International Journal on Emerging Technologies 1(1): 41-45(2010) ISSN : 0975-8364

Fuzzy logic applications for traffic control "an optimum and adaptive controlling application"

Fani Bhushan Sharma, Ajay Sharma*, Nirmala Sharma**

Deptt. of Electrical Engg., St. Margaret Engg. College Neemrana, (HR) INDIA

*Deptt. of Electrical & Electronics Engg., Maharishi Arvind International Institute of Technology Kota, (RJ) INDIA

**Deptt. of Computer Sci. Engg., Rajasthan Technical University, Kota, (RJ) INDIA

(Received 15 Dec., 2009, Accepted 10 Jan., 2010)

ABSTRACT : Over the past years, Fuzzy logic has been widely used to develop an adaptive traffic signal controller, as it allows qualitative modeling of complex systems. A system and method for controlling traffic and traffic lights and selectively distributing warning messages to motorists is discussed. Traffic information is obtained from various traffic information units. The traffic information units have intelligent controllers. The intelligent controllers are used to determine appropriate action based on the congestion parameters and the warning information. Fuzzy logic is used to determine optimum traffic light phase split based on the traffic information from the traffic information units. The optimum traffic light phase split is determined for each of the intelligent controllers. This paper describes an adaptive fuzzy logic signal controller for an isolated four-way intersection suitable for mixed traffic. The applications comprises of: signal analysis at induction sensors, field equipment supervision, incident detection / traffic flow analysis, weather condition detection, and intelligent speed limit control. However, these fuzzy logic signal controllers are not appropriate to the mixed traffic conditions of developing countries where the traffic streams consist of different types of vehicles with a wide variation in their static, dynamic and operating characteristics. Fuzzy logic controllers are used to execute fuzzy logic inference rules from a fuzzy rule base in determining the congestion parameters and the warning information and the appropriate action. Input variables and output variables are defined as members of the universe of a discourse, having degrees of membership determined by membership functions.

Keywords : Field Equipment Supervision, Incident/Accident Supervision, Weather Condition Analysis

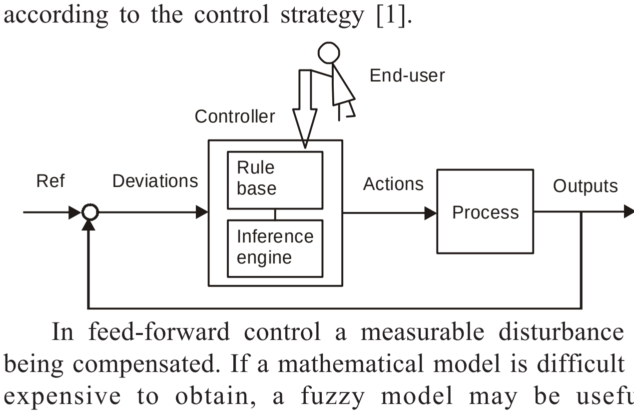
2000 MSC Classification Numbers : 03B50, 03B52, 03E72, 65F35, 68T27, 68T37, 94D05

I. INTRODUCTION

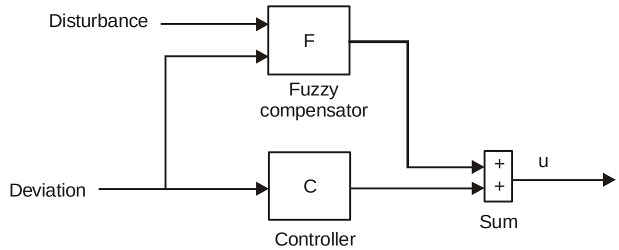
The monitoring and control of Road traffic is becoming a major problem in many countries. With the ever increasing number of vehicles on the road, the Monitoring authorities have to find new ways or measures of overcoming such a problem. In this paper we discuss the implementation of an intelligent traffic control system using fuzzy logic technology which has the capability of mimicking human intelligence for controlling traffic lights. The rules and membership functions of the fuzzy logic controller can be selected and changed and their outputs can be compared in terms of several different representations. Fuzzy logic technology allows the implementation of real-life rules similar to the way humans would think. The beauty of fuzzy logic is that it allows fuzzy terms and conditions such as "heavy", "less", and "longer" to be quantized and understood by the computer. Fuzzy control is a control method based on fuzzy logic. Fuzzy logic can be described simply as "computing with words rather than numbers" or "control with sentences rather than equations". A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants. The collection of rules is called a *rule-base*. The rules are in IF-THEN format, and formally the if-side is called the *condition* and the then-side is called the *conclusion.* The system is able to execute the rules and compute a control signal depending on the measured inputs *error and change in error.*

