Intelligent Auto-driving Vehicle Based on Conversation with Dynamic Obstacle

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Recently, the number of accidents for an electric four-wheeled vehicle increases. User's driving skill and knowledge shortage are enumerated as the cause. Especially, it is difficult to judge other traffic participants' movement and to decide the content of the evasive action. Up to the present, we had developed an automatic driving system that can correspond also to a dynamic obstacle by building the driving algorithm based on the predictive fuzzy control into the controller, and adding the driving knowledge to human safety. In this paper, the pavement is assumed as an actual life environment, and the behavior of the automatic driving system was confirmed by the simulation.

Keywords: Predictive fuzzy control, Dynamic obstacle

1 Introduction

To assist the movement of the senior citizen etc., an electric four-wheeled vehicle that doesn't worry about fall and doesn't need driving license is marketed. However, the accident number increases as the number of the users increases.[1] User's driving skill and knowledge shortage are enumerated as the cause. Especially, a high driving skill and the physical strength to drive safely while flexibly evading a dynamic obstacle are demanded because dynamic obstacles such as pedestrians and other electric four-wheeled vehicles exist when it drives in the passage and the pavement. But, there are a lot of users with insufficient those skill and ability. Therefore, a function to evade dynamic obstacles is indispensable for building an auto-driving system for electric four-wheeled vehicles.

So far, we have developed the intelligent auto-driving system[2][3] by building humans' driving knowledge into a controller, so that the user with insufficient driving skill and knowledge may do at ease availably.1 These systems drive while flexibly corresponding to the given target automatically. However, these systems are the one in a static environment, and the correspondences to a dynamic obstacle such as pedestrians and other electric wheelchairs are difficult.

Then, we have developed the auto-driving system for an electric four-wheeled vehicle that evades a dynamic obstacle by adding knowledge to humans' safety to the controller. In this research, the pavement is assumed as an actual life environment, and it aims to construct the auto-driving system for electric four-wheeled vehicle in the pavement based on this system. In this paper, the situation of the movement of the auto-driving system in the pavement is confirmed by the simulation.

Fig 1: Intelligent auto-driving system

2 Human's driving method

We think that human beings predict the future state of their vehicle for safely before they do a certain operation, and select the operation that can reach the target safely. For instance, human beings select the steering candidate such as "The steering wheel is turned a little" and "Advance without turning the steering wheel", by evaluating such as "It will be getatable to the target roughly" and "It will be getatable to target well".At the same time, they predict the future state of the dynamic obstacle too, and evaluate safety to dynamic obstacle from "Distance with the dynamic obstacle", "Relative speed with the dynamic obstacle", and "Direction of the dynamic obstacle".We think that human beings have selected the operation to be getatable to the target well and evade the dynamic obstacle by adding this safety to the evaluation of the target attainment previously described.

3 Outline of the system

To do automatic driving safely, the algorithm based on human's driving method is divided to three layers and is built into a soft controller shown in figure 2.

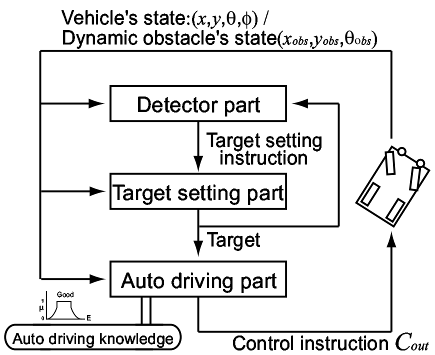

Fig 2: Outline of the system

3.1 Detector part

Detector part is observing the vehicle whether reach the target. When judging that it reaches the target or the attainment to the target is difficult in the obstacle contact possibility, the target setting instruction is sent to the target setting part.

3.2 Target setting part

We consider that human beings set a target while considering the dynamic characteristic of the vehicle, during a way to a destination arrival. When a target setting instruction is output from the detector part, a new target is set by the relation of current position of the vehicle and the destination[4].

3.3 Auto driving part

Into the auto driving part, the steering instruction and speed instruction are output by the predictive fuzzy control at intervals of 0.1 seconds. The predictive fuzzy control is an algorithem as evaluating future states assuming candidates $C_i(i = 0, \cdots, n)$ will be done and selecting an instruction C_{out} which can most accomplish the purpose (in this sysytem "approach the target safely").At this time, the evaluated item is "target deflection", "distance with obstacle", and "safe grade". "safe grade" is a value in which safety to dynamic obstacle from distance and relative speed of vehicle and dynamic obstacle is quantified[5].

