

A Study on Selection Ability in the 3D Space by the Finger

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Abstract. Intuitive gestures are very effective for interactions. Pointing gesture with a finger would be used for interactions like pie menu selection. It has been researched as to the appropriate numbers of menu items being displayed in a pie menu. However, no research has been made for the case where menus are selected by using gestures. We will experiment in order to examine the ability of pointing gesture (selection ability) in the 3-dimensional space. The experiment was conducted in order to find out the test subjects' selection ability of pointing gesture. By combining the obtained resolution abilities of pointing gesture at the 2-dimensional surface of Pitch and Yaw, it is suggested that the selection ability of selection behavior in the 3-dimensional space is 22 areas.

Keywords: Gesture, Selection Ability, Menu, Pie menu.

1 Introduction

Intuitive gestures are very effective for interactions. In recent years, the researches on interactions, which operate various products and services such as music players and TV by using gestures, are being actively conducted.

It is difficult for computers to recognize the intentions of users from their natural gestures. Although it is relatively easy for computers to recognize standard gestures like sign language (commands), users need educations and trainings to be able to use them. Both have merits and demerits. Generally speaking, gestures are very effective for interactions if the use is limited to interactions like making selections from the displayed menu[1].

However, as the case now stands, there is no coherence between gestures and the allocations of interactions, and each application and service makes its own allocations. Products and services have become diversified and multifunctional, and there are more functions and interactions which need to be allocated to gestures, thereby the allocation has become difficult.

Therefore, pointing gesture with a finger would be used for interactions like menu selection. It is possible to select with simple gesture even when there are many menu items. In addition, pointing gesture is intuitive, thus users need no special education or training.

Pie menu is a kind of GUI menus. It displays menu items in a radial fashion centering on the mouse pointer. Users select a menu item by the direction to which they move the mouse pointer. Pie menu can be selected by the angles. It is suitable for interactions using pointing gesture.

It has been researched as to the appropriate numbers of menu items being displayed in a pie menu. However, no research has been made for the case where menus are selected by using gestures. In order to find it out, it is necessary to know human ability of pointing properly. Therefore, we will experiment in order to examine the ability of pointing gesture (selection ability) in the 3-dimensional space.

2 Related Research

Miyamoto et al. have discussed how they should allocate menu items to the extended pie menu[2]. They examined how the selection accuracy varied depending on the sizes and locations of each area within the pie menu so that they could discuss the most appropriate area pattern of the pie menu.

Saeki et al. have attempted to examine the selection ability of pointing gesture in the 3-dimensional space[3]. The experiment was conducted without posing restrictions on the arm joints of the test subjects, which allowed the free movements. Because each test subject had different pointing gestures, they were not able to conduct statistical analysis effectively.

Therefore, we thought it was necessary to examine the range of motion and the arthresthesia of joints of shoulder, elbows, wrists and fingers separately.

3 Experiment 1

The experiment was conducted in order to find out the test subjects' selection ability of pointing gesture. With their forearms fixed horizontally, the selection ability for Pitch (vertical) direction was obtained. The selection ability for Yaw (horizontal) direction was obtained for the each obtained selection ability for Pitch (Fig.1.).

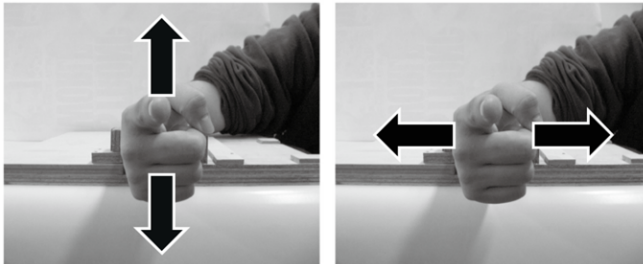


Fig. 1. Pointing Gesture by the finger(Left: Pitch, Right: Yaw)

3.1 The Experiment to Obtain the Selection Ability for Pitch

The below restrictions were added to the vision and arm joints of the test subjects

1. Visual feedback was eliminated.
2. The joints of arms and fingers, which were except for wrists, were fixed. (Fig.2.).
3. The joints of wrists were fixed in a way to prevent adduction and abduction.

