Visualization of Information Flows and Exchanged Information: Evidence from an indoor fire game

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ABSTRACT

Understanding information flows is essential to improve coordination information systems. Aims of such systems are typically reducing information overload and improving situational awareness. Yet, there is a lack of intuitive and easily understandable tools that help to structure and visualize the ad hoc information flows that occur during search and rescue operations. In this paper, we present the concept of such an analysis, and present findings from an indoor serious fire game. For this game, we describe the interactions of Emergency Responders (ER), including individual information (over-)load, and descriptions of content of communications. This approach therefore provides an effective way to learn about active teams, information flows, exchanged information, and overload.

Keywords

Emergency Management, information flow, information tracking, situational awareness, visualization

INTRODUCTION

Emergency response involves a complex network of different Emergency Response Organizations (EROs) such as fire & rescue services, police forces, health care, and media. During the response, responders need to coordinate and share information with each other to ensure they have a common understanding of the situation and align their actions. During Emergency Response, coordination, however, is a challenging task as it involves uncertainties, and highly volatile information.

Information sharing aims at ensuring that the right people get the right information at the right time (Singh et al., 2009). However, it is hard to get a clear picture of the entire emergency in its full complexity, because data is heterogeneous and, different responders who are dispersed geographically at the emergency site have to cooperate and interact for developing and maintaining Situational Awareness (SA) (McEntire, 2002).

Situational Awareness refers to the understanding that a responder has of an emergency situation, the dynamic understanding of 'what is going on' (Sarter et al., 1991) (Vieweg et al., 2010) (Endsley, 1995). Coordination and information sharing can improve SA. However, simply sharing more information will result in information overload and poor coordination among teams (Reddy et al., 2009). Sharing the right information to ensure that appropriate actions can be taken is therefore key to good emergency management(Yang et al., 2009).

To understand the information flows and communication barriers among different responders and teams, augmented reality games are excellent instruments. Particularly for emergencies, when errors result in harmful consequences, and only very mature systems can be tested in reality, experiments are vital to help researchers and practitioners to better understand the communication and collaboration patterns emerging within and across emergency response teams (Kurapati et al., 2013). In this paper, we report the lessons from a search and rescue game experiment. The game was designed to enable a research team to track information flows, communication barriers, information overload, SA, and information exchange.

We present a network visualization analysis to reconstruct information exchange, SA, and collaboration among teams during the game. The visualizations were designed only after the game, and not for real-time error identification and learning. The method used for information tracking in a game context and the visualization can be considered as the main contributions of this paper. The purpose of network visualization in this paper is to make the EROs learn by highlighting specific aspects of the response behavior: active ERs, redundancies, SA, and information load. We envision that such information can be used in trainings and exercises improve the behavior of teams and individuals by targeted design and tracking of individual performance.

This paper begins with the description of the developed emergency scenario, which was used to collect the data. The paper then explains the research method, which includes benchmarks of expected communication patterns and technologies in the experimental design. The conclusion part summarizes the lessons learned from this research and discusses directions for future research.

EMERGENCY SCENARIO

The game designed was based on an indoor fire to investigate and learn the behavior of information tracking, flow, and communication to gain SA during emergency response. The emergency scenario was developed by a research team consists of 7 members. The developed scenario was with noisy environment including real fire alarms, smoky corridors, and technological communication tool.

In the scenario development process, three main requirements are taken into account: complexity (the scenario must be complicated enough to involve multiple teams); concreteness (the scenario must include sufficient details to allow the participants to identify the relevant actors); and realism (the scenario must be realistic) (Eide et al., 2013). The developed scenario was about search and rescue operation. The developed scenario is as follows:

Fire accident happens in the third floor in A ’block building of the university. The building consists of many students (who might be normal, disabled, and sick), books, labs and storage rooms. Several students have observed smoke, flames, and loud noise in the university building. Some of the witnesses also report fire escalation.

Due to the fire, the emergency site has become chaotic and many people in the building are wounded and traumatized. The number of people within the building is unknown. But, the people who are running out of the building were giving information about the seen victims. In addition to the textual descriptions, participants will be further supplemented with a map of the floor layout in the building where the incident occurred to get an idea of the view of the floor.

