Collaborative Navigation in Virtual Search and Rescue

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ABSTRACT

Disaster relief responders aim to quickly locate and extract survivors from dangerous environments. This research explores the use of a collaborative guidance system for search-and-rescue in a complex building. We implemented and evaluated a proof-of-concept system that allowed a scene commander and responder to efficiently search a building using visual, nonverbal communication. Participants found the interface to be both intuitive and fun, and results suggest that the collaborative navigation system was effective.

KEYWORDS: Virtual and augmented reality, navigation, collaboration, disaster rescue, search and rescue

INDEX TERMS: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

In designing a collaborative navigation task for the 2012 3DUI contest, we chose to focus on a real-world scenario of disaster relief. In building disasters (such as with fires and earthquakes), hazards and structural damages require constant changes to path planning and cause difficult navigation in 3D spaces. Our task specifically looks at communication between a scene commander and a disaster relief responder during a search and rescue operation. The *responders* inside the environment have great difficulty navigating because of hazards, reduced visibility, disorientation, and lack of survey knowledge of the environment. Observing the operation from outside of the disaster area, *scene commanders* work to help coordinate the response effort [1, 2]. With the responder's notifications about the environment, scene commanders can provide new instructions, alert the responders to risks, and issue evacuation orders. Since neither the commander nor the responder has complete information about the environment, effective communication is essential.

As technology advances, the incorporation of new tools into search and rescue protocols shows promise for improving operation efficiency and safety. In this research, we explore the use of 3D user interfaces to assist collaborative search-and-rescue. Ideally, users should be able to focus on their primary tasks in the VE, rather than struggle with travel and wayfinding. Using virtual reality (VR) as a prototyping testbed, we implemented a proof-of-concept collaborative guidance system. Preliminary evaluation has demonstrated promising results for efficient rescue operations.

2 INTERFACE DESIGN

In our system, a scene commander and disaster responder communicate to each other by simple marker placement and graphical notifications. The goal for the search-and-rescue exercise is safe and efficient search of a building during a disaster. The commander's task is to guide the responder through the building, while the responder finds survivors and points out environmental hazards and blockages to the commander. Thus, in this design, the guidance system has two main components: the commander view and the responder view. The commander view corresponds to a virtual 3D blueprint layout of the building (see Figure 1). The responder sees the actual disaster environment from a first-person view (see Figure 2). The commander and responder views are both updated in real time based on their actions and commands.

Figure 1. Commander view. Markers and path markers supplement the model of the building structure.

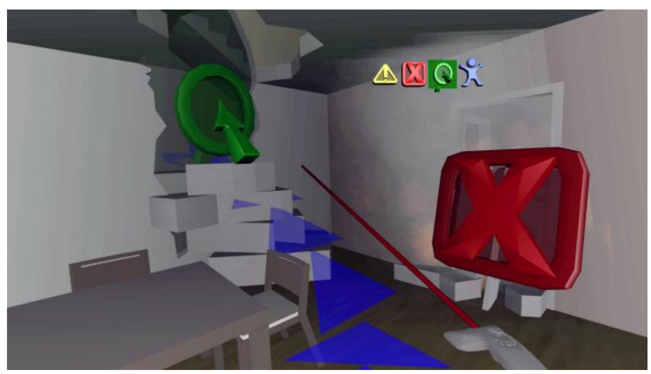

Figure 2. Responder view in the HMD. The blue arrows show the path, the red X marks a blockage, and the green symbol marks a new passage.

2.1 Commander View

This prototype assumes that the commander has a 3D model of the disaster building's architecture, as could be constructed based on the building's blueprints. The building view is separated by floors and can be rotated with the mouse (see Figure 1). The scene contains an avatar to show the position and orientation of the responder (assumed to be possible through appropriate sensor technology). Areas of the building that have been traversed by the responder are highlighted in green to help track search coverage.

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The commander's job is to guide the responder through a complete and efficient search path through the building by placing virtual waypoints to guide the responder's navigation. The commander can indicate locations on the floors to place waypoints, which are connected by a string of blue arrows. Each waypoint automatically disappears when the responder moves close. The commander can also delete waypoints manually.

