Demonstration: Disaster Evacuation Support

Christopher J. Carpenter   Christopher J. Dugan   Joseph B. Kopena
Robert N. Lass   Gaurav Naik   Duc N. Nguyen
Evan Sultanik   Pragnesh Jay Modi   William C. Regli

{cjc54, cjd48, tjkopena, gnaik, urlass, dn53, eas28, pmodi, regli}@cs.drexel.edu
Secure Wireless Agent Testbed
Drexel University
Philadelphia, PA, USA

1. INTRODUCTION

Evacuation or sheltering of neighborhoods, cities, or regions is a major component of responding to any natural or other disaster. Poorly chosen and uncoordinated destinations can quickly overwhelm shelter capacities. Insufficient knowledge and decision processes may also lead to mismatches between evacuee needs and shelter capabilites, such as advanced medical units. Unfortunately, the intuitive and easy response of moving evacuees to the closest refuges can easily lead to this situation. This work attempts to address this problem by developing tools and techniques to help emergency personnel create a shared and accurate understanding of the situation, make the best decisions for the group, and effectively conduct disaster evacuations.

A central premise is that there are area wardens or emergency personnel leading groups of evacuees to available shelters. These authorities are equipped with handheld, networked devices to monitor and coordinate actions. Figure 1 depicts an example scenario. There are several groups of people and available shelters within the local area. Each group has several traits such as size and medical needs. Shelters mirror these with capacity and medical capabilities. The problem is that of assigning groups to shelters in a globally optimal fashion, i.e. not overcrowding any shelter, and not wasting available medical resources.

This demonstration presents an application of distributed constraint optimization and wireless networking to this task. The system assists the emergency personnel in directing evacuees to safety points by:

- Keeping them informed of the current situation, e.g. shelter and group sizes and locations.
- Sharing situational data, e.g. to note group sizes and needs as well as shelters discovered to be unavailable.
- Aiding users in making decisions by suggesting destinations coordinated with other users to generate group optimal decisions based on the known situation.
- Help users implement and monitor those decisions.

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For this demonstration, the system is built on handheld computing devices—tablets or PDAs—communicating wirelessly over a mobile, ad hoc, Wi-Fi network. Such networks enable significant data exchange without infrastructure such as wires or access points, adapt to changing conditions such as host movement, and operate over moderate geographic distances. However, such networking presents challenges distinct from traditional networking, such as high latency, data loss, and frequent connectivity disruptions.

Some of the major points of this work include:

- Initial development of a new application area for distributed constraint optimization.
- The first investigation into properties and optimizations of distributed constraint optimization in the high latency, high loss environment of wireless networking.
- Adaptation of distributed constraint optimization for on-the-fly, continual solving in a dynamic world.

The following sections will briefly describe some related work and sketch out more details of this demonstration.

2. RELATED WORK

The application of planning to evacuation operations has been studied in several projects, such as [2]. Most work in this area is focused on centralized, *a priori* development of plans and procedures. In contrast, the work here focuses on supporting the actual conduct of such operations via situational data exchange and distributed decision making aids. These are largely complementary areas. A priori plans are an assumed input here, e.g. candidate routes and destinations, while emergency response planning tools may make use of systems such as that presented here to monitor execution and conduct decision-making.

Work also exists on the use of sensor networks for emergency navigation, such as [3]. The focus is generally on sensing hazards such as fire and gasses, determining a route around the obstacle, and using environmental signals such as lights to safely route people toward safety. This is also largely complementary work to that presented here. Such navigation systems are generally based distributed path planning or network routing and operate at a low level of detail, navigating around obstacles. The work here aims to reason on more abstract properties such as available space and medical capabilities, which could very well then rely on emergency navigation systems to help carry out decisions.

