An Intelligent Auto-Driving System by Interactive Acquisition of Driving Knowledge as Information on Route

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***Abstract*— For senior citizens and physically handicapped persons who use a welfare electric cart, an auto-driving system is effective to reduce stresses of driving operations. However, the system requires information on route to reach the destination. Furthermore the system should be able to be treated without difficulty for users. In this paper, the system interactively acquires driving knowledge composed of landmark's information and action rules as the routing information from users, and drives a cart flexibly to the destination by using the driving knowledge and the operation knowledge of four-wheeled vehicle. Results of auto-driving experiment by human's riding show the effectiveness of the system.**

Fig. 1. Electric four-wheeled vehicle (Pihsiang Machinery Mfg Co., Ltd.) used for the proposed system.

I. Introduction

An electric four-wheeled vehicle on the market (we call welfare electric cart) shown in Fig.1 is used as transportation for senior citizens and physically handicapped persons. However, driving operation is difficult and tiresome for users to whom eyesight and muscular power failed.

Thus an auto-driving system is effective to reduce stresses of their driving operations. Such the system should be able to treat without difficulty in consideration of human's getting on a welfare electric cart.

Meanwhile, the intelligent driving system [1] with the predictive fuzzy controller has been developed for a welfare electric cart. This system drives the cart flexibly to a target which is set by an user by using operation knowledge of four-wheeled vehicle. However, this system doesn't have a method to acquire information on route to reach user's destination.

Therefore, if the system can acquire the routing information from user's driving knowledge [2], it is possible to treat easily regardless of users or environments. In this paper, we develop an auto-driving system that acquires the driving knowledge interactively from an user, and drives the cart to the route decided by using the knowledge.

II. Driving Knowledge

Driving knowledge is information about routes to destinations for drivers. Human uses several sets of information on characteristic points and actions there to drive to the destination. For example of the route guide, human explains as follows from a present point to a destination. ”First, turn to the left in the intersection ” and ”Next, go straight on the road with the post”, etc. In this paper, the driving knowledge is defined as sets of landmark's information (place's information) and action rules.

A. Landmark's Information

Landmarks are used as common information about places that can be recognized by both users and the system. Landmark's information consists of world coordinates and template images, which is used for pattern matching. Users can provide a template image as the landmark's information from the image obtained by the camera which is set in front of the cart.

B. Action Rule

An action rule is description of a cart's movement at a place. In this paper, users can provide five action rules as follows about a landmark.

”Go straight”
”Approach”
”Pass”
”Turn to the left”
”Turn to the right”
”Park”

The system sets targets and drives a cart by using these action rules.

III. System Configureration

The system's configuration is shown in Fig.2. The system is constructed by two personal computers (the driving knowledge processor and the intelligent controller), a camera that is set in front of the cart, and a touch panel display for a user interface. The driving knowledge processor acquires the driving knowledge from an user by

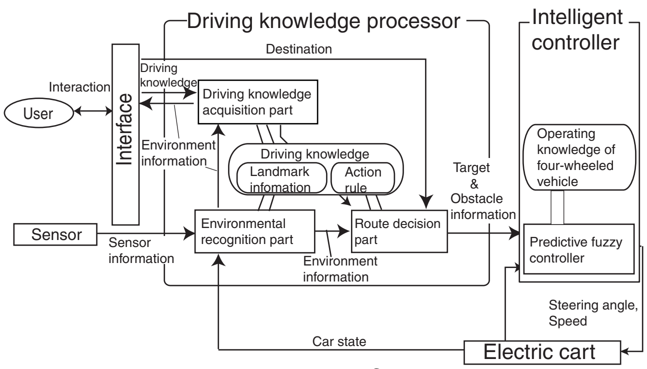

Fig. 2. System configuration.

