Driver's Modeling with System Identification Algorithm to Aim Reducing Drowsiness

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Abstract. The purpose of this study is to develop a biological model between skin temperature change and cooling stimulation to prevent drivers from becoming drowsiness. The traffic accident by an operation mistake or aimless operation has occurred. A factor of these accidents has a driver's nap. In recent years, many researchers have studied eagerly this theme. The purpose of their studies is to detect a driver's drowsiness. On the other hand, the aim of our study is to contribute to development of technology for safe drive assistance to maintain a driver's arousal levels. This technology may give a technical innovation in the relevant area. In general, a change in blood volume in nasal part depends on the vasoconstrictive effect of the sympathetic nervous system along with changes in physiological and psychological conditions. The nasal skin temperature changes depending on the blood flow, thus, the temperature reflects the physiological state. The temperature also decreases as the blood flow in the nasal area decreases during sympathetic hyperactivity. The temperature increases as the blood flow in the nasal area increases due to sympathetic suppression. Previous studies have showed a relationship between nasal skin temperature reflecting autonomic nervous system activity and arousal level. The experiment was conducted to gather data for constructing a biological model of a driver and the relationship between cooling stimulation and nasal skin temperature was modeled with system identification. And the usefulness of models was examined with time response simulation and nyquist diagram. In summary, it is possible to construct biological model based on relationship between thermal stimulation and nasal skin temperature by using ARX, ARMAX and BJ of low order.

Keywords: Nasal skin temperature · Autonomic nervous system activity · Driver's drowsiness · System identification · Biological model

1 Introduction

So far, we have studied safety driving support technology to reduce driver's drowsiness based on nasal skin temperature reflecting sympathetic nerve activity [1, 2]. Approximately 30% of the total traffic accidents in Japan are inattentive accidents such as mucking [3]. One of the factors is thought to be transient drowsiness. Therefore, it is a social problem to reduce accidents caused by dozing driving. In general, the

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sympathetic nerve accelerates and the arterio-venous anastomoses shrinks when the driver concentrates on his driving. The skin temperature becomes lower than the temperature at rest. Also, the sympathetic nerve suppresses and the arterio-venous anastomoses returns to previous size when the driver feels drowsy. Then, the nasal skin temperature rises. Based on this physiological mechanism, our system had given cooling stimulations to keep the driver's nasal skin temperature at the lowest value. The current system operates by switching biological models at regular intervals using Box - Jenkins method. The biological signal is a nonlinear time-varying system. Therefore, periodic switching of the biological model is effective. However, if biological signal characteristics change immediately after switching biological models, it is difficult to properly control them. Also, the current biological model is a high order number. Therefore, stability cannot be guaranteed.

Therefore, the purpose of this study is to examine the possibility of adaptive biological modeling which sequentially updates the identification algorithm. The voltage to the thermoelectric element and the nasal skin temperature are measured for driver in the experiment regarding this study. Based on these data, biological models are constructed in which the applied voltage is an input signal and the nasal skin temperature is an output signal. Then, the models are evaluated by time series analysis and frequency analysis.

2 System Identification

The experiment is examined whether four modeling methods are effective for constructing biological model. The four models are Auto Regressie eXogeneous (ARX), Auto Regressie Moving Average eXogeneous (hereafter, ARMAX), Output Error (OE), Box and Jenkins (BJ) model. ARX, ARMAX, OE, and BJ model are polynomial models. The parameters of these equations are shown in Table 1. The parameters are determined based on the least squares method.

Table 1. Models of system identification.

Model	$G(q)$	$H(q)$
ARX	$B(q)/A(q)$	$1/A(q)$
ARMAX	$B(q)/A(q)$	$C(q)/A(q)$
OE	$B(q)/F(q)$	1
BJ	$B(q)/F(q)$	$C(q)/D(q)$

3 Experimental Method

The experimental system is shown in Fig. 1. A subject wears a thermistor (503 ET - 3 H 87 U, SEMITEC) at nose and an electrode (LT - USB 1, Gram Corporation) for measurement of nasal skin temperature and a thermoelectric element (TEC 1 - 12706) in neck. Afferent fibers from peripheral temperature receptors are transmitted to the center of the brain by the spinal nerve. Therefore, the cervix is selected at the place to stimulate. The skin temperature of subject's neck is controlled by the thermoelectric

