Navigation by auditory feedback

M. de Jager (4005104), J. Struijk (4103823), D. Sleegers (4097378), N. Skënderi (4177754)

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Abstract

The possibilities of navigation by auditory feedback has been researched. This is done by researching and examining the sound signals, different angle queues, different distant queues and the number of sources that can be distinguished from one another. A group of 20 unexperienced people have been examined through a sound test. Each had to locate 20 random generated sound in seven different sections of the experiment. Through the angle/distance error and the reaction time the most accurate option is selected and implemented in the simulation. These would be the a randomly generated sound with equal energy per octave, the Head Related Transfer Function, the Monophonic Volume Change and five sources equally spread over 180 degrees.

1 Introduction

Every day more and more vehicles are driving autonomous, with one person controlling them from a remote location if something has gone wrong. When this person is controlling one vehicle he needs to keep an eye on the other vehicles via monitors. So if he can control a vehicle without his sight, he can use his sight to keep an eye on other vehicles.

Therefor a system with auditory feedback is considered useful. But what kind of sound is most accurate and fast in determining where the sound is originated and how far it is, thus where an object is? How many sound sources can be used to successfully determine the location of the sound?

2 Method

Experimentation using a computer simulation among test subjects was necessary to determine human response to the auditory display. The simulation separately tests location of an object and the distance to an object to quantify performance of both concepts. For testing, a randomly generated sound with equal energy per octave (pink noise) is modulated for each concept and correlated to a visual reference scale, see Figure 1. The pink noise was selected having the highest resolution and being the most pleasant, through literary research[1].

The concepts being tested, regarding location, are interaural volume difference (IVD), interaural frequency difference (IFD), interaural time delay (ITD) and the head related transfer function (HRTF). The concepts regarding distance are monophonic volume change (MVC), monophonic frequency change (MFC) and increasingly frequent repetition (IFR). Twenty test subjects, selected to represent labour force, are asked to swiftly estimate the angle or distance of twenty modulated sounds per concept, representing random virtual locations or distances.

The estimations are logged by a graphical input, in Figure 1 seen as an intersection of a horizontal and vertical line, combined with the virtual angle or distance and the reaction time. The retrieved data is analysed per test subject on average and deviation of the absolute difference between the estimation and virtual angle or distance (the error). Next a five number summary of the average error and reaction time of each test subject is calculated. Additionally the results will be visualised with scatterplots and boxplots.

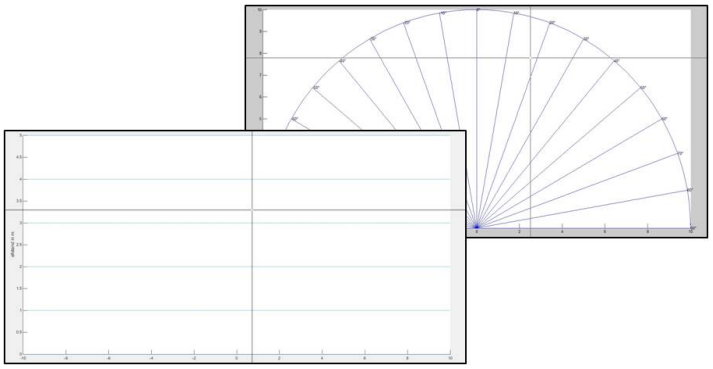

Figure 1: Graphical User Interfaces

The auditory navigation is done by radially spaced sound sources (See Figure 2). These sound sources represent an object in a 45 degree radial spread around its own line. An object is only displayed in the front hemisphere because the navigation is forward orientated.

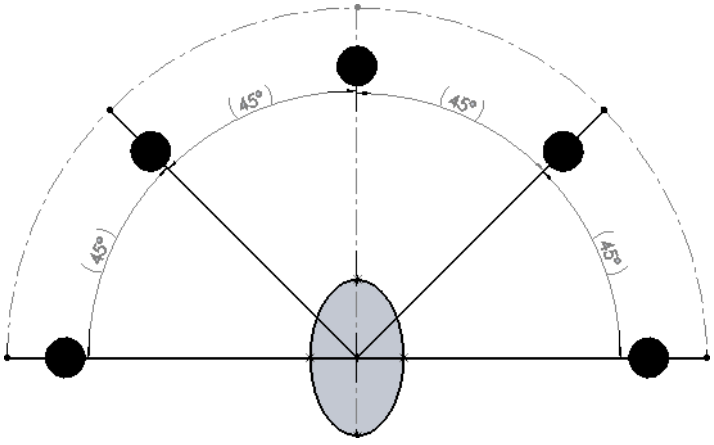

Figure 2: Spatial audio detection

3 Results

After analysing and processing the raw data obtained by the location and distance experiment, the absolute error of the angle and reaction time of the location experiment is shown in Figure 3 for each of the four methods.

