Lane-Change Detection Based on Vehicle-Trajectory Prediction

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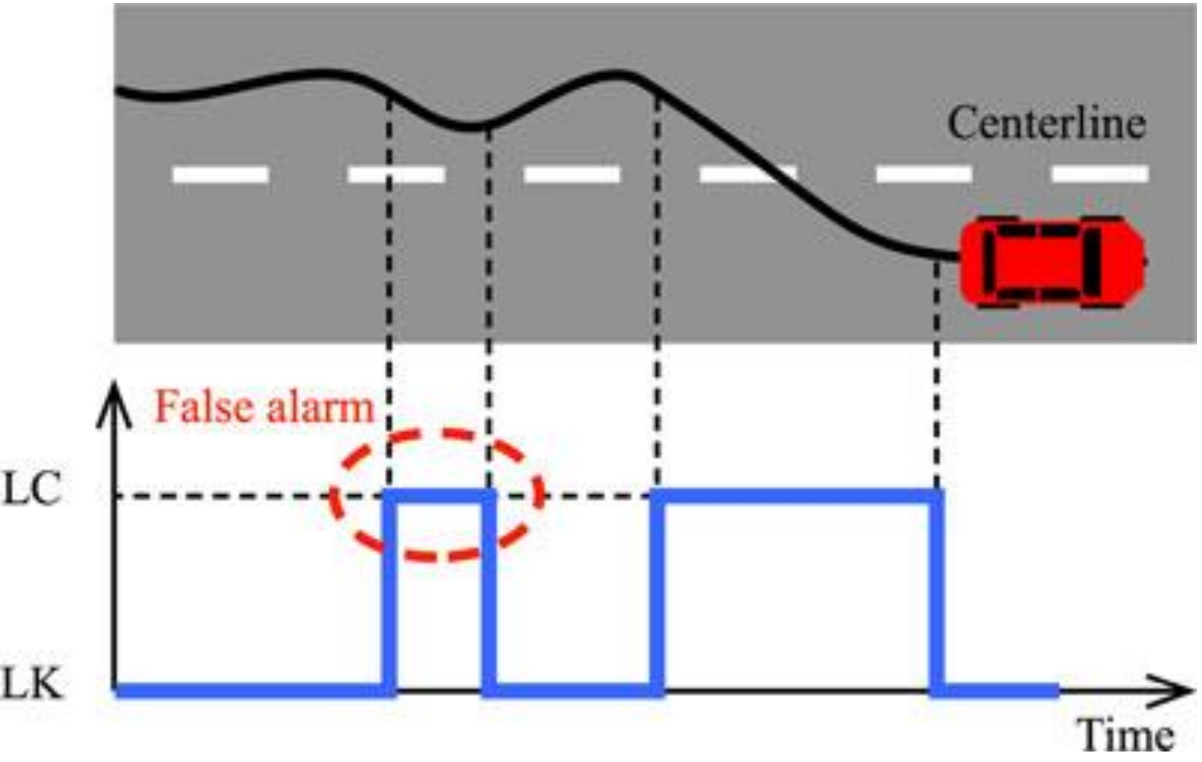
CONTENTS

Introduction

- In this paper, it was determined that there was a problem with a false alarm when a vehicle changed lanes.
- It also proposes a method to predict the trajectory of the vehicle and use it to detect lane changes because this can lead to distrust of the driver's driving support system.
- Predict the trajectory that a person moves unconsciously.

