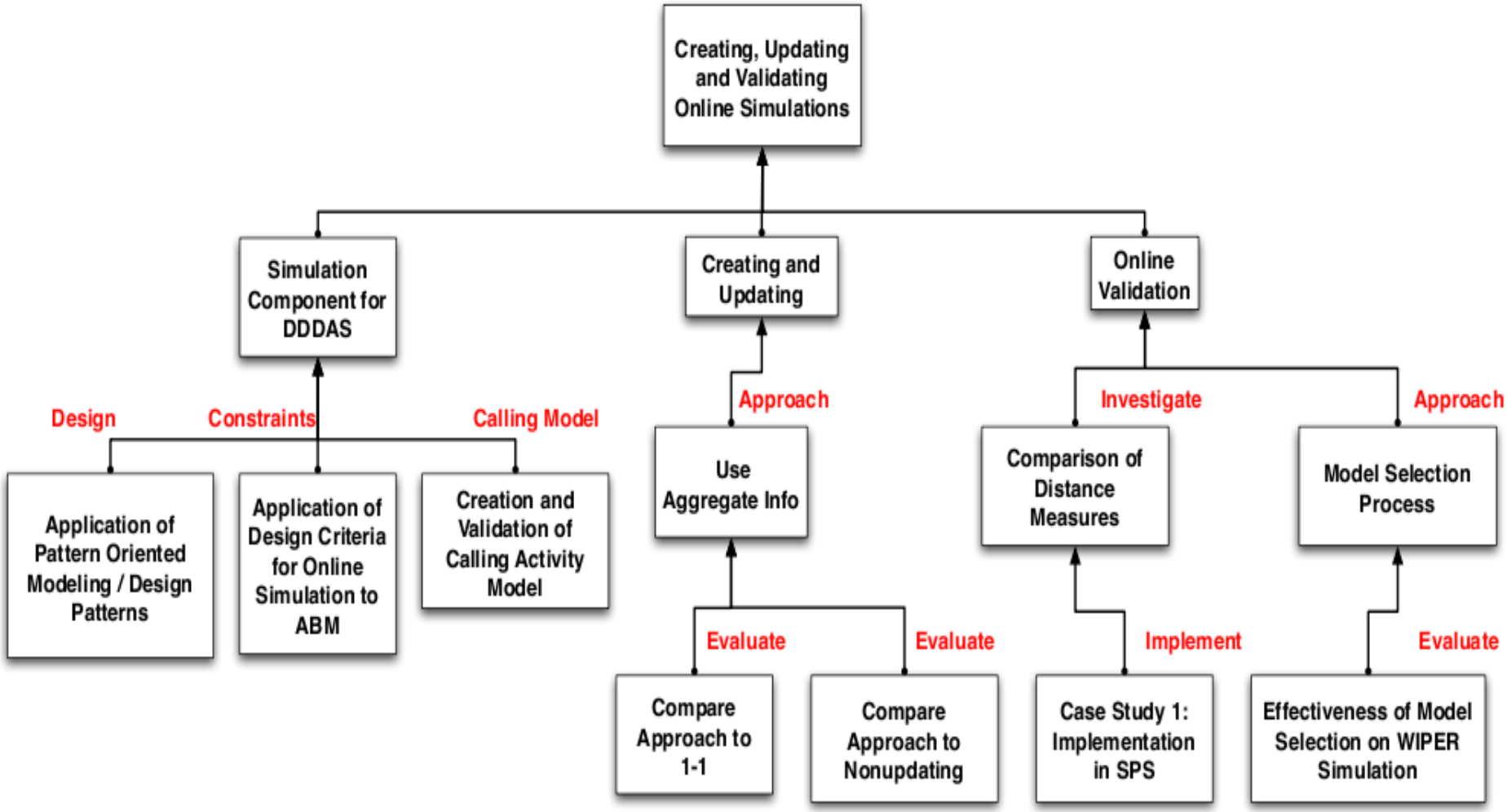
Animation



DDDAS Architecture of WIPER System



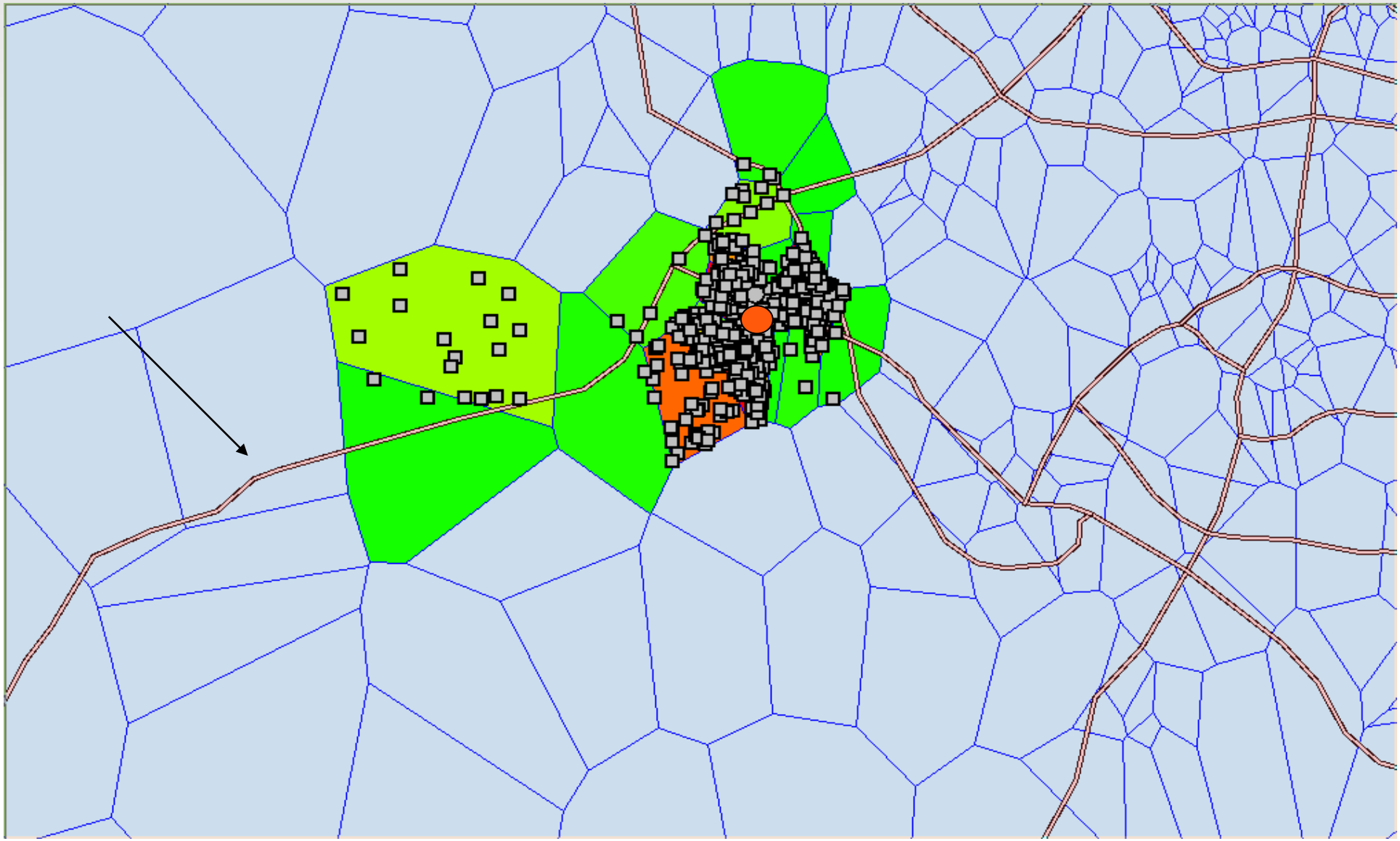
Architecture of WIPER Simulation



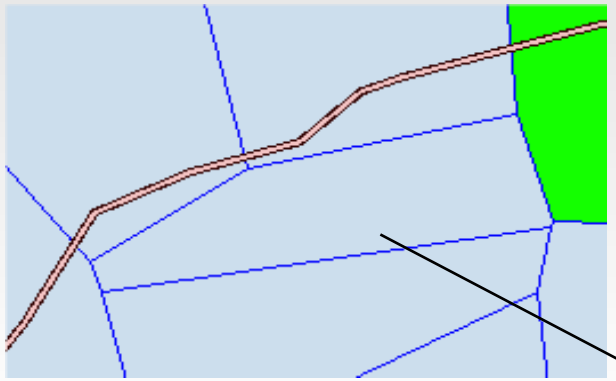
Movement Models

- Null Movement — A placeholder, no movement
- Random Movement — Moving in a random fashion
- Move And Return Movement — Back and forth between home and work location
- Basic Flee Movement — Moving along a straight line.
- Bounded Flee Movement — Agents stop after they reach a safe distance
- Road Flee — Moving path constrained by road network
- Congestion Flee — Limited road sources generate traffic jams
- Mixed Flee — Pedestrians and cars evacuate simultaneously
- Reactive Pedestrian Model — Calculates attractive and repulsive regions

