WENCHAO JIANG

# INVESTIGATING INTERACTIONAL ISSUES OF AGENT PLANNING SUPPORT

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In Disaster Response domain

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Wenchao Jiang: *Investigating Interactional Issues of Agent Planning Support,* In Disaster Response domain , © August 2012

—— something.

Family means nobody gets left behind, or forgotten.

— Lilo & Stitch

Dedicated to the loving memory of Rudolf Miede.

1939 – 2005

# ABSTRACT

This thesis contributes to the understanding of the potential socio-technical issues that might emerge from the interaction between responder teams and automated planning support and propose design solutions to them.

(Problem) Recently, Frequent natural and man-made disasters in Haiti, Chile and Japan drew attention of Researchers. A lot efforts have been made to study the technologies that can assist human responders to improve their performance. In the disaster response domain, a disaster response team, which contains several incident commanders and field agents, is faced with the problem of carrying out geographically distributed tasks under spatial and time constraints in a quickly changing task environment.

Effective planning and coordination can be a key factor for the success of disaster operation but it is difficult to achieve. Recent advance in the multi-agent technologies leads to the possibility of building agent software which supports Team coordination by automating the task planning process. However , it is unknown how the agent software can fit into the team organisation in a way that improve rather than hinders the team performance. The interaction between human operators and planning support systems need to be carefully designed before technology deployment.

(method) This work presents three field studies which investigates the impact of different interactional arrangements between human teams and automated planning support. The studies adopt serious game approach which is arguably an established vehicle to vehicle to

explore socio-technical issues in complex real world settings.

We developed AtomicOrchid, an emergency response game to create a task setting which mirrors real aspects of disaster response operation. In the game trials, participants are recruited to play as field responders and incident commanders to carry out rescue missions. Participants' experiences are observed and recorded as they coordinate with each other to achieve game objectives, with the support from an intelligent planner software. Interaction analysis is carried out on the data, leading to descriptive results which unpacks interactional issues. By iteratively designing and examining different interactional arrangements through three iteration of studies, we progressively explore requirements and social implications of planning support system for responder teams.

In the 1st study,field responders and incident commander coordinate without support of the intelligent planner. The study establish baseline performance of the game play and derived several requirements for planning support system. In the 2ed study, an intelligent planner was introduced to support field responders directly. In the third study, Incident commander mediate task assignment between field responders and the planning agent.

(results) Overall these studies show that ...

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# ACKNOWLEDGMENTS

*To my parents, wife, friends*

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d

# INTRODUCTION

Disaster response operations such as Urban Search And Rescue (USAR) can be very challenging. In large-scale disaster, DR teams may have limited resource and personnels to deal with multiple incidents across a large impact area. Task planning and execution need to be carried out by geographically distributed DR teams in real time against uncertainties in the environment. The challenge requires DR teams to carry out highly coordinated activities in an uncertain task environment. The challenges create the opportunity of technology support for real time Task planning and execution.

Recently, various Information and Communication Technologies (ICT), ranging from communication infrastructures to social media platforms, have been playing increasingly significant role in the disaster management. Moreover, Muti-agent system researchers have devised various real-time task planning algorithms to automate planning in time critical task domains such as disaster response. The advances in both ICT and Multi-agent optimisation algorithms lead to the opportunity of intelligent planning support in the DR domain. However, before we apply this algorithm to to support, we need to understand how can we configure the interactions between responder team and planning support system in a way that improve team rather than hinder. The aim of this work is aimed to explore potential interactional issues surrounding a planning support system, which in turn, informs interaction design of such systems.

This PhD work is a ORCHID sponsored research, which contributes to the understanding needed to build Human Agent Collectives (HACs)

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in disaster domain. As computational systems becoming increasingly embedded into our life, the researchers from ORDHID project envision a future in with people and computational agents operates at a global scale, forming human agent collectives. The ORCHID project is aimed to realise the vision of HACs by studying the science that is needed to understand, build and apply HACs that symbiotically interleave human and computer systems (www.orchid.ac.uk).

This Chapter will give an overview of the PhD work, which covers research objectives, approach, research questions and contributions, followed by a list of publications related to this thesis and an overview of thesis structure.

## 1.1    PROBLEM DEFINITION AND OBJECTIVES

In large scale disasters, Disaster Response team(DR) may have limited resource and personnels to deal with large amount of incidents across large geographic area under time pressure. In this situation, task and team allocation become a grand challenge for DR team. The responders and resources need to be assigned to teams and tasks in a way that to minimise loss of life and costs (e.g., time or money) . For instance responders with different capabilities (e.g., fire-fighting or life support) have to form teams in order to perform rescue tasks (e.g., extinguishing a fire or providing first aid). Thus, responders have to plan their paths to the tasks (as these may be distributed in space) and form specific teams to complete them. These teams, in turn, may need to disband and reform in different configurations to complete new tasks, taking into account the status of the current tasks (e.g., health of victims or building fire) and the environment (e.g., if a fire or radioactive cloud is spreading). Furthermore, uncertainty in the environment (e.g.,road connectivity, task status update) or in the responders abilities to complete tasks (e.g., some may be tired or get

hurt) means that plans are likely to change continually to reflect the prevailing assessment of the situation.

Recent advances in multi-agent systems research leads to some real-time simulation and optimization technologies, some of which has great have potential to be adapted to support task planning for DR teams. One of a good example can be coalition formation algorithms devised by xxx (More details, see section x) Although the opportunity space has been recognised, most coalition formation algorithms has only be tested in computational simulations. None of them has be deployed to guide real human in DR situations. Many CSCW literatures have pointed out ill-designed work-flow management/automation system can lead to undesirable results, not only fail to improve work efficiency but also hinders human performance. Field studies of CSCW technologies have shown that it is vital to study technology in use to understand potential tensions raised for teamwork. Bowers et al. found that extreme difficulties might be encountered when introducing new technology support for human teams. New technologies might not support, but may disrupt smooth workflow if they are designed in an organisationally unacceptable way.

We believe the same is true for intelligent planning support. Before we can build intelligent systems that support human task planning, field trials are needed to understand the potential impact of technology support for team coordination. Although most multi-agent coordination algorithms have been tested to perform well in the computational simulations, they have never been excised to guide real human responders in the real world environment. Currently, there are few studies aimed to unpack the interactional issues relating to a socio-technical aspects of the intelligent planning support system. Interactional issues of a human-agent system can be defined as the issues related to interaction design and more importantly, the social aspects of the a human-agent. system. "Social issues" of human-agent systems are thought to be as important as technical issues []. There-

fore, this PhD work is aimed to fill this gap by exploring and unpacking interactional issues surrounding the intelligent planning support system from a HCI perspective.

## 1.2 APPROACH

To meet our research objective, we adopt a serious-mixed reality games approach (Fischer et al., 2012) to create a game probe (i.e. AtomicOrchid) that enables studying team interaction with planning support system in a real-world disaster scenario whilst providing confidence in the efficacy of behavioural observations. Mixed-reality games bridge the physical and the digital (Benford et al., 2005). Arguably, They serve as a vehicle to study distributed interactions across multiple devices and ubiquitous computing environments in the wild (Crabtree et al., 2006).

The AtomicOrchid [reference the AO2012 paper] is a serious mixed-reality game designed to mirror aspects of real-world disaster. In this game, field responders use smartphones to coordinate, via text messaging, GPS, and maps, with headquarters players and each other. The players in the game faces a distributed task planning problem with both time and spatial constraints. To achieve game objectives, the players need to dynamically change their team configurations. The task planning process in the game is supported by a planning support agent software. The planning support agent is based on a state-of-art coalition formation optimisation technology. In Chapter x, design and implementation of AtomicOrchid will be introduced in more details.

In order to explore human agent interactional issues, three studies are conducted with different research focuses. In the 1st study,field

responders and incident commander coordinate without support of the intelligent planner. The study establish baseline performance of the game play and derived several requirements for planning support system. In the second and third studies, an intelligent planner was introduced to support task planning with two different interactional techniques. The second study adopts a arrangement of human-ON-the-loop(HOTL) in which the planning agent automatically generate plans and instruct field players to execute plans. In the third study, we adopts an human-IN-the-loop (HITL) technique in which every plan generated by planning agent will need to be approved and edited before it is sent to field players before execution. More details of these two interactional arrangements will be introduced in Chapter x.

The work also adopted an ethnographically-inspired approach for data analysis. Game plays were recorded and qualitative interaction analysis were carried out to unpack human agent interactional issues.

## 1.3 SCOPING

This thesis is relevant to several research areas.

- Human Computer Interaction (HCI) for Disaster Response(DR). With the vision of HACs system, the current ICT for DR may eventually evolve into HACs in the future. The thesis is aimed to help realise the vision by providing design implications for ICT systems with intelligent task planning agents from a HCI perspective.

- Multi-agent systems. The muli-agent simulation technologies underpin the technical possibility of intelligent planning support, providing the opportunity space of human agent collective planning.

- Human agent interaction. Existing human agent interaction research is the overarching research area of this thesis.

- Ethnography. The thesis adopts a Ethnographically-inspired approach to study human system interactions in field trials.

There are various ICT and AI-based technologies supporting disaster management activities in the different stages of the crisis circle including preparedness, response and recovery. This thesis is going to limit the scope on operations of rescue and evacuation in the immediate aftermath of a disaster impact, which typically requires high level of team coordination and real-time task planning and execution.

The thesis also focus on socio-technical issues related to human team interacting with the intelligent planning support from a HCI perspective. The work involves planning support agents based on multi-agent coordination algorithms, but the effectiveness of particular coordination algorithms are not concern of this work.

As part of ORCHID project, the AtomicOrhid serious game platform was developed as A research "Probe" to trial human agent collective planning in the domain of disaster response. As mentioned in section x.x, the AtomicOrchid platform consists of two major components: a game engine, and a embeded task planning agent. The core game engine was developed , deployed and maintained by the author, whereas the task planning agent was developed by ORCHID research partners - Feng Wu and Savapali Ramchun. Both Feng and Ramchun have expertise and research interest in the performance of task planning algorithm, where the author's research interest is the interaction between human and the intelligent task planning agent.

## 1.4 RESEARCH QUETIONS

The recent advances in ICT and multi-agent optimisation technologies have created the opportunity space for intelligent planning support system in disaster response domain. Before we deploy such a planning support system, a deep understanding of interactional issues are required for appropriate interaction design between human teams and computational agents. This work adopted serious game approach to explore the interaction design space. Integrated with intelligent planning support, the AtomicOrchid game platform is used as a testbed for human agent interaction techniques. The AtomicOrchid is further configured with two different interaction techniques to produce game "probes" for field trials. Through field observation, this work is aimed answer the following two research questions:

A What interactonal issues will emerge if we try to automate planning process in a disaster response team? Interactional issues can be seen as an umbrella term for all issues relating to interaction design, which can range from social, organisational issues to interface design issues. This work is aimed to conduct an exploration of the interactonal issues in the interaction design space of agent planning support.

B How can we design interaction to support human agent collaboration in task planning? Following the first question, the emerged interactional issues will need to be handled with appropriate interaction design. This work seeks to produce interaction design implications through field observation and interaction analysis, both of which are grounded in literature review (Chapter x)

[The research is primarily interested in two interaction techniques, what are they and why?] Both two questions will be answered with respect to the two different interaction techniques which will be detailed in Chapter x.

## 1.5    CONTRIBUTIONS
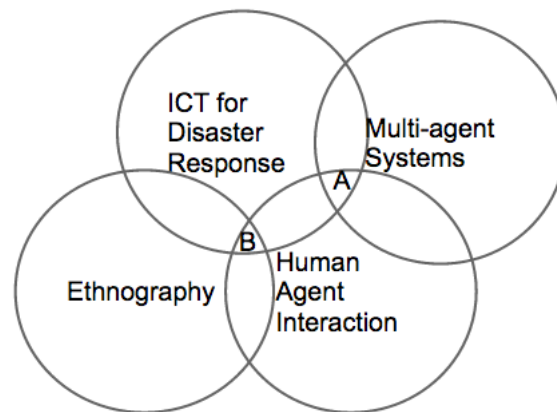


This thesis contributes to the knowledge in the following areas:

A  A real-world interactive prototype and trials to investigate team coordination in a disaster response settings.

B  The field observation of serious game trials leads to enriched understanding of interactional issues surrounding human agent collective planning in disaster response domain.

C  For each study, field observations are further analysed to generate design implication which contribute to future deployment of agent-based planning support system.

## 1.6    PUBLICATIONS OF THIS THESIS

Parts of the contents of this thesis have been accepted by peer-review for publication in conference proceedings in HCI or are in submission:

Chapter x expands on the contents in Fischer, Joel E., Wenchao Jiang, and Stuart Moran. "AtomicOrchid: a mixed reality game to investigate coordination in disaster response." In Entertainment Computing-ICEC 2012, pp. 572-577. Springer Berlin Heidelberg, 2012.

The exploration of Requirements for building coordination support system in Chapter x has been published in Fischer, J.E., Jiang, W., Kerne, A., Greenhalgh, C., Ramchurn, S.D., Reece, S., Pantidi, N. and Rodden, T. (2014). Supporting Team Coordination on the Ground: Requirements from a Mixed Reality Game. To appear in: Proc. 11th Int. Conference on the Design of Cooperative Systems (COOP 14). Springer.

The exploration of interactional issues related to human-on-the-loop arrangement in Chapter x have been published in Jiang, W., Fischer, J.E., Greenhalgh, C., Ramchurn, S.D., Wu, F., Jennings, N.R. and Rodden, T. (2014). Social Implications of Agent-based Planning Support for Human Teams. In: Proc. of the 2014 Int. Conference on Collaboration Technologies and Systems (CTS 14). IEEE.

## 1.7 STRUCTURE OF THE THESIS

This thesis is structured as four parts. Part I surveys the relevant background literatures. The chapter of literature review will firstly introduce a brief history of automation, agent software and Study of human agent interaction. In the following section, an overview of task planning activities will be introduced together with command and control structure of DR teams. In particular, the section will review the state-of-art agent simulation technologies that can help support task planning. The following section will review relevant CSCW Literatures which will lead to the potiential challenges of real deployment of the agent technologies. The rest of the chapter give an overview of serious mixed reality games which underpins the foundation of research approach of this PhD work.

Part II develops the approach and methodology employed to study interactional issues of planning support system in two chapters. The first chapter develops framework of interactional arrangement under which interactional issues can be explored. The rest of this chapter will introduce serious mixed reality game as approach to study interactions ,followed by detailed description of a game used as testbed for this study - AtomicOrchid. Chapter 5 describes the methodology used to study the interactional issues. In particular, this chapter will describe ethnographic observation and interaction analysis, which is supplemented by interviews and questionnaires.

Part III covers observational studies in this thesis. Chaper x reports the first observational study with AtomicOrchid. This version of AtomicOrchid do not have planning support agent included. The study establishes baseline human performance of task planning and derives general requirements of communication support. The Chapter x give an account of second observational study of AtomicOrchid. In this study, an planning agent was built into the game with human-on-the-loop interactional arrangement. Chaper x reports the third field study of AtomicOrchid with human-in-the-loop arrangement.

Finally, Part IV concludes this thesis with a summary of contributions and future work.

# Part I

## BACKGROUND

You can put some informational part preamble text here.

# LITERATURE REVIEW

## 2.1 AUTOMATION AND HUMAN AGENT INTERACTION

The study Automation design and Human agent interaction are two heavily intersected research areas which overarches this PhD work.

### 2.1.1 *A History of Automation*

The original goal of Automation is to replace the tasks originally performed by human with a machine. [1] . It can be defined as the execution by machine, usually computer, of a function previously performed by human [Parasuraman and Riley 1997] The tasks that can be automated is used to be limited by technical capabilities, but this is no longer the case. With quick growth of machine's speed and intelligence, the tasks that can be automated is rapidly increasing, including complex cognitive activities such as information analysis, planning and decision making.[RAJA] The boundary between human machine capabilities has blurred. With little cannot be automated, the automation designers have to make hard choice about what to automate and to what extent.

One traditional approach for automation design is to simply automate all system functions that can be automated easily in a cost-effective way, leaving the all remaining tasks to human operators. The main considerations in this approach are technical capability and cost. The assumption of this approach is that the automation of sub systems functions can lead to optimisation of whole system with no

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detrimental impact results from the automation. However this is not always the case, Large body of empirical work in automation design have shown that xxxx .

