Location-Aware Augmented Reality Gaming for Emergency Response Education: Concepts and Development

Zachary O. Toups
Interface Ecology Lab | Computer Science Department
Texas A&M University
College Station, Texas 77843, USA
toupsz@cs.tamu.edu

Andruid Kerne
Interface Ecology Lab | Computer Science Department
Texas A&M University
College Station, Texas 77843, USA
andruid@cs.tamu.edu

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Abstract
This paper describes the design and development of a location-aware augmented reality game designed to help fire emergency response students learn embodied team coordination skills. This work incorporates design implications from a fire training school ethnography to develop a game design. It addresses how game design affects the participant experience, and helps teach team coordination skills. Emphasis is placed on the iterative design process, and how emerging ethnographic data has resulted in ongoing evolution of the game design.

Keywords
Location-aware games, game design, emergency response

ACM Classification Keywords
H2.5. User-centered design.

Introduction
Using a location-aware augmented reality game to teach firefighters team coordination skills is a new application for mobile spatial systems. We are developing such a system, a game called *Rogue*

Signals. *Rogue Signals* will utilize head-mounted displays, global positioning receivers (GPS), speakers, radio, and a backpack-mounted computer to create an immersive game environment in which players will need to coordinate effectively in order to be successful.

Our game design is informed by an ongoing ethnography of fire emergency response work and training practice. It mirrors certain aspects of this practice. Through close contact with the Emergency Services Training Institute (ESTI), we have developed design implications for teaching emergency response students to coordinate: leveraging information differential, mixing communication modalities, and utilizing audible clues [1]. We develop a design for a location-aware augmented reality game that uses these implications to support fire emergency response education. We plan to develop this game, and deploy it using fire emergency response students as subjects to gauge its effectiveness for training coordination skills.

Game Overview

In *Rogue Signals*, human players work together as a team to find artifacts hidden in the real world while avoiding computer-controlled *predators* in a virtual world overlay. The team is split into two parts that can communicate using radio: several seekers and a coordinator. The *seekers* look for the artifacts, while being tracked using GPS and a wireless network. Their real-world positions are mapped to virtual world overlay positions, so that they concurrently exist in the real and virtual worlds. While seeking real objects, they must avoid virtual hazards. Their view of the virtual world is local and indirect.

The *coordinator* has no direct access to the real world, but instead can observe a global view of virtual world. This player can see the relative positions of the seekers, the predators, the real-world artifacts, and other virtual objects. In order to discover what is actually happening in the field, the coordinator must get information from the seekers, and must guide them around the virtual obstacles to the goals.

Rogue Signals is being developed iteratively, with an early design described in [2]. We have created a series of low-fidelity and functional prototypes. The functional prototypes simulate the game terrain and employ a workstation interface.

Incorporating Design Implications

Through interviews and observations, we discovered aspects of fire emergency response practice that rely on coordination skills. In this section, we develop design implications based on building these skills, and explain how they are being incorporated into the design of our location-aware augmented reality game.

Leveraging Information Differential

In fire emergency response, teams operate with heterogeneous pieces of an information picture. These pieces must be put together by each individual at the scene, in order to make sense of the situation. Dealing with information differential, requires sharing the information needed by other team members. At the same time, the limited communications bandwidth of the shared radio channel must be conserved. This is a critical skill for fire emergency responders. As part of this, fire emergency responders use overhearing, listening in on radio communications directed at others, to acquire a mental model of the remote situation. [1]

Figure 1. Coordinator interface from the current version of *Rogue Signals*. Artifact uncertainty areas are highlighted in yellow. Andruid and Ross are looking for an artifact while Zach tries to lead the predators away.

