

The membership function and its role in Autonomous Vehicle Control

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Abstract

In our search we explained mean and roll of the membership function used to control the vehicle with fuzzy system . Autonomous vehicle suffers from problem of autonomous navigation because of uncertainty that is inherent of natural environments. Fuzzy logic has features that make it an adequate tool to address this problem to get vehicle steering angle

Key words:fuzzy system,membership function,Gaussian Membership, Propagation, Defuzzification, center of gravity ,Center- of –Maximum.

الخلاصة

البحث يتضمن شرح مفصل عن كيفية توظيف دالة العضوية في السيطرة على مركبة تتحرك ذاتيا في البيئة الواقعية بكل ماتعانية من عدم وضوح باستخدام الانظمة المضببة وذلك من خلال التحكم بزاوية المقود
الكلمات المفتاحية: النظام المضبب، دالة العضوية، دالة العضوية لكأوس، النشر، إعادة القيمة الغير مضببة

1-Introduction

A linguistic approach is developed by Zadeh to deal with linguistic vague information based on fuzzy logic and fuzzy sets .Since there are a number of applications of variety of fields including meteorology, engineering ,medicine, management, computer science expert systems, and system scienceL. A. Zadeh(2008), L. A. Zadeh(1965) .

In the field of systems ,many complex plants are difficult to deal with by conventional approach because of their nonlinear, time varying behavior and imprecise measurement information .Nevertheless ,human operators can handle these complex plants by their practical experience. They only need imprecise system states and a set of imprecise linguistic *If Then rules*. Zadeh develops system theory depending on fuzzy set and fuzzy logic that can be dealt with complex systemsL.A. zadah(1994) .

Fuzzy systems accept numeric inputs from real world and convert then into linguistic value that can be manipulated by using fuzzy logic operations with linguistic If-Then rules given by human operator. The linguist outputs ,the result of the fuzzy logic operations, are converted in numeric outputs which are then delivered to the real world.

Fuzzy logic is the name given to the analysis that seeks to define the areas of grayness that are so characteristic of the world we live in. The objects in the real world are classified into different categories. For such categories as tall man, beauty woman etc., all of them convey linguistic vague information. The concept of membership of an object in such categories is not obvious and not precise. In classical set theory an element either belong to set or does not belong to a set. In fuzzy set theory, an element may partially belong to set. Fuzzy sets have gradations of set membership which are represented by a function referred to as membership function, and so they resemble the kind of the categories ordinary people use in natural thought or communication Miller, Byron (July 1998):-

Fuzzy logic is an alternative to the A -or- not A, Boolean 1 and 0 logic definitions built into society. It seeks to handle the concepts of partial truth by creating values representing what is between total truth and total falsity. Fuzzy logic can be used in almost any application and focuses on approximate reasoning while classical logic puts such a large emphasis on exact reasoning.

2 -Related Work

Some of the earliest attempts at applying fuzzy logic to control mobile robot vehicles were made by Uragami et al. and Sugeno and Murakami. Uragami and Colleagues implemented a fuzzy program to control a simple inchworm robot to simulate a person wandering through a town. They conclude that robots could be used to explore spatial region, with human issuing commands in the form of fuzzy instructions later, Sugeno and Murakami conducted successful experiments in embedded fuzzy control of model car for parking based on operators control actions. This early work was done before the initial reports on the consumption architecture became available and thus, was not influenced by the behavioral decomposition proposed by books Ouwerkerk, S.F.J., (February 1995), Miller, Byron July 1998).

Ming Cao and Ernest Hall in 1997, described the use of fuzzy logic control for the high level control systems of a mobile robot. The advantages of the fuzzy logic system are that multiple types of input such as that from vision and sonar sensors as well as stored map information can be used to guide the robot. Sensor fusion can be accomplished between real time sensed information and stored information in a manner similar to a human decision maker. Vision guidance is accomplished with a CCD camera with a zoom lens. The data is collected through a commercial tracking

device, communicating to the computer the X,Y coordinates of a lane marker. Testing of these systems yielded positive results by showing that at five miles per hour, the vehicle can follow a line and avoid obstacles. The obstacle detection uses information from Polaroid sonar detection system. The motor control system uses a programmable Galil motion control system. This design, in its modularity, creates a portable autonomous controller that could be used for any mobile vehicle with only minor adaptations Ming Cao and Ernest Hall (1997) .