The other approach is to achieve division of labour between human and automation according to their strength and weakness. As in Fitts list [2] , a set of strengths and weaknesses of humans and machines is identified. Some study pointed the division of labour would not be as simple as a labour division according to strength and weakness[]. Firstly the time factor could be important because human and machine's availability may change overtime. Secondly By delegating the same task to machine, the nature of human tasks can be changed as well. Large body of work has shown clearly that automation does not simply supplant human activity but rather changes it, often in a way that is unanticipated by the system designer. [Coordination and Supervision interaction required, expand ] [1] [Later , proposed by Licklider in the un-Fitts list [3], automation is aimed to leverage and extent human capability by using agents (not replacing).[1].]

2.1.2   *The Level of Automation*

More recently, another alternative model of automation to guide automation design is proposed by proposed by C. D. Wickens[],known as 10 level model of automation. The model 10 levels of automation (LOA) has been later extended by R Parasuraman [] with more detailed classification of automation types. The extended model of LOA informs study approach of this PhD work, which will be documented in chapter x. This section will give an introduction of this model.

Most tasks can be fully or partially automated, which implies that automation is not all or none, but can vary across a continuum of level[]. At the lowest level, all system functions are performed manu-

ally by human operators. At highest level, system are fully automated, taking over all system functions. In between this two extremes, 10 different levels of automation are proposed by xxx. As shown in table x.

### 2.1.3 *Definition of Software Agent*

Since creation of the term "software agent", there are a lot of debates about its definition . One definition commonly shared by the Multi-Agent system(MAS) literatures is that the software agents are designed to operate independently without constant human supervision. In the AI community, the software agent evolves from multi-agent system research which in turn, derived from the field of Distributed AI [6]. This strand of work investigates infrastructure, language and communication to realize coordinated agent software system. The goal was to specify, analyse, design and integrate systems comprising of multiple collaborative agents.[5]

More recently, the use of the word software agent become much more diversified. [5] has made attempts to investigate broader classes and types of agent. Nwana's [5] topology of agents identified three characteristics of agents, learning, autonmous and collabroitive, Based on this characteristics, software agents can be categorised into 8 classes, rangin g from collaboration agents, information agents to interface agents.

With a broader definition, researchers begin to investigate broader issues surrounding development of agent systems, among which human agent interactions have attracted a lot of attention of researchers and practitioners.[get one reference here!!!]

### 2.1.4   *Human Agent Interactions*

Automation design and Human agent interactions have big overlaps as both concerns the impact of automation(by computational systems) on human performance. While automation design is trying to answer the question of what and to what extent the automation should be, the study of human agent interaction concerns the issue of interaction design related to development of human agent system, with the aim to develop agents which is good at teamworking with human operators.

The agent researchers adopted a view that human and agents are equally important team players in a human agent system.[] It highlights the importance of mutual interaction between human and agents that can enhance the competencies of both human and systems. From this perspective, the aim of automation is no longer "replace" human but achieve an human-machine symbiosis through effective human agent coordination, which is similar to the view adopted by xxx in developing un-fitts list. As researchers realize the effective human-machine symbiosis requires sophisticated interactions design between human and agent, the "interactional" issues of automation is thought to be as important as technical issues.[Expand discussion about this issues.] [1]

Several interaction techniques have been devised by agent researchers to achieve effective coordination between human and agent. [expand on mixed initiative and flexible autonomy]

[define the interactional issues!!!!]

### 2.1.5   *Issues in Human Agent Interactions*

Combine both

Why the social issues of designing agent system is important? [Norman1994] state lesson from CSCW

### 2.1.6  *A summary*

Because this PhD work sits in the overlapping research area of human agent interaction and automation design, the later chapters will consider automation and agent software as two interchangeable concepts.

## 2.2  CSCW WORKFLOW MANAGEMENT

## 2.3  TASK PLANNING IN DISASTER RESPONSE

What is coordination(Coordination theory) Team Coordination. Malone (1990 361) defines coordination as the act of managing interdependencies between activities performed to achieve a goal. One of the very important component of coordination in DR, following sections will firstly... and then discuss how the coordination is carried out through command structure of DR team.

### 2.3.1  *Task Planning*

In disaster response, team coordination is essential in order that groups of people can carry out interdependent activities together in a timely and satisfactory manner (cf. Bradshaw et al., 2011). Disaster response experts report that failures in team coordination are the most significant factor in critical emergency re- sponse (Toups et al., 2011: 2) that can cost human lives. Shared understanding, situation awareness, and alignment of cooperative action through on-going communication are key requirements to enable successful coordination. Convertino et al. (2011) design and study a set of tools to support common

ground and aware- ness in emergency management.

One important characteristic of large-scale disaster is the presence
of multiple spatially distributed incidents (Chen et al., 2005). To deal
with multiple incidents, the disaster response team has to coordinate
spatially distributed resources and personnel to carry out operations
(e.g. search, rescue and evacuation). Depending on the proliferation
of incidents, response personnel may need to dispatch, deploy and
redeploy limited resources. Coordination is required to efficiently al-
locate limited resources to multiple incidents with temporal and spa-
tial constraints imposed by the nature of disasters.

(The requirements of multiple incident response from Chen.)

((Coordination game) Below confirms that in a single target need
multiple responder teams) While the present work applies generally
to disaster response, our iterative design and theory-building pro-
cesses have been specifically informed by work practice in the sub-
domain of fire emergency response. We work from fire emergency re-
sponse in small-scale structural fires, observing practice in the United
States of America. Fire emergency response is undertaken by small
teams distributed throughout the incident, coordinated by an inci-
dent commander (IC) [Toups and Kerne 2007; Landgren 2006; Jiang
et al. 2004; Landgren and Nulden 2007; Wieder et al. 1993; Carl-
son 1983; U.S. Department of Homeland Security 2008]. Multiple re-
sponse teams, or companies, are dispatched to any incident and coop-
erate around the fireground (Figure 1). A company officer leads each
team, which consists of firefighters and/or engineers.2 Normally, each
company is associated with a firefighting vehicle; an apparatus, such
as an ambulance, engine, or ladder truck.

The fireground and surrounding space constitute a dangerous and
dynamic interface ecosystem [Kerne 2005] of distributed cognition,
connecting responders, victims, fire- fighting equipment, communi-

cation media, and information artifacts. Upon arriving at an incident, multiple companies distribute in and around the fireground. Compa- nies and their apparatuses are placed at strategic locations, and are moved as needed. Human operators work on and from these platforms. Firefighters and rescue workers deploy from them, taking equipment into the fireground; equipment, such as firehoses and radios, may be technologically supported by the apparatus itself (pumps and water sources, or high-power repeaters, respectively). Each apparatus, and in many cases, each human worker, is equipped with a half-duplex radio to facilitate long-range, broad- cast communication.

(Geographic distribution as a also a key factor)
Muti-objective natural of the the DR response lead to its connection with multi-agent simulation and optimisation.

Therefore task planning envlove xxx challenges and opens the opportuntiy for technology intervention. Current state of art practice will be reviewed in section........

2.3.2    *DR Command structure*

A relatively generic model of C and C is proposed by The development of Information Technology System (ITS) to support the emergency response team work has many work published in the literature. For long time, crisis management systems were based in the military model of CC [1]. For many authors [2, 3 and 4] the need to change the theories of emergency management creating new paradigms is imperative to improve the flexibility of the CC structures. Their aim is to make them more efficient, multi-disciplinary and multi- institutional, increasing the collaboration between CC and the field responders and allowing sharing planning and resources to stabilize the crisis [5]. Stanton et. Al. [7] proposes a new generic model of CC based

on field observation. One important conclusion he made concerning common characteristics in the different domains of CC: 1. The presence of a remote control room; 2. The great dependency on verbal communication and; 3. The existence of collaborative discussion between field teams and command.

Gold-Sliver-Bronze control model is documented in xxxx(wiki)

## 2.4   TECHNOLOGY SUPPORT FOR TASK PLANNING

This section reviews state of art technological practice to support task planning. Task planning toolbox containing various components including data sets, (meta-)information, storage and query tools, analysis methods, theories, indicators.

Greetman review of planning system. not real time, The systems can be categorized according to several criteria (Aims, Capabilities, Content, Structure, Technology). None of them is adapted to real-time coordination.

Multi-agent paraghim

Graph to position the my system.

### 2.4.1   *Disaster simulation, optimisation*

The section will briefly review current status of the simulation and optimisation technologies for disaster response.

## 2.5   SERIOUS GAME

## 2.6 MIXED REALITY GAMES

### 2.6.1 *Definition and examples*

### 2.6.2 *Game for Serious Purpose*

Part II

METHODOLOGY AND APPROACH

# APPROACH

## 3.1 SOCIO-TECHNICAL PERSPECTIVE OF TECHNOLOGY SUPPORT FOR ORGANIZATIONAL WORK

[Introduce command and control scenario introduced in literature review?]

This research is aimed to inform the design of technical support for organizational work conducted by responder teams. Integrating new technology support into a human organisation is a well-known challenge for building a socio-technical system.

The term socio-technical systems was originally coined by Emery and Trist (1960) to describe systems that involve a complex interaction between humans, machines and the environmental aspects of the work system. nowadays, this interaction is true of most enterprise systems. The corollary of this definition is that all of these factors people, machines and context need to be considered when developing such systems. Within the context of CSCW the term stands for the recognition that aspects of both, technical as well as social subsystems, need to be considered when an organization introduces new technology and that there is a very complex relationship between the two. Social systems are characterized by phenomena such as communication and cooperation between human individuals, emergence of meaning systems, self-referential development of structures and In contrast, technical systems are characterized by artifacts, control, anticipation, state-transitions, pre- programmed adaptability, learning in respect to purposes which are determined from outside the system. Introducing a tech support system into an organization requires the technical

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system and a social system to be integrated, which causes lots of well-known problems in CSCW studies.

In the context of this study, [Need to have more integrated with this study, fully present the context, factor some words out to the literature review] the technology support is based on coalition formation algorithm, which requires a set of rigid inputs and produces task assignments. On the other hand, planning activities of responder teams are characterized by natural social processes such as communication, negotiation and cooperation. To support the responder teams with coalition formation technologies, the confrontation between social and technical is inevitable. Some researchers have pointed out the existence of the inherent social technical gap, the great divide between what we know we must support socially and what we can support technically. Some argued that human activity is highly flexible, nuanced, and contextualized and that computational entities such as information sharing, roles, and social norms need to be similarly flexible, nuanced, and contextualized. However, current technology support systems for organisations are often rigid and inflexible, failing to fully support the social world. Computer science is learning how to use techniques such as machine learning, user modelling to fill social-technical gap. It is hard to disprove that a technical solution is imminent. However, some argued that such a technical solution is unlikely, given that computer science, artificial intelligence (AI), information technology, and information science researchers have attempted to bridge the gap without success for at least 20 years.

We argue that the social aspect does not need to be fully supported through technological advance. A deep understanding of social issues and appropriate interaction design may lead to possible "workaround" of the socio-technical gap. Although technology support may be not fully integrated with the social aspects, appropriate interaction design can reduce its negative impact on social process so that the benefits of technology can overweight its adverse social

impact. The field of HCI achieved widespread recognition with its inherent focus on the importance of the interaction between people and technology at the fundamental level rather than just the design of the user interface. It explicitly recognised the importance of the roles of the social and technical aspects of work. HCI Literatures have identified a wide range of different methodologies that helps inform the development of socio-technical systems such as (1) Cognitive Work Analysis, (2) Ethnographic workplace analysis, (3) Human-centred design. Some of the recognised HCI methodologies underpin the serious game approach employed by this PhD work to understand socio-technical design space of agent-based planning support. [The switch to HCI is not smooth]

[Field trials supported by interaction analysis speech act]

[Andy s literature review of 2004 supporting ethnographic study should be cited]

## 3.2 SERIOUS MIXED GAME AS A TESTBED

- Define serious game and serious mixed reality game [serious game literatures typically has different concern] - What is serious game? - Highlight its support for Ethnographic study, User-Centered design.

## 3.3 THE ATOMICORCHID PLATFORM

We designed and implemented the mixed reality game AtomicOrchid as a testbed for our field trials of different system interaction designs. The game involves field players on the ground (play as field responder) and online players in a control room (play as Headquarter).

In the following sections, we describe the game design including grounding of the design rationale, iterative design process, and the system architecture.

### 3.3.1 *Game Design Rationale*

The AtomicOrchid is based on the fictitious scenario of radioactive explosions creating expanding and moving radioactive clouds that pose a threat to responders on the ground (field responders), and the (virtual) targets to be rescued from around the game area. We chose a radiation scenario because other than disasters that cause physical devastation it poses an invisible threat, which creates the need to monitor the environment closely with sensing devices, and communicate frequently.

Field responders are supported by a centrally located headquarters (HQ) control room, staffed by coordinators who exchange messages with field players through an instant messaging style communication system. The messages are broadcasted, which means they are visible to all players. Whilst formal response teams tend to use radio to communicate (e.g., Toups et al., 2011) we chose text-based messages for its flexibility to support scenarios with many distributed (volunteer) field responders.

Core game mechanics are designed to allow us to explore specific aspects of team coordination. In particular, this is inspired by the real coordination challenge of resource and task allocation to coordinate spatially distributed resources and personnel

The game's two-tiered organisational structure is derived from real world disaster response organisation and from NIMS (Homeland Security, 2008). The game's HQ is loosely modelled on sector coordina-

tors, whose role is to manage resources and communications between their assigned teams, and command and coordinate action within their sector (INSARAG, 2012). Field responders are modelled on team leaders and members. We ignore this distinction to simplify roles, assignments, and game mechanics.

**Responder roles and targets**. Each field responder is assigned one of four roles:

There are four types of (virtual) targets:

The objective of the field responders is to rescue as many targets as possible by 'carrying' them to a drop off zone. To pick up and carry one of the target objects, two responders with particular appropriate roles are required in immediate proximity to the object. For example, a soldier and a transporter are required to pick up and carry fuel, and a medic and a soldier are required to pick up an animal.

The role-target mapping mechanic requires players to engage in resource coordination. Field responders have to engage in 'agile teaming' forming, disbanding, relocating and re-forming in teams over the course of the game in order to complete the game objective. This is an example of what Toups et al call, information distribution (2011).

**The radioactive cloud**. The cloud is a danger zone that can incapacitate field responders. It imposes spatial and temporal constraints on task performance and well- being. The cloud is analogous to various spatial phenomena in disasters (e.g. spreading fires, diseases and floods). In require communication between HQ and field responders, the spatial position and movement of the cloud is only known to HQ.

**Command-and-control structure**. The division of responsibility into HQ and field responders simulates a situation where volunteer re-

sponders are connected to a simple two level Command-and-control structure, similar to the real-time layer of the existing professional disaster response organizations (e.g., Chen et al., 2005).

**System interface**.System interface design is closely related to specific interaction designs, and it keeps evolving throughout three iterations of field trials. Therefore, the details of interface evolution is left to be introduced in the subsequent chapters (Chapter x,x,x) of field trials.

3.3.2  *Iterative design*

We briefly describe three cycles of iterative game design and evaluation before the system is ready for the first formal field study.

In the first iteration, we used a paper-based prototype to test and refine the core game mechanics. We recruited 12 participants, allocated one of four roles to them, and equipped them only with paper maps with locations of targets. They had to form different kinds of teams to retrieve the different kinds of boxes placed in the game area. The paper prototype demonstrated the demand for better support of situation awareness and communication to enable coordination.

The technology prototype was first tested with users in the second iteration. Users were equipped with the responder smartphone app to communicate, navi- gate, locate and pick up targets in teams formed according to role requirements. HQ was staffed by members of the research team. A pilot study was conducted with members of the public that visited an Open Day at a local university. A total of 20 members of the public tested the game in four ad-hoc game trials. The les- sons learned in the pilot study revealed problems with user

interaction, network- ing, and game parameter tuning, which we subsequently addressed.

In the third iteration, we improved system stability and interface designs. We conducted a pilot study at the campus of another university, to test the system in place. The full-fledged study we report on here was conducted shortly thereafter.

### 3.3.3 *System Architecture*

The AtomicOrchid is based on the open-sourced geo-fencing game MapAttack that has been iteratively developed for a responsive, (relatively) scalable experience. Our mixed-reality game relies especially on real-time data streaming between client and server. The client-server architecture is depicted in figure 3. Client-side requests for less dynamic content use HTTP. Frequent events, such as location updates and radiation exposure, are streamed to clients to avoid the overhead of HTTP. In this way, field responders are kept informed in near real-time.