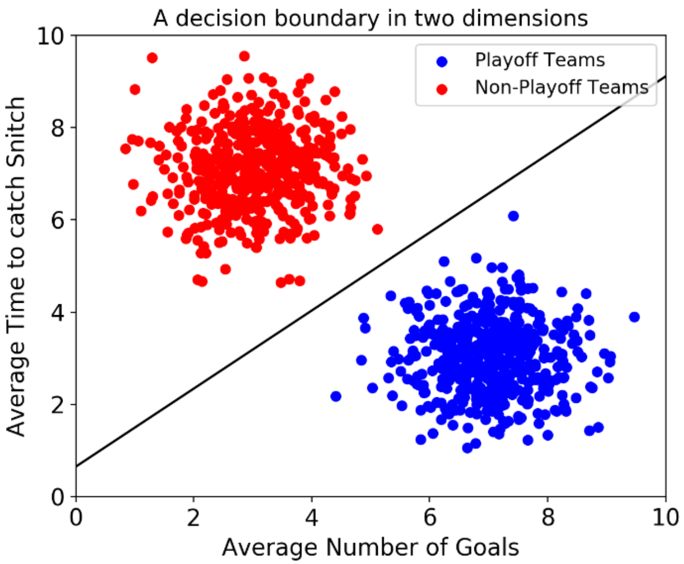


Data set

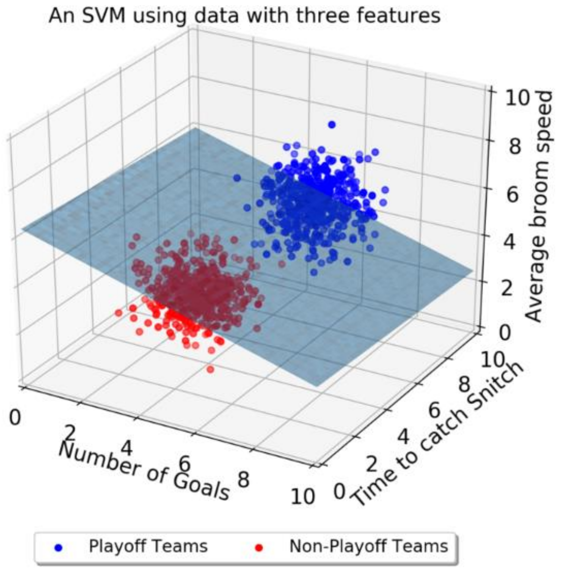
- used a real-world traffic dataset published by the Federal Highway Administration.
- collected from eastbound I-80 in the San Francisco Bay Area.
- The measurement area was 500 m long and consisted of six highway lanes.
- measured three times per 0.1 second over a 15-minute period and collected data from 5678 vehicles.
- used 300 lane change data for training and 523 lane change data for testing.

