Show me the direction – how accurate does it have to be?

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ABSTRACT
One factor which can be expected to influence performance in applications where the user is expected to point a device in some direction to obtain information is the angle interval in which the user gets feedback. The present study was performed in order to get a better understanding of the influence of this angle interval on navigation performance. Results indicate that users are able to handle quite a wide range of angle intervals, although very narrow and very wide are less suitable.

Categories and Subject Descriptors
H5.2: Auditory (non-speech) feedback, H5.2:Haptic I/O, H5.2: Prototyping, H.5.1: Artificial, augmented and virtual realities.

General Terms
Design, Human Factors.

Keywords
Gesture, audio, navigation, pointing, angle, non-visual.

1. INTRODUCTION
The introduction of compasses in more and more hand held devices has opened the way for applications making use of pointing gestures to provide information about objects or locations in the real world. A device with a location-aware and direction-aware application (based on e.g. GPS and an electronic compass) can display geo-tagged information to the user when the user points in the direction of a point of interest. So far the bulk of work focuses on adding visual information on the screen of the mobile device (cf. http://layar.com)., although there is recent research showing how to make use of the non-visual channels. The roaring navigator [1], ONTRACK [2], AudioBubbles [3], SoundCrumbs [4], Sweep-Shake [5], and SocialGravity [6] are all examples of applications displaying geo-tagged information with audio-haptic feedback.

In addition GPS and compass[1] information can be used for navigation. The GPS device knows your position and together with the compass it is also possible to provide a pedestrian user with information about which direction he or she should go.

As was illustrated by the SoundCrumbs [4] application pointing the device in different directions and getting non-visual feedback when on target, is a way of both providing information about a target as well as giving information about in which direction the user should be walking.

One basic question for this type of interaction is the angle interval in which the user gets feedback. In [7] we report the results of an outdoor study. The present paper compares the results of this outdoor study with a computer simulation.

2. SIMULATION
The investigated interaction is illustrated in Figure 1. The application has a database of GPS locations and the user is guided towards the next location in the sequence by audio or vibratory feedback. Each GPS point is surrounded by a circle. As soon as the user is inside this circle the point is considered to be reached, and the user is guided towards the next point in the sequence.

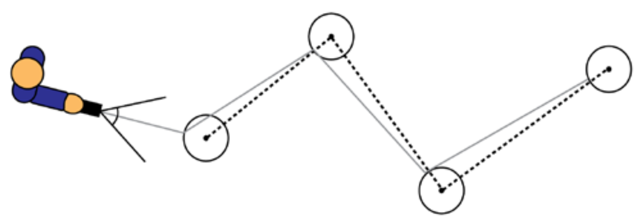

Figure 1. The interaction principle.

In Figure 1 the track of GPS points is shown together with the circles around each point. The grey line indicates the path a user would follow if he or she walked in the direction pointing directly towards the points. The angle interval around this direction which will also generate positive feedback is indicated in front of the device.

[1] The GPS compass used in car applications relies on the movement of the device, while pedestrians have a tendency to stop when they are unsure where they should go or when they are looking around to see what sights are available. A magnetic compass on the other hand (such as can currently be found in many smart phones) works also when kept stationary.

Inspired by [6] we decided to implement a simple computer simulation to gain a better understanding of the interaction. We had seen in [7] that two basic user strategies existed: 1) those who tried to find the center of the angle interval and 2) those who started walking as soon as they had a good signal. To get an overall simulation we simulated navigation towards a single point assuming the user will chose a random direction within the interval that produces positive feedback. To get a simulation of the kind of behavior resulting from walking as soon as you have a signal we also looked at the worst case scenario where the user walks in the least advantageous direction possible.

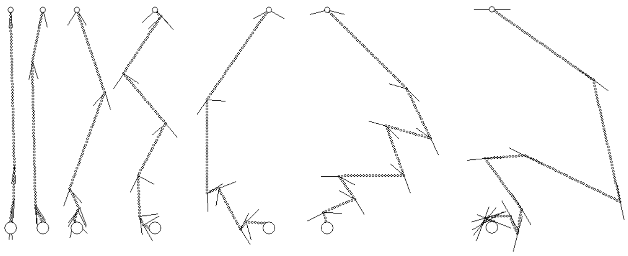

Figure 2. A selection of random tracks for the angles 10º, 30º, 60º, 90º, 120º, 150º and 180º (left to right).

