Angle sizes for pointing gestures

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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, gestures and strategies in a more realistic outdoor setting. Results indicate that users are able to handle quite a wide range of angle intervals, although there are differences between narrow and wide intervals. We observe different gestures and strategies used by the users and provide some recommendations on suitable angle intervals. Finally, our observations support the notion that using this type of pointing gesture for navigation is intuitive and easy to use.

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. With geo tagged information on a device which knows where it is (through GPS or other means) and also knows in which direction it is pointing (through a compass) it is possible to show the user information on important buildings, restaurants, future or past events etc etc in the direction the device is pointing (http://layar.com). So far the bulk of work in this direction focuses on adding visual information on the screen of the mobile device, although there is recent work making use of the non-visual channels eg. The roaring navigator [1], ONTRACK [2], AudioBubbles [3], SoundCrumbs [4], Sweep-Shake [5] and SocialGravity [7].

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. Some earlier works have partially addressed this but a study on the influence of angle size on performance, gestures and strategies in a more real outdoor navigational setting is still missing. The present study is aimed at improving this state of affairs.

2. TEST DESCRIPTION

2.1 Equipment
For this particular test we used an external magnetometer (a SHAKE SK 6 device) connected via Bluetooth to a Sony Ericsson Xperia mobile phone running Windows Mobile. We initially tested an implementation also on the android developer phone, but since both running the vibration motor and the magnet snap for the keyboard influenced the compass, we decided to use a separately held magnetometer for the test. Due to connection/software delays the effective magnetometer update rate was not constant. The times between our data points ranged roughly between 150 ms – 250 ms with an average of 200 ms (measured over 500 data points from one of the log files).

[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.

2.2 Test design

The test was done outdoors, but to keep the duration of the test around one hour we decided to perform the test within a limited space. Most test rounds were done in a park like area outside our department which contained open areas, foot/bike paths, trees, bushes and some artistic installations. We had decided on this type of fairly open environment for several reasons:

- A road network would impose a limited number of possible directions making it harder to discern the effect of the angle interval alone.
- One can expect users to visit parks and open squares, and the test environment contained elements natural for that type of environment.
- This type of environment allows more freedom in the design of different trails.

To see what happens in a completely open environment we also carried out three tests in an open field further away. The test tracks were based on a grid structure (see figure 1).

Figure 1. The grid points for the test trails. All trails started at 1. At 2 you could turn either right or left. The same happened at the following point (3 or 4). The four possible goals were located at 5,6,7 and 8. Picture made with GPSVisualizer, http://www.gpsvisualizer.com/.

The grid distance in the (5,1,7) direction was defined by a latitude difference of 0.00018 and a longitude difference of -0.00049, while the distance in the perpendicular direction (1,2) was defined by a latitude difference of -0.00025 and a longitude difference of -0.00027 (decimal degrees). At this location these values correspond to 37 m and 33 m respectively (using the haversine formula [8]).

Each point in the track was surrounded with a circle of an approximate[2] radius of 10 m. If the user was inside this radius the point was considered to be reached and the application would lead the user towards the next point in the sequence. Thus all points had to be visited in a sequence and you would not find the goal unless you had reached all the previous track points. When the user was within an approximate radius of 20 m of the goal waypoint the phone started to vibrate slowly. When the user was 10 m (or closer) to the target the goal was considered reached and the phone started to vibrate quickly.

[2] The formula used in the implementation overestimated longitudinal distances with a factor of 1.19 compared to the haversine formula. For distances of 10 m this is within the GPS accuracy and should not influence the outcome of the test.

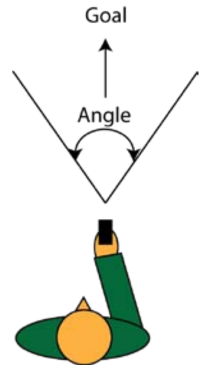

Figure 2. The angle interval. When the device is pointing in a direction within this interval the audio feedback is heard.

The user got information about which direction to go by pointing the device in different directions (as was done in [4] and [7]). If the device was pointing in the right direction audio feedback playing a wave file (the sound of waves against the shore) was played. The volume did not change – the sound was either on or off. The direction was considered to be right as long as the device was pointed to a direction within a specified angle interval as shown in figure 2.

