Personal Space of Small Mobile Robot Moving towards Crouching, Sitting and Supine Adult Males

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Abstract: In this paper, the authors present a basic study of the planning techniques for human-robot living spaces. Taking into account the previous studies, the authors clarify at what distances adult males feel comfortable with a small mobile robot. The authors investigated the impact of differences in position in a personal distance of the robot. The authors make the robot to move towards the subjects at different speeds and from five different angles (0°, 45°, 90°, 135° and 180°) while they were crouching, sitting on the floor and supine. In this experiment, about setting up a small mobile robot, the authors explained the robot does not have a support function for the people watching. A questionnaire survey was also conducted before and after the experiments. The result is that differences were out to personal distance with the robot due to the difference in position. The research finds that personal distance also becomes small position changes, sight line becomes lower. In addition, individual distance is increased when the slow speed as well as the paper before.

Key words: Small mobile robot, personal space, living space, position, the height of the eye.

1. Introduction

1.1 Research Introduction

Currently, many kinds of robots are produced, such as communication robots and bipedal robots. In addition, more robots are expected to be developed in Japan due to its aging society.

These robots will be put to work doing currently human jobs (robot receptionist), doing household chores (cleaning robot) and keeping their owners company (pet robot).

In this way, since the robot will be incorporated into people’s everyday lives, living spaces need to be designed that people and robots can share harmoniously.

1.2 Research Objectives

In this paper, the authors present a basic study of “study on planning techniques of living space in harmony with robots”. Taking into account the previous studies, they clarify at what distances adult males feel comfortable with a small mobile robot.

The authors had the robot move towards the subjects at different speeds and, from different angles while they were crouching, sitting on the floor and supine.

2. Methods

2.1 Experiment Method

The experiments were conducted over a ten-day period from July 20 to 30, 2011. The subjects were 24 male university students from 18 to 23 years of age. All subjects had 1.1 for the average visual acuity and were all able-bodied in Fig. 1.

The experiment using the experimental apparatus shown in Fig. 2, was performed in the gymnasium of the university campus. For details and shape of each part is shown in the figure.

A small mobile robot in Fig. 3 approached each subject from a distance of 5 m from five different
2.2 Experimental Conditions

In this experiment, “explained the robot does not have a support function for the people watching” About setting up a small mobile robot, to consider personal distance. The small mobile robot approached a subject from the right at 5 angles at a distance of 5 m. After the robot was stopped, the distance was measured from the reference point shown in Fig. 4 to the stop point. The measurement range was from the right side of the subject. Since there was no major difference between the left and right in previous studies, the authors assumed symmetry.

The subjects were given the following instruction: (1) Measure the distance when you do not want the robot to come any closer; (2) Twenty distance patterns will be measured for each position, five directions and two speeds. During measurement, avoid changing the direction of the body and please face the robot.

3. Experiment Conclusions

3.1 Tendency for Movement Angle and Velocity

From the data obtained from the experiment, the authors tried to consider the ideal distance between the people and a small mobile robot.

In Figs. 5-7, all three graphs have upward slants to the right.

