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Intelligent Soft Driving System for an Electric Four-wheeled Vehicle Eluding Dynamic Obstacles

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Abstract

There are electric four-wheeled vehicles to assist elder people. Because of the vehicles' dynamic characteristic such as impossible to move abeam, it is difficult for these people who has little experience and has little knowledge to drive. Also to judge the future state of dynamic obstacles and to decide how to elude them safely are more difficult. We installed the predictive fuzzy controller (evaluates the future states which several kinds of operation candidates were done and chooses the best one) that modeled humans' algorithms in the system. Human predicts the future states of dynamic obstacles and chooses an operation(wait, steer, go back, etc) to elude safely. To elude dynamic obstacles flexibly, we added expert's knowledge for safe driving to this controller. In this paper, we propose the intelligent soft driving system by the controller that can elude dynamic obstacles safely, and we confirm the effectiveness by a simulation.

Keywords: Predictive fuzzy control, Dynamic obstacle, Vehicle control.

1 Introduction

There are electric four-wheeled vehicles(figure 1) to assist the movement of elder people. Knowledge and skills of the counter steer etc. are necessary to drive these vehicles well. Because the acquisition of the license etc. is unnecessary, a lot of users who do not understand the dynamic characteristic of the vehicle exist [1]. Then, operation support systems [2] are researched so that the user with an insufficient knowledge and skills might make the four-wheeled vehicle available. Especially, it is necessary to user to drive with considering other traffic participants, when using the vehicle with shopping to the vicinity etc. The document [3] shows that older drivers are weak in right and left turn of the intersection with dynamic obstacles. One reason is necessity of paying attention to not only driving operation of own vehicle but also behavior of dynamic obstacle of another vehicle and pedestrian. And another reason is necessity for doing operation quick even if body has become

Figure 1: Electric four-wheeled vehicle and dynamic obstacle(pedestrian)

weak. Therefore, function to evade the dynamic obstacle is indispensable for building an automatic driving and support system for these electric four-wheeled vehicles.

So far, we have developed an automatic driving system which accepts and cooperates with human by building humans' driving knowledge into the controller [4]. In this paper, we propose an automatic driving system which has a function to elude dynamic obstacles flexibly by installing humans' safe knowledge on the past system.

2 Human's driving method

In this paper, we treat a vehicle which had a steer mechanism in front wheel. This vehicle is driven by steering with the bar handle and accelerating with the speed adjustment lever. Because the vehicle has a non-holonomical characteristic such as impossible to move abeam, skill and experience are required to drive a vehicle. And, it is difficult to control it automatically from nonlinear of that.

To achieve an automatic driving system that makes humans relaxing by same method and knowledge as theirs, we analyzed their driving algorithm. It was thought that human drives a vehicle while observing the situation of the vehicle and roads while setting targets which should pass to a destination while considering the characteristic of the vehicle while predicting future states of the vehicle. If there are dynamic obstacles, human predicts dynamic obstacles' future state and chooses an operation that can safely elude these obstacles. In the following, human's driving knowledge is divided into three layers.

2.1 Observing surrounding circumstance

Human always observe surrounding circumstances and the vehicle's state, and judge whether to reach a destination.

2.2 Setting the target

While thinking about the characteristic of a vehicle, human set a point (target) so as to reach the destination. Moreover, to reach the target, they judge whether to advance or to retreat.

2.3 Driving operation

For safety, human predict the future state of their vehicle, before they do a certain operation. At the same time, they predict the future state of the dynamic obstacle too, and select the candidate(Stop, Speed down and Steer opposite etc) that can reach the target safely. And they always keep a safe state by considering not only current safety but also the future safety. For instance, the human: to the steering candidates such as "The steering wheel is turned a little" and "Advance without turning the steering wheel". A vague evaluation "It will be getatable to the target roughly" and "It will be getatable to the target well" is done. Because they are continuously evaluating safety, they can flexibly correspond to the change in the movement of the dynamic obstacle. For example, when the dynamic obstacle stops, human changes the operation of "Greatly right steer" to "Small right steer" so as to reach safely the target. For example, when the dynamic obstacle accelerates, human changes the operation of "Speed down" to "Stop" so as to elude the dynamic obstacle. In the next chapter, the humans' concept of continuous future's safety is explained as safe quantity.

3 Outline of the system

To do automatic driving safely, the algorithm based on humans' driving method is divided to three layers and is built into a soft controller shown in figure 2. This controller is given dynamic obstacles' position $(x_{obs}, y_{obs}, \theta_{obs})$ at intervals of 0.1 seconds. If a dynamic obstacle is a vehicle, its steering angle ϕ_{obs} is calculated from its position.

3.1 Detector part

One function is to detect the current state of the vehicle and obstacles. Another is to observe to the vehicle advances toward a target set in the target setting part. The target setting instruction is sent to the target setting part if reaching at a target.

