Self-Parking System Based in a Fuzzy Logic Approach

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Abstract. – This paper describes a control system which automatically parks a scaled automobile inside a rectangular reduced space given certain conditions and making decisions based in fuzzy logic. The control is developed by the processing of entry variable data from simulated sensors of a specific scenario, and the run of three models in cascade to achieve a decision-action method. Finally, this paper shows a description of the way this project was achieved, and concludes with the acceptable results that a fuzzy control can provide in a management of this kind of mechanism by the use of taking decision models.

1. Introduction

The control of systems and machines has been studied since the beginning of the last century. To control simple and linear systems the approaches based in the frequency response and root locus have been widely used, but when complexity increases or the systems performance exhibits non linearity, more complex design approaches based in space state variables are preferred increasing too much the computational demands on the processing system.

In 1965 Zadeh presented the foundations of the fuzzy set theory [1]. Nowadays, this mathematical sub discipline has obtained considerable applications on a wide kind of problems. There are some industrial and nonindustrial processes that do not permit a precise mathematical modeling needed in classical control theory approaches, due to the nonlinearity relationship between the system variables. In case it is possible to implement fuzzy controllers in processes where a human operator can controlled successfully the process such as cement kilns, steel furnaces, DNA production or parking a car [2]. This paper considers the solution of the problem of the automatic car parking as an accessory in real cars to help to inexpert drivers when the vehicle must be parking in a reduced space (Fig.1). The solution proposed use fuzzy set theory as the base to develop the making decision models and carry on such process.

In reference [3] a fuzzy control system was developed in combination with neuronal-network to park a simulated truck. Baturone and et. al. [4] had worked to design and implement a fuzzy control system to perform diagonal parking in a constrained space. Chen [5] developed a suboptimal solution of the problem of automatically back-driving of a truck that uses the natural parabolic paths as the shortest moving distance requirement and by applying fuzzy control.

In 1992 Volkswagen [6] applied a new technology of self parking in the Futura Concept car named Integrated Research Volkswagen (IRVW). The IRVW provided control over the car that the driver can get out of the car and look how the vehicle parking by itself. However, since that this technology increase the price of the car, the idea never was commercialized. In 2003 [7] the self-parking project of Toyota named "Intelligent Parking Assist" was implanted in the Japanese hybrid car Prius, and, three years after some companies in England decided to commercialize the idea of the self-parking feature. A last example [6] is a group of students from the Linköping University in Sweden supported by the Volvo Company whose worked to obtain a system which automatically parks a car controlling the steering wheel and brakes of a Volvo S60 obtaining satisfactory results.

2. Project description

In this project a fuzzy knowledge base has been developed to enable a car to perform the self-parking parallel parking process, when the car is located in parallel position respect to the sidewalk as illustrated in Fig.2 by choosing the most efficient sequence of movements of the steering wheel. The movements of the steering wheel are given in function of the parking space and the initial position. A 3D animation has been developed to display the movements of the car which allows modifies the initial position and change the park space with sliders.

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Fig. 1 Parking Assist Intelligent System. (Image courtesy Seimens VDO)

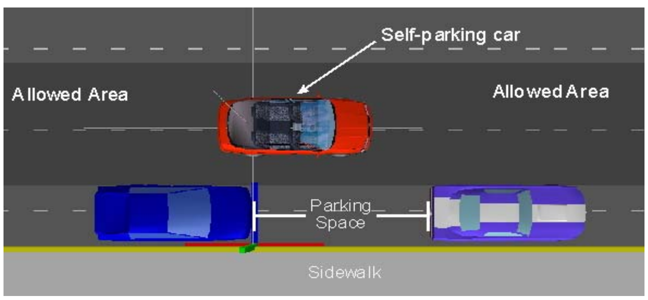

Fig. 2. Parallel parking problem

The self-parking process is carrying on the allowed area where the parking space can be changed by the user at the beginning of the sequence. The Fig. 3 shows an alternative3D view mode in the graphical interface designed.

The fuzzy control consists of three models showed in **Error! Reference source not found.** that can be seen like steps that one person follows in order to park. First, the control has to make a decision concerning the parking space and the location of the vehicle. Then it takes the initial position and finally it is able to proceed to the action of parking. If the space is wide the control is going to make the decision (*Model* 1.= *Decision*) to park forwards (Model 2.= Forward) or if the space is just enough, the control is going to choose to park backwards (Model 3.= Backward). If there isn't enough space, the control chooses not to move.

