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Abstract. In this paper, we draw on serious mixed reality games as an approach to explore and design for coordination in disaster response scenarios. We introduce AtomicOrchid, a real-time location-based game to explore coordination and agile teaming under temporal and spatial constraints according to our approach. We outline the research plan to study the various interactional arrangements in which human responders can be supported by agents in disaster response scenarios in the future.

1 Introduction

Disaster response (DR) typically include groups of human, canine, computational and embodied agents (such as robots) coordinating a response to a disaster such as an earthquake, a flood, a terrorist attack, an epidemic outbreak or a nuclear disaster. Responders may have to coordinate and perform their operations potentially under critical temporal and spatial constraints, with limited resources and personnel, where failure may cost human lives. Particularly, coordination is an essential requirement in DR in order that groups of people can carry out interdependent activities together in a timely and satisfactory manner [1].

The ORCHID project[1] investigates the potential of human-agent collectives (HACs) in a DR scenario, where groups of humans and computational or embodied agents collaborate to achieve a common task. The critical nature of the DR domain makes it difficult to evaluate and study systems designed to support or enable HACs 'in the wild'. On the other hand, computational simulations of such scenarios are not only extremely difficult to construct, but the veracity of results may be impossible to verify [2]. In particular, simulations may misconceive the emotional response induced in realistic settings, such as stress, fear or panic [3].

Conversely, reports of Mixed Reality Games (MRGs) have unpacked people's interaction 'in the wild', for example how they achieve spatially distributed coordination to orchestrate a game [4]. More specifically, 'serious' MRGs have been suggested as an approach for exploring scenarios that are typically hard to study in the wild, such as DR [5]. To clarify, we do not interpret the prefix 'serious' to mean that the game itself is inherently serious – players could still find it fun to play – more that the underlying research objectives are 'serious'.

[1] www.orchid.ac.uk

We apply this approach to study HACs 'in the wild' by situating both agents and participants in real world environments, and presenting them with compelling game scenarios analogous to disasters. The objective is to study coordination, interaction and communication amongst actors while also having greater confidence in the efficacy of behavioural observations.

A shared understanding and situation awareness are key requirements for coordination in settings that involve human-agent interaction [1]. We are particularly interested in how the coordination of DR can be supported and designed for by studying and designing for coordination in MRGs. In particular, MRGs share a common set of characteristics with DR scenarios that we outline in the following section.

2 Coordination in DR and MRG

Drawing on related work, we now illustrate some key characteristics that highlight how coordination is achieved in MRGs, and how these key characteristcs are shared with DR.

1. **Bridging the physical and the digital.** Both DR as well as MRGs routinely bridge the phyiscal and the digital as part of their actors' coordination [6]. While DR for example makes use of the twitterverse to inform the real world response [9], MRGs provide hybrid spaces to enable playful and artistic performances and public experience [7], often across different media [8].
2. **Orchestration.** The work of managing a DR as well as MRGs are highly orchestrated activities. Authoring and orchestration tools 'behind the scenes' of an MRG as well as player interfaces provide managers, players and spectators with different temporal and spatial views of the game world in order to support the experience [4]. These settings are somewhat comparable to the 'control room' of a first response operation, if only in their collection of various technological arrangements to communicate and coordinate real-time information streams to create a holistic as possible picture of the setting of interest.
3. **On-the-ground and online.** In both DR as well as (many) MRGs people on the ground work with people online to solve a common problem [7]. In [9], the authors show how an understanding of online content can help to understand medical coordination challenges in DR from pre-deployment to on-the-ground action. MRGs often leverage the fact that people on the ground and people online have different views of the world that are turned into different abilities within the game. For example, Uncle Roy All Around You [6] involved online and physical players collaborating in order to achieve a common goal - finding the mysterious Uncle Roy in the back streets of London.

Despite not being a comprehensive list, these key characteristics illustrate the overlap between coordination in MRGs and DR that underlie our motivation to explore the approach of serious mixed reality games further.

3 AtomicOrchid

As a test bed for HACs in DR we designed and implemented an MRG called AtomicOrchid, that we continue to describe in this paper. In the following sections, we describe the game scenario, gaming and authoring interfaces, and the research-driven design rationale behind the game mechanics.

Game scenario. AtomicOrchid is a location-based real-time MRG based on the fictitious scenario of radioactive explosions creating expanding and moving radioactive clouds that pose a threat to responders on the ground (the field players), and the targets to be rescued around the game area. Field responders are assigned a specific role (e.g. 'medic', 'transporter', 'soldier', 'ambulance') and targets have specific role requirements, so that only certain teams of responders can pick up certain targets. For example, an 'injured person' can only be picked up by an 'ambulance' and a 'medic'. Field responders must not expose themselves to radioactivity from the cloud for too long, else they risk becoming 'incapacitated'.