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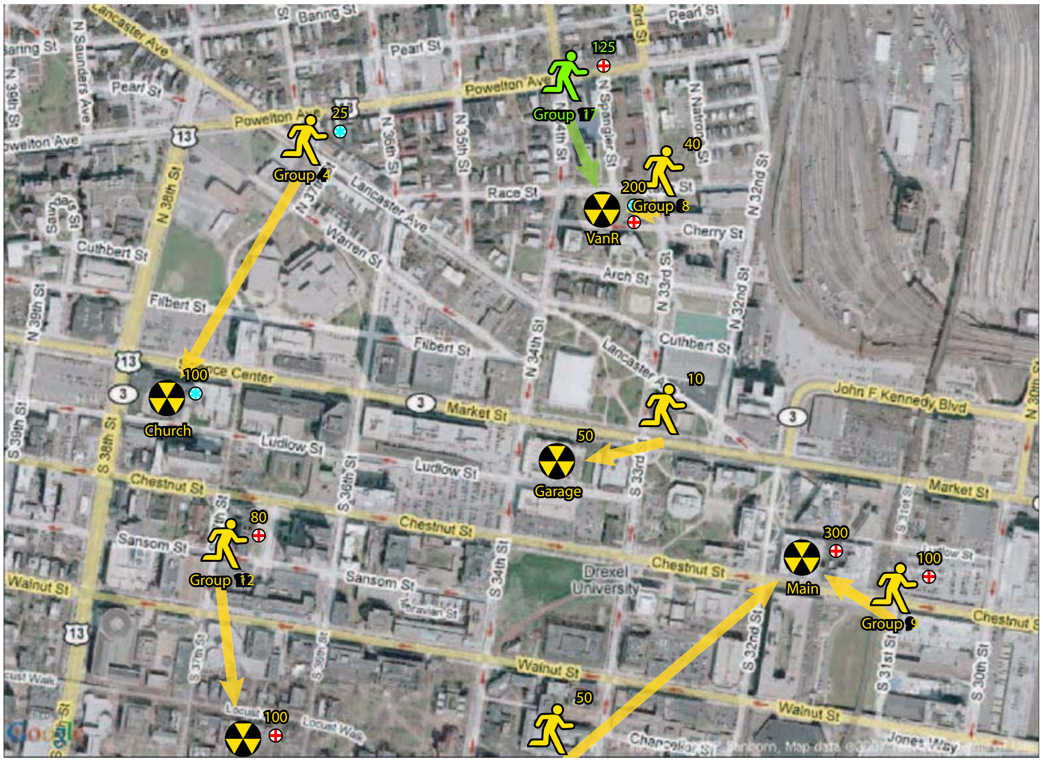

Figure 1: Example neighborhood sheltering scenario and possible shelter assignments.

3. TECHNICAL CONTENT

The primary artificial intelligence components of this demonstration are the agents which act on their behalf of their users to monitor the situation, coordinate decisions, and provide guidance on optimal destinations and routes. This task is represented and solved as a constraint optimization problem. Variables are evacuation routes and destinations, constraints include route and shelter capacities, and optional costs include time traveled, sites used, and shelter crowding, among others. Central to this is the use of Adopt [1], an optimal, distributed constraint optimization solver. Decentralized solving reduces infrastructure and networking requirements, an important goal in this application, and improves robustness by eliminating the need for distinguished nodes.

This is a new application of distributed constraint solving, and is an example of its applicable to real life problems. The use of wireless, ad-hoc networks as the communications medium for the distributed constraint optimization is also novel and poses a new set of challenges for the solving process. Behind this demonstration is research extending Adopt and constraint optimization for these kinds of settings by:

- Incorporating network knowledge into the solving process to reduce communication costs.
- Supporting a dynamically changing world, adapting or re-solving as the world state evolves.
- Increasing fault tolerance by detecting and responding to the loss of computation nodes.
- Incorporating networking research into the algorithm to operate under high latency and packet loss.

4. CONCLUSION

This demonstration presents an application of distributed constraint optimization to developing tools for disaster response and evacuation management. Requirements of this application such as decentralization and coordination make it a natural fit for such an approach. However, the underlying communications capabilities and dynamic nature of the world pose several challenges for distributed constraint optimization algorithms and implementations developed to date. The goals of this demonstration system are both to present initial work on meeting these challenges as well as to provide a platform to explore and develop improved solutions.

5. REFERENCES

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