유전자 알고리즘과 퍼지 제어를 적용한 자율운송장치의 경로 계획

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Path Planning of Autonomous Guided Vehicle Using Fuzzy Control & Genetic Algorithm

Yong-Gug Kim, Yun-Bae Lee

요 약

유전자 알고리즘은 탐색, 최적화 및 기계 학습의 도구로 많이 사용되고 있는데, 구조는 단순하지만, 다양한 분야에서 적용되고 있다. 그리고 변화하는 환경에서 유연하게 대처 할 수 있는 자율운송장치의 능동적이고 효과적인 제어기에 관한 연구와 스스로 진화하여 학습할 수 있도록 하는 행동 기반 시스템에 관한 연구 또한 활발히 진행되고 있다. 퍼지 제어기 설계를 위한 소속 함수와 제어규칙의 구성 시 전문가의 경험적인 지식에 전적으로 의존하는 문제점을 가지고 있다.

본 논문에서는 자기 조직이 가능한 자율 운송 장치를 구성하기 위해서, 유전자 알고리즘을 이용하여 최적에 가깝도록 멤버십 함수를 조정했으며 제어규칙의 자기수정과 생성에 의해 제어 성능을 향상시켰다.

ABSTRACT

Genetic algorithm is used as a means of search, optimization and machine learning, its structure is simple but it is applied to various areas. And it is about an active and effective controller which can flexibly prepare for changeable circumstances. For this study, research about an action base system evolving by itself is also being considered. There is to have a problem that depended entirely on heuristic knowledge of expert forming membership function and control rule for fuzzy controller design. In this paper, for forming the

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fuzzy control to perform self-organization, we tuned the membership function to the most optimal using a genetic algorithm(GA) and improved the control efficiency by the self-correction and generation of control rules.

Ⅰ. Introduction

There is no definition of "Intelligent Machine"(IM) as a technological entity. Here we assume that the major property of intelligent machines will be to perform an "intelligent motion". Intelligent motion can be understood through the definition of intelligence: this a motion in a system with redundancy determined appropriately to a combination of known long-term factors, and a description of the immediate situation. Intelligent autonomous machine(IAM) are understood as a part of the class of IM which assume operation with no human involvement. autonomous operation is essential for proper formulation of technical requirements and specifications of autonomous mobile robots. There are many studies about artificial intelligent robots, but robotics is difficult to study because it requires integrated studies and the knowledge of various parts. An AGV (Autonomous Guided Vehicle) limits the category of an AMR (Autonomous Mobile Robot) to the industrial field. The study is about an active and effective controller which can prepare for changing circumstances as they progress. For this study, the research about a self-evolving action base system is also actively being conducted.

In this paper, we composed an active and effective AGV controller using a fuzzy controller which is able to perform self-organization. For forming the fuzzy control to perform self-organization, we tuned the membership function to the most optimal using a genetic algorithm(GA) and improved the control efficiency by the self-correction and generation of control rules.

The existing AGVs employed a differential and integral calculus(D&I) type controller whose intuitiveness, were flexibility and controlling efficiency was lower[1][2]. Therefore, it didn't have the ability to actively prepare for the changeable circumstances. However, the self-organizing control(SOC), the fuzzy controller is capable of learning and adapting. It can also generate and correct the control rules. It can then flexibly prepare for changing circumstances and can effectively express the ambiguous and approximate phenomena in the real world by using fuzzy logic.

The SOC fuzzy controller proposed in this paper is capable of self-organizing by combining the characteristics of a fuzzy controller and a genetic algorithm. It intuitionally controls the AGV and can easily adapt to circumstances as a human would.

