# The Influence of Angle Size in Navigation Applications Using Pointing Gestures

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# The influence of angle size in navigation applications using pointing gestures

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**Abstract.** One factor which can be expected to influence performance in applications where the user points 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.

**Keywords:** Non-visual, pointing, gesture, audio, mobile, location based

## 1 Introduction and related work

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). Using non-speech sound or vibration in a handheld device to guide pedestrians in a wayfinding situation has been studied previously but not extensively. One group of proof-of-concept systems make use of spatial audio for navigation purposes and thus require headphones. AudioGPS by Holland et al. [1] displays the direction and the distance to a target uses stereo together with a repeated fixed pitch tone and a repeated varying pitch tone to give the user the directional information. A Geiger counter metaphor is used to convey distance from target (more frequent tone bursts the closer to the target the user is). In gpsTunes created by Strachan et al. [2] the user's preferred music was placed with spatial audio to provide bearing and distance information. As long as the user kept walking in the direction of the goal, the music was played at the desired volume. Stahl's The Roaring Navigator [3] guides visitors at a zoo by playing the sounds of the three nearest animals. The system also uses speech recognition for interaction and speech to display further information about the animals to the user. Jones et al. modify the volume of music stereo playback to guide users toward their destination in the ONTRACK system [4]. The full sound is given in both ears within an angle of 90 degrees around the target. Between 90 and 180 degrees, the sound is shifted 45 degrees to the left or right, and it is completely shifted to the left or right ear for angles above 180 degrees. Their field trial also showed that visual distraction may interfere with audio guiding.

The AudioBubbles concept by McGookin et al. [5] is similar to AudioGPS, but does not require the use of headphones. The context is somewhat different in that is not specifically targeted to navigation, but to support tourists to be aware of and locate points of interest while wandering freely. The SoundCrumbs application described by Magnusson et al. in [6] enables the user to place virtual spheres of sound in a virtual georeferenced system and locating them again to support finding ones way back to a starting location, or to create virtual trails to share with others. It is possible to locate the next soundcrumb on the trail by pointing - when the magnetometer points in the direction of the next sound crumb, it will be played with adjusted volume, depending on whether the user points directly at the target or beside it.

Instead of using audio as a beacon at the target, tactile feedback such as vibration has also been used. In the SweepShake system presented by Robinson et al. [7] the user point in a direction and receives vibratory feedback when the device is pointing at the target. The targets are different in size depending on their information content (a larger target indicates more information content) and the use case described is primarily browsing and selecting geolocated information while standing still. Ahmaniemi & Lantz [8] similarly use vibratory feedback to investigate target finding speed in a laboratory set-up. The user scans or sweeps a handheld device while standing still. The study considered feedback angles between 5 and 25 degrees, concentrating on the speed of the sweeping movement. The possibility of missing the target at high speeds for smaller angles is stated. The results show that reaching a target with a vibratory angle of 5 degrees is significantly more difficult than with larger angles. The Social Gravity system described by Williamson et al. [9] intends to guide a group of people toward a common meeting point, called a “centroid” that adjusts its position according to the individual members of the group, using vibration feedback. The users are also here expected to scan for the target (centroid), and a 60 degree target indication angle was used in the field trial. Before choosing the field trial angle a simulations was made with angles from 5 to 180 degrees.

A more detailed 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

The present study was set up to answer the following questions: What happens when you vary the angle interval? Is there a preferred angle? What kind of strategies/gestures do the users adopt when interacting with this type of pointing application?

For the test we used an external magnetometer (a SHAKE SK 6 device) connected via Bluetooth to a Sony Ericsson Xperia mobile phone running Windows Mobile. The test was done within a limited space outdoors. 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 at both locations were based on a grid structure (see Fig. 1 A).

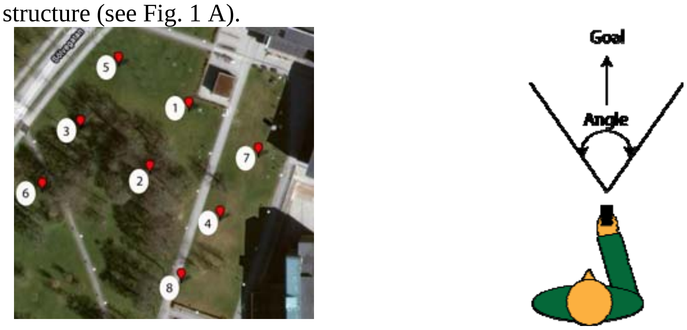


**Fig. 1.** A) The grid points for the test trails. B) The angle interval.

The four different tracks available can be worked out from Fig 1A. Each track started at point 1 and went on to point 2. At 2 you could turn either left or right. The same would happen at the points 3 or 4. The track ended at one of the corner points 5,6,7 or 8. The turns at the points 2, 3 and 4 were made in an alternating fashion so that if you turned left at the first turning point the first trial, you turned right during the next trial. Thus if your first trail was 1, 2, 3, 6 and your second trail 1, 2, 4, 8 your third trail would be 1, 2, 3, 5. The same design was used for the following turn. The initial values for the turns in the sequence were assigned randomly. Since there were four tracks and eight tests each track occurred twice. Due to both GPS inaccuracy as well as deviations due to different angle intervals the users did not walk the same way every time even though the underlying GPS track was the same. When asked about it after the test, none of the users had noticed that some paths were the same. Furthermore the order in which the angle intervals were presented was randomized to cancel out possible learning effects.

