A System for Visualizing Human Behavior based on Car Metaphors

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ABSTRACT
There are many accidents such as bumping between walkers in crowded places. One of reasons for them is that it is difficult for each person to predict the behaviors of other people. On the other hand, cars implicitly communicate with other cars by presenting their contexts with equipments such as brake lights and turn signals. In this paper, we propose a system for visualizing the user context by using information presentation methods based on those found in cars, such as wearing LEDs as brake lights, which can be seen by surrounding people. The evaluation results when using our prototype system confirmed that our method visually and intuitively presented the user context. In addition, we evaluated the visibility effects of changing the mounting position of the wearable devices.

Categories and Subject Descriptors
J.4 [Computer Applications]: Social and Behavioral Sciences

General Terms
Human Factors

Keywords
Visualizing, Car Metaphor, Wearable Computing

1. INTRODUCTION
In crowded places like busy shopping complexes, there are many accidents such as bumping between walkers. For example, to suddenly stop walking sometimes causes bumping into a person from behind, or a stream of pedestrians interfering with a person who wants to go to the other side. It is especially difficult for elderly people or handicapped people to adapt to such a fast stream of people. Moreover, in the situation where two walkers get in the way of each other on an even less crowded street, they may become panic-stricken. One of the reasons for these troubles is that it is difficult for each person to predict the behaviors of other people. On the other hand, forms of transportation, such as trains and cars, implicitly communicate with others by presenting their contexts using their equipment such as signals or the horn. In particular, although a car does not have a centralized facility to regulate traffic like a control room, they present their behaviors to the surrounding cars and people implicitly and intuitively. The reason why people can intuitively understand car behaviors is that we have implicit knowledge of the context presentation methods of cars.

There is a possibility that people can grasp the contexts of other people by visualizing human behaviors using such implicit knowledge from the presentation methods using a car. In this paper, we propose a system for visualizing a user’s context for the surrounding people that is based on the information presentation mechanism in cars. Our system offers a safe and smooth walking using car-metaphors such as wearing LEDs for use as brake lights and turn signals.

We assume that a presentation method using implicit knowledge is more easily understandable than methods directly presenting the content of the contexts and the intelligibility of implicit knowledge of cars is affected by the position of the wearable devices. To clarify these assumptions, we experimentally evaluated our method using a prototype and confirmed the validity of these assumptions. We found from the evaluation results that our approach could possibly be used to present a principle of the information presentation method for universal communications in the real world.

The remainder of this paper is organized as follows. Section 2 explains the related work and Section 3 details our method. Section 4 describes the implementation, and Section 5 evaluates our system. Finally, Section 6 presents our conclusion and planned future work.

2. RELATED WORKS
Various systems that visualize human activities have been proposed. Eco-MAME [1] promotes environmentally conscious activities in local communities. The system accumulates the user activities via the Internet and shows the activities of other users who are in a similar environment such
Table 1: Information presentation methods for cars

<table>
<thead>
<tr>
<th>Presentation method</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake light</td>
<td>Slowing down, Stop</td>
</tr>
<tr>
<td>Turn signals</td>
<td>Turning, Changing lanes, Pulling over</td>
</tr>
<tr>
<td>Hazard lights</td>
<td>Stop, Presenting emergency, backing up</td>
</tr>
<tr>
<td>Reversing lights</td>
<td>Caution</td>
</tr>
<tr>
<td>Passing lamps</td>
<td>Presence of car</td>
</tr>
<tr>
<td>Horn</td>
<td>Presence of car</td>
</tr>
<tr>
<td>Clearance lamps</td>
<td></td>
</tr>
<tr>
<td>Caution sound</td>
<td></td>
</tr>
</tbody>
</table>

as people living in similar neighborhoods. Since this system aims to present the feeling of cooperation and competition by visualizing the activities, it differs from our system, which visualizes the activities of walkers in real-time. On the other hand, there is the application Sprocket [2] for the iPad that is used as a method for visualizing the behaviors of a bicycle rider. A rider uses this application while carrying an iPad on their back. The application displays four pictograms such as an arrow and a pointing finger that are used to signal turning right, turning left, going straight, and slowing down. However, since the pictograms are originally made, it is difficult for surrounding people to intuitively recognize their meanings. In addition, the system does not resolve the problems for walkers mentioned in the previous section because it displays information after the completion of a user’s activity.

