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Development of Intelligent Parking Support System for Welfare Vehicle

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Abstract

Welfare vehicles are convenient equipments for a senior citizen. Because they have a nonholonomic characteristic, driving them are uneasy. Especially, since the area that can move in the parking lot is limited, the operation is very difficult.

To help his parking, an intelligent parking support system by fuzzy control that built in expert's knowledge is developed. This system does the support that accepts easily like guidance member by using voice information and the image information. In this paper, the effectiveness of the developed system is shown by testing the operation support.

1 Introduction

Welfare vehicles can be used as a movement means for a senior citizen to participate in the society. Generally, the welfare vehicle is used so that the senior citizen may move the long distance, and carry luggage easily. And, they are parked at the garage etc. to charge battery and to avoid rain[1].

Because the four-wheeled vehicle has nonholonimic characteristic, it should be skilled for the drive [2]. Especially, to park in the limited area is very difficult. This is why the minimum turning radius of the vehicle is directly related to the control performance. In addition, another consideration is necessary for a senior citizen who haven't enough acknowledgment and judgment ability.

There is a research of parking control of the four-wheeled vehicle which acquire parking knowledge by the technique of reinforcement learning[3]. This is effective as the method of setting the parking knowledge when there is no foresight knowledge. On the other hand, when expert's parking knowledge can be set in some degree, a system which offers running support information in real time has been developed[4]. This can offer a flexible information by using fuzzy inferences.

Even when the senior citizen parks, if it follows the instruction of the guidance member parking can be achieved. From this, the model of the parking support of the guidance member is made, and a hierarchical intellectual control system is composed based on it. The language and the image are used for support information for the operational procedure and the guide of the now state. Achieve the system that can do the parking support that accepts easily by offering these information, and experiment on the parking support with a welfare vehicle.

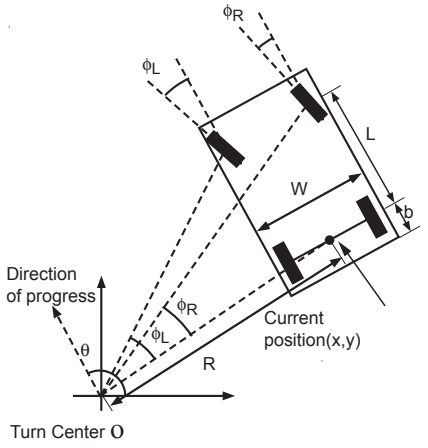

Figure 1: Steering mechanism of Ackerman-Jeantaud

2 Welfare Vehicles

In this paper, an electric wheelchair for self-propelled of four-wheel type to which the steer corner is decided by the steering wheel control is targeted. This is called a four-wheeled vehicle or a welfare vehicle thereafter.

The four-wheeled vehicle of the front wheel steer does geometrical movement as shown in Fig. 1. This is called the steer mechanism of $Ackerman - Jeantaud$. The conditional expression in the movement study based on the Ackerman turn theory becomes like next equations.

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

Here, x and y are the positions of the four-wheeled vehicle, θ is an angle that the progress direction of the x axis and the four-wheeled vehicle does, v is a speed of the car, ϕ is an angle of the steering wheel that instructs in movement by turning radius R, L is a wheelbase of the vehicle. O is center of the turn circular arc. The precondition for the parking control in this paper is shown below.

Preconditions

- The shape of the parking lot is already-known.
- The vehicle runs in low speed.
- A dynamic obstacle doesn't exist.
- Vehicle enter the parking lot from the rear side.

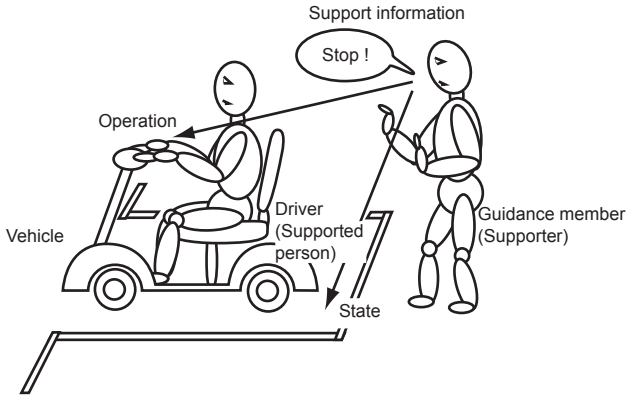

Figure 2: The model of human parking support

3 Intelligent Parking Support System

3.1 Model of Human's Parking Support

Human's parking support is modeled as follows. The support knowledge of the guidance member in the parking lot like Fig. 2 is targeted.