Road Network Around Crisis Center



GIS For Guiding Agents



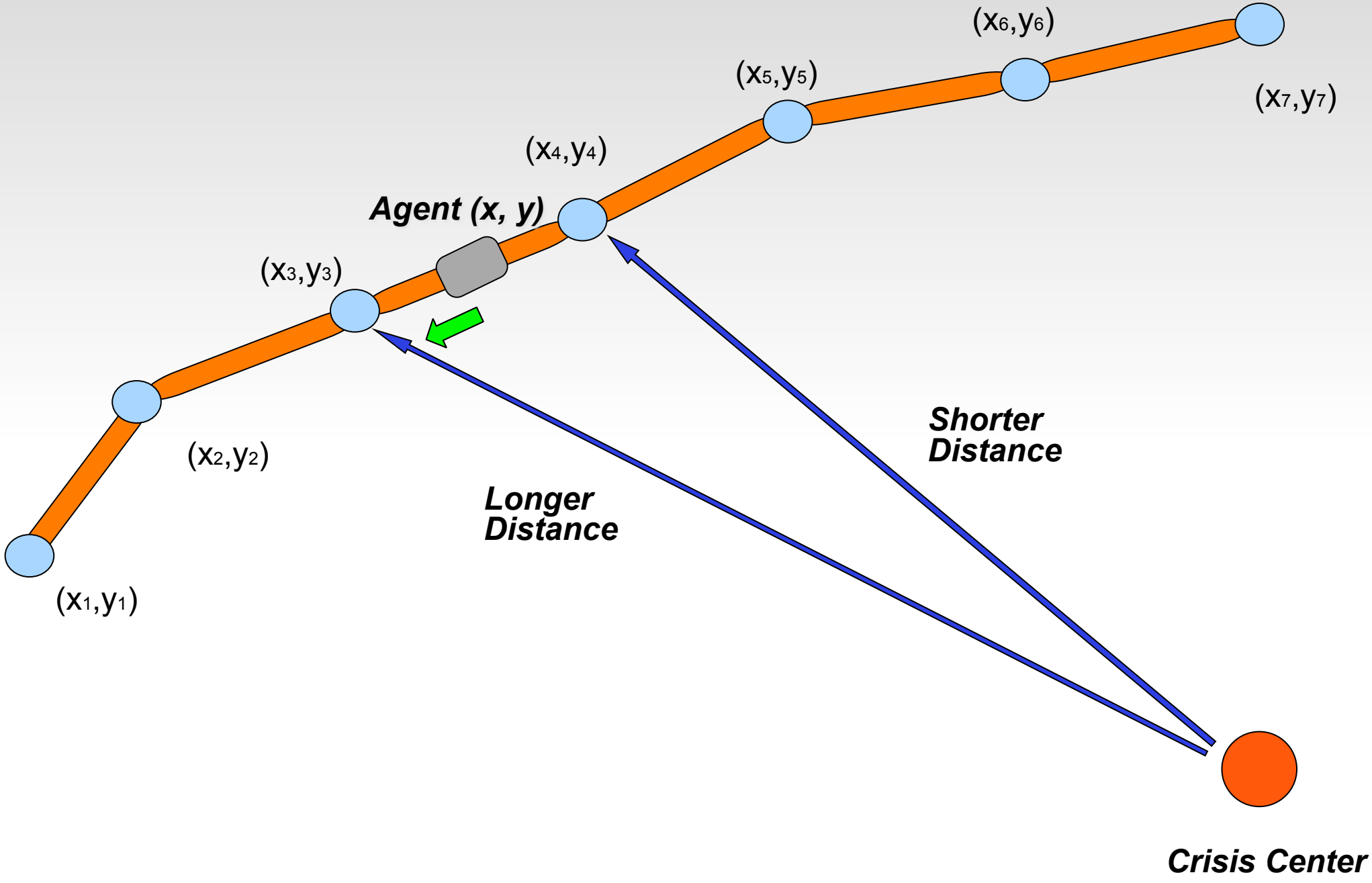
X: Latitude
Y: Longitude

(x_0,y_0)
(x_1,y_1)
(x_2,y_2)
(x_3,y_3)
(x_4,y_4)
(x_5,y_5)
(x_6,y_6)
(x_7,y_7)
(x_8,y_8)

Agent
(x,y)