A. Fuzzy controllers

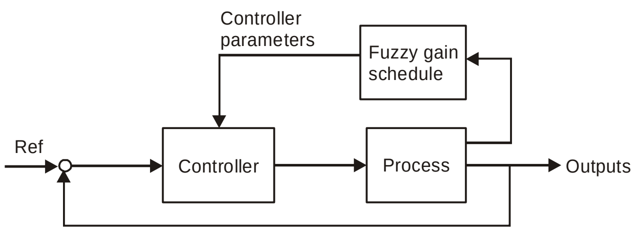
Fuzzy controllers are being used in various control schemes. The most obvious one is direct control, where the fuzzy controller is in the forward path in a feedback control system. The process output is compared with a reference, and if there is a deviation, the controller takes action according to the control strategy [1].



In feed-forward control a measurable disturbance is being compensated. If a mathematical model is difficult or expensive to obtain, a fuzzy model may be useful. Following figure's shows the controllers and the fuzzy compensators, the process and the feedback loop are omitted for clarity.



Fuzzy rules are also used to correct tuning parameters in parameter adaptive control schemes. For a nonlinear process, there are changes in the operating points; it may be possible to change the parameters of the controller according to each operating point. For this purpose, a gain scheduling controller is used; it contains a linear controller whose parameters are changed as a function of the operating point in a preprogrammed way.

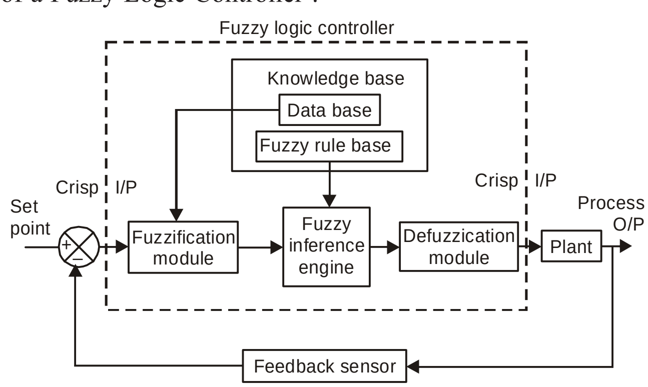


The linear behavior of a fuzzy controller may be expressed in the form,

$$u(t) = G\left(e + R\int e.dt + D\frac{de}{dt}\right)$$

Where, $u(t)$ is the control action signal and $e(t)$ is the error signal. To obtain proper control action it is necessary to consider issues such as operator interfaces, smooth switching between manual and automatic mode, transients due to parameter variation, effect of non-linearity of actuators.

Following figure shows the basic building block diagram of a Fuzzy Logic Controller :



(*a*) Design procedure

Parameters

FUZZIFICATION RULES AND INTERPRETATION.

Data base :

1. Dicretization/ normalization of the universe of discourse.
2. Fuzzy partition of input and output spaces.
3. Completeness.
4. Choice of membership function of a primary fuzzy set.

Rule base :

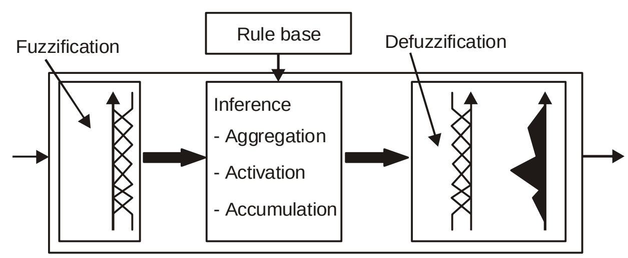
1. Choice of process state (input) variables and control (output) variables
2. Source and derivation of fuzzy control rules.
3. Types of fuzzy control rules.
4. Consistency, interactivity and completeness of fuzzy rules.

B. Fuzzy inference mechanism

Defuzzification strategies and interpretation of the defuzzifier.

Based on procedure adopted by the Rule base and the fuzzy inference engine Fuzzy Logic controllers can be classified under standard models.

Following Fig. shows the basic functional elements of a fuzzy controller :



II. DESIGN PROCEDURE

A. Fuzzy logic controller for traffic monitoring and controlling

The heart of the FLC is to form the knowledge base that can be obtained form the human experts. In designing FLC for the traffic monitoring & controlling, following five steps are to be followed:

Step 1 : Identification and declaration of inputs and outputs.