Model Used

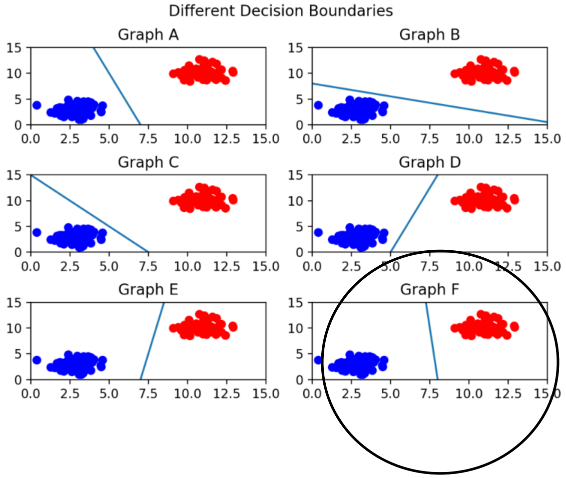
- SVM Model



Decision Boundary

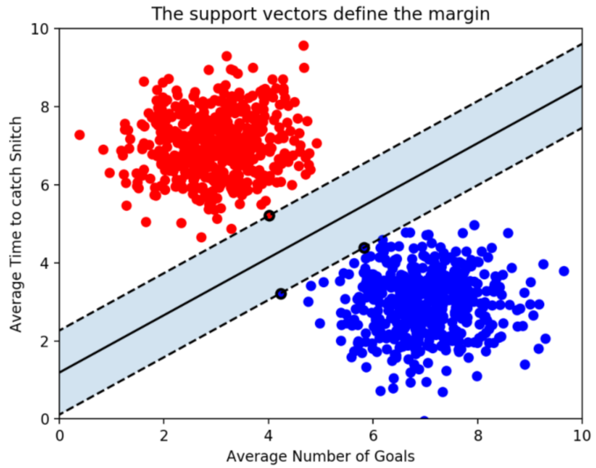


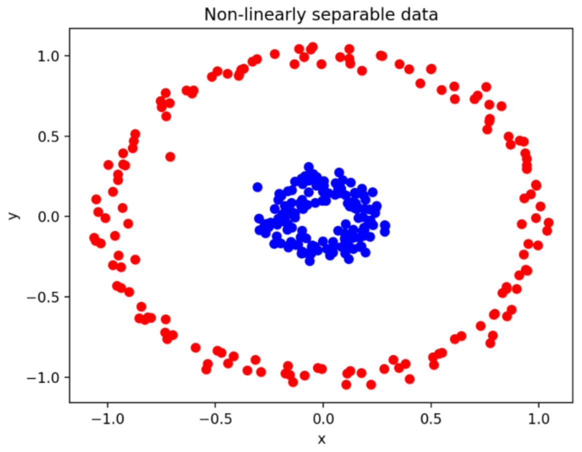
hyperplane

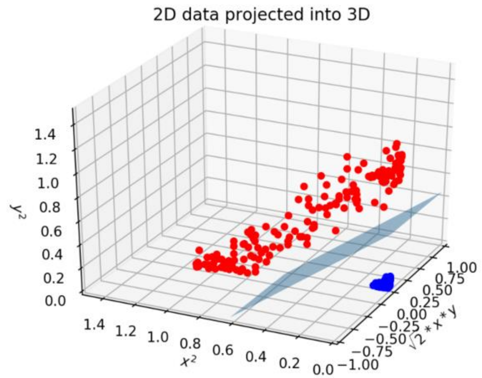


Model Used

- SVM Model





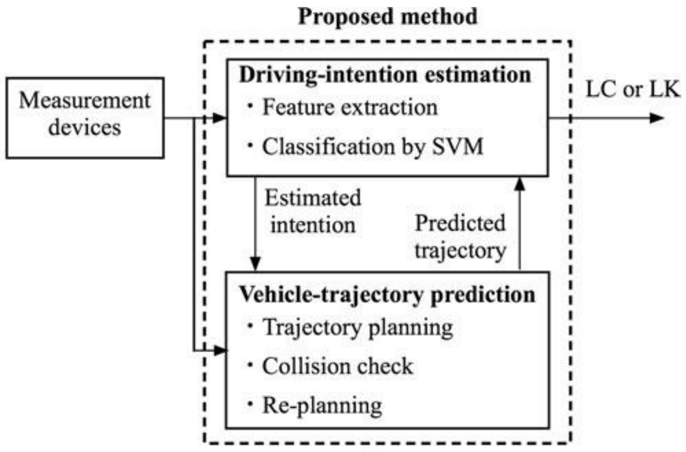


Margin

Kernel

Distance between Decision boundaries and support vectors

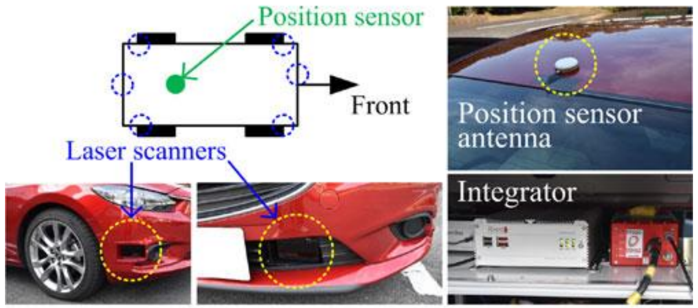
Methods



(a)