Ⅱ. Fuzzy Controller

Fuzzy theory start with a recent interview with Professor Zadeh that appeared in the communications of the ACM[4]. This illustrates his basic philosophy, and so gives us a persecutive from which to interpret this significant body of scientific work. We start, naturally, with the very first published paper on fuzzy sets[4] in which Professor Zadeh introduces the seminal idea and defines inclusion, union, intersection, complement, relation and convexity. Decision-making under ambiguous circumstances can't be explained using classical logic, it must be explained by the introduction of fuzzy logic. Fuzzy logic is a representative tool which can artificially make a human-like decision. It can realize an expert system which performs the same functions as human experts, since it describes the experiential knowledge by "if-then" rules and then artificially implementing the mechanism of human decision-making. Since fuzzy logic imitates the ability of human decision-making, it is applied in a variety of areas such as technology, social science, and medical science[3][4].

2.1 The determination of input variables and fuzzy values in the fuzzy control

The fuzzy inference used in this paper can be expressed as a Multiple Input, Single Output(MISO) rule set, which has the rule base as follows[9][10].

R_1 : IF X is A(1) and Y is B(1)
THEN Z is C(1), also
R_2 : IF X is A(2) and Y is B(2)
THEN Z is C(2), also

.

.

R_n : IF X is A(n) and Y is B(n)
THEN Z is C(n).

Here, A(1), A(2), -----, A(n) and B(1), B(2),-----, B(n) and C(1), C(2),-----, C(n) are the fuzzy sets of linguistic terms of input variables X, Y and output variable Y. The above expression is transformed into a fuzzy relation as follows[5].

R=also (R , R ,-----R)

The two variables used in an "if-clause" express the AGV's distance d from the target line and its moving direction θ.

An output variable used in a "then-clause" expresses the AGV's handling direction.

Here, the fuzzy sets for each input and output variable is as follows.

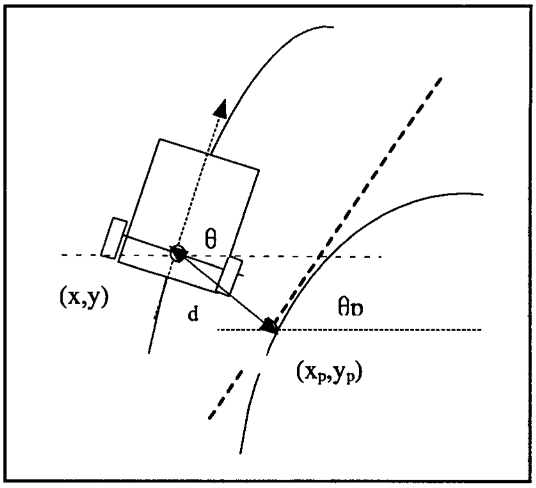


Fig. 1 AGV input variables used in simulation.

a. AGV's distance from the target line (D)

The fuzzy variable LF indicates that the AGV runs far apart from the target line to the right. MD means that it runs on the target line. RN means that it runs near the right side of the target line.

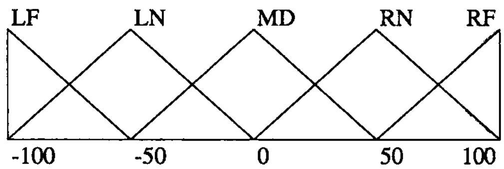


Fig. 2 The membership function for distance from target path

b. AGV's navigating direction (V)

The fuzzy variable LN shows that the AGV is moving to the left side of the target line. MD means that it is moving in the direction of the target.

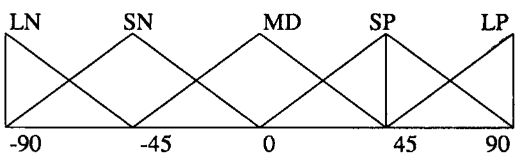


Fig. 3 The membership function for the moving direction of AGV

c. AGV's handling angle (A)

The fuzzy variable LN means to turn the AGV's handle far to the left. ZE means to move straight without touching the handle. SP means that the AGV's handle should be turned slightly to the right.

Although each step must be divided into more details for fine control, we divided them into steps as the above figures for the intial steps of our experiment.