The angle intervals tested were 10º, 30 º, 60 º, 120 º, 150 º and 180 º. The order in which these were presented to the test person was randomized. Before the actual test a practice round at 30 º to allow the user to familiarize himself/herself with the equipment (and also to make sure the GPS reception had some time to stabilize) was carried out.

The users were observed during the test by an observer walking slightly behind (not to disturb the navigation) and to the side (to be able to see what the person was doing). After the test they were asked about which strategies they used for small and large angles, how much they felt they needed to concentrate or if they had any other comments about the interaction design. The test application logged time, GPS position and magnetometer heading. It also logged when the user passed different waypoints and when the goal was reached.

2.3 Test users

The test was pilot tested by three persons to check the equipment and the setup. The actual test was done by 15 persons. Of these users, 6 were female and 9 male. The age range was wide – our youngest test user was 13 while the oldest person who did the test was 70.

3. RESULTS

Contrary to our expectations users were not very sensitive to the angle interval. Even for the 180 º condition all test users (and all the pilot testers) found the goal.

Some differences were still seen. If we start by looking at the time to find the goals in table 2 we see that on the whole the 10 º angle interval and the 180 º angle interval takes longer. Statistical analysis using ANOVA showed significant differences ($p<0.0001$). A Bonferroni test showed significant differences with a confidence level of 95% between 10 º and the angle intervals 30 º, 60 º, 90 º and 120 º. 180 º was significantly slower than all other intervals except 10 º.

Table 2. Time in minutes to find the goal for different angles

Nr	10 º	30 º	60 º	90 º	120 º	150 º	180 º
1	5,32	4,31	3,93	3,49	3,52	5,65	4,49
2	2,89	2,65	2,62	3,71	1,75	3,12	2,52
3	4,27	3,16	3,24	2,89	2,91	2,35	5,81
4	5,02	2,85	2,82	2,43	3,66	3,56	8,25
5	6,48	2,16	2,27	2,01	2,13	2,61	2,52
6	4,09	3,26	2,33	2,37	2,00	2,73	7,22
7	2,50	2,95	2,19	1,77	2,28	6,02	8,89
8	6,87	3,43	2,51	2,90	2,08	2,68	6,26
9	3,23	2,01	1,94	1,82	1,93	1,53	2,34
10	2,78	2,29	2,09	3,13	2,58	5,72	5,29
11	3,19	1,78	2,26	2,96	1,85	2,14	5,13
12	5,14	3,21	3,21	2,43	4,58	2,88	5,59
13	6,23	3,05	2,50	2,87	2,88	4,42	4,69
14	7,50	3,65	2,60	2,92	2,58	3,67	3,35
15	5,41	2,66	2,69	2,09	3,71	2,79	10,09
Av	4,73	2,89	2,61	2,65	2,69	3,46	5,50

That the 10 º and 180 º conditions take longer to complete can be seen clearly if we look at the average times shown in the figure 3 below. We also note that there is little difference between the 30 º, 60 º, 90 º and 120 º angle intervals.

Trails at the main (more realistic) test location can be seen in the following sequence of images.

Figure 3. Trails for 10 º (left), 30 º (center) and 60 º (right)

Figure 4. Trails for 90 º (left), 120 º (center) and 150 º (right)

Figure 5. Trails for 180 º

In figure 3 we can see the intended paths quite clearly. Also in left picture in figure 4 some clustering can be seen, while the picture gets less and less organized towards the right. Figure 5 shows a spaghetti like mess where several trails appear to make loops as well as deviating a lot from the intended paths. All these pictures were made with GPSVisualizer, http://www.gpsvisualizer.com/.

3.1 Gestures and strategies

We saw three main types of standing still gestures. The first, which basically all users made use of, was to hold the device out in front of the body, keeping the arm and hand position fixed relative to the body, and walk around on the spot (sometimes in a small circle), see figure 6a. A gesture which was used both while walking and while standing still was the arm scan. In this gesture the arm was moved to the side and back again, see figure 6b. This gesture occurred to one side only or from side to side. The third type was hand movement only – the user moved the hand by flexing the wrist (figure 6c). This gesture was also used both standing still and while walking.

