Heat Map Thermal Display for Visually Impaired

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Abstract  
In this workshop we describe our ongoing work on a prototype presenting heat map data to visually impaired users. We try to reduce the stress level of blind travelers by presenting information about the number of other blind persons who can help with navigation. This is reached by augmentation of the users’ environment by social proximity metaphor mediated by our heat map thermal display of the prototype.

Author Keywords  
Visually impaired; haptic interaction; thermal interaction

ACM Classification Keywords  
H.5.2 [User Interfaces]: Haptic I/O.

Introduction  
Blind people experience a high level of stress while traveling independently outside of well known areas [11]. Our idea how to reduce their stress is to provide them with the information about the probability of getting help from other blind person who knows well the corresponding area. The probability of getting help increases with the number of blind people who have already visited the corresponding area. If this number is high enough, the stress level can decrease due to the increased feeling of safety caused by the feeling of higher social proximity.
This idea came out from the crowdsourced navigation system for blind people [1] which we have designed. The system is based on sharing of detailed descriptions of regularly walked routes in the urban environment, rich in navigation points and orientation cues used by blind people. Analyzing this data we are able to determine the number of blind persons who can help in particular areas. This can be typically visualized as a heat map (see Fig. 2) which is unfortunately unusable for the blind people.

In our previous work [2] (see Fig. 1) we focused on metaphors for lowering the stress level and presented a haptic heat map prototype allowing rich haptic interaction with a heat map. This prototype exploits several metaphors such as the density of the heat map (low density means cold, high density means warm), language expressions for social proximity (warm welcome, icy stare), and animal behavior (bristling of skin in danger). We tried to let the blind users sense a social proximity of other blind people traveling in the same area.

Several haptic interaction techniques were used to express described metaphors. The change of temperature to express heat map value and social proximity [5, 3, 6]. The change of surface (spiky or smooth) as a metaphor for safety. Ring shape to evoke affordance for grasping.

There were several issues influencing the physical form of the prototype. The prototype should: afford touching and grasping to let the user hold it correctly without the use of vision, be handled by one hand only as blind people use one hand for holding a white cane (or a dog leash) while walking, be easily removable as blind people use touch and wrists for exploring environment.

The work we present at this workshop focuses on determining the position of the thermal display on a hand and its expressivity in the use-case of communicating heat map data to blind users. Our approach combines affective computing approach and virtual reality approach.

Related Work
Thermal displays are often used to provide a user with precise sensation of different materials in virtual environments [4]. On the other hand they are used in affective computing for sensing cold-warm stimuli [3, 6] not focusing on particular temperature.

Thermal Interfaces
Ho et al. [4] created a thermal display for discrimination of different materials. Kron et al. [9] used a multi-finger thermal display in combination with vibro-tactile feedback for usage in virtual environments. Gooch et al. [3] experimented with thermal feedback for remote communication showing increased feelings of social presence. Iwasaki et al. [6] created a thermal display that communicated emotional information to other user through augmentation of an existing mobile phone. Wettach et al. [13] used thermal feedback to map the distance to the destination during navigation with a mobile phone. Lee et al. [10] used a bracelet for communicating interpersonal messages suggesting potential in this area.

Temperature Perception
The interaction with a thermal display is limited by human perception and thus it should exhibit a number of properties: the rate of change of the temperature (ROC) should be in range of 1-3 °C/s with respect to subjective comfort of users [14], ROC should not be lower than 0.1 °C/s [8] with respect to the adaptation to certain temperature, minimum and maximum temperatures should respect pain thresholds 13-45 °C [7]. Jones et
al. [8] suggest using range of 22-42 °C. Wettach et al. [13] also investigated discrimination among three different temperatures showing that subjects were able to discriminate them after the training with 25% error rate. According to [12] the neutral zone (where no changes of the temperature are distinguishable) shifts based on the temperature of the skin.

Thermal Display
The thermal display is placed on the ring of the haptic heat map prototype that can be held in a hand (see Fig. 1 and 3).

Figure 3: The haptic heat map prototype with 1. thermal display (red) and 2. pressure display (green).

Figure 4: The course of the output from the thermal display.

Thermal Output
The thermal output is designed in a way, where the user distinguishes between different steps of temperature and is able to count the number of steps introduced by the system. We do not try to communicate concrete temperature values that are mapped to concrete values (e.g., 33 °C equals 5 people who can help) as in various environment conditions the ability of determining concrete temperature can be very limited. Based on Wettach et al. [13], who described problems with discriminating separated temperatures, we focus on continuous change of temperature to let the user know the final temperature by comparison to previous temperatures.

To preserve the metaphor of social proximity tied to the temperature, we increase the temperature in given range by equal steps. For each step the temperature remains constant for certain period of time. Then the temperature rises one step higher with speed of 1 °C/s (see Fig. 4).

Our future study will be focused on determining which position on the hand is the most suitable, and the number of steps that can be mapped to certain temperature range.

Technical Implementation
The aim of the technical implementation was to develop a reliable thermal display that can be wirelessly connected to the user’s mobile phone (see Fig. 3) and that corresponds to the physical form of the haptic heat map prototype.

Figure 6 depicts connections of individual HW components of the thermal display. It is implemented using two, serial connected, 15×15 mm thermoelectric coolers (TEC) that are able to transfer the heat between their respective sides (max. current through each TEC is 2.6A, max. voltage 3.66V). In our case, TECs are powered by electrical currents up to 1.2A at voltage 3.3V (1.65V each), controlled from the Arduino Pro Mini using a H-Bridge drive. The temperature on the active side of the TEC is controlled using a feedback circuit. TEC generates voltage that corresponds to temperature difference on its respective sides. The temperature feedback is implemented using a thermistor and the TEC itself. Temperature on the active side is calculated as a sum of the absolute temperature value measured by the thermistor and relative temperature difference measured using the TEC itself. High accuracy is achieved by using a precise 16-bit A/D controller with integrated stabilized voltage reference.

Evaluation Design
The future experiment is 3×3 within subject design. The independent variables are position on a hand, and the number of steps that can be mapped into certain range. We have defined three positions on a hand: fingertips, head of metacarpal bones, and palm (see Fig. 5), and three different numbers of steps of temperature: 3, 6, and 9. According to the adaptability of the skin [8] we set the period of time where the temperature remains constant to 2s.
The main measures are the speed, calculated as time to identify a temperature step, and the error rate, calculated as a number of incorrectly identified steps. Subjective judgment about the level of comfort, speed and accuracy is collected by means of Likert scale.

Conclusions
We demonstrate a method for augmentation of urban areas with social proximity metaphor. This method can lower the stress level of a blind person while travelling independently in an unknown area. The social proximity is presented by temperature change implemented as a heat map thermal display of the prototype. The method will be evaluated in a future study which will focus on the position of the thermal display and its expressivity.

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References