講演番号 077 文献番号 20226077

Online Driving Anomaly Detection Based on Parameter Estimation of Intelligent Driver Model

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Human engineering, Driver behavior, Anomaly Detection, Parameter Estimation, Dual Particle Filter (C2)

Abnormal driving behaviors such as speeding, aggressive, reckless, and distracted driving have long been recognized as primary factors in countless traffic accidents. Hence, in tandem with the recent developments in autonomous driving technologies and driving support systems, significant attention is being paid to the systems capable of identifying or detecting driving anomaly. Most current driver monitoring systems can be applied to the detection of abnormal driving, but most of them require either in-car cameras for face recognition or the use of contact/non-contact physiological sensor devices. However, the accuracy of facial recognition systems can be degraded by the driver's eyeglasses or mask, and the output of physiological sensors can be corrupted by high noise levels. In addition, these techniques are applicable to human drivers only although driverless vehicles will penetrate the market in the near future.

In response to these issues, this paper proposes a new approach for driving anomaly detection that requires neither in-car cameras nor physiological sensors. Instead, this approach assumes that driver state including the anomaly is reflected in his or her car-following behavior especially vehicle acceleration. If such behavior in relation to the preceding vehicle could be modeled by mathematical formulae, then the model parameters should contain valuable information related to the driver's attention state, intention, and sensitivity, etc. Herein, we report on an attempt to make online driving anomaly detection based on dual particle filtering.

The driver model used in this study is the Intelligent Driver Model (IDM), which is a family of social forces models that encourage drivers to reach desired speeds and maintain appropriate vehicle distances so as not to cause rear-end collisions. Note here that the IDM is a collision-free model. The formula of the IDM is given by:

$$a_i(k) = a\left[1-\left(\frac{v_i(k)}{V}\right)^4-\left(\frac{s+v_i(k)\cdot T-\dfrac{v_i(k)\left(v_{i-1}(k)-v_i(k)\right)}{\sqrt{2ab}}}{d_i(k)}\right)^2\right], \quad (1)$$

where, a, b, V, T, s are the model parameters and $a_i(k)$, $v_i(k)$, $d_i(k)$ are acceleration, velocity, and headway distance of vehicle i at time k.

The five parameters of the IDM contain valuable information about driver characteristics such as driving abnormalities. The Dual Particle Filter (DPF) then attempts to estimate them so that the observed and modeled accelerations by the IDM are minimized. The results show that the estimated parameters and the IDM perfectly capture the actual acceleration behavior and describe it very precisely (full model). Thus, the parameters reflected the characteristics of the driver, such as his/her intention to control the vehicle to avoid a collision. Therefore, if the driver accelerates inappropriately from the standpoint of avoiding a collision, the estimated parameters will also include some inappropriate behavior.

In DPFs, acceleration can be accurately reproduced by estimating only two of the five model parameters and treating the remaining parameters as constants (partial model). However, if there are situations that cannot be accurately reproduced with only two parameter estimates, it is possible to define that the driving behavior was so far from normal that the remaining three parameters cannot be treated as constants.

Fig. 1 shows an example of the detection of a driving abnormality where the IDM with two model parameter estimates, i.e. the partial model, cannot reproduce the actual acceleration behavior (see top). As the IDM is a collision-free model, the estimated acceleration (green) is the recommended acceleration to avoid a rear-end collision. However, the driver may not have taken the appropriate action (orange) for whatever reason. In addition, the time headway is always low, sometimes less than one second.

In conclusion, the proposed method significantly detects abnormal driving due to sudden deceleration and is highly sensitive and accurate in its detection.

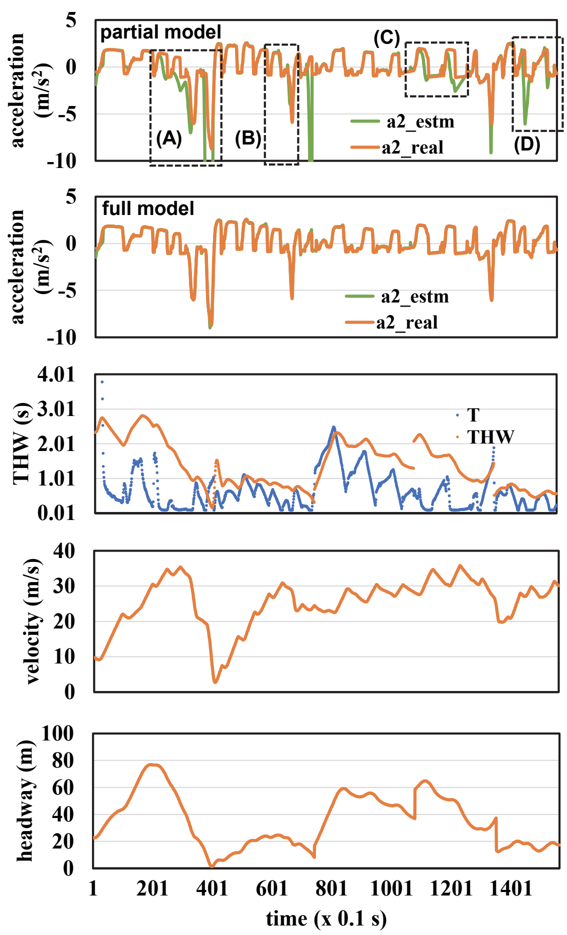

Fig. 1 Estimated and Real Acceleration, THW, T, Velocity and Headway for ID01 WC2

2022 JSAE Congress (Autumn) - Summarized Paper

Issued on October 7, 2022