Intelligent Soft Driving System Cooperating with Human

Seiji Yasunobu and Masaki Inoue
Institute of Engineering Mechanics and Systems
University of Tsukuba
Tsukuba, Japan
yasunobu@esys.tsukuba.ac.jp

Abstract

An automatic driving for a four-wheeled vehicle has such problems as must be flexible for the surrounding environment and must get human's reliance. In this paper, we propose an intelligent soft driving system by a predictive fuzzy controller that can cooperate with human. To accept and cooperate with human, the system is based on expert's driving knowledge. Experiments show the effectiveness of this system.

Keywords: Predictive fuzzy control, Cooperate with human, Vehicle control.

1 Introduction

Automatic driving systems for a vehicle are studied actively, in the last few years. An automatic driving in an expressway without obstacles is more difficult than the expressway with obstacles [1][2]. On a general road with many obstacles, following two points are important to achieve an automatic driving system with humans relaxing.

- Flexibility to surrounding environment, with considering that dynamical characteristics of a vehicle is nonholonomical.
- Affinity to cooperate and accept human's intentions.

A conventional control method for automatic driving draws a tracing target line between a start point and a destination that a user specified beforehand, and control along the line. This control method does not have expert's driving strategies. It is that after human intervene automatic driving operations for a vehicle, they cannot predict the behavior of their vehicle. It means that users cannot trust driving to the conventional control method.

We have control a train intellectually by making rules from expert's operating knowledge and building it into a predictive fuzzy controller[3]. Afterwards, to control a vehicle intelligently, the controller has been enhanced[4]. Figure.1 is an experiment vehicle under constructing to evaluate this proposed system. There is other research such as acquire parking knowledge by PSP-learning[5].

Figure 1: Intelligent soft driving system cooperating with human

In this paper, we apply the predictive fuzzy controller to an automatic driving system, propose this system which can drive with human cooperatively, and prove effectiveness by experiments.

2 Human's driving knowledge

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.

The conventional control method assumes a drawn target line to be a control target and does follow-up control. So the controller steers when missing from the following target line even a little. However human does not recognize it as a problem usually, when a little coming off from the center of a lane. And, human drives a vehicle while predicting the behavior of it while aiming at a fuzziness point.

Moreover, the automatic driving system should reflect human's intentions in driving, in order to make user be relaxing. For that, the controller have a driving strategy same as the user's strategy so that the user can predict the future of

the vehicle driven by the automatic driving system, and it is a cooperating system by which human can intervene the automatic driving are necessary.

Because the conventional control method doesn't have the driving knowledge same as experts', system and human's driving strategies are different. It means that the controller has a possibility of doing steering wheel operations rapidly, when the human's intervention ends. Therefore, if the driving was entrusted to the controller, human cannot be relieved.

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. In the following, human's driving knowledge is divided into three layers.

2.1 Observing surrounding situation

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

Human predict the future state of their vehicle, before they do a certain operation. And, select an operation to be getatable to a target well. 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.

3 Outline of the system

Figure.2 is a soft controller built into an algorithm based on expert's driving knowledge. This controller is composed of three hierarchical "Detector Part", "Target Setting Part", and "Auto Driving Part" based on the knowledge. When human intervenes a driving operation in the automatic driving, the controller operates the steering wheel and the accelerator while esteeming human's operation.

The controller steers by a motor that connects directly with the steer mechanism of the vehicle, and adjusts its speed by a motor installed in the speed adjustment lever connected directly with the power mechanism of the vehicle. Human steers by the steering wheel bar connected directly with the steer mechanism of the vehicle, and adjusts the speed by the speed adjustment lever connected directly with the power mechanism of the vehicle. Therefore, human can intervene putting the more torque than the motor that the controller operated on the steering mechanism and the speed adjustment lever made.

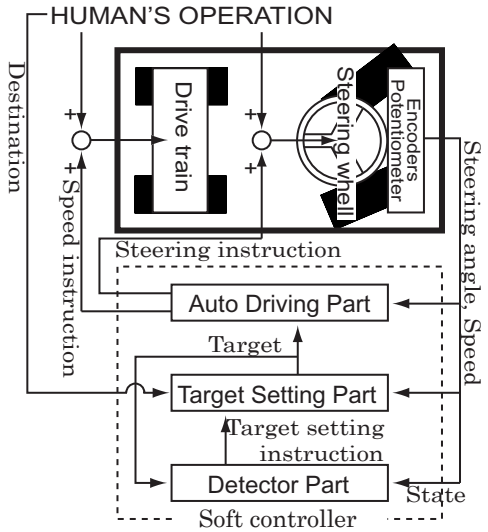

Figure 2: Outline of the system

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.