The platform is built using the geoloqi platform, Sinatra for Ruby, and state-of-the-art web technologies such as socket.io, node.js, redis and Synchrony for Sinatra, and the Google Maps API. Open source mobile client apps that are part native, part browser based exist for iPhone and Android; we adapted an Android app to build the Mobile Responder App.

### 3.3.4 *The planning agent*

In study 2 and 3, planning agents are integrated into the AtomicOrchid to support player's planning activities. Two types of agent has be used in study 2 and 3 respectively.

The input and output of the planning agent are. The difference between the two agent are in the input.

Simulations has been applied to ensure the planning agent produce computationally optimal plans for the agents.

The agent is then integrated via a http protocol.

Interaction design and presentation of the agent is detailed in Chapter a and b.

The agents are developed by ORCHID Reseach partners from Southampton, technical details of the planning agent.

## 3.4 THREE INTERACTION DESIGNS

[Justify the relation between the three iterations] - avoiding pitfalls that undermines observation of interaction arrangement - HQ agent interaction can be parallel/ HQ FR interaction follows progressive design interaction - The first iteraction: base case/ need to understand the organization before we do anything.

Based on serious game approach, three iterations of prototyping are planned to explore the interactional issues related to the socio-technical integration. The 3 different system prototypes are partially (loosely) inspired by the model of Level Of Automation (LOA) in

the study of automation design. The LOA model has been developed to categorise systems into a linear spectrum according to degree of automation. There are several variations of the LOA models. One example is the two-dimensional LOA model proposed by Parasuraman (detailed in literature review section x). Several limitations of the LOA has been identified in chapter x. Most importantly, the LOA model has a focus on one-to-one operator-system interaction (e.g. autopilots, tele-oportation). It fails to capture complexity of the interactions in the context of technology support for organisational work. Therefore, it does not fit into the context of socio-technical system, which is the main focus of this research.

Despite the limitations, the terminologies that come with the model have been borrowed and adapted to inform the interaction design of three system prototypes in this research.

- Human Out of the Loop (HOuL) HOuL represents the highest level of automation. HOuL system is supposed completely run independently. Human is replaced with machine, therefore no human system interaction is required. It is unlikely to be realized in a socio-technical system in which organisational work is mainly carried out by human and supported by technologies.

- Human In the Loop (HuIL) vs. Human On the Loop (HuOL) There is no precise definition for the term HuIL. Some automation researchers use the term to describe a system with high level of automation, which requires minimum level of human intervention. However, in this research, we use the term HuOL to describe this kind of system. Further, this research adapts definition of HuIL to represents medium level of automation. The HuIL system requires constant human interactions to achieve goal of socio-technical system.

[More of this study, make clear the contribution, We also anticipate HuIL would be desirable ]

Although the terms are originally used to describe degree of automation, this can also be used to inspire the interaction design of

the system prototypes. Next section will go through the interaction design.

## 3.5    A FRAMEWORK OF INTERACTIONAL ISSUES

interaction techniques [Which Interaction Technique Works When] refer to interaction techniques may refer to is a set of interface widget design.

We follows a process of interaction design documented in the [Designing interactions p 15], the process is interactive, with a special focus on understanding issues and generating design implications . The issues emerges in previous iterations will be feedback to next iterations.

interactional issues:

Interface aspects: tech dependent or not? interaction aspects: concerned with interaction patterns Social aspects: Corncerned with what?

(Sedig, K.Parsons, P) pattern based approach. (Most interaction techniques literature reviewed so far is about study in visual representation. ) (Interaction design, wiki)

# 4

## METHODOLOGY TO INVESTIGATING HUMAN AGENT INTERACTION

### 4.1 MIXED METHOD APPROACH

### 4.2 ETHNOMETHODOLOGICAL PERSPECTIVE

### 4.3 INTERACTION/VIDEO ANALYSIS

Part III

STUDIES

# 5

ATOMICORCHID STUDY 1: NON AGENT VERSION

This chapter presents the first iteration of AtomicOrchid field trials. In this section, we focus on investigating requirements for time critical distributed team support relevant for domains such as disaster response. In this Field responders of the AtomicOrchid game use smartphones to coordinate, via text messaging, GPS, and maps, with headquarters and each other. Interaction analysis is conducted to examine log data and field observations revealing local and remote coordination within the responder team. We uncover requirements that highlight the role of local coordination, decision-making resources, geospatial referencing and message handling.

## 5.1 INTRODUCTION

Disaster response (DR) has been characterised as highly coordinated, time-critical collaborative activities [4]. Coordination is essential in such settings so that time critical interdependent activities such as search and rescue can be completed in a timely and satisfactory manner [1]. Opportunity space for building 'intelligent' coordination support for such activities has been recognised by the researchers of HACs systems (see chapter 1). However, little study has explored the design space for HAC systems to support time-critical coordination settings. Therefore, little is known about the challenges and requirements in building systems to support team coordination in such settings.

Due to the critical nature of the disaster operations, it would be hard to design and deploy 'intelligent' coordination in the field before we thoroughly explored the requirements of interaction design. On the other hand, computational simulation of an 'intelligent' system is fundamentally insufficient for studying interactional issues (see section 3.5). Therefore, in this study, we are aimed to use AtomicOrchid game as a game probe to uncover the requirements for building 'intelligent' coordination support system.

The AtomicOrchid game creates socio-technical setting in which player teams plan and executes spatially distributed tasks (see section 3.1). Although HACs researchers has envisioned that an intelligent agent can team coordination by providing computational optimised task allocations in real-time, we focus on a base version of AtomicOrchid which does not involve any agent support in study. The aim is to conduct a field trial to baseline performance human coordination in the game and base requirements for supporting such coordination, which in turn, supports our later system prototyping and studies.

This study is the first of three iterative system trials in this PhD work. The non-agent trial supports the two later (chapter 6, 7) agent-supported system trials by 1) Revealing baseline performance of human coordination 2) Generate design requirements which can be feedback to subsequent prototyping of AtomicOrchid. The requirements are critical in that 1) the later trials and studies can use them to isolate non-agent related design factors and 2) It also can inspire the interaction design between agent and responders in later system prototyping.

In the following section, we will go through AtomicOrchid system description with a focus on interface and interaction design.

## 5.2 SYSTEM DESCRIPTION

Basic game mechanic and system architecture has been introduced in the 3. This section will give a detailed description of the system interface that support coordination between the field responders and headquarters players.

The HQ is manned by at this two coordinators. All of the coordinators are provided with a web-based coordination interface. The interface gives them an overview of the game status and enable them to communicate with the field responders.



Drop off zone  Radioactive cloud  Players and tasks  Player status panel  Chat window
(blue circles)  (heat map)  (icons)
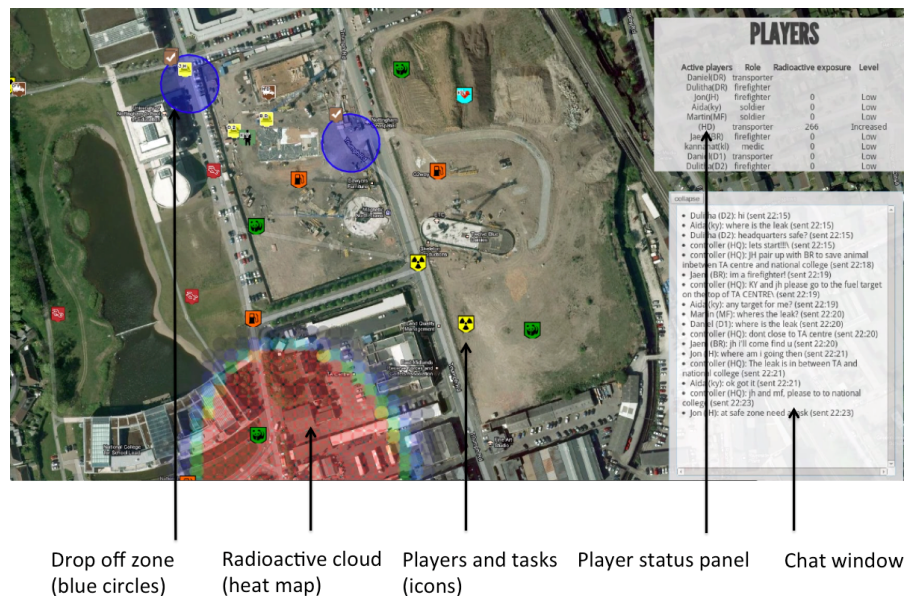
Figure 1: The HQ interface

As you can see in the figure 1, the majority space of the interface is occupied by a map-based presentation of the game status. Roles and locations of field responders are represented on the map as icons. The field responders can be uniquely identified by their initials shown on the icons. The target types and locations are also shown as icons on the map. Location and intensity of radioactive is indicated by a heatmap. Heath status (health value ranges from 0 to 100) of the field

responders is displayed on the right-top panel. A chatbox is placed on right bottom for HQ to browse and send messages. The messaging system is very simple and straightforward. Everyone can send messages to one public channel, and the messages are visible to every play through the mobile and HQ interface.

Field responders are equipped with a mobile responder app providing them with sensing and awareness capabilities (figure 2). There are two tabs in the responder apps. The "map" tab displays a map showing locations of field responders and targets, which is similar to the map on HQ interface, except that the radioactive is not showed. The radio level of players' current location is displayed as a Geiger counter reading (shown as a number on the top left of the screen ), which ranges from 0 to 100. Health status of the field responder is indicated by a health bar on the right side of the Geiger counter. The chatbox (similar to the one on HQ interface) is placed on the "Messages" tab for field player to receive and send messages.

The app shows a reading of radioactivity, their health level based on radioactive exposure, and a GPS-enabled map of the game area with the targets to be collected and the drop off zones for the targets. Icons according to responder roles that additionally have their initials on them can be used to identify individuals. Another tab reveals the messaging widget to broadcast messages to the other field responders, and to headquarters.

## 5.3 STUDY DESIGN

To explore socio-technical issues around team coordination, we ran two Radiation Response Game sessions, with volunteers recruited from the local university. We describe participants, procedure, session
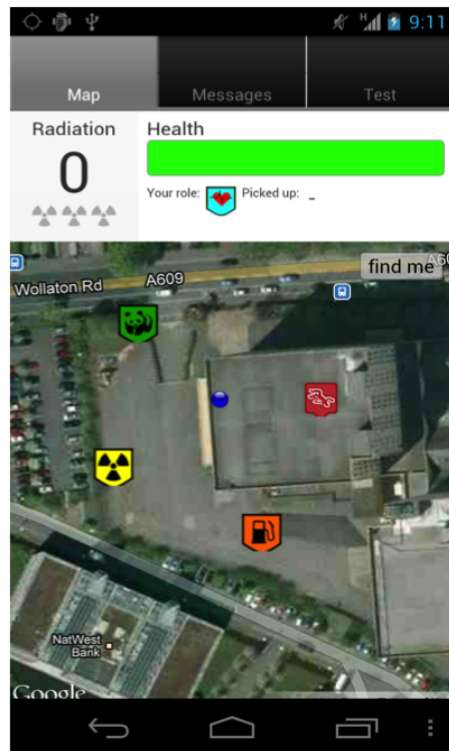
Figure 2: The mobile responder app

configuration, and methods used to collect and analyse quantitative and qualitative data.

Study participants were recruited through posters and emails. A total of 18 participants were recruited (8 female); 7 participated in session A and 11 in session B. All participants were reimbursed with 15 pounds for 1.5 hours of study. The majority of participants were students of the local university. Procedure. Upon arrival in the HQ (set up in a meeting room at the local universi- ty), participants were briefed and asked to consent to participate. Roles were ran- domly assigned to all participants (HQ/field responders: firefighter, medic, trans- porter, soldier). Field responders were provided with a smart-phone; HQ coordinators with a laptop. Game rules and interfaces were introduced, and partic- ipants were assisted in setting up their phones and laptop clients. Field responders and HQ coordinators were given 5 minutes to discuss a common game strategy. All field

responders were accompanied to the starting point within the designated game area, about 1 minute walk from headquarters.

Once field responders were ready to start, HQ sent a "game start" message. Gameplay commenced for 30 minutes. A "Game over" message by HQ concluded the game. Field responders returned to HQ for the post-game session.

The post-game session consisted of a questionnaire aimed at collecting participants' feedback on (1) first impressions of the game; (2) usability of the system,and; (3) coordination issues in the game. A group interview was then conducted, before participants were debriefed and dismissed.

The size of the game area on the local university campus was 400 by 400 meters, without heavy traffic. The terrain of the game area includes grassland, a lake, buildings, roads, and footpaths and lawns. There are two drop off zones and 16 targets. The pilot study showed that this was a challenging, yet not too overwhelming number of targets to collect in a 30 min game session. There were four targets for each of the four target types. The pattern of cloud movement and expansion was the same for both game sessions.

We took a mixed methods approach to data collection and analysis. In addition to quantitative questionnaires, a semi-structured group interview was conducted aimed at eliciting important decision points, strategies and the overall decision-making process. Furthermore, five researchers with camcorders recorded the game play. One researcher recorded action in the HQ, and four other researchers each recorded a field responder team.

We developed a log file replay tool to help with data analysis of time stamped system logs that contain a complete record of the game

play, including responders' GPS location, their health status and radioactive exposure, messages, cloud location, locations of target objects and task status.

Interaction analysis of local coordination. We focus on the analysis of local field responders' interaction to unpack team coordination, including handling of mes- sages sent by HQ. Video recordings of field action were catalogued to identify sequences (episodes) of interest (cf. Heath et al., 2010). Key decision points in team- ing and task allocation served to index the episodes. Interesting distinct units of interaction were transcribed and triangulated with log files of relevant game activity for deeper analysis that we present in this paper.

Message classification. How are remote messages used as a coordination resource? We used speech-act theory and the notion of adjacency pairs in linguistics to classify messages sent between and among responders and HQ.

According to speech act theory, utterances in dialogues can be considered as speech acts from three dimensions. We were primarily concerned with the illocutionary dimension of speech acts. Searle's classification of illocutionary acts (Searle, 1975) is used to categorize messages in the communication system.

## 5.4  DATA ANALYSIS AND RESULTS

Here, we present findings from interaction analysis supported by message classification that reveal how team coordination was achieved. Results of the message classification will be presented first, followed by detailed analysis of episodes.

By example of the first episode, we unpack how field responders account for messages from HQ, in particular issues with how directives on task allocation and execution are addressed. An overview shows that directives from HQ are frequently not brought up locally. A further episode demonstrates how field responders instead draw on technological and embodied resources to achieve local coordination, without HQ involve- ment. Finally, two more examples illustrate how responders routinely employ messages as a resource to support situational awareness.

5.4.1   *Speech act analysis on text messages*

Overall, responders rescued 7 and 9 targets in session A and B respectively, out of 16 targets in total per session. Two players were incapacitated in session A, and 1 player was incapacitated in session B. 117 and 70 messages were sent in session A and B, respectively. We used Searle's classification of speech acts to categorize messages (see table reffig:speachact). We also add requests to the table to categorize all of the messages (Searle does not classify those as speech acts).

| Speech acts | Session A | | Session B | | Example | Total |
|---|---|---|---|---|---|---|
| | HQ | FR | HQ | FR | | |
| Directives | 57 | 0 | 32 | 0 | *JH pair up with BR to save animal in between TA centre and national college.* | 89 (47%) |
| Assertives | 25 | 2 | 8 | 4 | *The leak around geospatial is bigger.* | 39 (20%) |
| Expressives | 5 | 0 | 0 | 0 | *Good Job, JJ, TV and RL.* | 5 (2%) |
| Declarations | 3 | 0 | 0 | 0 | *NOTICE - TEAM B: NS + TD.* | 3 (1.6%) |
| Commissives | 0 | 4 | 0 | 4 | *ok got it.* | 8 (4%) |
| Requests | 8 | 6 | 1 | 19 | *wheres the leak?* | 34 (18%) |
| Unclassified | 7 | | 2 | | | 9 (5%) |

Figure 3: Speech act classification

5.4.1.1  *Directives*

Most messages in the category of directives are instructions sent by headquarter (HQ) players. The content of instructions can be related to two themes: task allocation and task execution. Therefore, we further categories the instructions into two categories: instructions for task allocation, and instructions for task execution. Instructions for task allocation.