Pointing gesture in this research is by using the wrist and finger joints. In order to separate pointing gestures into Pitch (vertical direction) and Yaw (horizontal direction), the condition (2) was added. With the forearm fixed, the hemisphere centering on the direction from the elbow to the wrist was considered. The test subjects were instructed to point at the center of a certain area, which was a part of the partitioned hemisphere. The accuracy of their pointing gestures was examined.

In order to obtain the pointing angles of the test subjects, 3D sensor module (TDS01V[4]) was attached on top of their index finger. TDS01V is a sensor equipped with a triaxial acceleration speed sensor and a triaxial geomagnetic sensor.

The test subjects were 18 males and females who were in early twenties and right-handed. All of them had normal wrists joints. It was defined that one trial consisted of the test subjects pointing at the center of an area as instructed one time. It was defined that one set consisted (135 trials) of one trial for each 2 to 16 partitioned areas of Pitch. Two sets were completed in the experiment. The order of the trials was random within one set. Each set had different order. The experiment took approximately 60 minutes.

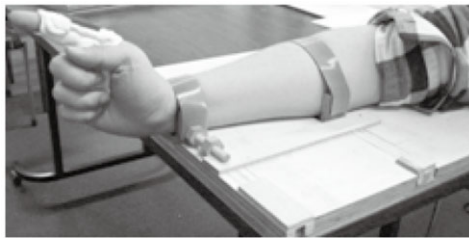


Fig. 2. The joints of arms and fingers were fixed

Evaluation Method. The results of measuring the pointing angles of the gestures were analyzed. The pointing angles in one particular area of all the test subjects were nearly normal distribution. We let the average pointing angle in a particular area be μ and its standard variation be σ , assuming that they were able to point with the accuracy of approximately 68.3% if $\mu \pm \sigma$ was within the area. they were able to point with the accuracy of approximately 95.5% if $\mu \pm 2\sigma$ was within the area. they were able to point with the accuracy of approximately 99.7% if $\mu \pm 3\sigma$ was within the area.

Because the wrists have a range of motion, it is not possible to point at outside the range. In the case of Pitch, the area above the center is outside the range of motion. It was necessary to evaluate by excluding such area.

Results. The results of pointing for Pitch are shown in Table 1. From Table 1, it is possible to obtain the selection ability of pointing gesture at the 2-dimensional surface. The column of $\mu \pm \sigma$ of Table 1 shows whether $\mu \pm \sigma$ from the distribution of the pointing angles were within a particular area. If so, it indicates that it was possible to properly point with that accuracy. It is same for the column of $\mu \pm 2\sigma$ and that of $\mu \pm 3\sigma$. check cell means possible to point, while blank cell means impossible to point properly.

Table 1. The accuracy of pointing gesture for Pitch

Number of partitions	Area No.	Central angle (degrees)	$\mu \pm \sigma$	$\mu \pm 2\sigma$	$\mu \pm 3\sigma$
2	1 (Up)	-45.0			
	2 (Bottom)	45.0	✓	✓	✓
3	1	-60.0			
	2	0.0	✓	✓	✓
	3	60.0	✓	✓	
4	1	-67.5			
	2	-22.5			
	3	22.5	✓		
	4	67.5	✓		
5	1	-72.0			
	2	-36.0			
	3	0.0	✓		
	4	36.0	✓		
	5	72.0	✓		

As to $\mu \pm 3\sigma$, it was possible to properly point at the area 2, which were parts of the three-partitioned area. As to $\mu \pm 2\sigma$, it was possible to properly point at the area 2 and 3 which were parts of the three-partitioned area. As to $\mu \pm \sigma$, it was possible to properly point at the area 3, 4 and 5, which were parts of the five-partitioned area.

