Homunculus: the Vehicle as Augmented Clothes

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ABSTRACT

In this paper we propose to add a new system with valuable functionalities to vehicles. We call it "Homunculus". It is based on a new concept of interactions between humans and vehicles. It promotes and augments nonverbal communicability of humans in the vehicles.

It is difficult to communicate with the drivers in the vehicles by eye contact, hand gestures or touching behavior. Our "Homunculus" is a system to solve these problems. The instruments of "Homunculus" are composed of three system modules. The First is Robotic Eyes System which is a set of robotic eyes that follows drivers eye movements & head rotations. The Second is Projection System which shows drivers hand gestures on the road. The Third is Haptic Communication System which consists of IR Distance Sensors Array on the vehicle and Vibration motors attached to the driver. It gives drivers the haptic sense to approaching objects to the vehicle. These three Systems are set on vehicle's hood or side.

We propose the situation that humans and vehicles can be unified as one unit by Homunculus. This system works as a middleman for communications between men and vehicles, people in other cars, or even people just walking the street. We suggest the new relationship of men and their vehicles could be like men and their clothes.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – Interaction styles

General Terms

Human Factors

Keywords

vehicle, eye-tracking, projection, physical feedback

1.INTRODUCTION

There are communication gaps between people who are inside the vehicles and people outside the vehicles(ex. pedestrians or other vehicles). Their intentions are different and consequently accidents or stressful situations occur. One of our goals of this project is that we can easily express our intentions from inside the vehicle to outside. In another word the human and vehicles become one through by our system.

2.RELATED WORK

There are several works related to our approach. As we pointed out it is important to make smooth communication between the inside of a vehicle to humans outside. There are advanced researches done on related subject matter by such as Matsumaru, et al.[1][2][3] which suggest the several ways to indicate the robotic system's next behavior. It uses Eye movement of robotic systems[1], Direction Display[2] and Projection[3]. These units indicate system's behavior to the human. However, these are the researches about the way to notify something to humans by robots. Therefore, these are not the human to human communication systems.

The difference between moving robot's interaction and vehicles' interaction is that the vehicle has its driver. The one of the

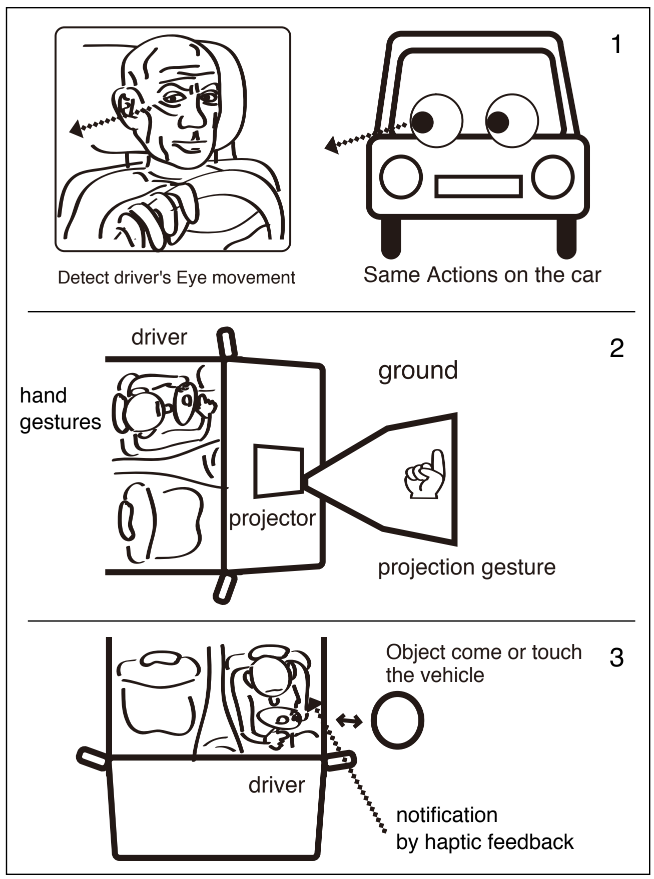

Figure 1. Our System Concepts(1.1,1.2,1.3)

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problems facing vehicle-human interaction is its difficulty of communicating between the driver and outside humans.We would like to refer to TOYOTA's advanced research project[4] in this field.TOYOTA made a system which indicated the direction that the vehicle should take by the lights emitted by the vehicle on the road. It is a kind of substitution for blinkers. We take different approach to enhance the communications by elevating driver's nonverbal communication with Homunculus system.