The purpose of task allocation instructions is to distribute plans to field teams and require them to execute it. Most instructions in this category follow a common pattern. Let's take a look at the example below:

> "HQ : JH1 pair up with BR to save animal inbetwen TA centre and national college"

The instruction sent from Headquarter consists of two parts: (1) Description of Team- ing (who are involved) (2) Description of Location (Targets) to go.

It is worth mentioning that HQ players use different strategies when they try to de- scribe a location to field players. HQ players in session D frequently referred to land- mark on the map in their description, while HQ in session C used simple directions (north, west, south east). For example:

> "HQ: TEAM A, can you head south to the radiation and animal targets? Instructions for task execution"

The purpose of task execution instructions is to help players execute their tasks after they have been assigned tasks. Most instructions

in this category are related to radio- active cloud. To help field players avoid radioactive clouds, HQ players frequently send directions to field players or simply urge field players to move quicker. For example:

"TEAM B you need to be quick"

### 5.4.1.2 *Assertives*

in this game, assertives provide plain information to recipients. Most assertives are sent by headquarter because they have access to critical information the cloud location. Some examples of assertives:

"the leak around nottingham geospatial is bigger"

"HQ:There's another leak by the lake!"

Interaction analysis shows that assertives are important for field players maintain situational awareness. We will talk more about this shortly in the section " awareness".

### 5.4.1.3 *Commssives, expressives and declarations*

We also identified a small number of commissives, expressives and declarations. Commissvies are field player's response to an assertive or directive. It can be an acknowledgement of receiving a piece of information or commitment to execute a plan. (e.g. "ok got it", "I am heading there" )

Expressives and declarations are only found in session C. Expressives are typically HQ's congratulations to field players. (e.g. "HQ:Good Job, JJ, TV and RL" )

In session C, HQ players sometimes declare field players to be in a team (e.g. "NOTICE - TEAM B: NS + TD"). The declaration helps HQ to refer to a team easier.

### 5.4.1.4 *Requests and Adjacency pairs*

In linguistics, adjacency pair is a term to describe conversational turn taking. The pairs can be question->answer, inform -> acknowledge, offer ->acceptance et al.

For simplicity, we ignore the typology of adjacency pairs and treat all pairs as re- quest-> response. Any utterance that expects a response is considered as a request.

We found a number of requests sent from Headquarters and field players (14 in session C and 20 in session D). Those requests can be related to a number of themes: Field players may send request for:

insert table

For headquarters:

insert table

In comparison, only a small number of adjacency pairs are found in both sessions (8 in C and 8 in D), which means not all requests are responded.

It is also worth mentioning that field players didn't send acknowledgements to directives from headquarter. Although we do not classify directives as a request which expect an answer, the headquarter players express their frustration for not having response to their in-

structions.

A HQ player said in the group interview: ï¿Œ ï¿Œ

> "I guess they did not look at it, they could not respond it, we were like saying "where are you, respond", but they did not respond. I guess they are busy seeing themselves and the targets"

A field players also commented on the issue:

> "I almost would not use the communication system because I was too focused on trying to save the targets."

> "Sometimes I check whether the radiation is close to us, but mostly the communication is between us (local team members)"

### 5.4.2    *Responding to directives from HQ*

We examine how field responders deal with messages from HQ that attempt to allocate tasks and manage task execution (i.e., directives). Classification of messages showed that directives were exclusive- ly sent by HQ, and that they were the most frequent kind of message (Table 1). Directives index (attempted) instances of remote coordination of field responders by HQ. The observed response to messages is critical to understanding relation- ships between local and remote coordination. The following episode depicts a team of three on their way to pick up fuel. Their path is blocked by radiation. Without a team, firefighter JH (on the left) has just joined soldier KY (on the right), and firefighter D2 who have just been allocated a task in a message by HQ.

insert episode here

This episode begins with a message by HQ attempting to help give directions to the target. D2's response to the message is hesitant (is that what we should do?). His following question (which junction is that?) suggests the referent in HQ's message is not understood. They attempt to go around the radiation. They realise their target is in the cloud. They refer back to the message to support their intent to go into the cloud to attempt to save the target (Yah this is what the head-quarters told us to do). Having run into the cloud, they refer to the Geiger counter and realise the exposure is too high. Meanwhile, their health is decreasing rapidly. They abandon the task and flee to safety, whilst JH expresses his frustration (We are not prepared for that. I blame our HQ.).

First, the episode shows that geospatial referencing in messages can be problematic. It is unclear to the responders which junction HQ is referencing (and the responders do not ask for clarification), so they revise the route themselves. At the same time, they draw on the messages to justify their entering of the cloud. It does not occur to the responders that HQ allocated the task at an earlier time, before the cloud had covered the target. HQ does not update the responders on the increased danger, or revise their earlier task allocation. When the responder team fails to complete the task, they place blame instead of thinking self-critically.

Overall, out of the 43 task allocation directives HQ sent, the recipient field responders brought up only 15 messages in conversation in the team. The instances in which task allocation messages were addressed reveal the handling and value of HQ di- rectives in the local coordination. Firstly, out of the 15 task allocation messages responders talked about, they decided to ignore the instructions only once. The re- sponders ignored instructions because they were engaged in

another task that they did not want to abandon. Secondly, four HQ instructions to rescue a certain target coincided with the same plan that had already been made locally by the respond- ers. In 10 cases, field responders chose to follow the instructions. However, due to confusion and misunderstanding they failed to follow them correctly six times. In fact, only 2 instances of directives from the HQ led to task completion. For the remaining 14 saved targets, field responders had locally allocated the tasks without HQ.

Secondly, some HQ instructions are consistent with a decision to rescue a certain target that has already been made locally by the re- sponders.

In 10 cases field responders chose to follow the instructions. Although players are willing to follow HQ's instructions, they failed to correctly follow the instructions due to confusion and misunderstanding in the communication. In fact, only 2 instances of directives from the HQ led to task completion. The field responders accomplished task allocation of all other 14 saved targets locally.

### 5.4.3  *Local coordination without HQ*

As presented, field responders predominantly coordinated teaming and task allocation of targets that were saved without HQ involvement. The following episode illustrates how field responders achieve coor- dination of teaming and task allocation locally. We join the action as BR and an- other responder are waiting at the drop-off zone without a compatible teammate, as MF and his teammate join and drop-off their target.

insert episode

The episode shows how teaming and task allocation are achieved opportunistically between BR and MF, with BR already waiting at the drop-off zone. Field responders also confirmed their opportunistic behaviour in the interview:

"Just save the closest target then just pair up and go to the other one" [P2] "We just check, with that group, which target we can get. We see on the map to find the closet one we can get." [P4]

BR and MF can then be observed sharing the screen of his device and using the map to identify potential targets. They realise one of them is already being pursued by another team. They agree on another target to pursue. Note that messages do not play a role in this episode. It exemplifies how teaming and task allocation are achieved locally, without consulting HQ.

5.4.4 *Messages as a resource of situational awareness*

In the Radiation Response Game, field responders need to be aware of what other responders are doing, where the 'danger zone' is (the cloud), and where it is likely to move. Awareness of each other's actions helps responders avoid conflicts in planning, while awareness of the danger zone is essential to survive. The following episode illustrates how responders use messages as a resource to gain situational awareness.

The episode takes place towards the end of game session B. The radioac- tive cloud has grown so much that navigation in the game area becomes increas- ingly difficult. MF is with a group of five re-

sponders, two of which are carrying an animal. The cloud is blocking their way towards the drop off zone; they stop.

MF: ((reads message from HQ out loud)) There is another leak around Geospatial. (1.0) Which is Ah: so there's a leak sprung up there. ((points)) Geospatial is like (.) that building right there. They say there is another leak. We should go all the way round (0.5) to the top left one, I think.

MF brings up HQ's message of the new leak, and suggests a route around the new cloud. The group ends up following MF's route suggestion as a result. News of the new cloud, provided by HQ, enables the group to change their route to avoid danger. We commonly observed responders sharing information that provides situational awareness through face-to-face conversation. In the previous example, MF shared the message with a group of responders he was with already. The following example takes place between D2 and his teammate, as they are approached by JH, who is currently without teammate.

insert fragment here

Making use of the map as he approaches them, JH asks the others to clarify which fuel they intend to pursue (the closest one to you?). He proceeds to inform the team that the "leak is somewhere near the other one". D2's re- sponse (Oh, which one?) suggests they did not know this. In turn, JH elaborates on the location of the cloud, using an anonymous "they" to refer to the source of his information. "They" is likely to refer to HQ as they previously sent a message with the information of the cloud's location. Conversational sharing of important information was a common resource responders employed to achieve and maintain situational awareness. However, requests for information were regularly not reciprocated with a response: out of 14 requests in session A, 8 were not responded upon; and in session B,

14 out of 20 requests were not responded upon.

## 5.5 DISCUSSION

We now discuss the requirements for team coordination that emerged from the game and relate them to broader concerns for the design of HAC systems that support team coordination.

The embodied game probe embedded responders in a challenging setting. They needed to communicate effectively to make time critical decisions on teaming and task allocation, both locally in the field as well as remotely through messaging. Field responders physically engage and navigate the environment to perform tasks while maintaining awareness of risk and danger. The data reveals multiple challenges for team coordination involving communication and decision-making.

Local decision-making. The study showed that teaming and task allocation were predominantly organised locally among field responders, in an opportunistic, on- the-fly fashion. Despite the fact that headquarters attempted to coordinate task al- location remotely, few of these directives were brought to conversation locally. Only 2 out of 16 tasks that field responders completed were remotely allocated by HQ. Local decision-making needs to be supported by HAC systems that aim to support time-critical team coordination, and need to integrate capabilities to ena- ble team-wide sharing of the local decisions.

Coordinate resources. While field responders made decisions on teaming and task allocation in a seemingly ad hoc fashion, game data reveals how field responders draw on resources to achieve situational awareness in order to coordinate successfully. A common understanding of the location and movement of the radia- tion cloud

was achieved by sharing information from game messages verbally in a local group. Face-to-face talk was an essential resource for relaying information from the Mobile Responder App to teammates, such as radioactive exposure, oth- ers' whereabouts, task status, and other monitoring of the broadcast messages. Future HAC systems need to take into account that such coordinate resources are likely to be comprised of digital as well as embodied human resources.

Geospatial referencing. The results show that geospatial referencing was problematic in various ways, particularly in directive messages sent to the field players. Participants had different levels of knowledge of the campus, which made understanding of landmark references uncertain. Some participants also struggled with making sense of north/south/east/west directions in relation to their current position and orientation. To deal with misunderstandings, players had to ask for clarification via messages or spend valuable time discussing the reference locally in order to understand it. Consistent with the findings of Toups et al. (2009), de- signers need to think carefully about how the presentation layer of HAC systems may be augmented with information that facilitates geospatial referencing (e.g., grids, labelling etc.) to facilitate human in addition to machine readability. Freshness of messages. Problems arose from erroneous instructions or otherwise out-dated messages sent to field responders. In one case HQ sent a message in which two players with non-compatible roles were instructed to team up. This was particularly costly, as the players attempted to team up, and lost valuable time until they realised the game mechanics barred them from forming a team.

As demonstrated in one of the episodes, reading out-dated messages in a dynamically changing environment can contribute to responders taking dangerous actions that they believe to be safe, because they do not realise that the infor- mation is out-dated. However, in most cases, recipients managed to identify tem- porally irrelevant

messages, and thus avoided following them.

To reduce confusion about message freshness, HAC systems should address these issues at the UI level, both for responders and for HQ. Develop functionality to flag messages as out-dated or retract incorrect messages. Up-to-date messages are particularly valuable. Thus, our findings support the use of fresh social media as a source of information for disaster response, despite problems that can arise with validation, because crowdsourced information will in many cases provide better coverage than official sources.

Acknowledgement of messages. In most cases, field responders did not acknowledge or respond to messages sent by the HQ. This was particularly problematic for directives (task allocation), as task status and field responder compliance often had to be inferred by observing their location updates on the map. This consumed HQ attention, with negative impact on HQ's overall work on state assessment and task planning. Observations in the field suggest that the physical demands (e.g., co-located team movement through terrain at speed) and cognitive demands to maintain situational awareness (e.g., monitoring of radioactivity and messages) are likely factors that explain lack of acknowledgement.

As a result, user interfaces that enable and encourage field responders to quickly acknowledge HQ messages, with minimum cognitive load, should be consid- ered for messaging in HAC systems in such high demand settings. For effective team coordination in disaster response, interface and workflow designs need to factor in cognitive load and task demands for effective information distribution.

## 5.6   CONCLUSION

The objective of the research presented here was to generate requirements for sup- porting time-critical team coordination. In particular, we focussed on a scenario in which responders coordinate role-based teaming and spatially distributed task al- location and execution using a real-time location and messaging system.

We presented the design and study of the Radiation Response Game as a mixed-reality game probe to investigate challenges for team coordination in a set- ting in which participants experience both physical strain through bodily activity, and cognitive challenge through time pressure and task complexity. We eschew high-fidelity simulations in favour of mixed-reality game probes as a platform for investigation of concomitant socio-technical issues: handling of mobile devices to communicate and maintain situational awareness (messaging, sensing, interaction, and display) intersect with face-to-face interaction, whilst the physio-cognitive challenges created through game mechanics and environment induce stress. We created a setting that allows exploring requirements to support team coordination of relevance to time-critical coordination domains such as real disaster response.

Findings from interaction analysis of field observations, triangulated with log files, reveal how field responders achieved coordination by drawing on local face-to-face conversation with fellow responders, and situational information provided by the interactive map, the Geiger counter, and the messages sent by HQ. Drawing on these findings, we generated requirements for supporting team coordination, emphasising the roles of local coordination, decision-making resources, geospatial referencing and message handling. These requirements inform future work on building human-centred HAC systems

by emphasising the role of human interaction in team coordination in time-critical settings.

# 6

## ATOMICORCHID STUDY 2: AGENT SUPPORTED HUOL DESIGN

This chapter presents the second iteration of AtomicOrchid field trials. In this study, a planning agent is integrated into the system by following a HuOL interaction design, in which the HQ only monitor and occasionally intervene the planning agent. The purpose of the trials is to investigate socio-technical issues relating to integrating the planning agent to rescue team with the HuOL interaction design. Interaction analysis is conducted to examine log data and field observations unfolding how human agent interaction plays out, which in turn, revealing the process by which players interpret and negotiate the agent guidance as well as how these are intertwined with social dynamics of the teams.

### 6.1 INTRODUCTION

Task planning in teams can be complicated by both spatial and temporal constraints, particularly in time-critical task domains such as disaster response (DR). In a DR setting, responder teams have to coordinate sparse resources and personnel to prioritize geographically distributed tasks, forming and disbanding teams dynamically to carry out DR operations [4]. Multi-agent researcher has devised a number of agent coordination algorithm to coordinate task allocations for multi-agent systems, which create opportunity for computational planning support for DR teams.

However, these algorithms typically model humans as computational agents with respective capabilities, for example to dynamically

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allocate teams of agents to tasks in order to maximise an objective
(e.g., number of lives saved), taking into account other aspects of the
real world (environment, infrastructures, victims, etc.) [14]. Therefore,
the quality of the planning results can be constrained by limited as-
sumptions of human behaviour (e.g., human psychosocial characteris-
tics, movement, and learning ability)and real world environment [18].
These limitations highlight importance of human input in the plan-
ning process. Thus, we argue that effective collaboration between hu-
man and agent is required to produce and execute high quality plans
in the disaster setting. (see section x.x.x).

In other to support effective Human agent collaboration, a num-
ber of interaction design strategies have been identified, including
design patterns such as HuOL and HuIL (see section x). In this study,
the planning agent is integrated into the AtomicOrchid system with a
straightforward HuOL design pattern. This interaction design pattern
assumes minimal Headquarter intervention and simple feedbacks from
field responders are required by the agent to perform task planning.
The interaction design is aimed to facilitate the division of labour be-
tween humans and agent: a planning agent routinely assigns tasks
to distributed responder teams, while human coordinators (the HQ)
monitor and support the task execution by responding to arising con-
tingencies. The agent is designed in a way to take into account simple
human feedback, i.e., a field responder can either reject or accept their
task assignment. The agent will consider the feedback for the next it-
eration of task assignment.