Discussion. In one trial of pointing gesture, deviation was developed between the actual angle of pointing gesture and the angle which was meant to be. The scatter diagram of the deviations shows the tendency that the actual angles deviated from the correct angles toward the center (toward the front). It was indicated that there was a certain tendency of deviation between the correct angles and the actual pointing angles. By doing a regression analysis, corrected values were obtained based on the regression expression. The corrected angle y of Pitch is Eq. 1.

$$y = -0.195x + 9.948 \quad (1)$$

The accuracy of pointing after the correction is shown in Table 2. As a result of the correction, the selection ability for Pitch was not improved at to $\mu \pm \sigma$. It was found out possible to properly point at the area 3 (the central angle 0 degree), the area 4 (-36 degrees) and the area 5 (-72 degrees) out of the five-partitioned area of Pitch.

Table 2. The accuracy of pointing gesture for Pitch after the correction

Number of partitions	Area No.	Central angle (degrees)	$\mu \pm \sigma$	$\mu \pm 2\sigma$	$\mu \pm 3\sigma$
2	1	-45.0			
	2	45.0	✓	✓	✓
3	1	-60.0			
	2	0.0	✓	✓	✓
	3	60.0	✓		
4	1	-67.5			
	2	-22.5			
	3	22.5	✓		
	4	67.5	✓		
5	1	-72.0			
	2	-36.0			
	3	0.0	✓		
	4	36.0	✓		
	5	72.0	✓		

Table 3. The accuracy of pointing gesture for Yaw (0 degrees) after the correction

Number of partitions	Area No.	Central angle (degrees)	$\mu \pm \sigma$	$\mu \pm 2\sigma$	$\mu \pm 3\sigma$
2	1 (Left)	-45.0	✓	✓	✓
	2 (Right)	45.0	✓	✓	
3	1	-60.0	✓		
	2	0.0	✓	✓	
	3	60.0	✓		
4	1	-67.5	✓		
	2	-22.5	✓		
	3	22.5	✓		
	4	67.5	✓		
5	1	-72.0	✓		
	2	-36.0	✓		
	3	0.0	✓		
	4	36.0			
	5	72.0	✓		

3.2 The Experiment to Obtain the Selection Ability for Yaw

It was experimented in order to obtain the selection ability for Yaw at the area of 3 and 4 out of the five-partitioned area of Pitch. As to the area 5, it was not experimented since the range of motion of wrists was extremely small.

The experiment was conducted under each condition where the movable surface of the wrists was fixed at 0 (horizontal) and -36 degrees. The experiment conditions and evaluation method were same as Pitch in the experiment 1.

Results. There was a tendency that the pointing angles uniformly deviated toward the same direction. Table 3 and Table 4 show that the accuracy of pointing which was obtained by using corrected data.

From Table 3, as to $\mu \pm 3\sigma$, it was possible to properly point at the area 1, which were parts of the two-partitioned area. As to $\mu \pm 2\sigma$, it was possible to properly point at the area 1 and 2, which were parts of the two-partitioned area. As to $\mu \pm \sigma$, it was possible to properly point at the area 1, 2, 3 and 4, which were parts of the four-partitioned area.

Table 4. The accuracy of pointing gesture for Yaw (-36 degrees) after the correction

Number of partitions	Area No.	Central angle (degrees)	$\mu \pm \sigma$	$\mu \pm 2\sigma$	$\mu \pm 3\sigma$
2	1	-45.0	✓	✓	✓
	2	45.0	✓	✓	✓
3	1	-60.0	✓		
	2	0.0	✓	✓	
	3	60.0	✓	✓	
4	1	-67.5	✓		
	2	-22.5	✓		
	3	22.5	✓		
	4	67.5			
5	1	-72.0	✓		
	2	-36.0	✓		
	3	0.0	✓		
	4	36.0	✓		
	5	72.0			

From Table 4, as to $\mu \pm 3\sigma$, it was possible to properly point at the area 1 and 2, which were parts of the two-partitioned area. As to $\mu \pm 2\sigma$, it was possible to properly point at the area 1 and 2, which were parts of the three-partitioned area. As to $\mu \pm \sigma$, it was possible to properly point at the area 1, 2, 3 and 4, which were parts of the five-partitioned area.