METHOD

The experimental game was designed according to workflows and processes elicited from fire fighter experts. For that the research team conducted a face to face interview with the three different levels of Grimstad fire department officials, two weeks before the game implementation to gain knowledge about their organizational structure and handling procedures during emergency response. Prior to the interview, the research teams were given with two documents i.e., one is about organizing fire departments in Norway (Beredskap, 2003) and another one is about firefighters operations in smoke filled or hazardous areas (Beredskap., 2003).These two documents helped the research team to get an idea of fire handling. The interview was audio recorded for later analysis and also a note was taken. The audio-recordings were carefully analyzed after the interview to ensure that all the details revealed during the interviews were taken into consideration for the scenario development.

Based on the interview, some details of our reference organization were incorporated in the emergency scenario development of the game. This game was performed with 23 voluntary student participants who are given with smartphones with Zello software app in it and 6 observers. This Zello software was used for communication and information sharing among students who have acted as ERs during game. After the game, voice communication data is used for analysis. A cluster analysis was conducted by comparing the teams' participation in the emergency scenario to establish a consistent categorization. The goal of a cluster analysis it to establish a classification of different units (here: teams and information) into groups, based on their similarities on some variables.

To examine the information being exchanged between teams, an analysis of the recorded voice was conducted, systematically sorting out both the information that the different teams would need from and provide to CM(Eide et al., 2013; Lewis-Beck et al., 2003). The visualization program Gephi was used to analyze and to visualize the pattern of information exchange, communication barriers and information flow among teams for SA. Gephi is open source software for graph and network analysis. It is used to work with complex and large data sets to produce valuable visual results (Gephi). So, the visualization tools are feasible to visualize any kind of large data sets.

Planned Communication during game

The total game is conducted for 30 minutes. In this game, out of 23 participants, 10 acted as rescuers, and 1 as Medical Care Unit (MCU), and rest 12 as victims. Rescuers are divided in to 3 teams and each team consists of 3 participants: one as Smoke Leaders ((SLs), and other as Smoke Divers (SDs). 1 as Crew Manager [(i.e., On-Scene-Commander)] (CM). Figure 1 shows the planned communication during game. The organization of the team is as follows: Team 1consists of SL1, SD2, SD3, Team 2consists of SL2, SD5, SD6, and Team 3consists of SL3, SD8, and SD9. All these rescuers are given with smartphones with Zello software. During the game, participants who acted as SDs are supposed to do search and rescue operation to save victims. If SDs spot any victims who are unconscious, critically wounded, then they are supposed to take the victims to either to a safe area or entrusted to MCU by reporting their health condition. When one of the teams spot victims, SDs are supposed to inform to SL and from SL to CM to observe information flows and exchanged information. But, when SDs need information about emergency, SL will provide and CM will provide to SL.

In this game, the research team did not use ordinary walkie-talkie for the communication as it do not have the feature of storing the history of the communication and also communicated data. So, Zello walkie-talkie software application is used to collect data during the game (Zellowalkie-talkieapp). In this app, 7 channels were created for communication (see Figure 1).

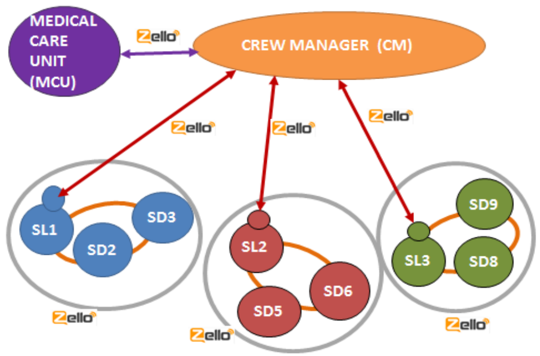

Figure 1. Zello Communication plan

RESULTS

After the game, we retrieved all data from Zello history. To analyze the data, first, the history of voice recordings were carefully examined to ensure that all the communication done during the game was documented in a excel sheet. The analyzed data was separated into 4 columns in excel sheet. The data which is listed in column 1 of the excel sheet is about from whom the information flow was triggered. Second column is for who has received that information. Third column is what they have communicated and 4rth column is for information categories (see table 1). The data which is exchanged during the game divided into 11 categories to simplify the exchanged data, which is documented in Table 1.

