Director: A Remote Guidance Mechanism

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Abstract
When using a mobile device as a navigation aid, we are used to receiving computer-generated routes and directions. Remote guidance, however, remains an underexplored design space in mobile interaction design. In this paper, we introduce *Director*, a novel, remote guidance mechanism for the positioning of people in outdoor spaces using mobile devices. We conducted a study to test our novel positioning technique, testing its guiding accuracy and effect on Preferred Walking Speed (PWS). Our results suggest that *Director* offers users a fun and playful experience, and that our novel guidance technique is a very accurate remote mechanism.

Author Keywords
Navigation; remote guidance; multimodal; heads-up

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Introduction
A large percentage of the global population own a mobile phone [8], many of which are smartphones. We are becoming increasingly reliant on these devices to guide us, aiding us in navigation whether in a vehicle or on foot. The portability of smartphones make them highly suitable

for navigation purposes. More often than not, the kind of navigation that occurs on a mobile device entails following a computer generated, predetermined route, down a particular path. However, there has been less research regarding remote guidance with mobile devices, where instructions and directions are exchanged between users on a live feed.

In this paper we introduce *Director*, a remote gesturing guidance mechanism to position people in space. For such an application to remain usable, the direction mechanism must be simple, effective and robust for both the controlling user and the guided. We based our design on heads-up interaction techniques that allow users to send and receive egocentric directions. A user can send simple directional instructions to another connected user through carrying out tilting gestures. Users receive these instructions as a simple arrow on their device that points them in the direction to walk in. Throughout the paper, we refer to the users who receive instructions as hotspots. Directions can be sent from any distance, though a direct line of sight is required to understand the location of the person being directed.

To test our remote guidance technique, we ran a controlled study, measuring both the guiding accuracy and effect on user's PWS. We conclude this paper by discussing potential uses for portable hotspots, arguing that remote guidance introduces new kinds of opportunities to both users and designers.

Related Work

Navigation and guidance with mobile devices is an area that has been explored thoroughly. Kenteris et al. carried out a detailed survey of electronic mobile guides [4], in which they identified four main types of guide.

Considering these guide types, we see *Director* as a mobile navigational assistant. Although many of the guides mentioned in [4] are now outdated, there is a recurring theme. These applications are mainly screen-based map visualisations. Maps provide a good representation of an area from a geocentric perspective, though they do not always provide a good representation of what a user observes from an egocentric perspective [2].

There have been numerous attempts at multimodal navigation using feedback aimed at the user's perspective on the ground, e.g. [5, 6, 2]. *Audio Bubbles* [5] was an attempt at audio navigation that uses simple non-speech sounds to signify proximity to a point of interest. The work builds on earlier audio navigation research [7], though removes the need for stereo headphones, by instead using a one-dimensional Geiger Counter metaphor. A different method of eyes-free navigation from the users perspective is discussed by Robinson et al. [6], this time using the haptic modality. Vibrations were used when a user pointed in the correct direction to move. However, for navigation over a small area, arrows have also been found to be a simple, unambiguous, egocentric instruction which are easy to interpret [2]. Arrows have been used in museum navigation before [9], though projected from a handheld pico projector. A similar approach was used to that mentioned by Chittaro et al. [2], where a photograph of a landmark was overlaid with an arrow.

Some researchers have experimented with remote guidance involving humans controllers before [1], though mainly to aid visually impaired people. In this case, the controlling user sat at a computer, viewing the scene through a camera and sending verbal instructions to the impaired person via a GSM voice call.

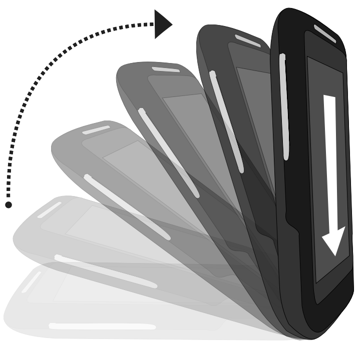


Figure 1: Tilting towards - sending an instruction to walk towards the controlling user. The controlling user can tilt their device backwards or forwards to make a hotspot walk towards or away, and left or right to turn left or right (not shown).

Prototype

Director is a mobile application that runs on the Android platform. To guide a hotspot, the controlling user must carry out tilting gestures (see Fig. 1). We used the tilt gesture specifically as it is a subtle gesture, and we believe its egocentric nature provides a strong correlation between the direction the device tilts and the direction the hotspot should move in. Hotspots receive directions as an arrow on screen (see Fig. 2).

The tilt gesture instructions work by first calculating the bearing from the controlling device to the hotspot device, for example 86°, and then adding 0°, 90°, 180° or 270° depending on whether the instruction is away, right, toward or left (see Fig. 2). Then, after taking the hotspot device orientation into consideration using the digital embedded compass, it displays an arrow pointing towards the resulting direction.