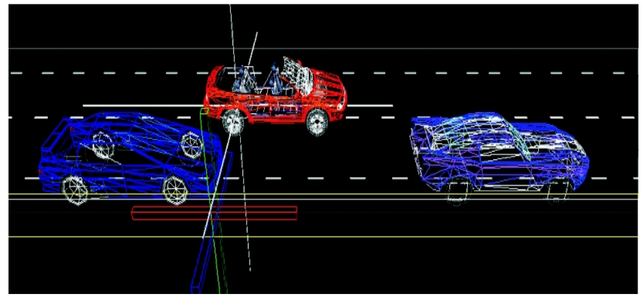

Fig. 3. Three dimensional World

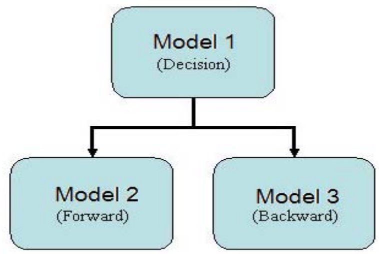

Fig. 4. Fuzzy Control Model

Concerning the simulation, it was realized using Simulink and other toolboxes like Fuzzy Logic Toolbox and Virtual Reality Toolbox, although it also contains code in Language C in some parts. On the other side, the 3D graphics were created using VRealm, a program compatible with Matlab.

3. Fuzzy Model

The Decision model that begins the parking procedures are based on three premises depending upon the available parking space or distance between cars (*DBC)*:

1. If parking space is large (over 60 cm), forward parking movements are performed.
2. If parking space is enough (more than 30 cm), backward parking movements are performed.
3. But if parking space is short (less than 30 cm), no action is performed.

Hence, parking space is one of five measurements inputs in the system which helps the system to decide whether it is possible to park the car or not. The other four measurements correspond to distance from side walk (DFS), Fig. 4; distance from front car (DFF), Fig. 5; distance from back car (DFB), Fig. 6; and inclination (Inclination), Fig. 7.

Once system has acquired the parking system value and it is in the permissible parking range, the car must take an initial position so that the scaled car perform movements to park and it stops until it satisfy the desirable parking conditions of rules. Then the fuzzy model which decides which action has to be taken at the beginning of the process is named decision model. It determines whether backward model or forward model has to be performer after parking space has been measured. One has to understand actions as the movements that an autonomous control has to perform instead a human driver. And these actions are in function of the controlling system outputs. The controlling car outputs are the following: (1)Car direction or tires angle, Fig. 8, (2) Speed of Car, Fig. 9 and (3) direction of movement, Fig. 9, Forwards or Backwards. The fuzzy process normally begins when the input variables are compared with their belonged fuzzy sets, then a membership degree value is deliver and fuzzy outputs are calculated. Finally, fuzzy outputs are defuzzicated by centroid method, at least in this case.

Each model has a specific number of rules that are taken to develop inference step of the mathematical base. To develop the inference step “Minimun—Maximun” or Mandami is used. Table 1 shows the ten rules decision model wich development, in function of the space between cars measurement, makes the car moves towards an initial position to begin parking forward or backward. Once having decided which king of parking to perform (backward or forwrad) and having achieved the initial position, other rules are aplied to control the car.

4. Implementation in Matlab

Simulink and MATLAB™ where used to implement a training system where a designer can simulate and modify the car’s dimensions and scenario characteristics, Fig. 10, give us a general idea of how fuzzy control works in Matlab.

Fig. 11 shows the simulink model where different blocks are interconnected such as the decision, backward and forward fuzzy models, a sensor simulation box, the 3D animation block, and interfaces and drivers between them. Fig. 12 shows the graphics where the operation of the linguistic model can be tested which include the animations of the different situations derived from the model execution.

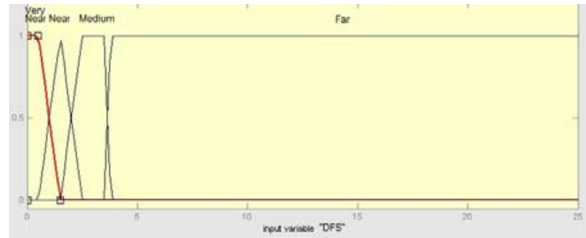

Fig. 4. DFS fuzzy set.

