Intelligent Evacuation System for Flood Disaster

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May 19, 2012

Abstract

Finding the best evacuation path algorithm during an emergency situation due to a flood disaster is the object of this research. The challenge lies in how to manage this situation that has dynamically changing conditions and the strict time constraints. In this paper, we will propose an adaptive system for flood evacuation. This system gives the best decisions to be taken in this emergency situation to minimize damages. It computes the best evacuation routes in real time by executing an algorithm which takes into consideration the spatial characteristics of hazard propagation. The system, based on sensors network, is adapted to the changes of the environment and provide directions for the shortest and less hazardous routes to the users. © 2012 Research.

Key words: *Flood evacuation, Intelligent Systems, emergency navigation, Wireless Sensors Network, making decision, algorithms of emergency, agent based model, flood, real-time.*

1 Introduction

Natural Disasters such us flood inundation, earthquakes, tsunamis, hurricanes, fires, etc... in urban cities usually result in damages for people and environments. During these natural disasters, emergency teams find difficulties to plannify the operations of rescue, evacuation, control, etc... especially in an uncertain area which is subject to continuous changes. For exemple, let see an ambulance that want to evacuate a victim. As the ambulance goes to rescue him, it reaches a flooded road which can't be crossed and realizes that the flood blocked the evacuation path he has chosen. So, he goes back and try to find another evacuation path hoping it won't be hazardous. However, he has lost time seeking for safe path while the hazard has increased. These have shown the necessity for developing intelligent systems supporting evacuation. This research will focus on flood inundation and how to manage this disaster taking into account changes generated by the environment to minimize human and material damages. So, how can we planify optimally the rescue operations in this strict time constraint, dynamic changes of the environment and the variety of factors affecting the decision making?

2 Related work

In this paper, we propose a simulation system that provides real-time decision support during the strict time of emergency situations in flood disaster. This system is based on collecting information, coordinating with multiple entities, allocating available resources and rescuing victims. Our solution consists on integrating multi-agent simulator with wireless sensor network. Intelligent agents are used to represent various types of actors that interact inside a virtual world [5]. The Wireless sensor network is used to monitor the spread of hazards and the sensed data are used by the simulator [5]. In addition, our system is based on Outdoor navigation. So, Geographic Information Systems GIS are used to models the area concerned.

There is a considerable research in emergency simulation by using GIS multi-agent-based models. Around project (Autonomous Robots for Observation of Urban Networks after Disasters) is a complete simulation system for response planning in case of earthquake disasters in urban area. It is a model based on Hanoi GIS data. It relies on a fleet of autonomous and communicating robots, with multiple sensors and able to self-organize in order to collect data about damaged sites. This fleet is viewed as a Multi-Agents System (MAS) [11]. Hence, each robot is viewed as an agent, able to adapt itself to face evolutions of its environment, which is by nature, unpredictable and open.

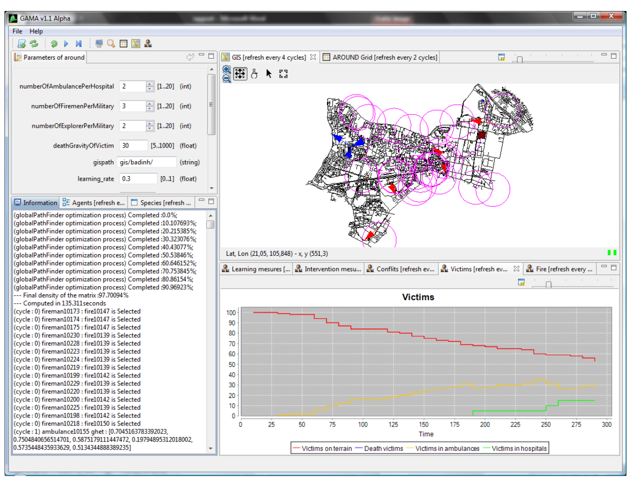

Figure 1: AROUND-Rescue Model using GAMA platform.

There is another simulation tool that implements emergency response during disasters. Robocup Rescue Simulation was designed to provide emergency decision support and simulate the rescue operations at the Hanshin-Awaji earthquake disaster. The challenge is to rescue as many civilians and buildings as possible after an earthquake disaster.