The proposed system visualizes user contexts and helps to alter the behaviors of the surrounding people. Previously, various walking control methods have been proposed such as a system that controls walking based on the congestion reduction in public facilities or a navigation system that guides a user in the right direction. "CabBoots" [3] is a guidance system using a device that inclines the soles of shoes. The system navigates users implicitly by controlling the user orientation using the devices on the soles. Moreover, Yoshikawa propose a pedestrian traffic control method using the Auditory Stimulation on Optokinetic Vection [4]. The vection is controlled by a lenticular lens placed on a floor that has an effect on the visual stimulus. In these systems, the system devices need to be placed on the floor or at the feet of those who are receiving guidance. Therefore, the system does not suit the usage environment of the proposed system in which the place where the system is used and the target who receives the information are unspecified.

3. SYSTEM DESIGN

3.1 Information visualizing methods

The proposed system visualizes user behaviors based on the visualization methods used in cars to inform surrounding people of the context of the user. To do this, the user wears sensors and actuators such as LEDs and accelerometers. Table 1 lists examples of information presentation methods for cars, such as informing about turning or stopping using turn signals or brake lights. Most people can intuitively recognize such meanings since they are familiar with the presentation methods for cars in their daily lives and they have implicit knowledge of these methods.

Figure 1 shows the structure of the proposed system, and Figure 2 illustrates a user wearing a Jacket Type prototype.

Figure 1: System structure.

The proposed system has the following visualizing functions:

Brake light: When the button on the input device is pushed or the sensors detect the user is slowing down or stopping, the red LEDs on the back illuminate, as shown in the upper left photo in Figure 4, to present the intention of slowing down or stopping. ① in Figure 3 also illuminates.

Blinker: When the button on the input device is pushed, yellow LEDs on the back blink, as shown in the upper right photo in Figure 4, to present the intention of turning, changing lanes, or pulling over. ② in Figure 3 also blinks.
Figure 3: Snapshot of information window.

Figure 4: Presentation examples of prototype.

Hazard lights: When the button on the input device is pushed, both yellow LEDs on the back blink, as shown in the lower left photo in Figure 4 to present the user’s presence.

Head lamps: When the button on the input device is pushed, white LEDs on the chest illuminate, as shown in the lower right photo in Figure 4 to present the user’s presence. Moreover, blinking head lamps will draws the attention of the surrounding walkers.

Engine sound: The system outputs engine sounds using a speaker to present the user’s presence based on the walking speed. 3 in Figure 3 changes according to the walking speed.

Horn: When the button on the input device is pushed, the system outputs a horn sound from a speaker, and draws the attention of the surrounding walkers.

Rear view camera and backup sensor: The user is made be aware the circumstance behind him/her from a sensor alarm or a rear view image. The rear view image is shown as 4 in Figure 3.

3.2 Information acquisition for visualizing

The system correctly recognizes the user context for visualizing user behaviors because presentation of incorrect information would cause an accident such as bumping between walkers. On the other hand, we assume that the system will be used in daily life, so that complex operations or unnatural actions are not practical as input methods for the visualization. Therefore, the proposed system recognizes user behaviors using wearable sensors [5][6][7]. The contexts that can be recognized by using wearable sensors do not need any input from the user. On the other hand, there are several contexts that are difficult to recognize by using wearable sensors, such as turning right, which should be recognized before the actual turning. For such contexts, the user informs the system of the context using simple operations such as pushing a button on the input device.

4. IMPLEMENTATION

We implemented a prototype of the proposed system. In this system, a user uses a Nintendo Wii remote controller as the input device, and wireless accelerometers (WAA-006) by Wireless Technology on the user’s feet are used to recognize the user walking states and speed contexts by calculating the variances of the velocity. We use a Single-eye HMD Shimadzu DataGlass3/A, a Microsoft LifeCam RLA-00007 as a rear view camera, and a Distance Measuring Sensor SHARP GP2D12 as a backup sensor. We developed the system software using Microsoft VisualC# 2008.