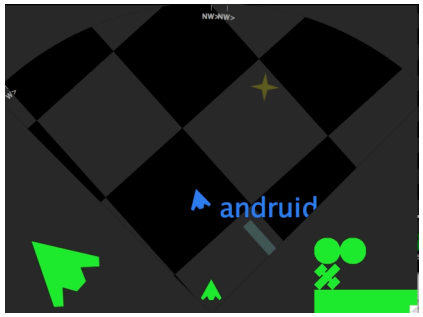

Figure 2. Ross's view, spotting the artifact.

Rogue Signals was originally designed with information differential in mind [2]. Each side of the team knows about different parts of the game, and these parts must be put together in order to succeed. Our pilot studies on the original game design indicated that information was flowing only from the coordinator to the seekers ("Player A, go here. Player B, go here", etc.).

In order to change the flow of information, we have iterated the design. One change increases uncertainty about game information. For example, rather than letting the coordinator (global view) see the exact location of each artifact, the coordinator can now only see what region of the map contains the artifact (Figures 1 and 2). The detailed information is only available to a seeker present in the local context.

Another change is in the coordinate system used for the virtual world: individual seekers will have access to a low-resolution grid of their position in the global map, allowing them to communicate about their place in the virtual world. We hope that this change leads to more communication about position, so that other players can overhear to learn about the locations of remote teammates.

Finally, because the coordinator is unable to see obstacles in the real world, another change is to introduce more obstacles that this player cannot see. This change will make it so that information coming in from the real world is more valuable to the coordinator, since she will then have to work closely with the seekers to guide them towards the artifacts.

Requiring Mixed Communication Modalities

In order to coordinate and communicate effectively, fire emergency responders must regularly mix face-to-face and radio communication. Because face-to-face communication is so expressive, it is preferred over radio whenever it can be used. Furthermore, radio has very limited bandwidth, but can be used to broadcast information to everyone at the scene. Decisions about which channel to use are important for effectively coordinating emergency responders. [1]

The freedom of movement in location-aware games makes them particularly effective for teaching the use of mixed communication modalities. Since players are able to move about in the real world, grouping and splitting up are natural activities, which is not true in traditional digital games. This leads to contexual communication needs, similar to those in real life (e.g., face-to-face is not possible when a group is split up, but is very useful when collocated).

Rogue Signals intentionally locates the coordinator away from the rest of the team. Frequently, the seekers will need to speak to the coordinator. This will require using the radio.

In order to further emphasize mixing use of the channels, we introduced time requirements to the real-world artifact collection. Originally, players could instantly collect an artifact, making the activity fast and safe. Now, they are now required to stand still for several seconds while they collect it, exposing them to the danger of the predators. Players can reduce the amount of time necessary to collect the artifact by working together. This should lead to a conflict when players decide what to do: they may find artifacts more easily by splitting up, but they can collect them more effectively by working together. Strategies emphasizing doing both (searching separately, then coming together to collect) will be the most likely to succeed, and will require use of both communication modalities to be effective.

Utilizing Audible Clues

Many of the expert fire emergency responders that we interviewed reported that in addition to overhearing, they also used ambient monitoring. *Ambient monitoring* involves listening to background sounds that reveal more about the situation, especially sounds that come through the radio communications of others. Concrete examples of this are the sounds of popping timbers in a burning building that is about to collapse, or the loud low-air bell that sounds when a responder's oxygen tank is about to run out. [1]

Originally, *Rogue Signals* was conceived with no sound. Results from our ethnography made it clear that audio will enhance the experience. One change that we are making is to equip seekers with small speakers. This allows the game to create sonifications from the virtual world that are perceived directly in the real world, allowing the real world space to come more alive with virtuality.

If a player uses his radio, these audible clues can inform the entire team about his state. Planned sonifications include a proximity warning for predators and artifacts. We believe that this will help players to become more in tune with background sounds, leading to better ambient monitoring skills.

Conclusions

We have presented a design for a location-aware augmented reality game, *Rogue Signals*, currently in development. This game is designed to enhance the team coordination skills of participants through its careful design. It is informed by an ethnography of fire emergency response practice.

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