Crisis Center

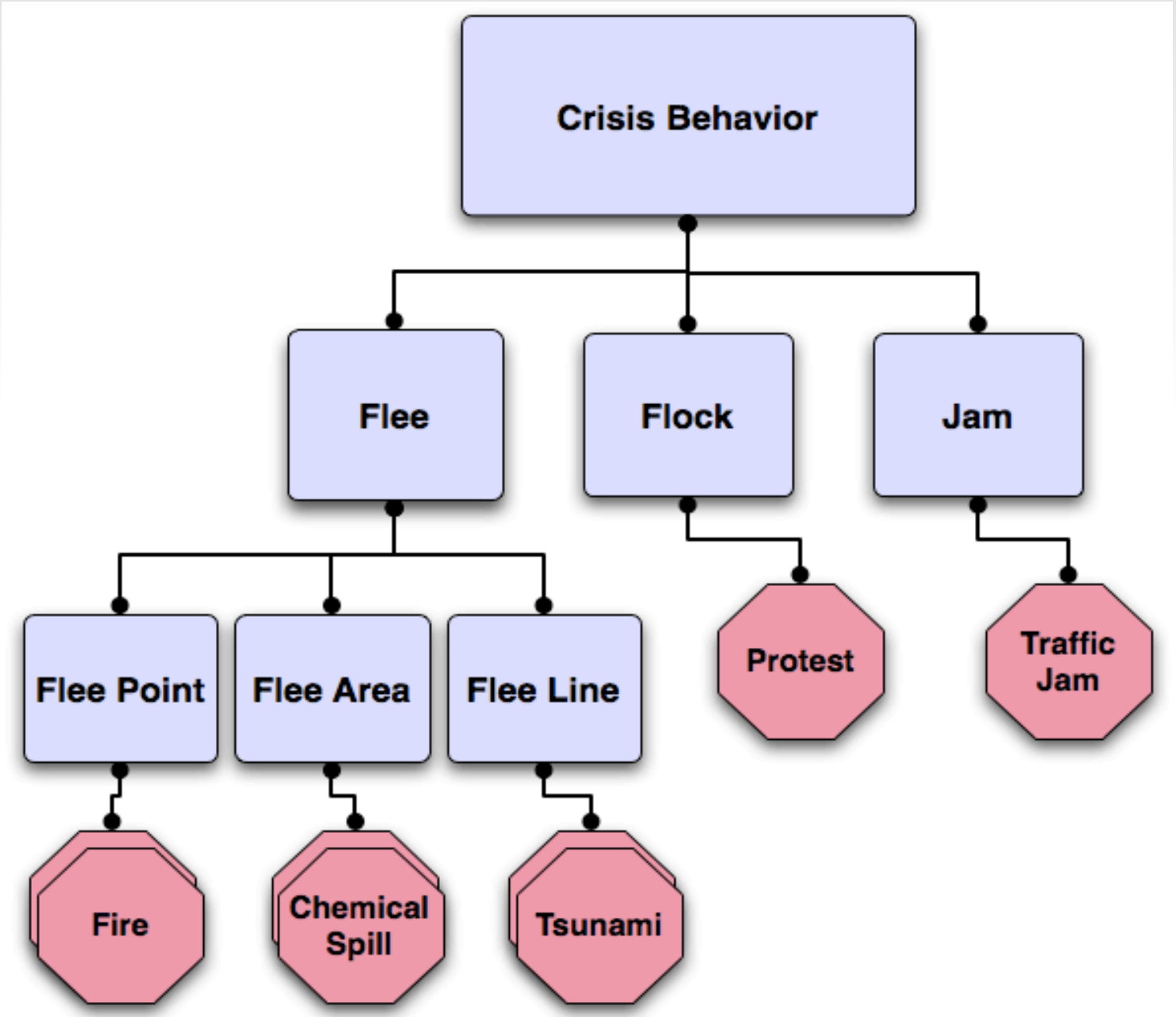
Get Coordinates
Find Shortest Distance
Move to Target


(x6,y6)
(x5,y5)
(x7,y7)
(x4,y4)
Agent (x, y)
(x3,y3)
(x2,y2)
Shorter Distance
Longer Distance
(x1,y1)
Crisis Center

