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Intelligent Robot Control using Personal Digital Assistants

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Abstract: **In this paper, we propose the intelligent robot control technique for mobile robot using personal digital assistants (PDA). With the proposed technique, the mobile robot can trace human at regular intervals by the remote control method with PDA. The mobile robot can recognize the distances between it and human whom the robot must follow with both multi-ultrasonic sensors and PC-camera and then, can inference the direction and velocity of itself to keep the given regular distances. In the first place, the mobile robot acquires the information about circumstances using ultrasonic sensor and PC-camera then secondly, transmits the data to PDA using wireless LAN communication. Finally, PDA recognizes the status of circumstances using the fuzzy logic and neural network and gives the command to mobile robot again.**

I. INTRODUCTION

In this paper, the intelligent remote control system for the mobile robot system using PDA (Personal Digital Assistants) is proposed. Recently, the mobile robot system has been used for various applications. The operator of robot system must keep his eyes to the robot continuously and control it by manual. Therefore the man who can know the situation and control the robot is needed to have a special skill but it is difficult to control the robot against the various cases. It is amazing to control the robot without the operator. If the robot system is operated by something that substitutes the man, it is very useful and helpful for man.

In this paper, we adapt the PDA, small and portable system, to control the robot system without a person who controls the robot system. To make it be possible, we let the PDA system learn the various control situation and rules using the soft computing method such as neural network and fuzzy logic.

To verify the performance of the proposed system, we select the mobile robot control problem. First, we decide the communication protocol between PDA system and remote robot system. Secondly, we set the wireless communication device both PDA and controller of remote robot system. At last, we program the intelligent algorithm for robot system to navigate without collision. The intelligent algorithm also makes the robot system follow the specific target without miss.

In the point of function, the robot system has several ultra-sonic sensors and USB-camera. The PDA and robot system communicate the data such as distance, color and shape, command of user and so on. With the several data, the PDA can decide the parameters used for control of the robot system instead of the person. A person only carry the PDA system and just call the command to control the robot system then, the PDA requests the data to robot system and the PDA controls robot system with the data to accomplish the order of a person.

Inside of the PDA system, there are neural network and fuzzy logic. The neural network decide whether the robot can operate or not by learning the status of the robot system and command. From the remote robot system, the PDA obtain the status data such as the distance between robot system and the around material, camera information to know whether the target is there or not and current parameter of the motor. The PDA infers the situation of robot system and decides whether the robot system can proceed the command or not. If the robot system can proceed, then the PDA provides proper parameters to the robot system. In this point, the PDA uses the fuzzy logic to decide the parameters for control of robot system. For example, we assume that a person commands robot system to go right but there is an obstacle in the right hand of robot system. The PDA can know that the right side distance of robot system is very small and the color from the camera on robot system means an obstacle. The PDA also decides for robot system not to go right and command 'keep' to robot system. Really, the PDA sends the parameters such as drive motor speed, steering angle value and turret angle to make robot system keep the current status. The above parameters are decided with the fuzzy logic. We introduce several experimental results to verify the ability of the proposed system.

II. FUZZY CONTROL

A. Fuzzy logic control (FLC)

The typical architecture of a FLC is shown in figure 3, which is comprised of four principal components: *a fuzzifier, a fuzzy rule base, an inference engine, and a defuzzifier*. The fuzzifier has the effect of transforming crisp measured data (e.g., distance is 120cm) into suitable linguistic values (i.e., fuzzy sets, for example, distance is too far). The fuzzy rule base stores the empirical knowledge of the operation of the process of the domain experts. The inference engine is the kernel of a FLC, and it has the capability of simulating human decision making by performing approximate reasoning to achieve a desired control strategy. The defuzzifier is utilized to yield a nonfuzzy decision or control action from an inferred fuzzy control action by the inference engine.

As mentioned above, FLC has fuzzy rule base, control rule and is composed with inference engine. The control rule of fuzzy system is the form of "IF-THEN". The example of "IF-THEN" rule is follows

IF X is NB and DE is PB, THEN S is NB
(X : distance, DE : the gap of distance, S : velocity)

In this paper, we use triangular method as a fuzzifier and Mamdani's min-max method as a fuzzy inference method and center of gravity method as a defuzzifier respectively.