3.1.1 For Crouch-Attitude

Fig. 5 compares the two speeds when subjects were crouching. It shows that subjects allowed the robot to come closer to them when it was moving at the slower speed. However, the robot was stopped at almost the same point at both speeds when approaching the
Table 1  Personal space of adult males (cm).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Angle</th>
<th>Speed</th>
<th>Average</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.08 m/s</td>
<td>0.24 m/s</td>
<td></td>
</tr>
<tr>
<td>Crouch</td>
<td>0 deg.</td>
<td>94.4</td>
<td>123.0</td>
<td>108.7</td>
</tr>
<tr>
<td></td>
<td>45 deg.</td>
<td>112.8</td>
<td>130.3</td>
<td>121.5</td>
</tr>
<tr>
<td></td>
<td>90 deg.</td>
<td>116.8</td>
<td>124.2</td>
<td>120.5</td>
</tr>
<tr>
<td></td>
<td>135 deg.</td>
<td>125.1</td>
<td>129.9</td>
<td>127.5</td>
</tr>
<tr>
<td></td>
<td>180 deg.</td>
<td>129.8</td>
<td>129.5</td>
<td>129.6</td>
</tr>
<tr>
<td>Sitting floor</td>
<td>0 deg.</td>
<td>121.7</td>
<td>123.2</td>
<td>122.4</td>
</tr>
<tr>
<td></td>
<td>45 deg.</td>
<td>123.5</td>
<td>132.0</td>
<td>127.7</td>
</tr>
<tr>
<td></td>
<td>90 deg.</td>
<td>117.2</td>
<td>120.7</td>
<td>119.0</td>
</tr>
<tr>
<td></td>
<td>135 deg.</td>
<td>121.0</td>
<td>131.0</td>
<td>126.0</td>
</tr>
<tr>
<td></td>
<td>180 deg.</td>
<td>130.5</td>
<td>133.5</td>
<td>132.0</td>
</tr>
<tr>
<td>Supine</td>
<td>0 deg.</td>
<td>106.9</td>
<td>115.0</td>
<td>111.0</td>
</tr>
<tr>
<td></td>
<td>45 deg.</td>
<td>122.9</td>
<td>122.4</td>
<td>122.7</td>
</tr>
<tr>
<td></td>
<td>90 deg.</td>
<td>113.7</td>
<td>113.0</td>
<td>113.3</td>
</tr>
<tr>
<td></td>
<td>135 deg.</td>
<td>127.3</td>
<td>126.3</td>
<td>126.8</td>
</tr>
<tr>
<td></td>
<td>180 deg.</td>
<td>206.3</td>
<td>204.5</td>
<td>205.4</td>
</tr>
</tbody>
</table>

Fig. 5  Average graph of crouching adult males.

Fig. 6  Average graph of sitting-floor adult males.

Fig. 7  Average graph of supine adult males.

When the robot approached from 180°, the stop points for both speeds were 0.3 cm apart.

Therefore, when the subjects were crouching, they tended to let the robot come closer when it moved faster depending on the angle.

3.1.2 For Sitting-Floor-Attitude

In Fig. 6, the slower speed obtains the same results from all angles. On the other hand, the faster speed obtains an M-shaped graph that depicts a gradual upward slant to the right.

The stop points between the faster and slower speeds are 8.6 cm apart at 45° and 10 cm at 135°, which are both notable differences.

3.1.3 For Supine-Attitude

In Fig. 7, all angles except 0° show the same graph because speed is unimportant. Also, compared with the other angles, 135° and 180° greatly slant upward to the right.

In the supine position is considered for the position of the foot of the subjects had an effect on these.

In approaching from the other angle is almost the same whereas the distance, and a large 8.1 cm difference was observed in the difference between the personal space by the speed difference when approaching from the direction of 0°.

3.2 Verification of the Interaction between Movement Angle and Velocity

Two-way layout analysis of variance was used to verify whether speed or direction affect stop point more. Table 2 list the results for both speeds in all directions for each position.

3.2.1 For Crouch-Attitude

Interaction of speed and direction, $F(4,230) = 0.291$. No significant differences were observed in the interaction. The main effect of speed, $F(4,230) = 1.49$, is statistically significant at the 1% level. The main effect of direction, $F(1,230) = 0.586$, is significantly different.

This means that crouching subjects made the decision not to let the robot come any closer on the basis of the distance rather than the speed or direction.
Table 2  Verification of interaction of angle and speed.