This study uses the agent integrated version of AtomicOrchid as
a probe to unfold socio-technical issues in human-agent interaction,
with focus on the implications of the HuOL design for human team
performance. The implications for the interaction design are discussed
that may improve team performance. More specifically, this chapter
addresses the following research questions on how agent guidance

affects the social organisation of team performance:

How do human teams respond to being instructed by an agent, particularly on switching teams and tasks?
The planning agent makes decisions based on limited assumptions about human behaviour, but what are the hidden costs of human behaviour that the agent does not take into account?

Findings from the study highlight the social processes in which members interpret, negotiate, and manage the agent guidance within the social dynamics of teams. We discuss the division of labour between humans and teams; the hidden costs of instructions that suggest team reformation and interrupt on-going tasks. We conclude the paper with a number of emerging interaction design recommendations to consider when building agent-based support systems for human teams, which emphasise the need for common ground between humans and the agent, facilitate accountability between team members, and balance responsibilities between humans and the planning agent appropriately.

## 6.2 SYSTEM EVOLUTION

Compared to study 1, the system has evolved to provide agent planning support through HuOL interaction pattern. This section will go through the changes of system, which includes integration of a planning agent, implementation of a quick feedback system, and improvement in both HQ and mobile interface.

### 6.2.1  *The planning agent*

The major change of the system is the integration of a planning agent into the AtomicOrchid platform. The planning agent is developed by ORCHID research partner Wu Feng, Savapali Ramchun. The coordination problem of the AtomicOrchid is modelled using a Multi-Agent Markov Decision Process (MMDP) that captures the uncertainties of task execution, extending earlier work [15].The modelling allows responder actions to be delayed or to fail during the rescue process. The MMDP modelling leads to a large search space, even with a small-sized problem. Hence, we devised an approximate solution to save computation time, which can be executed to support real time planning. The planning algorithm takes into account both time (cloud and human movement speed) and spatial (path planning for responders) constraints. The planning algorithm run by the planning agent produces high task allocations that minimise the travelling distance of first responders, and maximise the number of targets rescued. Before the agent was deployed to support human teams in the game setting, computational simulations were done by Wu Feng to benchmark our MMDP algorithm against greedy and myopic methods (see Table 1). The results confirm that our algorithm produces efficient task allocations.

The agent is wrapped in a Java server framework and deployed on an independent server separate from AtomicOrchid. The agent server exposes a HTTP interface for AtomicOrchid to request plan. Each plan request issued by AtomicOrchid is appended with updated game status, which includes players' health, distribution of radioactive cloud and locations of players, and targets. Based on the updated game status, the agent will produce an optimised task allocation and return it to AtomicOrchid. The plan requests are triggered frequently in game sessions so that the task allocation can be frequently ad-

justed according to task execution status. Plan requests (and thus re-planning) is triggered by two kinds of game events:

1. Completion of task. On successful rescue of a target, a new plan (i.e., allocation of tasks to each responder) is requested from the agent.

2. Explicit reject. On rejection of a task allocation by any of the first responders, a new plan is requested. The feature of rejection is part of a feedback loop between human and agent, will be introduced in next section.

### 6.2.2 *A feedback loop*

The feedback system is part of the HuOL interaction design, which enables the agent to take into account simple human feedback. It is also partly inspired by a requirement generated in the study 1, which highlights the importance quick acknowledgement from field responders. The feedback system can be seen as system level support for the field team to provide quick response to the HQ. This section will go through implementation details of the feedback loop.

Once a plan is received from the agent, the AtomicOrchid game engine splits the plan for a given team into individual task allocations and sends these to each responder s mobile app. The app displays the task allocation in a pop-up and details it in the task tab, including: i) the responder to team up with, ii) the allocated target (using target id), and iii) the approximate direction of the target (e.g., north, east).

On receiving a instruction from agent, the field responder can choose to either reject or accept the instruction. In the case of rejection, new

plan will be requested and the agent will consider the feedback for the next iteration of task assignment. More importantly, the rejected allocation is used as a constraint within the optimisation run by the planner agent. For example, if two responders (a medic and a soldier) were allocated a task and the solider rejected it, the planning agent would return a new task allocation with the constraint that this soldier should not be allocated this task.

### 6.2.3 *Interface improvement*

Apart from the integration and feedback system, two small modification of the interface is inspired by the requirements of coordination system generated in the previous section (See section xxx). Firstly, all icons of targets are now marked by a unique target number for HQ and field responders to cross-reference. Secondly, all the messages are labelled by timestamps for players to identify outdated messages.

### 6.3 STUDY DESIGN

In this study, we aimed to probe a straightforward [interaction design] between a planning support agent and human teams (Fig. 1). The interactional design is designed to facilitate the division of labour between humans and agent: a planning agent routinely assigns tasks to distributed responder teams, while human coordinators (the HQ) monitor and support the task execution by responding to arising contingencies. The agent is designed in a way to take into account simple human feedback, i.e., a field responder can either reject or accept their task assignment. The agent will consider the feedback for the next iteration of task assignment.

By examining the socially organised interaction between team members occasioned by this interactional arrangement, we aimed to explore social implications of human-agent interaction. In turn, these inform the design of agent-based systems. In the following, we describe the study in detail.

A real-time algorithm was developed to support the coordination problem created by the game mechanic. The coordination problem (described in IV, A) is modelled using a Multi-Agent Markov Decision Process (MMDP) that captures the uncertainties of task execution, extending earlier work [15]. The modelling allows responder actions to be delayed or to fail during the rescue process. The MMDP modelling leads to a large search space, even with a small-sized problem. Hence, we devised an approximate solution to save computation time, which can be executed to support real time planning. The planning algorithm takes into account both time (cloud and human movement speed) and spatial (path planning for responders) constraints. The planning algorithm run by the planning agent produces high task allocations that minimise the travelling distance of first responders, and maximise the number of targets rescued. Before the agent was deployed to support human teams in the game setting, computational simulations were used to benchmark our MMDP algorithm against greedy and myopic methods (see Table 1). The results confirm that our algorithm produces efficient task allocations.

In their mission to rescue all the targets from the disaster space, a centrally located HQ and the planning agent support the responders on the ground. In what follows, we present the player interfaces and the interactions with the planning agent. A demo video can be viewed at http://bit.ly/1ebNYty.

First responders are equipped with a mobile responder tool (Fig. 2) providing sensing and awareness capabilities in three tabs (Geiger

counter, map, messaging and tasks). The first tab shows a reading of radioactivity, player health level (based on exposure), and a GPS-enabled map of the game area to locate fellow responders, the targets to be rescued and their drop off zones. The second tab provides a broadcast interface to message fellow first responders and the HQ. The third tab shows the team and task allocation dynamically provided by the agent that can be accepted or rejected. Notifications are used to alert both to new messages and task allocations.

HQ controls the HQ dashboard that provides an overview of the game area, including responders real-time locations (Fig. 2). The dashboard provides a broadcast messaging widget, and a player status widget so that the responders exposure and health levels can be monitored. HQ can further monitor the current team and task allocations to individual responders by the planning agent (by using buttons in the player status widget). Crucially, only HQ can see the radioactive cloud, graphically depicted as a heatmap. The rationale was to entice frequent communication between field responders and HQ.

## 6.4    DATA ANALYSIS AND RESULTS

This section presents episodes to reveal how teams accomplish the tasks in the rescue mission, particularly focusing on the social organisation of interaction with and around the agent instructions. In the following fragments, players can be uniquely identified by their initials. Targets are denoted by their unique numeric target id. Task assignments from the agent are represented as two initials and one target id connected by a rightward arrow. For example, the notation PC, CR -> 22 means player PC and CR are instructed to team up and go for target 22. A standard orthographic notation [8] is com-

plemented by timestamps [0:00], and system messages from remote players and HQ.

### 6.4.1 *Task assignment*

The following episode depicts a team of two dropping off a target and planning the next step.

At the beginning of this episode, the team (PC, CR) drops off a target at a drop off zone. Player PC vocalises that they have finished the task (PC: I think we dropped off now. OK). After about 7 seconds, PC says she received a new task allocation from the agent (PC: I have a task now). PC confirms the initials of the other player (CR), and suggests CR to join her to go for target 22. The action is consistent with the agent instruction (PC, CR -> 22), suggesting that PC has read through the instruction and decided to follow it. CR said that they have already finished target 22 (CR: We have done 22), which indicates he is confused about the current task allocation. PC resolves the confusion by pointing in the direction of 22 and repeating to go for it. Later, the team successfully drop off target 22 as instructed by the agent.

The episode shows how an agent instruction is brought up and followed by a team in relative straightforward manner. The instruction was delivered immediately after the drop off of a previous target (7 seconds after). PC successfully locates the new target in the instruction and leads the team to pick it up. Although CR is confused at first, PC manages to rectify CR mistake and they finish the task successfully.

This episode is a typical case of task assignment to existing teams, i.e. the agent sent a new task to a team immediately after they finished

their previous task. Out of a total of 51 agent instructions, 23 fall into this category. The rate of compliance is high for these cases of task assignment to existing teams (21 out of 23; 91

### 6.4.2  *Team reformation*

Unlike episode A, sometimes the agent instruction implies players need to disband and form new teams after finishing their previous task, in order to enact the computationally optimal plan. 10 out of 51 agent instructions fall into this category. The compliance rate of instructions that require reteaming (50 percent) is substantially lower than compliance of instructions where players can stay in the same teams (91 percent). The following episode depicts a typical case in which team reformation fails.

The episode begins with a recommendation by HQ to LT to go for 10 (message A). The message is topicalised by LT, but it is soon overridden by an agent instruction (NK, LT -> 16). When CR proposes to team up with LT to go for target 10, LT declined (LT: mine is 16). HQ then withdraws its previous suggestion to go for 10 in message B. Shortly after; a new instruction (NW, LT-> 15) prompts LT to read out the target number (15), but she fails to raise the other players attention. While other group members engaged in planning next steps, LT does not engage and keeps looking around. She can be seen turning and walking back and forth (Fig. 3). Perhaps LT is trying to locate the player NW who she had been instructed to team up with. LT does not take any action until prompted by CR (CR: are you LT? NW is looking for you). Then, LT begins to walk to find her teammate. However, when she finally manages to meet up with NW two minutes later, NW has already been assigned another task.

On one hand, LT seems to feel obliged to follow the agent instructions. She turns down other teaming invitations and appears to try to look for NW in her immediate vicinity, indicating difficulty with locating teammates out of sight (despite the real-time location map). On the other hand, her body orientation displays a sense of attachment to the existing group. Her indecisive walking and turning back and forth suggests she struggles to leave. She does not leave the group to follow the instructions until prompted by someone. When CR points out NW message, LT does not answer the message either. The episode illustrates a combination of interactional troubles as a result of which the reteaming fails: being attached to the local group, struggling to locate teammates out of sight, and failing to reciprocate messages.

Further, we found the distance between instructed players to be a key factor in successful reteaming. That is to say, if instructed players are not within line of sight, the rate of non-compliance with the agent instruction is high. Take episode B as an example, player LT was instructed to team up with a distant player twice. Neither one of the instructions was successfully implemented. Overall, there were 17 agent instructions that implied teaming with distant players; only 1 of them were actually followed by players. Players explicitly rejected 11 of them by pressing the rejection button; the other 5 were not followed without an interface action.

### 6.4.3    *Task interruption*

In some other cases, the agent also sent new instructions to teams that had already commenced their task; that is, teams were interrupted by the new instructions. The following two episodes C and D describe how players handled task interruptions caused by the agent.

This episode begins with an instruction (AW, HB -> 44) from the agent. At that moment, there were 5 players at the drop off zone (AR, KD, LC, HB, AW). Immediately after the instruction, HB starts looking for AW in the local group. Shortly after, AR and HB team up to go for 44 as instructed. However, 13 seconds later the team is interrupted with a HQ message telling them not to go for 44 (Target 42 and 44 is not reachable). Four seconds later, a conflicting agent instruction was delivered, implying they disband the team (AW, KD -> 44, HB, AR->31) but still pursue the target 44. At first, AW stops walking and topicalises the instruction (AW: I got a new instruction), followed by both teammates simultaneously turning towards each other (Fig. 5). The bodily alignment in the action suggests agreement to follow the new instruction. On their way back to drop off zone, HB and AW confirm their intentions (HB: I need to team up with AR, AW: I need to team up with KD!). In this case, the teammates respond to the interruption by mutually agreeing to abandon the current team and task in favour of following the new assignment.

It should be noted that the interruption was received only 17 seconds after the team commenced the task, probably contributing to a low perceived cost of abandoning the current task. Further, all players involved in the subsequent reteaming were not far away from each other. AW and HB had not walked too far from the drop off zone; so everyone was still within line of sight, further facilitating successful reformation.

### 6.4.4 *Disagreement on task interruption*

In this fragment, we can observe disagreement and negotiation of team reformation. Following episode C, player AW disbands his team with HB and teams up with KD. However, 20 seconds after the ref-

ormation, AW is instructed to abandon the on-going task again. AW laughs, but turns back to find player HB again. Before AW sets off, KD disagrees with the new instruction and proposes to reject it (Ehh, have they gone? Because we can just decline and carry on). AW accepts KDs suggestion and turns back to KD.

After the rejection, AW receives 2 consecutive reteaming instructions from the agent, finally teaming them up with LC, while KD does not receive another instruction. KDs question (Do they know we are already on the task?) suggests that he might think the agent is unaware of their situation, and that he disagrees with disbanding the existing team. In spite of KDs disagreement, AW declares his intention to follow the new instruction (got new instruction again, [team up with] LC) and he turns to find LC. However, KD ignores this (KD: Alright, Lets go to 46), indicating he does not agree with AWs intention to disband the team. AW interjects (I dont know, I got a new task with LC), and continues to walk towards LC, denying KD. As KD realizes he is without assignment (Ah, I do not have a task), he follows AW to find LC.

In this episode, teammates agree to reject the first task assignments. We found task interruption could be a major reason to reject new instructions. 10 out of 11 rejected instructions are associated with task interruption. In an extreme case (not pictured), one team reached an agreement to ignore any agent instructions after the agent tried to interrupt the teams on-going task.

In the end, the player that received the new instruction disagrees with his teammates suggestion to ignore the instruction and decides to leave the current team. The team is disbanded in disagreement, in contrast to episode C where both teammates agree to leave the team after both received new instructions at the same time. Here, the teammates spend a fair amount of time arguing whether to follow

or ignore instructions, hinting at the hidden social cost of coalition formation algorithms when applied to human teams.

Overall, the majority of new instructions that interrupted on-going tasks required team reformation. When tasks were interrupted, the rate of compliance (22 percent) is substantially lower than when teams were required to reform after a task was completed (50 percent). Task interruptions were also much more likely to lead to rejection of the new assignment. 10 out of 11 assignments that interrupted tasks were rejected.

### 6.4.5 *The headquarters*

HQ sent a total of 147 messages in the two sessions. We identified 50 assertives and 68 directives in two sessions through speech act analysis. The majority of assertives were focused on providing situational awareness and safe routing the responders to avoid exposing them to radiation. E.g. NK and JL approach drop off 6 by navigating via 10 and 09. Or Radiation cloud is at the east of the National College.

16 out of 68 directives were directly related to task allocations and teaming, which is substantially less then the number of agent instructions (51). Among the 16 directives, HQ sent 11 direct instructions to the field players (e.g. SS and LT retrieve 09), while the remaining 5 are related to forward planning, (e.g., DP and SS, as soon as you can head to 20 before the radiation cloud gets there first). 6 of the HQ instructions are consistent with agent instruction, while 5 other HQ instructions override the agent instructions. It is worth mentioning that field players implemented only 5 out of 16 HQ instructions. In the interview, HQ reported that they felt they supported the agent rather than take control.

6.5 DISCUSSION

In the previous sections, we described how the agent guidance is interleaved with the social interaction, in which teammates organise the task planning and execution. We found that while the agent supported division of labour, the agent guidance had various social implications. We now reflect on (A) how division of labour is achieved; (B) the social implications and hidden cost incurred by team reformation and task interruption; and (C) the limited feedback mechanism.

6.5.1 *Division of labour between the agent and the human teams*

Overall, players followed 30 out of 51 agent instructions, out of which 21 tasks were completed according to the instruction (success rate of 70 percent). Only 2 targets were evacuated without agent instruction, which indicates that, to a large extent, the agent successfully supported routine task planning activities. Episode A demonstrates a typical case of division of labour: the agent handles planning of teaming and task assignment, freeing the team to focus on navigational issues (identifying the target on the interactive map and finding directions). The following of agent instructions speaks of players trust in the agents decisions. In the 30 cases where instructions were followed, we can observe similar patterns of labour division.