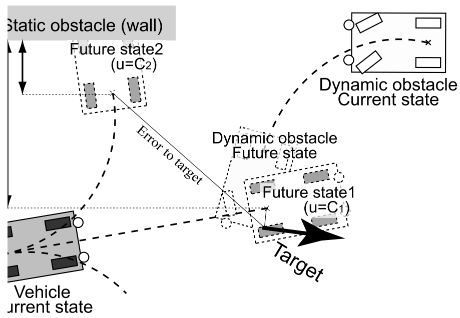

Fig 3: Operation candidates with predicitons

3.3.1 Prediction of the future states

Shown in figure 3, the future states after t_a are predicted of the vehicle and dynamic obstacles at intervals $Deltat$. The vehicle's future state is predicted by C_i estimated by ϕ_{obs} calculated from (x_{obs},y_{obs},θ_{obs}). Attainment forecast time t_a is calculated by dividing the distance from current position to the target by a velocity candidate.

3.3.2 Safe grade

Human beings predict their vehicles' future state and dynamic obstacles' and select an operation that will satisfy their purpose safely. Then, the controller is built into humans' safe driving knowledge. In this paper, we define two words, one is safe grade(y_k), the other is safe grade($SafeG_i$) in the operation candidateC_i. The possibility of collision with the dynamic obstacle every Δt is defined as safe grade(y_k), when estimating the operation candidate is done. Minimum safe grade during t_a is defined as safe grade($SafeG_i$) in the operation candidateC_i.

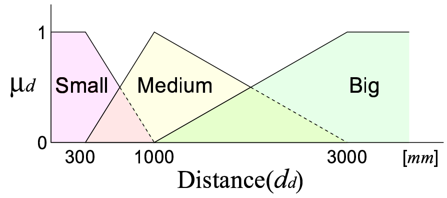

Fig 4: Fuzzy sets of distance to dynamic obstacle

The procedure for calculating safe grade(y_k) and safe grade($SafeG_i$) in the operation candidateC_i is as follows.

Firstly, the Δt future states of the vehicle and dynamic obstacles are predicted by operation candidate C_i, (x,y,θ) and $(x_{obs},y_{obs},\theta_{obs},\phi_{obs})$. Secondarily, the relation between the vehicle and the dynamic obstacle (distance, relative speed, and angle of relative speed) is calculated. Thirdly, the adaptability ω_j of the relation and 27 rules shown in table 1 is calculated by equation (1). Fourthly, equation (2) shows that safe grade(y_k) is calculated by multiplying the adaptability ω_j and grade(D_j). As shown equation (3), safe grade($SafeG_i$) in the operation candidateC_i is the minimum value of safe grade.

$$\omega_j = \mu_{dj}(d_d) \times \mu_{vj}(d_v) \times \mu_{aj}(d_a) \tag{1}$$

$$y_k = \frac{\sum_{j=0}^{26} \omega_j D_j}{\sum_{j=0}^{26} \omega_j} \tag{2}$$

$$SafeG_i = \min(y_1, \cdots, y_k, \cdots) \tag{3}$$

表 1: Safe rules based on humans' safe knowledge

j	$\mu_{dj}(d_d)$	$\mu_{vj}(d_v)$	$\mu_{aj}(d_a)$	Grade D_j
0	Big	Big	Big	55
1	Big	Big	Medium	40
⋮	⋮	⋮	⋮	⋮
20	Small	Big	Small	0
21	Small	Medium	Big	40
⋮	⋮	⋮	⋮	⋮
26	Small	Small	Small	25

3.3.3 Multipurpose evaluation

he purposes(dr_i:distance between current state and the target, $d\theta_i$:angle error between current state and the target, d_{Fi}:margin between obstacles and the front of the vehicle, d_{Li}:margin between obstacles and the left side of the vehicle, and d_{Ri}:margin between obstacles and the right side of the vehicle) are calculated by the future state later t_a. These 5 parameters and safe quantity($SafeQ_i$) are evaluated by multipurpose fuzzy inference. And the best candidate is output as a safe control instruction C_{out}, shown in figure 5.

4 Simulation

A simulation is done in the situation shown figure 6. Two kinds of of the case for the obstacle to (a)go straight and (b)turn left on the way were simulated. There is dynamic obstacle which is a vehicle driven by human. It will advance as almost constant-speed and straight. The coordinate value of the destination (2.0m, 1.2m, 0.0rad), the form of static obstacle(walls), and the current coordinate value of the dynamic obstacle are input to the controller evry 0.1 seconds.

