On the Impacts of Utilizing Smartphones on Organizing Rescue Teams and Evacuation Procedures

Parvaneh Sarshar
CIEM, University of Agder, Norway
parvaneh.sarshar@uia.no

Jaziar Radianti
CIEM, University of Agder, Norway
jaziar.radianti@uia.no

Jose J. Gonzalez
CIEM, University of Agder, Norway
jose.j.gonzalez@uia.no

ABSTRACT

A serious fire game with two different scenarios for the search and rescue (SAR) operation was designed and played. In the first scenario, the SAR operation was performed without any smartphone app assistance, while in the second scenario, our recently developed smartphone app was employed to carry out the evacuation. In this paper, the effects of utilizing this app on organizing firefighting teams, performance of the firefighters, and the evacuation procedure are studied. The results collected from a post-game questionnaire, which was answered by the players of the firefighter role, are analyzed, turning out that the employment of the smartphone app is not only preferable and effective, but also user-friendly. It is also shown that a semi-centralized firefighting organizational model suits the second scenario, whereas a decentralized one is typically used in other scenarios, such as the first one.

Keywords

Fire, Game, Organizational Models, Search and Rescue, Smartphone App

INTRODUCTION

Fighting the fire and rescuing the victims are very critical tasks that require the most accurate information. By interviewing different organizations involved in a fire incident, such as firefighting department, police, and medical care unit, they all agree that the most essential key that is often missing during an emergency management procedure is precise and appropriate information. During an emergency such as fire accidents, a great amount of adequate information is required. Therefore, they are always looking for the best possible approaches to get the information they need, including victims' locations, number of victims, and the condition and location of the fire.

There have been many research and developed technologies to support firefighters to accomplish their goals and tasks mentioned above efficiently. Smartphones and their embedded technologies are examples of these supporting tools. For instance, they can transfer the needed information from the affected area to the emergency responders or from the responders to the victims. In very recent years, countless smartphone apps have been developed for different types of smartphones that can support firefighters and victims during a fire. In (Bekker, 2013; FireRescue1, 2015; Jerrard, 2011), a long list of these apps can be found.

NowForce (NowForce, 2015) is another emergency response solution that is aiming at minimizing response times and maximizing situational awareness. CoenoFire (Feese et al., 2013) is a smartphone-based sensing system that monitors

temporal and behavioral performance of the firefighter for the post incident feedbacks. In the same paper, a comprehensive study on the existing technical projects that aim at supporting firefighters can also be found. Monares et al. (Monares et al., 2011) presented a low-cost mobile collaborative application in order to help the firefighters with their communication problems by allowing ad-hoc communication. In (Colunas et al., 2011), DroidJacket®, uses a wearable jacket and an Android-based smartphone for monitoring the fatigue and stress of the responders. Also in (Kulakowski et al., 2010), a wireless sensor network is designed to gather temperature data in order to create a map of fire and to take necessary actions.

For testing these technologies and training firefighters with these recently developed technologies and approaches, many methods such as serious games are applied. Game-based training of firefighters, children, or building occupants has been widely investigated (see, e.g., (Backlund et al., 2007; Dugdale et al., 2004; Jones et al., 1990; Lehmann et al., 2013; Schmitz et al., 2014; St Julien et al., 2003)). Different methods of serious games such as computer-based or paper-based with the aim of training responders and victims about the fire are studied and compared in these papers.

On the other hand, introducing these technologies and applying them in any emergency management practices such as firefighting, can have a significant impact on these procedures and even on the dynamic of the firefighting teams. These questions then arise as to how smartphones and their apps can affect the structure/organization of the rescue teams, the procedures they follow and the decisions they make, and the rescuers' performance. In this paper, we try to answer these questions by testing the dynamic of three firefighting groups with using our developed SR app support in a serious game context.

In the literature, the projects that support firefighters mostly focus on three aspects: monitoring the behavior and health of the firefighters, monitoring the environment where firefighters are in toxic gases/smoke and high temperatures, and providing navigational supports. The uniqueness of this study lies on the fact that we have studied the behavior (mobility and performance) of those playing the role of the firefighters in the game regarding a smartphone app that monitors fire and smoke to investigate how it affects their decision making and path finding. This means that we have covered all the aspects above. The results gained in this paper prove this statement.