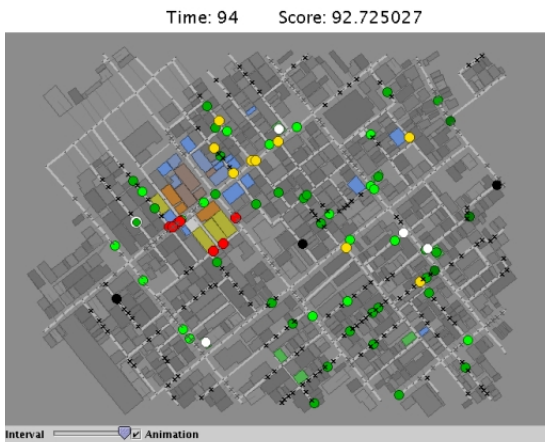

Figure 2: Robocup Rescue Simulation.

3 Simulation model

3.1 Geographic Information Systems (GIS)

The simulation environment should be based on GIS that contain a complete and reliable spatial data. The approach consists in drawing a parallel between the real environment and the simulated environment.
We use Geographic information Systems (GIS) street map of a specific region and convert it information into a graph. Each node represents a location where the road curves or where there is a choice of edges to travel on. Each edge represents a straight line of walkway or traffic road. People and vehicles are constrained to move only among the edges of the graph[10]. Edges can be unidirectional or bidirectional. The location of buildings is approximated to the nearest node on the graph.

3.2 Actors in real world

Flood inundation results in human damages (injured and dead people) and property damages (equipment, vehicles, buildings, ...).
Fires can take hold, buildings can be flooded, infrastructure is deteriorated and damaged, roads are blocked due to floods, traffic jams or accidents, victims are drowned or injured, civilians are seeking for refugees. The organization of rescue operations is performed by police, fire brigades, ambulances, explorer, helicopter...

Therefore, the actors are composed of: victims, ambulance, fire brigade, police, explorer, hospitals, civilians, refugees, vehicles, animals, fires, ...

Figure 3: Actors in flood disaster

3.3 Agents in simulation world

These actors in real world need representatives in simulation world to perform some tasks for them. These representatives should inspect the area, evaluate the danger and interact with other representatives to cooperate and coordinate. So, agents would be the best representatives who can perform these tasks.
In the real environment, knowledge is limited since actors misperceive the spatial data in real world. But, the simulation environment closes this weakness. Agents are able to perceive and monitor the environment. Therefore, every actor in real world will be represented by agent in simulation world.
Every agent has his own role for example fire brigade agents extinguish fire and ambulance agents help injured and bring them to hospitals.

3.4 Wireless Sensors Network (WSN)

In this paper, we introduce a novel approach for automatic detection and assessment of damaged roads in urban areas using wireless sensors network. These sensors are used to monitor the hazard that can occur on road transport networks and determine road damages degree. The hazard can occur in case of different events. These events can be divided into two categories: external events related to road transport in wintertime such as ice formation, snow, floods... and internal events caused by traffic such as accidents, congestion...
The sensors can be viewed such small computers extremely basic in terms of their interfaces and their components. They integrate a unit of environmental data acquisition (temperature, precipitation, humidity...) that can be transformed in numerical quantities, a processing unit with limited computing power and limited memory, a communication device (radio transmission) and a battery. They cooperate with each other to form a communication called Wireless Sensors network.
In real world, these sensors are deployed in the area concerned to monitor the hazard while they are represented by hazard agents in simulation world.
So, the sensor network models the danger levels sensed across every hazardous

area and gives the user the ability to navigate to the goal region by avoiding this areas.

3.5 Multi-agent System (MAS)

Our Multi-agent system is described as:

$$\text{System} = \{\text{T, A, E, S, P}\}$$

T: Task or activity that emergency centers try to solve at flood disaster such as evacuating a victim, rescuing a property, extinguishing a fire.
A: Agents such as ambulance team, fire brigade, victims, police, etc... These agents simulate human conditions and are called human agents. There are others that represent sensors which explore the environment and are called hazard agents.
E: Environment where agents act such as road networks.
S: Physical sensors. These sensors are used to monitor the environment and control the hazard intensity.
P: Actions or protocols that agents can be used to communicate with each other or interact with the environment.

4 Proposed model

In this section, we expose the solution related to our problem described above. We begin by presenting our model. Then, we describe the algorithm proposed.

4.1 Description of the model

We present an evacuation route algorithm which is adapted to specific dynamic situations under the flood disaster. My work is inspired from [1] and [2]. We assume that our environment is represented as a graph G(V,E). This graph is based on Geographic Information System data. Vertices V are the intersection between two roads or terminal extremity of a road while edges E represent the physical path that can be taken by the civilians.