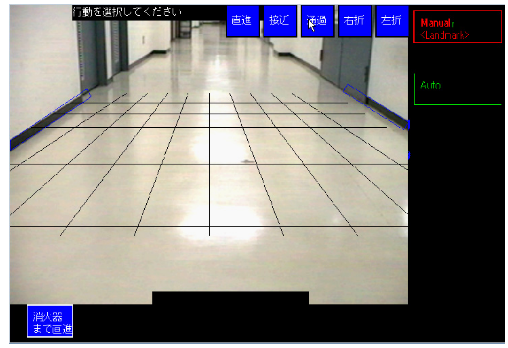

Fig. 3. Example of touch panel display for the interactive user interface.

using a touch panel, and sets targets that used the knowledge to reach the destination. The intelligent controller drives flexibly to the target.

A. Driving Knowledge Processor

The driving knowledge processor is configured by ”the driving knowledge acquisition part”, ”the environmental recognition part”, and ”the route decision part”.

1) Driving knowledge acquisition part: The function of this part is acquisition of the driving knowledge from an user. The contents of touch panel display that is shown in Fig.3 is used as the interactive user interface for acquisition of the driving knowledge.

a) Acquisition of landmark's information: Landmark's information is acquired by this part while a user drives the manual operation. A user specifies a range of a template's image by using the touch panel display from the image obtained by the camera, and gives a name to the template. The system calculates world coordinates of the landmark from the relative position of it, and acquires a template and coordinates as a landmark's information.

b) Acquisition of action rule: The system recognizes a landmark by using acquired information, and shows it to a user. The user instructs about the action that is the cart's movement at the landmark to the system. The system acquires the action rule from the user's instruction. Exceptionally, the target coordinates of action rule ”Park” is input directly by using touch panel, because it is considered that the parking method and the parking space are various.

2) Environmental recognition part: The functions of this part are recognition of landmarks for obtaining relative position, and recognition of obstacle objects for making obstacle maps. Recognition of landmarks and obstacles use image processing software ”Halcon” (MVTec Software GmbH).

The method of landmark's recognition is pattern matching [3], which use landmark's information that is in sight of the camera. Relative positions of landmarks are obtained by inverse perspective transform [4].

Recognition of obstacle objects uses black line that is on a passage's wall. This line is prepared in hospitals and

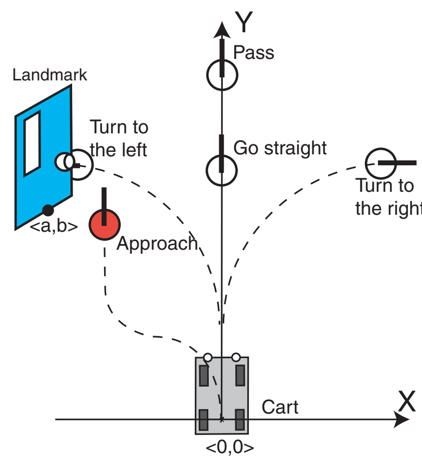

Fig. 4. targets calculated from driving knowledge.

welfare facilities too. Therefore, it is effective to recognize the line for auto-driving indoors. The method of black line recognition is a thresholding method. Connected regions obtained by the thresholding method are judged to whether it is black line or not by using areas, lengths and ratios of length to width.

3) Driving knowledge using part: This part sets target coordinates to reaching the destination for the intelligent controller by using the driving knowledge that is acquired from a user. Input of this part is action rules, coordinates of the landmark, and an obstacle map. Output is target coordinates, which are set for the intelligent controller to reach the destination. The example of target coordinates that are set by using landmark's relative position and action rules is shown in Fig.4. ”Go straight” sets a target on a place that is the distance of a traveling direction to a landmark. ”Approach” sets it at near a landmark. ”Pass” sets it to the distant traveling direction to a landmark. ”Turn to the left (right)” sets it on the position in the direction that intersects with the traveling direction at a landmark. ”Park” sets it to a relative position from the previous target by using the coordinate value that the user input. Basically, the target is set in parallel to the wall.