The distribution of HQ messages may also indicate a division of labour between HQ and the agent. Only a small proportion (16 out of 147) is directly related to task assignment, indicating routine task allocations were delegated to the agent. A relatively large proportion (118 out of 147) of messages are used to provide situational awareness and safety routing the responders to avoid radiation exposure. However, the fact that only 5 (out of 16) HQ instructions are implemented sug-

gests that HQ was unable to effectively override the agent when they wanted to. This fact highlights that the planning agent plays a strong role in the control loop, compared to the human coordinators in the HQ. The planning agent can directly instruct field responders without consent of the HQ, and the HQ does not have an effective way of overriding the agents decision. This has implications for interaction design that are discussed in the next section.

6.5.2    *Hidden costs of team reformation and task interruption*

While team compliance rate with agent instructions was high when no reteaming was required (91 percent), we found that the rate of compliance with agent instructions is much lower when team reformation is involved (50 percent), and even lower when in addition an on-going task is interrupted (22 percent) (see Table 2). Our interaction analysis shows the ways in which team reformation and task interruption are associated with hidden costs in the social organisation of team performance.

Firstly, we found that team disbanding can be difficult. Players have to make their actions accountable to gracefully disengage from an existing team to avoid breaching social norms (e.g., politeness). Members have displayed a sense of attachment to a local group (section V.B), which delayed the task substantially until the team reformation failed. Despite interrupting an on-going task, new instructions for both teammates can facilitate smooth, mutually agreed disbanding (V.C), while instructions for only one member have coincided with interactional trouble, disagreement and delays (V.D).

Secondly, the impact of attachment between co-located teammates was further amplified by distance between proposed teammates. While they frequently accounted for actions with co-located players, they

did not make their actions equally accountable to remote team members. For example in episode D, the agent interrupted the local teams task and instructed them to team up with distant players. The co-located team decided to reject the instruction without contacting the potential teammates they rejected. The system lacked support of accountability between remote members.

A further observation is that players were unwilling to give up ongoing tasks after a certain time. In episode D, the teammates first agree to ignore new instructions. This preference to stick with ongoing tasks may also explain the high rejection rate for instructions involving task interruptions.

The social organisation of coordination reveals implications for the simplistic model of interaction held by the agent. The agents coalition formation re-plans and reshuffles teams, in order to optimise group performance by minimising the travel distance to the targets. However, our study has revealed the ways in which social norms and the accountability of social conduct get in the way. This raises questions of the effectiveness of approaches that treat coalition formation of humans as unproblematic. The agent does not consider the social cost of team reformation and task interruption. Our field study has shown that the social process to disengage from groups and on-going tasks can be costly. The tension between the social process and the model held by the agent echoes the notion of workflow from within and without [1]. The authors point out that models imposed by technology (from without) may come into tension with the actual workflow achieved through methods internal to the work (from within).

6.5.3    *Feedback to the agent*

To recap, a feedback mechanism is included in the interaction design to give responders some control over the task assignment. On receiving an instruction, players can either accept or reject instructions. On rejection of a task allocation, a new plan is requested. The rejected allocation is, in turn, used as a constraint within the optimisation run by the planner agent, which means the rejected target will not be assigned to the rejecting player for a while (1 minute).

Our observations show there may be a significant cost associated with rejection. Overall, 6 out of 25 re-plans were triggered by rejections. In turn, tasks were re-assigned to all players. Frequent new instructions may cause extra coordination overhead (time spent on interpreting new instructions, more team reformation and task interruptions, and over-constrain the planning). Players did not seem to be aware of the implications that their rejections had on others.

We also found that players expectations of the rejection were not always aligned with its actual effect. Instructions involving reformation and interruption are more likely to be rejected. Players statements indicate they perceive the rejection as a way to reverse to previous states (see ep. D). Other statements indicate rejections were expected to pair them with a new teammate instead of a new target. The mismatch between expected and actual effect highlights the lack of intelligibility in the current interaction design. We aimed at simplicity (by providing only accept/reject options), which might be important for interaction in time-critical task settings, but it comes at the cost of intelligibility. Therefore, we argue that intelligibility and simplicity need to be carefully balanced according to details of the setting.

## 6.6 DESIGN IMPLICATIONS

Our observations reveal the tension between agent planning support and the social organisation of teamwork. The tension does not simply mean the model held by the agent is incorrect; it highlights potential trade-offs we need to consider in system design [1]. Providing a detailed design solution is beyond the scope of this paper. Instead, we propose three design implications to scaffold the division of labour when building agent-based planning support for human teams.

### 6.6.1 *Achieve common ground*

Two main issues arose that challenged this basis for collaboration [2,19]. Firstly, a notion of the social cost associated with instructing teams should be taken into account when designing planning agents. For example, disbanding teams can be difficult and time-consuming as it is governed by rules of social conduct and etiquette, particularly where the new teammates are out of sight or only one of the teammates received a new instruction. Secondly, a mismatch between the expected and actual function of rejections further shows intelligibility needs to be improved. Therefore, we suggest the design of agent support that a) takes social factors into consideration (e.g., ensuring team disbanding is facilitated by reteaming both teammates at the same time; avoiding task interruptions etc.), and that b) agent functionality is appropriately surfaced to help achieve common ground (e.g., by providing explanations of agent action at the interface level).

### 6.6.2 *Facilitate accountability*

while the rules of social conduct ensured accountability of action among co-located teammates, we found the impact of rejections on

remote players was not properly appreciated; nor did the interaction design support making these rejections accountable. Therefore, we believe the interaction design shall reveal the hidden cost of certain actions (e.g., rejections) to facilitate making local decisions accountable to remote team members, ensuring consequences of local decisions for the welfare of all teams are understood.

### 6.6.3 *Balance responsibilities between humans and agent*

The social implications and other situational contingencies are likely difficult to be modelled computationally. Alternative approaches argue for mixed-initiative control and flexible autonomy between humans and agents [2]. The ways in which the HQ used messsages to provide situational information that complemented the agent instructions show that humans are readily able to deal with arising situational contingencies. The division of labour between humans and the agent appeared most effective in that the agent took on routine and repetitive jobs (task assignment), which freed the responders to focus on the situated rescue mission. In our interactional arrangement, the role of the human HQ was relatively weak. For example, the HQ struggled to overwrite the agents instructions through the messaging channel. In the future, we seek to allow the HQ to play a stronger role in the control loop to enable more direct mediation and amendment of agent instructions (e.g., by directly modifying the task assignments, or by adding information relating to the assignments, such as safe routing).

### 6.7 CONCLUSION

# ATOMICORCHID STUDY 3: AGENT-SUPPORTED HUIL DESIGN

This chapter presents the third iteration of AtomicOrchid field trials. Based on the section prototype of AtomicOrchid (see chapter x), the system have gone through another development iteration to facilitate a HuIL interaction pattern. The HuIL pattern assume that constant interaction between human HQ and the agent is required for planning. The purpose of the trials is to investigate socio-technical issues relating to agent planning support with the HuIL interaction design. Interaction analysis is conducted to examine log data and field observations unfolding how human agent interaction plays out with a HuIL design. The results of the analysis reveals the process by which HQ, field players and the agents collectively generate and executes plans, as well as both social and technical issues emerged from this process.

## 7.1 INTRODUCTION

The most disaster operations requires responder teams to plan and carry out task under spatial and time constraints. which means the teams often have limited resource and personnel to deal with large amount of geopolitically distributed tasks in limited amount of time. How do they optimise the use their rescue resources become computationally complicated problem. Multi-agent system researchers have developed multi-agent task allocation algorithms. As software components, they have all done very well in the computational simulation, therefore there is potential to apply those algorithms to support plan-

ning activity of human responder teams.

However, there is concern that the algorithms hold over-simplified model of the environment and human behaviours. Therefore, effective interactions with the responder teams are required to ensure the planning agent actual support (rather than hinder) the planning process of responder teams, which highlight the importance of appropriate interaction design. In the previous study, a HuOL design pattern has been explored. The results of the previous study highlight the need for human HQ to play a strong role in the planning. The result is consistent with the assumption of a HuIL design pattern in that the pattern assumes frequent HQ supervision and intervention is required to ensure the agent works properly. In this study, the AtomicOrchid system has evolved to facilitate a HuIL interaction pattern.

Partly inspired by the previous study [], this HuIL design enables HQ human to strongly involve in the planning process by:

1. allowing HQ to review and approve every instructions generated by agent.

2. allowing HQ to reject and override instructions generated by agent.

3. allowing HQ to cancel the plan in execution.

Compared to the HuOL design in the previous study, the major change is the rebalance of responsibilities in the control room (between HQ and agent). The interaction between field responder and the control room is mostly unchanged. Therefore, this study has strong focus on control room interaction compared to the study 2. More specifically, this chapter addresses the following research questions on how a HuIL interaction design affects the team workflow: [preliminary]

1. How does the division of labour between human and agent play out in the HuIL setting, particularly in the control room?

2. What are the design implications that help the HQ involve in the planning loop.

(Present the findings)

## 7.2 SYSTEM EVOLUTION

The HuIL version of AtomicOrchid is not designed from scratch, but evolved from the HuOL version introduced in previous study. The study 2 has observed HQ struggling to get involved in the planning loop, which lead to the argument of rebalancing responsibility of HQ and the agent in the control room(see section x.x.x). The argument highlights the need for HQ's a stronger role in the planning loop, which is consistent with the principle of HuIL design. Based on the observations from study 2, we further generate several system requirements which support the HuIL control.

1. HQ should be able to review and approve every instructions generated by agent.[HQ take to responsibility for final decision, can be kept aware of all the allocations sent]

2. HQ should be able to override instructions generated by agent and create new instructions.[HQ can send instructions in a structured way]

3. HQ should be able to cancel the plan in execution. [In study 2, HQ is unable to override the existing plan]

4. HQ should be able to send task specific information. [Divided communication channel to deliver info accurately]

5. HQ should be able to be aware of the feedback (accept/reject) from the field players. [Maintain situational awareness of HQ]

6. HQ should be able to decide when the agent should re-plan.

7. HQ should be able for part of the team, leaving the agent to plan for the team left.

While requirements 1-6 are all inspired by implications from study 2, the requirement 7 enable to HQ and the agent to collectively generate plan even when HQ decide to intervene. The set of interface functionalities have been implemented to support above requirements, which will be introduced in next section.

### 7.2.1 *Interface functionalities*

A set of fully functional interactive web-based and mobile interfaces have been developed to facilitate the HuIL design. There are two interfaces designed for the 2 HQ players in the control room. One mobile responder interface is designed for the field players.

The task assignment interface is operated by one of the two HQ players. As an overview, the interface has a map on the left [Fig x, ]. Player/target locations, assignments are presented on the map. At right side of the interface is a task assignment panel. The left (1) column of the panel shows pending assignments while right column (2) shows existing task status. The (x) shows an example of individual assignment. (Player a and b are assigned to target x)

1. Plan request button:
   This button triggers agent re-planning. The agent will calculate an optimized plan based on task status, and present it to the HQ on the pending panel. The button allow HQ decide when

to initiate a re-plan (meeting requirement 6)

2. Plan keeping checkbox:

   These checkboxes are attached to every task assignments in the confirmed panel. If the checkbox is ticked, the planner will keep the corresponding assignment in next re-planning. In other words, the planner will keep the assignment fixed, performing partial planning for the rest of the team. The partial planning functionality is implemented to meet requirement 7.

3. Plan edit panel:

   Manual plan edits will be activated by clicking this button. The assignments in pending area will change to edit mode. Assignment can be created, modified and deleted through drag and drop interaction. The functionality is implemented to meet requirement 2

4. Plan approval button:

   This button approves all pending assignments. All pending assignment will switch to confirmed area. Alternatively, assignments can be approved individually by clicking individual confirm button on the pending assignment when the edit mode is activated. The functionality is implemented to meet requirement 1

5. Text messaging panel:

   The messaging panel can be toggled by clicking msg button on the confirmed assignments. The panel is supposed to be used for assignment-specific information. Therefore, the messages in this plan are only visible to the two involved players and HQ. The functionality is implemented to meet requirement 4

6. The Feedback indicator:

   The feedback indicators are attached to the right hand side of the confirmed assignments. The field players can easily provide feedbacks of their assignment through mobile responder interface (introduced later). There are three possible values for the indicator (no response, reject, accept). Because rejections typically indicate issues that needs to be followed up by HQ, the rejection will be highlighted with red color to grab attention of field players. The functionality is implemented to meet requirement 5

   When two involved players both accept the assignment, the keep checkbox will be ticked automatically. This is a mechanism to avoid interruption for the accepted assignments in the subsequent re-plans.

7. Stop button:

   The stop button can be used to indicate an emergency termination of an assignment. If this button is clicked, the assignment will be dismissed both in the mobile and HQ interface. The functionality is implemented to meet requirement 3

Compared to the HuOL version of AtomicOrchid, the mobile interface is mostly unchanged except for the HQ task tab (see figure x). The task tab now displays a task with text description and map visualisation on the top. The bottom half of the interface is a message box showing task-specific information from HQ. It should be note that the HQ can still send broadcast information (visible to everyone), which will be displayed in the chat tab.

### 7.2.2 *The planning agent*

One big change of the planner (compared to iteration 2) is the partial planning feature. The agent can takes a list of fixed assignment as input. It then allows optimize the players and targets that are not involved in the fixed assignment list. The functionality has two potential usages:

1. allows human operators to contribute part of a plan and ask the agent optimize the rest.

2. allows human operators to annotate some on-going tasks, that should not be changed in dynamic re-planning.

Apart from the partial planning feature, the input/output of agent is not changed.

## 7.3 WORKSHOP WITH RESCUE GLOBAL

The feedback from Rescue Global, Undecided where to put this section.

## 7.4 STUDY DESIGN

Participants were recruited through posters and emails. A total of 20 participants were recruited. 10 participated in session A and 10 in session B. All participants were reimbursed with 15 pounds for 1.5 hours of study. For each game session, there are 2 HQ players and 8 field players. The majority of participants were students of the local university. The HQ players are recruited from researchers in the com-

puter science department.

Because the HQ interface is a lot complicated compare to the that of the study 1 and study 2, we add an extra 0.5 hour training session before the formal study for HQ players to get familiar with the new task assignment interface. We anticipate the workload of operating the HuIL interface would be a lot more then that of operating the HuOL interface. Therefore, there are two HQ payers recruited in each session to split work in the control room. One of the two HQ player operates the new HuIL interface (described in section x.x.x) to manage task allocation, while the other player operates the old HuOL interface described in study 2 (see section x.x.x) to assist the other HQ by providing situation awareness and sending broadcasting information.

Upon arrival in the HQ (set up in a meeting room at the local university), participants were briefed and asked to consent to participate. Roles were randomly assigned to field players (field responders: firefighter, medic, transporter, soldier). Field responders were provided with a smartphone; HQ coordinators with a laptop. Game rules and interfaces were introduced, and participants were assisted in setting up their phones and laptop clients. Field responders and HQ coordinators were given 5 minutes to discuss a common game strategy. All field responders were accompanied to the starting point within the designated game area, about 1 minute walk from headquarters.

Before the formal session begins, there is a training session for field players to get familiar with the mobile interface. The training session has a very simple game setting with only four targets nearby the starting point. The training session ends when field responders collect all four targets nearby. Once field responders were ready to start formal session, One research start the game engine, triggering a "game start" message to be sent to mobile interface. Gameplay commenced for 30

minutes. A "Game over" message by HQ concluded the game. Field responders returned to HQ for the post-game session.

The post-game session consisted of a questionnaire aimed at collecting participants' feedback on (1) first impressions of the game; (2) usability of the system,and; (3) coordination issues in the game. A group interview was then conducted, before participants were debriefed and dismissed.

The size of the game area on the local university campus was 400 by 400 meters, without heavy traffic. The terrain of the game area includes grassland, a lake, buildings, roads, and footpaths and lawns. There are two drop off zones and 20 targets. The pilot study showed that this was a challenging, yet not too overwhelming number of targets to collect in a 30 min game session. There were four targets for each of the four target types. The pattern of cloud movement and expansion was the same for both game sessions.