The grid distance in the (5,1,7) direction was 37 m while the distance in the perpendicular direction (1,2) was 33 m. Each point in the track was surrounded with a circle of an approximate[1] radius of 10 m. If the user was inside this radius the application would lead the user towards the next point in the sequence. 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.

The user got information about which direction to go by pointing the device in different directions (as was done in [6] and [9]). 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 Fig 1B.

The angle intervals tested were 10º, 30º, 60º, 120º, 150º and 180º. The order in which these were presented to the test person was randomized. A practice round at 30º was carried out before each test.

The users were observed during the test. 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.

15 persons did the test. 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 180º condition all test users found the goal.

Some differences were still seen. If we start by looking at the time to find the goals in table 1 we see that on the whole the 10º angle interval and the 180º 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 10º and the angle intervals 30º, 60º, 90º and 120º. 180º was significantly slower than all other intervals except 10º. That the 10º and 180º conditions take longer to complete can be seen clearly if we look at the average times. We also note that there is little difference between the 30º, 60º, 90º and 120º angle intervals.

If we instead look at the trails we can pick up some general features. As expected the more narrow angles lead to more precise route following, while for the wider angles people would stray more and would even occasionally walk in circles for a while.

[1] 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.

**Table 1.** Time in minutes to find the goal for different angles.

| Nr | 10° | 30° | 60° | 90° | 120° | 150° | 180° |
|---|---|---|---|---|---|---|---|
| 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 |

Looking at the three tests done on an open field we can see the trend quite clearly. In the top row of Fig. 2 we see the angles 10º, 30º, 60º and 90º. All these trails follow the intended path quite well, although we begin to see some deviations in the rightmost picture. In the bottom row of Fig. 2 we see the wider angles resulting in more deviations and finally also loops.

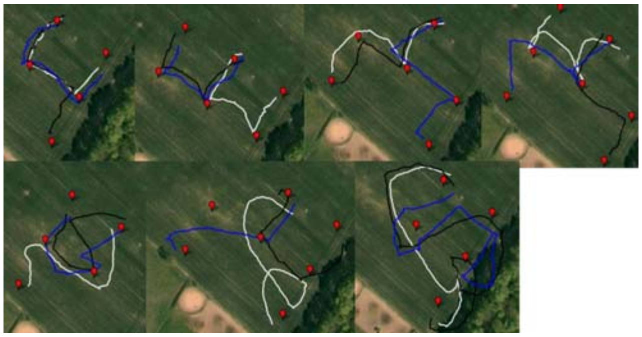

**Fig. 2.** Trails for 10º, 30º, 60º, 90º (top row), 120º, 150º and 180º (bottom row).

At the main (more realistic) test location there were objects such as trees, footpaths, cyclists etc that the test persons would have to avoid. In addition we also had more problems with the GPS signal. The trend is still the same, as can be seen from Fig 3. In the top row of Fig 3 we can see the intended paths quite clearly. In the bottom row things are getting less and less organized and the last picture at the bottom right 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/.

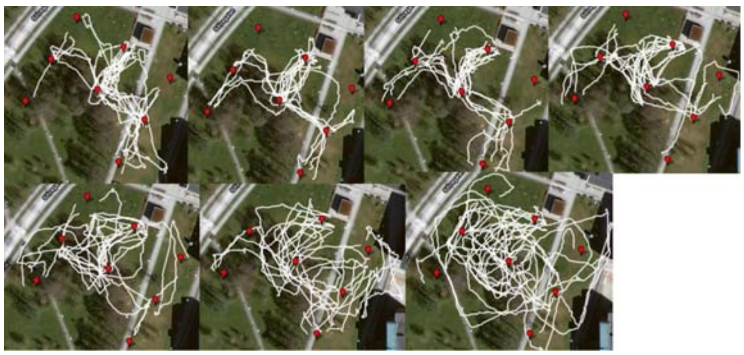

**Fig. 3.** Trails for 10º, 30º, 60º, 90º (top row), 120º, 150º and 180º (bottom row).

For the finding of the appropriate direction while standing still we saw three main types of 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). A second 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. This gesture occurred to one side only or from side to side. The third type of gesture was hand movement only – the user moved the hand by flexing the wrist. Also this gesture was used both standing still and while walking. 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 (10º and sometimes also 30º).

