

Towards Monitoring Firefighting Teams with the Smartphone

Sebastian Feese, Bert Arnrich, Mirco Rossi, Gerhard Tröster
ETH Zurich

Wearable Computing Laboratory
{feese, barnrich, mrossi, troester}@ife.ee.ethz.ch

Michael Burtscher, Bertolt Meyer, Klaus Jonas
University of Zurich

Department of Psychology
{m.burtscher, b.meyer, k.jonas}@psychologie.uzh.ch

Abstract—Two important aspects for efficient and safe firefighting operations are team communication behavior and physical activity coordination. In close cooperation with a firefighting brigade we investigate the potential of modern smartphones to acquire objective data on team communication and physical activity in an automatic way. We envision that such a monitoring is helpful for improving post incident feedback to enhance the efficiency and safety of firefighting operations. In this contribution we present our findings of a feasibility study in which two firefighting teams had to extinguish a kitchen fire. We present the obtained measures of speech and physical activity levels and show how the difference in performance between the two teams can be explained by the smartphone measures.

I. INTRODUCTION

Firefighting is a dangerous and possibly life threatening task. Firefighters save lives and prevent loss or destruction of property and the environment. Besides fighting fires, firefighters are also often the first responders to people in other critical situations. The variety of firefighters tasks ranges from dealing with hazardous material to rescue work during natural disasters. Independent of the emergency type, time is the most critical factor. As fires can rapidly spread and endanger many lives, firefighting is a race against time and delays can have serious consequences. Two important aspects for efficient and safe firefighting and rescue operations are team communication and coordination. Even though the performance of firefighting teams depends on many varying aspects like the incident type, environmental conditions and architectural constraints, important behavioral rules have evolved. A good firefighting team works calmly and coordinates its actions. The coordination between firefighters can be explicit relying on verbal communication or implicit which can be observed by well coordinated actions without any verbal communication. We therefore focus on the quantification of team communication and team movement activity because these measures play important roles across many tasks. We envision the use of smartphones to monitor firefighting teams in order to improve post incident feedback and hence to enhance the efficiency and safety of firefighting operations. As a first step, the aim of the present paper is to explore which basic team behaviors such as team activity and team communication can be measured with the smartphone in the context of firefighting.

A. Related Work

In the field of human computer interaction several ethnological studies with firefighters have been carried out to learn about work practices in firefighting in order to design ubiquitous computing support of firefighters [1], [2], [3], [4], [5]. In [1] large display prototypes for supporting the incident commander were designed. Jiang et. al. identified four design rules naming accountability of personnel, situation assessment, resource allocation and communication support. The need for processing and communicating information as well as implicit coordination in firefighting teams is highlighted in [2]. In addition Landgren suggested that “verbal communication should be made persistent, visible and accessible in order to support accountability” [3]. Taking the work practices of firefighters into account Toups et. al. developed a simulation game to train coordination in teams [6]. Several prototypes of localisation and navigation systems have been developed to support firefighters. Fischer et. al. have compared the benefits and drawbacks of preinstalled location systems, wireless sensor systems and inertial tracking systems for emergency responders [7]. Measurements during firefighting incidents have so far focused on physiological parameters such as heart rate, breathing rate, body core temperature and oxygen saturation, as well the exposure to toxic gases [8].

B. Paper Contribution

In this paper, we investigate to monitor communication and coordination behavior of firefighting teams with the smartphone. Based on previous research that highlighted the importance of coordination in first responder teams, we focus on two modalities, namely speech and body motion and make the following contributions:

- An experiment in which two firefighting teams take out a real kitchen fire in a simulation building during a training incident.
- We evaluate how well voice activity of firefighters during incidents can be detected with commodity smartphones placed in the firefighting jacket.
- We investigate how speech and body movement activity might help to explain why one team was faster than another.