Methods. We took a mixed methods approach to data collection and analysis. In addition to quantitative questionnaires, a semi-structured group interview was conducted aimed at eliciting important decision points, strategies and the overall decision-making process. Furthermore, five researchers with camcorders recorded the game play. One researcher recorded action in the HQ, and four other researchers each recorded a field responder team.

We developed a log file replay tool to help with data analysis of time stamped system logs that contain a complete record of the game play, including responders' GPS location, their health status and radioactive exposure, messages, cloud location, locations of target objects and task status.

We focus on the analysis of players' interaction with the system to unpack interactional issues. As this study have strong focus on the interaction in the control room, the interaction analysis started with observations in the control room. Video recordings of control room field action were catalogued to identify sequences (episodes) of interest (cf. Heath et al., 2010). Key decision points in teaming and task allocation served to index the episodes. Interesting distinct units of interaction were transcribed and triangulated with log files and field actions for deeper analysis that we present in this paper.

## 7.5    DATA ANALYSIS

Overall the 28 of 40 targets were evacuated in two sessions (16 in Session A and 12 in Session B). The player's health status in session 1 is better (Avg 90, Sd 9.3 ) then that in session 2 (Avg 48, Sd 41). Two deaths occurred at the begging of session 2, more details of death will be presented as episodes later in this section.

### 7.5.1    *Messaging system*

One change of the messaging system made for this iteration is separating channels for assignment-specific and general messages. The HQ1 is responsible for sending message in assignment-specific channel, while the HQ2 is responsible for sending messages in general message channel. This section will reveal how this design plays out in the field trials.

figure

We found HQs frequently send messages to update location of radiation cloud, (e.g. " Radiation Status- 38 39 37 and Drop Point 7 all out of bounds " ) and provide navigational guidance (e.g. " go north and west around the water " ). HQ is also observed to send messages to repeat and enhance the task assignment (e.g. " turn to 49 ").

On the other side of the message channel, field responders send messages to request tasks (e.g. "please advise") and cloud status (e.g. "Which wy is it moving?"). Field responders also occasionally send acknowledgments to HQ's messages (e.g. "Copy that.").

Most messages in the general message channel are general information about the clouds. However, we also found 11 messages in the general message channel (out of 82) are clearly addressed to individual teams. The specific player initials are mentioned in those messages. (E.g. "NG and YI approach quicker to 41 drop off to 8")

### 7.5.2  *Overview of task assignments*

In the following tree diagrams, Plans are break into individual task assignment. Each individual assignment may go through 4 stages in the planning process (Creation, approval, feedback, and execution). The assignment status for each stage is summarized in the following diagrams.

The summary indicates that both HQ and the planning agent both contribute to the task planning activities in the control room. The planning agent created a total of 45 task assignments with additional 5 assignments created manually by HQ. HQ approved a total of 39 assignments. Field responders accepted most of the approved messages (30 out of 39). 9 assignments were rejected or not responded. During

the task execution, occasional HQ interventions result in 5 task cancellations and 5 assignments override. In the end, these two groups managed to evacuate a total of 28 (out of 40) targets.

Although the diagrams show a sequential planning-execution process (creation->approval->feedback->execution), we actually found that various planning activities (e.g. assignment creation, approval, intervention, communication) are highly intertwined in the control room setting.

In the rest of the section, episodes of game play will be used to show how the interaction design of HuIL plays out in the field trial. In the following fragments and episodes, players will be uniquely identified by their initials. Targets are denoted by their unique numeric target id. Task assignments from the agent are represented as two initials and one target id connected by a rightward arrow. For example, the notation PC, CR -> 22 means player PC and CR are instructed to team up and go for target 22. A standard orthographic notation is complemented by timestamps [0:00], and System Message from remote players and HQ. The HQ players will be denoted by HQ1 and HQ2. HQ1 refers to the player operating the task-assignment interface, while HQ2 refers to the player operating the situational-awareness interface.

### 7.5.3 *Approve the plans generated by planner*

Firstly, HQ players in the control room are observed to carry out a set of routine activities, collaborating with the planning agent to organize task assignment. The episode 1 demonstrates a typical case of routine task planning process in control room.

Insert episode 1 here

At the beginning of this episode, the team MV, XW was carrying a target (43), approaching drop off zone. At [16:45], the HQ2 noticed the team was going to be freed up soon, so he began considering next target for them [16.51]. HQ2 proposed to HQ that 36 should be prioritized [Fig. 1]. HQ1 agreed with the suggestion and decided to send the assignment after the team free up from existing task [Fig. 2][17:07]. At 18:10, the team dropped off target. After the drop-off, the HQ requested a re-plan. The agent assigned the team MV, XW to target 36, which is consistent with decision of the HQ players. At the end, HQ approved the assignment [18:28].

[Discussion? In this typical case of task planning, we found HQ closely monitored the task execution, and request new task assignments when field team freed up. HQ's discussion suggested that the agent task assignment was approved after a careful review of player, target and radiation status.] [In addition, the HQ's planning happen before the team dropped off the target. It can be seen as a forward planning activity, which we observed several times in this observation]

7.5.4 *Editing assignments generated by planner*

Apart from routine task monitoring, HQ players occasionally chose to intervene the task planning activities by utilizing functionalities provided by the task assignment interface. The following simple episode demonstrates how HQ manually priorities target in order to implement their planning strategy.

Insert Episode 2 here

This episode happened at the beginning of the session 2. It begins with HQ requesting initial task assignments for the whole team. When the agent gives HQ a set task assignments for approval, HQ complained about it [01:29, HQ: why, it is stupid.], indicating he is not satisfied with the plan. HQ then click edit button to switch to edit mode. Under the edit mode, HQ dragged 3 targets to replace the targets in agent assignments. The three prioritized targets are the ones that are closet to the radiation cloud [fig 3]. After HQ confirmed his modification [02:03], he said to HQ2 that the far away targets should be rescued first [02:07]. The execution result of this heavily edited plan is not ideal. Among the 3 three modified assignments, 1 finished 1 assigment is cancelled later, 1 assignment leads to player death.

### 7.5.5  *Cancelling approved assignments*

HQ's interventions are not limited to modification of agent proposed assignment. HQ also manually cancels (stop) approved assignments 5 times due to changing task status. The next episode exemplifies how HQ adapts task assignments to changing task status.

Insert Episode 3 here

After confirming assignments in Episode 1, the HQ2 point out one assignment may be impractical because the route to target has already been blocked by a radiation cloud [02:09] [Fig. 5]. HQ immediately open message panel to send warnings and urging the team to move fast [Fig. 6]. However the cloud expansion seems to be faster then HQ originally expected [02:51]. Apart from sending route guidance in the team, HQ started to consider cancellation of the assignment. After HQ2 agree with the cancellation, HQ send a message to the team to inform them the assignment is going to be cancelled and instruct them to go to new target 07. The assignment is formally cancelled in

[04:11]. After HQ1 cancelled the task, he started to request new assignments from planner and allocated target 07 to the team later.

Insert field response?

### 7.5.6  *HQ avoiding task interruption*

As it is shown in the previous episodes (3), the existing tasks may be interrupted by HQ interventions. Apart from HQ interventions, the task interruption can also be caused by the re-planing performed by the planning agent. In one case, we observed HQ picked up this kind of interruption proposed by the agent and veto it in the approval stage. This next episode illustrates the case in more details.

insert pics here

After HQ requested a re-plan, agent proposed a set of assignments, one of which (CE KH -> 06) interrupts existing task of a team (CE KH -> 03). HQ immediately picked up this interruption ("What? Why I am getting?") and figured out the reason [Fig 7] ("Ahh, one of these guys does not accepted"). It should be noted that this kind of task interruption only happens when field players did not accept the tasks (See interaction design section x), making agent think they are idle at that moment. After finding this problem, HQ then requires the agent to "keep" existing assignment [04:29] and performs a plan request again to get desired assignments.

The next episode will show a problematic case of task interruption caused by agent re-planing . This episode involves 3 field players NG, YI and DI. The NG, YI formed a collocated team, and they just finished their previous task. DI is a player remote to NG and YI, alone at a drop off zone waiting for new task. This episode is divided into 2 parts. Part 1 is about observation in control room and part 2 is about team reaction in the field.

insert episode 5 here

In this episode, the HQ1 request assignment twice for idle players, which is a routine activity for HQ1 (As discussed in episode 1). Firstly, HQ1 request and approve new assignment for NG, YI [08:32]. 30 seconds later, DI become idle [09:09], so HQ1 request plan again. Because DI is closer to target 50 [fig], and NG YI have not accepted their assignment, the agent replaces DI with NG in the new assignment to minimize travelling distance of field players. HQ1 quickly approves this assignment (within x seconds). Although HQ1 did not verbalize his reasoning process, the quick approval may indicate HQ1 has not inspected new assignment carefully and did not notice the approval will cause task interruption.

Although the episode does not seem to be problematic from the HQ's perspective, we actually observed problematic sense making process in the field. The part 2 of this episode (following) reveals how field responders react to the task interruptions.

insert episode 5 - part 2 here

This part begins with a new task assignment for team NG, YI (NG, YI -> 50). This assignment is followed by a discussion about the loca-

tion of the new target. At [24:50], the team figured out the route to pursue the target. However, a new task assignment arrived, requiring YI to team up with the remote player DI to pursue the same target 50. The team is confused after the change of task. YI thought the task did not change because the target is still 50 [24:57, YI: No, it is the same.], and NG thought the interface is no longer working [25:34, NG: I think the page is not loading.]. After YI confirms NG's initials, she realized she needs to switch teammate (to DI).

Overall, we found the task interrupt resulted in a problematic sense making process in the field. The control room observation also reveals that several factors could have led to the task interruption including the untimely response from field responders; computational optimization performed by agent; and HQ's carefulness in assignment approval. [Discussion: This example shows that computationally q optimized q assignment is not socially optimized for teams and interaction design failed to tackle the issue.]

7.5.8   *The importance of player feedbacks*

Episode 5 highlights the importance of feedback from field players. Lack of feedback leads to false assumptions of the agent (players are still available), which in turn compromises its optimization. In one case, we also found that HQ may also be distracted by the lack of response, in that they have to guess playerQs intention without their feedback.

insert Episode 6 here

In this episode, the team MV, XW was assigned target twice [12:30,13:48], but the team neither rejects nor accepts those two assignments. The HQs are observed to guess intentions of the field responders 3 times

[see 13:32, 13:51,13:59] and complain about the non-response twice [see 13.22, 13:48]

### 7.5.9    *The incident of player death*

Two players are dead in the session 2 , the following episode will report this particular incident. This episode can be seen as a follow up of episode 2, in which the HQ modified 3 agent assignments. In that plan, the team CE, KM is instructed to go for a target very close to a radiation cloud. The episode is also divided into two parts. The part 1 illustrates what happened in control room while part 2 shows the field observation.

Insert episode 7 part 1

At the beginning of the task, the radiation cloud has already got in the way between target and the field team CE and KM. The cloud was expanding quickly, which caught the HQ1 in surprise. As a result, 2 messages were sent by HQ1 to guide the team to avoid the cloud [4:56,5:46]. However the team was still excessively exposed to the radiation when they reached the side of the target, so HQ1 decide to abort the task. After HQ1 cancelled the assignment, the team was still exposed to radiation. HQ1 then tried to assign the players to other targets by requesting agent for new assignment. However, the agent does not assign the team to any task because the team's health is too low. HQ1 seems to be confused about why the agent refused to assign targets. He continuously requested plans for three times and said "No targets for them? There are lots of them (refer to targets)."[9:50] During this process, the team was still standing in the cloud. They finally lost all the health points and become incapacitated. The second part of the episode showed what happened in the

Insert episode 7 part 2

The part 2 began with player CE reading the HQ message ("You are approaching the cloud, move extremely fast"). After this message, CE grabbed teammate KM and starts to run through the cloud [Fig. 8]. After they ran through the cloud, the team checked their remaining health value [07:19] and started searching for the target at the edge of the radiation cloud. About half minute later, the assignment was cancelled by HQ [08.43]. Although the task has been cancelled, the HQ failed to assign new task to the team [part 1, 9:50] . The team simply ignored the cancellation and kept searching for the target until they loss all their health [09:57].

### 7.5.10  *Division of labour in HQ*

In session 1, the responsibility for HQ1 and HQ2 to send messages are not fixed as original design, but dynamically negotiated between the two HQ operators. The following fragment is a typical case of the negotiations.

insert fragment 1 here

In this fragment, HQ1 asks HQ2 to send a message to instruct a team to go for a target 36. The message is a task-specific, but it is sent by HQ2 through the public message channel.

In session 2, we do not find similar negotiations. However, in the post game discussion, the HQ2 expressed that he has too little to things to do (other then sending general messages), while HQ1 has too much to do:

Q The interface I use was completely useless, became I can only message everyone at the same time, basically spamming everybody, so the only thing that I can do is, Oh , the cloud moves there and there. At the same time, Khaled (HQ1) had to message to everybody privately. While he was doing that, he coudn't do new plans. So there is a lot stuff for him be I coudn't do anything. Q

## 7.6    DISCUSSION

In previous section, episodes are presented to illustrate how the HuIP interaction design plays out in the field. We found that, to large extent, human the HQ players were successfully involved in the control loop. However, we found some confusions and misunderstandings occur between agent and human. This section will reflect on xxx

### 7.6.1    *How does HuIL design play out?*

The designed interface functionalities enable HQ to engage in arrange of interface interactions such as plan requesting, editing, approval and cancellation. This section will exam how this functionalities are utilized and to what extent do they help HQ stay in the control loop.

1) Plan request and approval The plan request function can be seen as a tool for HQ to trigger the agent re-planning. The design of the plan approval stage gives HQ an opportunity moment to review and influence the final plans before it is sent to field responders. Both functions are essential for human and agent to collectively produce task assignment, constituting the routine task planning work in control room. As presented in previous section, the two functions are the two most frequently used interface functionalities. [HQ requested plans for 45 times; approved 39 task assignments] Deciding appropriate moment to request plan and approve desired assignments require

HQ to closely monitor the task status. The uses of the two interface functionalities are usually observed together with discussion of task execution status, which indicates HQs are engaged in the planning-execution loop with a supervisory role. [awareness]

2) Plan edits The "plan edits" enables HQs to directly intervene the planning. We observed HQ's modified undesirable agent plans twice throughout the field study [one case, and the other case, show them in details]. It should be noted that the function is designed to be used infrequently, because the planning agent is supposed to take over the majority of the computational aspects planning activities.

3) Plan cancellation Further, the task cancellation functionality allows HQ to influence task execution after the plan approval. In episode 3, we observed assignment being cancelled and teams being reassigned due to unexpected cloud activities. This may indicates that combination of cancellation and re-planning can be a useful tool for HQ to respond to contingencies in the task execution.

4) Partial planning The partial planning functionality allows HQ's to indirectly influence on the planner. For example in episode 4, HQ identified task interruption in proposed plan. He then required the agent to keep an existing assignment and perform re-planning again. This episode can be seen as a case in which HQ is able to make sense of the task status and utilize the partial planning functionality to influence the assumption of the planner agent.

### 7.6.2 *Division of labor*

[It is unclear whether this section is about division as we observed or it is a design] The HuIL interaction design is aimed to involve human in the control loop, and at the same time facilitate division of labour between human and agent. The previous section has reviewed how a list of interface functionalities supports the HuIL interaction pattern. This section will exam the how the division of labour play out as a

result of HuIL design. Overall, We found HQ players contribute to the planning with a set of supervisory activities, while the agent take over computational optimization of task allocation.

insert figure here

1) Firstly, HQ players are observed to closely monitor the plan execution. For example in Ep 1, field players' task progress is mentioned by the HQs. In episode 3, HQs expressed their concerns about cloud and player locations, while in episode 6, HQ's are more concerned with the uncertainty of field players' intention.

2) The task monitoring enables HQs to decide appropriate moments for re-planning (by plan requesting) and approve plans proposed by the agent. [data here or next section?]

3) Occasionally, HQs also need to modify plans when agent proposed plan is not desirable. For instance in Ep 2, HQ overridden 3 our of 4 agent proposed assignments to implement his own strategy. Further, HQ's intervention is also required when contingency rises from task execution. For example, The HQ terminated an approved assignment due to unexpected cloud activities. A re-plan is quickly followed up to assign new assignments to the affected teams.

