Poster: Designing Navigation Aides for Wildland Firefighters

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ABSTRACT

In this research, we explored the design of navigation technology for wildland firefighters. We worked within a set of empirically informed design constraints to create prototypes of a wearable system that provides peripheral navigation cues via visual and haptic feedback. We used physical and interactive prototypes of this system as technology probes to provoke discussions with wildland firefighters about their navigation and location technology needs. Our pilot study results indicate that our prototypes helped to uncover ideas for future technical work in the domain of wildland firefighting, as well as on mobile and wearable navigation systems, more broadly.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing systems and tools**.

KEYWORDS

firefighting, navigation, wearable technology, technology probes

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1 INTRODUCTION

Wildland firefighters are specialists responsible for forest fire suppression, control, and prevention [11]. Due to factors including rising temperatures and earlier snowmelt, regions such as the Western United States have been experiencing longer wildfire seasons and larger wildfires in recent decades, putting additional demand on these professionals [13]. Wildland firefighters often need to navigate in remote, unfamiliar terrain. They typically use technologies such as compasses and maps, handheld GPS units, or smartphone applications to navigate in the field. The use and non-use of these technologies is influenced by a variety of factors including low internet connectivity, prohibitively high cost of wilderness navigation smartphone applications, and limited access to power sources. Wildland firefighters also often need to carry equipment in their hands, which can make using handheld GPS units or even handheld compasses challenging.

We discuss here early design work investigating navigation technology for wildland firefighters, taking into account the unique constraints of this context. We used prototypes of a wearable peripheral navigation system as technology probes [5] to provoke discussion with individuals working in wildland fire about navigation technologies.

2 RELATED WORK

An existing class of UbiComp systems for firefighters works by automatically dropping small sensors or "breadcrumbs" behind a firefighter as they are walking, which transmit physiological and location data back to an external base station [6]. The Landmarke Project helps firefighters with way-finding in indoor environments by letting them create an ad-hoc indoor reference system to aid in spatial decision-making during firefighting. This sensor network differs from that created by the breadcrumb method because sensor nodes are placed intentionally rather than dropped automatically, as they are meant to act as a navigation reference for the firefighters themselves [10]. These systems have not specifically considered a wildland context, however, where dropping sensor nodes is infeasible due to environmental concerns.

Wearable navigation aides have been developed for helping, for example, blind people and bicyclists navigate. The Headlock system uses computer vision integrated into smart glasses to provide auditory feedback to guide users with low vision to a destination. The intensity of beeps increases as a user veers more from the intended path [3]. A system by Zhang et al. provides haptic feedback along a belt indicating the direction a user needs to walk relative to their current position, along with auditory commands [14]. The LEaD system provides directions for scooter or bicycle riders via a helmet-mounted strip of LEDs. LEDs light up to indicate turning directions in a user's peripheral vision as they are riding [12]. Our prototype system provides similar peripheral navigation cues.

3 DESIGN CONSTRAINTS AND SYSTEM PROTOTYPE

We developed a series of design constraints by reading materials such as *S-190, Introduction to Wildland Fire Behavior* [8], an introductory course for wildland firefighters, and *Incident Response Pocket Guide (IRPG)* [7], a small notebook carried by wildland firefighters working in the field. We also had informal conversations with six individuals with wildland firefighting or wilderness search and rescue experience about their navigation challenges and current technology use.

Design Constraints

- *Hands-free*—The interaction should not require a user to be continuously holding a device in their hands. Wildland firefighters often have to carry other items such as chainsaws, pulaskis, and hoses.
- *Low power*—Often the only way to charge a phone or other devices is within a support vehicle, which is not always available. Therefore, the solution would ideally be low-power or run on AA batteries, which are carried by support crews.
- *Complementary to gear*—Wearable devices would need to be worn over or under protective clothing. There should be no exposed metal that could conduct heat towards an individual's skin.
- *Complementary to work environment*—The technology has to complement existing training materials, hierarchies, and procedures. It should ideally integrate with wilderness navigation smartphone applications already in use in the field.
- *Easy to learn*—Because wildland firefighters are a seasonal, temporary workforce, the technology has to be easy to learn and intuitive to use.
- *Reliability*—Technical solutions in this space need to be very reliable, or else users will quickly lose faith in the solution in favor of time-tested methods or industry-standard equipment. In the most extreme case, inaccuracy of a navigation aids might put an individual in danger.

Figure 1: Physical prototype representing the design of a proposed helmet-mounted visual peripheral navigation aide.

Figure 2: Physical prototype representing the design of a proposed pair of arm-worn haptic peripheral navigation aides.

Our proposed wearable system uses three devices, one helmet-mounted (Figure 1) and two arm-worn (Figure 2).

For the helmet-mounted device, a housing in the front of the mount contains a microcontroller connected to a GPS receiver, accelerometer, magnetometer, and a Bluetooth LE module. A connected LED strip is secured under the brim of the helmet. The device is powered by a AA battery pack at the back of the helmet.

The device combines information from the magnetometer and accelerometer to calculate a tilt-compensated compass heading. The current latitude and longitude detected by the GPS module are compared with the latitude and longitude of the intended destination to calculate a bearing as well as a distance to the destination. The behavior of the LED strip under the helmet brim depends on the current difference between the heading and bearing and distance to the destination. As the user rotates their head, the LED strip continuously indicates an azimuth relative to the direction they are currently facing. As a user gets closer to a destination, the number and intensity of LEDs lit surrounding the primary indicator light increases.

