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Automobile driver's stress index provision system that utilizes electrocardiogram

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Abstract— **This research intends to develop devices that make drivers rest and to verify in the early stage by effectively detecting the electrocardiogram (ECG) signal, one of the signals of living body, in the vehicle during the operation and providing ANS information and degree of stress. Recording the regular activity of heart clinically, ECG reflects the health state of subject as well as checks the degree of operation of autonomic nervous system through analysis of Heart Rate Variability (HRV). As this alteration of autonomic nervous system predicts the stress level of drivers during operation and provides the possibility of warning by continuous detection, it may lead to the recognition and safe driving of driver by detecting the stress during driving altered by diverse factors such as changing mood, bio rhythm, condition, fatigue, boredom or disease and preventing the driver from reaching the inappropriate state for driving. Thus, the reliability and utilization level of system was confirmed to be satisfactory by providing new ECG measuring method familiar to drivers and comparing it with the result of judging drivers' emotion through this research.**

I. Introduction

RECORDING the regular activity of heart clinically, ECG reflects the health state of subject as well as checks the degree of operation of autonomic nervous system through analysis of HRV [1][2].

As living body signal information analysis technology necessary to keep health and prevent disease, the above HRV technology is being actively researched [3][4][5][6]. Especially, Home automation and health Care Project is in progress in USA by using HRV analysis technique of ECG signal, sympathetic nerve and parasympathetic nerve as well as stress index is applied to diagnose the disease caused by the influence of earth magnetic field in North Europe and Russia [7].

Thus far, basic research that measures ECG in the steering wheel of vehicle and other research that presents the possibility of measuring basic living body signal by placing clinically used electrode of electrocardiograph in the steering wheel of vehicle have been made. However, the position of steering wheel that considers the concrete form of electrode or driving situation has not yet been presented [8][9][10].

Since the existing driver monitor restricts the position of measuring living body information to the steering wheel, the driver is restricted in measurement or the position or form of measuring electrode is not concretely presented, though drivers operate shift lever while driving and put their hands on various places as per driving habit. Furthermore, it merely provides the form that grasps the drivers' state by measuring living body signal called ECG without presenting the correlation between the value calculated by analysis of ECG and the drivers' state.

Thus, in order to solve the above mentioned problems, this research aims to construct measuring system that effectively checks the ECG signal of drivers during vehicle operation, to analyze the alteration of drivers' ECG checked during operation so as to calculate ANS information and stress index for monitoring drivers' state in real-time so that driver stress index provision system and method utilizing ECG can be provided to ensure safe driving in abnormal situation.

II. Hardware and System

The system is devised in the structure that can measure ECG while driving vehicle by attaching ECG electrode on steering wheel, armrest and shift lever in the vehicle. Installing ECG electrode on the right and left sides of steering wheel, this structure may detect ECG signal if steering wheel is operated while driving. To provide relatively free and flexible system in consideration of drivers' driving habit, the scope of electrode was expanded. As the scope is expanded to armrest where left hand can be placed and shift lever where right hand can be placed, the inconvenience that gripping steering wheel is necessary for measurement has been eliminated.

A. Electrode

Though silver chloride is the most efficient ingredient to contact patient so as to clinically measure living body signal, it is subject to discoloration. Thus, in order to prepare electrode applicable in the vehicle, the researcher used electrode in which silver chloride is mixed with carbon to

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cover steering wheel and other measurement positions.

B. Position of sensor and ECG circuit

To satisfy the 3 electrodes method of ECG, the electrode was positioned as Fig. 1, namely, LA on the left and RA, RL on the right in double places. Wires are placed inside steering wheel to minimize the inconvenience in driving and the wires concentrated at the center of steering wheel are connected to living body signal measurement system by Shield Cable. To ensure flexible and free living body signal measurement system for driving, electrode in the same property is positioned on the armrest of driver's seat and shift lever so that convenience can be maximized for driver. The signal measured at electrode is detected as ECG signal by hardware. Fig. 2 is the schematic of ECG detection circuit.

