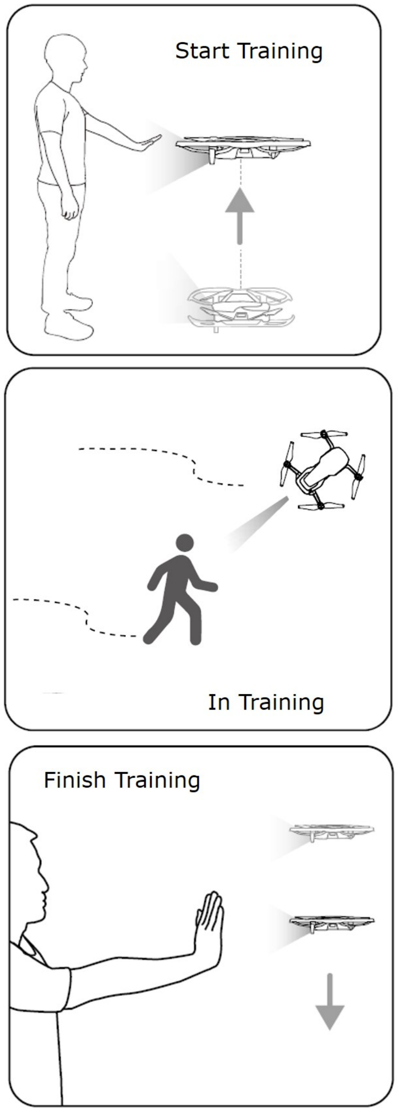

Figure 1: Scenario of HeliCoach System

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HeliCoach: A Drone-based System Supporting Orientation and Mobility Training for the Visually Impaired

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ABSTRACT

Orientation and mobility (O&M) training is essential for improving the independence and wellbeing of the visually impaired. However, the shortage of qualified trainers and the unengaging training

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contents limit the number of O&M training recipients. In this paper, we propose a drone-based intelligent tutor system - HeliCoach - to provide cost-effective and personalized O&M training. We first elaborate on the system design and potential scenarios of HeliCoach use. We then demonstrate the effectiveness of this concept using a preliminary user study. Finally, we discuss the implication and challenges of this system.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility systems and tools**.

KEYWORDS

Orientation and Mobility Training, Visually Impaired, Drone

Figure 2: Conventional O&M training

Figure 3: Drone-based O&M training

INTRODUCTION

Visually Impaired (VI) people need O&M training to gain the skills to travel independently and safely[10]. Orientation represents the ability to recognize and control one's position in relation to one's environment. Mobility is the ability to move through the environment in a orderly, efficiently and safe manner[7]. VI people are expected to manage various risks associated with everyday life, especially those from uncontrolled environments[4] through O&M training. Therefore, they need to enhance their mobility skills by using their residual vision, other senses such as touch and hearing[5], and assistive devices such as long canes[10]. Despite the widespread acceptance of O&M training and belief in its value[6], only about 40 percent of VI people receive O&M training due to the shortage of qualified trainers [8]. Moreover, the training should be personalized for consider the living environment and learning style of the VI person, encourage home practice, and provide mental support [11]. Therefore, a cost-effective and personalized training program is needed.

[1–3] showed positive impacts of a drone's stereo sounds on navigation tasks for VI users. Moreover, the camera and other sensors on the drone offer opportunities to recognize the user's status and environment, and generate adaptive changes such as real-time training feedback. On the other hand, with the development of artificial intelligence, more intelligent tutoring systems that aim to provide personalized and unmanned tutoring are being developed[9].

Here, we proposed a drone-based system - HeliCoach - to provide unmanned and personalized O&M training for VI users. At first, a semi-structured interview with VI users was conducted to explore their status-quo and expectations of traveling and O&M training. Then we elaborated the system design of HeliCoach including its implementation and training scenarios. The following is a proof of concept through a Wizard-of-OZ-style experiment.