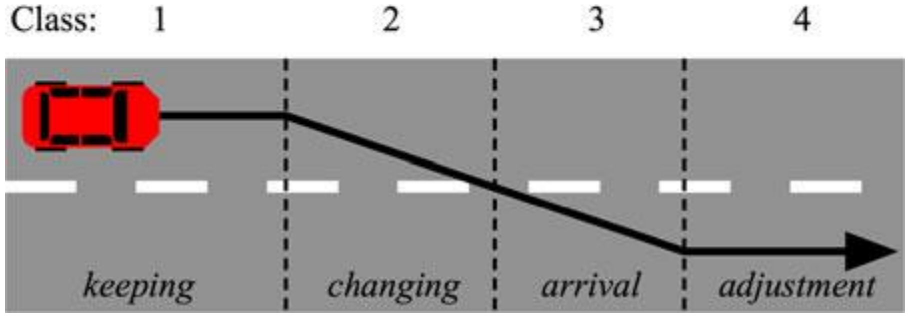
sensor (RT3003) and six laser scanners (ibeo LUX)

(a) (b)



(b)

Each driving intention is defined as a class,
and the proposed method treats the driving-intention estimation as a multi class classification problem



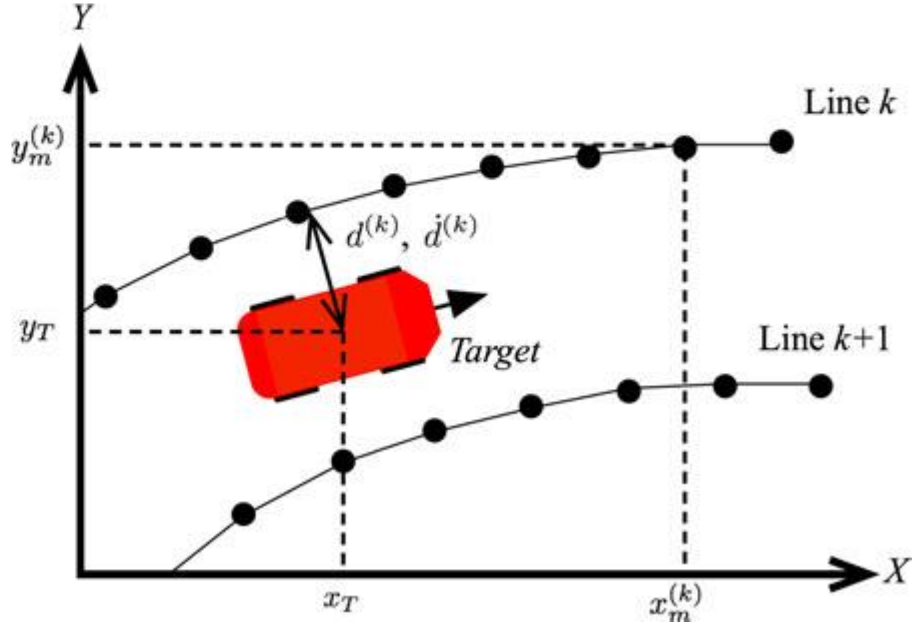
The extracted feature vector is inputted to the estimation model, following which the driving intention at the current time is determined

Methods

DRIVING-INTENTION ESTIMATION

A. Feature Extraction

B. Driving-Intention Estimation



The proposed method defines three types of features. Features of distance from the center line, lateral velocity, and potential.