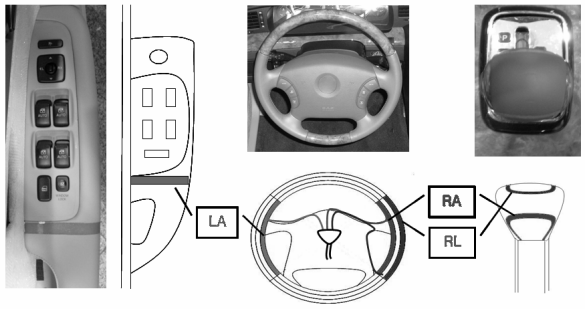

Fig. 1. Position of electrodes

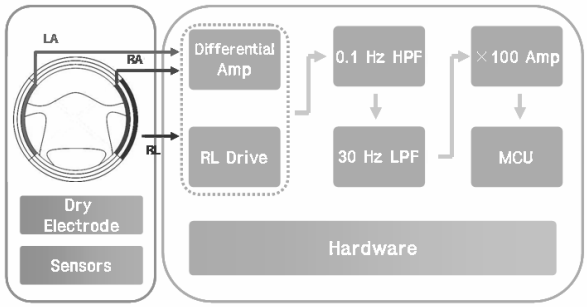

Fig. 2. Schematic of ECG detection circuit

C. Analysis of data

The interval between heart rates (RR interval) constantly changes even during stability. This is called HRV. Among the analysis methods to search the indicator that reflects the activity of autonomic nervous system form the HRV signal, this research used the interpretation of frequency area. As a method to observe the relative strength among signals of each frequency ingredient by analyzing HRV wave form, the interpretation of frequency area provides very useful information to estimate the antagonistic activity between sympathetic nervous system and parasympathetic nervous system of autonomic nervous system [11][12]. As this alteration of autonomic nervous system predicts the stress level of drivers during operation and provides the possibility of warning by continuous detection, it may lead to the recognition and safe driving of driver by detecting the stress during driving altered by diverse factors such as changing mood, bio rhythm, condition, fatigue, boredom or disease and preventing the driver from reaching the inappropriate state for driving with prior alarm (warning). As physiological property of drivers in the vehicle, the mixed area of sympathetic nervous system and parasympathetic nervous system and the decreased amount of alteration in the area of parasympathetic nervous system indicate increased stress and the increased amount of alteration in the area of sympathetic nervous system also indicate increased stress. Stress increases as driving vehicle for longer time. Based on the above clinical ground and physiological property, objective stress index is detected by adding the weighted value of above mentioned amount of alteration in the autonomic nervous system to this autonomic nervous system information (ANS). This stress index is classified into multi stages ranging from 0 to 6 (0- no stress index at all; 6- very high stress index). The following Fig. 3 is the block drawing of alteration of autonomic nerve and stress index detection algorithm that considers the property of vehicle.

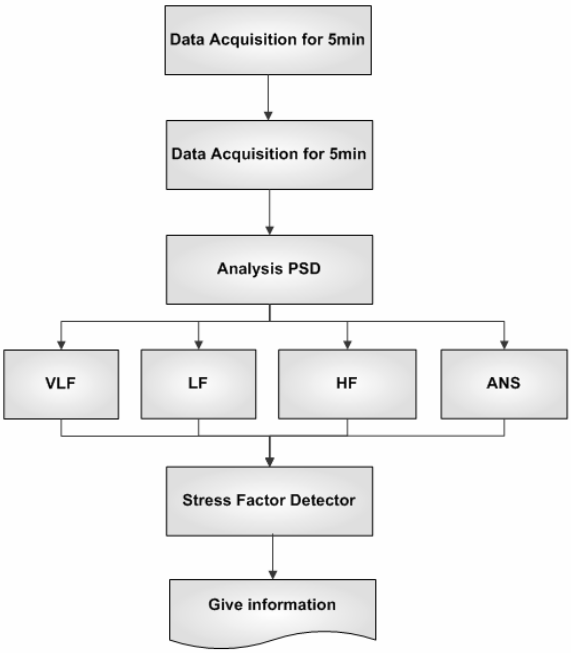

Fig. 3. Block drawing of alteration of autonomic nerve and stress index detection algorithm

III. Experiment and Result

A. Traveling experiment protocol

To repeat the vehicle experiments in the designated course each time, traveling protocol was prepared from South Wonju to West Daegu (TABLE I). The distance from South Wonju to West Daegu is some 200 Km. It takes 2 hours and half to travel this distance in one way. The traveling experiment was