The main contributions are three-fold: 1) designing an innovative drone-based system - HeliCoach - to provide personalized and cost-effective O&M training based on literature review and semi-structured interview; 2) achieving a proof-of-concept through a user study about one typical O&M training task; 3) discussing the feasibility, implication and challenges in utilizing drones and intelligent tutoring systems to provide O&M training for VI users.

SYSTEM DESIGN

Interview Survey

Before designing our drone-based intelligent O&M training system, we organized several interviews in China to investigate the current travel and O&M training status of VI people, and their acceptance of intelligent machines (especially drones) supporting travel and O&M training.

Five VI participants (male undergraduate students of age 18 to 22, of whom three had low vision and two were blind) participated in semi-structured interviews. Each interview session lasted about 60 minutes and participants were given $15 as compensation for their participation.

The interviews began with general questions about how they travel independently, and what they have learned from O&M training (if they have taken any). We asked them about what difficulties they have encountered in their independent travel experience and what the shortcomings of traditional O&M training are. We also asked for their thoughts on intelligent devices/robots supporting travel. In particular, a recording of a drone flight was prepared and they were asked to listen and express their opinions about drone-based O&M training.

All interviews have live text recordings and full video recordings using GoPro cameras. After thematic analysis, we have the following findings listed in the sidebar.

Through the interviews, we found that the drone-based orientation and mobility training intelligent system can provide cost-effective, personalized, and dependable O&M training and travel assistance. These features are urgently needed by VI people, and are unfortunately not available economically in the conventional O&M training methods.

Findings from Interview Survey:

- People with varying degrees of visual impairment have different travel barriers. For example, individuals with congenital blindness have difficulty to understand complex road information while those with low vision and one eye blindness have difficulty to walk straight. All of them should receive more professional O&M training, especially VI people without residual vision.
- Traditional O&M training requires professional teachers and high training costs. As a result, only a portion of blind youths (those that have not yet entered junior high school) are undergoing formal O&M training.
- The visually impaired desire to live and travel independently. In addition, their acceptance of smart devices and intelligent robots is very high, and two interviewees even mentioned expecting the psychological companionship of intelligent robots. What's more, all participants expressed acceptance of the drone training tutor after listening to its audio.

HeliCoach Concepts

As shown in Figure 4, our drone-based O&M intelligent tutoring system mainly consists of four parts: a drone, a cloud server, a smart phone-based remote control panel and a bone conduction earphone. What's more, optional devices from VI people's families or teachers can get the training reports and assist training remotely. The drone can collect a large amount of image information of the environment and the user, while the sound and wind of its rotors can guide the user directly. Real-time user tracking and obstacle detection can be edge calculated by the drone or the smart phone. The cloud server can run a large number of complex, non-real-time algorithms, such as the initial training environment reconstruction. The users can use both gestures and voice commands to adjust training.