In their mission to rescue all the targets from the radioactive zone, the field responders are supported by (at least one) person in a centrally located 'headquarters' room.

Player interfaces. Field responders are equipped with a 'mobile responder tool' providing them with sensing and awareness capabilities (see figure 1). The app shows them a reading of radioactivity, their health level, and a GPS-enabled map of the game area with the targets to be collected and the 'safe' drop off zones for the targets. They can also use the tool to broadcast message to the other field responders, and to headquarters.

Headquarters (HQ) is manned by at least one player who has at their disposal an 'HQ dashboard' that provides them with an overview of the game area, including real-time information of the players' locations (see figure 1). HQ can also broadcast messages to all field responders (not shown), and can review the responders' exposure and health levels. Importantly, only headquarters has a view of the radioactive cloud. 'Hotter' zones correspond with higher levels of radioactivity.

Authoring. We have designed a simple graphical authoring interface for AtomicOrchid that allows non-programmers to set up a game on the fly, including specifying GPS-locations of the game area, targets, and drop-off zones. An important feature is that the game can be played anywhere (in principle), which is an essential requirement for deployments 'in the wild'.

Design rationale. It is worth mentioning that certain game mechanics are designed to allow us to explore specific aspects of coordination in HACs. Sensing and awareness of the environment are necessary requirements for coordination

Fig. 1. Player interfaces in AtomicOrchid.

in DR. However, in order to create the need for more communication amongst HQ and field responders, the spatial position and movement of the cloud is only known to HQ. Furthermore, the specifics of role-target allocation creates the requirement for field responders to form 'agile teams' – forming, disbanding, relocating and re-forming continously in order to complete the game objective. Agile teaming is seen as one of the key challenges of DR that can be supported by computational agents [10].

While the described game scenario does not include computational or embodied agents specifically, the scenario allows the creation of complex role-target allocations that, together with spatial and temporal constraints, provide an interesting use case for computational agent support. We will elaborate the integration of agents in AtomicOrchid in the next section.

Platform. AtomicOrchid is based on the open-sourced geo-fencing game MapAttack[2] that has been iteratively developed for a responsive, (relatively) scalable experience. It is essentially a client-server platform relying on real-time streaming of location data built using the geoloqi platform, Sinatra for Ruby, and state-of-the-art web technologies such as socket.io, node.js, redis and Synchrony

[2] `http://mapattack.org/`

for Sinatra[3]. Open source mobile client apps that are part native, part browser based exist for iPhone and Android; we adapted the Android app to build the AtomicOrchid mobile responder tool.

4 Researching HACs with AtomicOrchid

Complexity in role-target allocation in AtomicOrchid can easily become a bottleneck for human decision making, given the critical temporal constraints. Field responders may struggle to decide on the order of 'targets' to save, and how to efficiently coordinate re-grouping in the required teams. 'Coalition formation with spatial and temporal constraints' is a well-defined and difficult problem in the multi-agent systems community, for which a computational solution efficient enough to be applicable in a real-time scenario has been proposed [10].

As an exploration of human-agent interaction in AtomicOrchid, we plan to integrate a computational coordinator agent that instructs field responders on when to form coalitions and which targets to rescue based on real-time analysis of the location and distances of responders and targets on the ground. Through a series of deployments, we will explore the effects of different interactional arrangements. Initially we aim to explore the following arrangements:

– The agent 'instructs' only headquarters, detailing teaming and target allocations for all responders. This arrangement relies on HQ 'translating' and delivering the instructions to the field responders.
– The agent directly 'instructs' the field responders individually, detailing teaming and target allocations on an individual basis.

Further configurations of these arrangements include whether the instructions are delivered initially as a 'one-off' plan for the entire game, or whether the instructions are delivered 'just-in-time' after the completion of a sub-task, i.e. after a target has been dropped off in the safe zone. The configuration of interactional arrangements allows us to explore various ways in which human responders can be supported by computational agents.

The 2x2 factor research design achieved through the combination of interactional arrangement (agent–HQ vs agent–responder) and delivery mechanism (one-off vs just-in-time) can be enriched by considering further research questions of human-agent interaction, such as

– How (and when) does the agent need to present the information or instructions most effectively to supports the responders' tasks?
– Where do agents fit into existing human disaster response practices?
– What are the benefits and shortcomings of using a software agent to instruct and assist disaster response compared to a human coordinator?
– How can people best respond to agent instructions and how can the agent improve/learn from the human response?

[3] `http://bit.ly/rf4pQ7`

5 Summary

In this paper, we proposed the application of serious mixed reality games to explore and design for coordination in disaster response scenarios. We introduced AtomicOrchid, a real-time location-based game to explore coordination and agile teaming under temporal and spatial constraints. We outlined the research plan by which we will study the various interactional arrangements in which human responders can be supported by agents in order to enable HACs in disaster response scenarios in the future.

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