TABLE I
TRAVELING EXPERIMENT PROTOCOL

	Upbound		Downbound		
	The location	The distance	The location	The distance	
Free speed driving	South-Wonju IC	0 Km	West-Daegu IC	0 Km	Free speed driving
	Chiak Service area	13.3 Km	Chilgok IC	9.9 Km	
	Sillim, Juchun IC	18 Km	Dongmyoung Service area	17.6 Km	
80 Km/h fixed speed driving	Jechon, Chungju IC	29.8 Km	Daboo, Waegwan IC	23 Km	80 Km/h fixed speed driving
	South-Jechon, Gumsung IC	37.9 Km	Gumi IC	30 Km	
Free speed driving	North-Danyang IC	50.3 Km	Gunwi IC	41.1 Km	Free speed driving
	Danyang Service area	52.7 Km	Gunwi Service area	49 Km	
	Danyange IC	64 Km	Uiseong IC	52 Km	
	Punggi, North -Yeongju IC	80.5 Km	South-Andong IC	74.8 Km	
	Yeongju IC	91.1 Km	Andong Service area	85 Km	
100 Km/h fixed speed driving	Yecheon IC	102.5 Km	West-Andong IC	88.8 Km	100 Km/h fixed speed driving
	West-Andong IC	115.3 Km	Yecheon IC	103 Km	
	Andong Service area	120 Km	Yeongju IC	114 Km	
	South-Andong IC	130 Km	Punggi, North -Yeongju IC	124 Km	
	Uiseong IC	152.5 Km	Danyange IC	141 Km	
Free speed driving	Gunwi Service area	155.5 Km	Danyang Service area	145 Km	
	Gunwi IC	165 Km	North-Danyang IC	154.5 Km	
	Gumi IC	175.1 Km	South-Jechon, Gumsung IC	166.6 Km	Free speed driving
80 Km/h fixed speed driving	Daboo, Waegwan IC	181.1 Km	Jechon, Chungju IC	174.3 Km	
	Dongmyoung Service area	186.5 Km	Sillim, Juchun IC	186.5 Km	80 Km/h fixed speed driving
	Chilgok IC	194.8 Km	Chiak Service area	191.5 Km	
Free speed driving	West-Daegu IC	205 Km	South-Wonju IC	205 Km	Free speed driving

made at 10:00 a.m. when the traffic of road was not so heavy. To give stress to the driver, the researcher changed regular traveling speed and the assistant on the auxiliary seat wrote down the driver's response stress index and detection stress index every 5 minute.

First of all, the driver's initial state was measured when starting the vehicle. Some 10-15 minutes later, the traveling speed was limited to 80Km/h to give stress during driving and the driver was instructed to drive at this speed for 15 minutes or so. After permitting to drive freely, the driver was instructed to drive the vehicle at 100Km/h, the designated speed on the expressway. Repeating the above protocol, the researcher measured the driver's stress alteration while driving the vehicle at regular speed for long time. However, it the vehicle detection or response stress index exceeds 5, traveling was suspended for safety.

B. Driver's response stress

To give stress to the driver, the researcher instructed the driver to change the regular traveling speed and to measure stress during driving every 5 minute by subjective personal judgment. The scale of measurement is indicated to be 6, the highest stress or fatigue and 0, the lowest stress or fatigue.

C. Result of experiment

The experiment was performed to 6 staffs of this research lab (Model I to VI), ranging from 26 years to 33 years and knowing how to drive. They are volunteers without the existing pathological change and physical abnormality (27.2±2.32 years old, Male: Female = 5 : 1)

The result of experiment could be checked by the driver's detection stress and response stress index, comparison of tendency in the traveling (Fig. 4). The diver's detection stress index and response stress index are acquired by the mentioned method in traveling experiment protocol. These data are generated every 5mimute but not shown a complete agreement. However, from the diver's detection stress index tendency and response stress index tendency that are computed by 5 point moving average filter, same flow was observed in the stress index detected in the vehicle and driver's response stress index as shown in the result.

IV. CONCLUSION

As system that monitor the psychological state of driver while driving the vehicle, this research can improve the convenience for driver by positioning electrodes on the steering wheel, armrest of left door and right shift lever.

Furthermore, it is appropriate to the driving environment, because it judges living body signal by considering steering wheel operation and other behavior related to operation while traveling to construct system and algorithm.

According to this research, ECG signal is converted into HRV for analysis of time area and frequency area and the response of autonomic nervous system and stress level is calculated through algorithm. As driver's state is monitored by using this information and driver is asked to take rest in case of judging abnormality, safe driving is ensured.