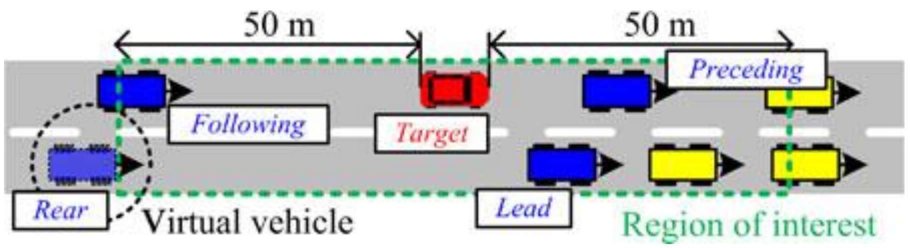
To consider the curvature of the road, use the distance from the center line instead of the lateral position instead of the distance from the center line

Methods

A. Feature Extraction

converted into feature vectors used as inputs to the driving intention estimation model

Carry out a crash check assuming that another vehicle is moving at a constant speed.



$$U_C = \omega_P U_P + \omega_F U_F \; (0 < U_C \leq 1) \quad (10)$$

$$U_N = \omega_L U_L + \omega_R U_R \; (0 < U_N \leq 1) \quad (11)$$

the red vehicle represents the target vehicle

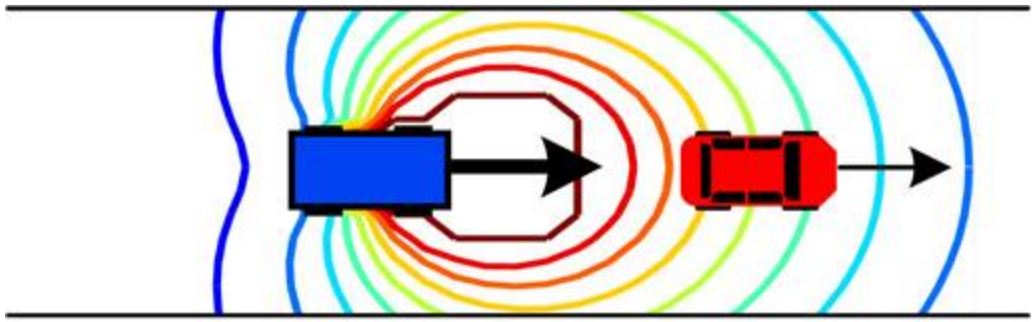
the blue vehicles represent the selected adjacent vehicles

the yellow vehicles are not considered.

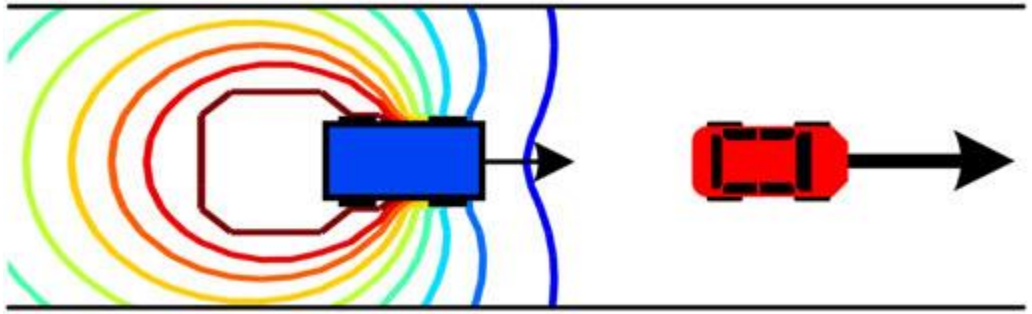
The transparent blue vehicle represents the virtual vehicle that is set by the proposed method.

Methods

B. Driving-Intention Estimation



(a)



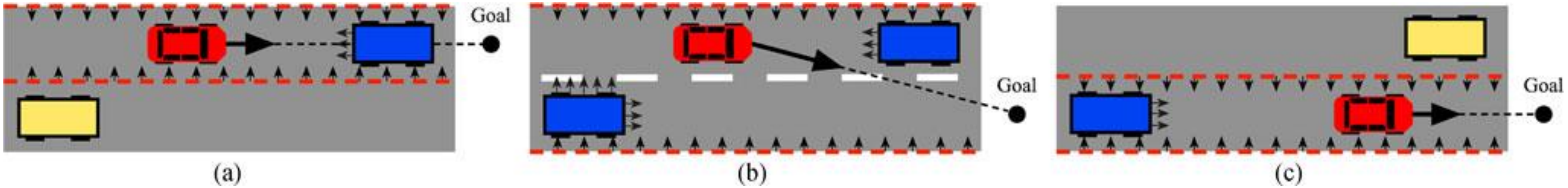
(b)

(a) the distribution of the potential field when vehicle i is faster than the target

(b) the distribution of potential field when vehicle i is slower than the target

The red vehicle is the target, and the blue one is vehicle i.