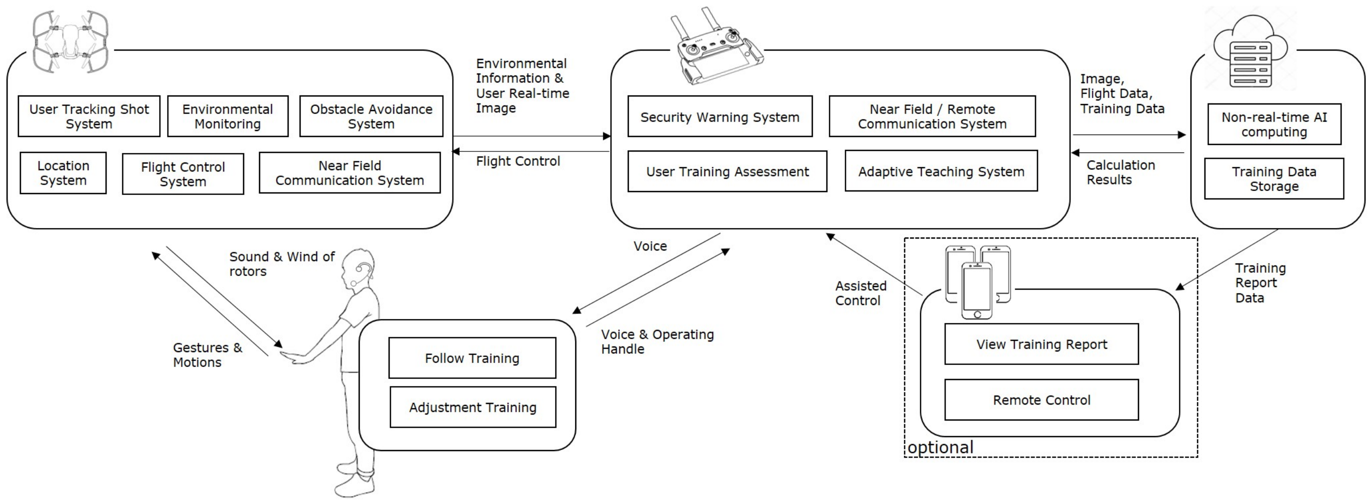

Figure 4: Drone-based orientation and mobility intelligent tutoring system architecture

Table 1: Instruments for User Evaluation

Instrument	Model
Drone	DJI Mavic Air (Onyx Black)
Mobile phone	Honor Play COR-AL10
Camcorders	Canon Legria HF R86
Rangefinders	Pro'sKit NT-8580

EVALUATION

This section, we achieved our proof of concept through a preliminary user study. We used the HeliCoach to train participants' abilities to orient themselves (i.e. audio localization), judge distances (i.e. to determine how far a sound is) and walk straight (i.e. to avoid veering when walking alone). Participants were required to take a test before, during and after training to quantify their concerned ability (Figure 5). Table 1 lists the instruments used in this evaluation.

Participants

Five individuals with healthy vision and auditory abilities (three males and two females of age 28 to 33, without prior drone experience participated in the user study. During the entire experiment, the participants were blindfolded to simulate the case of patients who just lost their sights. The experiment lasted about 30 minutes per participant, and $15 was given as renumeration.

Performance Test

Three trials were required in each test session. At the beginning of a test, the participant was led by the experimenter to stand at the startpoint of a 10-meter track, facing directly to the targeted

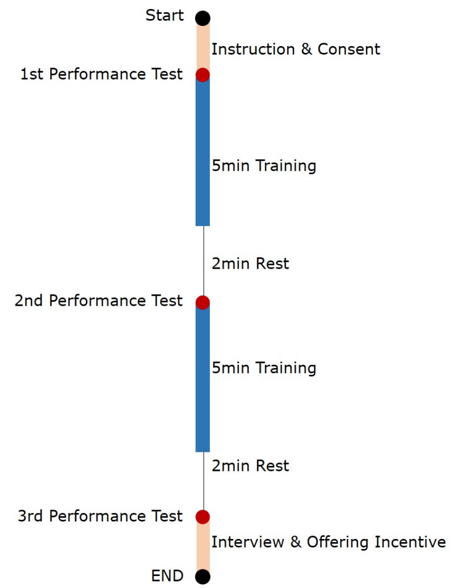

Figure 5: Evaluation procedure

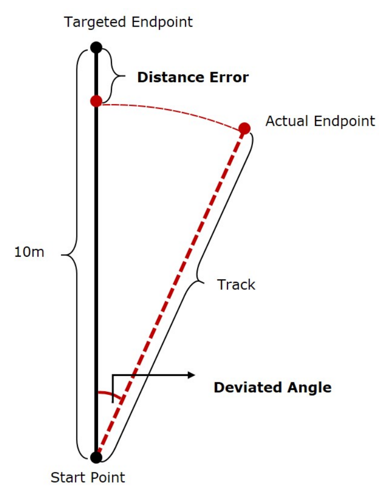

Figure 6: Deviated angle and distance error in O&M test

endpoint of the track. An audio was played by a mobile phone (Table 1) at the endpoint at the same height as the participant's ears. After that, the participant was required to walk to the endpoint as accurately as possible without any help (Figure 2). Distance error (i.e. the absolute difference between 10-meter and participant's actual displacement) was measured, as well as the deviated angle (Figure 6). Then, the participant returned to the startpoint to begin a new trial, no feedback was given during the entire user study.