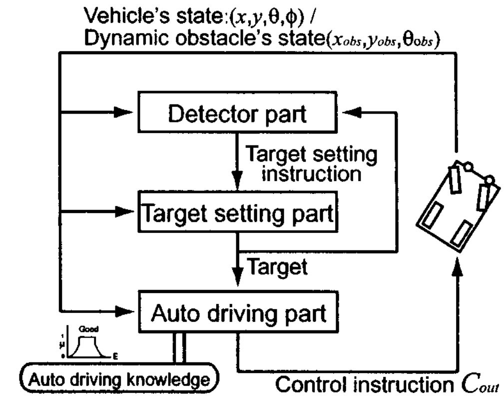

Figure 2: Outline of the system

3.2 Target setting part

Human sets 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. This target setting algorithm is shown in [5].

3.3 Auto driving part

In the auto driving part, the steering instruction and speed instruction are output by predictive fuzzy control at intervals of 0.1 seconds. Predictive fuzzy control is an algorithm as evaluating future states assuming candidates $C_i(i = 1,\cdots,n)$ will be done and selecting an instruction C_{out} which can most accomplish the purpose (in this system "approach the target safely").

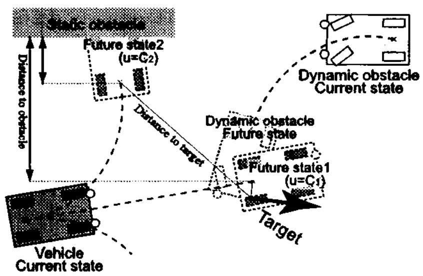

Figure 3: Evaluation of predictions

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 of Δt. The vehicle's future state is predicted by C_i estimated to use. The dynamic obstacle's future state is predicted by ϕ_{obs} calculated from $(x_{obs}, y_{obs}, \theta_{obs})$. Attainment forecast time t_a is calculated by dividing the distance from current position to the target by a velocity candidate.

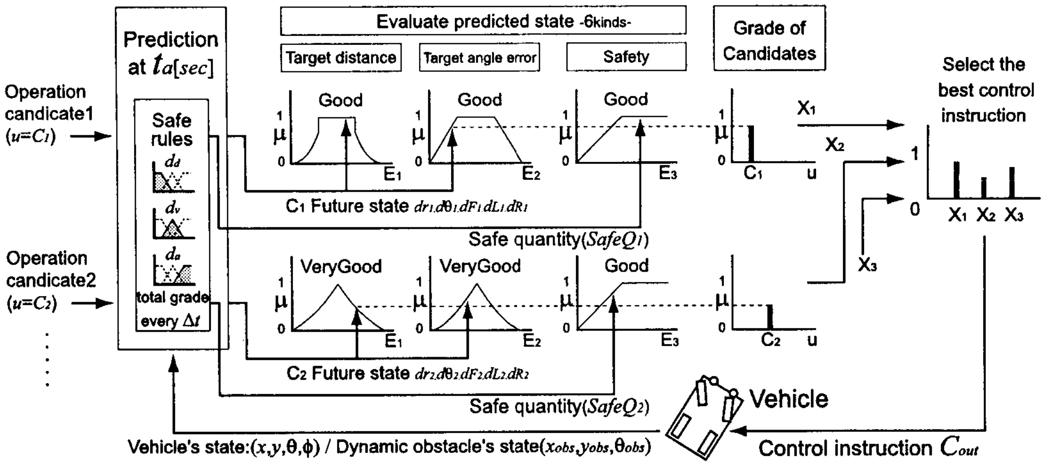

Figure 4: Predictive fuzzy controller

3.3.2 Safe quantity

Always to be safe, human 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' knowledge of safe driving. In this paper, we define two words, one is safe grade and the other is safe quantity. The possibility of collision with the dynamic obstacle every Δt is defined as safe grade(y_k), when estimating the operation candidate is done. The possibility of collision with the dynamic obstacle during t_a is defined as safe quantity($SafeQ_i$). To judge the safety always, safe quantity($SafeQ_i$) is calculated by summing safe grade(y_k) during the total predicted step $K(=t_a/\Delta t)$. For human, the near future's safety is more important than the far future's safety. Shown in the equation of safe quantity (1), safe grade(y_k) is divided by predicting time($=\Delta t\times$predicting step k), to reflect the importance of the near future's safety. Human evaluate the relation to dynamic obstacles vaguely. Fuzzy sets that quantified humans' fuzziness are shown in figure 5. Humans' knowledge, "The dynamic obstacle exists near position, and advances toward here, so I will become very danger" which is an example, can be converted to fuzzy rules that "If distance is SMALL, velocity is BIG and angle of velocity is SMALL Then VERY DANGER". Table 1 is knowledge, based on humans' safe knowledge, expressed by 27 fuzzy rules.

