Development of a Driver-monitoring Vehicle Based on an Ultra Small Electric Vehicle

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Abstract

From the viewpoint of aging society in Japan, there is a need for vehicles adaptable for the elderly. Author et al. have developed an ultra small electric vehicle, which has a driver assist system suitable for elderly drivers. This system can take into account the various profiles among the elderly drivers, by monitoring the status of the driver and changing the vehicle response by means of by-wire technology. Driver-monitoring vehicle was developed based on this ultra small electric vehicle. This vehicle was equipped with measuring instruments, which monitors many aspect of driver's status. It was designed to monitor driver's operations and vital reactions in sync with vehicle conditions to find out the way to support drivers.

In order to verify the function of the driver-monitoring vehicle, EMG measurements were taken. Effective measuring points of EMG were the tibialis anterior for braking and the deltoid muscle for steering. In the driving experiment, EMG rise occurred 0.5 second before driver's operation was implemented. And the feasibility of support system using EMG was indicated.

Keywords

electric vehicle, low speed vehicle, NEV, driver assist system, EMG

1. INTRODUCTION

In Japan there are increasing elderly drivers because of our aging society. The number of elderly over 65 years olds who has a driving license reached 9.3 million by the end to 2004, and the number of elderly drivers is expected to increase at an accelerated pace because of our population composition. It may be recognized affirmatively that elderly drivers drive by themselves, because it gives them a mobile freedom. On the other hand, the number of accidents caused by elderly drivers is also increasing. So a vehicle, which is adapted to elderly drivers, is a request of our society.

Author et al. have developed a small electric vehicle, which is called "Micro UV" (Micro Universal-designed Vehicle). This vehicle is equipped with driving assist systems adaptable for elderly drivers. Author et al. planned that this electric vehicle must have not only an environmental friendliness but also user friendliness especially for elderly drivers. And a driver assist system can give new value for the electric vehicle to introduce it into the market.

The quality of elderly during driving has variations. Then an assist system for average driver is not always suitable for elderly drivers. In order to fit their variations in driving quality, it is proposed that an assist system monitors the condition of the driver and change the property of vehicle response to tailor it to the driver's conditions. In addition to the steering and pedal operations, it is proposed that the assist system uses driver's vital reactions, such as gaze, face temperature, and myoelectric activity. In order to find an effective reaction, an experimental vehicle called driver-monitoring vehicle that can monitor many properties of driver's reaction has been needed. In this paper the development of the driver-monitoring vehicle based on an ultra small electric vehicle, which has a platform of "Micro UV" is reported. And result of the experiment using electromyography is also described.

2. DEVELOPMENT OF THE DRIVER-MONITORING VEHICLE

2.1 Concept of the driver-monitoring vehicle

The final target of this driver-monitoring vehicle is a driver assist system on the "Micro UV", which gives a secure feeling to elderly drivers. The assist system will monitor the status and operation of the driver and control the vehicle by using by-wire technology, in which mechanical connections on a vehicle are replaced by electrical connections such as sensors and actuators. Electric vehicles, which have no mechanical connection

between accelerator pedal and drive motor, can be considered a partly by-wired vehicle already. In the "Micro UV", control parameters will be tuned to the status of driver in real time.

In order to find out the way to support drivers with their driving quality, driver-monitoring vehicle equipped measuring instruments, which can monitor driver's operation and vital reactions, was used. This kind of vehicle had been built on a normal sized internal combustion engine vehicle. In this research, the driver-monitoring vehicle was built on a small electric vehicle that has limited room and resources available, because the driver's environment of "Micro UV" is different from that of normal passenger vehicles.

One of the objectives in this research is finding the relation between driver's status and their intentions during driving. This vehicle must be able to record a wide variety of driver's reactions in real time, in sync with vehicle condition.

2.2 Platform of the driver-monitoring vehicle

Autec Japan Inc. manufactured the platform of this driver-monitoring vehicle, which is that of "Micro UV" prototype. The platform for driver-monitoring vehicle doesn't equip by-wire systems for braking and steering yet. So brake and steering system on this driver-monitoring vehicle has normal mechanical connections.

