Impact of Distance to Screen upon Spacial Awareness

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Abstract. In this paper, we conducted an experiment on what impacts the distance between the user and computer screen as well as the size of FOVs would give on the spacial awareness of 3D virtual worlds. One of the interesting findings is that the distance between the subject and computer screen plays an important role in the spacial awareness of 3D virtual worlds. The spacial awareness is improved when we see the computer screen in the distance.

1 Introduction

In recent years, the increase of computers' processing speed is significant and makes it possible to draw 3D virtual worlds precisely in real time. Second-Life of social networking service or SNS sites, and "Call of Duty" and "Metroid Prime" of first-person shooters on Nintendo Wii or Sony PlayStation are some of good examples. Even mobiles such as iPhone and Android devices can deal with 3D virtual worlds. 3D virtual worlds are now commonplace. In order to draw a 3D virtual world we often use a virtual camera. A virtual camera is an imaginary camera in a virtual world, which is used to generate screen images. Then we observe these images on a computer screen. When it comes to field of views or FOVs, there is a concern about inconsistency between them. That is, there are two FOVs. One is of the virtual camera and the other is of our eyes looking at the computer screen. The FOV of our eyes looking at the computer screen is not always the same with the FOV of the virtual camera. As for the size of the FOV of our eyes, Kobori [1] showed that the efficiency of finding a way to the exit in 2D mazes tends to worsen when we see them through a narrow window. The efficiency is defined as a ratio of the shortest path to the path taken by the subject.

Our study is about what impacts the inconsistency between the FOVs as well as the size of them would give on the spacial awareness of 3D virtual worlds. In this manuscript, we conducted an experiment on the impact of three cases of the FOVs, upon the spacial awareness. The first case evaluates the impact of the wideness or narrowness of FOVs. The second one evaluates the impact of the distance between the subject and computer screen with constant FOVs. The third one evaluates the impact of the difference between the FOV of the virtual camera and the one of our eyes. In our experiment, we used some 3D mazes for 3D virtual worlds.

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This paper is organized in the following manner. Sect. 2 explains the experimental method then Sect. 3 shows the results. Finally, Sect. 4 gives the concluding remarks.

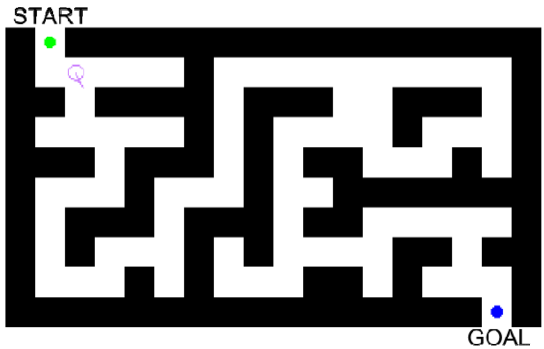

Fig. 1. Top view of one of the 3D mazes used in the experiment

Fig. 2. Screenshot of a subject's view during the experiment

2 Experimental Method

A 3D maze is a system of paths separated by walls in a 3D virtual world, that is designed so that it is difficult to find your way through. Fig. 1 shows one of the 3D mazes used in our experiment. There were 14 subjects between the age of 21 and 22. Each subject was given five mazes from a set of pre-prepared ten mazes at random. Each maze was designed ten blocks wide and 18 blocks long. The ratio of the number of blocks for paths to the number of blocks for walls is set to about 40 percent, making the maze most difficult to be solved [2] [3]. Each subject was asked to solve them on five conditions of the following 15 ones at random. During the experiment, the system tracked the subject's position and orientation.

Table 1. All the 15 conditions of the experiment

Distance \ Our eyes' & camera's FOVs	10°	20°	30°
50cm	1	2	3
100cm	4	5	6
150cm	7	8	9

Camera's FOV \ Our eyes' FOV	10°	20°	30°
10°	-	10	11
20°	12	-	13
30°	14	15	-

- **Condition 1, 2** and **3:** Both the FOVs of the virtual camera and our eyes looking at the computer screen are fixed to 10, 20 and 30 degrees, respectively, and the computer screen is placed 50cm away from the subject.
- **Condition 4, 5** and **6:** Both the FOVs are fixed to 10, 20 and 30 degrees, respectively, and the computer screen is placed 100cm away from the subject.
- **Condition 7, 8** and **9:** Both the FOVs are fixed to 10, 20 and 30 degrees, respectively, and the computer screen is placed 150cm away from the subject.
- **Condition 10** and **11:** The FOV of the virtual camera is fixed to 10 degrees and the one of our eyes looking at the computer screen is fixed to 20 and 30 degrees, respectively, and the computer screen is placed 50cm away from the subject.
- **Condition 12** and **13:** The FOV of the virtual camera is fixed to 20 degrees and the one of our eyes looking at the computer screen is fixed to 10 and 30 degrees, respectively, and the computer screen is placed 50cm away from the subject.
- **Condition 14** and **15:** The FOV of the virtual camera is fixed to 30 degrees and the one of our eyes looking at the computer screen is fixed to 10 and 20 degrees, respectively, and the computer screen is placed 50cm away from the subject.