Methods



(a) a case in which the driving intention is keeping

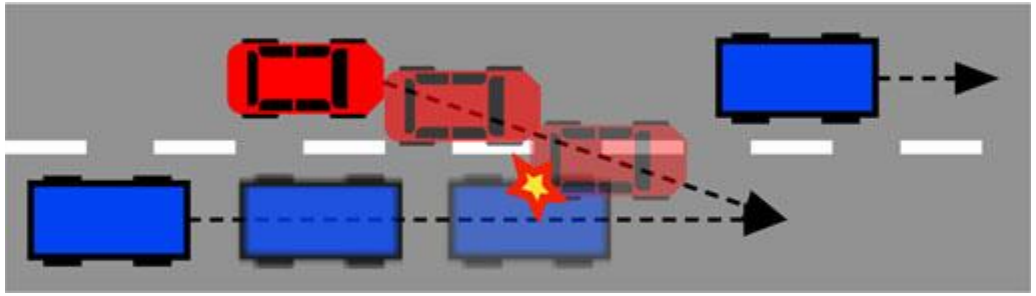
(b) a case in which the driving intention is changing and arrival

(c) a case in which the driving intention is adjustment.

The red vehicle represents the target

The blue one generates repulsive potential energy

The yellow one does not generate repulsive potential energy



The red vehicle is the target

blue ones are adjacent vehicles

Transparent color denotes the predicted position

If a collision occurs during a lane change, the predicted trajectory is re-planned.

Experimnets / Conclusion

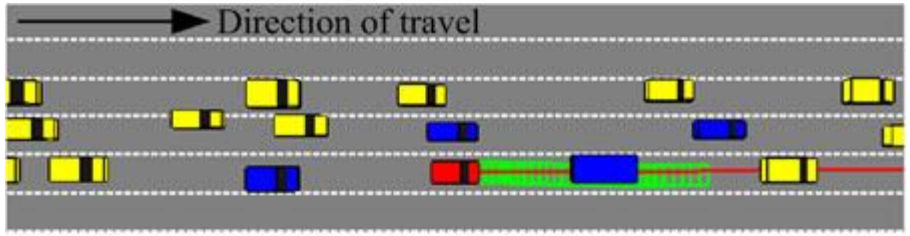
The green rectangle represents the predicted position at each time step