This platform is designed to fit the Japanese Low Speed Vehicle (LSV). The Japanese LSV, which is regulated by Japanese traffic law, must have an internal combustion engine whose displacement is less than 50 cc, or an electric motor whose one-hour rated power is less than 600 Watts. And maximum speed is limited to 60 km per hour. Our classification is similar to the U.S. LSV regulation, which provides GEM NEV and other neighborhood electric vehicles. And Quadricycle standard in Europe is also similar. Though the U.S. LSV has no limitation of seat capacity, the Japanese LSV seat capacity is limited to only one, which has been a barrier to introduce them into the Japanese market. On the other hand, LSV in the U.S. has been used in many retirement communities along with golf carts. It proves that the LSV has compatibility for the elderly. In Japan, it is supposed that there are also potential customers in spite of legal limitation regarding seating capacity.

The "Micro UV" is designed to be easy to drive and desirable size for the elderly. Especially in urban areas, compact vehicle is reasonable, because even a space for parking is limited. This vehicle occupies four times less area than a normal compact sized passenger vehicle.

The significant feature of Autec platform is its lightweightness. It is only 145 kg in tare, which is about half of other electric LSVs. This is a result of aluminum

space frame structure and lithium ion batteries. This vehicle has two driving motors in front wheels as hub motors. Because of its lightweightness, the maximum speed reached 64 km per hour in driving experiments. And the acceleration time from stand still to 30 km per hour achieved 5.7 seconds, which satisfies the technical standard regulated by the government. Its lightweightness also gives energy effectiveness. The energy to run 1 km at 30km per hour at constant speed is estimated 33-watt hour, which gives an advantage against internal combustion engine vehicles and also hybrid vehicles. Its lightweightness also generated synergetic effect to the cost because of the reduced quantity of batteries, which is expensive component of electric vehicle.

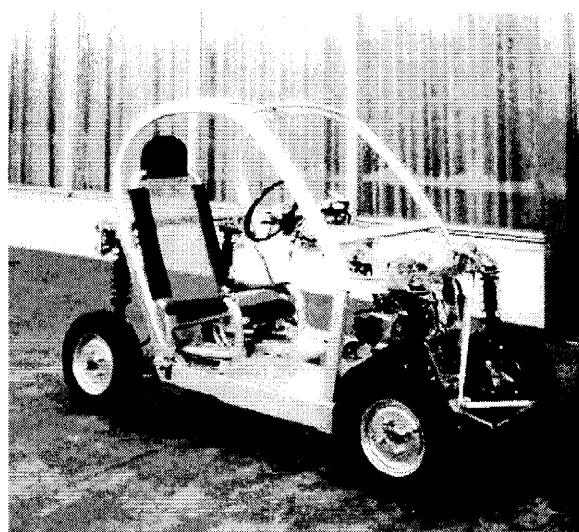Figure 1 shows the exterior of the plat form chassis.

Fig. 1 The exterior of the plat form chassis

2.3 Installation of measuring instruments

To make up the driver-monitoring vehicle, measuring instruments were installed on the platform. Measurements taken from this driver-monitoring vehicle are organized into three major parts. These are vehicle information, driver input, and vital reaction. Table 1 shows the measured items.

Table 1 Measured Items

Vehicle Information	Drive Input	Vital Reaction
Vehicle velocity	Gas pedal	Face image
Battery status	Shift lever	Eye point
Frontal image	Park brake	Head position
Rear image	Turn signal	Facial temperature
	Steer angle	Electrocardiograph
	Steer torque	Electromyograph
	Brake force	

In the vehicle information section, vehicle velocity and battery status are obtained by a communication link with the control unit on the vehicle. Vehicle velocity is approximated by motor revolution speed from motor inverters. Battery status is reported from battery management system via serial communication interface. And CCD cameras in front and rear record the road situation nearby the vehicle.

In the driver input section, positions of gas pedal, shift lever, parking brake and turn signal are also obtained by a communication link with the control unit. In order to measure the steering angle and torque, sensors are added to steering shaft. And brake force meter is added to the brake pedal.

Finally, sensors were set to obtain driver's vital reactions. A stereo camera was set on the dashboard to obtain driver's face image. Driver's eye point and head position are calculated from the stereo camera images by the PC, which has an image analysis system. An infrared thermography was set to obtain facial temperature. These instruments for measuring vital reactions are contact-less, which is desirable for car driving. And finally, portable bio amplifier was set to obtain electrocardiographs and electromyographs. These are recorded with contact type electrodes.