The guidance member understands surrounding circumstances, the situation of the vehicle and the situation of the operation (Detect). Next, the strategy is mapped out based on empirical knowledge they have, and the target is set based on it (Target setting). Next, it thinks about the best operation to reach the target by predicting the state after a few seconds (Decison of operation candidate). Once operation candidate is decided, the guidance member think about offer information according to the situation of the vehicle and the operation at that time (Decision of support language information). Information offered next is changed by the offer interval, the last offer information and the operation situation, so the operator can receive it easily (Decision of support language information). Moreover, the guidance member plays the role to inform the state of the vehicle and the target position (Processing and offering visual information).

3.2 Configration of this System

Intelligent parking support system based on the above model is shown below.

In this paper, the general situation target set based on the strategy is called a strategy target. To reach the strategy target, the local target set on the way is called a tactical target. The combination of the steer corner, the direction of progress, and the steer method for the attainment to the tactical target is called a tactics.

When it divides roughly, this system consists of the three parts, detector part, target setting part and offer support information part. Each part use the fuzzy inference. By using the fuzzy inference, the inference rule can be made based on a human's linguistic knowledge, and a multipurpose evaluation can be done. By using the obtained information and the used knowledge during the inference, a flexible language information can be offer. Hereafter, it explains the function of each part respectively.

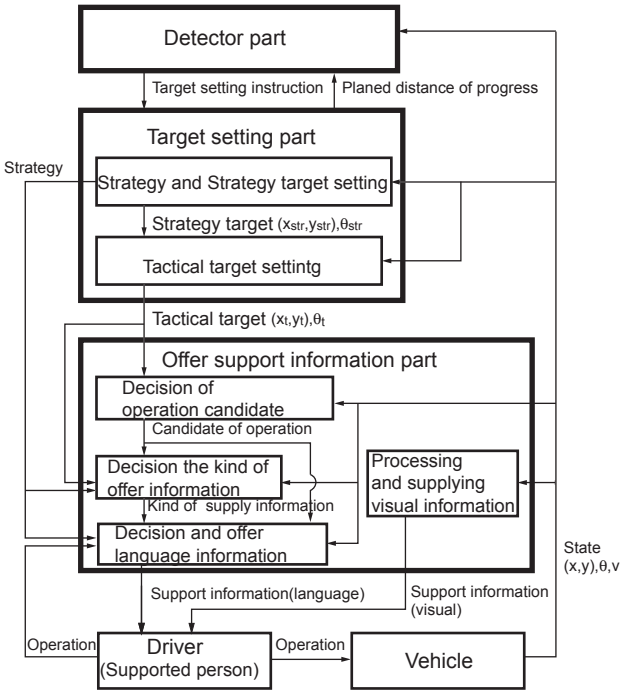

Figure 3: Configration of intelligent parking support system

3.3 Detector Part

In the detector part, the attainment to the target set in the target setting part and the contact to the obstacle are observed, and it is judged whether a new target is necessary. The passing target line is set, and judged whether the vehicle passed the target street line. In addition, the future state is predicted using the equation (1), and it is judged whether it will come in contact with the obstacle. As a result, if it is necessary, the target setting instruction is output.

3.4 Target Setting Part

In the target setting part, target is set considering to the characteristic of the four-wheeled vehicle and a relative position to the final target. Moreover, the running schedule distance from the present state to the calculated tactical target is requested.

Setting strategy and strategy target

Strategy is decided from the difference between the now state and the final target by using the rule given beforehand. The best strategy is chosen by fuzzy inference of which it inputs x_{now}, y_{now} and θ_{now}. It is selected from "Keep the horizontal", "Approach the parking lot", "Counterattack and enter the parking lot", "(Directly) Enter the parking lot" and "The control is ended".

Next, the strategy target that considers the movable range according to that strategy is set. The strategy target is set in the state to achieve the purpose of each strategy ideally based on the present state.