3.Concept

3.1 Our Approaches

We have repeatedly said our system supports human nonverbal communications. The nonverbal communications are often categorized into three categories[5]; "Communication Environment", "Communicator's Physical Characteristics" and "Body Movement and Position". Our system targets "Body Movement and Position" and especially to "Eye Behavior", "Gestures" and "Touching Behavior". We focused on these communications because drivers use their one hand, both feet and legs for the driving at least and they could use their eyes, one hand and skins for nonverbal communication. We applied these three nonverbal communications to vehicle's ability. This was important since our foremost aim is to set a seamless communication between human(driver) and the vehicle. In order to realize this aim we chose the following methods.(fig.1).

Firstly, in regarding to the Eye Behavior we made the eye detecting system and the robotic eyes follow driver's eye movements.(fig.l.1). It is a second set of eyes of the driver so to speak. The people outside the vehicle are able to understand where the driver's eyes are focused since they can see the robotic eyes movement in front of the vehicle.

Secondly, about the road projection system. This system shows the driver's hand gestures and his movements to other vehicles and pedestrians which are projected on road (fig.l.2). It provides shared information of driver's intention and what's going on inside vehicle to outsiders.

Thirdly, we focus on the fact that inter-vehicle communication or human-vehicle communication is lack of Touching Behavior. To solve this problem we relied on the haptic device and used multiple IR distance sensors (fig.l.3). These sensors detect the objects approaching or touching the vehicle. Then, driver inside the vehicle feels haptic feedback on his skin.

We combined these three features in one system in order to realize the human nonverbal communication on the vehicle.

3.2 Human as a "Homunculus" in the vehicle

The word homunculus is Latin meaning little human. It originally came from a myth. It is said that there are small humans inside of men's brains and those little humans control our physiological and psychological conducts. Although it is totally unscientific it was a kind of eye opener for us. A little driver in a vehicle can command the movement of the vehicle through nonverbal communications. It can be said that the mythical Homunculus is a perfect example of our system. Hence, we name the system "Homunculus".

4.SYSTEM IMPLEMENT

Homunculus is implemented as three system parts that are explained below. These system sets on the vehicle as figured in fig.2. Three systems are separated to six functional modules. These are Limbus Tracker + 2D Marker Detection System, Robotic Eyes, Distance Sensors Mapped on the vehicle's hood or side, Vibration feedback system on the human clothes or skin, Gesture Capturing System by depth camera and Gesture Projection System. The combination of these modules enable us seamless communication between drivers and outsiders of vehicle.

4.1Robotic Eyes and 2D marker based Limbus Eye-tracker

In this part, we state a part of our system that shows driver's eye behavior in order to support eye contact between driver and pedestrians or other vehicles.

We set the two Robotic Eyes outside of the vehicle(fig.3). It is connected to the 2D marker(fig.3.1) based Limbus Eye tracking system(fig.3.2). Our Robotic Eyes(fig.3.4) move horizontally and it could turn around 140 degrees. Our eye tracking system based on the 2D marker system[6] for recognition of head position and rotation. 2D marker is recognized by web camera(fig.3.3) beyond the steering wheel. Then, "Limbus Xtracker" system checks the eye movement. After that, this system calculates where the driver looks at. There are some systems using Limbus tracker[7] for Eye tracking, such as Aided Eyes[8]. Our Limbus tracking system targets on especially horizontal eye movements. For this reason, we set Limbus Tracker as X shaped.

