See through the Fire: Evaluating the Augmentation of Visual Perception of Firefighters Using Depth and Thermal Cameras

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Abstract
Our visual perception is limited to the abilities of our eyes, where we only perceive visible light. This limitation might influence how we perceive and react to our surroundings, however, this limitation might endanger us in certain scenarios e.g. firefighting. In this paper, we explore the potential of augmenting the visual sensing of the firefighters using depth and thermal imaging to increase their awareness about the environment. Additionally, we built and evaluated two form factors, hand held and head mounted display. To evaluate our built prototypes, we conducted two user studies in a simulated fire environment with real firefighters. In this workshop paper, we present our findings from the evaluation of the concept and prototypes with real firefighters.

Author Keywords
Thermal Imaging; Depth Cameras; Firefighters.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction and Background
The increasing power of technology changed the way humans perceive their universe. Namely, imaging technology has shown promising advancement in visualization and perception of the environment. For instance, depth cameras

Figure 1: Hand Held prototype consisting of thermal, depth camera and a display for visualization.

(e.g. Kinect) allowed sensing the environment in 3D by utilizing near-infrared spectrum [4, 5, 6]. What makes depth sensing appealing and applicable in various scenarios, its non-visible operating spectrum extends the human visual sensing, yet not occluding with their experience.

Recently, thermal imaging (which is also known as far-infrared) has become affordable for commercial and personal use in terms of cost and size, to the extend thermal imaging has been integrated in mobile phones[1]. As well as deployed in various interactive systems [7, 3, 1]. Hence, enabling an extension for how we perceive, visualize and interact with the surroundings. Thermal imaging provides a heat map for the scene to the user in a non-distributive way, as it operates in a robust manner; independent on the light condition and with no need to any external or special light/illumination source. Moreover, infrared imaging (including both near- and far-Infrared) enhances and extends the perception of our visual sensing, whereby utilizing these cameras we are capable to perceive light outside the limited visible spectrum.

The ability to extend human vision into the infrared spectrum already exists using prosthetic devices such as goggles and binoculars. Nowadays, HMD and AR has shown significant advancement in visualization and interaction challenges in multiple domains, namely, gaming, medicine, manufacturing [2]. Despite the advancement of AR application, it has been under-explored in critical scenarios like firefighters.

Thermal camera is a typical hand-held tool for firefighters, however, there as far as we explored it has been limited work on evaluating different form factors and the usage of depth sensing.

[1] http://www.catphones.com/en-gb/phones/s60-smartphone

We combined both imaging and two form factors: (1) HMD and (2) mobile technologies to explore the potential of augmenting human visual sense by extending the perceived electromagnetic spectrum to include the near- and far-Infrared bands. The multiple spectral visual perception will be presented to the user via HMD or a mobile display.

Our primary focus was to evaluate the usage of both imaging technology in a simulated fire situations and to evaluate the performance of the depth vs. the thermal camera. Additionally, we evaluated the form factor for amplifying the visual abilities. We conducted two studies, in a form of simulated fire environment, in a dark, closed and foggy basement, to explore and investigate the potential of deploying extended visual perception for firefighters.

Study I: Evaluation of Depth Vs. Thermal Vision Extension

In our first study, we aimed to asses the usage of amplification mode, in other words the benefit of augmenting depth as opposed to thermal information. We used a simulated challenging fire environment, by using a dark basement with obstacles as depicted in figure 2.

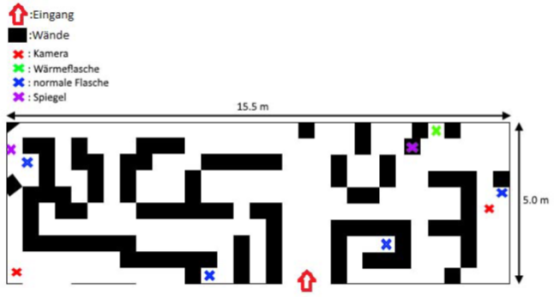

Figure 2: Map of the Basement.

Figure 3: HMD prototype.

Figure 4: Hand Held prototype.

We invited 16 participants aged between 20-30 years, 12 males and 4 females. None of the participants have been to the basement before with no prior experience with depth cameras.

We used the hand held prototype shown in figure 1, participants can change the views either using the depth or thermal view. We focused on navigation task, since, its one of the most challenge tasks of firefighters. Participants were asked to perform two tasks:

- Estimate the size of the basement
- Find the warm bottle

After tasks completion, participants were interviewed to rate the usage of depth and thermal camera to perform the tasks. Additionally, we logged the view the used to perform the tasks as well as the camera feed.

Results and Discussion
We analyzed the views and the recorded feed from both cameras to identify the camera used to perform the tasks. We found out that 87% of the participants used the depth camera to perform the navigation task to estimate the size of the basement. On the other hand, all participants switched to the thermal view to locate the warm bottle.

Our findings from the interview confirms our findings. All participants reported that they had an enhanced experience using the extended views and the complexity of the tasks were drastically reduced. Additionally, 6 participants recommended the usage of both imaging technology in the same view through combing the depth and thermal information via sensor fusion.

The first study reflects the importance of both imaging technology, where extending the visual perception to the depth band allowed better navigation skills, and thermal layer allowed sensing non-visible information (i.e. temperature of the bottle) as well as performing fine search tasks. Accordingly, we performed a second user study with three different views: (1) Thermal, (2) Depth and (3) Thermal and Depth fused view. Additionally, we used two different form factors.

Study II: Hand Held Vs. Head Mounted Display

The firefighters are used to the hand held form given it is the typical form of the currently used devices. However, we wanted to evaluate different form factors namely; hand held and Head Mounted Display.

We invited 11 participants aged between 19-51 years. Non of the participants have been to the basement before with no prior experience with depth cameras. Six participants used the HMD and the other 5 used the hand held setup. The participants were asked to perform the same tasks as in study I.

We logged the time spent in each view of the thermal, depth and fused views. Additionally, we conducted post-interviews with the participants.

Results and Discussion
We computed the time spent in each view, we found that 39% of the time was spent using the thermal and depth fused view, followed by 35% and 26% in the depth and thermal views respectively. This confirms the effectiveness of the fused view, and the usage of both imaging technology to maximize the augmentation of the human's visual perception. Additionally, the interviews reflected the preferences of using the HMD. However, all participants mentioned that the prototype should be integrated in the firefighters' helmet to be usable in real fire scenarios.

Conclusion

This paper presents two studies conducted with firefighters to investigate the potential of augmenting and amplifying their visual perception using both depth and thermal cameras. We aimed to evaluate the impact of using thermal vs. depth, additionally, the preferred form factor. Our findings reflect the effectiveness as well as the acceptance of the amplifying prototypes, where all participants reported the enhanced experience while using the prototypes. Moreover, participants from study I recommend the use of the thermal and depth fused view. Hence, we modified them to include the fused view in study II, and it was the most used view confirming the reported user preferences. We also found out that, the firefighters preferred the HMD more than Hand held, due to its hand free operation.

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