Figure 6. a) Whole body rotation keepting the arm and hand fixed relative to the body, b) arm scan, c) wrist flex

In addition two users also scanned by keeping the hand and arm still, but instead walking in a zig-zag/serpentine fashion forwards. One user also tried to scan by moving the device with the fingers (keeping the hand in the same position). For finding the direction while standing still all the three main gestures were used. Some users preferred the whole body rotation only, while some started with the arm pointing and only made use of whole body rotation if this didn't give any result. The hand pointing was mostly used for the narrow angles (10 º and sometimes also 30 º).

In general our users would keep walking as long as they heard the audio feedback. When they lost it they stopped and checked the direction. The only exception was the 10 º angle. As was noted already in [6] narrow angles make targets easy to miss, and for this angle it was really hard to keep a steady signal. This led either to the person stopping a lot, or to keep walking a while without signal and then stopping to check if he or she was walking the right way. Some users also tried to use arm or hand scan while walking to keep the signal, but given the noise in the signal, the limited update rate and the delays present this tended to work badly leading instead to a complete loss of signal. With better technology this might be a useful way of dealing with narrow angles, but with the current apparatus it was less useful.

For the wider angles we saw that we had two basic types of users. One group was more analytic and explored the width of the angle interval and then tried to walk towards the middle. The other group walked as soon as they felt they had a steady signal. The difference between the groups was most clearly seen in the 180 º condition; although some of the more analytical users also had problems with this angle interval in general the analytical strategy made users better able to cope with the wider angles. In the analytical group we would often see the user trying to check the limits of the angle interval by doing a sideways scan (while walking) to find the border. Persons from the other group would not do this, but kept walking as long as they had a steady signal. The less analytic users would still tend to avoid the borders of the angle interval. Due to noise/jumps in the magnetometer signal the sound would start "hiccupping" near the border. All users made use of this info, although not everyone realized this was useful right from the start. While scanning standing still, this meant that the user would keep moving the device until the signal was steady (and often a little further) which meant that also the less analytic users would avoid walking right along the borders of the angle interval. While walking, the hiccup would either trigger a stop to scan a new direction, or the user would try to re-orient by doing an arm scan while walking.

In general users expressed that they felt more "secure" with the wider angles (although they didn't like the 180 º which was said to be too wide). The 10 º made users feel insecure, and they tended to walk noticeable slower in this condition. We did not explicitly test cognitive load, but we did probe this by trying to talk to our subjects. Both from the responses to this, and also from answers to explicit questions it was clear that the narrow angles were more demanding. Particularly the 10 º angle required a lot of concentration from the user. One user said "you have to concentrate so hard that you almost forget where you are". All users disliked the 10 º and thought it was too narrow. With wider angles people were more relaxed and would often start talking spontaneously with the observer. They also commented that with larger angles you didn't have to concentrate that much, but could relax and enjoy the walk.

4. CONCLUSION

We find that users are able to handle quite a wide range of angle intervals. The only intervals generating significantly slower completion times were the 10 º and 180 º angle intervals. Among the angle intervals that appear to be working reasonably well, we still find some differences. 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. Thus there is no single preferred angle interval – instead this depends on the task. If exact track following is important we would recommend an interval of 30 º to 60 º while we recommend an interval of 60 º to 120 º if low cognitive load is important. The 60 º used in [7] agrees with these findings. The task dependence of our recommendations indicates that angle interval is a variable which should be possible to customize.

In this test we observed three main scan gestures: the whole body scan, arm pointing and hand pointing. Users tended to keep walking as long as they had a signal and stop to scan for direction if they lost it. Some users scanned also while walking. For narrow angles this was done in order to keep the signal, while if it was perfomed for wide angles the scanning would be to check that the user was still heading roughly towards the middle of the angle interval. We also note the importance of information about when you are near the border of the interval, and we have an indication of the usefulness of distance information.

We have seen two basic types of strategies for dealing with the interaction: we have the analytic strategy where one checks the size of the interval and then tries to head for the center, and we have the direct strategy where you scan until you get a signal and then head in that direction. Finally, our observations extend the observation made in [5] that this type of pointing gesture is intuitive and easy to use also for navigational purposes.

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