Jurnal Teknologi

Full paper

A Simple Fuzzy Logic Diagnosis System for Control of Internal Combustion Engines

Mohammad Javad Nekooei, Jaswar*, A. Priyanto

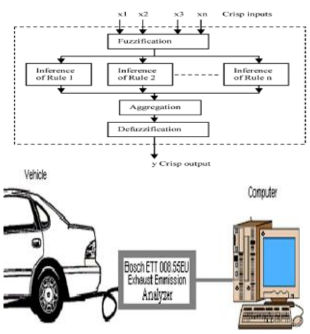
Department of Aeronautics, Automotive and Ocean Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor

*Corresponding author: jaswar@fkm.utm.my

Article history

Received :25 December 2014
Received in revised form :
25 March 2015
Accepted :15 May 2015

Graphical abstract



Abstract

Fuzzy logic (FL) systems are widely established as a technology offering an alternative system to tackle compound and ill defined problems. They can be trained from examples, are fault tolerant in the sense that they are capable to grip noisy and deficient data, are able to deal with non-linear problems, and once trained can perform prediction and generalization at high speed. in this paper a simple fuzzy logic control has been developed which is used for defining engine system faults and control and maintain them in a normal range without use any complicated mathematical equation and any fault sensor.

Keywords: Fuzzy logic; IC engine; exhaust emission

1.0 INTRODUCTION

Modeling and control of internal combustion (IC) engine is a vital and complicated process, for the reason that internal combustion engines are nonlinear, and time variant. There have been more than a few engine controller designs over the years in which the main aim is to improve the efficiency and exhaust emissions of the automotive engine [1].

High ratio emissions that consequences from misfire or incomplete combustion cause air pollution, lower the performance of the engine and raise fuel consumption (Bauer, 1996; Bishop & Stedman, 1996; Heywood, 1989). Exhausts caused by engines contains high level of carbon dioxides (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_X), and other of particles due to the heavy fuel oil used for combustion. For these reasons, a method will be developed for modeling and control ic engines by fuzzy logic to avoid of air pollution and raise engines performance [5].

2.0 FUZZY LOGIC

The main significant reasons to utilized fuzzy logic technology have the ability to give approximate recommended solution for unclear and complicated systems to easy understanding and flexible. Fuzzy logic provides a technique which has the capability to model a control for nonlinear plant with a couple of IF-THEN rules, or it could identify the control actions and describe them by utilizing fuzzy rules. It must be mentioned that application of fuzzy logic is no limited by a system that's hard for modeling, however it can be utilized in clear systems which have complicated mathematics models due to most of the time it could be shortened in design but there's no good quality design just sometimes we could find design with high quality [2].

Fuzzy logic supply a practicable way to know and manually influence the mapping behavior. Generally speaking, fuzzy logic uses simple rules to explain the device of interest as opposed to analytical equations, which makes it an easy task to implement. Given its advantages such as for example robustness and speed, the fuzzy logic method is one of the finest solutions for system modeling and control. An FIS contains three primary elements, the fuzzification stage, the rule base, and the defuzzification stage. The fuzzification stage is employed to transform the so-called crisp values of the input variables into fuzzy membership values. Then, these membership values are processed within the rule-base using conditional 'if-then' statements. The outputs of principles are summed and defuzzified right into a crisp analogue output value.

The results of variations in the parameters of a FIS could be readily understood and this facilitates calibration of the model [3].

The device inputs, for instance: 'most suitable value of CO, HC, NOX, CO_2 are called linguistic variables, whereas 'high' and high' are linguistic values which are characterized by the membership function. After the evaluation of the rules, the defuzzification transforms the fuzzy membership values right into a crisp output value, for instance, the penetration depth [4].

The complexity of a fuzzy logic system with a fixed input-output structure is set by the how many of membership functions employed for the fuzzification and defuzzification and by the number of inference levels. The block diagram of an over-all fuzzy logic system is shown in Figure 1, where: x1, x2, . . . ,xn are a symbol of n crisp inputs and y could be the crisp output [3].

