ON-GOING DATA COLLECTION FOR DRIVING BEHAVIOR SIGNAL

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ABSTRACT

We are developing a large-scale real-world driving database of more than 200 drivers using a data collection vehicle equipped with various sensors for the synchronous recording of multimedia data including speech, video, driving behavior, and physiological signals. Driver's speech and videos are captured with multi-channel microphones and cameras. Gas and brake pedal pressures, steering angles, vehicle velocities, and following distances are measured using pressure sensors, a potentiometer, a velocity pulse counter, and distance sensors, respectively. Physiological sensors are mounted to measure driver's heart rate, skin conductance, and emotion-based sweating. The multimedia data is collected under four different task conditions while driving on city roads and an expressway. Data collection is currently underway and to date 70 drivers have participated in the experiment. Data collection is being conducted in international collaboration with the U.S. and Europe. This paper reports on our on-going driving data collection in Japan.

Keywords — driving behavior, multimedia database, synchronous recording, physiological signal

1. INTRODUCTION

The automobile industry is becoming one of the most important industries for future economic development in the world. With the increasing emphasis on driving safety, comfort, and convenience, advanced driver assistance systems including adaptive cruise control, lane-keeping assist systems, and car navigation systems with speech interfaces have been developed over the last few decades. Future research directions will also focus on developing intelligent technologies for enhancing interaction between humans and vehicles.

For such research purposes, we are constructing a large-scale real-world multimedia driving database. We designed a data collection vehicle equipped with various sensors for the synchronous recording of speech, video, driving behavior, and physiological signals. Driver speech is recorded with twelve microphones distributed throughout the vehicle. Face images and a view of the road ahead are captured with three CCD cameras. Driving behavior signals including gas and brake pedal pressures, steering angles, vehicle velocities, and following distances are recorded. Physiological sensors are mounted to measure driver's heart rate, skin conductance, and emotion-based sweating on the palm and sole of the foot for detecting stress [1].

Multimodal data are collected while driving on city roads and an expressway under four different task conditions: reading words on signs and billboards while driving, being guided to an unfamiliar place by a human navigator on a cell phone with a hands-free device, reading random four-character alphanumeric strings by repeating after hearing, and interacting with a spoken dialogue system to retrieve and play music.

The characteristics of driving behavior differ from country to country based on their cultural and social backgrounds. We are collaborating internationally with research groups in the U.S. and Europe to share the worldwide driving data of various drivers [2], [3]. Similar kinds of data collection vehicles have also been developed in the U.S. and Europe. Data collection is currently underway in the three areas of the world.

The multimodal database will be published for research purposes such as noise robust speech recognition in car environments, detection of driver's stress while driving, and the prediction of driving behaviors to improve intelligent transportation systems. This paper reports on our ongoing driving data collection in Japan.

2. DESIGN OF DATA COLLECTION VEHICLE

A data collection vehicle was designed for synchronous recording of driving data. The configuration of the recording system is described as follows:

Fig. 1: Vehicle used for data collection
(TOYOTA Hybrid ESTIMA).

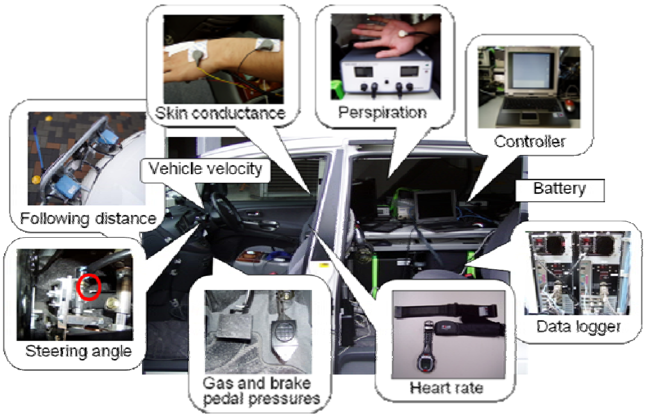

Fig. 2: Sensors mounted on vehicle.

2.1. Vehicle

TOYOTA Hybrid ESTIMA with 2,360cc displacement (Fig.1) was used for data recording. Various sensors and synchronous recording systems are mounted on (Fig.2). The design of the recording system is arranged as shown in Fig.3.

2.2. Microphones

Eleven omnidirectional condenser microphones (SONY ECM-77B) and a close-talking headset microphone are mounted on the vehicle to record driver's speech. The recorded speech is amplified through YAMAHA amplifiers. The positions of the microphones are shown in Fig.4.