In order to achieve synchronization among measured data, PC is installed as a data recorder. This PC has several expansion cards such as serial communication interface, image capture board, and AD converter.

3. EMG MEASUREMENT

3.1 Concept of EMG measuring

Electromyogram (EMG) shows myoelectric activity, which results from muscle excitation. Every driver must use their muscles when they drive a car under normal operations, such as when operating the steering wheel, pedals, and levers. EMG measurement can show how drivers use their physical body, and when their intentions appear in the nerve system. One of the final targets in measurement of the EMG is a detection of driver's intentions to support their driving. And it may be used in the future as a man-machine interface to drive, as it is imagined from EMG controlled prosthetic limbs for amputees.

EMG measurement used a bio amplifier and an AD converter of a PC. Disposable argentic-chloride surface electrodes were used.

3.2 Measuring point of EMG

At first a target muscle must be selected, which was used in certain driving operation. Specific signals must be measured when driving operations occur, such as braking and steering.

In braking operation, measuring point was selected as the following. When driver changes the position of one's leg to change pedals, it must be an appropriate estimation that they use muscles under the knee. Figure 2 shows the muscular anatomy chart of a human body. In a human leg, there are muscles called tibialis anterior, soleus, and gestroenemius. Electrodes were attached on these muscles and examinee changed pedals repeatedly. These three muscles were measured simultaneously for comparison.
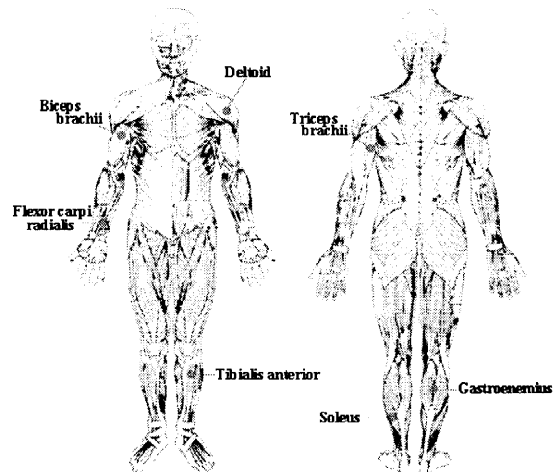

Fig. 2 Muscular anatomy chart

As shown in Figure 3, there is a specific wave pattern in tibialis anterior. So in this paper, tibialis anterior was selected for the measuring point for braking.
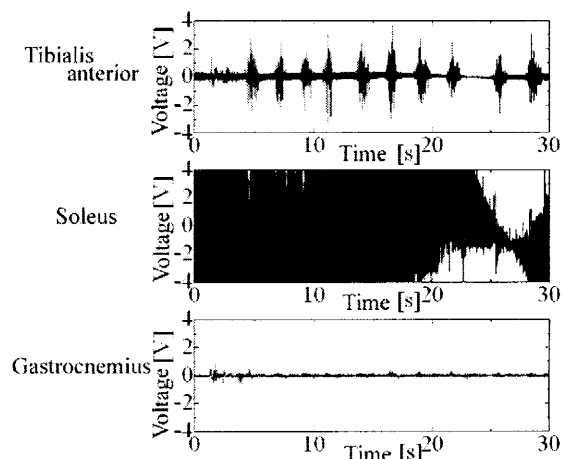

Fig. 3 EMG of right leg on breaking

Correspondingly in steering operation, there are muscles such as flexor carpi radialis, biceps brachii, triceps brachii, and deltoid muscle in a human arm. Electrodes were attached on these muscles and examinee turned steering wheel repeatedly. These four muscles were measured simultaneously for comparison. As one can

see from the results in Figure 4, there is a specific wave pattern in the deltoid. So in this paper, deltoid was selected for the measuring point for steering.
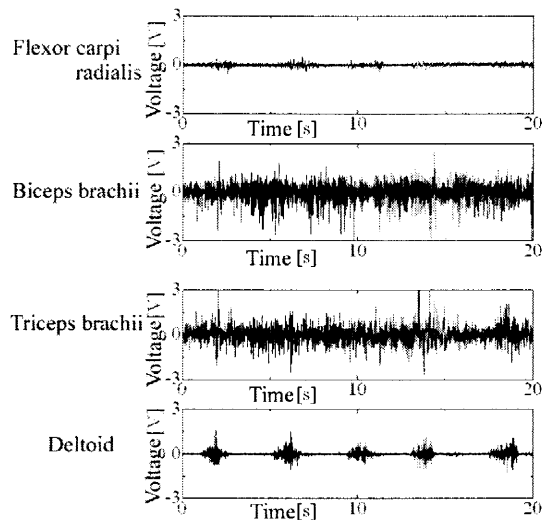