We implemented the following four types of visualization devices.

Jacket type (Figure 2): It has lamps, a sensor, and a camera on the front and back of a jacket. A user uses the system by wearing it.

Movable type (Figure 5): It consists of a rear unit including turn signals and brake lights, and two front units including turn signals. A user uses the system by attaching these units anywhere such as their backpack, bag, or belt.

Bracelet type (Figure 6): It consists of turn signal rings that works as turn signals and brake light rings that work as brake lights. A user uses the system by wearing the rings on his/her wrists.

Headphone type (Figure 7): It has turn signal lights and brake lights on a set of headphones. The structure of the lamps is almost the same as that of the Bracelet type. A user uses the system by putting on the headphones.

The Jacket type controls the light of the LEDs using a microcomputer called Gainer connected to a wearable PC via a USB cable, and the others control the LEDs using Arduino with xBees wireless unit.

5. EVALUATION

We conducted three experiments to evaluate the effectiveness of the proposed system. The first experiment was a visualization ability measurement in a real environment, the second was a comparison to the other information presentation methods, and the last was a comparison of the presentation efficiency among visualizing devices.

5.1 Evaluation of effectiveness in real environment

We made subjects watch videos in which the system is being used in a real environment and answer a questionnaire to evaluate the effectiveness of the proposed system. There were 16 male subjects ranging from 21 to 24 years old, and they evaluated the five videos recorded in a busy shopping center.
complex and around an elevator. The screenshots from each video are shown in Figure 8. Each video contains a scene in which a system user presents his/her next action using lighting or blinking lamps, and the video was finished before the user actually does the next action. Table 2 lists the contents and examples of the correct answers for each video. The subjects were shown these videos in random order and answered the forecast of his/her next action on the basis of the system functions in the videos. We showed each video only once to the subjects. Whether the answer is correct or not is decided based on the example answers in the table. For example, in video No. 4, \( \text{He will pass on my right side.} \) or \( \text{He will go leftward.} \) are correct answers. However, \( \text{He is greeting.} \) is not a correct answer.

Table 3 lists the number of people giving correct answers and examples of incorrect answers for each video. As a result, we believe that the proposed system plainly showed the user contexts in the four videos except for in video No. 3. One of the reasons for this result is that this video showed the user wearing the system for very short time since he/she suddenly appears from the stream of other walkers. That is, there is a possibility that even the proposed system cannot correctly show the presentation when the surrounding people glance at it.

Although the number of people choosing the correct answer is minimal for the above mentioned reason in video No. 3, we confirmed that the presented information from the proposed system in a real environment was effective throughout the experiment.

5.2 Comparison to other information presentation methods

Our proposed system visualizes user context using the presenting information methods of cars. The reason why we selected these methods is that we believe the surrounding people swiftly and exactly understand the user context based on their implicit knowledge about the context visualizing methods of real cars. To confirm the hypothesis, we conducted comparative evaluations of four situations: with the proposed method, with two other information presenting methods, and without visualization. We prepared the comparative methods using figures (pictograms) and words (in Japanese), moreover, we used 7-inch displays on the front and back of a user as the presenting information device for these methods. Figure 9 shows the presentation examples...
Table 2: Content of each video.

<table>
<thead>
<tr>
<th>No.</th>
<th>Scene Used</th>
<th>brake function</th>
<th>Camera viewpoint</th>
<th>Example answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Walking in mall</td>
<td>brake lights</td>
<td>Following user</td>
<td>Slowing down</td>
</tr>
<tr>
<td>2</td>
<td>Walking in mall</td>
<td>Left blinker</td>
<td>Following user</td>
<td>Turning left</td>
</tr>
<tr>
<td>3</td>
<td>Walking in mall</td>
<td>Right blinker</td>
<td>Passing on his right side</td>
<td>Turning right</td>
</tr>
<tr>
<td>4</td>
<td>Getting off elevator</td>
<td>Left blinker</td>
<td>Waiting for elevator</td>
<td>Passing on my right side</td>
</tr>
<tr>
<td>5</td>
<td>Standing in mall</td>
<td>Hazard lights</td>
<td>Approaching the user</td>
<td>Standing still</td>
</tr>
</tbody>
</table>

Table 3: Experimental results from actual environments.