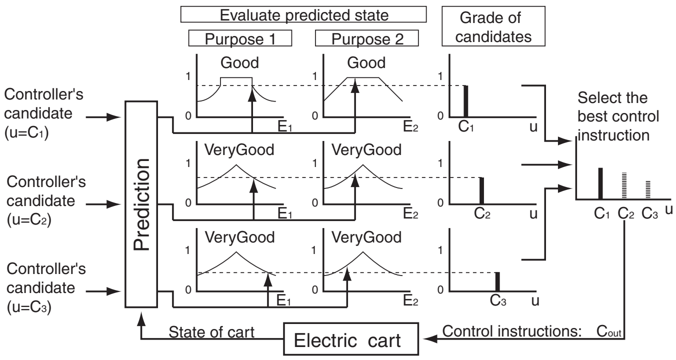

Fig. 5. Predict fuzzy cotrol.

B. Intelligent Controller

The intelligent controller use predictive fuzzy control [5] that flexibly drives a cart to a provided target from driving knowledge processor in consideration of the characteristic of the four-wheeled vehicle [6]. This controller predict the state of the future when the controlled object is operated during the fixed time about several operation candidates(steering angle), and select the best operation by multipurpose fuzzy evaluation such as distance of target and obstacle. This process is done every control cycle.

IV. Experiment

A. Hardware

The hardware construction of the system is shown in Fig.6. This experiment uses the welfare electric cart on the market(spec of the cart is shown in Table 1) that equips personal computers, a camera, a touch panel, and sensors(encorder and potentiometer) to detect the cart's position. The appearance of the cart is shown in Fig.7.

TABLE I

Spec of the welfare electric cart

wheelbase		0.80m
tirewidth		0.435m
smallest radius		0.95m
steering angle		50.0deg
velocity	forward	0.35m/s
	stop	0.0m/s
	backforward	-0.19m/s

B. Contents of Experiment

Contents of the experiment are acquisition of driving knowledge, and auto-driving by using the knowledge. The environment of experiment is shown in Fig.8. A purpose of the experiment is driving from the starting position(-4.0m,0.0m,180deg) to the destination(-3.0m,-5.5m,0deg). The experiment was conducted by the student who didn't have the experience of using the system.

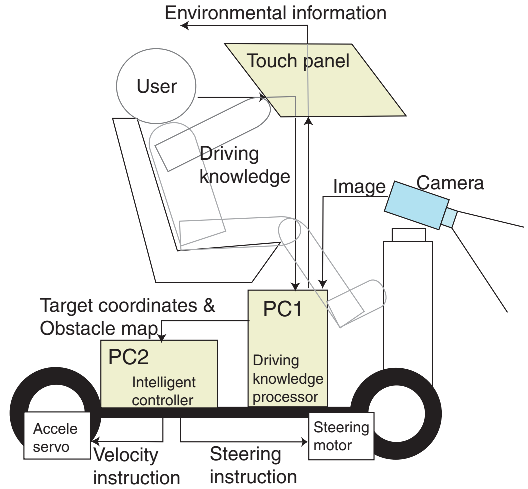

Fig. 6. Hardware construction of the system.

Fig. 7. Welfare electric cart with the auto-driving system.

C. Driving Knowledge Acquisition

1) Acquisition of landmark's information: The system acquired the obstacle map and landmark's information shown in Fig.9 while a user was driving the manual operation.

· The intersection:(0m,0m) (Landmark-*a* in Fig.9)
· The door:(-1.5m,-5.5m) (Landmark-*b* in Fig.9)

Coordinates of landmark and obstacles are dealt with on the grid of 50cm$\times$50cm.

2) Acquisition of action rules: The system acquired action rules as follows.

· [Turn to the left in the intersection (Landmark-*a*)]
· [Approach the door (Landmark-*b*)]
· [Park to the destination]

D. Driving the Cart by Using Driving Knowledge

Fig.10 shows the result of the driving in the experiment, and Fig.11 shows targets that are provided to the intelligent controller by the driving knowledge processor in the experiment. First, the environmental recognition part in the driving knowledge processor recognized the landmark of "The intersection(0m,0m)(Landmark-*a*)", the route decision

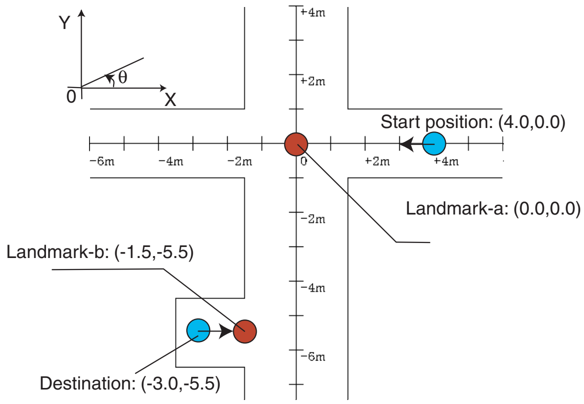

Fig. 8. Experiment environment.