3.3 Discussion

In one trial of pointing gesture, deviation was developed between the actual angle of pointing gesture and the angle which was meant to be. The analysis was made based on the idea that non-overlapping of adjacent areas meant that they were able to point properly, rather than obtaining the selection ability based on whether they were able to point at where they intended.

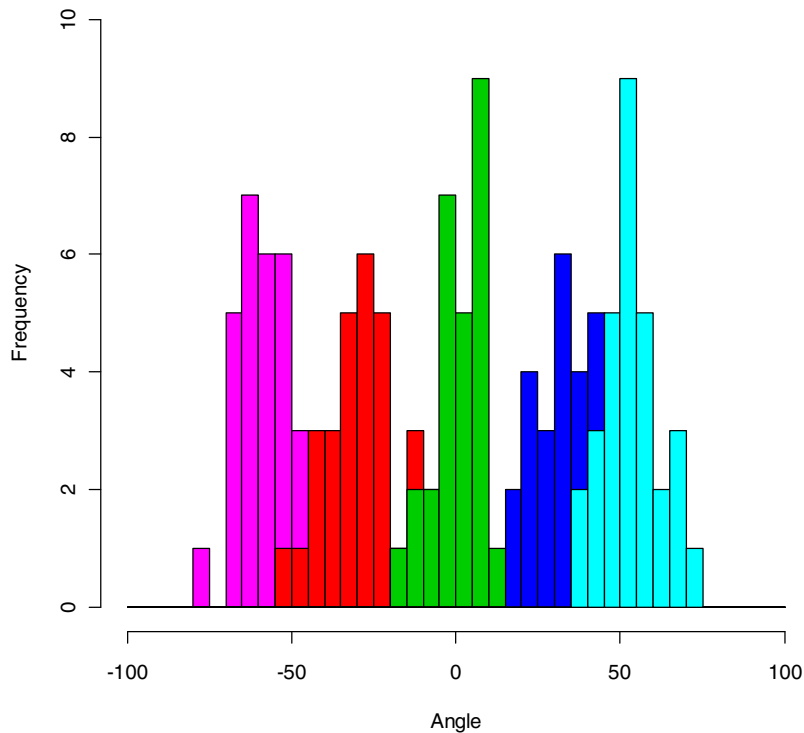


Fig. 3. Histogram of pointing gesture for Pitch of five-partitioned area

Figure 3 is the histogram of the results of partitioning the area into five toward the Yaw direction and at 0 degree of Pitch direction (horizontal surface). It is suggested that they can properly point more areas than four partitions. It is necessary to experiment while considering the analysis methods.

4 Experiment 2

It was experimented by removing the condition 3 of the experiment 1 and adding the adduction and abduction of wrists to the experiment 1. The experiment conditions and evaluation method were same as experiment 1. The experimental order was same as the experiment 1. The test subjects were 20 males and females who were in early twenties and right-handed. All of them had normal wrists joints.

4.1 The Experiment to Obtain the Selection Ability for Pitch

As the experiment 1, there was a tendency that the pointing angles uniformly deviated toward the same direction. By doing a regression analysis, corrected values were obtained based on the regression expression. Table 5 show the accuracy obtained by using the corrected data.