Congestion Flee Movie

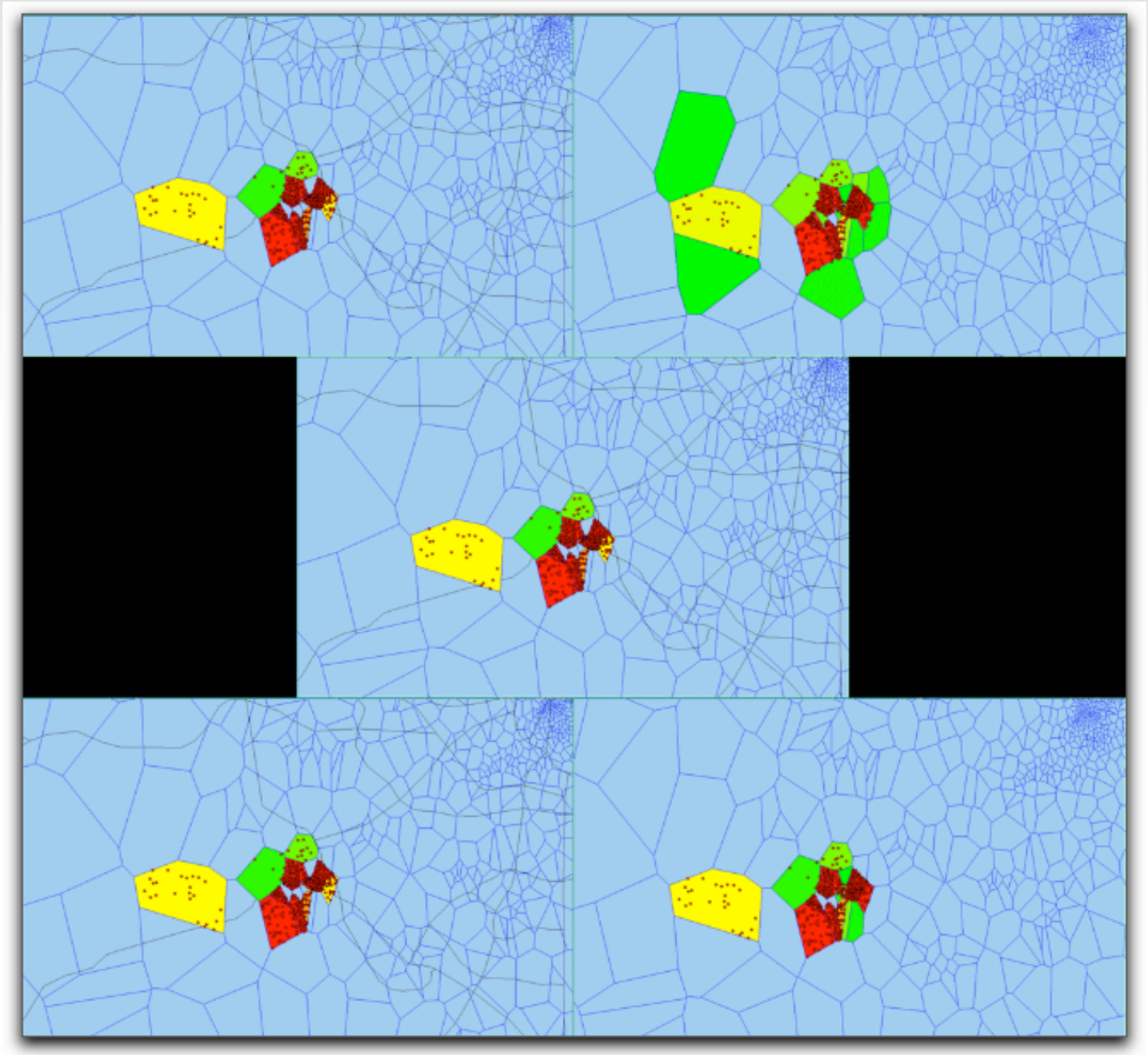
- Add movie here.