3- Membership Functions

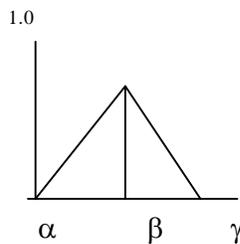
Every element in the universe of discourse is a member of the fuzzy set to some grade ,maybe even zero. The set of elements that have a non-zero membership is called the *support* of the fuzzy set. The function that ties a number to each element x of the universe is called the membership function $\mu(x)$. There are four shapes that are mainly used J.W. Goethe-Universität Frankfurt am Main (1999) Inma P. Cabrera, Pablo Cordero, and Manuel Ojeda-Aciego(2003) Dr. Lorraine M. Parker(May 2005) vonne C. Lucero and Patricia A. Nava, Ph.D.(2001) Taner Bilgic, and İ. Burhan Türksen,(2000). The one we used is membership function

3-1- Triangular Membership Function

It is defined as follows:

$$\begin{aligned} \Lambda(u;\alpha,\beta,\gamma) &= 0 & u < \alpha \\ &= (u-\alpha) / (\beta-\alpha) & \alpha \leq u \leq \beta \\ &= (\alpha - u) / (\beta-\alpha) & \beta \leq u \leq \gamma \\ &= 0 & u > \gamma \end{aligned}$$

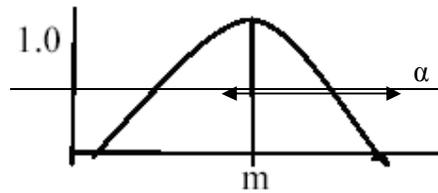
The plot of the triangular membership function is shown in figure (1)



Figure(1):: Typical Form of the Triangular Function

3-2 Gaussian Membership Function

It is defined by $G(u:m,\sigma)=\exp[-\{(u-m)/\sqrt{2\alpha}\}^2]$. Where the parameters m and σ control the center and width of the membership function. A plot of the Gaussian membership function is presented in figure (2).



Figure(2): Gaussian Membership Function

3-Suggusted method

The structure of fuzzy inference system is shown in figure (3) below.

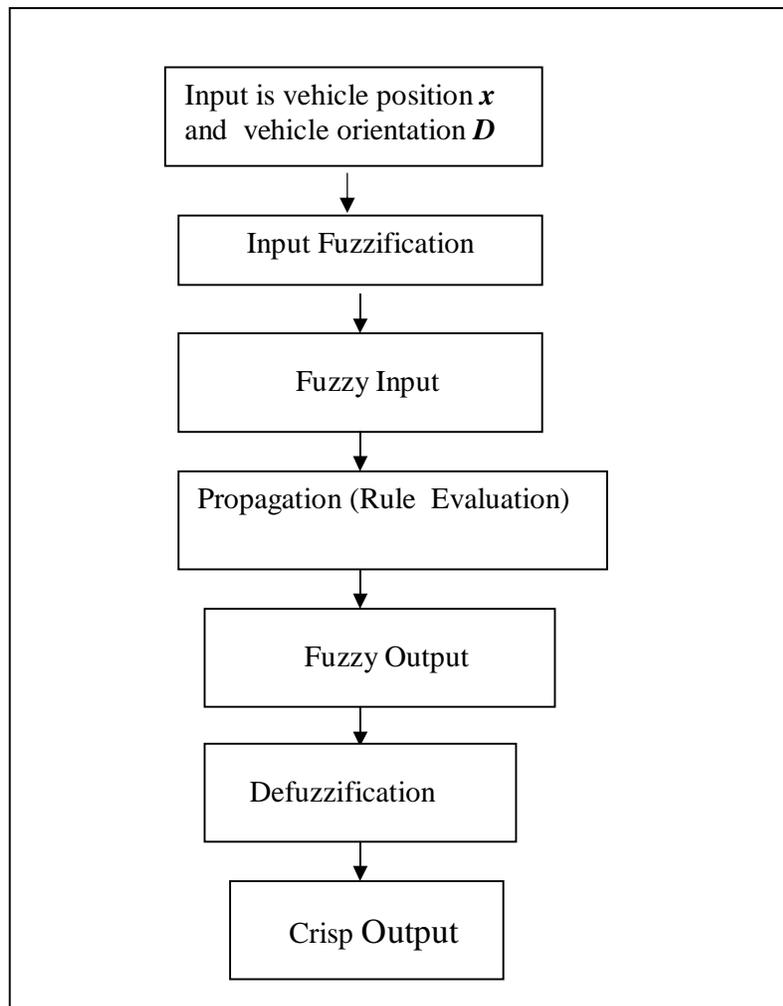


Figure (3): Structure of Fuzzy Inference System

The algorithm of fuzzy inference system is shown below.