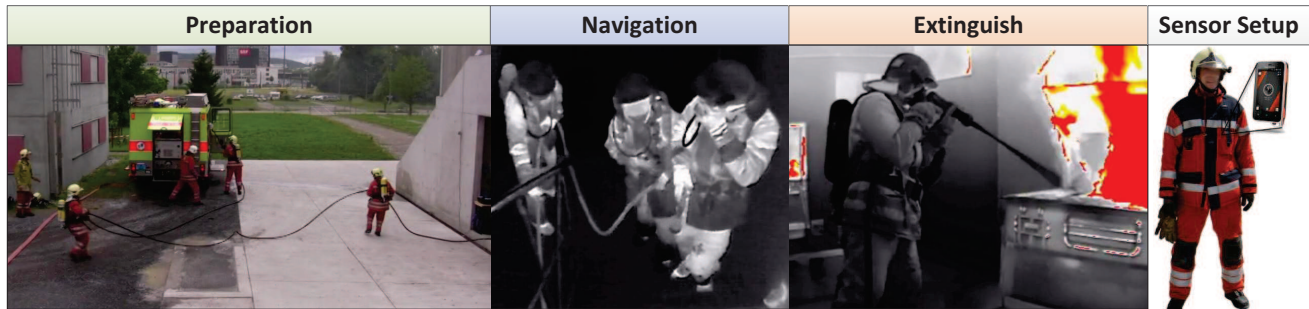


Fig. 1. Illustration of incident phases. In the preparation phase the hose is laid out and the troop puts on their self contained breathing apparatus. Under low visibility the troop then navigates through the house carrying the hose with them. In the extinguishing phase the fire is put out. On the right the placement of the smartphone is shown.

II. FIREFIGHTING TRAINING

We have recorded motion and audio data of 10 firefighters during a one day training. The experiment was conducted in the fire simulation building at the training facilities of the Zurich fire brigade. In the fire simulation building a variety of fire scenarios can be realistically simulated ranging from kitchen fires to a burning car in the garage. During training, firefighters are confronted with real fires, extreme heat, high humidity, severely restricted visibility and thick smoke.

In the chosen scenario a kitchen fire in the third floor of the training building had to be extinguished. Two teams of a voluntary fire brigade completed the scenario one after the other. After the first team finished the scenario, the instructor gave feedback to all firefighters and highlighted mistakes that should be improved. Afterwards, the second team started with the same scenario.

Each team consisted of five firefighters, the incident commander (IC) who led the whole team, the engineer (E) who operated the fire truck engine and the troop, which went inside the building to find and extinguish the fire. The troop itself consisted of three firefighters; two troop members (TA, TB) where led by the troop leader (TL).

In the scenario, the firefighters arrived with the fire truck at the building and the incident commander gave the command to extinguish the kitchen fire. Subsequently, the preparation phase started in which the troop prepared the hose and the engine operator took care of the water supply. As soon as the troop was ready, they put on their self-contained breathing apparatus (SCBA) and entered the building, which by that time was filled with thick smoke. Now, the navigation phase started in which the troop had to navigate through the building, climb the stairs and find the kitchen fire. In the navigation phase the troop had to navigate through the building under very low visibility and had to handle the hose correctly to make sure that it would not stuck anywhere. When the fire was found, the extinguishing phase started and the fire was put out.

After the training run of team T1 the instructor gave feedback to both teams, so that team T2 could benefit from the

mistakes that team T1 had made. The instructor highlighted that the engineer E1 of the first team was to passive meaning that he did not fulfil his task during the preparation phase. Additionally, the first team T1 had problems with the hose management, which led to the hose being stuck in the staircase during the navigation phase. Both points were addressed by team T2, which resulted a shorter incident duration time. T2 was more than five minutes faster than team T2. Consequently, the instructor also evaluated the performance of team T2 one grade better than that of team T1.

III. DATA COLLECTION AND PROCESSING

A. Data Collection

For data collection, we used the Sony Xperia Active smartphone and a custom Android app. Based on the funf-open-sensing-framework¹, we designed an Android app to record acceleration, orientation and ambient sound data. For robustness reasons, each sensor was sampled in a separate background service and we extended the framework to also save the raw data to the memory card. Audio data was recorded with 11250Hz and upper body acceleration and orientation was resampled to 50Hz using linear interpolation. The phone was placed in the left pocket of the firefighting jacket. As the firefighters were used to carry their mobile phone with them also during incidents this did not disturb their working routine.

B. Verbal Communication

In order to capture the amount of verbal communication during a firefighting incident, we employ the robust voice activity detection algorithm presented in [9]. At it's core a long-term signal variability (LTSV) measure is used to measure the degree of nonstationarity in the audio signal and it is hypothesized that speech has a higher degree of nonstationarity as compared to noise sources. Because the LTSV-measure is independent to amplitude scaling of the input signal it is robust and well suited for the noisy firefighting environment. We choose as frame size 30ms with a step size of 10ms, which are

¹<http://funf.org/>

standard values in speech processing and applied the following output smoothing: first all frames within 1000ms were merged to one detected segment and subsequently all segments shorter than 300ms were deleted.

We tested the detection accuracy by manually annotating speech of four firefighters during the training scenario. In total we annotated 50 minutes of audio data taken from the two incident commanders and the two troop leaders. In Figure 2 the frame-based receiver operator curve is shown. It can be seen that the voice activity detection works better for the incident commanders (IC1, IC2) who were outside the building compared to the troop leaders (TL1, TL2) who were inside. The mean area under the curve for the two troop leaders is 0.89, whereas the mean area under the curve is 0.96 for the two incident commanders. This difference in detection accuracy can be explained by different levels of environmental noise as the building ventilation was very noisy.

