Detection Method of Lane Change Intentions in Other Drivers Using Hidden Markov Models

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Previous researches reported that a lane change is the main cause of vehicle accidents. Therefore, inferring behaviors in other drivers and alarming to a driver are crucial tasks for safety. In this paper we propose a method to estimate lane change intentions in other drivers using Hidden Markov Models (HMMs). Comparing the proposed method with previous researches, we confirmed this method has higher accuracy to detect a lane change in other vehicles. And the method can recognize a slow lane change which is remained as a problem.

1 INTRODUCTION

Recently many researches have been carried out on Intelligent Transport System (ITS). Driving safety support system (DSSS) included in ITS presents informations to a driver in order to avoid vehicle accidents. For the adequate informations, it is necessary to estimate intentions in other drivers specially a lane change which is the main cause of vehicle accidents [1].

A lane change estimation can be classified to own driver's intentions and others'. Kuge et al. proposed a method to detect a lane change using Hidden Markov Models (HMMs) [2]. The method uses lateral positions, steering angle, and steering angle velocity for features. However, steering angle and steering angle velocity in other vehicles are not easily measured, thus it cannot be applied to the detection of lane change intentions in others. On the other hand, Mandalia et al. suggested a lane change detection method only used lateral positions data which are measurable by distance sensors [3]. However, the method uses the distribution of lateral positions as features. As the results, the method has a problem that cannot recognize a lane change on slow speed, because a slow lane change has indistinguishable distribution of lateral positions in a lane keeping.

In this research, we propose a detection method of lane change intentions in other drivers using HMMs. An HMM is the model which can estimate internal states of the human are not directly observable using measurable data. The proposed method only needs lateral positions data as features which can be measured by distance sensors like a laser range finder or position recognition systems like GPS. This paper describes the method to detect a slow lane change which is remained as a problem, and the detection accuracy is compared with previously developed techniques.

2 PROPOSED METHOD

HMMs have proven to be one of the most widely used tools for learning probabilistic models of time series data. Figure 1 shows conceptual configuration in this study. In the Fig. 1, "mine" represents the vehicle which the proposed method is applied and estimates lane changes of other vehicles, whereas "target" is the vehicle which is estimated to change lanes. A lane change consists of three steps as "keeping", "changing", and "adjustment". Each step is defined as one state of the HMM. The proposed method estimates the time when the state transition occurs from "keeping" to "changing" using the Viterbi algorithm. Among variable structures, left-to-right structure is the most effective structure according to the previous research [2].

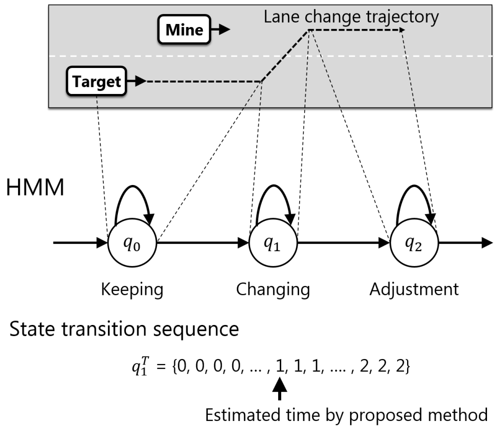
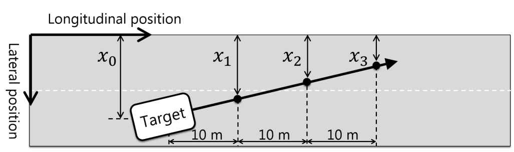


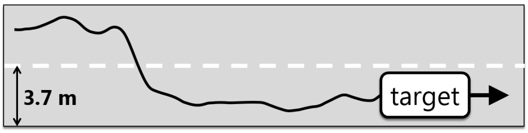
Fig. 1 Conceptual configuration.