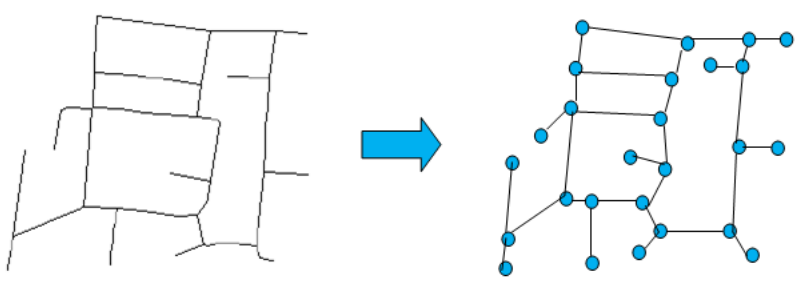

Figure 4: GIS network and Graph representation

Sensors are used to monitor the hazard and determined road damages degree. Each sensor is associated to a link (i,j) and measures the hazard intensity H(i,j) along the link.

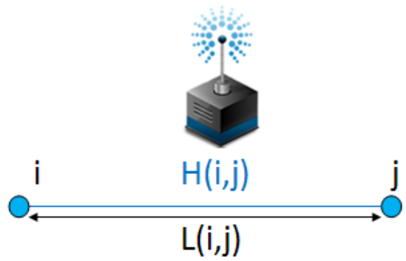

Figure 5: Sensors that monitor the hazard intensity in a link between two nodes

Edges have multiple characteristics: edge length l(i,j) which is the distance between vertices i,j , H(i,j) which is the hazard intensity along this edge, T(i,j) which define the possibility to use this edge by the current type of user and L(i,j) which is the coast of this edge. Note that:

$$\mathrm{L(i,j) = l(i,j) \ x \ H(i,j) \ / \ T(i,j).}$$

H(i,j) = 1 if there is no hazard and it increases with the observed hazard. As the value of H increases, the edge becomes more hazardous to traverse. If the road is completely damaged then H(i,j) = ∞ . The value of L(i,j) will change only when the hazard value increases along this link.

$$H(i,j) = \begin{cases} 1 & \text{if no hazard} \\ \infty & \text{otherwise.} \end{cases}$$

T(i,j) = 1 if the road can be taken by this type of user and T(i,j) = 0 otherwise.

$$T(i,j) = \begin{cases} 1 & \text{if the current type of user can take this edge} \\ 0 & \text{otherwise.} \end{cases}$$

For example, there are some roads that can be taken only by small vehicles whose height doesn't exceed a certain value such as tunnels, bridges. In addition, there are some roads for pedestrians such as sidewalk, crosswalk. Therefore, the type of user is an important parameter. If the user can take a specific road, T(i,j) = 1, then L(i,j) = l(i,j) x H(i,j) .

4.2 Description of the proposed algorithm

We describe the decision support algorithm that will be used in our system. We propose a distributed shortest path algorithm which is similar to principals developed in [1] and [2] but adapted to flood disaster.

This algorithm is based on Dijkstra for calculation the shortest path. It is executed by each node and the output is the next node, called the Decision Node, which is on the best available path to the destination. Each decision node u stores the following information:

- The effective length L(u,n) to every neighbor of u.
- The effective length L(n,d) of the path from every neighbor to the destination.
- The effective length L(u,d) of the shortest path from u to the destination.
- The next suggest Decision Node which is the output.

The algorithm:

```
Function NextDecisionNode(u)
    for all n do
        Send L(u, d) to n
        Get H(u, n) from Sensor
        Calculate L(u, n) = l(u, n) x h(u, n) / T(u,n)
    end for
    Update L(u, d) = min{L(u, n) + L(n, d)}
    Set u = argmin{L(u, n) + L(n, d)} = next suggest node
    Result go to v
end Function
```

In the begining of the algorithm execution L(u, d) = 0.
Because of the quick changes of the environment, the Decision Nodes will periodically execute this algorithm, update the distance information and communicate the most recent valid advice to neighbouring evacuees or other active entities such as rescue personnel.
The suggestion will be of the form "go to v" [1].

4.3 Study case

In this section, we describe a rescue scenario of a flood disaster:

Situation: Floods occur in a city. One person is drowning. He is calling for help.
Map: The road network and buildings of the city are presented by 2D map generated by GIS.
Sensors: A wireless sensors network is installed in the road network to monitor the hazard that can occur.(flooded road, collapsed road...).
Agents: The agents of this situation are: victim (the drowned person), firebrigade, sensor agents.
Activity: firebrigade rescue the victim.

Description:

The victim is blocked in the flooded road. He is calling for help. The system locates the victim via GPS and informs the closest and available firebrigade about his position to rescue him. The firebrigade receives the information and goes to evacuate the victim.