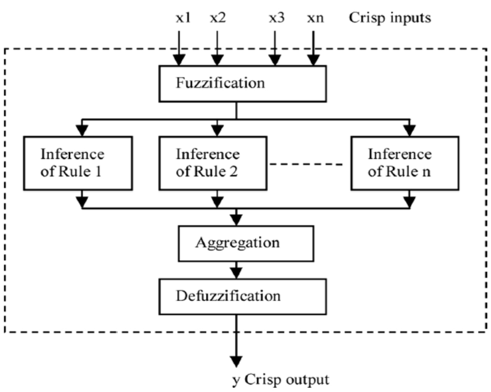


Figure 1 Block diagram of a general fuzzy logic system [3]

2.1 Fuzzification

Fuzzification alludes to the process of taking a crisp input value and transforming it into the degree needed by the terms. The fuzzification subsystem; measures the values of input variables, performs a scale mapping that transfers the scope of values of input variables into corresponding universes of talks, performs the function of fuzzification that converts input data into appropriate linguistic values which might be viewed as labels of fuzzy sets (Lee, 1990). Such a function is called the membership function and it was determined by the experts. Also, these functions were determined by preprocessing of the raw data in a membership function module [6]. The two mainly used membership functions are triangular and trapezoidal functions. in addition, generalized bell function, Gaussian function, two-sided composite of two different Gaussian functions, sigmoidal function, difference between two sigmoidal functions, product of two sigmoidal functions and polynomial (Z, S and Pi curves) functions are as well used as membership functions in fuzzy logic applications (The MathWorks, Inc., 1999).

2.2 Inference Mechanism

In the inference mechanism fuzzy consequences are inferred from the memberships of fuzzy sets with the assist of knowledge base (Frantti &Ma¨ho¨nen, 2001). The knowledge base consists of data (D) base and rule(R) base. D base has information for a good functioning of the fuzzification, rule base and defuzzification phases. Its information includes fuzzy membership functions and bodily domains with their scaled counterparts, type of fuzzy relations, kind of interaction and union operators and number of hierarchical levels in reasoning. The D base was constructed through the expert system development by the expert (or knowledge engineer). The set of rules in a fuzzy expert system is known as the rule (R) base and it uses the information of D base and represents at the linguistic level the functioning of the modeled system in the form of linguistic equations. The R base was collected of by expert together with experimental consequences and theoretical information.

There are two main forms of fuzzy rules: the Mamdani like form (Mamdani & Assilian, 1975) and the Takagi–Sugeno–Kang (TSK) form (Sugeno & Kang, 1986; Tagaki & Sugeno, 1985). amongst the two, the Mamdani-like rules are better suited for the detection of human understandable knowledge from real w data. Both forms have been used in fuzzy control. A classic rule in a fuzzy expert system typically takes the form:

If x is low and y is high then z = medium

where x and y are input variables, z is output variable, and low, high and medium are membership functions definite for x; y and z; respectively.

2.3 Defuzzification

Defuzzification is the method of taking the fuzzy outputs and converting them to a single or crisp output value. This process may perhaps performed via one of several defuzzification methods. Some general methods of defuzzification contain the max or mean–max membership principles, the centroid method, and the weighted average method (The MathWorks, Inc., 1999).

3.0 FUZZY LOGIC ANALYSIS

In this section, fuzzy expert system for the optimization of fuel consumption and the level of emission will be discussed. This system at first, defines the fuel consumption of an IC engine as fuzzy by measuring emission values. for this purpose must used one measurement device for example : Bosch ETT 008.55 EU. after that, if the fuel consumption is excess, this system take a decision whether there is fuel system fault, ignition system fault, any fault caused by engine wearing, exhaust and intake valves fault or not by using the emission values and gives recommendation to repair these faults. Structure of fuzzy diagnosis and advice system (FDAS) is shown in Figure 2.

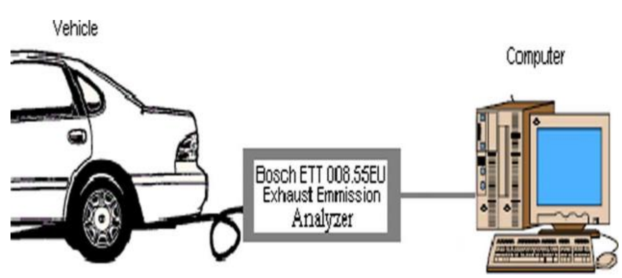


Figure 2 Structure of FDAS

This system could be design for any of internal combustion engines. Measurements of engine emissions (CO, HC, O2, CO2 and λ) will be made between 3000–3500 rpm and 60–80 8C that engine provides the maximum moment in these intervals.

