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A Deterministic Feedback Model for Safe Driving based on Nonlinear Principal Analysis Scheme

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Abstract

For intelligent driver assistant service, research works have been conducted using sensors to analyze drivers' behavior and score for safe driving. There have been many studies on safe driving, but there was a limit on providing the driver with a comprehensive solution for safe driving. The studies mainly focused on a method to quantify the driving characteristics or the indicators that can be used to assess the driving risk. In order to practically utilize those indicators, it is necessary to provide the driver with the feedback on how to change which controllable factors to fix the indicators to desired values. However, there has been no study to provide feedback on interpretable factors. To improve the problem, in this paper, we propose a model that provides comprehensive feedback to the driver by offering quantitative driving improvement instructions. In the proposed model, K-means clustering is used to classify the safe driving level and the non-linear principal component analysis (NLPCA) model is trained by the classified low-risk data to analyze arbitrary driving data and provide feedback. To evaluate proposal model, we collected sensor data while driving vicinity of Daejeon Metropolitan City in Korea, and analyzed the principal component extracted using the NLPCA. We evaluated the classification accuracy of the principal components to verify the validity of the proposed model, and showed that the characteristics of safe driving can be represented through the proposal feedback model.

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Keywords: Advanced Driver Assistance Systems; Intelligent Vehicle; Driving Risk; Machine Learning; Safe Driving Analysis;

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1. Introduction

Detecting driver behavior and assessing the risk of accidents are important parts of the advanced driver assistance system(ADAS)[1]. If an accident caused by an abnormal driving behavior is detected and reacted in advance, an accident can be prevented. In the case of drowsy driving, a driver may avoid an accident by a warning from the assistance system[2]. These kinds of driving assistance systems have been studied extensively over the last decades. Driving risk models were studied to classify the driving hazard[3] and make a numeric model for time-to-x (TTX) to assess criticality[4]. In addition to analysis of driving risk model, general driving patterns was also studied, e.g., visualization of driving pattern analysis was conducted using extracted hidden features[5]. In addition, mobile application[6] was developed that can detect inattentive driving by using various sensor data and then reflect the score to the driver.

Even though the previous studies[3,4,7,8,9] provided driver assistance system by detecting the risk of accidents and scoring the driving behavior, how to improve the drive for safety cannot be provided since only the assessing indicators were provided and the factors that can be manipulated were not offered. As an example, the quality of the lane change behavior was analyzed using image data and kinematics data[9], the criticality was assessed[4,7], and driving risk was analyzed[3,8]. However, if the indicator, which can be manipulated and guide drivers to drive more safely, is given, then driving behavior can be improved to reduce accidents by reflecting the practical driving feedback. The numeric driving feedback to improve safety is not only helpful to the driver, but can also be reflected in intelligent automotive systems. Therefore, in this paper, we propose a model detecting driving risk level based on collected mobile sensor data and providing quantitative driving indicators about how to alleviate accident risks. In the proposed model, measured sensor data are pre-processed to classified by the three risk-levels through the K-means clustering. The clustered low-risk data are fed into the nonlinear principal analysis (NLPCA)[10] to train it and the trained model evaluates the numeric safe driving feedback for driving behavior inputs.

The remainder of this paper is organized as follows. Section 2 describes the model of our work. Evaluation for what we propose is provided in Section 3 and we finally conclude the paper in Section 4.

2. A Deterministic Feedback Model for Safe Driving

To handle the numerical feedback for safe driving, we proposed a quantitative feedback model, which consists of two main steps: model training and inference analysis (refer to Fig. 1). Firstly, in model training step, in-vehicle sensed data is collected and pre-processed. To analyze driving behavior and provide feedback to the driver, we used the NLPCA auto-encoder model. Before training the model, the pre-processed data is classified to label the risk level, and then the low risk labeled data as a safe driving data is used to train the NLPCA model. After training the model, in the inference analysis step, the reconstructed values can be obtained from the observed input data through the trained model. Analyzing the observed data and its reconstructed values, the quantitative feedback for safe driving is provided to the driver.

2.1. Data Preparation and Training the Model

- Data preparation

To implement the feedback service for safe driving, local dynamic status information of the vehicle is required as an input for the model. Therefore, we defined the sensor feature vector $\mathbf{x} = (x_1, x_2, \cdots, x_N)$ to describe the behavior of the driver and be used as the input to the NLPCA model. In the sensor feature vector $\mathbf{x}$, each element x represents the characteristic indicator value of the sensor data. The collected raw sensor data is pre-processed to construct the sensor feature vector. In this paper, as the elements of the sensor feature vector, we employed 4 sensing types (acceleration in x-axis and y-axis, yaw rate, and velocity), each has 10 characteristic indicators as shown in Table 1.

- Risk labeling

To train the NLPCA model using the safe driving data, the criteria for safe driving is required. Therefore, we applied the method that classifies data to the several risk levels[3]. In the previous study[3], it was shown that the driving risk level could be classified by the minimum acceleration, the average acceleration, and kinetic energy reduction ratio that are shown to be correlated to the crash occurrence rate using the K-means clustering method. In this study, using those 3 indicators we classified the data into 3 risk level: low risk, moderate risk, and high risk through the K-means