Category	*Description*
Order	Order is given by CM to teams to perform some actions. Eg., check stairs
Barrier|	Tried to call, but no communication occurred
Request_for_information	SLs requesting CM for additional information and SDs requesting SLs.
Report	SLs Reporting to CM and SDs reporting to SLs about no.of victims saved.
Checking_teams_location	SLs and CM check their team's location
Call_within_team	Communication done within the team
Asking_help	Asking extra resources
Confirmation	Confirm that they received the orders
Request_for_equipment	Request for extra equipment
Taking_victim	Take the victim to MCU
Call_Within_team	Group call established within the team and communicated

Table 1. Information categories

Information flow and tracking

Visual data presentation is a useful means for communicating the activities which are being occurred during the game. Figure 2 illustrates the exchanged information and information flow network clearly and efficiently and its complexity by representing information categories and rescuers as nodes (circles) in the network. The visualization, in this paper is done after the game.

In the network, each node represents a rescuer and an information category. These are colored according to their group for clearly distinguishing among different groups. A line connecting two or several nodes represents an information flow path within team or with CM represented by the nodes. The number of thickest lines each rescuer has with other rescuers in the figure makes clear that how the communication is done with each other, the way information is flown, and the information which is exchanged among and within teams.

In the below Figure 2, there is both one and two way communication is done and it is easier to follow the information flow and information categories. CM mostly had communication with Team 1 and having lot of information load. But, CM also made contact with MCU, SL2 and SL3. The most information categories that are communicated by CM were Request_for_information, Report, Order, and Confirmation. When it comes to Team 1, the information exchange is done mostly about Report, and Checking_teams_location. The information that is flown within Team 2 was Report and Checking_teams_location. In team 3, the information is about Report, Request_for_information, and Taking_victim.

However, based on this visualization it is evident that teams had a better overview of the situation. In a nutshell, the analyzed data indicates that the most active persons in the game were CM, SL1and Team 1. Other teams and MCU typically have either a much smaller role or facing barriers in the game. By looking at the thickness of the connections between teams, CM, and MCU, it is easy to understand the most occurred communication, information load and information exchange was between CM and Team 1.

The visualized data confirms that there is a significant difference of situational awareness between different teams which is showing that information has an effect. Team 1 has a good overview of the situation as they are most of the time communication with CM and sharing information. The way in which information is visualized can make the CM to order teams to identify about imminent danger.

Teams during the indoor game have a lot of data and activities to be performed. In Figure 3, we have shown the measured data on how much each team has flown the information and Communication Barrier (CB). It is evident in the figure 3 that Team 1 has done more than 53% information flow and faced 47% communication barrier. Here, communication Barrier might be because of the poor internet connection or not active during the game. Team 2 has only 20% of the information flow and rest faced communication barrier. When it comes to Team 3, 30%of the information is flown and rest 70% might be faced CB or not active. Based on the information flow, we can observe that CM had lot of information overload than other responders.

As mentioned earlier, the exchanged information is divided into 11 categories. In Figure 4, we can observe which responder has shared which information to whom. During the search and rescue operation, SL1 called to his teammates 8 times, reported 31 times, equipment request made 3, requested for additional information 5, and confirmed 5times. When it comes to SL2, he had only 4 times barrier, made 3 times call, reported 1 time. SL3, called within team, reported 6 times. Smoke Diver SD2, had 12 times barrier, reported 14 times. SD3 had 11 times barrier, 3 times checked for his other team members' location, and reported 1 time. CM has shared information about confirmation, asking help, reported 3 times ordered 7 times, request for information for 9 times and had barriers for 13 times. MCU had 10 times barrier, 3 times report, and 1time request for information. SD5 and SD6 are not at all active. SD8 and SD9 had 8 times barrier and reported 2 times, taking victim 1 time and report information 2 times.