Crises Taxonomy



Animation

Sim 1 =>



<= Sim 2

Sim 3 =>

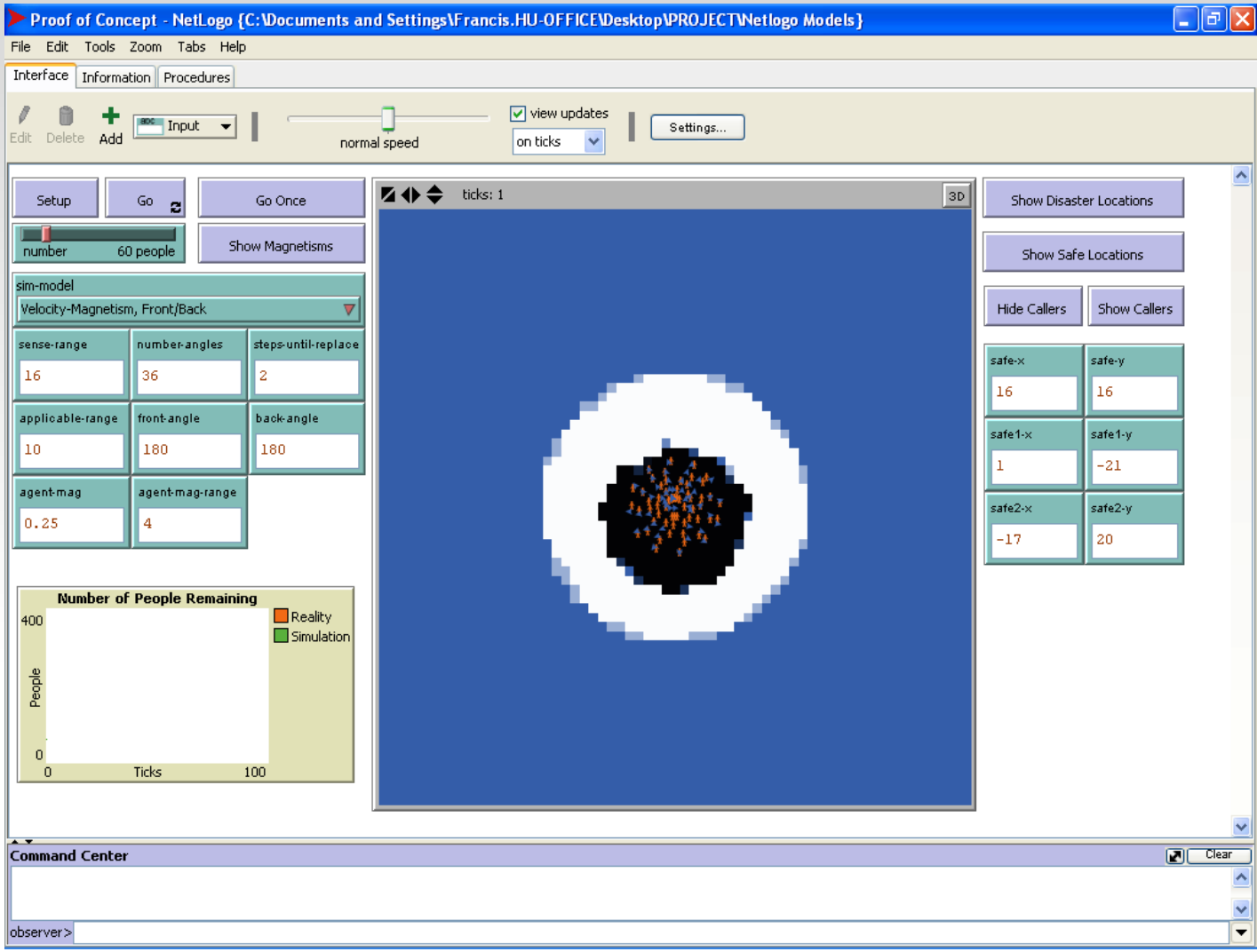
<= Sim 4

Reactive Pedestrian Model

Is built around cell phones as sensors; location and time are the only data used

Calculates attractive and repulsive regions for simulation

Is effective for all hazards



A snapshot showing beginning of the simulation; agents start in the middle. (White = attractive region, black = repulsive region)