3.2 Target setting part

Experts set a target in consideration of the characteristic of their vehicle as described in the preceding clause[4].

The current position is $(x,y,\theta)=(x_0,y_0,\theta_0)$, the destination is $(0[m],0[m],90[deg])$, the steer corner is $\phi=0[deg]$. If the relation between the current position and the destination is "Δx is small and $\Delta\theta$ is small", a target (x_1,y_1,θ_1+90) that is able to reach the semi-final destination by turning radius R is calculated by the following equations geometrically. The vehicle can reach the target if the steering wheel is turned right and left and the vehicle turns by turning radius R.

$$x_1 = \frac{1-cos(\theta_0)}{2}R+\frac{x_0}{2} \quad (1)$$

$$y_1 = y_0+R\{\sin(\theta_1)-\sin(\theta_0)\} \quad (2)$$

$$\theta_1 = \cos\left(\frac{1+\cos(\theta_0)}{2}R-\frac{x_0}{2R}\right) \quad (3)$$

3.3 Auto driving part

Human drives a vehicle well while predicting the state in the future responding at the speed of the vehicle. So an automatic driving system should predict the future states. Moreover, the system should accept human's intentions and cooperate with them. Shown in figure.3, the controller selects one operation C_i which is the most appropriate now.

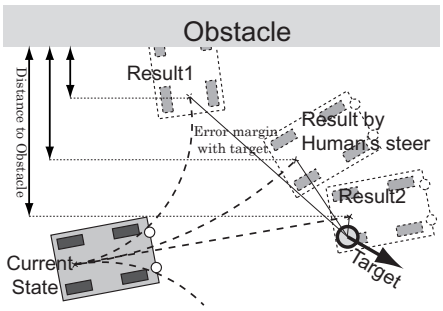

Figure 3: Evaluation of predictions

The procedure of predictions is as follows. First, attainment forecast time $t(s)$ is calculated by dividing the distance between the current state and the target by the current speed. Secondarily, the future state when ten kinds of operating candidates and each steering candidate executed to drive only during $t(s)$ is calculated by numerical integration. If the automatic driving is being intervened by human, the future state is calculated by the similar way as the above sentence. Thirdly as shown figure.4, five items "Distance between the future state and the target", "Angle between the future state and the target", "the smallest distance between the corner on bumpers and the obstacle", "Distance of the left side of the vehicle and the obstacle", and "Distance of the right side of the vehicle and the obstacle" of all the predicted results are multiobjective evaluated by a fuzzy inference. Fourthly, the steering candidate with the highest evaluation value of all candidates is decided as the control instruction C_{out}.

The member ship functions which evaluate an interventional human's operation were designed so that the high estimation may go out easily compared with the member ship functions used for the usual evaluation, to esteem the interventional operation of human and to do a smooth automatic driving.

Figure.3 shows an easy example of evaluating a prediction and a result. In this example, when human intervenes the automatic driving by a left steer, the prediction is done.

In this case, when the controller succeeds human's operation, the predicted result becomes "The distance with the target is a little large" and "The distance with the obstacle is small". The best result of operating-candidates of the controller becomes "The distance with the target is small" and "The distance with the obstacle is a little large". At this time, to reflect intentions of human, the controller succeeds human's operation though it is not the best. However, if a danger of colliding to walls or if a possibility to part from the target greatly is high, another operating-candidate is selected.

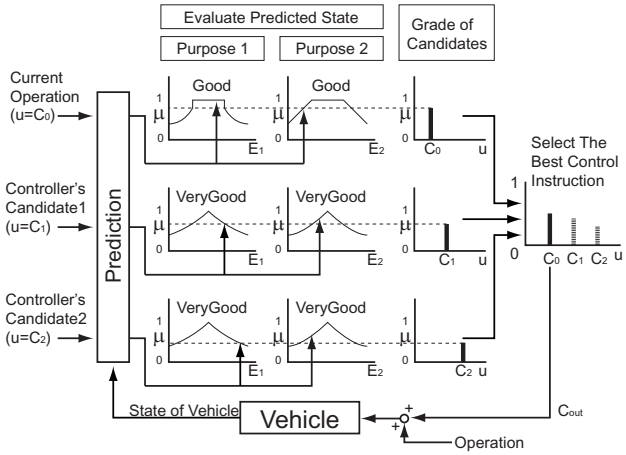

Figure 4: Predictive fuzzy controller

4 Experiment

In this section, a real machine experiment by the proposed system (figure.1) and a simulation by the conventional method are done. To compare the response of two methods after the human's intervention, the experiment and the simulation are done in the same environment. Therefore, the vehicle coordinates value by the proposed method are input to the controller of the conventional method at the same timing. The both of controllers outputs the steering (-0.92 to +0.92[*rad*]) and speed instructions at intervals of 0.1 seconds.