However, because the commander's view only shows the original state of the environment, it does not account for structural changes or hazards that may have been caused by the disaster (e.g., collapsed walls or floors). Virtual markers on the model (provided by the responder) show such structural changes and allow the commander to adjust the responder's search route. For example, if the responder indicates that a path is blocked, the commander can re-route the responder via a different path to the target destination. Virtual markers provided by the responder also show the locations of victims in the commander view.

2.2 Responder View

The responder view is a first-person view within the building. The structural environment is augmented with the semi-transparent 3D blueprint model used by the commander. This allows the responder to easily identify discrepancies between the actual building and the commander's model of the building. The responder can place virtual markers to communicate these discrepancies (as well as environmental hazards and locations of victims) to the commander. Our prototype includes four types of markers: hazards, blockages, new paths, and victims. Responders use raycasting to place markers on surfaces of the environment.

The responder also sees the disaster environment overlaid with virtual guidance arrows that connect the waypoints placed by the scene commander. The guidance arrows always begin at the responder's feet and lead to the next waypoint in the route. Guided by the waypoints, the responder is able to travel without worrying about wayfinding and path planning.

3 Experiment

We performed a preliminary study to evaluate the effectiveness of the system design.

3.1 Task and Environment

The experiment task was to completely search all rooms in a four-story building. Each floor was approximately 160m^2 and the building contained a total of 39 rooms. Prior to the disaster, the building contained two stairwells connecting the floors; however, due to collapsed floors and hazards, not all floors were accessible by stairway. The disaster also introduced new holes in the floors and walls, which created new paths for traveling between rooms and floors. Figure 2 shows examples of a collapsed wall and a new opening (both tagged with virtual markers). The building contained 13 victims spread throughout all floors. There was animated fire, smoke, and falling debris through the entire building. Additionally, burning, creaking and crashing sounds added to the ambience of the scenario.

3.2 Apparatus

Each evaluation session was conducted with two participants (a responder and a commander). The commander viewed the scene on a 42" TV and interacted with a keyboard and mouse. The responder used a head-mounted display (HMD) and a wand with buttons and a joystick. Headphones played 3D positional sounds. Physical 360° view rotation was enabled with the tracked HMD (physical translation was disabled). Responders could also virtually rotate and translate by using the joystick. Using the 6DOF tracked wand, responders used raycasting to place markers. The HMD station and TV station were located in different physical rooms to prevent verbal communication.

3.3 Participants

Four pairs of participants attempted the search and rescue task. However, one pair dropped out due to simulator sickness from the HMD, leaving three pairs that completed the entire exercise. Participant ages ranged from 25 to 60, and three participants were female.

3.4 Procedure

Participants completed a background questionnaire and were instructed on the collaborative task. They were then separated into different rooms and were given further instructions for their specific roles. Participant pairs then practiced the search-and-rescue exercise in a sample disaster environment (different from the primary task environment). After completing the primary task, participants were interviewed separately, and then brought together for a joint interview.

3.5 Results and Discussion

All pairs completed the task with relatively high rates of search coverage and victims found (see Table 1). The results suggest that the collaborative navigation system was effective for searching.

Table 1. Experiment Results. Participant pairs had high rates of search coverage and target identification.

Pair	Time (m)	Distance Traveled (m)	Victims Found (%)	Coverage (%)
1	16.3	728	100	100
2	10.3	452	92.3	94.87
3	14.7	785	100	94.87

Participants reported that the commander view was intuitive and straightforward for guiding the responder and planning paths. Participants reported that it was fun and satisfying to see the responder successfully follow the planned path and to help them find victims. The responders reported that although the environment was disorienting, the guidance arrows simplified navigation and helped them to find unexplored areas. Responders felt that they were able to focus on searching for victims along the path instead of keeping track of which areas were explored and which needed to be searched. Participants also reported that it was effective and fun to place markers to communicate to the commander.

Even though the 3D environment was complicated with many blockages and new openings, the visual communication allowed participants to complete the task efficiently and with a high level of accuracy. The results suggest that collaborative guidance tools with visual communication could have positive effects on real-world search-and-rescue operations. In future work, we will compare our visual guidance system to verbal communication systems (such as that presented in [2]), and investigate various visual communication methods.

References

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