The rest of this paper is organized as follows. In the next section, the serious game which this paper is part of is presented. In the third section, the adopted scenario in this study is explained in details. Results are delivered after that and the final section is the conclusion.

A SERIOUS GAME

The presented research is a part of the SmartRescue project (SmartRescue, 2014). In the SmartRescue project, an android-based smartphone app, called SmartRescue (SR) app, has been developed. This app enables users, first responders, and victims to send and receive demanded data, which is gathered by the embedded sensors and technologies inside the smartphones such as accelerometer, gyroscope, GPS, humidity, thermometer, and so on. Therefore, this app gets a real-time overview of the location and condition of the fire and those (firefighters and/or victims) having the smartphone app installed and activated in their smartphones. It also can predict the fire spread in the next few minutes by means of the Bayesian networks concept.

For testing the SmartRescue app, a serious game was designed at University of Agder (UiA) including 22 participants, playing the role of firefighters (called "smoke divers (SD)" in our game), smoke diver leaders (SDL), crew manager (CM), medical care unit, and victims. There were also 6 observers from fire departments in cities Grimstad and Arendal.

We have set the structure of the teams based on the interviews with firefighters and the guidelines extracted from (DSB, 2015). According to Figure 1, extracted from Norwegian Directorate for Civil Protection (DSB) guideline (DSB, 2005), SDs enter the building on fire in pairs. They are responsible for the SAR process to evacuate all the victims from the affected area.

An SDL is the leader of the smoke divers that receives orders from the CM and gives orders to SDs. He is responsible for the lives of his SDs. He does not enter the building for firefighting, but he rather stays near the entrance of the building to

obtain the big picture of the situation by monitoring the temperature and the size of the smoke and fire in the building (using smartphones app, SR app, and walkie-talkie, as the communication tool in our scenario). Then he decides whether to keep the SDs in the building or take them out. If an incident happens to any of the SDs, he has to inform the CM and takes the role of the injured SD.

CM is responsible for the safety of his crew and reports to an on-scene commander. The role of the on-scene commander was not considered in our game, as it is out of the scope of this study. The reference organizational model of the firefighter in fire disaster is shown in Figure 1.

OUR SCENARIO FOR THE GAME

Two scenarios were designed for the game. In the first scenario, not of our interest in this paper, the players, both victims and SDs, did not have the smartphones. In the second scenario which is our adopted scenario for the game, the players were equipped with smartphones that had the SmartRescue app installed on them. There were 10 firefighters (6 SDs, 3 SDLs, and 1 CM), 13 victims (including two dummies), and one medical care unit involved in this scenario.

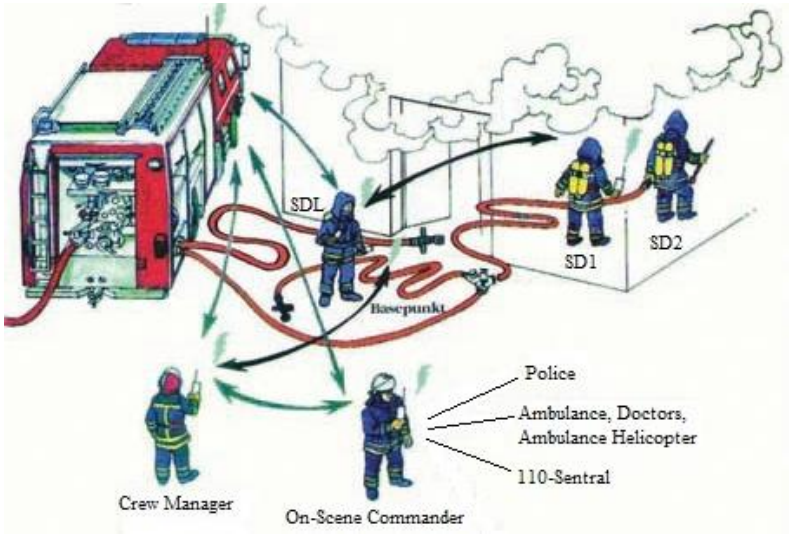

Figure 1. Reference organizational model of the real firefighter operation (DSB, 2005)