<table>
<thead>
<tr>
<th></th>
<th>Speed</th>
<th>Main effect</th>
<th>Significance probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crouch</td>
<td>Main effect</td>
<td>$F(4,230) = 0.586$</td>
<td>0.673</td>
</tr>
<tr>
<td>Angle</td>
<td>Main effect</td>
<td>$F(1,230) = 1.49$</td>
<td>0.223</td>
</tr>
<tr>
<td></td>
<td>Main effect</td>
<td>$F(4,230) = 0.291$</td>
<td>0.884</td>
</tr>
<tr>
<td>Speed and angle</td>
<td>Main effect</td>
<td>$F(1,230) = 0.869$</td>
<td>0.38</td>
</tr>
<tr>
<td>Sitting floor</td>
<td>Speed</td>
<td>Main effect</td>
<td>$F(1,230) = 0.38$</td>
</tr>
<tr>
<td>Angle</td>
<td>Main effect</td>
<td>$F(4,230) = 0.269$</td>
<td>0.898</td>
</tr>
<tr>
<td></td>
<td>Main effect</td>
<td>$F(4,230) = 0.037$</td>
<td>0.997</td>
</tr>
<tr>
<td>Supine</td>
<td>Speed</td>
<td>Main effect</td>
<td>$F(1,230) = 0.009$</td>
</tr>
<tr>
<td>Angle</td>
<td>Main effect</td>
<td>$F(4,230) = 16.725$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Main effect</td>
<td>$F(4,230) = 0.045$</td>
<td>0.996</td>
</tr>
</tbody>
</table>

3.2.2 For Sitting-Floor-Attitude
Interaction of speed and direction, $F(4,230) = 0.037$. No significant differences were observed in the interaction. The main effect of speed, $F(4,230) = 0.38$, is statistically significant at the 1% level. The main effect of direction, $F(1,230)=0.269$, is significantly different.

The decisions of sitting subjects to stop the robot were probably not affected by the speed or direction.

3.2.3 For Supine-Attitude
Interaction of speed and direction, $F(4,230) = 0.045$, significant difference was observed. No significant differences were observed in the interaction. Looking at each main effect, the main effect of speed, $F(1,230) = 0.009$, significant difference was observed. The main effect of direction, $F(4,230) = 16.725$, is statistically significant at the 1% level.

To put the body in the direction of 180° for supine is considered that due to take that long a distance, this significant difference.

4. Consideration
A small mobile robot approached subjects who were crouching, sitting on the floor, or supine until they decided they did not want it to approach them anymore. The robot was stopped at different distances from the subject depending on the speed, angle and posture.

The differences between postures were small as can be seen in Figs. 8 and 9. At the slower speed, the robot was allowed closer to the crouching subjects, especially when approaching from the front. Floor sitting was seen as the speed difference between the non-diagonal position is squatting.

When the subjects were supine, the robot was stopped the same distance from the subject at both speeds, as shown in Figs. 7 and 10. When supine, subjects had a lower line of sight, which might have impaired their sense of distance. Also, supine subjects had difficulty seeing the robot when it approached from 0°.

Therefore increased hostility, and a small mobile robot approaching at a faster rate, and take a lot of distance.

For each of the three positions, when the robot was moving at the faster speed, the subjects stopped it at similar distances at 45°, 90° and 135°.
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Fig. 8  Personal space of adult males in crouch (cm).

Fig. 9  Personal space of adult males in sitting-floor (cm).

Fig. 10  Personal space of adult males in supine (cm).

Fig. 11  Comparison of personal space of each posture.
In addition, the authors compare the experimental results of this and standing, sitting. Fig. 11 depicts the height of the eye and the average distance of each posture. From this figure, personal space with the robot has been close enough. Compared with the previous results of subjects sitting in chairs and standing, the subjects in our experiment had a lower line of sight. This is considered to be close the personal distance as the distance approaches the robot and human.

5. Conclusions

This study found the following about how people reacted to a small mobile robot coming towards them while they were crouching, sitting on the floor or supine.

1. Subjects were less susceptible to speed when the robot approached from behind;
2. How they reacted to the robot when it moved more slowly depended on their posture;
3. Considered impact on the personal distance by the speed and almost no about “supine”;
4. Subjects stopped the robot closer to them when their line of sight was lower.

References