Design and Implementation of an Agent-Based Simulation for Emergency Response and Crisis Management

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Introduction

WIPER

The *Wireless Phone Based Emergency Response System (WIPER) is* a prototype software system that provides emergency responders and planners with information on unfolding crisis events. WIPER is capable of real-time monitoring of normal social and geographical communication and activity patterns of millions of wireless phone users, recognizing unusual human agglomerations, potential emergencies and traffic jams.

DDDAS

Dynamic Data-Driven Application Systems (DDDAS) is based on an innovative concept for tightly coupling sensors into the simulation process. DDDAS Systems incorporate streaming data into running simulations and allow the simulations to influence the measurement process.

ABM

Agent-Based Modeling (ABM) is an approach to simulating social, ecological and biological systems where the system-level behavior is an emergent property of the interaction of many independent individuals (agents) with each other and the background environment, in which the agents may display complex behaviors and interactions.

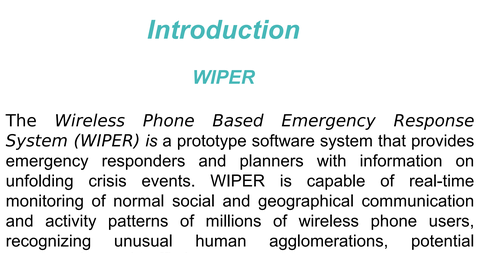

Fig. 1 Architecture of the WIPER Simulation

Simulation Tools

Eclipse	Open source software for running Java code
GeoTools	Loading geometrical information
Repast	Agent-based modeling toolkit
OpenMap	Display tool for geographic information
PostGIS	Works with PostgreSQL as a backend database
GRASS	Tool for geospatial data management and analysis
NetLogo	Rapid development for agent-modeling

Fundamental Models

Null Movement

A placeholder, implementing the move method but without causing the calling agent to actually move.

Random Movement

Agents move on the map in a random fashion.

Move And Return Movement

Agents travel from a home location to a work location and move back.

Basic Flee Movement

Agents flee from crisis site along a straight line.

Bounded Flee Movement

Agents stop after they reach a safe distance, as shown in Fig. 2.

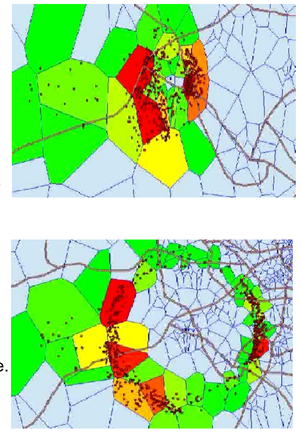

Fig. 2 Bounded Flee Movement

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. See Fig.6.

Extended Models

Road Flee Movement

When a crisis event happens, some agents will choose vehicles as their transportation method, so their moving routes are constrained by the road configuration. From Fig. 3, we can see vehicles are following the highways to flee from the crisis center.

Congestion Flee Movement

When a great number of vehicles simultaneously attempt to access limited road resources, a traffic jam will occur. In this model, the roads are given limited capacity and the agents physical size. If a car tries to move to its destination and no other cars are closer to that spot, the car would move at its full speed. Otherwise, it has to slow down and wait for other cars.

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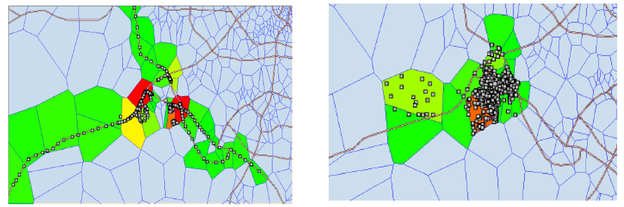

Fig. 3 Road Flee Movement

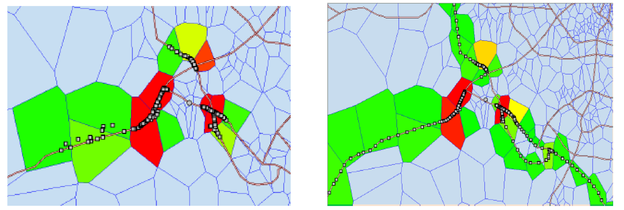

Fig. 4 Congestion Flee Movement

Mixed Flee Movement

During crisis events, when people are trying to flee, they may have several options: they can choose to drive a car, a truck, or simply run. So, a mixed flee movement model is meant to simulate this kind of mixed situation. In our model, we combine the basic flee (walk) and congestion flee (vehicle) model, creating a new model that incorporates both the pedestrian movement and vehicle movement as shown in Fig. 5.

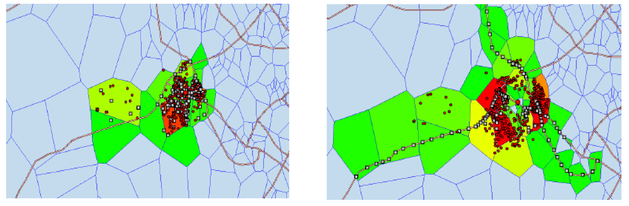

Fig. 5 Mixed Flee Movement

Reactive Pedestrian Model (Netlogo)

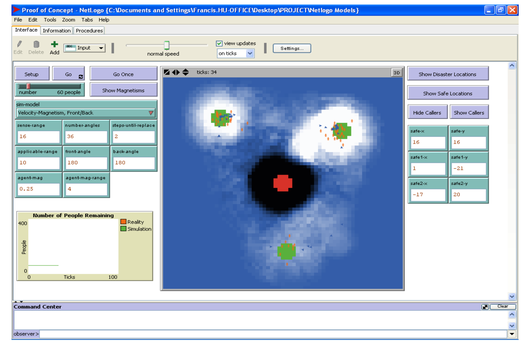

Fig. 6 A snapshot showing the simulation results after 34 “ticks” (time units). Calculated attraction and repulsion regions match locations of disaster (red) and safe area or destination (green).

Conclusions

WIPER integrates sophisticated GIS-enabled agent-based simulations and visualization tools together to enhance the decision making process of emergency management.

We provide a more detailed analysis and model of human activity patterns under different types of disasters. Written in Java, our simulation runs on Eclipse and is implemented in OpenMap and Repast 3. In terms of runtime performance, through a scalability exploration,we verified that the simulation meets our expectation in the time-critical emergency planning.

References

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