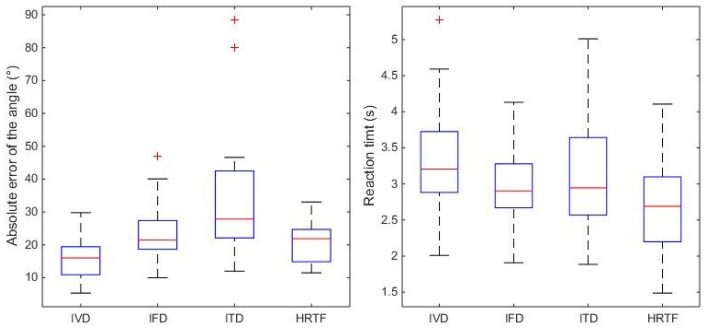

Figure 3: Absolute error of the angle & reaction time

The left boxplot shows a wide spread of the whiskers and the high offset of the median from the IDF and ITD methods, resulting in a low accuracy. The IVD and HRTF methods satisfy the needs of the set up in Figure 2, because the median is below the 22,5 degrees which is necessary to detect the location of sound.

The right boxplot represents the reaction time of the location experiment in seconds. The further research is about the ILD and HRTF method. The boxplots start at 2 seconds because the pink noise sound itself took 2 seconds to complete. The boxplot of the HRTF is striking, because the lowest whisker is at 1,5 seconds, this means a value was noted before the sound was finished. By comparing the reaction time of the IVD and HRTF methods, the HRTF method is better than the IVD method. The choice goes to the HRTF method because both methods satisfies the conditions of the set up, but the HRFT method stands out in the boxplot of the reaction time.

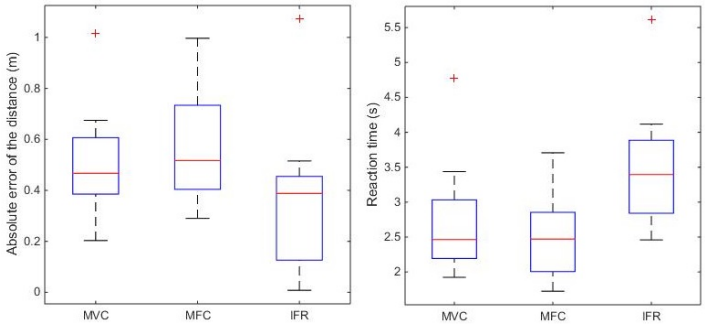

Figure 4: Absolute error of the distance & reaction time

The left boxplot in Figure 4 is the absolute difference in meters of the distance experiment. The MFC method has a wide spread of the whiskers and the accuracy is less than the MVC and the IFR methods. The boxplot of reaction time of the distance experiment results in a better reaction time for the MVC method. The reaction time of the MVC consistent with the reaction time of the HRTF. The combination of the HRFT method for location and the TVC method for the distance is selected.

4 Discussion

The results were not all as expected. The HRTF was thought to be the most accurate distinction of the sound source because it is a simulated natural sound output. But after analysing Figure 3, the ILD is slightly more accurate than HRTF. As seen in Figure 4 the IFR is most accurate, as expected.

When the experiments were done and the results were analysed, a few things caught our attention. One test subject did one test the other way around. A sound orientated at the left quadrant was appointed from the right quadrant and vice versa. Since it was highly unlikely that it was a measurement error the obtained data was valid and the irregularity most likely originated in the subjects sense of direction.

Another irregularity that was detected was the way that Matlab determined the angle when clicked just outside the window. Instead of getting an angle slightly beneath -90 degree Matlab notates an angle slightly above 269 degree. This is just a different notation of the same angle so in every file where this was noted the angle was adjusted manually.

5 Conclusion

After analysing and discussing the results, a conclusion is made. the most accurate sound for determining at what angle a sound is originating from, is the head related transfer funtion. The most accurate sound for determining how far the sound away is from you, is the monophonic volume change. The sounds were determined correctly with five sources.

After implementing the selected sounds in the simulation we made, we can conclude that you can indeed navigate a vehicle with your eyes closed.

6 References

[1]SUSNIK, Rudolf, SODNIK, Jaka and TOMAZI, Saso. An elevation coding method for auditory displays. Applied Acoustics, 2008, vol. 69, no. 3, p. 233 241. referenties komen hier