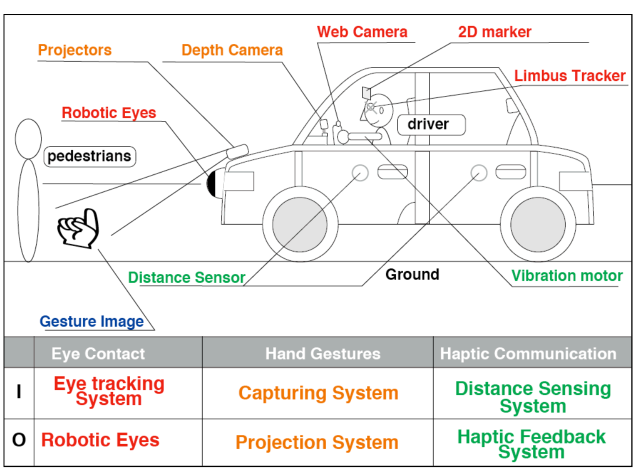

Figure 2. System Overview

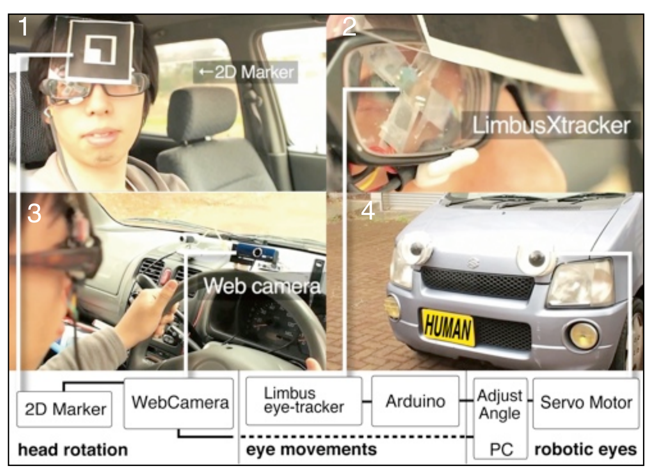

Figure 3. Eye Tracking System & Robotic Eyes

The combination of 2D marker and Limbus Tracker enables us the recognition of the rotation and movement of driver's head and Eye movements. For these features, this system could be able to detect which direction the drivers look through the windscreen and Robotic Eyes set outside could follow the driver's eye movements. So, the pedestrians or other driver's in other vehicles could recognize driver's eye movements. This system supports that they could recognize as if they are making real eye to eye contact.

4.2Gesture Projection System
In this part, we state a part of our system which enhances driver's hand gestures.

Our current vehicle system has projection navigation system for the road[9]. We use this road displaying system also as gesture displaying system(fig.4). The depth camera(fig.4.1) is set in front of the driver's seat. It is programed to recognize the depth and erases other objects such as steering wheel, driver's arm off camera images by using depth parameter. Then, this system captures the images from programmed area of the driver's seat. After that, this system sends 3D transfer images(depth parameter mapped as alpha channel) for the road projection(fig.4.2). The image is rotated in the projector before it is projected. We used road as the external display of the vehicle from the viewpoint of gesture images' position, their sizes and information sharing.