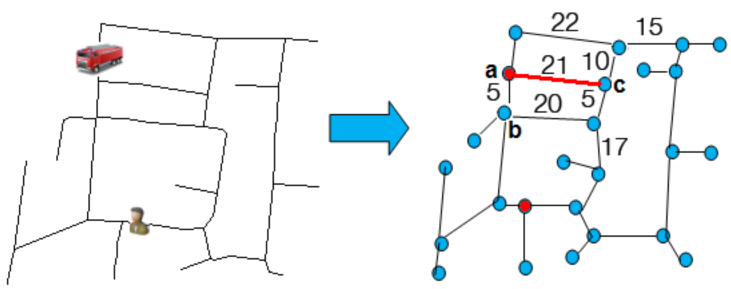

Figure 6: Scenario

The firebrigade uses the system to find the shortest and less hazardous route. The system executes the algorithm proposed above to find the path. This algorithm gives the shortest and safest route taking into consideration the dynamic changes of the environment via sensors that give the hazard intensity in real time.
As the firebrigade goes to evacuate the victim, the road (a,b) becomes flooded. The sensor, located in road (a,b), gives information to the system about the hazard intensity in this edge. So, $H(a,b)=\infty$. The system takes into account this value while executing the algorithm to calculate the best route towards the victim.
The roads (a,b) and (a,c) can be taken by any type of user.
So, $T(a,b)= T(a,c)=1$. Therefore, $L(a,b)=\infty$ and $L(a,c)=l(a,c)$.
The system executes the function described above at each decision node and suggests to firebrigade the optimal path to the victim. When the victim is evacuated. The firebrigade informs the system.

5 Proposed Architecture

We propose a system based on four layers for this emergency situation. This system makes a relation between the real environment and the simulation environment. The architecture that we propose is inspired from [12].

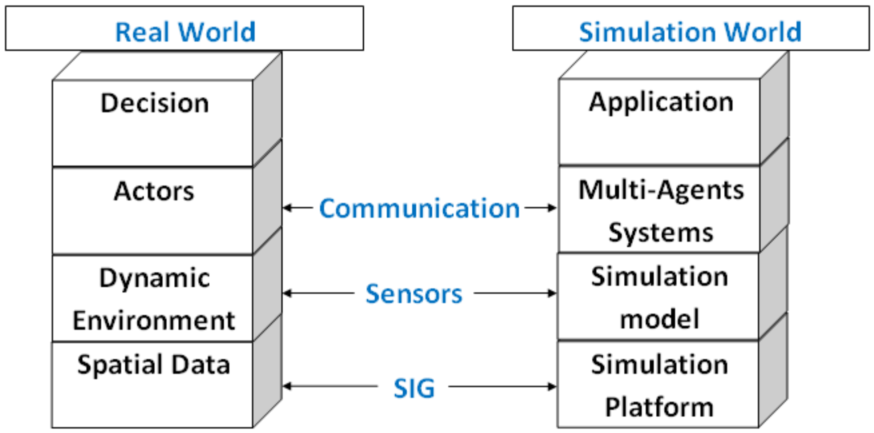

Figure 7: Architecture System

Simulation platform layer (GAMA) :
GIS is necessary to model the real spatial data. So, we should model this GIS data using a simulation platform. We propose the use of GAMA platform which provides a complete modeling and simulation development environment for building spatially explicit agent-based simulations.
advantages of GAMA:

- It is an open-source project.
- It gives the ability to use complex GIS data as environment for the agent.
- It gives the possibility to run simulations with vast numbers of agents.
- It can work on different Operating Systems (Window, Linux, Mac).

Simulation model layer:
The real environment is subject to continuous changes due to flood disaster. The simulation model refects this dynamic changes. The input data of this model is updated as the evolution of the situation. Sensors are used to ensure the updating of the data. These sensors, located in real environment, monitor the area and communicate the sensed data periodically to the simulator.

MAS Layer:
Every actor in real world is represented by agent in simulation model. The agent can perceive the environment, communicate and coordinate with other agents.

Application layer:

This layer represents the application of flood management. It consists on planification of rescue operations during flood disasters and providing the user with the best decisions to be taken in this emergency situation.

6 Conclusion

In this paper, we have proposed an intelligent evacuation model during a flood disaster. We have presented the model and described the algorithm proposed for calculating the shortest and safest path towards the destination to evacuate persons, go to refuges etc... This solution is based on Dijkstra algorithm and takes into consideration the dynamic hazards occurring in the environment. The result is communicated to the evacuees via wireless devices. Finally, we have illustrated the architecture of the system and described each layer.

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