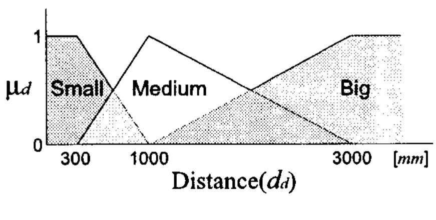

Figure 5: Fuzzy sets of distance to dynamic obstacle

The procedure for calculating safe grade and safe quantity is as follows. Firstly, the Δt future states of the vehicle and dynamic obstacle 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 (3). Fourthly, equation (2) shows that safe grade(y_k) is calculated by multiplying the adaptability ω_j and grade(D). As shown equation (1), safe quantity($SafeQ_i$) is the total value of safe grade with time weight during t_a, by using operation candidate C_i.

$$SafeQ_i = \sum_{k=1}^{K} \left(y_k \cdot \frac{t_a}{\Delta t \cdot k} \right) \quad (1)$$

$$y_k = \frac{\sum_{j=0}^{26} \omega_j D_j}{\sum_{j=0}^{26} \omega_j} \quad (2)$$

$$\omega_j = \mu_{dj}(d_d) \times \mu_{vj}(d_v) \times \mu_{aj}(d_a) \quad (3)$$

Table 1: Safe rules based on humans' safe knowledge

j	$\mu_d(d_d)$	$\mu_v(d_v)$	$\mu_a(d_a)$	Grade D
0	Big	Big	Big	+15
1	Big	Big	Medium	+10
⋮	⋮	⋮	⋮	⋮
20	Small	Big	Small	-30
21	Small	Medium	Big	-10
⋮	⋮	⋮	⋮	⋮
26	Small	Small	Small	-15

3.3.3 Multipurpose evaluation

The 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, such as "If (u is $C_i \rightarrow dr_i$ is GOOD, $d\theta_i$ is GOOD, d_{Fi} is GOOD, d_{Li} is GOOD, d_{Ri} is GOOD, $SafeQ_i$ is GOOD) Then (u is C_i)". And the best candidate is output as a safe control instruction C_{out}, shown in figure 4.

4 Simulation

A simulation is done in the situation shown figure 6. There is a dynamic obstacle which is a vehicle driven by human. It will advance as almost constant-speed and straight. The coordinate value of destination ($0m$,$2m$,$1.57rad$), the form of static obstacle(wall), and the current coordinate value of the dynamic obstacle are input to the controller every 0.1 seconds.

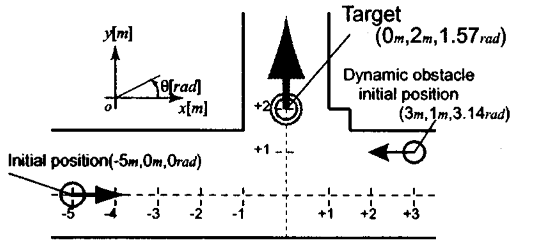

Figure 6: Situation of simulation

4.1 Simulation result

The system reached the destination safely while eluding the dynamic obstacle. The running tracks of the system and the dynamic obstacle are shown in figure 7.

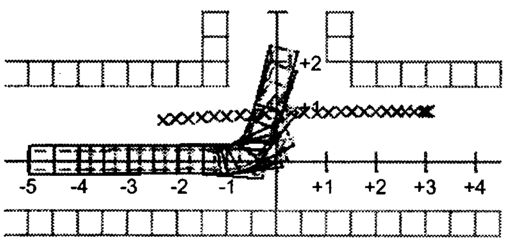

Figure 7: Running tracks of vehicle and dynamic obstacle

4.2 Evaluation of the result

At a left turn, human advances and stops his car to the place not closing the course of other oncoming car. Then after oncoming car is passed, human turns the left. Shown in figure 8, the proposed system predicted the oncoming dynamic obstacle's future state, and stopped to elude it during 3.6 to 6.8 seconds. And after elusion, the system resumed advancing toward the target.

The proposed system drives a vehicle safely by same safe knowledge as humans', thus the users can understand the movement of the vehicle. So they, relaxing, can use this system.

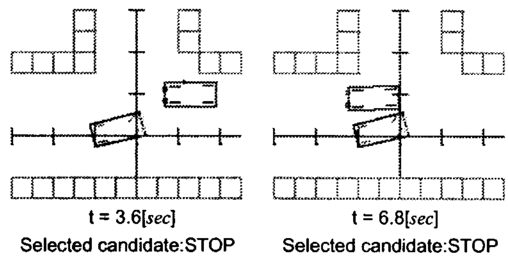

Figure 8: Positions at elusion

5 Conclusion

In this paper, we proposed an automatic soft driving system for a four-wheeled vehicle, by adding the humans' safe knowledge to the predictive fuzzy controller built into the humans' driving knowledge. This system predicts future state of the vehicle and the dynamic obstacle, so can drive safely eluding the obstacle. It was shown in a simulation's result. So it is thought that elder people can use the vehicle with the system while relaxing. An experiment to evaluate this system is scheduled in the near future.

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