In this system, a computer must be used which has Intel P4 microprocessor and at least 256 MB ram memory. Data communication between computer and emission measurement device will be realized by a special interface card.

System software include of two computer programs that must be prepared in Matlab and Delphi. Block diagram of software shown in Figure 3.

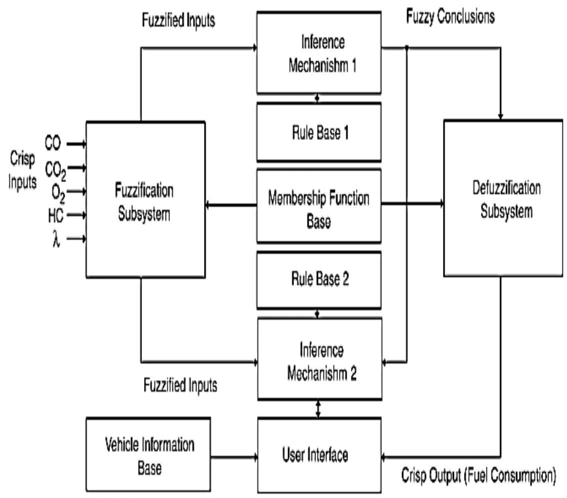


Figure 3 Block diagram of software [6]

The communiqué between user and system will be realized via an interface. This interface's screen out shown in Figure 4.

System will be run by operating of FDAS interface software. At first, user must selects brand, model, production year and engine volume of the car and click the new measurement.

Thus, the membership function information of the specific cars will taken from the knowledge base. Most of membership function information has been generated via consideration of expert views and catalog values for most of different brand cars (Technical Data Cars and LCVs, 1993). Membership functions of a sample car shown in Figure 5.

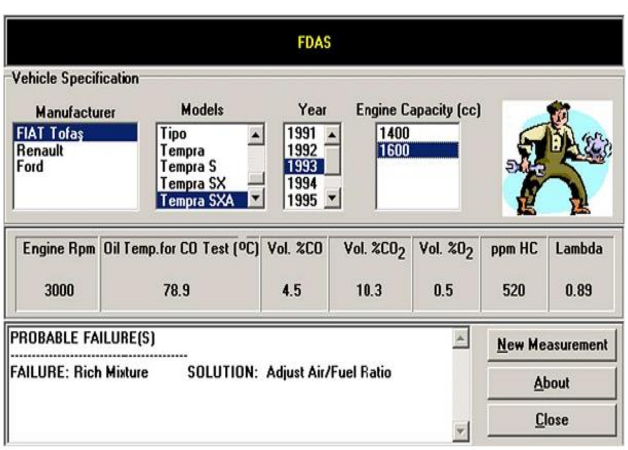


Figure 4 FDAS interface

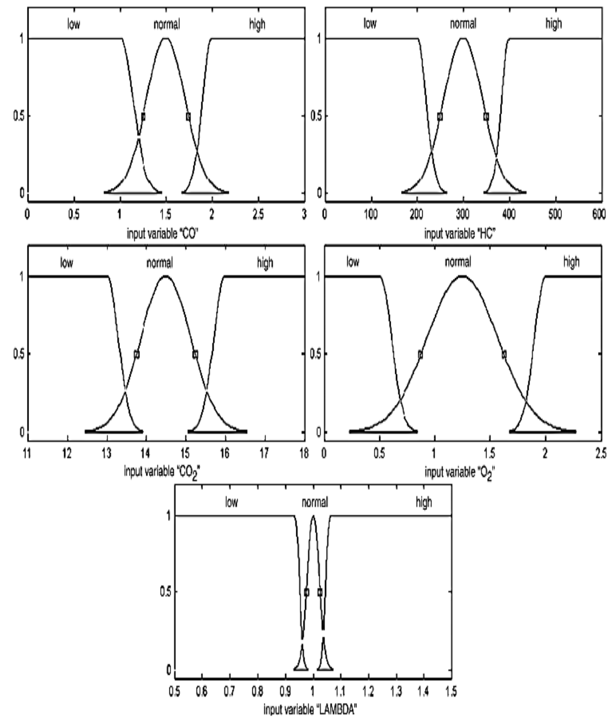


Figure 5 Input membership functions of 1993 Tempra [6]

Membership function information and the emission measurement values of specific car which are obtained from interface card will send from FDAS interface software to Matlab. In Matlab at first, input crisp values will be change into fuzzy values. Fuzzified values will be entered as first inference mechanism. fuzzified inputs will be realized via the first rule base in the first inference mechanism. Some of these rules in the rule base are shown in Table 1.

