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Parking Control Based on Predictive Fuzzy Control

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Abstract— **The drive of the car is operated by the drive knowledge of the driver who knows the dynamic characteristic of the car well. To achieve the control based on this drive knowledge, a car operation system was constructed of fuzzy control scheme that consisted of two hierarchies of state evaluate fuzzy control and predictive fuzzy control. The computer simulation of the parking control was executed by using this system. It was confirmed that the proposal method is effective.**

I. Introduction

The try of applying fuzzy set[1] where man's subjectivity can be described by using the numerical value to various controls is actively done[2]. This fuzzy control was applied to real systems such as an automatic operation system of the Sendai-city subway[3] and home electric products. It was proved effective. The controlled system in here is a four-wheeled vehicle that we most frequently use. The movement of the body is not understood easily, a car parking is difficult[4]. On the other hand, the skilled person understands the dynamic characteristic of the car and drive it well. Because knowledge and the drive operation of this skill person are made an algorithm, the system by which the beginner can easily park the car is important. In this paper, fuzzy control system by which predictive fuzzy control method by which the control knowledge concerning the parking control of skill person's four-wheeled vehicle can be built in is assumed to be a base is proposed.

II. Parking by Human Operation

Man roughly recognizes the situation and the movement speed in surroundings. And he can park a car to the target position. The computer can drive a car by using the man's drive knowledge as a proxy.

A. Steering mechanism for four-wheeled vehicle

We think about the case to do the turn movement at low speed that the four-wheeled vehicle of the front wheel steer can disregard the generation of the centrifugal force. The car will have the turn center in the circle turn of the body in the rotation center axis each wheel extension. This extension's intersecting with the extensions of two front vehicle circle axes by one point becomes a condition because the wheel axis is on one wheel axis after the inside and outside. This intersection C is a turn center. When the vehicle keeps the above-mentioned turning relation, the equation of motion is as follows.

$$\begin{aligned} \frac{dx}{dt} &= v\cos\phi\cos\theta \\ \frac{dy}{dt} &= v\cos\phi\sin\theta \\ \frac{d\theta}{dt} &= \frac{v}{L}\sin\phi \end{aligned} \qquad (1)$$

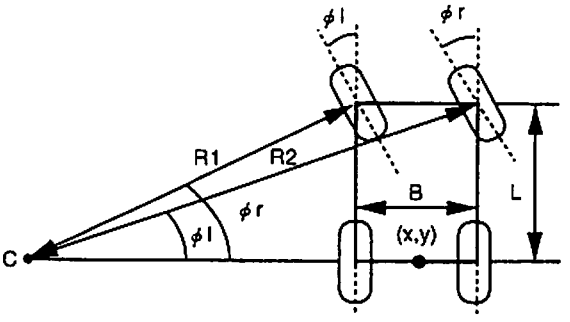

Figure 1: Geometrical relation in turn of four-wheeled vehicle.

The average speed of the front wheel is v. The distance of the front and rear wheel is L. The azimuth of body is θ. The steering wheel angle is ϕ_r and ϕ_l. The car position is (x, y) (Hereafter, it is called the position of the body) in the middle of two wheels in the back.

B. Manual Operation Process of a Car by Skill Person

It is possible to think about the drive operation of the skill person as two hierarchies shown next.

B.1. Setting of target

He sets some temporary target to reach the final target on the way. When the first target about attains, he switches the target to next one. From the

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position and the azimuth of a present body, the temporary target position and the speed are set by operators rule as follows; "The target position is in the front of left and if the azimuth of the car is parallel, the body is turned to a little left in the intermediate position."

B.2. Steering wheel operation

To reaches the target position and azimuth, the steering wheel operation is executed. The experience rules are shown as follows.

- If steering wheel is maintained, it will approach good to the target then the steering wheel is maintained.
- If the car goes straight, it will approach good to the target then it goes straight.
- If steering wheel is turned right, it will approach accurately to the target, then the steering wheel is turned right.
- If steering wheel is turned left, it will approach accurately to the target, then the steering wheel is turned left.

These experience rules assume that the steering wheel operation to do straight advancement, right turn, and left turn, evaluate those execution results, and execute the most appropriate operation.