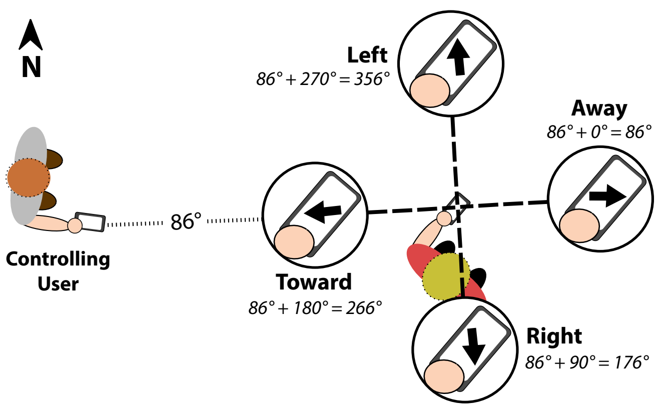


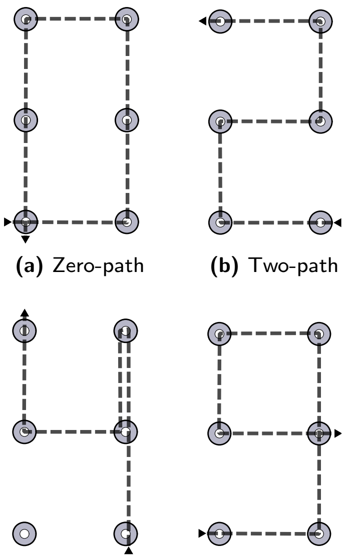
Figure 2: Tilt gesture directions the hotspot receives are based on the bearing between the controlling and hotspot devices. All instructions are egocentric.

Study

As our tilt gesture guidance mechanism with arrows was a novel, untested concept, we conducted a study focusing on determining the value of the approach.

There have been numerous cases where researchers have measured the capabilities of mobile guiding technologies when walking. Goodman et al. [3] give a number of important pointers on using field experiments to evaluate mobile guides, one of which is *"the extent to which the use of a device disrupts normal walking."* This can be measured in percentage preferred walking speed (PPWS), taking into account first the participant's preferred walking speed. Bearing this in mind, we developed a collection of tasks that would allow us to determine the PPWS of hotspot users and the accuracy to which they could be controlled.

To determine user's PPWS, we first had to capture users normal Preferred Walking Speed (PWS), as well as their walking speed when using the system. To determine a user's PWS, we arranged a set of sports cones in a 4x5 grid formation, 4 metres apart from each other and defined a path through them with a blue ribbon. The study was conducted on a flat field and the distances between each of the cones was accurately measured between each study session. As the path traversed 6 sides inside the grid, the ribbon path was 24m long. Each participant was asked to walk along the blue ribbon from start to finish at their normal walking speed. The second part of this task involved introducing the guidance mechanism to participants. Participants were briefed on the system's workings and were asked to assume the starting position on the grid. Participants were asked to begin the task as soon as they received the first instruction. The second path was a mirror image of the



(a) Zero-path **(b)** Two-path **(c)** Four-path **(d)** Nine-path

Figure 3: The four 7-segment numbers used as paths. An extra layer of cones around the edges allows errors to occur.

first, ensuring that the path complexity remained the same, but without any learning effects.

The third and final task was an attempt to understand how accurately participants could be directed around complex paths in a small area. For paths, we used the sides of 4 different numbers from a 7-segment display (see Fig. 3). In this task, we measured deviations in two different ways. When participants deviated less than a cone away from the correct path, but then righted themselves by rejoining the correct path, we recorded a 'self-correction'. When participants walked to the wrong cone, we recorded an 'error'. In the instance that participants made an error, they were redirected back to the last correct cone on the path, and continued.

In an attempt to keep the level of guidance skill fair throughout all participants, the same expert user was used as the controlling user in all tasks. This user was an investigator. For each of the sessions, the controlling expert user stood around 30m away from the grid (see Fig. 4), increasing the distance between both devices in an attempt to compensate for GPS inaccuracies.

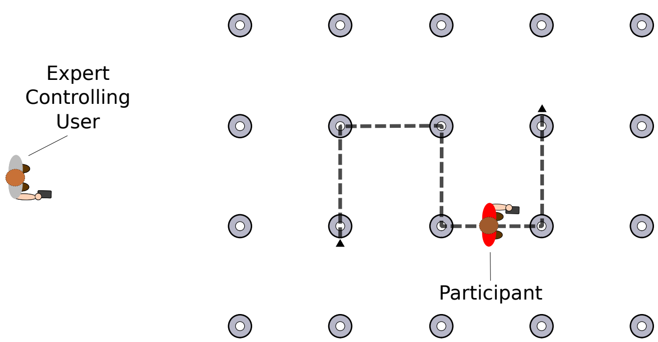


Figure 4: Expert Controlling User guiding a participant around the two-path. The numbers 0, 4 and 9 were also used as paths.

When participants finished the tasks they received a questionnaire, followed by an interview to discuss the overall experience. All tasks in this study were video recorded for later in-depth analysis of timings, errors and general user behaviour.

In total, we recruited 20 participants (10M; 10F) with an average age of 21 (Min: 18; Max: 26). All participants were University students from a large range of subject areas. Each study session lasted around 30 minutes, and participants were given a £5 voucher for taking part.