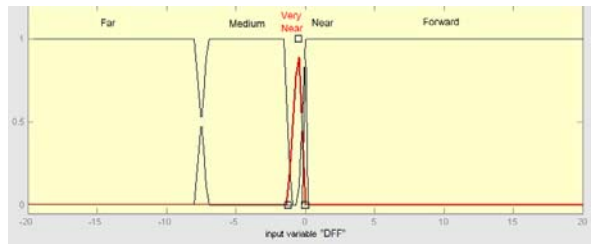

Fig. 5. DFF fuzzy set.´

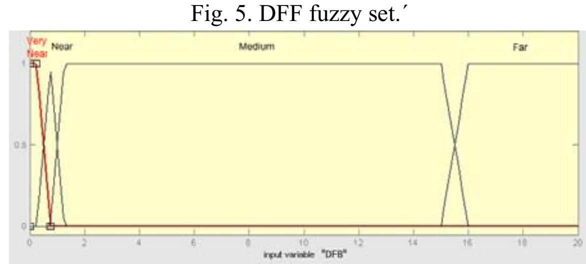

Fig. 6. DFB fuzzy set.

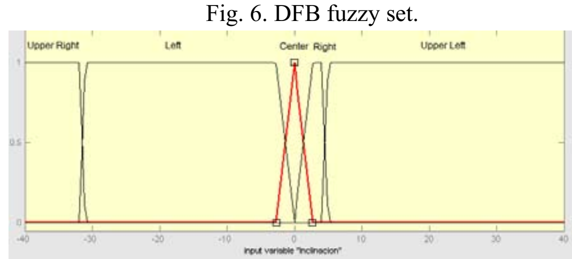

Fig. 7. Inclination fuzzy set.

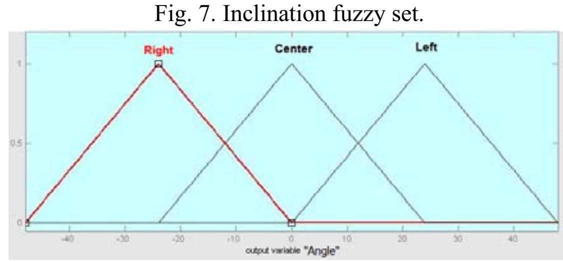

Fig. 8. Angle of tires fuzzy set.

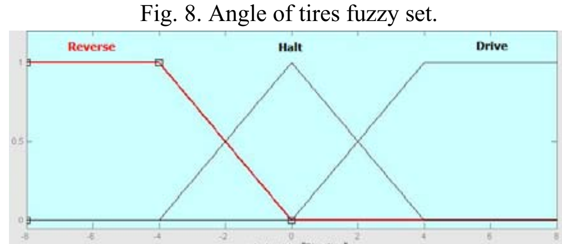

Fig. 9. Direction and speed of car fuzzy set.

Table 1: Decision Model Rules

Decision Rules								
Rule	X	Activated	Constant Decision	Terminado In	Angle	Direction	Decision	Terminado Out
1		No			Center	Halt	No	No
2	Atrasado	Yes	Forward	No	Center	Drive	No	No
3	Posición	Yes	Forward	No	Center	Halt	Forward	Yes
4	Adelantado	Yes	Forward	No	Center	Reverse	No	No
5	Atrasado	Yes	Backward	No	Center	Drive	No	No
6	Posición	Yes	Backward	No	Center	Halt	Backward	Yes
7	Adelantado	Yes	Backward	No	Center	Reverse	No	No
8			No	Yes	Center	Halt	No	Yes
9			Forward	Yes	Center	Halt	Forward	Yes
10			Backward	Yes	Center	Halt	Backward	Yes

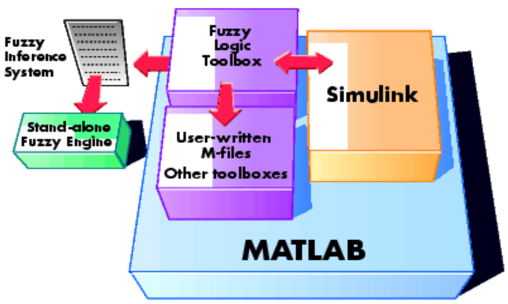

Fig. 10. Matlab architecture for fuzzy implementations [8].