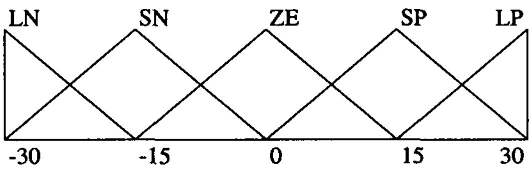


Fig. 4 The membership function for the handling angle of AGV

Generally, triangles and trapezoids or Gaussian functions are used as the shape of a membership function, but we can use a triangle in this paper. We can use a correlation minimum method for fuzzy inference and a centroid defuzzification method for defuzzification.

In this paper, the AGV is controlled by fuzzy rules which have two input variables. The controller's character and efficiency are determined by the number of input variables or the shapes of their membership functions, so their selection must be made properly. The experienced operator's knowledge and the control expert's knowledge or real data are used for fuzzy partition, since there are no general algorithms and laws for it. Because it is difficult to describe the experiential knowledge completely, a "Cut-and-try" method is required to find efficient rules. In this paper we used the GA for their optimal decision.

2.2 Fuzzy Control Rule

There is "state evaluation" and "object evaluation" in the fuzzy control rule used for fuzzy controller design. The state evaluation is generally introduced in fuzzy control, and it is also used for simulation in this paper. Its general type is as follows.

Ri : If x is Ai, ... , and y is Bi
then z is fi(x, ... , y)

The object evaluation is called the predictive fuzzy control rule, its general form is as follows.

Ri : If(u is Ci → (x is Ai and y is Bi)
then u is Ci

If this control rule is used, we can predict the next state of plant and control it more smoothly.

These are the methods for extracting the fuzzy control rule:

1) The method introducing the expert's experience and knowledge.
2) The method extracting a operator's function.
3) The method using the controlled process's fuzzy model.
4) The method adding learning ability to the controller.

The aim of this study is to organize an active controller which has learning and adapting ability. After giving heuristic control rules, we composed the SOC fuzzy controller by using a genetic algorithm, which can revise the existing control rules or generate new control rules.

2.3 Fuzzy inference and defuzzification

Inference means to extract new facts or relations from the given facts or relations. It can get the new controller's outputs combined using the controller's inputs and control rules. In this paper the Max-Min rule of the various inference methods was used. It is proposed by E.H Mamdani. Its implication and inference are as follows.

e', ce' and co' are fuzzy sets of input and output values of each controller and the inferred

direction \ distance	LF	LN	MD	RN	RF
LN	LP	LP	LP	SP	ZE
SN	LP	SP	SP	ZE	SN
MD	LP	SP	ZE	SN	LN
SP	SP	ZE	SN	SN	LN
LP	ZE	SN	LN	LN	LN

Fig. 5 control rule

output values. μ is the value of member function.

Since the final value gained through fuzzy inference can't be a determinative value for plant control, we can make it a constant to use as a plant input. We call the above course defuzzification.

The following are the most common methods for defuzzification: (1)Simplified center of gravity(COG), (2) Center of gravity method (3)Max criterion method and (4) the Mean of maxima.

In this paper, we employed the COG method which is generally used for defuzzifi- cation.

After quantifying the representative set u, the defuzzification value u* is defined as follows.

$$u^{*} = \mathrm{def}\,uzzifier(B') = \frac{\sum_{j=1}^{n} \mu_{B'}(u_j) \cdot u_j}{\sum_{j=1}^{n} \mu_{B'}(u_j)}$$

Ⅲ. Genetic Algorithm

A genetic algorithm(GA) is a calculation model which is based on the evolutional phenomena of the real world. It expresses likely solutions to the problem as genetic data structure of a specific form, and gradually transforms them into better solutions. This course is similar to survival of the fittest and prepotency. It is used as a means of search, optimization and machine learning. Its structure is simple, but it is applied to various areas. It is an effective method for finding an approximate value for optimization. These days, it is actively being combined with the various theories. The genetic algorithm which imitates the evolutional course of an organism basically keeps the genetic types within a group for problem solving. It generates the new genetic types through the operator like crossover or mutation, it selects the genetic types which have a high degree of benefit for the group, and forms a new group composed of the selected new genetic types. And it solves the problem using them. The basic genetic algorithm is as follows(Fig.6):

```
// genetic algorithm
step 1 : initialize(population)
         evaluation(population)
step 2 : if termination-condition = O.K.
           then end
step 3 : reproduction(population)
         alter(population)
step 4 : go to step 2
```