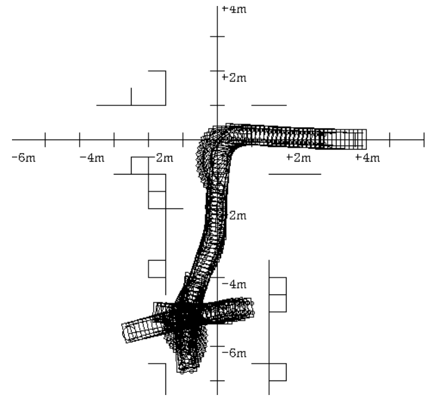

Fig. 10. Result of auto-driving.

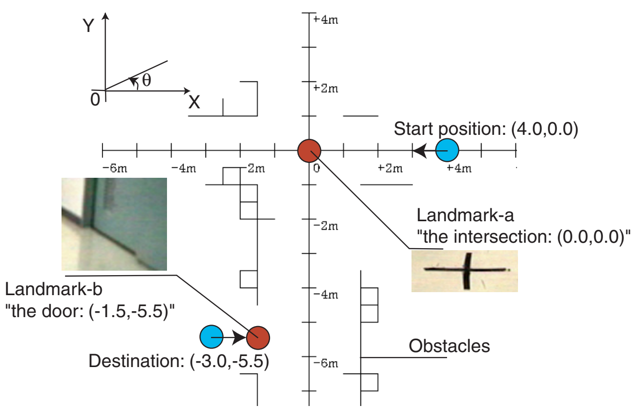

Fig. 9. Acquired driving knowledge and obstacle map.

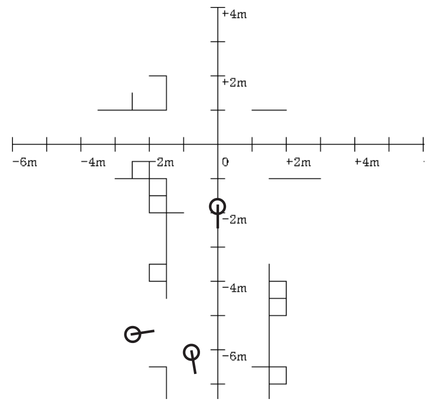

Fig. 11. Targets set in the experiment.

part in the driving knowledge processor set the target by using the action rule of [Turn to the left in ”The intersection(Landmark-*a*)”], and the intelligent controller drove to the target automatically. Secondarily, the environmental recognition part recognized landmark of ”The door(-1.5*m*,-5.5*m*)(Landmark-*b*)”, the route decision part set the target by using the action rule of [Approach ”The door(Landmark-*b*)”], and the intelligent controller drove to the target automatically. Finally, the route decision part sets the target by using the action rule of [Park], the intelligent controller drove to the target automatically, and the cart reached to be near the destination (-3.0*m*,-5.5*m*,0*deg*).

E. Consideration

From results of the experiment, it was proved that system can acquire the driving knowledge from an user by the interactive user interface, can set targets by using the knowledge, and can drive the cart to the user’s destination. And, even the user who did not have the experience to use the system was able to treat it easily. In this experiment, numbers of the landmark and action rules were few. However, the system can drive the cart a longer distance, if there are more landmarks and action rules.

V. Conclusion

In this paper, the system interactively acquires driving knowledge composed of landmark’s information and action rules as the routing information from users. As a result, the user can easily treat the system under various environments to reduce stresses of driving operation. From result of the experiment by using a cart on the market that a human rode on, it is proved that the system can acquire the driving knowledge easily from a user by using the interactive user interface and can drive the cart flexibly to the user’s destination by using the knowledge.

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