Intelligent Trace Algorithm of Mobile Robot Using Fuzzy Logic

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Abstract: In this paper, we propose the intelligent inference trace algorithm of the mobile robot using fuzzy logic. With the proposed algorithm, the mobile robot can trace human at regular intervals. The mobile robot can recognize the distances between it and human 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, the mobile robot acquires the information about circumstances using ultrasonic sensor and PC-camera then secondly, recognize the status of circumstances using the fuzzy logic.
We also evaluate the experimental navigation test at several times to verify the ability of the fuzzy logic controller.

1. Introduction

The mobile robot system (MRS) has taken parts of transfer of products at the site of industry, search for unknown area like as space and rescue activity in the dangerous circumstances [1][2]. Recently, the researches for MRS that can lives with people and is friendly with human life are introduced.
Another hand, the research area of fuzzy control system is developed very fast. As a result of that, fuzzy system and fuzzy control theory are used for industry processes and products for a common consumer.
Fuzzy control makes the control for MRS easy by deciding knowledge base as a suitable linguistic value with fuzzy membership functions and fuzzy rule bases though there isn' t an exact model for a certain system [3].
In general, recognition for around circumstances is an essential condition for MRS to trace human and so, we use fuzzy control for MRS to detect the angle and distance [4]. In this paper, we use the variation of distance and position of MRS and control MRS with them at real time.

2. Fuzzy Control

2.1 Structure of MRS

MRS operates with three motors that are asychronous and make driving and steering operation independently or dependently. The same power is provided to each wheels. The controller for motors is PID controller. The maximum number of ultrasonic sensors to calculate the distances is 24 and the each sensor operates selectively. The decision for maximum distance or minimum distance is also possible and the controller can make ascendant or descendant order among the distance values acquired from sensors.
MRS can connect the PC-camera, USB type, to process the image and all the other devices can connect to MRS with USB port. For control the MRS, labtop is used. The labtop controls the MRS by executing an operation program using the input data and displays the status of MRS.
The figure 1, 2 show the structure and appearance of MRS.

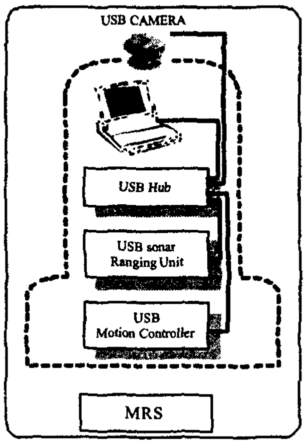


Figure 1. The Structure of MRS

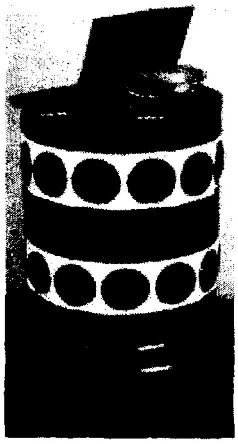


Figure 2. The Picture of MRS

2.2 Fuzzy Logic Control (FLC)

The typical architecture of a FLC is shown in Fig. 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 afuzzifier and Mamdani's min-max method as a fuzzy inference method and center of gravity method as a defuzzifier respectively.

2.3 MRS Control

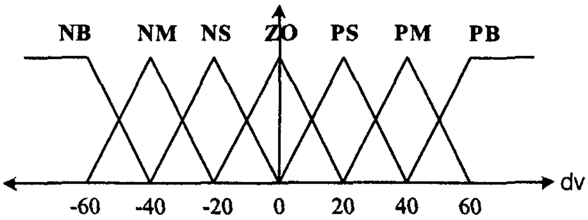
MRS controller controls the velocity and rotate angle to trace the target using ultrasonic sensors and USB-camera. MRS takes the distance from ultrasonic sensors and position of the target from camera and then, inferences the set parameter of the MRS with FLC.

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.

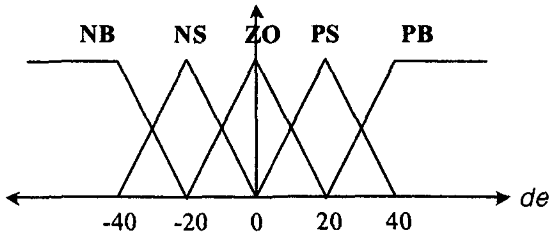
The last problem is how MRS recognizes the target. The answer is that MRS recognizes the target with the RGB information from the input image using USB camera. More specific, the information of an image from the camera is a set of numerous pixels and the each pixel has the bit information of red, green and blue colors. We can not decide the color by the absolute parameter, RGB, because the RGB has brightness and saturation. Namely, if the rate of red in the RGB isn't relatively bigger than it of green or blue, then the apparent color is not shown as red color. When we use the separate a certain color such as red using the PC-camera, we first compare the red and the bigger one among green and blue in the RGB data and if the red is bigger than the bigger one, we decide the RGB as red color. Finally, we make the target by a red sheet of A4 size and controls the USB camera so that is enable to track the target for distance and position.