Fig. 6 The basic genetic algorithm

Step 1 generates each initial value randomly in the range of the fittest variables, which is the potential solution set population composed of a single chromosome. It forms the initial potential solution set, and reproduces objects which have high fitness in the next generation. Step 3 alters the individuals of the reproduced group and repeats the global search by using mutation and crossover. To alter(population) means to mutate and to crossover the reproduced potential solution sets to ensure high probability. Step 2 is closed after a specific generation, or it is closed when there is no improvement after the regulated generation has passed.

3.1 The genetic expression types

In this paper, we expressed the parameters of the fuzzy system used to control. The AGV as genetic types, generated new genetic codes by the mutation and the crossover of the parameters having the high fitness, applied them to the fuzzy system, and obtained the fittest parameters(Fig.7):

The structure of the genetic types are as follows.

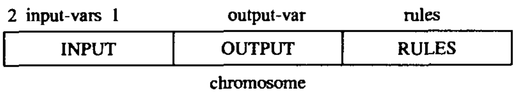


Fig. 7 The structure of genes.

That is, two fuzzy input variables, a output variable and the control rules are encoded. The encode of the fuzzy input and output variables needs 36 bits, since each variable of input and output needs 12 bits to determine the membership function as in

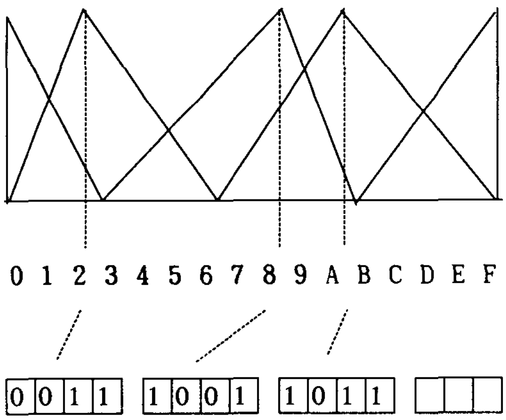


Fig. 8 The coding method of the membership function.

3.2 The coding method of control rules

To code the control rules as chromosomes, we substitute a control rule with integers, and arrange it in the previously fixed order. To code the fuzzy controller as the genetic algorithm, after coding each input and control variable according to the coding methods of the membership functions and the control rules, we should arrange them in a chromosome and arrange the coded control rules next to them.

distance / direction	LF	LN	MD	RN	RF
LN	0	0	0	1	2
SN	0	1	1	2	3
MD	0	1	2	3	4
SP	1	2	3	3	4
LP	2	3	4	4	4

↓

00012 01123 01234 12334 23444

Fig. 9 The coding method of control rules

3.3 The genetic operator

1. Reproduction : As a method to make a fit individual, produce more sons in the next generation, the dominance selection method is used.
2. Crossover : In the reproduced parental individuals, select a part of string arbitrarily and cross them over.
3. Mutation : Randomly generate a value between 0 and 1 for each individual gene in each set. If the generated value is less than that of the mutation actor, alter the value of the gene.

3.4 The mutation of the control rules

The gene encoded control rules cause mutations as a constant probability, similar to the mutation operation of the general genetic algorithm. The control rules of the conclusion part can be expressed as any of a number of linguistic terms. Therefore, they have the new control rule which has one of the remaing values, if mutation occurs.

Ⅳ. A simulation and the results

4.1 Simulation

In this simulation, the proposed self-organizing fuzzy controller optimally learned the fuzzy membership functions and rules, and performed the fuzzy control. The speed was assumed to be constant.