5. Communication Interface

The digital control method for self-parking is the fuzzy clustering. After the downloading of the fuzzy models, a previous computer simulation is made, the knowledge base must be downloaded to the car and then the car works in an autonomous mode when the self-parking is required. It is possible to manipulate the car through a manual control unless the self-parking process has already begun. The training interface generates three different fuzzy models: (1) Decision and initial positioning model, (2) forward parking model; and (3) backward parking model. The coordination in the execution of the three model permit to the car can park itself. The **decision model** is activated after the distance between two cars (DBC) has been measured. If DBC is less than 30 cm the self-.parking procedure does not start because there is not enough room to execute the process On other hand, if DBC is between 30 and 60 cm then the **backward parking model** is activated. When the DBC is more than 60 cm. then the **forward parking model** is activated.

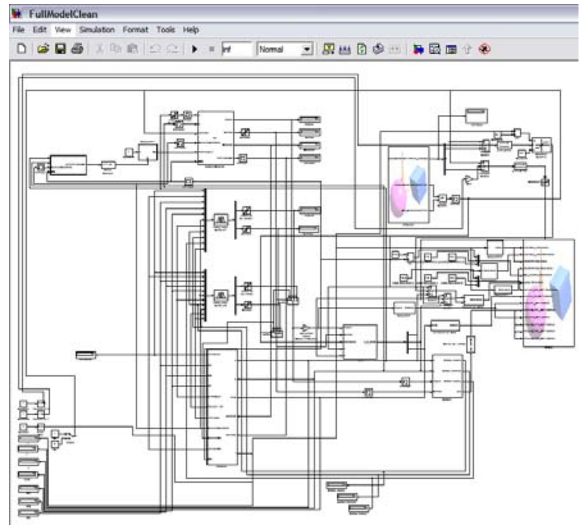

Fig. 11. Simulink.

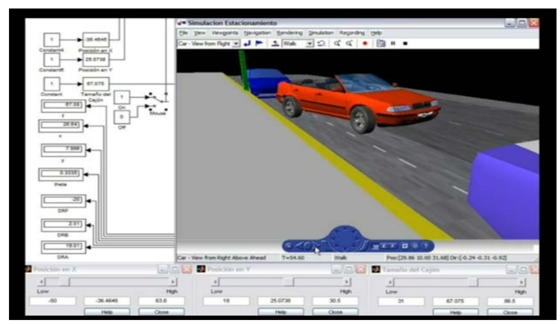

Fig. 12.atlab Interface with animation.

Because front wheels movement is limited (30 degrees from the center to the right or left side), the initial position of the car needs to be appropriate for the parking movement. This can be done thanks to the Decision Model.

A Visual Basic Interface (Fig. 13) has been developed in order to download the database generated in the training interface. The downloading interface accepts a text file from the training system containing the knowledge base with the definition of all the input and output fuzzy sets of each of the three decision models. The interface take the text file with the knowledge base and gives its the adequately format to be sent to the digital system on the car clicking the command button ***Write to PIC*** (*Escribir en PIC*) and then clicking the button ***send*** (*enviar*). The model to be sent must be selected between ***Forward***, ***Backward***, ***and Decision***. The data base is kept in a 2K x 8 RAM memory. Another possibility is to send the sequence of the evolution in the behavior of the sensor mean the button ***send measures*** (*enviar mediciones*).

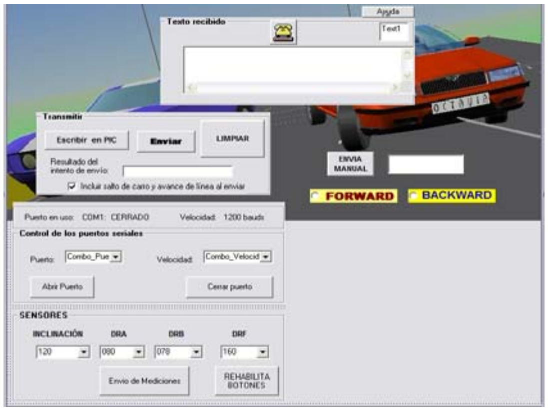

Fig. 13 Download Interface PC-Prototype.

6. Scaled Car Characteristics

A prototype is obtained from a scale model mobile whose components have been modified to response adequately to the commands and drivers designed to control the mechanisms. Details about the car specifications are given in the Table 2 and Fig. 14 shows the car with its mechanical components and its hardware including microcontroller system, wire communication interface to the PC, and drivers. The mobile operate as a real automatic car, it moves forward and in reverse sense when the making decision computers gives the **DRIVE** and **REVERSE** commands. In the same way the car turns its tires right or left when the command **RIGTH** and **LEFT** are emitted. To obtain these degrees of freedom the mechanism has a DC motor to make the mobile move towards front or to back direction, and a step motor to control de front tires angle which are operated mean PWM (Pulse Wide Modulation) an H-bridge driver (L293B) and a microcontroller PIC16F877.