III. Parking Controller and Steering Wheel Control by Predictive Fuzzy Control

A. Hierarchical fuzzy control algorithm

The controller that makes an intellectual activity concerning the man's knowledge for parking that is described in Chapter II an algorithm is regarded. At decision part, the traveling speed and a temporary target on the way are set and the passage is decided. At practice part, the steering wheel operation to reach the temporary target is decided. The fuzzy control controller who consists of these two hierarchies is regarded. The ideas of the hierarchical fuzzy control that consists of the state evaluate fuzzy control and the predictive fuzzy control is applied to it.

Decision part : From the numerical value based on the experience of the past now, present states and system parameters, the best control target is decided.

Practice part : The execution part outputs the control command in consideration of the control strategy (target) decided in this decision part.

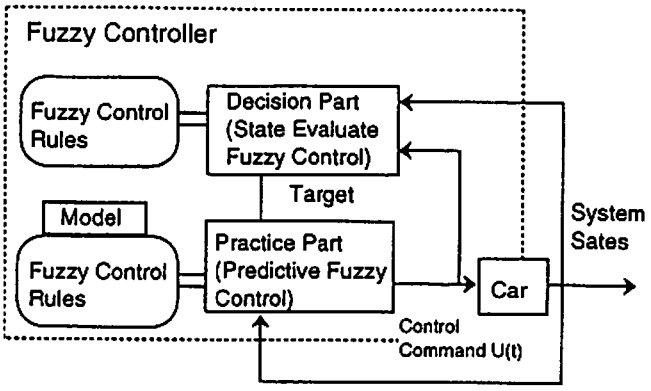

Figure 2: Structure of hierarchical fuzzy control.

B. Setting a temporary target by the state evaluate fuzzy control

A temporary target position (xn, yn), target azimuth (θn), and traveling speed (vn) are obtained now by the fuzzy control rules, position (x, y) and azimuth (θ). The state evaluate fuzzy control method which Mamdani had proposed was used for this control. This control rules are the following forms.

- If x is 0m and y is 0m and θ is 90deg. then (xn = 0m, yn = 0m), θn=90deg.,vn= 0.0m/s.(Stop)
- If x is +4m and y is -12m and θ is 90deg. then (xn = +2m, yn = -8m), θn=110dig.,vn= 0.4m/s.
- If x is +2m and y is -8m and θ is 110deg. then (xn = +1m, yn = -4m), θn=90deg.,vn= 0.4m/s.
- If x is 0m and y is -4m and θ is 90deg. then (xn = 0m, yn = 0m), θn=90deg.,vn= 0.4m/s.
- If x is +4m and y is 0m and θ is 90deg. then (xn = +2m, yn = +4m), θn=135deg.,vn= 0.4m/s.
- If x is +2m and y is +4m and θ is 135deg. then (xn = 0m, yn =+10m), θn=90deg.,vn= 0.4m/s.
- If x is 0m and y is +10m and θ is 90deg. then (xn = 0m, yn = 0m), θn=90deg.,vn= -0.4m/s.

C. Steering wheel operation by predictive fuzzy control

The predictive fuzzy control method[3] is applied to real robotics and mechatronics system using a dynamical system model. A control rule of this method is described for example by "If u is C1 → x is Good and y is Big, then u is C1." This fuzzy control generates control command alternatives, predicts control results' x and y using a dynamical system model, and finally selects the best control command from the alternatives. The control rules of a general predictive fuzzy control are shown as follows.
If (u is Ci → x is Ai and y is Bi) then u is Ci. (i=1,N)

This predictive fuzzy control rules are the same form as the experience rules of the car operation of the skill person. Then, this control method is used to operate the steering wheel. Figure 3 shows fuzzy sets of distance and azimuth for steering wheel operation.

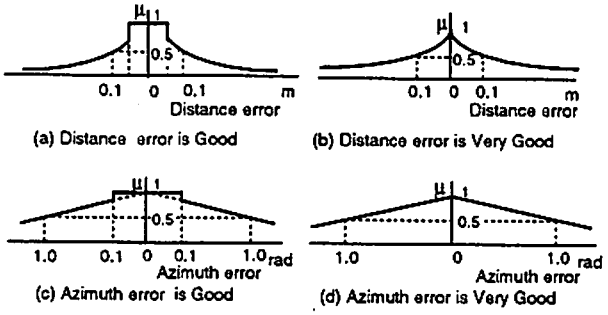

Figure 3: Membership functions of fuzzy evaluation indices.