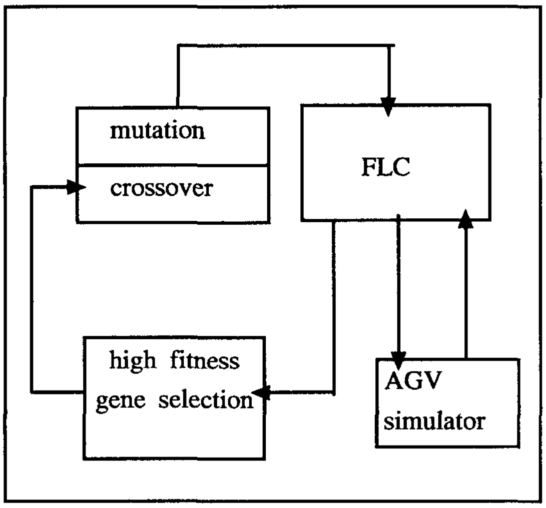


Fig. 10 The tuning structure of the fuzzy system by GA

(Fig.1) shows the input and output state variables of the AGV used in the simulation. The distance d from the target line and the vehicle's navigating direction θ are the conditional variables and the handle's turning angle θ is the conclusive variable. Variable d expresses the distance between the AGV and the target path, the sign of d is determined by the AGV's position.

If the AGV is on the left side of the target path, sign of d is "-". If the AGV is on the right side, sign of d is "+".

The length of d is transformed into a fuzzy variable and inputted as a linguistic value.

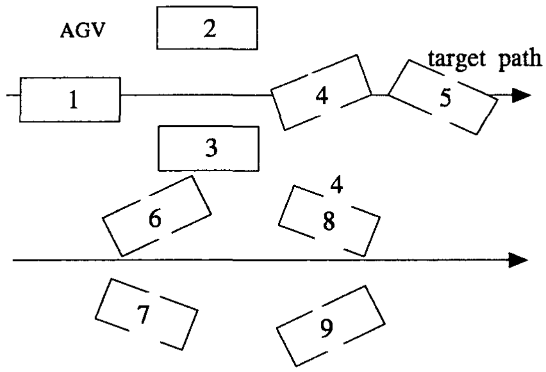


Fig. 11 The target path and the location of AGV

In order to evaluate the navigating efficiency, error e, Δd and Δe are used as inputs of function evaluation. The AGV's navigating efficiency is measured using this function.

θ expresses the AGV's navigating direction. We can calculate the relation between the AGV and the target path by comparing θ with θ_p. It is possible to make a fuzzy rule like fig.11 by using this relation. (Fig.11) expresses the location relationship between the AGV and the target path. The control rules are illustrated in (Fig.5). The simulation was performed on the local path as in (Fig.12) using the discussed genetic algorithm and fuzzy inference.

4.2 AGV's path planning and navigation

The following algorithm expresses the AGV's global navigation algorithm.

step 1 : Making a global map of workspace
step 2 : Global path planning
step 3 : Local navigation of AGV
    (1) : IF current position = goal point
            THEN navigation terminates
    (2) : IF an obstacle exists
        THEN obstacle avoidance ,
            local path planning ,
            go straight to sub-goal

point, path recovery ,
(3) : go straight to goal point
step 4 : go to step 3

The AGV's pilot module makes the AGV navigate toward the target on the path generated by the global planning. In this paper, we used the path planning seen in(Fig.12) for the simulation.

It is assumed that the information of workspace is already known. We evaluated the AGV controller's performance by using the above path planning. The lateral position error, as a function to evaluate the navigating performance, expresses its displacement from the target path. The absolute value of the displaced distance is defined as e. The total lateral position error at a specific distance is defined as its evaluating function. The lower the value of the evaluation function is, the closer the AGV navigates to the target path.