For the overall simulation we assumed a user walking in a random direction within the angle interval, changing direction only when the feedback stops. Although some users adjusted their direction while walking (by scanning during walking [7]), they did not in general change direction until the feedback indicated this was necessary.

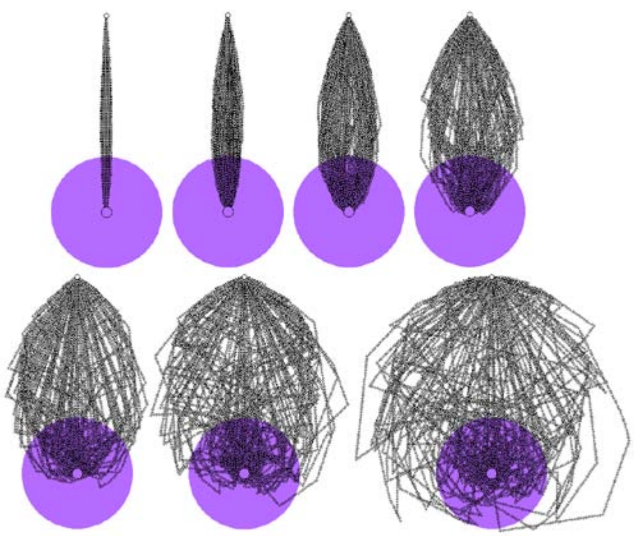

Figure 3. Simulation results for the angles 10º, 30º, 60º and 90º in the top row and 120º, 150º and 180º in the bottom row (increasing angles to the right). The large transparent area indicates the goal area in the 10m radius condition.

Figure 3 shows trails for 10º, 30º, 60º, 90º, 120º, 150º and 180º (these were the angles used in [7]). Although the goal was surrounded by a circle, the feedback was generated from the central point in the circle (corresponding to a GPS point in real life). Thus, also the smallest angles led to corrections, even though these might not be needed to actually take the user into the goal area. This way it may actually be advantageous for larger goal areas to have a slightly wider angle interval since the possibility of being able to get to the target without having to make corrections can be larger.

The simulation was run 100 times in each condition. The proportions were selected to correspond to a distance between start and goal of 35 m with a step size of 0.5 m. To see the effect of the size of the goal circle we looked at goal radii of 1m and 10m. The result of the simulations can be seen in Figure 3.

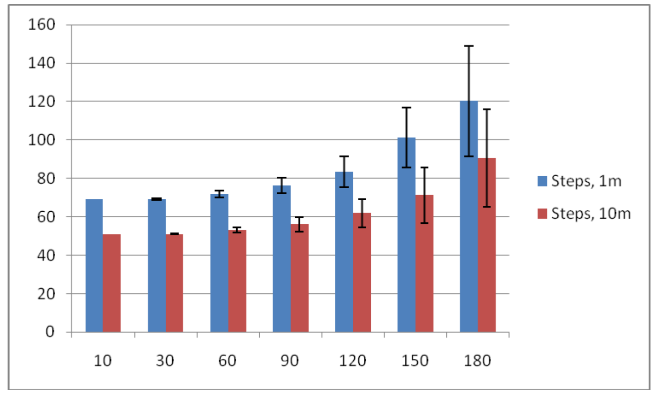

Figure 4. The number of steps for different angles in the 1m and 10m conditions (error bars indicate the standard deviation).

The average number of steps it took to reach the goal can be seen in Figure 4, and the average number of turns is found in Figure 5.

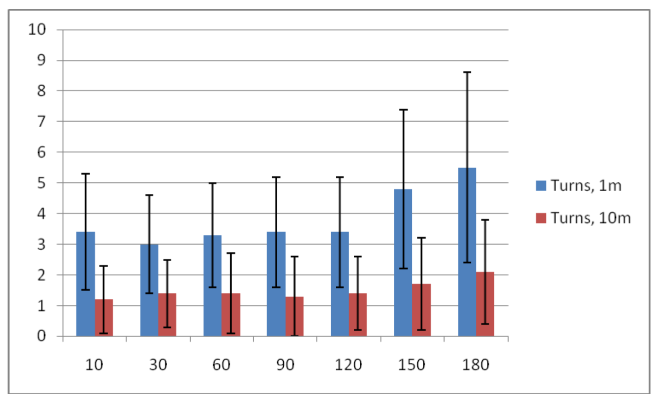

Figure 5. The number of turns for different angles in the 1m and 10m conditions (error bars indicate the standard deviation).