The red line shows the ground truth

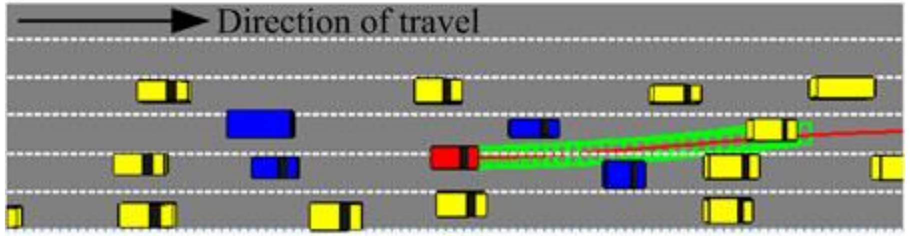
The red vehicle is the target

The blue ones are adjacent vehicles

The yellow ones are other vehicles that are not considered



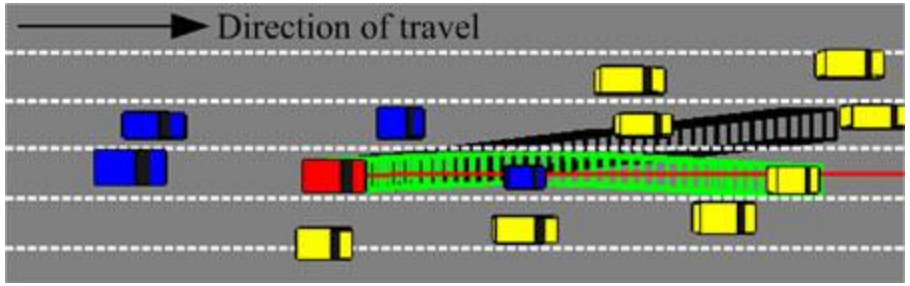
(a)



(b)

(a) when the target keeps the lane

(b) when the target changes the lane



The black rectangle represents the initially predicted trajectory

Re-planning was conducted because of the collision

The green rectangle shows the re-planned trajectory

The red line shows the ground truth

Experimnets / Conclusion

Two evaluation criteria were used: detection time τ_d and detection accuracy F1 score

$$\tau_d = \tau_c - \tau_j, \qquad (23)$$

$$F_1 = 2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}}. \qquad (24)$$

First, the detection time : $\theta_d = \theta_c - \theta_j$

where θ_c is the moment the target crosses the centerline

θ_j is the moment the proposed method determines that the target will change lanes

A large value of θ_d means a high initial detection performance, defined as follows

Based on detection time τ_d:
1) Success: $0 < \tau_d < 5.0$ (judged within the time limit).
2) Failed: $\tau_d \leq 0$ (judged too late).
3) False alarm: $\tau_d \geq 5.0$ (judged too early).

Experimnets / Conclusion

Two evaluation criteria were used: detection time τd and detection accuracy F1 score

$$\tau_d = \tau_c - \tau_j, \quad (23)$$

$$F_1 = 2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}}. \quad (24)$$

Including precision in the F1 score allows you to evaluate the false alarm rate when determining that the proposed method does not change lanes as an incorrect lane change.

Lane change estimation method must satisfy recall with 100% accuracy

Conclusion

TABLE I
RESULT OF LANE CHANGE DETECTION

		Without trajectory prediction		Proposed method	
		Detection result		Detection result	
		LC	LK	LC	LK
Ground Truth	LC	523	0	523	0
	LK	36	487	17	506

TABLE II
PERFORMANCE COMPARISON WITH PREVIOUS METHODS

Method	Precision	Recall	F_1	τ_d
Mandalia [8]	80.0 %	81.1 %	80.5 %	1.33 s
Schlechtriemen [7]	93.6 %	99.3 %	96.4 %	1.65 s
Proposed method	96.3 %	100 %	98.1 %	1.74 s

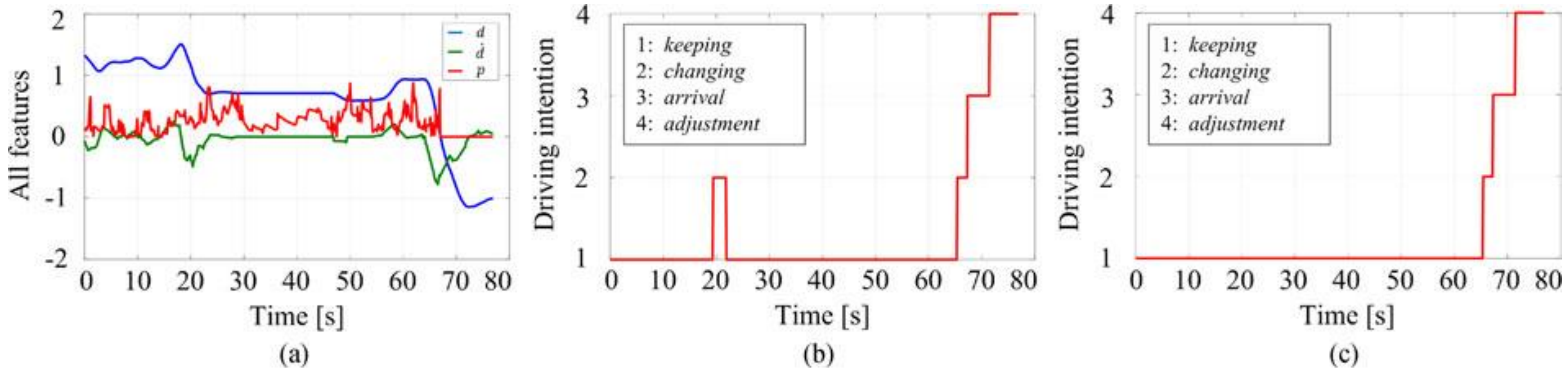
LC (lane changing) and LK (lane keeping)