<table>
<thead>
<tr>
<th>Percentage of correct answers</th>
<th>Example of incorrect answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>14/16</td>
<td>Turning left. Having passed.</td>
</tr>
<tr>
<td>16/16</td>
<td></td>
</tr>
<tr>
<td>4/16</td>
<td>No idea. He is greeting acquaintance.</td>
</tr>
<tr>
<td></td>
<td>He will step to right side.</td>
</tr>
<tr>
<td>14/16</td>
<td>He greeted person who suddenly appeared.</td>
</tr>
<tr>
<td>15/16</td>
<td>No idea.</td>
</tr>
</tbody>
</table>

Figure 9: Presentation examples of comparative systems.

![Turning left](image)

Method using Figures

![Standing still](image)

Turning left

Method using Words

![左折します](image)

Turning left

![停止中](image)

Standing still

Figure 10: Snapshot of user using comparative method.

Figure 11: Scene for turning left.

Figure 12: Scene for standing still.

As a result of the multiple comparisons, there are significant differences between the scores of the proposed system and those of the system using figures for the easiness of recognizing the meaning for Turning left (p<0.01), and between the scores of the proposed system and those of the system using words for the easiness of seeing presentation in both scenes (Turning left: p<0.01, Standing still: p<0.01). In addition, there were also significant differences between the scores of the proposed system and no visualization (Turning left: p<0.01, Standing still: p<0.01). From these results, we confirmed that the context of walkers was barely understood without visualization.

When we took into consideration items in which significant differences were found, moreover, we confirmed that the system using figures could not exactly convey the meaning...
Table 4: Average score for each situation.

<table>
<thead>
<tr>
<th>Turning left</th>
<th>Standing still</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easiness of recognizing meaning</td>
</tr>
<tr>
<td>No system</td>
<td>2.1 (Points)</td>
</tr>
<tr>
<td>System with figures</td>
<td>4.1</td>
</tr>
<tr>
<td>System with words</td>
<td>4.9</td>
</tr>
<tr>
<td>Proposed system</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Figure 13: Positions of worn devices.

of the presentation in the standing scene. This may be because people sometimes mistakenly recognize an illustration of a hand as a command for them (not as the information of the system user), while a presentation itself is conspicuous. Even if other illustration are used, the same problem will happen. On the other hand, for the system using words, the scores of the easiness of seeing the presentation were low because the system presents information only in characters, which cannot be seen at a distance. The system is perfectly conveys the information, but it requires more time for surrounding people to know the contents the system presented. In contrast, the proposed system presents the information conspicuously because it only uses simple lighting, and presented information is easily understandable since we employ car-metaphors. Accordingly, we confirmed that our proposed system had advantages over the comparative methods.

The results in this section suggest that information presentation for surrounding people outdoors should be swiftly and exactly presented using a small amount of information without using a method that provides several meanings such as pictograms, but then, methods using implicit knowledge that people already have are effective for presenting information. This is because the implicit knowledge complements the presented information even if it is insufficient. When using methods that do not have the complementation, the surrounding people may misunderstand the meaning of presentation or it may take too much time for them to recognize the information because they need too much information to convey the context perfectly.

5.3 Evaluation of differences between presentation devices

The Jacket type device that we used in the evaluation in the previous subsection has lamps at chest level. In this section, we examined whether the various types of devices mentioned in Section 4 can also convey the information to the surrounding people.

Figure 13 shows snapshots of a user wearing each type of device. The positions of the wearable devices were on the lower portion of a knapsack (Knapsack A), the upper portion of a knapsack (Knapsack B), Shoulder bag, Bracelets, and Headphones. The subjects watched six videos of each wearable position including the Jacket type and answered the questionnaire. Each video consists of the three scenes: a user turning left, a user slowing down, and a user standing still. The subjects evaluated the easiness of recognizing the meaning or intention and the easiness of seeing the presentation for each position by comparing the Jacket type on 5 levels (5: easier than Jacket type, 3: same as Jacket type, and 1: harder than Jacket type). Figure 14, 15, and 16 show some screenshots of these scenes.