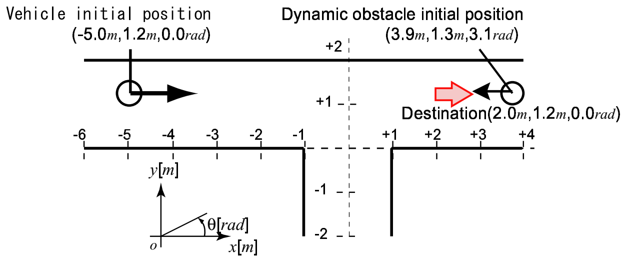

Fig 6: Initial condition and destination of simulation

4.1 Simulation result

The system reached the destination safely while eluding the dynamic obstacle. The runnig tracks of the vehicle and the dynamic obstacle are shown in figure 7, and figure 8.

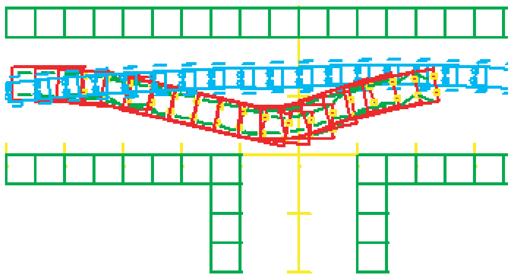

Fig 7: (a)The running tracks(go straight)

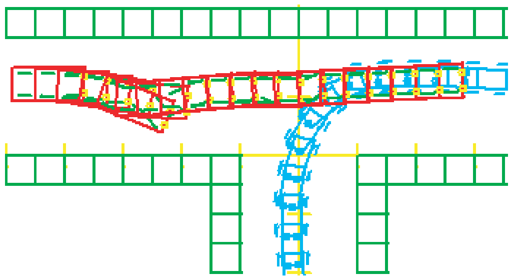

Fig 8: (b)The running trachs(turn left on the way)

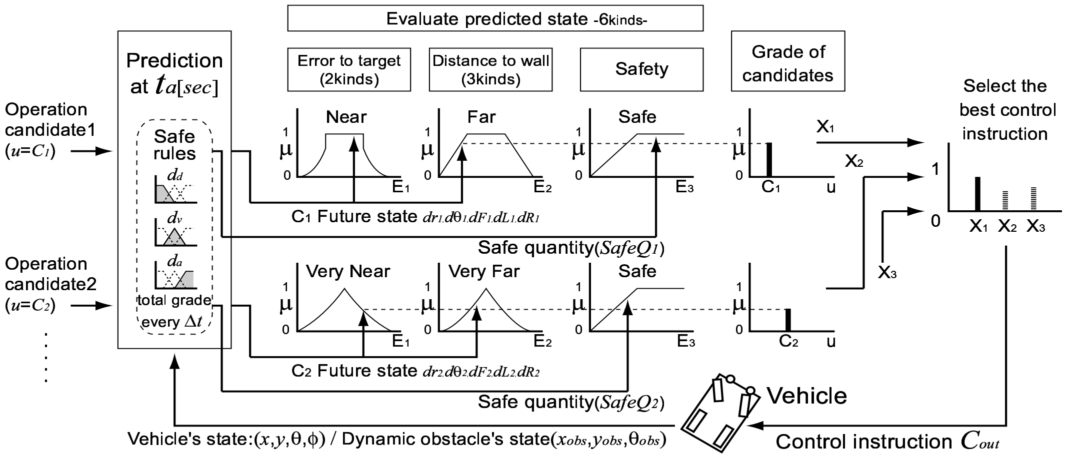

Fig 5: Outline of predictive fuzzy controller

4.2 Evaluation of the simulation result

Human being can evade safely by being predict the future state of a vehicle and a dynamic obstacle, and selecting the operation that considers safety to the dynamic obstacle.

a)When a dynamic obstacle goes straight, this system has evaded coming in contact beforehand by selecting the right steer that doesn't come in contact with the wall.

b)When a dynamic obstacle turns left on the way, this system has been selecting the right steer as well as the case where the dynamic obstacle goes straight after 5.0 seconds the experiment beginning. However, because the dynamic obstacle turned left on the way, this system has evaded coming in contact by being select a left steer in 7.0 seconds.

Thus, it was possible to flexibly evade a dynamic obstacle in the simulation environment that assumes the pavement.

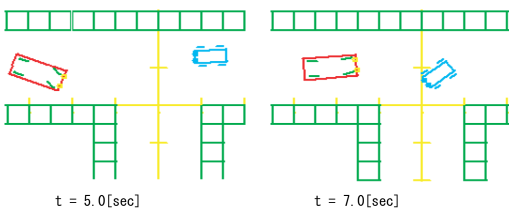

Fig 9: (b)Positions at 5.0, 7.0 seconds

5 Conclusion

In this paper, we In this paper, the pavement is assumed as an actual life environment, and the behavior of the automatic driving system that considers dynamic obstacle was confirmed by the simulation. The experiment with a real machine is scheduled to be conducted in the future.

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