The car has sensors in strategy locations in order to measure three distances: (1) to the frontal car, (2) to the behind car, and; (3) to the sidewalk. The mobile answer to the distances signals controlling the velocity and the direction according to the sensor measurements Other important sensor is an electronic compass to establish the relative inclination of the car at the moment when the parking process begins. All the commands of control are adapted in relation with the initial orientation of the car.

7. Results

Results are appreciated comparing the simulation outputs in the training systems versus real outputs in the scale model of the car. The real and simulated behavior

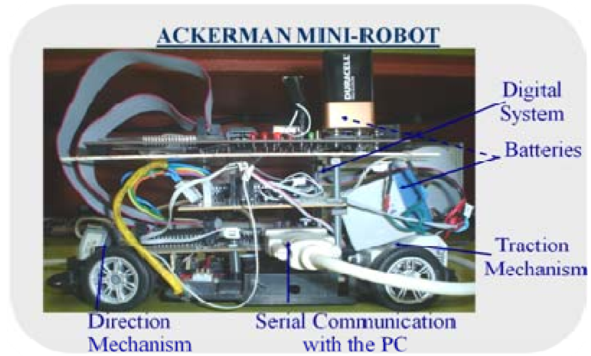

Fig. 14. Scaled Car.

Table 2: Car Dimensions	
A-Rear Overhang	4 cm
B-Wheelbase	15.3 cm
C-Long	25.5 cm
D-Wide	11 cm
E-Tall	12.5 cm
F-Wheel Diameter	3.9 cm
G-Wheel Wide	1.4 cm

is very closer. The mobile execute the correct movements for a backward and forward parking when the distance between cars is about 31 cm and over 61 cm, respectively. Fig 15 and 16 show the simulation and real performance in one of the movements.

The differences in the results can be explained considering the microcontroller's 8-bit resolution and some little mistakes in the measurement of the distances between objects. Even so, the results are acceptable because they are very approximates to the real ones. If interested of a visual demonstration, some videos have been uploaded in www.youtube.com. You have to search videos UDLA_SPC_V1, and series of the number.

8. Conclusions

The main goal of this project was to demonstrate that the model based on the human knowledge can be translated in a real world situation. In this case the fuzzy models to make decision in the problem of automatic car parking were implemented on scale model of an automatic car with satisfactory results. The models generator and training interface were developed in Matlab™ and its outcomes are a text file containing the fuzzy models which is sends to the car to successfully execute the parking action. This project is another demonstration of the utility and efficiency of the linguistics models used to implement real solution of complex systems and the facility in the technological implementation of them.

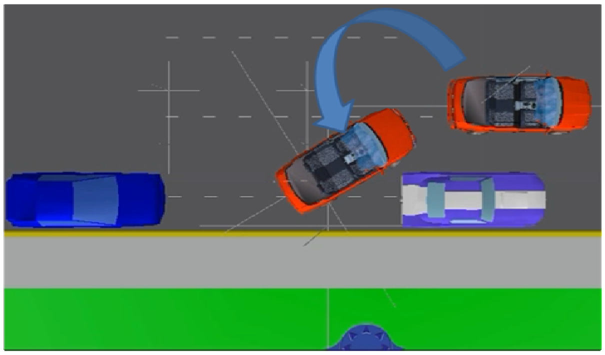

Fig. 15. Virtual intermediate movements - Backward.

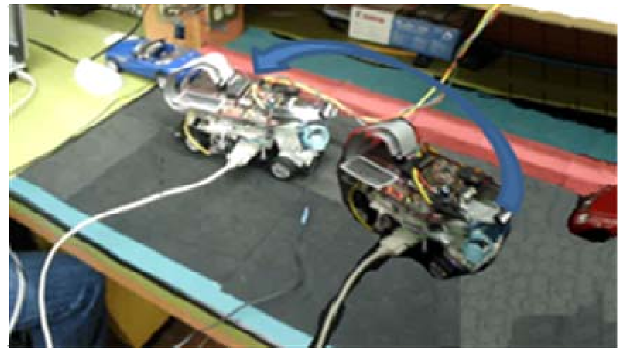

Fig. 16. Real parking process (getting initial position).

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