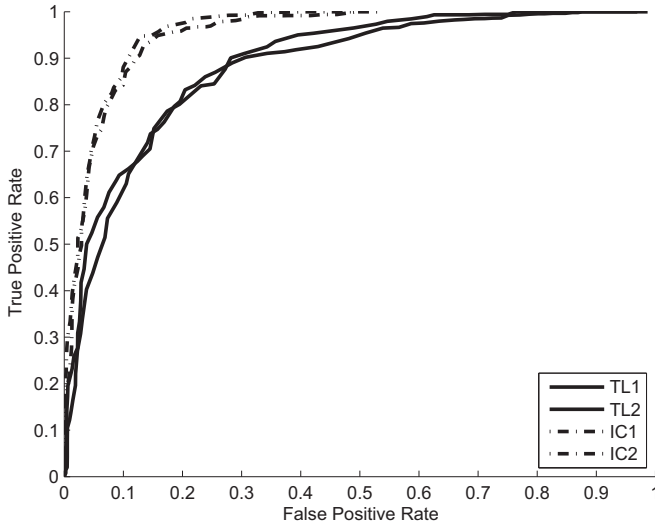


Fig. 2. Receiver Operator Curve of Voice Activity Detection. Mean AUC of the troop leaders (TL1, TL2) is 0.89, whereas the mean AUC of the incident commanders (IC1, IC2) is 0.96. The difference can be explained by different levels of environmental noise.

Based on the detected voice activity va , we calculate the speech activity level as the time fraction of a two second long window that voice activity was detected. The speech activity level is calculated every second.

C. Physical Activity

For the motion activity detection, we used a threshold based approach. On a one second long sliding window the standard deviation of the acceleration magnitude σ_{accmag} is calculated. Body activity is detected when σ_{accmag} exceeds a predefined threshold θ which we set to 0.1 for our experiments. The body activity level is then calculated every second as the fraction of time that body activity is detected within a two second long window.

IV. COMPARING FIREFIGHTING TEAMS

Having observed that team T2 was more than five minutes faster, we were interested to compare both teams in terms of their speech and body activity. The simplest way to compare both teams is to aggregate all variables over the entire length of the simulated training incidents. In Fig. 3 the aggregated body activity of each team member and the speech activity of the incident commander and the troop leader is displayed. Looking at the complete incident (Fig. 3 left), we notice a large difference in the body activity of the Engineer E. The observation that E2 was much more active than E1 fits well with feedback of the instructor that E1 was too passive. We can also infer that the troop leader TL2 was about 10% less active, whereas incident commander IC2 was about 10% more active. In terms of the amount of speech activity both teams seem to be equal considering the complete incident.

Zooming into the different incident phases, we can better understand where the observed differences stem from. Looking at aggregated variables over incident phases (Fig. 3 right), we observe that the additional activity of E2 is spread across all incident phases, that the higher activity of IC2 stems from the preparation phase and that TL2 is less active in the navigation phases, but more active in the extinguishing phase. Also in terms of the communication amount a more differentiated picture emerges. In the preparation phase IC2 and TL2 spoke more, whereas they spoke less in the navigation phase. This could indicate that team T2 spent more time on planning in the preparation phase and consequently had less to communicate in the navigation phase as opposed to team T1.

A detailed picture of the complete incident is illustrated in Fig. 4, which shows the body and speech activity level of the two teams. Inspecting the preparation phase, we could conclude that team T2 appears to be better coordinated as all members are first active and before they continue to work first stop to communicate, which can be seen by more speech activity between the troop leader and the incident commander. This pattern is notably absent in team T1. In fact, when we reviewed the video, we found out that the incident commander IC1 first gave a command to the troop leader TL1 and afterwards gave a second command to the troop member TB. In contrast, IC2 only gave one command to the TL2 who then distributed the command the troop members.

V. CONCLUSION AND OUTLOOK

We have demonstrated that the amount of communication and body activity, both being indicators of team coordination, can be measured with the smartphone in a typical firefighting scenario. Moreover, we showed the potential of how the measures could explain why one team was faster than another. In future research this needs to be validated with a larger sample size to proof generalizability.