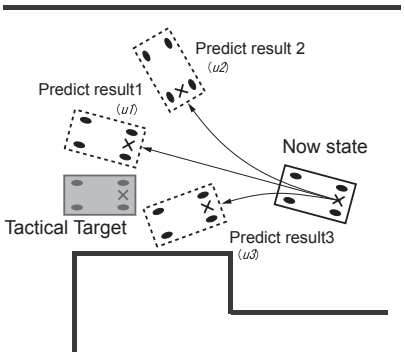

Figure 4: Operation candidate for arriving at tactical target

Setting tactical target

A temporary route that reaches the strategy target is decided from the difference between strategy target and the present state. That is decided by using fuzzy inference of which it inputs the axially and directional difference between now state and strategy target. The tactical target is calculated based on the route. At that time, a general running characteristic that tracks of the four-wheeled vehicle draw circle is used.

3.5 Offer Support Information Part

This part processes the output of two support information "Language" and "Image".

The part where language information is output consists of the three processes "Decision operation candidate", "Decision the kind of offer information" and "Decision and offer support language information".

The part where the image information is output consists of "Processing of the support image", and does processing and output of visual support information.

First of all, the decision process of language information is sequentially described, and next, the visual support is described.

Decision of opereation candidate

A predictive fuzzy control is used in this part. The predictive fuzzy control can do the control similar to the predictive control based on the experience of human's "*It seems to approach the target well if it operates it so*"[5].

First of all, the control result of each operation candidate when having executed at some time is predicted(Fig.4). The predicted result of each operation candidate (error margin with tactical target and distance with obstacle) is evaluated from fuzzy multipurpose evaluation, and the candidate of the highest evaluation (the steer corner, method of the steer, speeds) is output.

Decision the kind of offer information

The kind of offer information is decided by a multipurpose fuzzy inference based on knowledge of human's "*If it is this situation at these intervals, it seems to only have to offer such information*". The kind of offered information (steering wheel operation, direction of progress etc.) is decided based on the elapsed time after the last offer information, the situation of present vehicle, the driver's operation, the decided strategy and

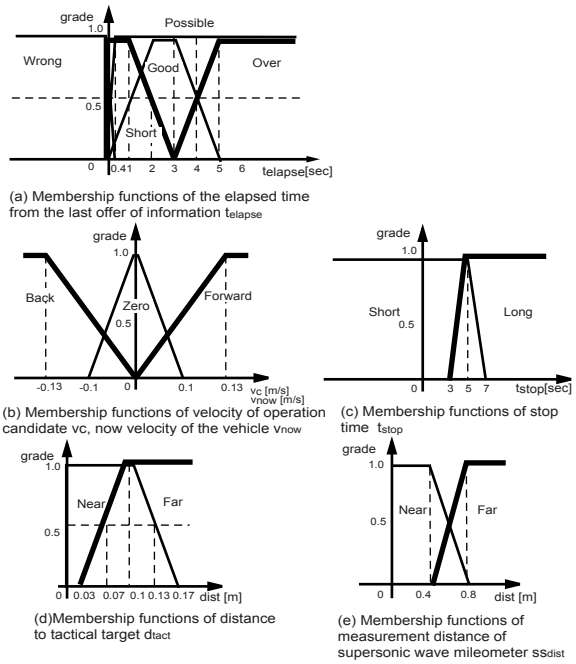

Figure 5: Membership functions for determining kind of support information

strategy target. The information is classified into eight kinds "*Don't offer information*", "*Steering wheel control*", "*Progress of direction*", "*Strategy*", "*Tactics*", "*The steering wheel is done straight*", "*Attention*" and "*Stop*". Used fuzzy set are shown in Fig.5.

Do not offer information
: When the last information is being offered or the elapsed time after the end of last information is short, "Do not offer it" is selected.

Steering wheel control
: When the elapsed time after last information is appropriate or long, and not a special situation, it is selected.

Progress of direction
: When the speed of the operation candidate and the speed of a present vehicle are different, it is selected.

Strategy
: When the strategy changes, it is selected.

Tactics
: When a detailed information of the operation that should be done now is necessary, it is selected.

Steering wheel straight
: When the distance to the target is short, it is selected.

Attention
: When a present velocity is negative and the obstacle is confirmed to the rear side, it is selected.

Stop
: When the tactics ais change, it is selected.