Each armband contains a pouch containing a battery, Bluetooth LE module, and microcontroller. There is a small motor in a pouch underneath the band, which fits snugly against the user's skin in order to provide haptic feedback. The armbands receive information from the helmet-mounted device over Bluetooth LE indicating when each armband should provide haptic feedback. The armbands act as a geofencing system. As a user deviates from an intended path to a waypoint, they are alerted via haptic feedback on the side towards which they have deviated, increasing in intensity as deviation increases.

This system would allow wildland firefighters to upload waypoints from a smartphone before they begin navigating either manually or via an integration with an existing smartphone wilderness navigation application. Users would not be required to carry a smartphone during active navigation.

To demonstrate this proposed design, we created physical prototypes representing the size and shape of the wearables. We also created an electronic prototype using An Adafruit FLORA™ [1] wearable microcontroller, GPS module, magnetometer / accelerometer module, and Neopixel™ [2] LED strip, as well as an interactive visualization using Processing [9], which shows a birds-eye view of an individual navigating using the system and the feedback that they would receive.

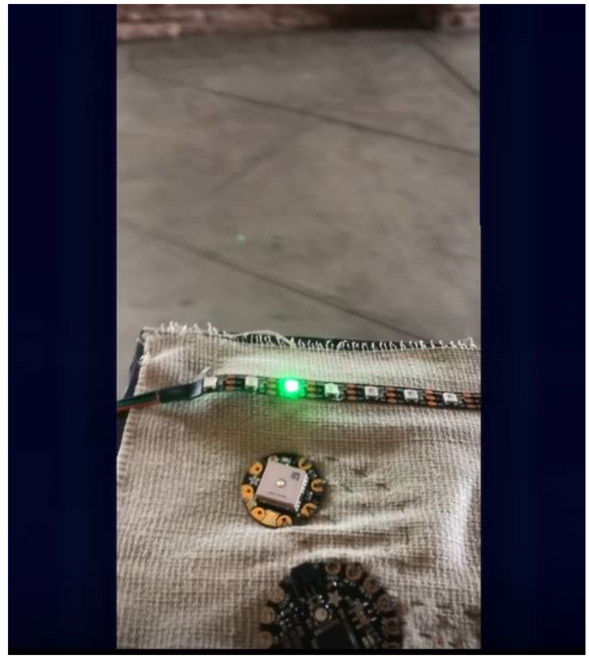

Figure 3: A frame from a video of a member of the research team using the electronic prototype (detached from helmet)

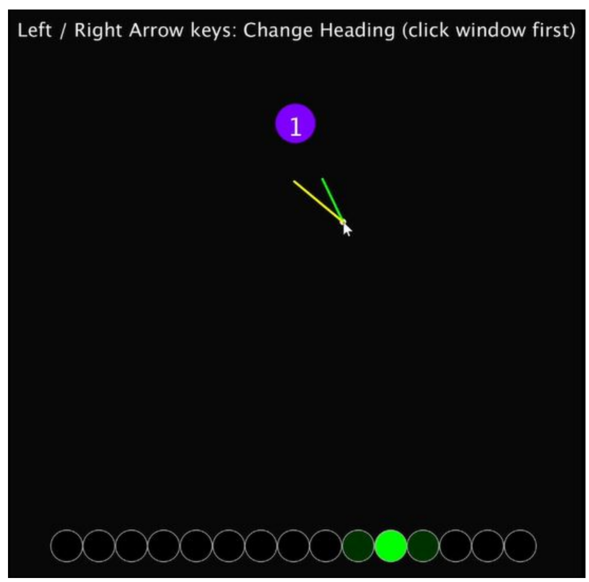

Figure 4: The interactive graphical prototype. The yellow line represents the direction a user is facing, the green line represents the azimuth, and the row of circles represents the LED display

4 PILOT STUDY

We interviewed three individuals with jobs related to wildland firefighting. Participants were shown the physical prototypes, a video of a member of the research team using the electronic prototype with mock data (Figure 3), and a video of the interactive Processing 3 prototype (Figure 4). They were asked to provide feedback about the prototypes, as well as provide ideas about their ideal navigation or location technology for wildland firefighting, as inspired by the prototypes.

The helmet prototype was praised for its ability to provide continuous feedback that would also allow a user to diverge from a straight path if they needed to use switchbacks to reach a waypoint high on a slope. However, participants were concerned about whether the device would comply with strict safety standards for helmets (e.g.,[4]) and about whether the lights would be distracting. The armbands were preferred by Participant 2 because they provided feedback that would not interfere visually. However, Participant 3 was concerned that the wristbands would not provide enough granularity of information to be useful. In general, participants were very concerned about the risks of distraction and error in a high-stakes environment—as well as about battery consumption.

Our discussion around the probes also provoked new ideas which suggest areas for future ubiquitous computing research. Participant 1, who is a fire chief, was primarily concerned about tracking his crew members. He said that such a system would only be useful to him if it could also send accurate location and physiological data about the firefighters wearing it back to his command post. Participant 3, who works on scouting wildfires, said that the helmet system would need to also support conveying altitude information in order to be useful. In his experience, reaching a waypoint often involves hiking up a slope to a specific altitude and then cutting across the slope to reach an intended destination.

5 CONCLUSION AND FUTURE WORK

Our pilot study validated our design constraints, helped us to identify strengths and weaknesses in our system prototypes, and suggested a number of promising directions for future work in this domain. Our technology probes helped us to understand the value of integrating remote tracking and bio-sensing into these kinds of navigation technologies as a benefit to both firefighters and their supervisors. We also uncovered the benefits of explicitly representing altitude information in wildland navigation visualizations, an approach that is currently underutilized and under-studied in navigational systems within the ubiquitous computing research literature.

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