DISCUSSION AND CONCLUSION

In this paper, we have investigated and analyzed the data which was collected through an emergency serious indoor fire game that has conducted to learn about the behaviors of information flow, communication barriers and information exchange. The experimental game was designed according to workflows and processes elicited from fire fighter experts. However, the game was conducted

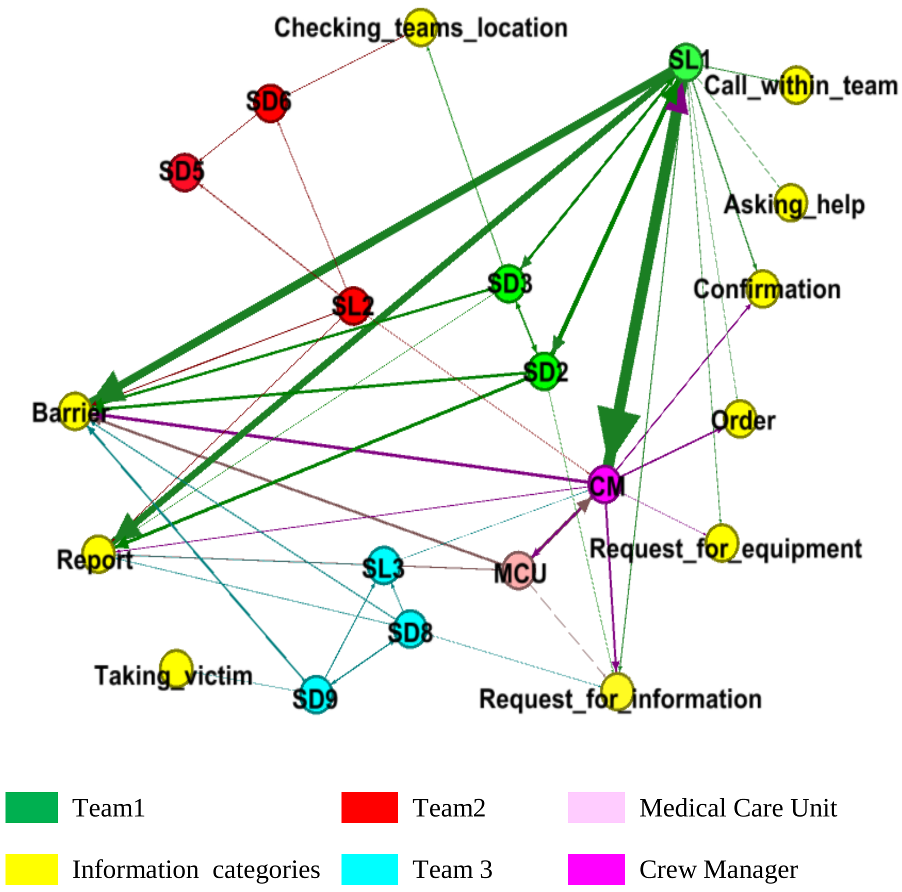

Figure 2. Information communication and tracking Network

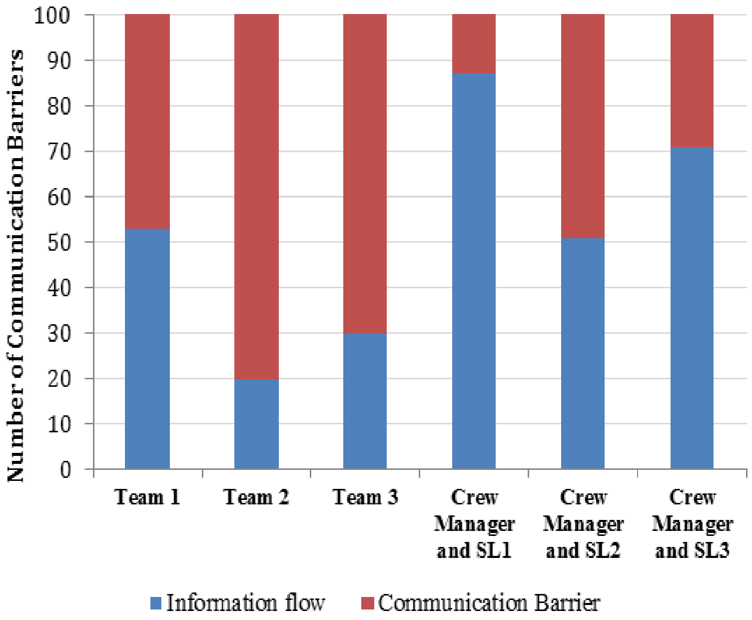

Figure 3. Overview of information flow and communication barrier among teams

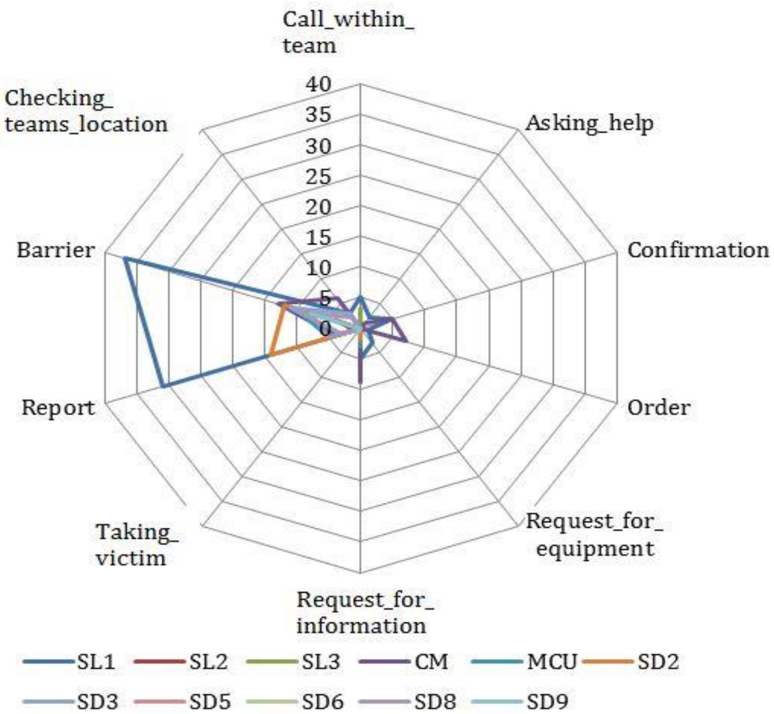

Figure 4: Overview of exchanged information with other responders

with students, and therefore some additional instructions and training were given prior to the experiment. Intervention during the game was kept to a minimum of observations and recordings of workflows and communications only, analyses and surveys were only conducted after the game. Figure 2 shows the instances of team communication, information flow and tracking network. These instances took place when teams were reacting to an emergency and responding to the requests, rather than just communication. When the information flow is centralized, the information load is high on CM. CM has to deal with different kind of information.

But, when the information is centralized, coordination can be improved (Brugghemans Bert 2013). Moreover, we can also observe in the figure 3 about the active teams during the game, how many times the flow of information are done and how many times communication barrier with other teams have occurred. One team has better communication and information exchange, but other doesn't. The reason for this might be either lack of understanding of the communication plan (which is briefed) or poor software connection. The overview of the exchanged information for SA among teams can be observed. The present study provides a framework for understanding of the behavior of information flow that is being done and tracking of the information that is being exchanged during an emergency situation by different visualization techniques. Visualization is a good way of communicating the data in an efficient way to create a mental picture by looking at the figures. The use of serious games is useful as it helps researchers to learn about the patterns of the information flow and exchange.

When information flow and exchanged information is visualized, we envision that EROs get an idea of lot of things i.e., participants those who are active during the game, where and when went wrong, what information is being used to get SA and so on. The results presented in this paper are based on the small dataset. But in real emergency situations, large datasets are observed and communicated. To visualize large sets of emergency data after any emergency, advanced techniques or tools are needed to sort the data for visualization which authors did not go through it. Developing software or algorithms for sorting large datasets and evaluation of the visualized networks with real EROs is considered as future work.

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