Fig. 4 EMG of right arm on steering

For the convenience of data analysis, data were converted. At first, in order to eliminate noise caused from the wire between electrode and bio amplifier, a high pass filter, which has a cut-off frequency of 20 Hz, was used. Then, full-wave rectification was made. Finally, smoothing was made by the low pass filter, which has a cut-off frequency of 2.5 Hz. Figure 5 shows an example of data conversion.
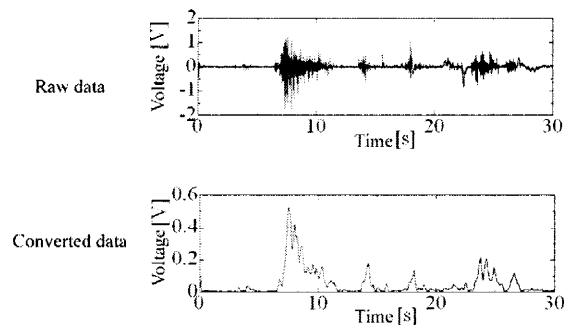

Fig. 5 Example of data conversion

4. DRIVING EXPERIMENT

To Check the function of the driver-monitoring vehicle, driving experiment was conducted.

4.1 Experimental condition

The experiment was conducted in the parking site of K-square campus Keio University. Figure 6 shows the map of the test course for this experiment. The number of examinee was seven. Their range of age was between

Fig. 6 Test course

22 and 67, and that of the driving experiences ranged from 2 to 37 years. Examinees were asked to drive under normal conditions as if they drove on public road. After sufficient practices, measurements were taken.

4.2 EMG result of braking

Figure 7 shows the result of right leg's EMG and brake force during pedal changing.
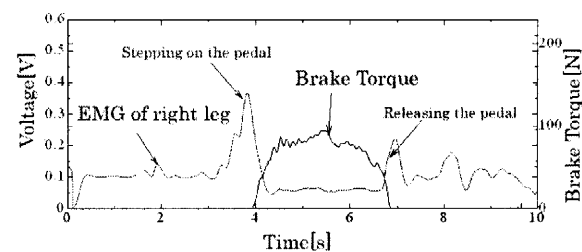

Fig. 7 EMG of right leg and break force

There were two peaks of EMG before and after brake force was generated. It means that tibialis anterior is used during releasing and pushing of the pedal. Interesting fact is that there is a rise of EMG just before the brake force was generated. Response times between EMG and brake force were sampled from every braking case. Table 2 shows the average response time between EMG and brake force rise individually. All examinee showed that EMG rise occurred before brake force was generated.

Table 2 Response time between EMG and break force

Examinee No.	1	2	3	4	5	6	7
Sec.	0.47	0.41	0.51	0.59	0.35	0.75	0.37

Human reaction time including a delay caused by one's nerve system is known to be from 0.15 to 0.3 seconds. This result showed that average reaction time to become about 0.5 seconds, which is longer than the general muscle reaction time. The reason seemed that it included a time lag to change pedals. In order to change pedals, they must release the gas pedal at first. EMG caught the first move in releasing the gas pedal. There is the proposal for a driving support system using gas pedal operations, which uses gas pedal release speed as a trigger

for brake support system. EMG can be used for the trigger of the support system instead of pedal operation.

4.3 EMG result of steering

Figure 8 shows EMG and steering angle, Figure 9 and Figure 10 shows EMG and steering torque respectively. From these figures, steering torque has closer correlation with EMG.
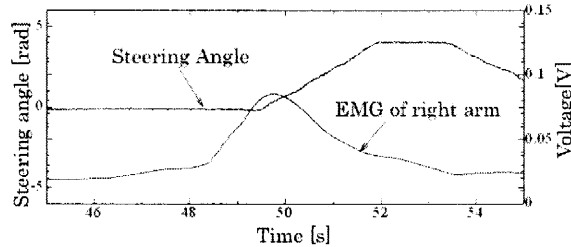