A key issue is the feature selection using recognition methods. Only using the most effective set of features has higher detection accuracy than set of all possible features [3]. As the purpose in this study is detecting lane changes of other vehicles, only measurable data must be chosen, and the data must have significant differences during a lane change against a lane keeping. Our method uses only lateral positions as features which are measurable by distance sensors and position recognition systems. Figure 2 shows the definition of features used in the proposed method. For example, "Lateral position 10" means the lateral position for the point 10 m directly ahead of the vehicle. It is derived from the current lateral velocity and longitudinal velocity. Lateral positions data are inputted to the HMM directly without converting to the distribution. Distributions of lateral positions are effective features for the recognition of a lane change pattern, but

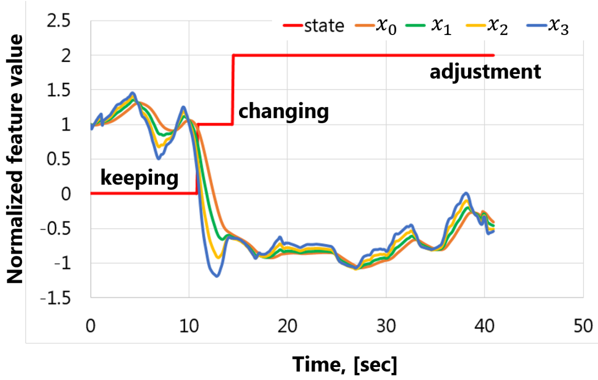


$$\boldsymbol{x} = \begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix} \quad \begin{array}{l} x_0 : Lateral\ position\ 0 \\ x_1 : Lateral\ position\ 10 \\ x_2 : Lateral\ position\ 20 \\ x_3 : Lateral\ position\ 30 \end{array}$$

Fig. 2 Features definition.

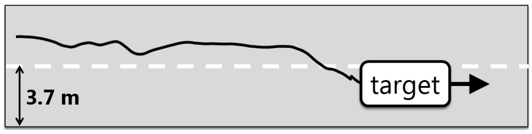


(a) Driving trajectory.

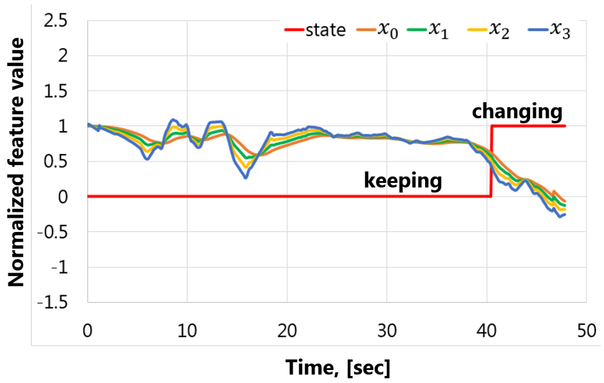


(b) Features and estimated states by proposed method.

Fig. 3 General lane change.



(a) Driving trajectory.



(b) Features and estimated states by proposed method.

Fig. 4 Slow lane change.

a slow lane change has indistinguishable values with a lane keeping. On the other hand, using the value of lateral positions directly is the absolute reference to distinguish a lane change with a lane keeping.

Using a continuous HMM based on the multiple vector needs to be normalized to prevent the influence of each dimensions. The detection accuracy is greatly affected to the normalization, but it is impossible to calculate accurate average and distribution of features in online tests by real vehicles. Because of using only lateral positions as features, the average can be set a constant value as the center line, and distributions are calculated by the data until the current time. However, a rapid lane change produces large deviations which make emission probabilities too small, and it causes the current state estimation using the Viterbi algorithm cannot work. For this reason, the proposed method sets the limit of deviations.

3 EXPERIMENTS

For assessment of the proposed method, we used the real-world data set has been published by The Federal Highway Administration on the web site [4]. 100 lane change samples and 100 lane keeping samples were used in the evaluation not used in training phase. The results are shown in Table 1. Among 100 actual lane change samples, 99 were detected correctly, and 95 lane keeping were correctly recognized. Comparing the results with previous methods, Kuge et al. achieved accuracy 98 %, but it used steering angle and steering velocity which are unmeasurable data from other vehicles. The proposed methods has almost same accuracy 99 % only using lateral positions data which are measurable by distance sensors and position recognition systems. Mandalia achieved 97.9 % using SVM and 80.2 % using HMMs. The proposed methods achieved higher accuracy comparing the previous technique using the HMM.

Figure 3b shows the normalized features and the estimated states by the proposed method in one general lane change sample, and Figure 4b is the result in one sample of a slow lane change. It was confirmed that the proposed method can detect a slow lane change even if the vehicle has indistinguishable distribution of lateral positions.

4 CONCLUSION

The proposed method has been confirmed that it has high accuracy of the lane change detection using the real-world data set. Moreover, our method can be the solution of the slow lane change detection which is not recognized by the previous method.

Table 1 Assessment results

	Lane change	Lane keeping
Test samples	100	100
Successful samples	99	95
Failed samples	1	5
Accuracy [%]	99	95

References

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