To study the structure of the firefighting groups and the impact of using smartphones on the SAR procedures and decision making, we have designed the structure of the firefighting groups as shown in Figure 2. We had 3 firefighting groups in each there were 2 SDs and one SDL that had walkie-talkie as the communicating device. All SDLs and the medical care unit had a direct contact with the CM. SDs were in direct contact with their SDLs, while they could be heard by the CM as well. For distributing SR app among rescuers, we have defined three organizational models, i.e., centralized, semi-centralized, and decentralized.

Group 1 is a centralized group, as SDL is the only one having the smartphone and

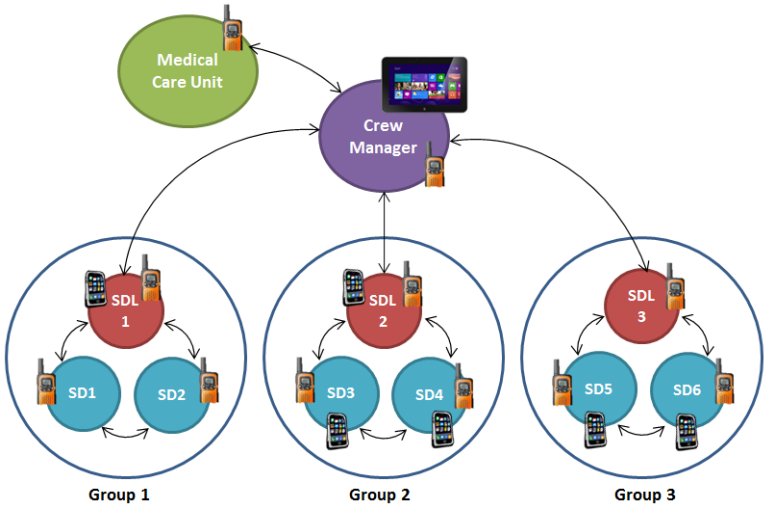

Figure 2. The organizational models

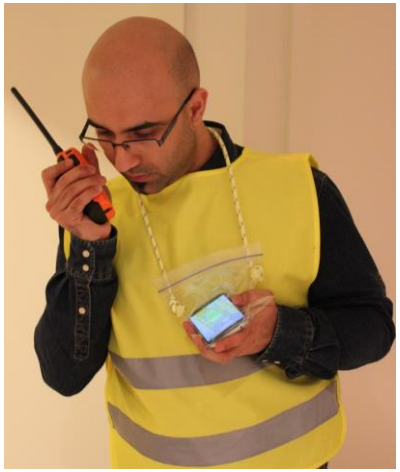

Figure 3. An SD using both walkie-talkie and SR app

the SR app. Therefore, the information is first received and viewed by SDL, and then he/she needs to pass it to their team through walkie-talkie. Group 2 is a decentralized one, as all the members of the group have smartphones and the SR app. Group 3 is a semi-centralized group, as SDs are those having smartphones and SR app, while the SDL of the group acquires the information only through walkie-talkie.

Figure 3 shows one of our SDs using both walkie-talkie and SR app. In order to ease the performance of the rescuers, we designed a plastic case that was used to carry the smartphones. Different from our game, a hook for carrying the walkie-talkie on the uniform of real firefighters exists. This also increases the performance of the rescuers.

RESULTS

The goals of this research are; G1) to study the impact of using the SR app on the evacuation procedure and time, G2) to investigate the effects of having smartphones in rescuers' hands on their performance and mobility, G3) to examine the role of smartphones in organizing rescue teams (organizational models).

To achieve these goals and evaluation purposes, we designed the fire drill (game) scenario described in the previous section, from which a questionnaire for analyzing the scenario was handed out. After the game the players as SDs, SDLs, and the CM were asked to fill in a questionnaire regarding their experience with using smartphones during the SAR procedure. In a part of the questionnaire, the rescuers were asked the questions listed in Table 1.