As was expected the increase in goal circle size is comparatively more beneficial for the wider angles. We also see that there is little difference between the angles 10º, 30º and 60º. A small increase is seen for 90º and 120º, while 150º and 180º appear less suitable to use.

For the worst case scenario it is clear that if the angle interval is 180º and above the user will never reach the goal. At 180º the user will walk in a circle around the target and larger angles will produce an outwards spiral. Smaller angles will result in an inwards spiral ending at the target as is shown in Figure 6.

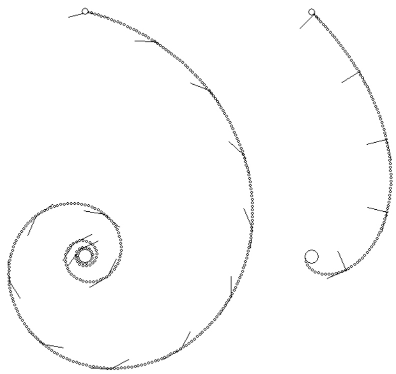

Figure 6. Worst case trails for 150º and 90º. The angle interval is indicated at regular intervals.

In the simulation we have used a finite step size, assuming that users do not adjust their direction "in stride" but only after a step. With this assumption the step size influences the trails – since we look at a worst case scenario the signal will be lost immediately and thus the simulated user actually takes the step outside the feedback angle. In the 180º case this results in a trail that is not a perfect circle, but rather a trail spiraling slowly outwards. For the 150º case in the picture the effect is that instead of spiraling in to the exact center, the trail will end in a small circle. Thus, for a wider angle, a large step size and a small goal area can result in a trail that circles the goal without ever reaching it.

The increase in the number of steps in the worst case scenario for a 1 m and 10 m goal circle is shown in Figure 7.

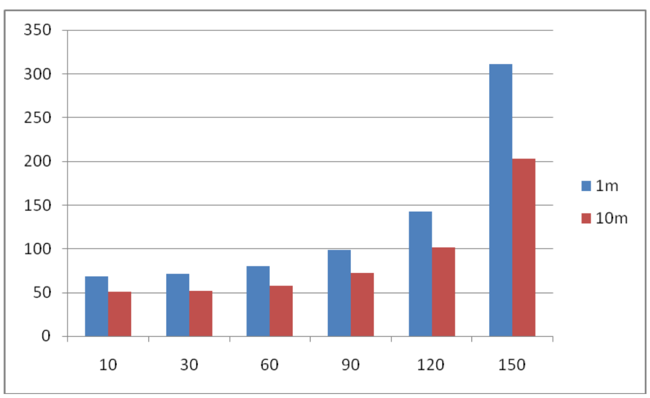

Figure 7. Number of steps to reach the goal with a fixed angle deviation in the 1m and 10m conditions.

Even though the underlying strategy is quite different we see the same type of results for the more narrow angles: 10º, 30º and 60º produce similar results. The problem with the wider angles is more pronounced than before, although it can to some extent be mitigated by using a wider goal circle. It should be noted that the above described results apply to any navigation where the user keeps a fixed angle deviation with respect to the direction pointing straight at the target.

If we compare these results to the time to complete in the outdoor study in [7] given in figure 8, we see that for most angles except the smallest the simulated results are in agreement with the test results. In reality we expect heading fluctuations to impact heavily on the narrowest angles, resulting in longer completion times.