Table 1 Some rule in the first rule base

CO	HC	CO_2	O_2	λ	Fuel consumption
Normal	Normal	Normal	Normal	Normal	Normal
Normal	Normal	Normal	High	Normal	High
Normal	Normal	Low	Normal	Normal	High
Normal	Normal	Low	High	Normal	High

The fuzzy termination obtained via first inference mechanism will entered defuzzification subsystem. In this subsystem, the fuel consumption of car will be calculated from fuzzy conclusion by centroid method.

Linguistic fuel consumption and emission values will send to the Delphi and then this program uses of second rule base to comparison between values. this software decide there are fuel or ignition system fault, any fault caused by engine wearing, exhaust and intake valves fault or not by using fuzzified CO, HC, CO_2, O_2 and λ values and will advice to repair them if there is. Decisions and advice according to some different possibilities shown in Table 2.

Table 2 Possible faults and solution advice according to some of linguistic emission values and fuel consumption

CO	HC	CO_2	O_2	λ	Fuel consumption	Possible fault	Advice
Normal	Normal	Normal	Normal	Normal	Normal	No fault	-
Normal	High	Low	High	Normal	High	Ignition system fault or valve fault	Check ignition system or valves
High	High	Low	Low	Low	High	Rich mixture	Adjust fuel system
High	High	Low	High	Normal	High	Valve fault	Check valves
Normal	Normal	Low	High	High	High	Very lean mixture	Adjust fuel system
High	Normal	Normal	High	Normal	High	Engine fault	Tune up engine

■4.0 CONCLUSION

In this paper a fuzzy logic control system has been developed. This system calculates fuel consumption by using emission values in IC engines. After than the system identify faults caused by engine wearing, exhaust valve fault and intake valve fault without any fault sensor .in the end this system could gives advice for repairing the faults if there is any. This system is very easy to design without any complicated mathematical equation.

References

[1] Javad Nekooei, Mohammad, Jaswar Jaswar and A. Priyanto. 2014. Review on Combustion Control of Marine Engine by Fuzzy Logic Control Concerning the Air to Fuel Ratio. *Jurnal Teknologi*. 66(2).

[2] Nekooei, Mohammad Javad, Jaswar Jaswar and Agoes Priyanto. 2013. Designing Fuzzy Backstepping Adaptive Based Fuzzy Estimator Variable Structure Control: Applied to Internal Combustion Engine. *Applied Mechanics and Materials.* 376: 383–389.

[3] Priyanto, Agoes and Mohammad Javad Nekooei. 2014. Design Online Artificial Gain Updating Sliding Mode Algorithm: Applied to Internal Combustion Engine. *Applied Mechanics and Materials*. 493: 321–326.

[4] Nekooei, Mohammad Javad, *et al*. 2015. Reviewed on Combustion Modelling of Marine Spark-Ignition Engines. 17(1).

[5] Nekooei, Mohammad Javad, *et al*. 2014. A Study on Combustion Modelling of Marine Engines Concerning the Cylindrical Pressure. *Journal of Applied Science and Agriculture*. 9(8): 39–44

[6] Li, Y. and Q. Xu, 2010. Adaptive Sliding Mode Control With Perturbation Estimation and PID Sliding Surface for Motion Tracking of a Piezo-Driven Micromanipulator. *Control Systems Technology, IEEE Transactions on.* 18: 798–810.

[7] Boiko. 2007. Analysis of Chattering in Systems with Second-order Sliding Modes. *IEEE Transactions on Automatic Control.* 52: 2085–2102.

[8] Hsueh, Y. C. 2009. Self-tuning Sliding Mode Controller Design for a Class of Nonlinear Control Systems. 2337–2342.

[9] Xiao, Baitao, Ph.D. 2013. Adaptive Model Based Combustion Phasing Control for Multi Fuel Spark Ignition Engines. Pro Quest® Dissertations & Theses. 383–389.