Dcision the offer language information

Support language information is decided according to the best operation candidatethe and the kind of decided support information. Decided support information is offered to the driver by the voice.

Do not offer information
: There is no offered information.

Steering wheel control

According to steer corner candidate and operator's steer corner,

"Maintain current operation", "Straight", "Return a little", "Right a little ", "In addition, right", "Right", "Full right" etc. are offered.

Progress of direction

According to the speed candidate,

"Advance" and "Retreat" are offered.

Strategy

According to strategy,

"Keep the horizontal", "Approach the parking lot", "Counterattack and enter the parking lot", "(Directly) Enter the parking lot" and "The control is ended" are offered.

Tactics

According to the speed candidate, the steer corner candidate, the method of the steer, and driver's steer corner,

"Maintain steer coner and advance", "Steer straight and advance", " Returne steer a little and advance", and "Steer right a little and advance", "In addition steer right and advance", "Steer left afterwards once steer right and advance","Steer right fully and advance" etc. are offered.

Steering wheel straight

Support information is "Straight".

Attention

According to the measurement distance of the supersonic wave mileometer at the right and left rear side,

"Attention to backward", "Attention to the rear side of the right(left) ", are offered.

Stop

Support information is "Stop".

Processing and supplying the visual information

In "Processing of the support image", based on the state of vehicle and maintained map information, three dimension image is generated. That draws the position of the vehicle and the parking lot that is seen from guidance member's aspect.

When parking, the guidance member outside the vehicle can put out an appropriate instruction as shown in Fig. 2. This is why he understands the situation such as the position of the obstacle and the vehicle, the speeds, and the steer corners easily.

Then, a floor was made on a virtual space, and the parking lot and the vehicle of the same scale as the experimental environment were prepared. The garage and the state of the vehicle are displayed on the monitor by using 3DCG as visual support information(Fig. 6).

3.6 Hardware Configration

To decide the position and the direction of the vehicle, the developed system detect the speed and steer angle using rotary encoder and potentiometer. A relative position and direction is calculated from eq. (1) of the dynamic characteristic of the vehicle. Moreover, the position is absolutely corrected by the laser mileometer on the servo motor to measure the distance from the wall of the parking lot. To output attention information when approaching to the wall, the supersonic wave mileometers at the back of the vehicle measure the distance to the wall. Fig. 7 shows the hardware composition of the system.

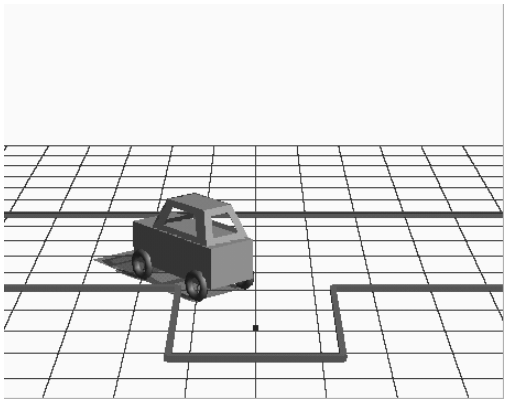

Figure 6: An example of display image

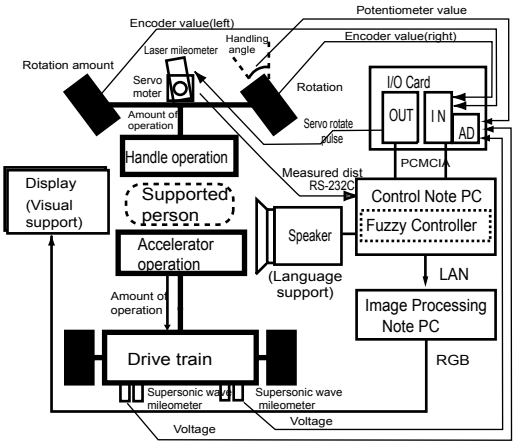

Figure 7: Hardware configration

4 Experiment with Welfare Vehicle

Table 1 shows the specification of the experiment vehicle. The welfare vehicle used in this experiment is "Shoprider"(Pihsiang Machinery Mfg Co., Ltd). Fig.8 shows the shape of the garage used in this experiment. Moreover, prepared wall of the garage is height that can be detected with the laser mileometer.