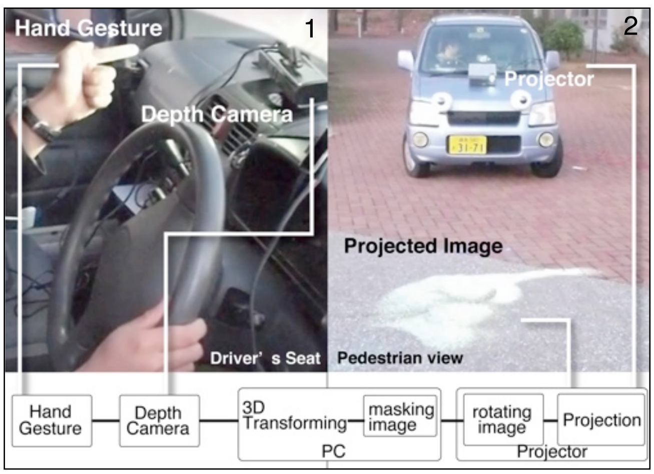

Figure 4. Gesture Projection System

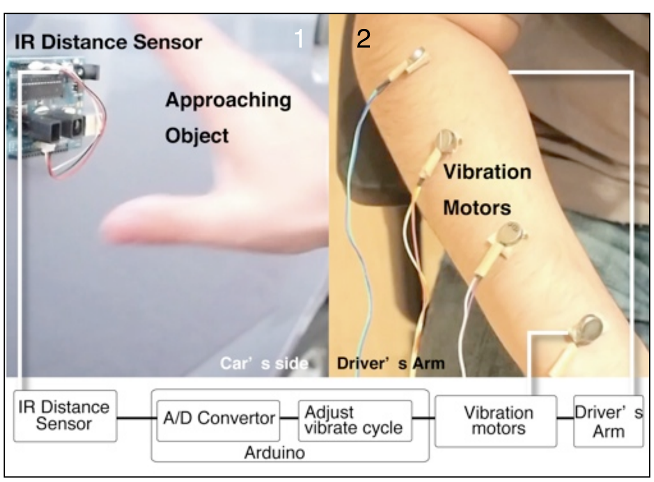

Figure 5. Haptic Communication System

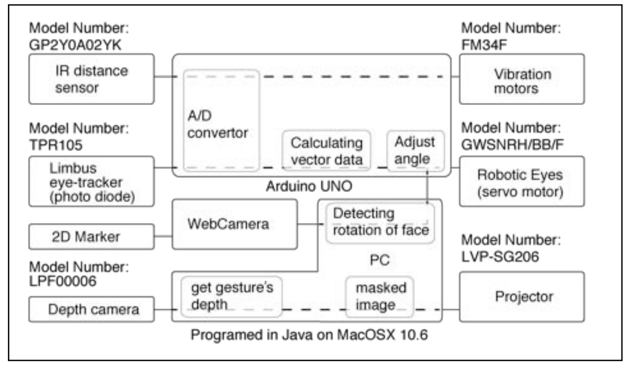

Figure 6. System Components

4.3 Haptic Communication System
In this part, we introduce a part of our system for the haptic communication between drivers and pedestrians or other vehicles.

Our Haptic Communication System(fig.5) consists of IR Distance Sensing Systems(fig.5.1) and Vibration Motors(fig.5.2). IR Distance Sensors are set on the vehicle surfaces. They are connected to the vibration motor on the driver's clothes or the skin. Distance Sensors measure the distance of surrounding objects to the vehicle. If someone or something is near by the vehicle, the system recognizes the approaching. Then, vibration motors gives physical feedback to the driver. The system is programmed that when the objects comes closer, the vibration becomes harder. It provides driver a haptic communication from the vehicle and near surroundings. The haptic feedback works as if driver's skin and vehicle's surface are unified.

4.4 System Specs & Using Modules
Homunculus is developed on MacOSX 10.6 & Programed in Java & C++. We used Arduino & Processing for all modules. Homunculus system components are posed in fig.7 and specs are explained in table 1.

Table 1. System Specs & Using Modules

System	Spec	Using Modules
Robotic Eyes	Eyes Rotation Speed: 60deg/0.11s	two acrylic transparent balls, two styrene balls (pupil), servo motor (GWSNRH/BB/F) and Arduino UNO
2D marker based Limbus Eye-Tracker	Accuracy : 70-90% (2D Marker) 50-60% (Limbus Tracker)	4 photodiode (TPR-105), ARToolKit for Processing and Arduino UNO
Projection system	Image processed in: 20- 30fps	Projector(LVP-SG206, Mitsubishi)
Capturing System	Captured by: 20- 30fps	Depth Camera, (LPF00006Kinect Microsoft)
Distance Sensing System	Detecting Distance: 150cm - 6cm	Distance Sensor (GP2Y0A02YK) andArduino UNO
Haptic Feedback System	13000rpm $17.6 m/s^2$(1.8G)	Vibration Motor (FM34F) and Arduino UNO

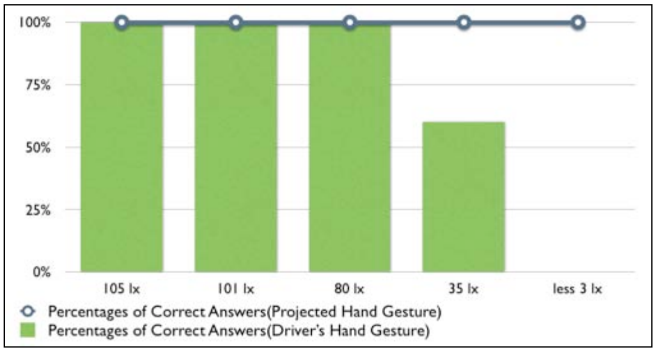

Figure 7. Experimental Results (Projection System)

5. RESULTS & DISCUSSIONS

5.1Robotic Eyes & 2D marker based Limbus Eye-tracker

Our Eye-tracking system separated into two parts. There is a difference of recognition accuracy in each system. We tested on 5 persons: 2D Marker based system could detect the markers in high accuracy(70-90%:depends on lighting condition) and Limbus Tracker system could detects eye movements approximately 50-60% after the calibration. Robotic Eyes System consists of servo motors. Their response speed depends on servo motors speed(60deg/0.12s). If they react with eyes high speed saccade movements, it is hard to understand where the driver is looking at.