Table 1 summaries all the 15 conditions. Each condition is numbered 1 to 15. The left part of Table 1 shows conditions where both the FOVs are set to the same. For example, if the FOV of the virtual camera is set to 20 degrees, the one of our eyes is set to 20 degrees as well. While holding this property, it varies in the size of the FOVs and the distance between the subject and computer screen. The right part of Table 1 shows conditions where the FOVs are not set to the same. For example, if the FOV of the virtual camera is set to 20 degrees, the one of our eyes might be 10 or 30 degrees. Along with the conditions, the distance between the subject and computer screen is kept constant. In this experiment, it is 50cm.

3 Experimental Results and Discussion

Fig. 3 shows the search efficiency at each condition across all the subjects. In the figure, the horizontal axes place all the conditions and the numbers correspond to those of Table 1. The z axis shows the search efficiency. The search efficiency is defined as the ratio of the shortest path P_{short} to the path taken by the subject $P_{subject}$:

$$\text{Search efficiency} = P_{short} / P_{subject} * 100 \quad (1)$$

The shortest path P_{short} denotes the number of blocks of the maze, where the shortest path lies. The subject's path $P_{subject}$ denotes the number of blocks where the subject walks. It does not matter if the subject walks on the same block multiple times. The search efficiency tells 100 if the subject takes the shortest path while it tells less if he/she takes longer paths.

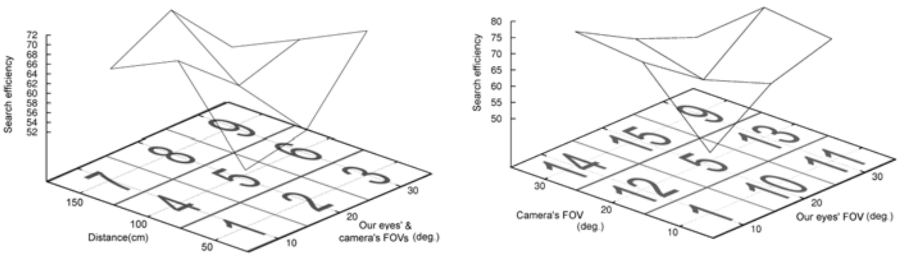

Fig. 3. Search efficiency for each condition

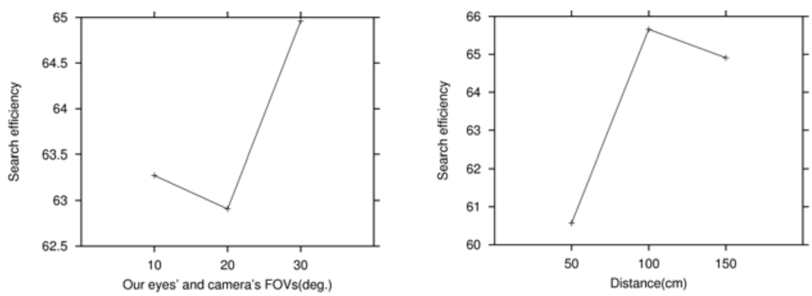

Fig. 4. Average of the search efficiency over the distance(left) and FOVs(right)

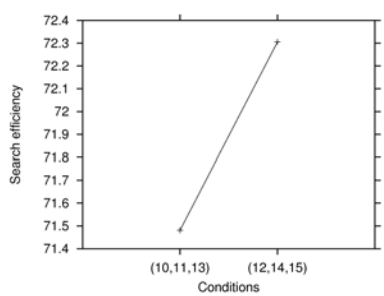

Fig. 5. Average of the search efficiency over the conditions 10, 11 and 13, and the conditions 12, 14 and 15

Fig. 4 is derived from the left graph of Fig. 3 by averaging the search efficiency over the distance and FOVs. The left graph of Fig. 4 shows that the search efficiency increases when the FOVs widen. Moreover, the right one of Fig. 4 shows that the search efficiency increases when the distance between the subject and computer screen becomes long. These results imply that the search efficiency will be improved when we see the computer screen in the distance with wide FOVs. Fig. 5 is derived from the right graph of Fig. 3 by averaging the search efficiency over the conditions 10, 11 and 13, and the conditions 12, 14 and 15. The former features that the FOV of our eyes is wider than the one of the camera while the latter features that the FOV of our eyes is narrower than the one of the camera. From the result, there is a certain difference in search efficiency between these two cases of FOVs. The search efficiency is likely to increase when we see compressed images on a small computer screen.