Results

The results have been divided into three subsections: the effect on walking speed, guiding accuracy and feedback.

Percentage Preferred Walking Speed (PPWS)

When timing participants' walk along the 24m blue ribbon path, the average time taken was 18.86s (Min: 14.2s; Max: 24.5s). Using a simple $speed = \frac{distance}{time}$ calculation, the average PWS for participants was 1.3m/s (Min: 0.98m/s; Max: 1.69m/s).

When timing participants' walk along the 24m path delivered as instructions through *Director*, the average time taken was 24.32s (Min: 18.2s; Max: 31.3s). Participants' average walking speed when using *Director* was calculated as 1m/s (Min: 0.77m/s; Max: 1.31m/s). When using the *Director* system, the average participant's PPWS was calculated as 78.35% (Min: 59.1%; Max: 92.68%). Comparing each participant's results, their walking speed when using *Director* was significantly lower than their PWS ($p < 0.0001$; paired t-test).

Of the six instructions given, on average, each participant paused around two to three times. Here, participants were either waiting for the next instruction, or confirming it before beginning to walk again. If we take these pauses into account, focusing only on the time that participants were walking, the average time it took for participants to complete the path with *Director* was 21.26s (Min: 17.3; Max: 29s). With these new times, participants' average walking speed was 1.15m/s (Min: 0.83m/s; Max: 1.39m/s). This means that if we only consider the time that participants spent moving, the average PPWS for participants was 89.16% (Min: 71.36%; Max: 111.22%). These individual results were also significantly lower than participant's PWS ($p < 0.0001$; paired t-test). The results are summarised in Table 1.

	Time (s)	Average Speed (m/s)	PPWS (%)
Ribbon	18.86	1.3	100
Director	24.32	1.0	78.35 (SD 9.58)
-without pauses	21.26	1.15	89.16 (SD 9.15)

Table 1: Results of the PPWS task.

Accuracy of Approach
Of the four 7-segment number paths used, every participant managed to complete the number zero-path and two-path with no errors. For the number zero-path, we did observe one deviation, though it was self-corrected. This meant that after 120 instructions, 1 (0.83%) had been mis-interpreted at first, but the participant corrected their direction after walking a step or two. We observed a similar self-correction rate with all paths, with 2% of instructions on the two-path being self-corrected, 3.33% on the nine-path and 4% on the four-path.

The only deviations that were not self-corrected–which caused errors–occurred on the four-path and nine-path. When following these paths, we witnessed 2 errors out of 100 instructions (2%) and 3 errors out of 120 instructions (2.5%) respectively. In each of these instances, participants left the correct path. From our results, considering all instructions, there were 16 deviations in total (3.64%). Of these deviations, 68.75% were self-corrected and 31.25% became errors. These results are summarised in Table 2.

	No. of Instructions	Deviations	
		Self-corrections	Errors
Zero-path	120	1 (0.83%)	0
Two-path	100	2 (2%)	0
Four-path	100	4 (4%)	2 (2%)
Nine-path	120	4 (3.33%)	3 (2.5%)

Table 2: Total instructions and deviations over all participants.

Feedback
Participants were very keen on the idea of remote guidance, with one claiming that it was *"comforting that another person was directing you."* All participants believed the system was effective in achieving simple navigation, though some questioned its ability in the real world, where instructions are *"not just left or right."*

Discussion
When looking at the effect of the system on PWS, it is apparent that there is a large effect (1.61; Cohen's d). However, there were times during the task where participants remained stationary at a cone. This was attributed to either waiting for the next instruction to arrive—sometimes due to connectivity lag—or pausing to confirm before they committed to the next instruction. Though we cannot omit lag entirely, we can speculate user's PPWS if instructions were received and followed simultaneously. If we negate the time where participants

were stationary during the task, on average, PPWS was nearly 90%. We believe this disruption to users PWS, even with the pauses (78.35%), is an acceptable figure.

The results of the accuracy task show a very low number of deviations, most of which were self-corrected by the participants themselves. After studying the errors in detail, it appears that every error occurred by participants continuing to walk in the same direction as the last instruction. We believe this was also due to lag, with participants still following the previous direction. Although the error rate was low, we believe that again, if the intermittent lag did not exist, we would be able to achieve an error rate much closer to zero.

Conclusions & Future Work

In this paper, we have demonstrated and evaluated *Director*, a remote guidance mechanism. Although we saw a detrimental effect on user's PWS, the guiding approach proved to be highly accurate, presenting few issues.

We envision many different uses for a remote guidance mechanism such as *Director*. First and foremost, it could be used by knowledgeable people to remotely guide groups around a large outdoor area, such as a heritage site. The direction mechanism could also be used for life-size games, such as positioning people in a game of chess. Or perhaps an even more extravagant example would involve attaching speakers and projectors to multiple hotspot users' devices, allowing the controlling user to trigger and orchestrate public performances.

We encourage other researchers to engage with this underexplored design space, where there are potentially many new and exciting experiences to uncover.

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