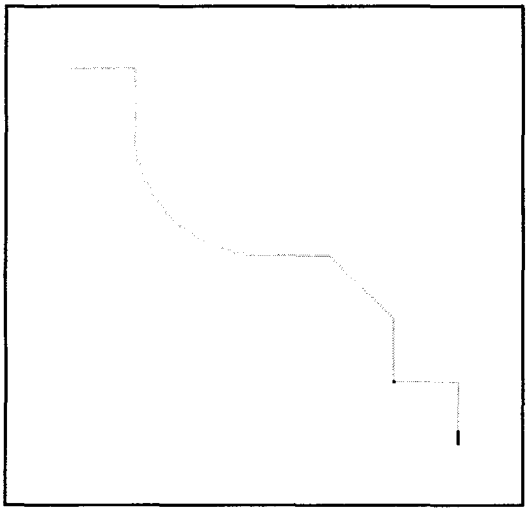


Fig. 12 The path used for simulation

(Fig.14) illustrates to us the member- function, or the fittest of the functions generated by the proposed method. From the comparison, the member-function's shape and control rules

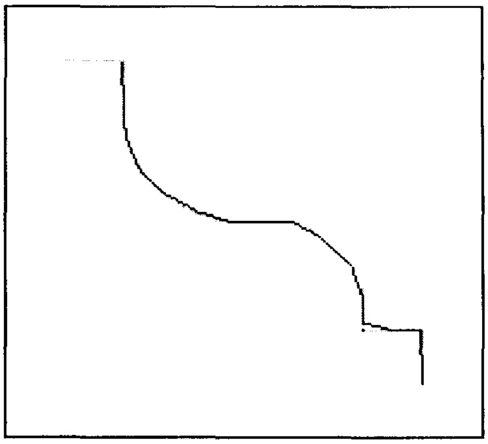


Fig. 13 The Moving path for simulation of AGV

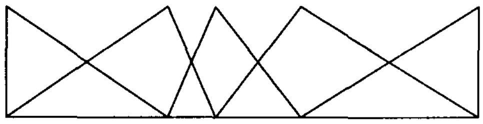
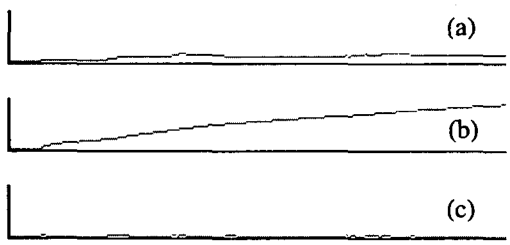


Fig. 14 Example of the adjusted membership function



(a) graph of error function
(b) cumulative graph of error function
(c) graph of Δe function

Fig. 15

generated by heuristic method with the membership function's shape and control rules initially generated by the genetic algorithm, we can see that the performance of a non-linear control is higher than that of linear control. It improved the ability to operate the handle as follows : if the error between the AGV and the target path is wide, move a large amount and if the error is small, do it slightly

V. conclusion

In this paper, we proposed the navigating controller which can be applied to the AGV's navigation by forming a self-organizing fuzzy control system for the AGV's efficient control. Since the control algorithms of the existing AGVs only depended on the knowledge of the expert, there were limitations in the optimization of parameters and the AGV's efficiency. Also it was very difficult to understand instinctively because of too many rules and the complicated calculations. Therefore we composed a controller which is instinctive and easy to understand. This controller is the fuzzy system which uses linguistic variables. For the composing controller to be able to actively prepare for the changeable circumstances, we optimized the membership-function by using the SOC fuzzy controller. We implied employing the genetic algorithm and ensured the fittest possible navigation through self-correction and the generation of control rules.

We can obtain a highly efficient fuzzy control in the case of off-line by applying fuzzy control rules using a genetic algorithm, but it cannot be applied to real time. A model which can be applied to real time is needed to actively prepare for changeable circumstances. We will continue to study the model, which can learn at real time and will be useful in avoiding arbitrary obstacles generated during the AGV's navigation.

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