Algorithm (1): :Fuzzy Inference System.

Input : the value of vehicle position (x) and the vehicle orientation angle (D) that calculated from genetic algorithm.

Output : the value of steering angle (φ).

Begin:

Step1: compute the membership function of vehicle position (x)

$$\mu_1 = (u - \alpha) / (\beta - \alpha) \quad \alpha \leq u \leq \beta$$

and the vehicle orientation (D)

$$\mu_2 = (\alpha - u) / (\beta - \alpha) \quad \beta \leq u \leq \gamma$$

Step2: apply the production rules on the inputs linguistic variable to conclude output variable

Step3: apply the defuzzification on the output variable to get crisp value of steering angle (φ)

End.

In this step real variables are translated into linguistic variables , vehicle position x and vehicle orientation D of position are translated into linguistic variables.

4-2 Propagation (Rule Evaluation)

Input to this step is the linguistic variable for vehicle orientated (x) and the linguistic variable for vehicle orientated (β). Because There are five terms for the linguistic variable, vehicle position (x), and seven terms for the linguistic variable, vehicle orientation , there are at most thirty five different rules available to form a consistent rule base. Because there only two input variables in this case , the complete rule base can be documented in a matrix form, as shown in figure(4).

AND		Vehicle position x				
		left	Left center	center	Right center	right
vehicle orientation β	Left down	Negative small	Negative medium	Negative medium	Negative large	Negative large
	left	Positive small	Negative small	Negative medium	Negative large	Negative large
	Left up	Positive medium	Positive small	Negative small	Negative medium	Negative large
	up	Positive medium	Positive medium	zero	Negative medium	Negative medium
	Right up	Positive large	Positive medium	Positive small	Negative Small	Negative medium
	right	Positive large	Positive large	Positive medium	Positive Small	Negative small
	Right down	Positive large	Positive large	Positive medium	Positive medium	Negative Small

Figure (4):Complete Linguistic Rule Base

A control strategy can be defined by using IF-THEN rules such as the following :

IF <situation> THEN<action>

The above rule format describes the necessary reaction ,or conclusion ,to a certain situation ,or condition .

IF vehicle position x is left AND vehicle orientation D left up THEN adjust steering angle φ to positive medium, OR

IF vehicle position x is left center AND vehicle orientation D left up THEN adjust steering angle φ to positive small.

Notes: The conditions of each rule are composed of uncertain linguistic terms like Left center, left up, and so on. Even the conclusion of each rule contains vague and imprecise facts such as negative small.

Each combination of a column and a row describes a certain maneuvering situation- the condition of a certain rule. The conclusion is given by the term at the intersection of the column and row.

4-3 Fuzzy output

Once all input variables values are translated into corresponding linguistic variables values, the fuzzy inference is executed to drive a conclusion from the rule base that represents the control strategy.

4-4 Defuzzification

This step translates the linguistic value for the output variable back into a real value representing the current value of the control variable(steering angle ϕ).

The relationship between the linguistic values and the corresponding real values always is given by the membership function detentions describing the terms of the linguistic output variable.

5-Results

The results when the starting point is (50,45) and range sensor is 5 and the distance of range is 20 ,as shown in table (1).

No	Vehicle position x m y m		Vehicle orientation (°)	Angle of Vehicle steering (°)
1.	50	45	45	19
2.	58	98	45	14
3.	96	139	45	18
4.	103	146	50	18
5.	148	208	85	21
6.	150	261	36	16
7.	181	278	9	5
8.	258	290	36	7

Table(1) : Vehicle Position, Vehicle Orientation , Vehicle Steering Angle using-Triangular Membership Function

No	Vehicle position x m y m	• Vehicle orientati on (°)	Angle of Vehicle steering (°)
1.	50 45	45	17.68
2.	58 98	45	15
3.	96 139	45	17.68
4.	103 146	50	18.58
5.	148 208	85	21.5
6.	150 261	36	16
7.	181 278	9	5.5
8.	258 290	36	7

Table(2) : Vehicle Position, Vehicle Orientation , Vehicle Steering Angle using Gaussian membership function

6- Conclusions

From this work for autonomous robotic vehicle control, the following conclusions were :

- 1-applying two types of membership functions (Triangular Membership Function, Gaussian membership function) give us nearest results.
- 2- Fuzzy logic gives us a valuable tool for writing coordination strategies, it does not give a solution to the general problem of behavior coordination
- 3- The defuzzification method Center- of -Maximum identical to the center of gravity method using singleton membership functions .

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