We need to take the driving factors to Robotic Eye Movements. There is a difference of eye movements(by heads or by eyes), whether the car is being driven or not. It is possible to improve more reliable Robotic Eye movements. Further more if the lights or cameras attached to this robotic eyes ,we can make more application on this system.

5.2Gesture Projection System

We did the gesture recognition test on 10 peoples. They could understand(which hand shape is displaying on the road) in more than 99% accuracy. It depends on the lighting conditions and projectors brightness but the 3D transfer, Depth Camera System and Projection Systems worked well. Adding to that, We did the experiment for recognition test of driver's gesture and projected gesture in different light conditions. The experimental result is posed as fig.7. Projected gestures under 105 lx light conditions are recognized 99% accuracy. Driver's hand gesture without projection is recognized 60% accuracy in 35 lx light conditions and 0 % accuracy(they couldn't find the driver's hand) in less 3 lx light conditions. It suggests when projected image is difficult to see in well-lighted conditions, pedestrians could see driver's original hand gestures instead of projected gestures.

There are some discussion remained about images on the ground. In our old system[9] it has projected pictograms, numbers and characters(information about speed, distance etc) on the road. There are rooms to discuss about which is easier to understand for people outside: pictures,images or somethings else.

5.3Haptic Communication System

We did Approaching recognition test on 5 peoples. They could understand approaching objects when the objects in the distance of 30cm - 110cm, their average recognition starts in 62cm. All people experienced the sense of being rubbed when something goes fast above the IR Distance Sensors Array.

There are rooms also to discuss about where and how each part of human body is ideally fitted to parts of vehicles, like a homunculus in motor cerebral cortex[10].

6.CONCLUSION & FUTURE WORK

Our system suggests the concept of Augmented Vehicle in the view of enhancement of nonverbal communications. As a result, interaction between human and vehicles became ever closely possible.

For the next work, we implemented verbal communication system by parametric speakers. It enables drivers to select the people or vehicles to talk to and communicate with nonverbal communications which are categorized with vocal factors.

REFERENCES

[1] Matsumaru,T., Iwase., K, Akiyama, K., Kusada, T, and T, Ito. 2005. Mobile robot with eyeball expression as the preliminary-announcement and display of the robot's following motion. Autonomous Robots. 18, 2 (May. 2005), 231-246.

[2] Matsumaru, T., 2009. Mobile Robot with Preliminary-announcement and Indication Function of Upcoming Operation just after the Present. International Journal of Factory Automation, Robotics and Soft Computing. 2009, 1 (Jan. 2009), 102-110.

[3] Matsumaru, T., Hoshiba, Y., Hiraiwa, S., and Miyata, Y., 2007. Development of Mobile Robot with Preliminary-announcement and Display Function of Forthcoming Motion using Projection Equipment. J. of RSJ. 25, 3 (Apr. 2007), 410-421.

[4] TOYOTA. Company. 2004. News Release: Toyota, Hino, Daihatsu to Jointly Exhibit at 11th ITS World Congress. (September 22, 2004). http://www.toyota.co.jp/en/news/04/0922_2.html

[5] Knapp, M. and Hall, J., 2007, Nonverbal Communication in Human Interaction(7th Edition), pp7-9

[6] Rekimoto, J., 1998, "Matrix: A Realtime Object Identification and Registration Method for Augmented Reality", Proceedings of Asia Pacific Computer Human Interaction 1998 (APCHI'98), Japan, July 15-17, 1998.

[7] Smith, M, W., Peter, J., Warter, J., 1960, Eye movement and stimulus movement; new photoelectric electromechanical system for recording and measuring tracking motions of the eye. J. Opt. Soc. Am., 50(3):245.

[8] Ishiguro, Y., Mujibiya, A., Miyaki, T. and Rekimoto, J., 2010, Aided Eyes: Eye Activity Sensing for Daily Life, The 1st Augmented Human International Conference (AH2010), Megève, France.

[9] Ochiai, Y., Toyoshima, K., 2009, Indicatable Road: Mixed Reality Navigation System, Video on Youtube, http://www.youtube.com/watch?v=dfJ6n_XWLRk (accessed 2010-12-24)

[10] Rasmussent, T. and Penfield, W. 1947. Further studies of the sensory and motor cerebral cortex of man. Federation Proceedings. 6. 452-46