A. The task in the future

This research suggests a first-stage pilot experiment for developing an automobile driver's stress index provision system that utilizes ECG. The measure judging stress index used to verify this system is the index that depends on the individual propensity. Thus, it is required to select the index to enhance the accuracy of experiment. Furthermore, it seems necessary to verify the suggested method by increasing the model numbers with statistical methods and to understand the

diverse correlations between emotional factors and physiological factors.

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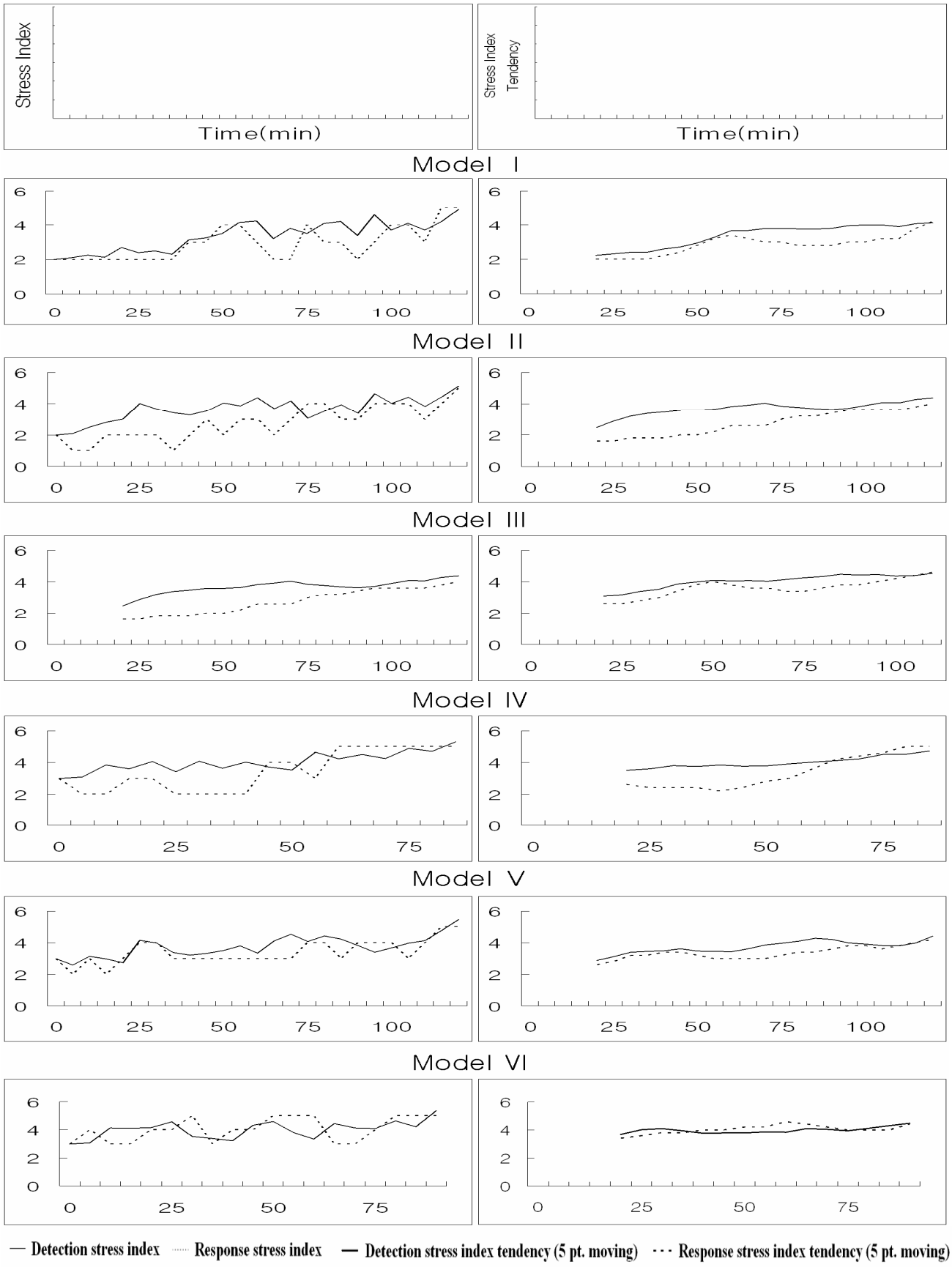

Fig. 4. Comparison of tendency in the driver's detection stress and response stress index