Figure.5 show that the proposed method is given an initial coordinates value (x,y,θ)=(-5.0,0,0) and an target coordinates value (2.1,-0.2,-1.6). The shortest straight line from initial position to a target is given to the conventional method as a target line to follow-up. And the vehicle is driven automatically when the experiment and the simulation started.

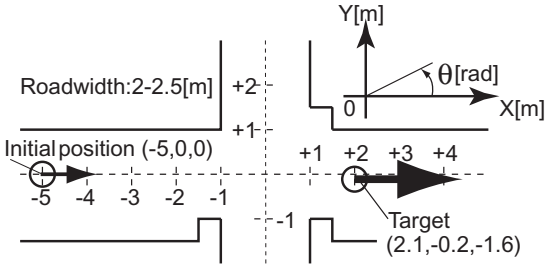

Figure 5: Situation of experiments

4.1 Results

At 1.4 seconds after the beginning of the experiment, human steers only 2.5 seconds left turn and intervenes the automatic driving. Afterwards the vehicle is driven automatically until reaching the target. The vehicle driven by the proposed method reached the target after 8.8 seconds pass, and another method reached it after 7.5 seconds.

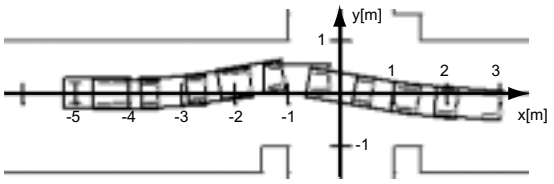

Figure 6: Running tracks by proposed method

Figure.6 is the running tracks of the vehicle driven by the proposed method.

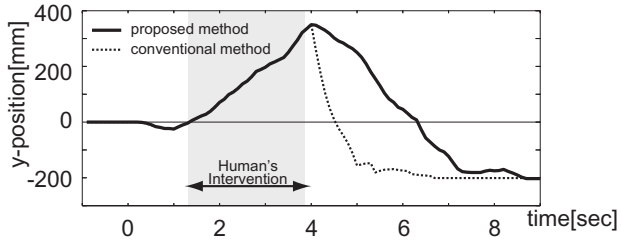

Figure 7: y-position

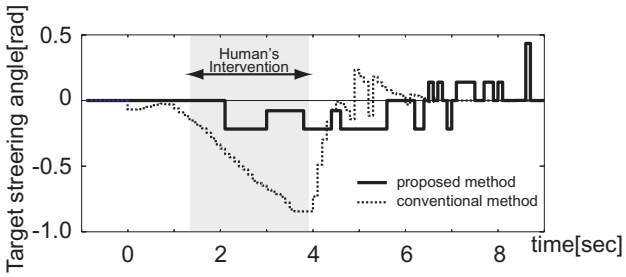

Figure 8: Target streering angle

Figure.7 is time series data of y coordinate value at the front wheel shaft center of the vehicle. Figure.8 is time series data of controller's target rudder corner. In both figures, the solid line shows the experiment result and the dotted line shows the simulation result. The proposed method changed the steering angle 22 times and the conventional method did it 63 times.

4.2 Evaluation of the Results

The following two points are shown from figure.7 and figure.8. In the past, the conventional method had output the steering instruction greatly repulsed to human while human is intervening it. Immediately after intervention, the proposed method maintained the rudder corner of intervention because the distance from the vehicle to the wall is far. On the other hand, the conventional method greatly steered the vehicle in the opposite direction without maintaining the angle of intervention. These results show that the proposed method can drive the vehicle while considering its surrounding environment while cooperating with human.

5 Conclusion

In this paper, we enhanced the predictive fuzzy control used practicably for the automatic operative method of the train for the vehicle, and proposed the intelligent driving system that decides the control instruction in consideration of the operation by human and its surrounding circumstances. Under a setting of the automatic driving intervened by human, the experiment by the predictive fuzzy control and the simulation by the conventional method were done. The result of experiment showed that the proposed system was possible to cooperate with human, and proved the effectiveness.

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