3. Simulations and Online Implementation

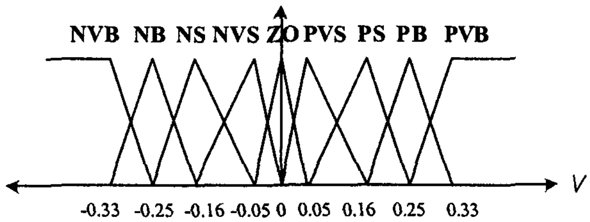
The membership functions and rule bases for the inputs such as distance and difference of between the target and MRS and the output of MRS, velocity, are shown in the figure 3 and table 1. The figure 3(a), (b) are the membership functions for distance and the difference between the target and MRS, the figure 3(c) is the membership function for the velocity, output of the MRS. Like the figure 3, 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 3(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



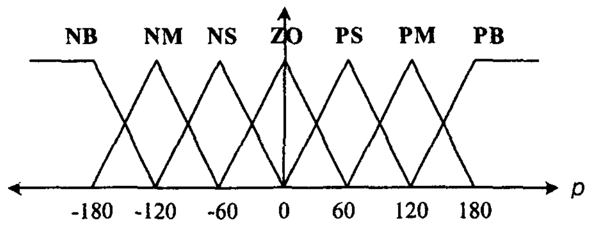
(c) Post-condition Membership Functions; Velocity

Figure 3. The Membership of velocity

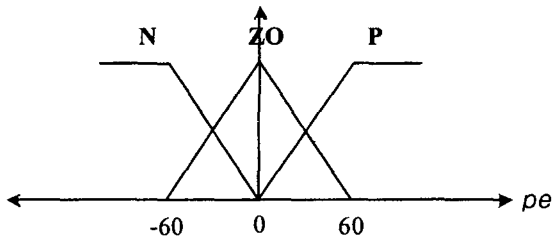
Table. 1. Rule Base for Velocity

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

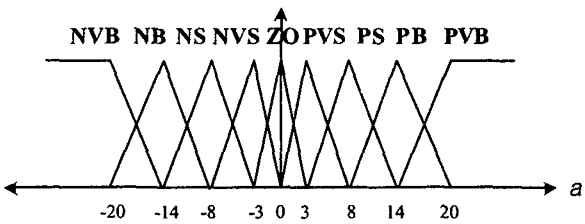
The follows are the fuzzy control about the rotation angle of MRS. The pre-conditions such as positions of MRS and the target and difference of the past and current position are shown in the figure 4(a) and 4(b). The rotation angle of MRS of post-condition is shown in the figure 4(c). The related rule base is like as the table 2.



(a) Pre-condition Membership Function; Position



(b) Pre-condition Membership Function; Difference of Position



(c) Post-condition Membership Function; Rotation Angle

Figure 4. The Memberships for Rotation Angle

Table. 2. Rule Base for Rotation Angles

pe \ p	NB	NM	NS	ZO	PS	PM	PB
N	PVB	PB	PVS	ZO	ZO	ZO	ZO
ZO	PVB	PS	PVS	ZO	NVS	NS	NVB
P	ZO	ZO	ZO	ZO	NVS	NB	NVB

4. 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 5.

The figure 6 shows the results of comparison about the rotation angle when the target moves right or left side.

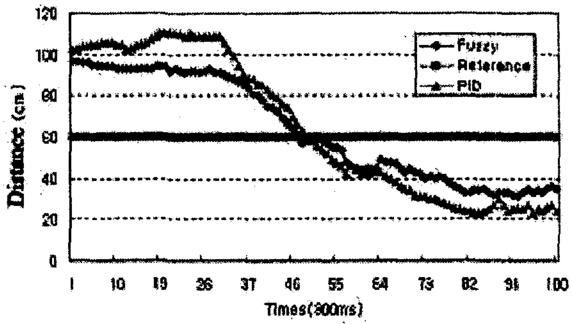


Figure 5. Results of Distance with Velocity Input

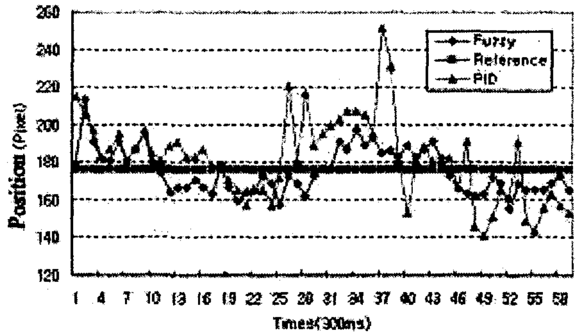


Figure 6. Results of Position with Rotation Angle

We compute the error mean using the below equation (1) based on the acquired data during online operation of the MRS.

$$E_{mean} = \frac{\sum_{i=1}^{n} |x_i - d_{ref}|}{n} \quad (1)$$

The results of comparison of average error are shown in the table 3 and figure 7.

Table. 3. Comparison of Average Error

Control \ Error	Distance (cm)	Position (pixel)
PID	37.76	18.2
FLC	22.75	10

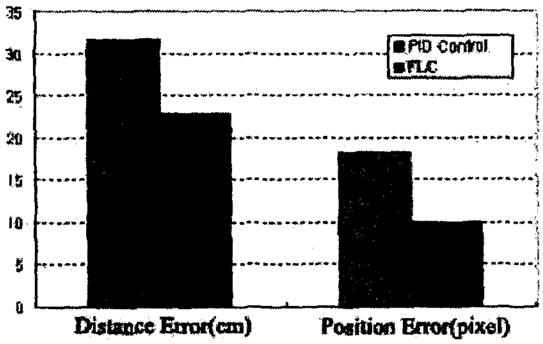


Figure 7. Graphs of Error Mean

In the above results, we confirm that the result of FLC about the difference of distance is better than PID controller over 28.34%, about the difference of position, 45.01%, respectively.

5. Conclusion and Future Works

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 a obstacle, not the target, within the area of sensing, the inference of distance has some mistakes. In the future works, it is demanded to use some another sensors for recognition of various circumstance more exact.

References

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