SPATIAL VIBROTACTILE NAVIGAION FOR THE BLIND

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1. INTRODUCTION

Blindness is a disability that affects millions of people throughout the world. According to the World Health Organization, there are 285 million people who are visually impaired worldwide. Performing normal navigational tasks in the modern world can be a burdensome task for them. We introduce a whole-body wearable, multimodal sensor-actuator field design that can be useful for aiding in blind navigation. In addition, we further develop a method of optimal use of sensor-actuator field navigation to best customize the alternative perception for the blind which, has the promise of being cheaper, easier, and more efficient to develop than those that rely on some form of computer vision or 3D imaging techniques. In short, we would like to optimally use the skin of a user to sense multiple properties of their surroundings, including range, thermal, and material properties of objects in the scene to assist them to better navigate and recognize scenes. One of the goals is to use the skin of a user to sense the environment for traversable path finding, obstacle avoidance, and scene understanding in navigation. The ultimate goal is the replacement of white canes and ETA devices that require the user's hand attention.

2. METHODOLOGY

2.1. Off the shelf components

While many of the commercially-off-the-shelf (COTS) sensors can be used in our test, we have designed a highly cost-effective sensory-actuator package: the IR-range-vibrotactile field system. The range-vibrotactile field system consists of very cheap (~$10 a pair) IR ranger-vibrotactile pairs that are worn on the whole body. A "display" of range information will be transduced via vibration on different parts of the body to allow the user to feel the range perpendicular to the surface of that part. Imagine feeling a whole body "range field" that will cause vibration on part(s) of the body which is near an obstacle; vibration intensifies as the wearer gets closer to the obstacle.

We have developed several prototypes based on this idea: hand sensor-display pairs for reaching tasks, arm and leg sensor sets for obstacle detection, and a foot sensor set for stair detection. Fig. 1 shows an arm sensor.

Fig. 1 Arm sensor

2.2. Modularity

A prototype device includes four types of equipment that are designed to be interchangeable with other equipment of the same type. The first is specially modified clothing with small pockets and straps to facilitate the placement of vibrators, sensors, wires, and electronics. The clothing is close-fitting in order to increase the perceived sensations from the vibrators. The second is the control electronics, which includes a microcontroller along with various transistors and other support electronics to power and control the sensors and vibrators. The third are flexible wires, which are designed to run inside the special pockets of the clothing and along the body to control the sensors and vibrators. The wires, control electronics, and sensors and vibrators are all fitted with connectors which are designed to allow them each to be quickly switched out and replaced if necessary. The fourth type of equipment are the sensor and vibrator "pods" which can be plugged into a wire going back to the central electronics and easily slipped into a pocket in the specially designed clothing.

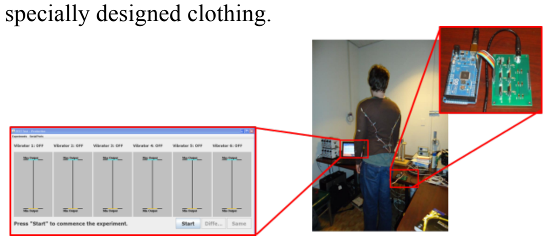

Figure 2. PEST test

3. EXPERIMENTS

3.1. PEST

At the moment we are conducting experiments investigating the sensitivity of the skin to vibrotactile feedback using the PEST algorithm (Fig. 2). The PEST algorithm presents the user with sensations of more and more similar intensity, until the user indicates that they feel the same. The PEST algorithm operates in a manner similar to binary search. On average it took about 20 minutes to test the six locations for each participant.

3.2. Results

The results of the PEST experiments are shown below. We wanted to find the average number of thresholds as well as the intervals between thresholds for vibrotactile sensitivity.

	Left Wrist	Left Elbow	Left Shoulder	Right Shoulder	Right Elbow	Right Wrist
Average Interval Length	77.6	77.6	82.5	94.3	94.3	94.23
Average Number of Thresholds	3.8	3.8	3. 7	3.3	3.3	3.3

4. CONCLUSION

Anyone who closes their eyes and tries to navigate their way around a room can attest to how quickly they begin to feel their way around, reaching out with their hand and arms, as their primary means of determining where they are. By allowing a person to feel their environment without touching it, we allow them to essentially "see" with their body. This paper describes the concept of a full-body wearable range-vibrotactile field approach for achieving this goal. As a first step, the experiments to determine the vibrotactile discrimination thresholds of perception on different parts of the body have moved us closer to creating this novel form of spatial navigation.

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