FingerSight: Vibrotactile Ring for Guidance of Hand-Held Tools by Visually Impaired

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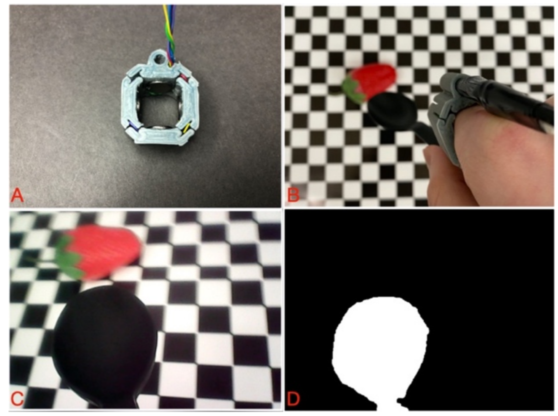
Introduction: Novel technologies are increasingly available to assist visually impaired individuals with querying their surroundings for tasks such as identifying landmarks, reading signage, and wayfinding. The commonplace problem of finding nearby objects remains troublesome, however. Accurate localization and feedback are needed particularly when objects are not suitable for touching with the hand and require tools to handle. "FingerSight" is a wearable device intended to help the visually impaired locate a target within close range and manipulate it. The device combines computer vision analysis and tactile feedback using a small device worn on the finger. Previous research by Satpute, et al., in our laboratory, demonstrated its effectiveness for guiding blindfolded participants to move their hand to reach an LED target in the frontal plane [1]. Here we redesign the hardware and develop guidance of hand-held tools. Preliminary results show the system's promise in real-life scenarios.

Materials and Methods:
The hardware design of our device aims to optimize tactile feedback delivery for guidance, while providing for portability and comfort over a range of finger sizes. It combines a miniature video camera and four vibrators (tactors) embedded into a soft plastic ring, connected to a portable Raspberry Pi computer. The ring has four expandable joints within a single 3D printed unit that reduces cross-transmission of vibratory signals and allow wires to be securely routed (Fig. A). The four cylindrical tactors are attached within the ring to contact the user's index finger, providing guidance in four directions relative to the finger (Fig. B). The software consists of three major components, which all run in real time: (1) *Tool detection*: We assume that the tool is not moving relative to the camera, and compute a running mean of intensity for every pixel. By comparing each pixel in the current frame with this running mean, we can segment the moving part (background) from the stationary part (tool) (Figs. C and D); (2) *Target detection:* We detect targets (for now) using a color filter and estimated size; (3) *Acquisition Guidance*: As the tool's tip approaches the target, we assume four possible outcomes: (a) firmly acquiring the target, (b) going past the target without touching it, (c) bumping the target away in the direction of motion, and (d) touching the side of the target so that it rolls off to one side or the other. By dividing the camera's field of view into four quadrants and taking samples from each, we are able to determine said outcomes and provide corresponding feedback to effect appropriate corrective maneuvers. For example, in the case of (d), the appropriate motion would be to follow the target to the left or right.



A. Ring with 4 tactors and hole for camera. **B.** Device with camera worn on finger. **C.** Video image during operation. **D.** Image with tool segmented.

Results and Discussion: Initial testing was performed by a sighted subject using a blindfold and attempting to scoop up a plastic strawberry with a spoon (Figs. B and C), establishing the functionality of the system as a whole. The subject's hand started at an elevated position from a checkerboard surface and was guided by FingerSight towards the target. Bumping and missing was detected and corrected for appropriately. We compared two forms of feedback: tactile feedback using the four tactors and four simple visual cues on a computer screen at locations corresponding to the four tactors (up, down, left, and right). Initial comparison shows no significant difference in efficacy. Several limitations became evident with the present system. The present tool detection algorithm requires a non-homogeneous background (the checkerboard) and the target detection algorithm is admittedly simple (color).

Conclusion: We have made significant progress towards adding the guidance of hand-held tools to the previous FingerSight paradigm of guidance of manual interaction and navigation for the visually impaired in real-life scenarios. Further experiments with volunteers and visually impaired individuals are needed for validation.

REFERENCES :[1] S. Satpute, J. Canady, R. L. Klatzky and G. Stetten, "FingerSight: A Vibrotactile Wearable Ring for Assistance with Locating and Reaching Objects in Peripersonal Space," in *IEEE Transactions on Haptics*. doi: 10.1109/TOH.2019.2945