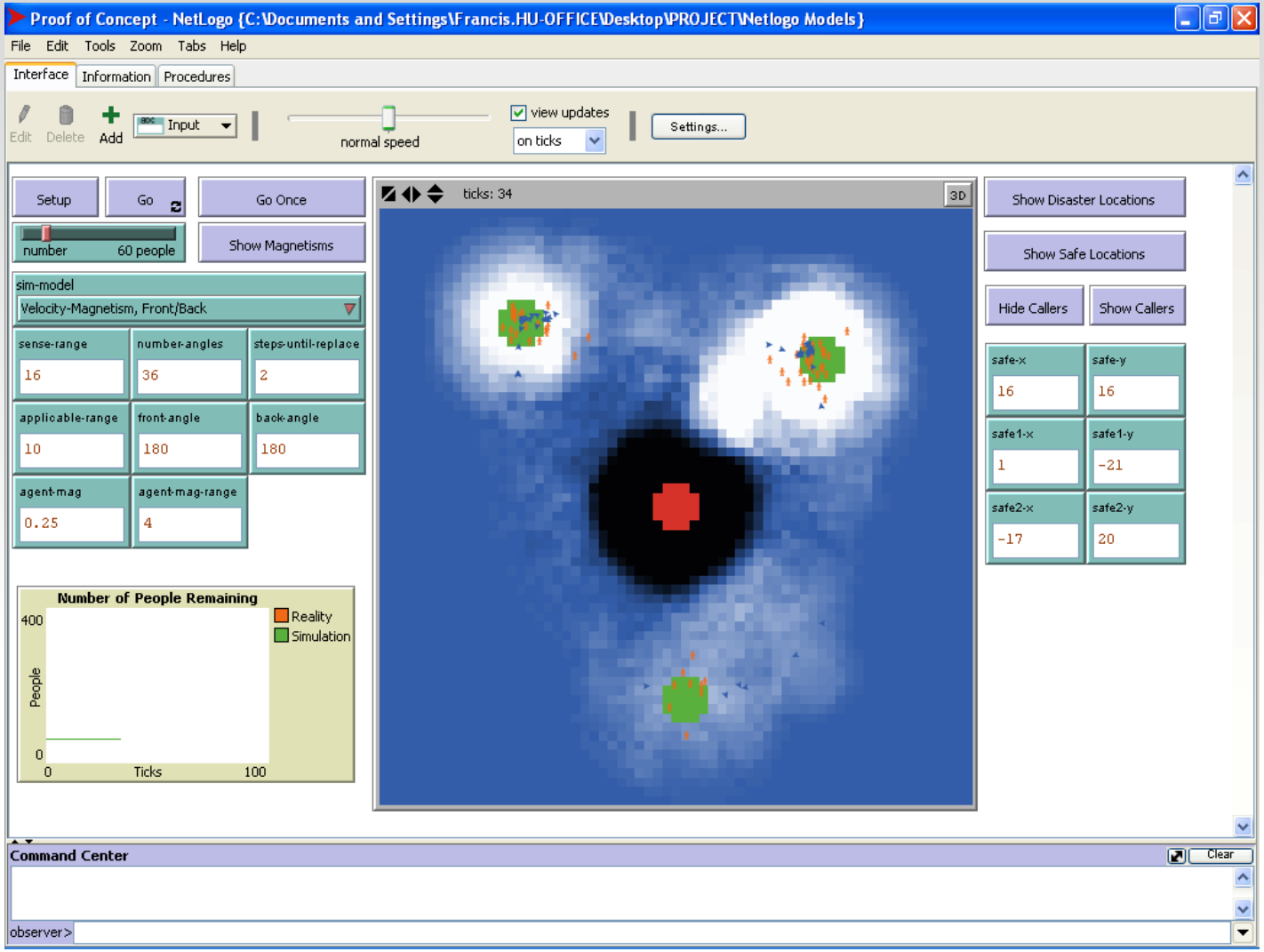


Fig. 2: A snapshot showing the simulation results after 34 “ticks” (time units). Calculated attraction and repulsion regions match locations of disaster (red) and safe area or destination (green).

Implementation

Java

RePast

OpenMap

GeoTools

Grass GIS

Acknowledgements

Ping Yan

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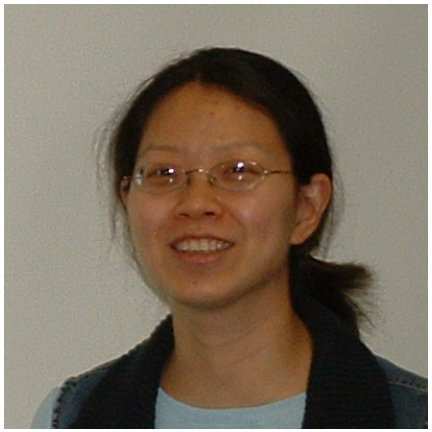

Conclusions

- Integrates GIS-enabled Agent-Based Simulations and visualization tools together
- More realistic simulation: accurate Geo-spatial constrains on agent behavior
- Enhance the decision making process of emergency management.

- Questions? Comments? Thank you!