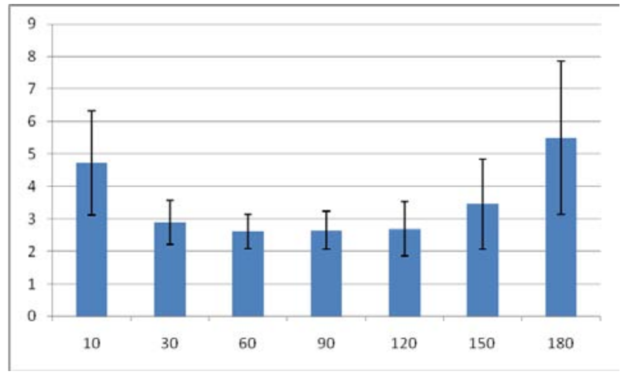

Figure 7. Time to complete for the different angles in the outdoor study. Error bars indicate the standard deviation.

It is also interesting to look at the trails generated by the participants in the outdoor test (although that test did not use a single goal to target track, but a track where two 90º turns should be made). These are shown in Figures 8a,b and c. The test tracks were generated from an underlying grid of 8 points which are indicated in the figure by red markers.

Figure 8a. Trails for 10 º (left), 30 º (center) and 60 º (right)

Figure 8b. Trails for 90 º (left), 120 º (center) and 150 º (right)

Figure 8c. Trails for 180 º

Just as in figure 3 the trails start to diverge more noticeably for the wider angles and at 180º we see the expected spaghetti like pattern. Although it is hard to see in the pictures, some users walked in curved trails and sometimes even in circles around the goal, indicating that they follow more of a "fixed angle" strategy. Observations indicated two different such strategies: 1) walk as soon as you have a signal (the worst case simulation was originally inspired by this behavior) 2) try to scan for the middle of the interval. There were of course more details to the strategies and gestures of the users, but on the overall level it appears as if the random simulation captures the picture quite well.

3. DISCUSSION

Both the computer simulations and the outdoor tests indicate that navigation performance should be fairly insensitive to the angle interval used. For small angles observations during the test lead us to believe GPS/compass fluctuations to influence the results heavily, while at the other end of the spectrum the very wide angle interval will cause many deviations and on the average leads the user to walk much longer than necessary that is problematic. This was confirmed by the simulation results.

Although the effect of heading fluctuations and GPS inaccuracies should be investigated in more detail, the presented simulated results together with the outdoor test performed gives a much stronger foundation for providing recommendations on suitable angle intervals:

- If it is important to get exact track following one should go for more narrow angles. This depends to some extent on the equipment at hand but we would recommend 30º to 60º.
- If you want a design that puts small cognitive load on the user it is better to use wider angles. We recommend 60º to 90º (or even 120º) for this purpose.
- In general people walk slower if the angle is too narrow. If you are targeting applications where the user wants to walk quickly or maybe even run (e.g. jogging applications) wider angles are preferable.

In this study we have looked at sound on or off as feedback since adding different sectors in the angle interval would introduce more factors that might influence the results and we wanted to focus on the basic influence the width of the interval. This does not mean that it is not a good idea to vary the feedback to give the user the advantage of having both a more precise direction combined with the advantages a wider angle provides. One example of such a design can be found in [4] where a central interval of 30º with 100% volume was followed by an interval out to 90º where the volume was 40%. Outside this the sound played at 20% level all the way up to 180º.

4. CONCLUSION

Both in the simulations and in real life we find that users are able to handle quite a wide range of angle intervals. The only intervals generating significantly slower completion times in the outdoor test were the 10º and 180º angle intervals. In the simulation we see that 10º to 90º (or even 120º) appear suitable for this type of interaction. Narrow intervals provide more exact track following but may be slower and require more attention/concentration from the user. Wide angle intervals result in less exact track following, but allow users to walk faster and be more relaxed. If exact track following is important we would recommend an interval of 30º to 60 º while we recommend an interval of 60º to 90º (or even 120º) if low cognitive load is important. The 60º used in [6] agrees with these findings. The task dependence of our recommendations indicates that angle interval is a variable which should be possible to customize.

One factor which may influence results is the size of the circles surrounding the goal point. The simulations were run for both small and large circles, and just by looking at these results it is clear that the larger circles make things easier for the user. Circle size is also influenced by the GPS precision. With a design like ours where you lead the user along a series of points, it is important that the user is able to actually get to the point. Using too small points may make this impossible since GPS inaccuracies might place a smaller circle entirely inside some area/object that is inaccessible for the user. Thus, also from this perspective small circles around the goal are in general less suitable and should be used with care (if at all).

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