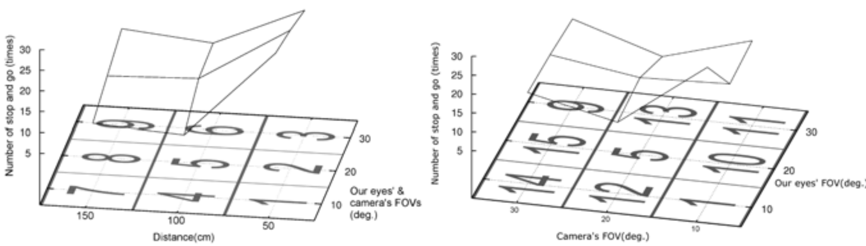

Fig. 6. Effort to solve mazes for each condition

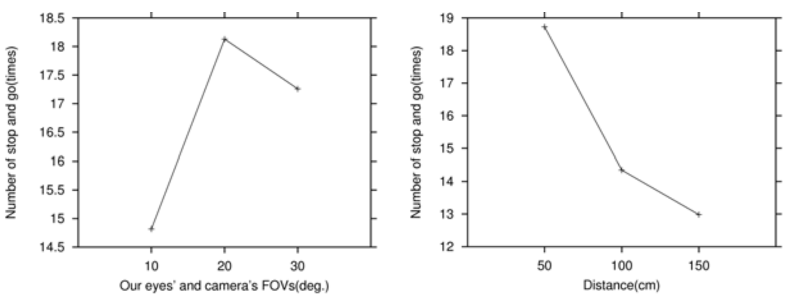

Fig. 7. Average of the effort over the distance(left) and FOVs(right)

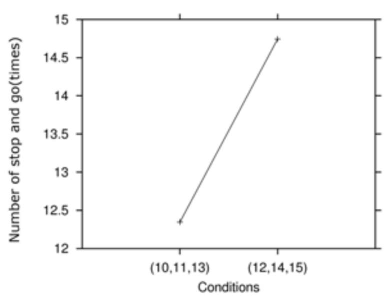

Fig. 8. Average of effort over the conditions 10, 11 and 13, and the conditions 12, 14 and 15

Fig. 6 shows effort to solve mazes at each condition across all the subjects. In the figure, the horizontal axes place all the conditions and the z axis shows the effort. The effort is defined as the number of stop and go during the subject solves each maze. If the number increases, it means that the subject is likely to put effort into recovering the spacial awareness.

Fig. 7 is derived from the left graph of Fig. 6 by averaging the effort over the distance and FOVs. The left graph of Fig. 7 shows that the effort increases when the FOVs widen. The right graph of Fig. 7 shows that the effort decreases when the distance between the subject and computer screen becomes long. These results imply that the subject puts less effort into solving mazes when he/she sees the computer screen in the distance with narrow FOVs. Fig. 8 is derived from the right graph of Fig. 6 by averaging the effort over the conditions 10, 11 and 13, and the conditions 12, 14 and 15. From the result of Fig. 8, there is a certain difference in effort between these two cases of FOVs. The effort is likely to increase when we see compressed images on a small computer screen.

All the findings above are summarized as follows.

1. 1) The search efficiency will be improved when we see the computer screen in the distance with wide FOVs while the subject will put less effort into solving mazes when he/she sees the computer screen in the distance with narrow FOVs.
2. 2) Both the search efficiency and effort are likely to increase when we see compressed images on a small computer screen.

The first sentence says that the distance between the subject and computer screen plays an important role in both the high search efficiency and less effort.

The second one says that we put more effort into solving mazes to improve the search efficiency when we see compressed images on a smaller computer screen. This means that when we design computer games with 3D virtual worlds for mobiles and portable game consoles, we must be aware of a tradeoff between the search efficiency and effort, leading to the settings of virtual cameras. Finally, note that we do not see any relationship between the search efficiency and effort in this experiment. Putting more effort into solving mazes does not necessarily mean making the search efficiency higher.

4 Conclusions

In this paper, we conducted an experiment on what impacts the inconsistency between FOVs as well as the size of them would give on the spacial awareness of 3D virtual worlds. One of the interesting findings is that the distance between the subject and computer screen plays an important role in the spacial awareness of 3D virtual worlds. The spacial awareness is improved when we see the computer screen in the distance. In future work, we are going to study with wider FOVs because the FOV of the virtual camera for common consumer games is set to 60 degrees. It is wider than those in our experiment. We are also going to conduct experiments in real space in order to evaluate the impact of our eyes' depth perception on the spacial awareness because we used a flat computer screen to display 3D mazes in the experiment.

References

1. Kobori, S.: Analysis of Ability of Problem Solving as for Searching in Maze. In: Proc. 42th Annual Convention IPS Japan (2), 269–270
2. Mizusawa, M., Kurihara, M.: Hardness Measures for Maze Problems Paramete-rized by Obstacle Ratio and Performance Analysis of Real-Time Search Algorithms. In: TJSAI, vol. 12(1) (1997)
3. Wang, Y., Matsushita, S.: A study about the space recognition by drawing of a sketch map and scenery after a maze search walk. Summaries of academic lectures of Architectural Institute of Japan E-1, 869–870 (2006)