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 10º angle. As was noted already in [8] 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.

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 180º 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. 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 180º which was said to be too wide). The 10º made users feel insecure, and they walked 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 10º 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 10º 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 Discussion

Contrary to our expectations our test users were surprisingly insensitive to the size of the angle interval. Our results indicate that also wider angles such as 90º and to some extent even 120º can work reasonably well. Our test results confirm that we had included a sufficient range of angle intervals – we had both a too narrow angle (10º) and a too wide one (180º). In between those the recommendation for which angle to use depends on several factors:

- 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 from this test 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. Judging from the results of this test 60º to 120º works 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 (eg. jogging applications) wider angles are preferable.

The 60º used in [9] agrees with these findings. Even so, the task dependence of the recommendations indicates that angle interval is a variable which should be possible to customize.

The fact that the 10º angle is difficult is very much depending on uncertainties in the signal (a nice overview of this topic can be found in [10]) combined with a discrete sampling rate. When the heading value “jumps” due to noise it is easy to miss the goal completely. The risk of missing the target if it is narrow is also pointed out in [8]. Thus, one factor which influences these recommendations is the properties of the hardware. With faster and more precise equipment one can expect that smaller angles will be easier to deal with. The general trend that smaller angles favor more precise but also more cognitive demanding navigation can still be expected to hold.

We were a bit surprised that all users found the goal also in the 180º condition. Although they would sometimes walk in wrong directions and also on occasion walk in circles they would eventually converge on the target. Potentially this could be due to obstacles in the environment causing fortunate deviations, which is why we did a few tests also in a completely open environment – and also in the open environment users were able to get to the goal eventually.

The size if the track points was set to a size that initial tests showed resulted in smooth navigation. With smaller track point size we would expect a need for more exact navigation. It should be noted that the actual directions used for the angle feedback was calculated using the GPS point in the middle of the circle so the size of the circles would not have any effects on the direction information provided to the user - it influences only which track point the application thinks the user is looking for and when the user is considered to have reached the goal.

It should be noted that our results are for a fairly open environment. In a street grid environment the number of possible directions is limited, and wider angles can probably be used without loss of precision (as an example: if you are walking along a road even a 180º interval is likely to tell you if you are heading in the correct direction or not).

Another outcome of our study is an improved understanding of the strategies users employ. Some users are more analytical and will scan the extent of the interval and try to walk towards the center, while others will “just walk” when they get a signal. In general users find it quite natural to scan, which implies that it is important to make use of a compass that is fast enough to support this behavior. The device used for these tests (the SHAKE SK6) was fast enough to support scanning although very fast gestures had to be avoided. It also had a filtering mode that gave more steady headings – but pilot tests showed that this unfortunately slowed down the compass too much when used with the scanning gestures.

The pointing interaction used in this study appeared to be easily understood, and none of our users had any noticeable problems dealing with it. This is in agreement with the results in [7] and [9] who also find this type of pointing/scanning interaction easy and intuitive for users.

The audio used (a sound of waves against a shore) was well liked. It was quite easy to hear, but even more importantly it wasn’t perceived as annoying or disturbing. Even the person who observed the tests and who listened to it for more than 17 hours found it nice to listen to. One further advantage of using a continuous sound was the “hiccupping” that happened near the borders of the angle interval which provided extra information. In a sense the continuous nature of the sound source made it easier to discern changes in signal. This agrees with the observation in [11] that changes in data are better mapped using continuous feedback – in this case audio. In the case of Geiger counter type designs (such as was used in [1]) you will miss this information. In cases where you want to mask irregularities in the signal this could be used to your advantage, but in the present case the border information is quite valuable.

In this study we used only 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 [6] 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.

## 5 Conclusion

The present study was performed in order to get a better understanding of the influence of angle size on navigation performance, gestures and strategies in a more realistic outdoor setting. We have been looking at what happens when you vary the angle interval, if there is a preferred angle, and what kind of strategies/gestures the users adopt when interacting with this type of pointing application.

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 10º and 180º 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 30º to 60º while we recommend an interval of 60º to 120º if low cognitive load is important. The 60º used in [9] agrees with these findings. The task dependence of our recommendations indicates that angle interval is a variable which should be possible to customize. It should be noted that the precise angle intervals in these recommendations depend both on hardware properties as well as the size of the circle around each track point within which the point is considered to be reached. The general trend indicated above should still be expected to hold.

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 performed for wide angles the scanning would be to check that the user was still heading roughly towards the middle of the angle interval. 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 [7] that this type of pointing gesture is intuitive and easy to use also for navigational purposes.

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