#Q	Question	Goals
Q1	I preferred to have the SR app during the evacuation.	G2
Q2	It was enough that one of us in pair had the SR app.	G3
Q3	I think the evacuation time was shorter when I used the SR App.	G1
Q4	It was hard for me to understand the SR app.	G2
Q5	It was hard for me to carry all the equipment given to me while helping victims.	G2
Q6	I preferred listening to my leader than using the SR app.	G1, G3
Q7	I think walkie-talkie was sufficient for getting overview of the situation the location of the victims and for making decisions.	G1

Table 1. The questions and the corresponding goals

In this section, the results of this questionnaire are presented. In total, 10 players (6 SDs, 3 SDLs, and 1 CM) responded to the questions. As can be seen in Figure 4, 60% of the firefighters preferred to have SR app during evacuation, while 40% did not want the app (Q1). Among those who wanted the app, the SDL in Group 3 that did not have the app believed that she needed the app to get the situational awareness as to better lead her team in the SAR process.

Concluded interestingly from Q2, those from the centralized group (Group 1) believed that both pair needed the SR app, as the SDs were supposed to move in pairs. Therefore, responders in centralized group preferred the decentralized one,

while those in centralized and semi-centralized groups thought equipping one of the pair with SR app (semi-centralized) was enough. Based on the answers achieved for this question, it can be concluded that a semi-centralized group in which the SDL and one of the SDs having the smartphone is the ideal organizational model. This statement can also be supported from the post-game discussions with real firefighters, as they found SR app very useful during the evacuation and believed that all SDLs and at least one of the SDs in pair need to have the app in hand.

In the first scenario, the evacuation time was recorded as 15 minutes, whereas it reduced to 12 minutes in the second scenario. This reduction can also be supported by the feedbacks (Q3) from 70% of the responders, who realized that the evacuation time was shorter in Scenario 2 (with the SR app) as compared to Scenario 1 (without SR app). Concerning Q4, 80% of the responders found the SR app easy to understand and work with.

Regarding the impact of carrying smartphones and walkie-talkie while evacuating the victims (Q5), 80% of the responders thought the mentioned devices did not affect their performance and mobility. Remarkably, only 20% of firefighters chose

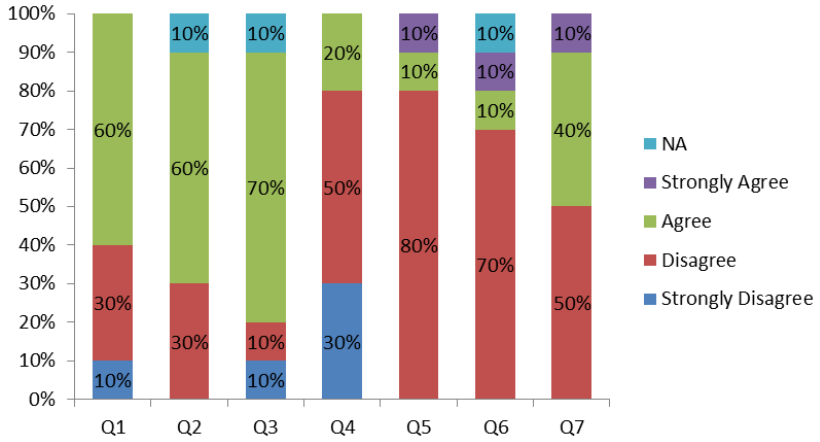

Figure 4. Results from the answers to the questionnaire

listening to their leader via walkie-talkie over using SR app to get the overview of the situation (Q6). This question was not relevant for the CM (she answered "NA"), as she had no leader in this game.

For the last question, 50% of the firefighters thought walkie-talkie was enough for getting overview of the situation and decision making, mentioning that it was more reliable than the SR app. On the other hand, the other 50% believed using only walkie-talkie was not sufficient as there was too much talking and sometimes irrelevant information. Plus, locating the victims without SR app was time consuming and tougher.

