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Take My Hand: Automated Hand-Based Spatial Guidance for the Visually Impaired

Paper Study Report

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1 INTRODUCTION

Spacial navigation through hand-based interactions poses a significant challenge for people with visual impairments because the absence of visual cues intensifies the difficulty of even seemingly simple activities, particularly those requiring precise hand navigation, such as selecting icons on a touchscreen or completing fields on printed forms.

Prior work explored the use of two types of feedback to address these challenges:

- **Audio Feedback**, also referenced as auditory feedback, dynamically generates verbal audio instructions to guide or instruct impaired users, being required to strictly follow the given commands.
- **Haptic Feedback** uses advanced vibration patterns to convey information to the user. Unlike audio feedback, it serves as a more discrete communication channel.

The studied paper proposes a novel approach that allows visually impaired users to reach targets on surfaces without having to interpret directional cues, intending to reduce the needed cognitive processing effort.

2 Related Work

Prior research has sought to address the absence of visual information using diverse sensor technologies and alternative sensory modalities.

2.1 Audio Feedback

Previous work in this area has followed approaches like generating verbal audio instructions to navigate or write on printed forms [11], writing English letters or numbers [15], and employing directional clues regarding orientation [5].

2.2 Haptic Feedback

Most of the haptic feedback-based techniques take the form of vibrotactile feedback. Research in this field has demonstrated a wide range of applicability, including navigation [3], reading printed text [4], and the usage of a wristband to provide directional guidance in target finding [6], [8].

2.3 Audio and Haptic Feedback

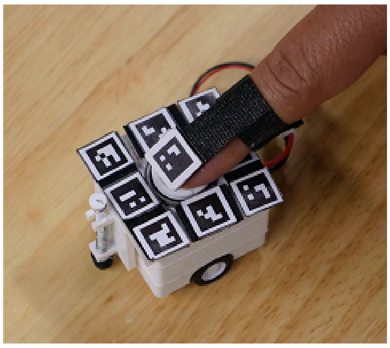
The previous techniques can also complement each other. Several works combined these two types of feedback for applications like navigation [14], guidance while exploring a tactile graph [12], shopping assistance [9], map interaction [10], and three-dimensional target localization [13].

3 Motivation

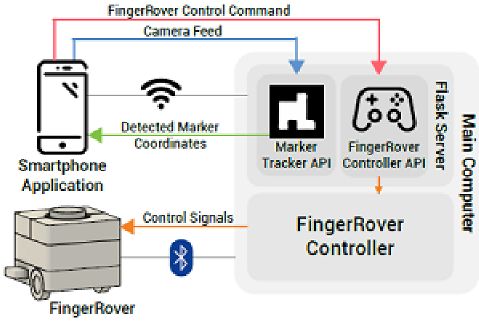
The authors of this paper argue that the previously shown methods can potentially increase the end user's mental load [2] while pointing to disadvantages for each one of these types of feedback.

Audio feedback may have limited applicability in noisy or context-sensitive environments [7]. Haptic feedback is less specific and informative, as it does not directly translate into movement and requires interpretation by the end user, which could lead to desensitization over time [1]. Multiple modalities can cause cognitive overhead to the user [2], leading to the misinterpretation of the cues.

All these points motivated the paper authors to create an innovative solution to mitigate the issues mentioned above.



(a) Marker configuration.



(b) Control system.

Figure 1: FingerRover.

4 Paper Work

4.1 Automated Hand-Based Spatial Guidance

The authors define the concept of Automated Hand-Based Spatial Guidance as actuating the user's hand to move from one point in space to another without the user's interpretation or manual effort.
On a higher level, it can be achieved using three core components: tracking the user's hand, tracking the target location, and actuating the hand to move towards the target location.