Training

Training was performed in a Wizard-of-Oz style, in that the HeliCoach was controlled by the experimenter (Figure 3). As the training began, HeliCoach was put on the ground and initiated by the Wizard of Oz. It would fly to a randomly selected position (varying in distances, angles, and heights) and then went repeatedly up and down. The motor sound when flying up and down indicated that the participant should begin to walk to the position directly below the HeliCoach. When the participant stopped and was within acceptable range according to the motor sound and wind generated by the drone, HeliCoach would consider it a success and fly to another random position, repeating the above-mentioned process. Participants were instructed to pay attention to their judgment of drone localization, distance, and walking straight to the drone during training.

Results

By comparing participants' performance in all three performance tests, we can investigate whether our training is effective. To be noted, the tasks and sound sources of tests were different from training in order to minimize the practice effect.

Figure 7 shows the performance results on deviated angle and distance error respectively. A one-way repeated-measure ANOVA was conducted to compare the performance of deviated angle and distance error before, during and after training. There was a significant training effect on deviated angle, $F(2, 8) = 6.588$, $p = .020$, with a smaller effect on distance error, $F(2, 8) = .036$, $p = .965$. Three paired samples t-tests were used to make post-hoc comparisons on deviated angle between conditions. The results indicated that there was a significant difference between before ($M = 6.53$, $SD = 3.057$) and after ($M = 6.47$, $SD = 3.412$) training; $t(4) = -5.742$, $p = .014$, Bonferroni corrected. No significant difference was found for the other two pairs.

DISCUSSION

We demonstrated that training by a drone is effective and practical in our study. In experiment, we trained blindfolded participants with HeliCoach for walking straight and distance judgment. Astonishingly, with only two five-minute training sessions, participants' performance on walking straight improved remarkably. and further study will be conducted to compare the training efficiency

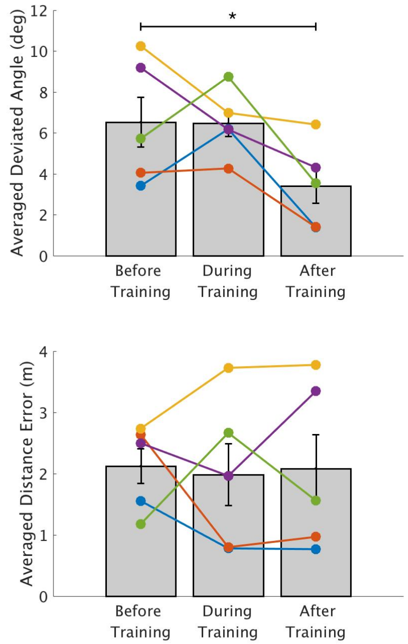

Figure 7: Results of averaged deviated angle and distance error

of HeliCoach and the O&M instructors. Furthermore, our tests and training tasks were cross-modal, i.e., the drone's sound during training was quite different from the sound we used in performance tests. This means that users transferred their improvements in walking straight while following the drone to their abilities to avoid veering. Performance on distance judgment, however, did not improve. To further this study, longer training times or training task redesign might be required.

Our preliminary user evaluation demonstrated the possibility to develop a more effective O&M training system with a drone. More importantly, the drone provides rich resources such as HD video recording and real-time control to develop more intelligent system to offer VI people automatic and personalized training.

Future work includes 1) design a more adaptive training system to promote learning effect, especially to VI users without residual vision who need it more urgently; 2)develop a high-fidelity prototype to realize a true intelligent tutor system; 3) conduct a longitudinal study with end-users to get systematic evaluation.

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