B. MRS Control

MRS controller controls the velocity and rotate angle to trace the target using ultrasonic sensors and USB-camera. MRS takes the distance from ultrasonic sensors and position of the target from camera and then, inferences the set parameter of the MRS with FLC.

We make the trace condition as like that MRS must trace the target at the 60cm interval. If the distance between MRS and the target is far from the set distance, 60cm, then MRS must move forward the target. If the distance is below then, MRS must move backward the target. In this process, we use the FLC. There are also some limit conditions such that the maximum measure distance of ultrasonic sensor is 3m and the range of view of USB camera is ±20 degrees.

The last problem is how MRS recognizes the target. The answer is that MRS recognizes the target with the RGB information from the input image using USB camera.

III. NEURAL NETWORK CONTROL

The proposed algorithm is designed according to the one of features of the MRS. A considered feature is that the MRS receives current distance values for the target with ultrasonic sensors. These values are stored in the memory with the values of next time and the MRS uses all stored data for deciding the velocity. Finally, the MRS can get current direction and velocity of the target from the Eq. (1) using the past distance value, the current distance value and the velocity of robot.

$$V = (D_A + 10 \times \pi \times Time \times V_B - D_B)/(10 \times \pi \times Time) \qquad (1)$$

V : *Current velocity of trace target*
D_A : *Past distance between the MRS and the target*
V_B : *Past velocity of the MRS*
D_B : *Current distance between the MRS and the target*

The term '$10 \times \pi$' is that can convert absolute velocity being measured with 'rps' dimension to companion velocity of the MRS. If the result of Eq. (1) shows negative or positive we make the value, 0 or 1, respectively and this is for calculation of the next data.

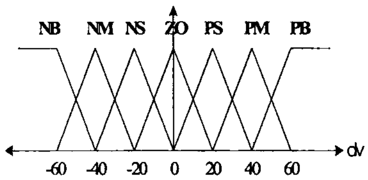
To decide driving velocity, we place emphasis on two decisions of compensation velocity by distance and velocity. First, compensation velocity by distance is for preserving distance with the target. Second, compensation velocity by velocity is for reduction of the velocity margin. In the MRS, the velocity is first compensated by the distance and if the MRS traces the target at regular intervals then, compensated by velocity to keep the current state. The target of our work is to show whether the neural network algorithm can learn the amount of the velocity variations using 3 inputs.

The 3 inputs of neural network are current distance between the MRS and target, difference between the current velocity of the target and past velocity of the MRS, and the variable 'change'.

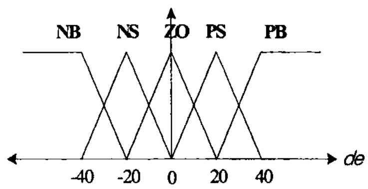
In the neural network, the number of hidden neuron is 20, activation function is a hyperbolic tangent and learning rate is 0.016. The back-propagation algorithm is used to update weight and the data for learning are 1600 survey data and the iteration for learning is 100000 times.

IV. SIMULATIONS AND ONLINE IMPLEMENTATION

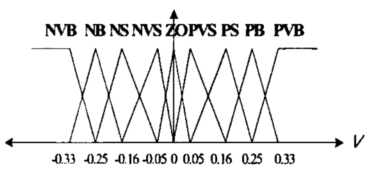
The membership functions and rule bases for the inputs such as distance and difference of between the target and MRS and the output of MRS, velocity, are shown in the figure 1 and table 1. The figure 1(a), (b) are the membership functions for distance and the difference between the target and MRS, the figure 1(c) is the membership function for the velocity, output of the MRS. Like the figure 1, we set the distance of the pre-condition as 7 linguistic variables, the differences of distance as 5 and last, velocity of the post-condition as 9 variables. In the figure 1(c), the MRS decide the velocity of MRS for the inputs such as distance and difference of distance in the pre-condition.