Table 1: Specification of the welfare vehicle

length	wheelbase	width	minimum radius of rotation
$1.10m$	$0.80m$	$0.55m$	$0.95m$

It experiments on the parking support in the precondition of the parking control that is above-mentioned. Drivers are four men and women of university student, and it is assumed driver (a), (b), (c) and (d). Three initial states of the vehicle were prepared (Fig. 8), and the parking support experiment was done to the driver.

Coordinates of initial states and final target is shown below.

(horizontal coordinates $x[m]$, vertical coordinates $y[m]$, angel $\theta[rad]$)

- Initial state 1 $(2.45, 1.67, 2.47)$.
- Initial state 2 $(1.12, 2.37, 2.90)$.
- Initial state 3 $(-1.50, 1.83, -3.14)$.

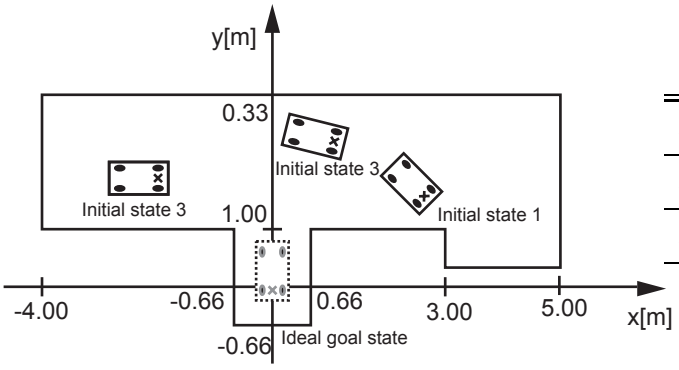

Figure 8: The shape of the garage and initial states of the vehicle

Figure 9: Appearance of this experiment

- Final target $(0.0, 0.0, \pi/2)$.

Before the trial, the drivers are explained the kind and the meaning of support information and directed to operate according to the support information. Fig.9 shows the appearance of the experiment.

4.1 Experimental Result

The running tracks based on the state of the vehicle that the system presumed are shown. Fig. 10 to Fig. 15 are the one that having drawn in the state of the vehicle from the support beginning to the parking completion at intervals of 1.5 *sec*. According to an initial position and the driver, results of experiment are named 1-a to 3-b. Table 2 shows the list of the parking time at each experiment.

Table 2: List of the parking time required[*sec*]

	driver (a)	driver (b)	driver (c)	driver (d)
Initial state 1	1-a 102	1-b 96	1-c 126	1-d 84
Initial state 2	2-a 105	2-b 114	2-c 126	2-d 124.5
Initial state 3	3-a 54	3-b 45	3-c 91.5	3-d 93

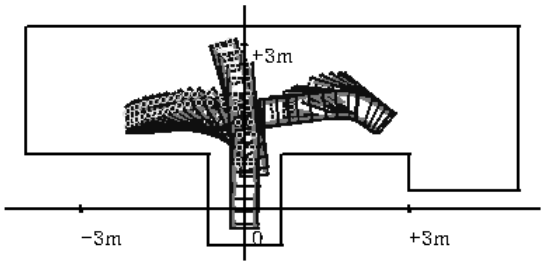

Figure 10: 1-a initial state 1(2.45,1.67,2.47), driver(a)

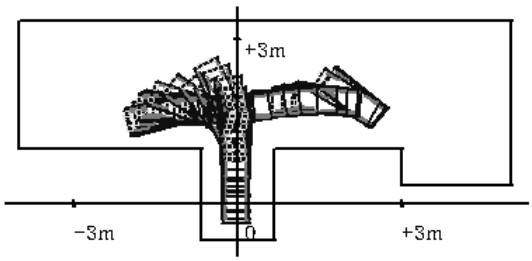

Figure 11: 1-b initial state 1(2.45,1.67,2.47), driver(b)

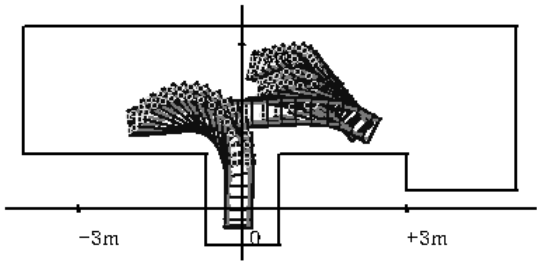

Figure 12: 2-a initial state 2(1.12,2.37,2.90), driver(a)