Mandalia : Only use SVM

Schlechtriemen : Detect lane changes using feature extraction

Proposed method : Apply vehicle trajectory prediction methodology

Conclusion



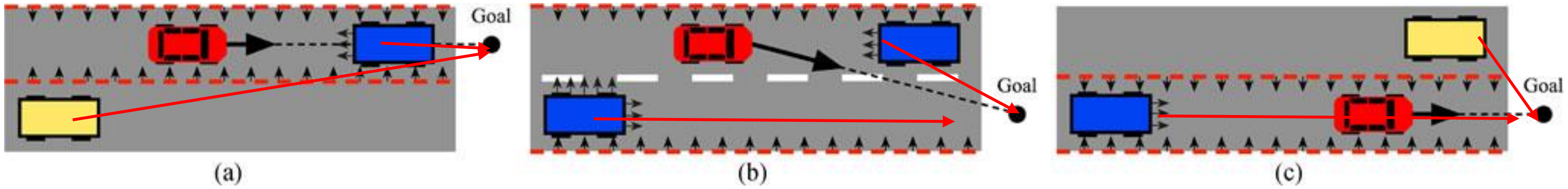
(a) record of all features that are normalized

(b) driving intention estimated by the method

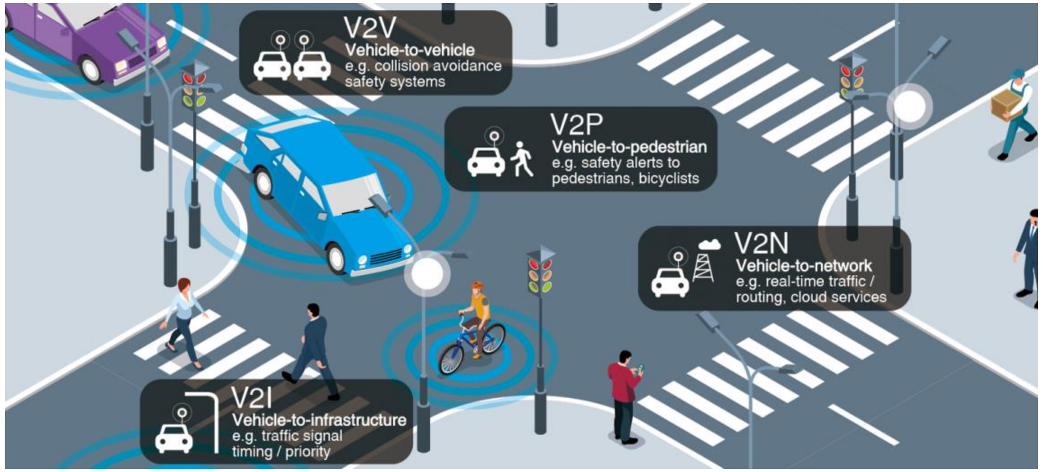
(c) the driving intention estimated by the proposed method

How I can use it in my model

1)



2)



There is a way to use V2X technology

Used V2V, V2I, V2N