C.1. *Control rules*

Ten control rules are described from the experience of the skill person as follows.

- If (ϕ= 0deg. → d=Good, dθ= Good) then ϕ= 0deg.
- If (ϕ=15deg. → d=very Good, dθ=very Good) then ϕ=15deg.
- If (ϕ=-15deg. → d=very Good, dθ=very Good) then ϕ=-15deg.
- If (ϕ=30deg. → d=very Good, dθ=very Good) then ϕ= 30deg.
- If (ϕ=-30deg. → d=very Good, dθ=very Good) then ϕ=-30deg.
- If (ϕ=ϕ+0deg. → d=Good, dθ=Good) then ϕ=ϕ+0deg.
- If (ϕ=ϕ+5deg. → d=very Good, dθ=very Good) then ϕ=ϕ+5deg.
- If (ϕ=ϕ-5deg. → d=very Good, dθ=very Good) then ϕ=ϕ-5deg.
- If (ϕ=ϕ+10deg. → d=very Good, dθ=very Good) then ϕ=ϕ+10deg.
- If (ϕ=ϕ-10deg. → d=very Good, dθ=very Good) then ϕ=ϕ-10deg.

The ϕ+5deg. means add is the left of 5deg. in here from a present steering wheel. The d is difference of the target position and predicted position. The $d\theta$ is difference of the target azimuth and the predicted azimuth.

Figure 4 shows a reasoning process of steering wheel operation by predictive fuzzy control. Three candidate control instructions of C1,C2,C3 can be taken. The predictive calculation of the state in the future is done by using equation of motion by

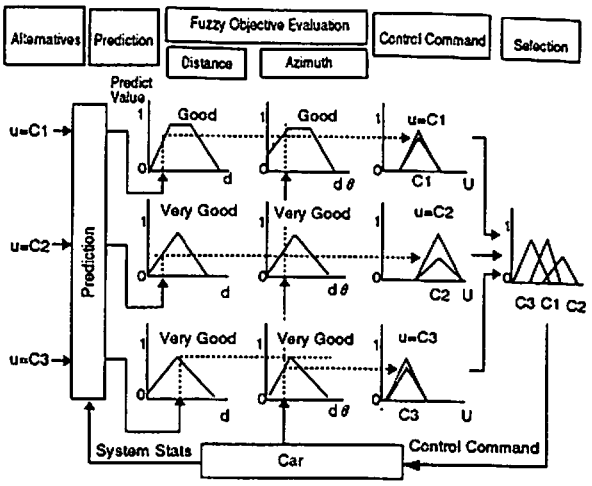

Figure 4: Inference process of steering wheel operation.

which the system situation of the control object was shown in value and assumption expression (1) now. The predictive value of a certain control purpose d (for instance, the future position 10 seconds after) is obtained. The fuzzy sets by which d is called Good (it is in the range of the allowance), or Very Good (it is accurate), are defined. Moreover, it is similar, another control purpose $d\theta$ is evaluated. These evaluated values are integrated by the logical product. And the inference result of the control instruction (fuzzy set) is obtained. The control instruction is selected by giving the operation of making too nonfuzzy to this inference result.

IV. Simulation Results and Discuss

The object system model by which the fuzzy control method proposed like the above-mentioned. The movements of the vehicle were simulated in the personal-computer. The control performance was evaluated. The result of simulating two patterns of a file parking and a horizontal movement is shown here. As for the vehicle, final target position (xe,ye) and final target azimuth (θe) are operated from initial position (x0,y0) and initial angle (θ0) aiming shown as follows. It was assumed that traveling speed V of the car is $0m/s$ (Stop), $0.2m/s$ (Advance), and $-0.2m/s$ (Back), wheelbase (L)= $2.6m$, tread width (B) = $1.5m$, and maximum rudder corner (ϕmax)=35deg..