(a) Pre-condition Membership Functions; Distance



(b) Pre-condition Membership Functions; Difference of Distance



(c) Post-condition Membership Functions; Velocity

Fig. 1. The Membership of velocity

Table. 1. Rule Base for Velocity

de \ d	NB	NM	NS	ZO	PS	PM	PB
NB	NVB	NVB	NB	NS	ZO	ZO	PS
NS	NVB	NB	NS	NVS	ZO	PVS	PB
ZO	NVB	NS	NVS	ZO	PVS	PS	PVB
PS	NB	NVS	ZO	PVS	PS	PB	PVB
PB	NB	ZO	ZO	PS	PB	PVB	PVB

The membership functions for the fuzzy control about the rotation angle of MRS are organized as a similar method of the case of velocity.

The following figure 2 shows comparison between the survey data and the data using neural network.

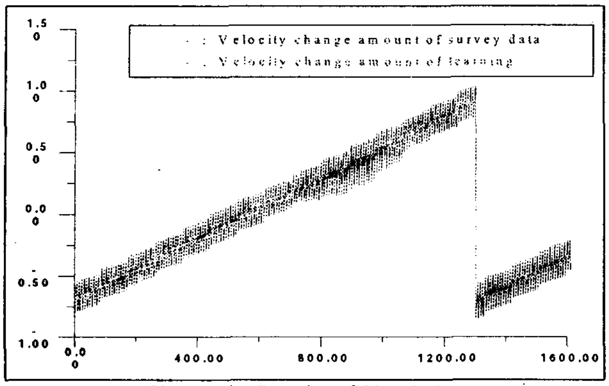


Fig. 2. The Results of Simulation

V. EVALUATIONS

We operate the MRS with FLC and PID controller for the same inputs and outputs of the controller such as velocity and rotation angle online, respectively. Both FLC and PID controller take the control inputs such as distance and position from ultrasonic sensors and PC-camera and then input the outputs such as velocity and rotation angle of controller to the MRS. We compare the distance and position at the time of before and after movement of the MRS.

We move the target in the direction of forward and backward and get the velocity output of the FLC and PID controller. The MRS moves using this velocity value and we compare the distances after movement of the MRS using FLC, PID controller respectively and set distance. The results are shown in the figure 3. In the figure 3, we know that the distance error of the MRS using FLC is more similar with the reference distance than it of the PID controller.

The figure 4 shows the result of comparison about the rotation angle when the target moves right or left side. The result in the figure 4 also shows that the operation by MRS is more efficient than by PID controller.

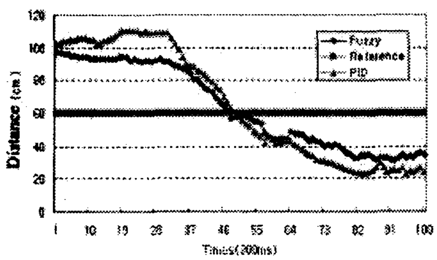


Fig. 3. Results of Distance with Velocity Input

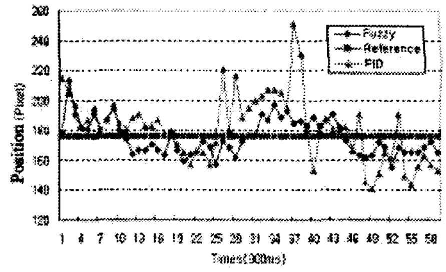


Fig. 4. Results of Position with Rotation Angle

VI. CONCLUSIONS

In this paper, we design the control system of MRS with FLC and the MRS can trace the target at regular intervals. We use the values, distance and position using ultrasonic sensors and USB camera, respectively. The simulation shows the advanced ability of performance using FLC on the point of the error of distance and position being compared PID controller. However, if there is an obstacle, not the target, within sensing area, the inference of distance has some mistakes. The proposed algorithm using neural network shows that MRS keeps the distance while tracing the target with the speed above 40 percent of the driving capacity, as long as the velocity of the target is within the absolute velocity of the robot. The result of the simulation showed that the proposed MRS is more robust to the dynamic environments compared to the common MRS.

In the future works, it is demanded to use some another sensors for recognition of various circumstance more exactly.

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