Table 5 lists the average scores for each position. There was no position in which the scores are clearly higher than those for the Jacket type. In addition, we conducted a statistical test against five positions besides the Jacket type. We measured the differences for each evaluation item, the easiness of recognizing the meaning and the easiness of seeing the presentation for each of three scene, using Steel-Dwass test.

As a result of multiple comparisons, almost all pairs that are significantly different are the combinations of the scores of the two positions on a knapsack and the scores for the others. In the easiness of recognizing the meaning, the scores for both Knapsack A and Knapsack B in all three scenes are different to those of the Shoulder bag, Bracelet type, and Headphones type (Turning left, Knapsack A vs Headphones type: p<0.05, the others: p<0.01). In the easiness of seeing presentation, the scores for Knapsack A when Turning left are different to those of the Shoulder bag and Bracelet type (Shoulder bag: p<0.01, Bracelet type: p<0.05), and the scores for Knapsack A when standing still are different to
Table 5: Average score for each position.

<table>
<thead>
<tr>
<th>Turning left</th>
<th>Slowing down</th>
<th>Standing still</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Easiness</strong></td>
<td><strong>Easiness</strong></td>
<td><strong>Easiness</strong></td>
</tr>
<tr>
<td>of recognizing</td>
<td>of seeing</td>
<td>of recognizing</td>
</tr>
<tr>
<td>Knapsack A</td>
<td>2.8 (Points)</td>
<td>2.9</td>
</tr>
<tr>
<td>Knapsack B</td>
<td>2.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Shoulder bag</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Bracelet</td>
<td>1.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Headphones</td>
<td>1.9</td>
<td>2.1</td>
</tr>
</tbody>
</table>

The reason for this seems that the mounting height of Knapsack B is higher than that of Knapsack A and the height is the same as that of the Jacket type. Overall, lamps at high positions were easily recognized as devices for presenting information, thus, the Headphones type system got slightly high scores too.

Given these facts, we found that both the visualization device of which the shape does not differ from that of cars can effectively convey the meaning of the presented information to surrounding people and that a device mounted in a high place within the limits of a body can effectively present information to them. This suggests that not only just the behaviors of the devices but also the positional relationship among devices are significant to make the surrounding people recall their implicit knowledge.

6. CONCLUSION

We proposed a system for visualizing the user context for surrounding people based on the information presentation mechanisms on cars for the purpose of preventing accidents between walkers and offering safe and smooth walking environments. Our prototype system visualizes the user behavior such as turning left or stopping, using car-metaphors such as wearing LEDs as brake lights and turn signals. Our evaluation results confirmed that the system could show the intent of a user to the surrounding people in real environments such as a busy shopping complexes. Additionally, our system using car-metaphors is superior to systems using other methods in intuitiveness and quickness in presenting information.

As a result of the evaluation experiments, to make communication such as the presentation of one’s information to their surroundings outdoors, the presentation method based on implicit knowledge such as that in the proposed system is superior to the methods using objects that can present the dual meanings such as a pictogram. We also found that the devices need to be placed at positions that make people recall their implicit knowledge because the position of these devices affects the easiness of conveying information.

In future, we will add more feedback to the users in the system. The current feedback includes only the walking state of the user, the run state of the system, and an image of the back view. However, we are considering adding feedback such as an overview image of around the user using a camera on the user and offering a safe direction to proceed when recognizing the flow of the walkers around the user by using a body camera. We are going to use actual traffic rules and the customs of cars when we do this.
7. ACKNOWLEDGMENTS

This research was supported in part by a Grant in aid for Precursory Research for Embryonic Science and Technology (PRESTO) from the Japan Science and Technology Agency and by a Grant-in-Aid for Scientific Research(A)(20240009) from the Japanese Ministry of Education, Culture, Sports, Science and Technology.

8. REFERENCES