2.3. Video cameras

Driver's face images from the right and left front and the view of the road ahead are captured with three CCD cameras (SONY DXC-200A) at 29.4118 fps. The positions of the cameras are shown in Fig.5. Figure 6 shows examples of video frames for cameras #1, #2, and #3.

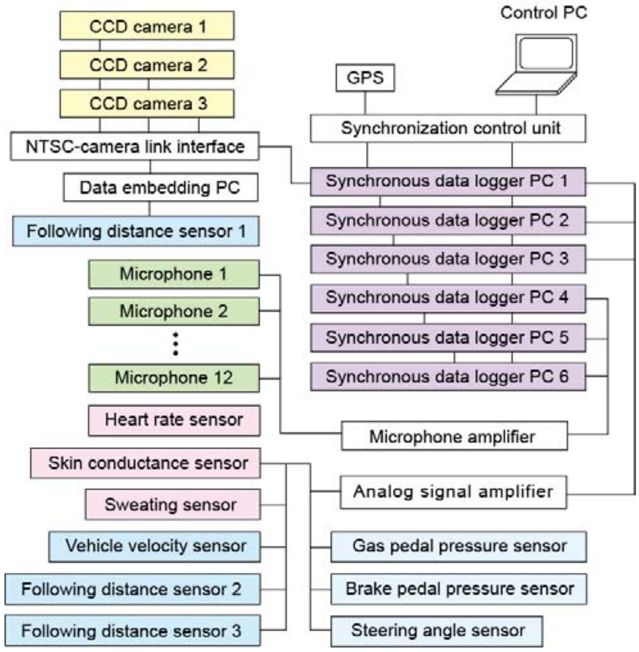

Fig. 3: Block diagram of recording system.

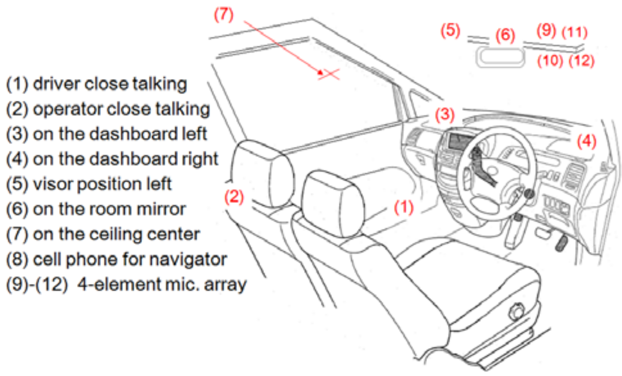

Fig. 4: Positions of microphones.

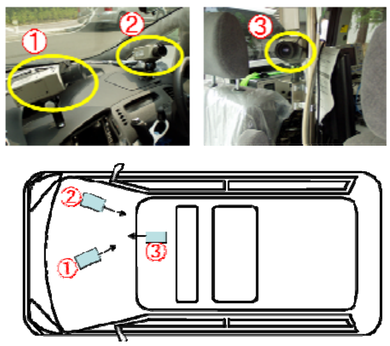

Fig. 5: Positions of video cameras.

camera #1

camera #2

camera #3

Fig. 6: Examples of video frames for three cameras.

2.4. Sensors for driving operation signals

Driving signals of steering angles and brake and gas pedal pressures are recorded. A potentiometer (COPAL M-22E10-050-50K) is used to measure steering angles, and pressure sensors (LPR-A-03KNS1 and LPR-R-05KNS1) are mounted on the gas and brake pedals.

2.5. Vehicle status sensors

The vehicle velocity is measured based on the output of the JIS5601 pulse generator. Distance per 100 ms is obtained by multiplying pulse intervals and tire circumference. Digital signals are converted to analog signals by a D/A converter.

2.6. Vehicle position sensors

The following distance from a lead vehicle is measured by distance sensors. Two kinds of distance sensors (SICK DMT-51111 and MITSUBISHI MR3685) are mounted in front of the vehicle for measuring short and long ranges, respectively.

2.7. Physiological sensors

Physiological signals are correlated to driver's stress [3]. Physiological sensors are mounted to measure driver's heart rate, emotion-based sweating on the palm and sole of the foot, and skin conductance. Driver's heart rate is measured using a chest belt sensor (POLAR S810i), the amount of sweating is measured through a perspiration meter (SKINOS SKD-2000), and skin conductance is measured with an electrodermal meter (SKINOS SK-SPA).

2.8. Synchronous recording system

For synchronous recording of the above signals, a multi-channel synchronous recording system (CORINS, MVR-303) is used. MVR-303 has a synchronous control unit and a system control PC and can record multi-channel synchronous videos and analog signals. Each PC node can store 240GB video data of 1.4 million pixels and 29.4118 fps, that corresponds to 90-minute videos.