CONCLUSION

The study done in this paper demonstrated that a semi-centralized organizational model is the most appropriate type of evacuation team dynamics in scenarios, such as Scenario 2 designed in this paper. It can also be concluded that our developed smartphone app was easy to work with and helped the evacuation time to be shortened. Besides, the responders preferred using SR app rather than just listening to their leaders for crisis mapping and making decisions. Therefore, the application of SR app in real-life scenarios is highly suggested. This can be done by employing the app in real firefighting drills.

REFERENCES

1. Backlund, P., Engstrom, H., Hammar, C., Johannesson, M., & Lebram, M. (2007, 4-6 July 2007). *Sidh - a Game Based Firefighter Training Simulation.* Paper presented at the Information Visualization, 2007. IV '07. 11th International Conference.
2. Bekker, W. (2013). Apps for that-Tried and tested downloads for firefighters. January 2015, from http://www.firefightingincanada.com/equipment/apps-for-that-14885
3. Colunas, M. F. M., Fernandes, J. M. A., Oliveira, I. C., & Cunha, J. P. S. (2011, 4-8 July 2011). *Droid Jacket: Using an Android based smartphone for*

team monitoring. Paper presented at the Wireless Communications and Mobile Computing Conference (IWCMC), 2011 7th International.

4. DSB. (2005). Veiledning om røyk og kjemikaliedykking (pp. 68). Norway: Norwegian Directorate for Civil Protection.
5. DSB. (2015). Norwegian Directorate for Civil Protection (DSB) from http://dsb.no/
6. Dugdale, J., Pavard, B., Pallamin, N., el Jed, M., & Maugan, C. L. (2004). Emergency fire incident training in a virtual world. *Proceedings ISCRAM, 167*.
7. Feese, S., Arnrich, B., Troster, G., Burtscher, M., Meyer, B., & Jonas, K. (2013). *CoenoFire: monitoring performance indicators of firefighters in real-world missions using smartphones*. Paper presented at the Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing, Zurich, Switzerland.
8. FireRescue1. (2015). Firefighter iPhone Apps, January 2015, from http://www.firerescue1.com/firefighter-iphone-apps/
9. Jerrard, J. (2011). Smartphone Apps for the Fire Service, January 2015, from http://www.firefighternation.com/article/training-0/smartphone-apps-fire-service
10. Jones, R. T., Ollendick, T. H., McLaughlin, K. J., & Williams, C. E. (1990). Elaborative and behavioral rehearsal in the acquisition of fire emergency skills and the reduction of fear of fire. *Behavior Therapy, 20*(1), 93-101.
11. Kulakowski, P., Calle, E., & Marzo, J. L. (2010, 11-13 Oct. 2010). *Sensors-actuators cooperation in WSANs for fire-fighting applications.* Paper presented at the Wireless and Mobile Computing, Networking and Communications (WiMob), 2010 IEEE 6th International Conference on.
12. Lehmann, A., Hofmann, M., Palii, J., Karakasidis, A., & Ruckdeschel, P. (2013). SanTrain: A Serious Game Architecture as Platform for Multiple First Aid and Emergency Medical Trainings *AsiaSim 2013* (pp. 361-366): Springer.
13. Monares, Á., Ochoa, S. F., Pino, J. A., Herskovic, V., Rodriguez-Covili, J., & Neyem, A. (2011). Mobile computing in urban emergency situations: Improving the support to firefighters in the field. *Expert Systems with Applications, 38*(2), 1255-1267.
14. NowForce. (2015). NowForce, January 2015, from http://www.nowforce.com/
15. Schmitz, B., Kalz, M., Klemke, R., & Specht, M. (2014). In the eye of the beholder: promoting learner-centric design to develop mobile games for learning *Mobile as a Mainstream–Towards Future Challenges in Mobile Learning* (pp. 92-106): Springer.
16. SmartRescue. (2014). SmartRescue Application, 2014, from http://ciem.uia.no/project/smartrescue
17. St Julien, T. U., & Shaw, C. D. (2003). *Firefighter command training virtual environment.* Paper presented at the Proceedings of the 2003 conference on Diversity in computing.