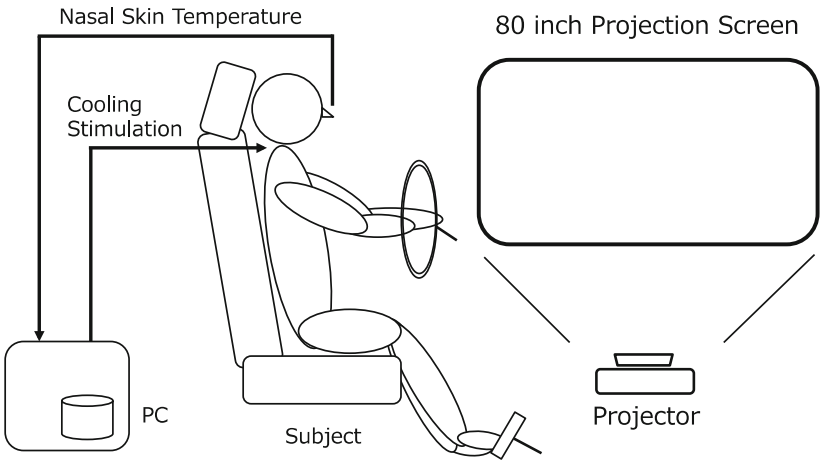

Fig. 1. Experimental system. The nasal skin temperature is measured while subject is driving on driving simulation. The measurement time is 1800 s.

element based on the nasal skin temperature change acquired from the thermistor. When a voltage signal is applied to a component of a thermoelectric element, the nasal skin temperature changes according to a cooling stimulation. The measurement time is 1800 s. A biological model is updated by sequentially performing system identification with these data. These models are evaluated using time series analysis and frequency analysis. In the time series analysis, the models are evaluated by the fitting rate of the estimated value and the measured value. The formula the fitting rate is shown in (1). In frequency analysis, the models are evaluated using the Nyquist diagram.

$$\mathrm{Fit}(\%) = \left(1 - \frac{\sqrt{\sum_{k=1}^{N}\left[\hat{Y}(k) - Y(k)\right]^2}}{\sqrt{\sum_{k=1}^{N}\left[y(k) - \bar{y}\right]^2}}\right) \times 100 \tag{1}$$

4 Result and Consideration

The estimation results of the model in the time series analysis are shown in Figs. 1 and 2. The estimated output value of the model is expressed as ye and the true value as y. In the case of ARX model and the ARMAX model, the approximate value of the true value y are estimated except for the start several seconds. The fitting rate of the ARX model was 94.46% on average. The fitting rate of the ARMAX model was 96.07% on average. On the other hand, when the OE model and the BJ model are applied, there is a difference between the true value y and the estimated value. The fitting rate was −2.63% on average for the OE model and 78.13% on average for the BJ model. The biological signal about human is a nonlinear time-varying signal. The ARX model and the ARMAX model is a linear model. The data suggest that these models are

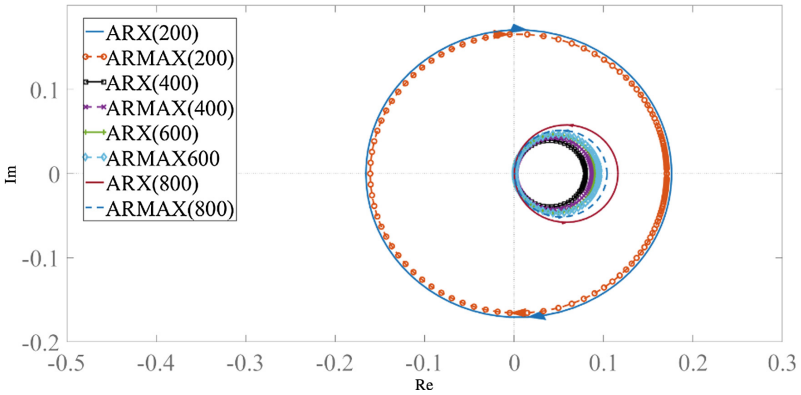

Fig. 2. An example of Nyquist diagram on driving. The Nyquist diagram of all models is on the right side of the real part of −1 and a circle is drawn around the origin at the time point of 200 s.

compatible with the sequential switching method. On the other hand, the OE model and the Bj model are nonlinear models. It can be considered effective if modeling is performed with a certain time width. However, there is a high possibility of becoming a high-order model that cannot ensure stability. The results of the Nyquist diagram in the ARX model and the ARMAX model are shown in Fig. 2. The Nyquist diagram shows results at 400, 800, and 1600 s. The Nyquist diagram of all models is on the right side of the real part of −1. That is, it can be seen that the controlled object is stable. At the time point of 200 s, a circle is drawn around the origin. This indicates that there is a dead time. In other words, it takes time to stimulate and react. The above results show that sequential update is effective for lower order. Therefore, these data suggests that the system contributes more stably than the conventional system. In addition, the point that the skin temperature changes gradually is considered to be one of the factors that the low order model functions effectively (Table 2).

Table 2. Fitting rate of each subject.

No	ARX	ARMAX	OE	BJ
No1	94.43	94.41	−3.23	59.89
No2	99.52	97.74	−5.55	99.77
No3	99.76	99.8	−2.19	61.68
No4	93.13	93.18	−2.22	93.19
No5	95.46	95.24	0.02	76.15
Average	96.46	96.074	−2.634	78.136

5 Conclusion

In this study, the effectiveness of the low order biological model based on the identification algorithm was examined. As a result, we showed that it is possible to construct biological models by sequential updating of system identification.

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