3. DATA COLLECTION

To develop a technique for quantifying the stress level of drivers, driving data are recorded under various conditions with four different tasks. The details of the tasks are described as follows with examples of spoken sentences.

(1) Signboard reading task

Drivers read aloud words on signboards such as names of shops and restaurants seen from the driver seat while driving, e.g., "7-11" and "Denny's."

(2) Navigation dialogue task

Drivers are guided to an unfamiliar place by a navigator on a cell phone with a hands-free headset. Drivers do not have maps, and only the navigator knows the route to the destination. The following is an example of a spoken dialogue:

> **Navigator:** You should see a restaurant on your left.
>
> **Driver:** Yes, I see Kobeya**.**
>
> **Navigator:** Well, yeah, umm, you are at the Hibarigaoka intersection. Turn left at the intersection.
>
> **Driver:** O.K. I'll turn left.

(3) Alphanumeric reading task

Drivers repeat random four-letter strings consisting of alphabet a-z and digits 0-9, e.g., "UKZC," "IHD3," and "BJB8." The instruction of the four-letter strings is heard by earphone.

(4) Music retrieval task

Drivers retrieve and play music from 635 titles of 248 artists by a spoken dialogue interface. Music can be retrieved by artist name or song title, e.g., "Beatles" or "Yesterday."

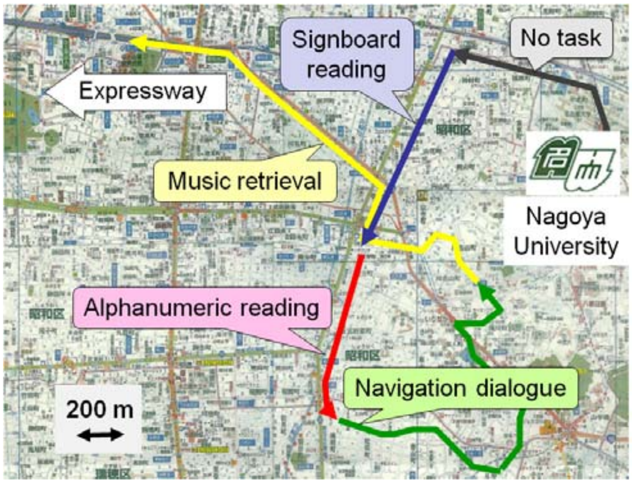

Fig. 7: Route for data collection on city roads.

Fig. 8: Route for data collection on expressway.

Each driver starts from Nagoya University and returns after about 70 minutes of driving. The route maps for data collection are shown in Figs. 7 and 8. Driving data are recorded under the above four task conditions on city roads and two conditions on an expressway. Driving data without any tasks are recorded as references before, between, and after the tasks. Driver's resting heart rate is also recorded before and after data recording in a quiet room.

3. EXAMPLES OF DRIVING DATA

Figure 9 shows examples of driving signals of steering angle, vehicle velocity, brake pedal pressure, and amount of perspiration recorded on the expressway. The amount of perspiration increased when the driver changed lanes.

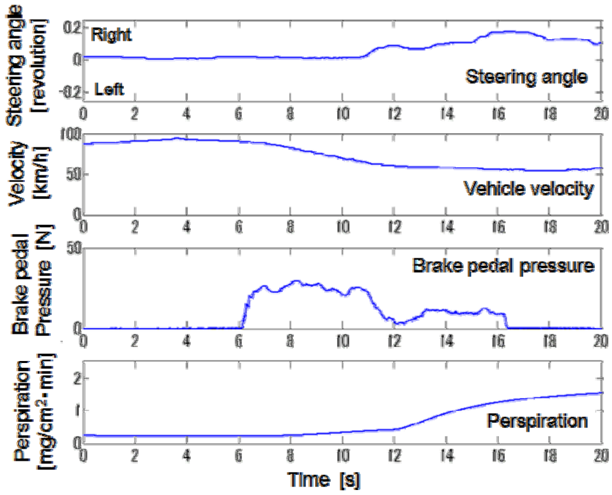

Fig.9. Examples of driving signals recorded on expressway (steering angle, vehicle velocity, brake pedal pressure, and amount of perspiration).

4. CONCLUSION AND FUTURE WORK

This paper summarized our on-going data collection of real-world driving at Nagoya University, Japan. The project involves international collaboration with the U.S. and Europe. Data collection is currently underway, to date and 70 drivers have participated in the experiment.

We will continue data collection and focus on comparative analysis of the driving data collected in the three areas of the world.

ACKNOWLEDGEMENTS

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