Table 5. The accuracy of pointing gesture for Pitch after the correction

Number of partitions	Area No.	Central angle (degrees)	$\mu \pm \sigma$	$\mu \pm 2\sigma$	$\mu \pm 3\sigma$
2	1	-45.0	✓	✓	✓
	2	45.0	✓	✓	
3	1	-60.0	✓	✓	
	2	0.0	✓	✓	✓
	3	60.0	✓		
4	1	-67.5	✓		
	2	-22.5	✓	✓	
	3	22.5	✓		
	4	67.5	✓		
5	1	-72.0	✓		
	2	-36.0	✓		
	3	0.0	✓	✓	
	4	36.0	✓		
	5	72.0	✓		

Table 6. The accuracy of pointing gesture for Yaw after the correction

Number of partitions	Area No.	Central angle (degrees)	-72deg $\mu \pm \sigma$	-36deg $\mu \pm \sigma$	0deg $\mu \pm \sigma$	36deg $\mu \pm \sigma$	72deg $\mu \pm \sigma$
2	1	-45.0	✓	✓	✓	✓	✓
	2	45.0	✓	✓	✓	✓	
3	1	-60.0	✓		✓		✓
	2	0.0	✓	✓	✓	✓	✓
	3	60.0	✓		✓	✓	
4	1	-67.5	✓		✓		
	2	-22.5		✓	✓	✓	
	3	22.5	✓	✓	✓	✓	✓
	4	67.5			✓		
5	1	-72.0					
	2	-36.0		✓	✓		
	3	0.0	✓	✓	✓		
	4	36.0			✓		
	5	72.0			✓		

As to $\mu \pm \sigma$, it was possible to properly point at the area 1, 2, 3, 4 and 5, which were parts of the five-partitioned area.

4.2 The Experiment to Obtain the Selection Ability for Yaw

It was possible to point properly up to five-partitioning of Pitch. It was experimented to examine the selection ability for Yaw as to the entire areas of five partitions of Pitch. The experiment was conducted under each condition where the movable surface of the wrists was fixed at -72, -36, 0 (horizontal), 36 and 72 degrees.

Results. The corrected measured values are shown in Table 6.

Discussion. It is the areas on the extreme left and the extreme right out of the entire area that showed a significant deviation of the observed values. It was found out that they became able to point properly at some areas after the correction. However, as to the extreme left of Yaw in the area 2 and area 3 in the five partitions of Pitch, they remained unable to point properly. It may be necessary to add other restrictions to pointing gesture.

5 Conclusion

In the experiment 1, they pointed with wrists joints under the condition where the arm joints were fixed and adduction and abduction of the wrists were restricted. By combining the obtained resolution abilities of pointing gesture at the 2-dimensional surface of Pitch and Yaw, it is suggested that the selection ability of selection behavior in the 3-dimensional space is 9 areas. The details of the 9 areas are the area 3, 4 and 5 out of five partitions of Pitch. The selection ability for Yaw in the area 3 of the five partitions of Pitch was four areas. The selection ability for Yaw in the area 4 of the five partitions of Pitch was four areas. The selection ability for Yaw in the area 5 of the five partitions of Pitch was one area. Combining those results indicates that the selection ability of selection behavior in the 3-dimensional space is 9 areas.

The experiment 2 was conducted by adding adduction and abduction of the wrists to the experiment 1. By combining the obtained resolution abilities of pointing gesture at the 2-dimensional surface of Pitch and Yaw, it is suggested that the selection ability of selection behavior in the 3-dimensional space is 22 areas.

6 Future Work

Since the selection ability obtained from the results had the added restrictions, they are not the true selection ability of free pointing gesture. As it is obvious from the results of this research report, the selection ability is improved as the degree of freedom of joints increases. It is necessary to experiment by changing the experimental conditions in the future to obtain selection ability of pointing gesture with more freedom.

In addition, the experiment methods used in this research were meant to obtain the 3-dimensional selection ability by combining those at 2-dimensional surface. It is necessary to further examine by using pointing gestures in the 3-dimensional space.

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