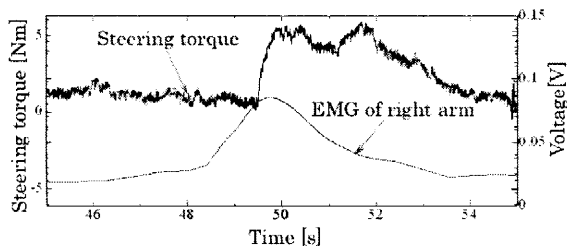**Fig. 8** EMG of right arm and steer angle

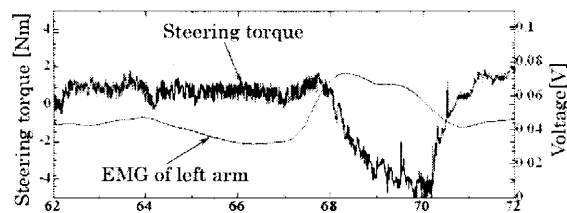**Fig. 9** EMG of right arm and steer torque

Fig. 10 EMG of left arm and steer torque

There is also a rise in EMG before the steering torque is generated. It means that driver's nerve system has response before actual steering moves. Response time between EMG rise and steering torque was sampled. Table 3 and Table 4 shows the time margin between EMG response and steer torque. All examinee showed that EMG rise occurred before steering torque rise.

Table 3 Time margin between EMG of right arm and steer torque

Examinee No.	1	2	3	4	5	6	7
Sec.	0.50	0.32	0.89	0.55	0.63	0.64	0.45

Table 4 Time margin between EMG of left arm and steer torque

Examinee No.	1	2	3	4	5	6	7
Sec.	0.42	0.49	0.57	0.52	0.44	0.67	0.42

In the steering case, there is also a longer response time than the time lag caused by the muscle and nerve system. There are also about 0.5 seconds between EMG and steer torque. The reason is supposed as follows. Deltoids are located at the shoulder, the root of the arm, and the steering wheel is connected at the other end of the arm, the palm. Deltoids must move at first to set the arm in motion. Because of the arm's physical structure, which has a large mass approximately 3 kg for one male's arm, the impetus for the motion of arm provided by the deltoid must be large.

Selected muscles gave initial responses before the actual operations were started, which give the support system preparative time to calculate and control actuators.

4.4 Feasibility evaluation of support system using EMG

EMG is supposed to be used for detection of driver's intentions, which was one of the measuring objectives. For example as mentioned in the section of EMG result of braking, there is a proposed support system using gas pedal speed, which is used as a trigger to brake. Gas pedal is used for a detection of driver's intentions. Instead of gas pedal, EMG can be used as the trigger for the support system. And in such case there is available information about the situation nearby the vehicle such as images from cameras and information from car-to-car communication system, and the assist system can support the driver more adequately.

From the results of the driving experiment, a support system using EMG can be verified. Accuracy of detection is examined. At first, braking intentions can be detected in case of EMG rise. Braking was detected from EMG rise at a 97.3 percent success rate. In other words, 2.7 percent of the time, braking could not be detected from EMG. And there was 9.3 percent that wrong detections were made when leg's EMG rises were occurred. Secondly, in the case of steering detections, 71.5 percent of the time, steering operations were detected from EMG rises. That is to say 28.5 percent of the time, steering operations could not be detected from EMG. And there were 15.5 percent wrong detections when arm's EMG rises were occurred.

There were errors and wrong detections because myoelectric activity and driver's operations could not be combined directly. Driver's myoelectric activity has an influence under the conscious or unconscious body

movement of the driver. Though there is difficulty when EMG is used independently, it can be one of the control triggers when it is used with other sensors such as pedal position sensor and steering angle sensor.

5. CONCLUSION

Driver-monitoring vehicle was developed, which was based on an ultra small electric vehicle. This small electric vehicle designed for elderly drivers was equipped with driving assist system, which monitors the status of the driver. Driver-monitoring vehicle was designed to monitor driver's operations and vital reactions to find out the way to support the driver.

In order to verify the function of driver monitoring, EMG measurement were taken. Effective measuring point of EMG was the tibialis anterior for braking and deltoid muscles for steering. EMG rise occurred in 0.5 second before driver's operation. And feasibility of support system using EMG was indicated.

Acknowledgements

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