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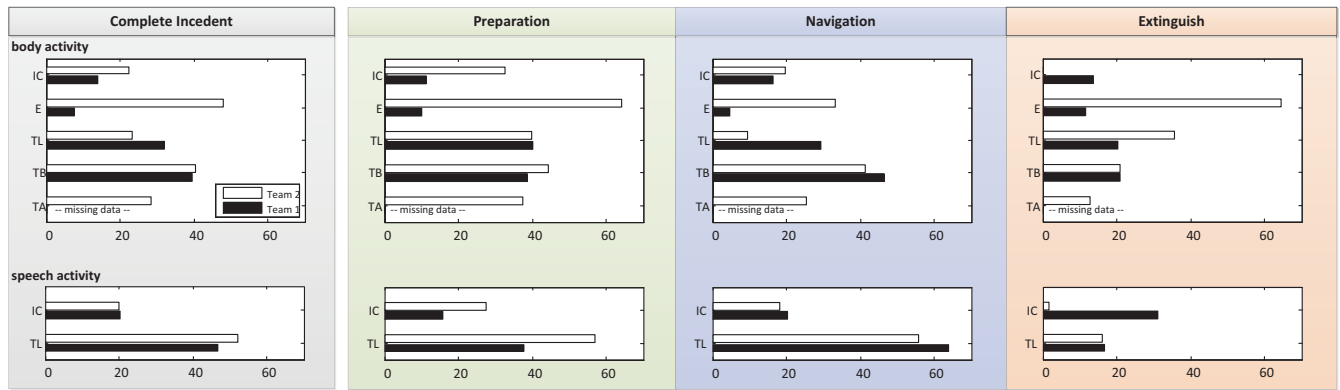


Fig. 3. Comparison of both teams in terms of their aggregated body and speech activity. Variables are aggregated over the complete incident and separate incident phases. The engineer E2 is more active during the entire incident, whereas the incident commander IC2 is more active in the preparation phase and the troop leader TL2 is less active in the navigation phase. Team T2 appears to be communicate more in the preparation phase and less in the navigation phase.

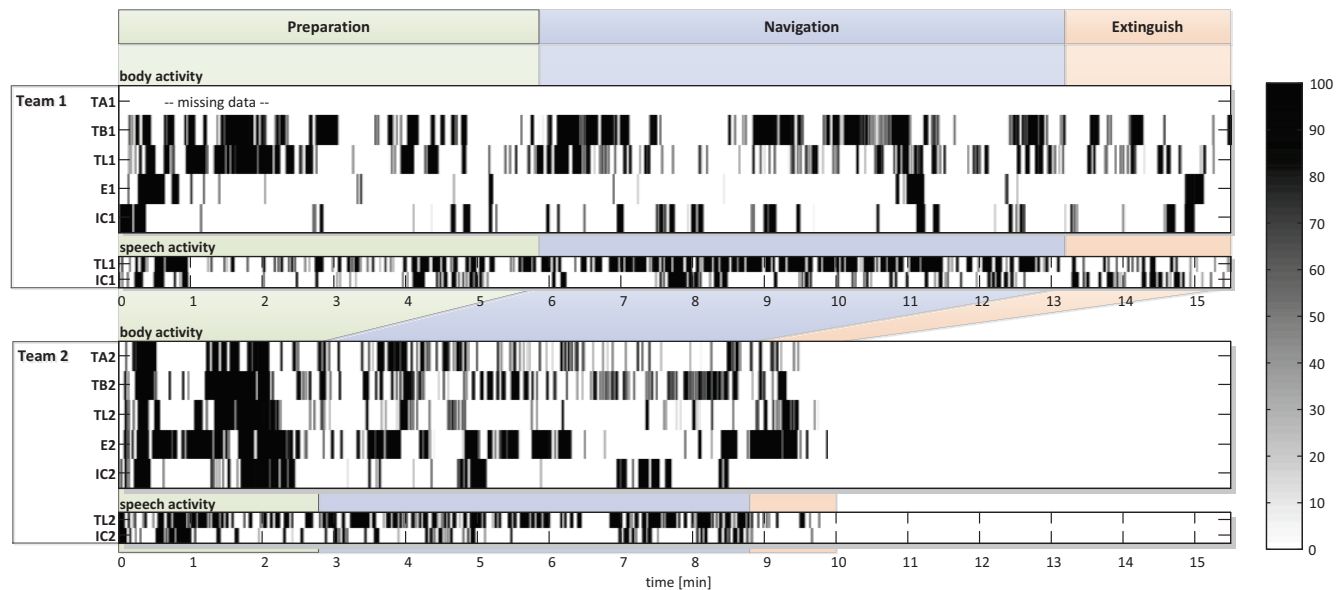


Fig. 4. Timing of body and speech activity for both teams. The preparation phase of team T2 appears to be much more structured and less communication between the incident commander IC2 and his troop leader TL2 is observed.

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