4) The forward planning activities are occasionally observed. For example, HQ's discussion of future plans for a team is observed in Episode 1. The forward planning activity is thought to be not well supported by the system and it is unclear whether this activity contributes to the planning. More details will be discussed in section x.

On the other hand, the agent is found to take over computationally complicated task optimization, freeing up the HQ to play their supervisory roles. Throughout the two sessions, the HQ requested the planner to re-plan for 49 times. The agent generated 45 task assignments, 34 out of which are approved by Headquarters. In comparison with the agent planner, Human only created 5 task assignments. The

fact that agent creates large proportion of assignments suggests the agent successfully takes over the routine planning to a large extent.

A pattern of labour division is also observed between the two HQ players in control room. To recap, the two HQ players in control room are split into two roles. The role of HQ1 is responsible for handle task assignment and send assignment-specific messages to field responders. [Have we fixed the role in briefing] The role of HQ2 is to support monitoring task status and send general chat messages. As a result, the messaging system of the messaging is split in to two channels (general information and assignment-specific, see section x). The messaging interface allows each HQ player to take control of one of the messaging channel. However, the system does not play out as designed in the field study. 11 messages in the general message channel are task specific, which indicate the HQ players may occasionally violate the designed division of responsibility. The field observation further confirms that the responsibilities to send messages are dynamically negotiated between the two HQ players regardless of the designed channel division [see fragment 1]. Further in the interview section, HQ players commented that one HQ is always doing too much while the other do not have anything to do [see section x]. The comments suggest there may exist imbalance of workload between the two HQ players. The observation is consistent with findings of the CSCW researches. Some CSCW researchers argued that the norms for using a CSCW system are often actively negotiated among users. These norms of use are also subject to renegotiation (Strauss, 1991). CSCW systems should have some secondary mechanism or communication back channel to allow users to negotiate the norms of use, exceptions, and breakdowns among themselves, making the system more flexible.

### 7.6.3  *Dealing with the imperfection if agent planner*

In the game probe, the planning can be seen as partially automated by the planner agent. The task optimization performed by agent is thought to be 'imperfect' because it fails to consider any organizational efforts/overhead required execute the plans and plan changes, that is, the social cost of implementing plans. The result of this imperfection has been exemplified in previous chapter (study iteration 2), and also Ep 5. In more details, In that episode, HQs failed to pick up unnecessary task interruption in the approval stage. Consequently, extra coordination overhead and problematic sense making process for field responders are observed. This case of failure reveals several factors that contribute to the failure:

(1) Lack of feedback,

(2) Failures of HQ monitoring,

(3) Computational optimization performed by agent, which ignores overhead of task interruption.

The point 3 can be seen as the main cause of imperfection of the agent. In this study, imperfection is thought to be "natural" for agent planning support, as computationally "optimized" assignments from the planner may not socially optimized for the responder teams. It highlights the importance of human involvement in the planning activities.

The failure case in episode has great similarity with the well-observed phenomena related to imperfection of automation called complacency. The complacency phenomenon refers to the human failure of detecting occasional automation failure. Study of automation suggests that complacency can be classified as attention-based monitoring failure, which is likely to happen when human is engaged in multi-thread tasking. In the case of episode 5, the quick approval of problematic

assignments suggests the plan is not properly reviewed. The HQ's attention could be a factor of the monitoring failure. As the HQ player is trying to allocate tasks for idle players, they may only focus on the new assignments for the idle players rather then other conflicting assignments. If the interface failed to attract HQ's attention to the confliction, HQ may approve the plan as long as idle players are properly assigned. Although failed in episode 5, the interface highlight does grabbed attention of the HQ in episode 4, which suggests that the a interaction design that properly drive the HQ's attention can may help to reduce complacency effects. [Connect to more literatures] Some study shows that complacency is found in both naive and expert participants and cannot be overcome with simple practice. Therefore, mechanism to counter the complacency effect may an important factor that need to be considered in the interaction design. [can we claim?]

### 7.6.4 *Forward Planning*

The agent performs n-step [need to confirm] looking ahead planning (see section of agent algorithm) for each re-plan. Similar to the agent, HQ players are observed to engage in forward planning activities. For example, in Ep 1, the HQ anticipated a team was going to finish assignment soon and plan to assign a new target for them. Later, HQ triggered a re-plan and the result was consistent with the HQ's previous plan. In some other cases, the result of agent re-planning was not consistent with HQ's plan. Therefore, HQ has to make decisions about whether to follow the agent or not. As both HQ players and the agent conducted forward planning, sharing of relevant information may help HQ to understand the agent's reasoning and make informed decisions. However, the extra information sharing may further complicate the interface. For example, for the agent to share information of its future planning, it may need to present the

future assignments and prediction of the future game status. It is would be problematic for HQ to digest the extra information in the time-constrained task environment. Various studies have identified the problem of information overload in the system interaction design [] [] []. The problem occurs when information presented at a rate too fast for a person to process [], and it may lead to a list of human performance consequence []:

1. Fail to respond to certain inputs, 2. Respond less accurately than they would otherwise, 3. Respond incorrectly, 4. Store inputs and then respond to them as time permitted, 5. Systematically ignore (i.e., filter) some features of the input, 6. Recode the inputs in a more compact or effective form, or quit (in extreme cases) [23].

Various techniques have been explored to alleviate the problem of information overload in different application domains such as security monitoring [], teleportation [], and communication systems []. However, the specific research of information overload for task allocation support in DR domain is still rare. We think that the extra forward planning support may introduce the risk of overloading human operators. Therefore, more studies are required to evaluate the trade-off between its benefits and human performance consequence.

### 7.6.5  *Lack of explanation from agent*

Some observations in the study showed that some agent actions are not sufficiently explained to HQ, which results in undesirable HQ performance. This section will exam two particular cases in details.

Firstly, the HQ sometimes become confused when the planner stop giving back assignments. As presented in episode 7, the HQ repeated requesting plans four times and complains about no response from planner. However, the planner does not produce more assignments simply because the idle players have little health to take any more

assignments. This misunderstanding indicates there is lack of explanation for the HQ to make sense of agent's reasoning process.

In another one case, we observed HQ drastically modified agent proposed plan (Ep 2). In episode 2, the HQ modified 3 out of 4 the agent proposed assignments. As the new targets are closer to cloud, the HQ's plan could be more risky. The risky plan turned out to be undesirable as it leads to 2 assignment cancellations and 2 player deaths (episode 7). As the planner has ruled out the risky plan at the first place, the reasoning behind the original plan may be important information that should have been exposed to HQ to inform their decisions. Depending on the implementation of the planner, evaluation of human proposed alternatives (or comparison with preferred plan) may also be available during the agent planning and can be exposed to imply risk. If HQ is aware of why the agent chose the original plan, HQ may be able to make informed decision when overriding the agent plans.

Again, excessive and ineffective explanation of agent plans may introduce the danger of overloading the HQ players. [Connecting to information overload]

### 7.6.6 *Coordination with Field Players*

Coordinating with field players is also a key component of plan-execution loop. For the coordination, there are two issues emerged from the field study. The first is about confusions around the task cancellation. The second issue is about lack of response from field players. This section will exam these two issues in details.

For field players, the task cancellation is presented a notification ("task changed") followed by a blank task page only with the text ("No task assigned at the moment"). The field study suggests the presentation could be problematic for the field players. Firstly, be-

ing assigned with no task does not successfully convey the meaning task cancellation ("Don't carry on"). The episode 7 (part 2) shows a case in which the players completely ignores the task cancellation and carry on doing and risky task. In episode 5 (part 2), the player NG even think the blank task interface implies malfunctionality of the mobile interface. Even if the players understand task cancellation, its implication can vary. Without a task, the players can chose to, for example, (1) stand by doing nothing, (2) find targets by themselves, (3) escape for life. Therefore, the field players may be confused about what to do next. In another example (not presented) of cancellation, the field players were stuck in a radiation cloud when their task was cancelled. With high radiation reading and loss of target, they don't know what to do next so they send messages to HQ for clarification. They finally left the radiation cloud after they receive and accept new assignments from HQ. This example shows the implicit instruction of "DON'T CARRY ON" is confusing. Instead, the explicit instructions, which directly point out what to do next may be desirable. However, apart from explicit task assignments, the communication system in the game probe does not support any other form of "explicit" instructions. Although it is hard to cover all possible explicit instructions, some built-in support for frequent ones can be useful. In the case of AtomicOrchid, the frequent instructions can be "stand by", "reverse back" and "escape".

Apart from the issues of task cancellation, the issues of field player feedback also emerged. The field observation showed that the feedback system is crucial for both agent and HQ players to keep track of the task status. Overall, most of (30 out of 39) the assigments have been responded by the field players. However, there are still a number of un-responded assignments that causes issues in coordination. For agent planner, the lack of field response may lead to false assumption of availability of the players, which in turn, compromises the subsequent re-planning (as presented in Ep 4 and 5). For the HQ

players, the lack of field response adds to the uncertainties in the task status as well. HQ players have to take efforts to guess the intentions (Ep 6). One strategy to view the issue of field response is to treat the lack of response as an uncertainty in the task execution. According to a classification of uncertainty by [], lack of field response can be classified as incompleteness of dataset. In Ep 6, we observed HQ's attempt's to eliminate the uncertainty by contacting the field responders. The unsuccessful attempt suggests more interface support shall be considered to help reduce uncertainty. However, it is often the case that uncertainties are inevitable. Interactive system researchers [] have outlined a list of strategies to tackle the inevitable uncertainties [Can you see me now]. It can be argued that for safe critical domains like DR, it would be important to reveal the uncertainties to operators so that they can make informed decisions []. Not only the uncertainties, but also all the plans and actions that may be affected by the uncertainties could be revealed. For example, in the scenario of AtomicOrchid, no matter how fast the responders accept assignments, agent planning may happen in parallel. The agent planning can suffer from the lack of response if it is triggered when players have not responded (Ep 4 and 5). Therefore, it is important for operators to be aware of both the uncertainties and affected plans. One straightforward approach for visualizing the uncertainties is to highlight the affected data. Different methods for highlighting have been proposed in literature []. However, in the real-time control scenario like AtomicOrchid, the highlighting approach has to be applied with caution. The operators have limited resources (attention, limited time and cognitive workload capacity) to tackle various issues in a multi threading, time constrained task setting. Abuse of interface highlighting may contend for the limited resources. There are evidences showing that, visualization of uncertainties is likely to overload decision makers in time limited decision-making, which in turn, degrade their ability to respond in a timely manner []. Further the observed complacency effects may also compromise the effectiveness of uncertainties

highlighting. Take ep 5 as example, although the system highlighted potential task interruptions as a result of lack of response, operator still ignored it.

Therefore, the interface features that counters the effects of uncertainties needs to be carefully designed. Excessive uncertainty visualization can cause information overload, and ineffective representations can be easily compromised by complacency effects.

7.* Smoothing the workflow

8.* Accountability become opaque by using the agent.

9.* Limitation
- Text message as communication modality.
- Voice vs Text trade-off
- Risk is not real. Have evidence of feeling threatened. Not real fear.

[a separate reading list available for this chapter]

Part IV

CONCLUSION

# CONCLUSION

Three studies have been done. For each study, systems with different interaction design patterns is field trialled. The first one is a non agent version of the game. The second and third studies are about HuOL and HuIL interaction pattern. Through field

## 8.1 SUMMARY OF FINDINGS

Three study happen iteratively, implications and requirements and implications generated in previous study are feedback to the next

### 8.1.1 *HuOL vs HuIL*

It is unfair to say HuOL is worse then HuIL

This two studies actually give implications to each other

1. maintain situational awareness of the key no matter what

### 8.1.2 *The role of HQ*

1. Whole manual is 2. The coordination overhead incurred by the agent planning. Generate 2 implications: involving human ; better modelling Reliability and capability of the agent would be the key issue. Flexibility and maintain situational awareness. 3. A rebalance make things better but still, the problem exists.

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### 8.1.3   *Common Ground*

Which is the common theme

## 8.2   LIMITATION

## 8.3   FUTURE WORK

What can we take away from it? Implication for future work?

Part V

<span style="color:red">APPENDIX</span>

# A

APPENDIX TEST

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Lorem ipsum at nusquam appellantur his, ut eos erant homero concludaturque. Albucius appellantur deterruisset id eam, vivendum partiendo dissentiet ei ius. Vis melius facilisis ea, sea id convenire referrentur, takimata adolescens ex duo. Ei harum argumentum per. Eam vidit exerci appetere ad, ut vel zzril intellegam interpretaris.

Errem omnium ea per, pro congue populo ornatus cu, ex qui dicant nemore melius. No pri diam iriure euismod. Graecis eleifend appellantur quo id. Id corpora inimicus nam, facer nonummy ne pro, kasd repudiandae ei mei. Mea menandri mediocrem dissentiet cu, ex nominati imperdiet nec, sea odio duis vocent ei. Tempor everti appareat cu ius, ridens audiam an qui, aliquid admodum conceptam ne qui. Vis ea melius nostrum, mel alienum euripidis eu.

## A.1 APPENDIX SECTION TEST

Ei choro aeterno antiopam mea, labitur bonorum pri no. His no decore nemore graecis. In eos meis nominavi, liber soluta vim cu. Sea commune suavitate interpretaris eu, vix eu libris efficiantur.

*More dummy text.*

Nulla fastidii ea ius, exerci suscipit instructior te nam, in ullum postulant quo. Congue quaestio philosophia his at, sea odio autem vulputate ex. Cu usu mucius iisque voluptua. Sit maiorum propriae at, ea cum primis intellegat. Hinc cotidieque reprehendunt eu nec. Autem timeam deleniti usu id, in nec nibh altera.

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| LABITUR BONORUM PRI NO | QUE VISTA | HUMAN |
|---|---|---|
| fastidii ea ius | germano | demonstratea |
| suscipit instructior | titulo | personas |
| quaestio philosophia | facto | demonstrated |

Table 1: Autem usu id.

Listing 1: A floating example

```
for i:=maxint to 0 do
begin
{ do nothing }
end;
```

## A.2    ANOTHER APPENDIX SECTION TEST

Equidem detraxit cu nam, vix eu delenit periculis. Eos ut vero constituto, no vidit propriae complectitur sea. Diceret nonummy in has, no qui eligendi recteque consetetur. Mel eu dictas suscipiantur, et sed placerat oporteat. At ipsum electram mei, ad aeque atomorum mea.

Ei solet nemore consectetuer nam. Ad eam porro impetus, te choro omnes evertitur mel. Molestie conclusionemque vel at, no qui omittam expetenda efficiendi. Eu quo nobis offendit, verterem scriptorem ne vix.

BIBLIOGRAPHY

[1] Jeffrey M Bradshaw, Paul Feltovich, and Matthew Johnson. Human-Agent Interaction. In G Boy, editor, *Handbook of HumanMachine Interaction*, chapter 13, pages 293–302. Ashgate, 2011. URL http://books.google.com/books?hl=en&amp;lr=&amp;id=4opHlu05SNIC&amp;oi=fnd&amp;pg=PA283&amp;dq=Human-agent+interaction&amp;ots=vxrpDdLbSa&amp;sig=07dujtzGjIcBLlZ6FVH33HjrWos.

[2] Fitts. Human Engineering for an Effective Air Navigation and Traffic Control System. 1951.

[3] Robert R Hoffman, Paul J Feltovich, Kenneth M Ford, West Florida, David D Woods, Gary Klein, Klein Associates, Anne Feltovich, Grinnell College, Editors Robert R Hoffman, and Patrick J Hayes. Human-Centered Computing A Rose by Any Other Name . . . Would Probably Be Given an Acronym. 2002.

[4] D Mendonca. Decision support for improvisation in response to extreme events: Learning from the response to the 2001 World Trade Center attack. *Decision Support Systems*, 43(3):952–967, 2007. ISSN 01679236. doi: 10.1016/j.dss.2005.05.025. URL http://linkinghub.elsevier.com/retrieve/pii/S0167923605000904.

[5] Hyacinth S Nwana. Software Agents : An Overview. pages 1–49, 1996.

[6] Nikos Vlassis. *A Concise Introduction to Multiagent Systems and Distributed Artificial Intelligence*, volume 1. January 2007. ISBN 9781598295269. doi: 10.2200/S00091ED1V01Y200705AIM002. URL http://www.morganclaypool.com/doi/abs/10.2200/S00091ED1V01Y200705AIM002.

# DECLARATION

Put your declaration here.

*Nottingham, August 2012*

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Wenchao Jiang