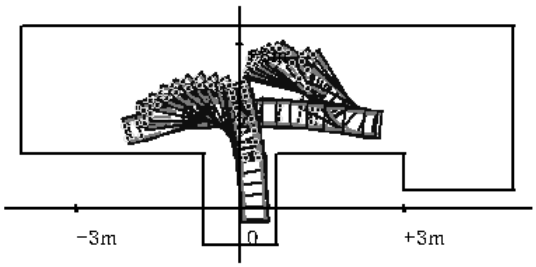

Figure 13: 2-b initial state 2(1.12,2.37,2.90), driver(b)

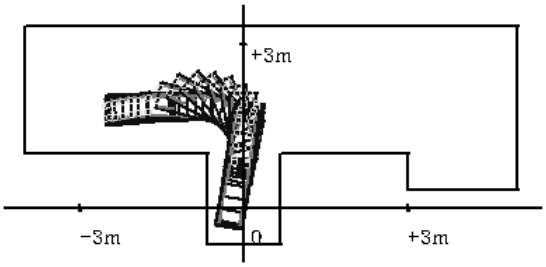

Figure 14: 3-a initial state 3(-1.50,1.83,-3.14), driver(a)

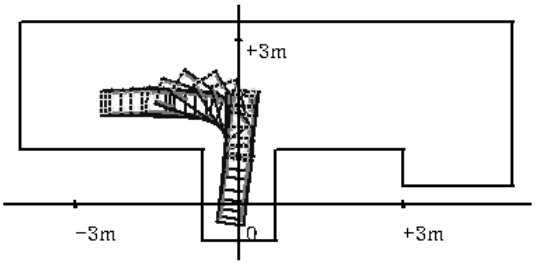

Figure 15: 3-b initial state 3(-1.50,1.83,-3.14), driver(b)

When having heard it from the driver by the questionnaire form after this experiment, the following answers were obtained.

- About the support device whole
  - All members answered the necessity of the support device, that is, "There should be the support device".
  - Plainly of the language support, "It cannot be said either" is two, "It may be comprehensible" and "It is not easy to understand"are one person respectively.
  - All members answered the visual support, "It may be comprehensible".
  - A useful kind of information in "Strategy", "Steering wheel control", "Progress direction", and "Attention information" was heard (the plural can be answered). All members answered "Strategy" and "Steering wheel control". Moreover, two people answered "Attention information".
- About the language support information

  The easiness of each information to accept was heard for four drivers. It is five-point full marks and so good if it close to five points. The average score for every element is shown below.
  - (A) Progress of direction: "4.25"
  - (B) Stop instruction: "2.5"
  - (C) Strategy(ex. draw it to the garage):"4.25"
  - (D) Attention information: "4.5"
  - (E) Information presentation interval: "2.5"

4.2 Discussion

To "Put it in the garage", it counterattacks twice in the experimental result 1-a. This is a result that the possibility of colliding with the garage because the operation of steering to the left was delayed is caused, and support information on the counterattack is presented again. It also counterattacks twice in result 2-a to "Keep the horizontal". This is because timing in which the steering wheel is returned was delay compared with 2-b.

When the driver's evaluation was considered, many people thought that stop instruction and offer information interval aren't accept easily. The cause seems that the instruction of "Stop" put out frequently, each time the target is changed. Oppositely, it is shown that the other information was presented necessary, and appropriately from a lot of opinions of goodness.

It is shown that the system developed in this paper can do flexible support to the driver who had a reactive error margin, and they could complete parking operation without hesitating. Moreover, from the driver's evaluation, it is shown that offered information was appropriately and accepted easily.

5 Conclusion

In this paper, to help parking of a senior citizen, an intelligent parking support system of a welfare vehicle which has nonholonomic characteristic was developed. First, the guidance member's support was made a layer model to build in expert's parking knowledge. Next, to achieve flexible parking support like human, the technique of the state evaluation fuzzy inference and the predictive fuzzy control was introduced into each layer.

From the experimental result of the parking support that used the welfare vehicle, it was shown that this support system achieved the parking support that accepted easily to the elderly people.

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