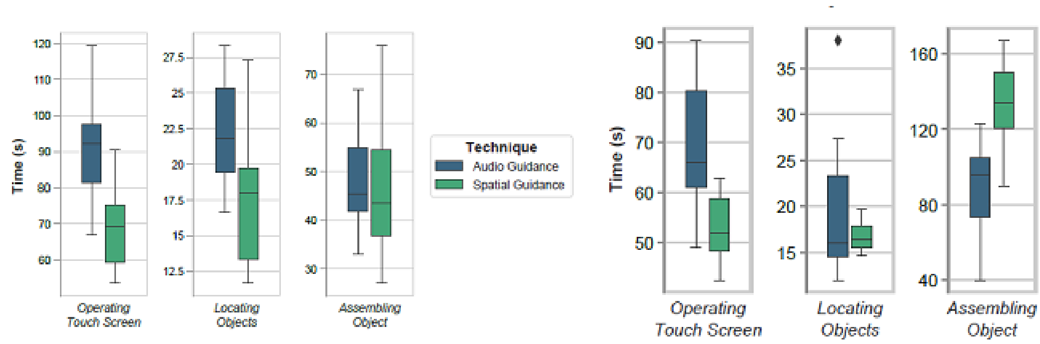
While previous solutions in accessibility have tracked the user's hand and targets, executing the actual motion has been entirely left to the user.

4.2 FingerRover

The authors envisioned designing a portable, unobtrusive, and easy-to-put-on and take-off mechanism that also aims to solve the problems mentioned in section 3. So, they developed *FingerRover*, an on-finger 2-wheeled miniature robot capable of automated hand-based spatial guidance over a plane.
Touch registering is also supported, as a tapper add-on is attached externally to its front.

4.3 Control System

FingerRover uses augmented reality with ArUco markers for tracking in three-dimensional space, visible in Figure 1a, with a smartphone camera. A central server controls the system, connecting to it via Bluetooth and the smartphone via WiFi. The controller minimizes the distance between *FingerRover* and the target point. The control system is illustrated in Figure 1b.



(a) Preliminary phase.

(b) Final phase.

Figure 2: Task completion time.

5 VALIDATION

To validate the developed concept, the authors conducted a study composed of three common accessibility tasks, evaluating its effectiveness for each one: touchscreen operability, object localization, and object assembling.
The authors separated the validation study into three distinct and sequential phases:

- The **Design Phase** occurred during the development period, which allowed the authors to test the prototype parallelly.
- A **Preliminary Phase** composed of twelve participants with normal vision blindfolded while performing the experiments.
- And a **Final Phase**, where seven visually impaired (completely blind) participants were recruited.

The effectiveness was evaluated by querying a survey to the participants and measuring the task completion time.

6 RESULTS

The design phase was skipped regarding results evaluation, as its main purpose was mainly the validation of the system, making sure it was running properly and had no issues.

The preliminary study validated the feasibility of the study design and *FingerRover*'s ability to facilitate automated hand-based spatial guidance, where the median completion time for each task was better than audio guidance, as illustrated in figure 2a. Participants reported *FingerRover* to be more effective and have lower physical and mental fatigue.
Although the results were optimistic, the authors focused on the final phase results.

For the final phase, the authors observed significant task completion time benefits for tasks that require accuracy, like operating a touch screen, which potentially prevents incorrect selections, thereby maintaining a higher overall efficiency. However, due to the *FingerRover*'s low velocity, tasks that do not require as much accuracy or involve more movement, such as assembling an object, are reported to be more time-consuming (2b).

The authors discussed that spatial guidance shows potential utility in interfaces prioritizing input accuracy and situations where correcting errors is costly, such as payment systems. It's crucial to emphasize that they don't propose spatial guidance as a substitute for audio or haptic feedback-based techniques, but introduce spatial guidance as an additional modality to enhance accessibility for the visually impaired.

7 Possible Improvements

7.1 Limitations

Automated hand-based spatial guidance holds great promise, but it is crucial to acknowledge its inherent vulnerabilities and potential risks associated with this technology.

Unlike traditional feedback methods, automated hand-based guidance leaves users with less discretion in deciding whether to follow the guidance, as the system assumes control over the user's hand movements, raising concerns about reliance and trust.

7.2 Future Work

Future research could explore alternative form factors (physical configurations) and actuation techniques, particularly for applications in larger and more diverse environments. This pursuit of innovation holds the potential to refine and expand the scope of automated hand-based spatial guidance, further enhancing the quality of life for those with visual impairments.

8 Conclusion

In this paper, the authors introduced automated hand-based spatial guidance, simplifying navigation for visually impaired individuals. The study with blind and low-vision participants using FingerRover showcased its potential to enhance daily tasks with reduced cognitive effort, suggesting valuable applications where precision is a key factor. The authors also anticipate their findings will inspire future research in advancing assistive technologies for the visually impaired through automated spatial guidance.

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