A. *Simulation of file parking*

This simulation parks a car along the side of a street. Initial position:(x0,y0) = (4.0m,-12.0m). Final target position:(xe,ye) = (0.0m,0.0m). Initial azimuth: θ0=90deg.. Final target azimuth:θ0=90deg.. Figure 5 shows a tracks of the car at every three seconds in

file parking. The stop position is (x,y)=(0.02m,0.0m), θ =94.90deg.. The controller set a temporary target based on man's parking strategy on (2.0m,-8.0m) and θ=125deg.. It is understood to reach the final target at last by operating steering wheel which is good through the target on the way of this.

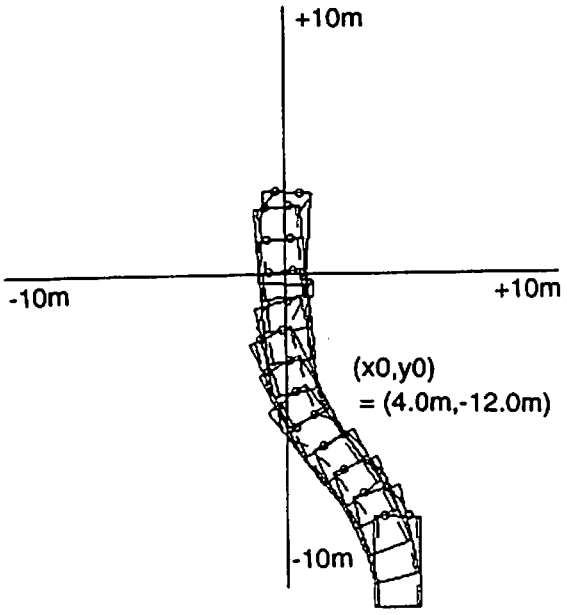

Figure 5: Sample tracks of file parking.

B. Simulation of horizontal movement

It is time when this simulation moves a car to the target position of true side. Initial position: (x0,y0) = (4.0m, 0.0m). Final target position: (xe,ye) = (0.0m, 0.0m). Initial azimuth: θ0=90deg.. Final azimuth: θe=90deg.. Figure 6 shows a tracks of the car at every three seconds in horizontal movement. The stop position is (x,y)=(-0.08m,0.22m),θ=84.85deg.. In this case, to take the position where the car can park easily to back in the final target, the controller put a temporary target forward of that. The controller got the final target after reaching the temporary target.

These simulation results show that the parking control is executable for various situations by the proposed hierarchical fuzzy control. In the judgment part, a temporary target can be skillfully set by using state evaluation fuzzy control. In the execution part, Predictive fuzzy control outputs the steering command to reach the target well.

V. Conclusion

In this paper, the experience rules about which we thought when man drove were described and we evaluated proposed controller by the simulation. The

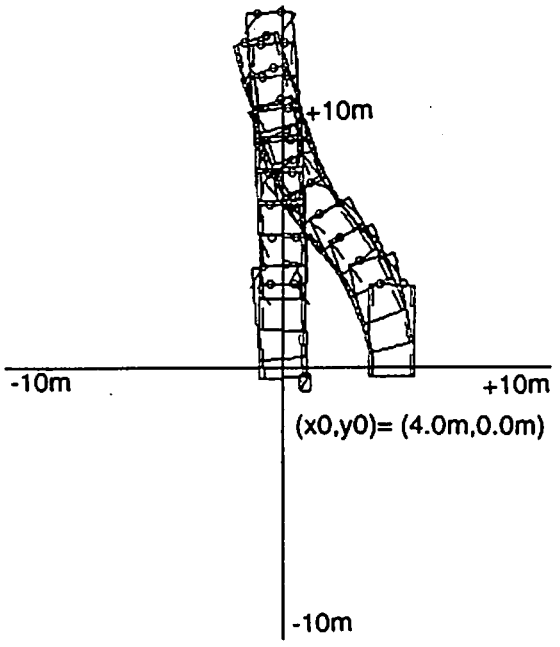

Figure 6: Sample tracks of horizontal movement.

controller consists of two hierarchies of state evaluate fuzzy control method and predictive fuzzy control method. As a result, it was confirmed to be able to execute a good operation by the proposal method even in a complex control like the parking control. The car was able to be moved to the target position by operating the steering wheel that was good in predictive fuzzy control method used for the practice part. This predictive fuzzy control method can achieve a gentle control to man. In this paper, the thing to which the proposal method was effective was shown by the computer simulation. This method will compose a drive system by which the computer cooperated with man.

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