This is the basic step in which the inputs and outputs are identified. In the controller design for traffic control, the inputs are *Length and Speed* and the output is *Class.* The process of declaring the values of the inputs and output called Universe of discourses is shown in Table 1.

Table 1 : Universe of discourse.

Name	Input/ Output	Min. Value *(assigned)*	Max. Value *(assigned)*
Length	**Input**	0mts	20mts
Speed	**Input**	80 Km/hr	140 Km/hr
Class	**Output**	Car	Truck

Required Information : Vehicle Speed and Type
Evaluate Speed : v = Sensor ab-stand/t_v
Evaluate Length : $L = v_{\text{Fahrzeug}} / t_L$
to Classify Vehicles in Cars and Trucks

Step 2 : Identification of control surfaces

In this step, the linguistic variables are identified and the membership values for each linguistic variable are calculated. In this FLC, five linguistic terms are used for length, three linguistic terms for speed and five linguistic terms for Class are defined. These are as follows :

Length :	Speed :	Class :
"typical";	*"fast";*	*"typical Car";*
"Long";	*"regular";*	*"Long Truck";*
"Single";	*"slow"*	*"Single Car";*
"Short";		*"Short Truck";*
"Tailgating"		*"Tailgating Truck"*

Step 3 : Behavior of Control Surfaces

Fuzzy rules are constructed in specify action for different conditions, that means, the control rules that associates the fuzzy output to fuzzy inputs are derived from general knowledge of the system behavior.

III. TRAFFIC MANAGEMENT

Automated systems were used to detect and control traffic to increase the traffic capacity. These traffic control systems use several detection stations along the road. These stations employ magnetic sensors for traffic detection, as well as weather stations transmitting environmental data from road surface and the air layer near the ground [2].

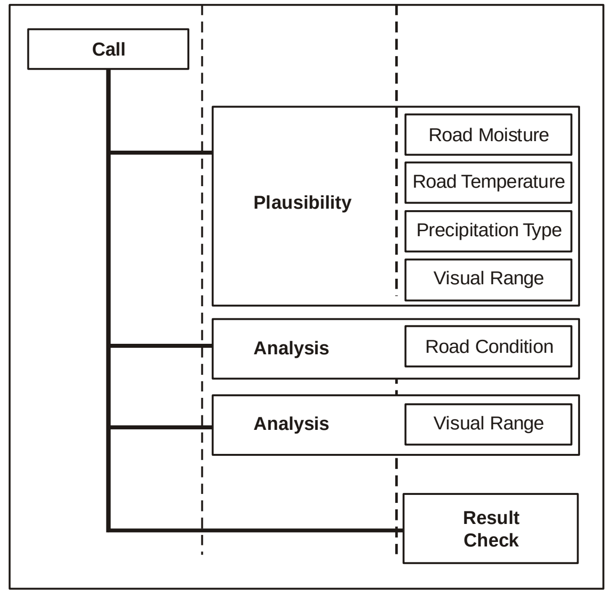
A central traffic control computer collects the data transmitted from the section stations. A control strategy derives an adequate speed limit for every section. The control objectives are :

1. keep traffic flowing in case of peak traffic,
2. slow down traffic at the inflow to congestion, and
3. warn for bad weather conditions such as fog or ice.

IV. ENVIRONMENTAL DATA ANALYSIS

The traffic situations depend highly on environmental conditions. An intelligent highway thus should warn drivers of slippery road conditions and low visibility. Sensors are used to indicate and classify icy or wet road pavement and to indicate the visual range. An ideal weather station uses road sensors measuring road surface temperature, road surface moisture, water film depth, and salt content of water film. Near the road, the ideal weather station detects air and ground temperature, amount of precipitation, type of precipitation, wind velocity and direction, sun beam intensity and illumination [3].

SW UNIT COMPONENT MODULE



V. FUZZY LOGIC SYSTEM ARCHITECTURE

The fuzzy logic data analysis unit was designed as part of a larger traffic control system. Shows the architecture of the analysis unit, separating a component to verify the sensor information from components to evaluate the road surface and visual range condition [4].

VI. SENSOR PLAUSIBILITY ANALYSIS

A *two-step approach* was used to verify the sensor signals. The first step utilizes the fact that no weather signal remains constant. In particular, if the signal jumps abruptly or remains completely constant over time, the sensor signal is considered to be faulty.

In this case, the fuzzy logic system regenerates the information from other sensors. A time frame is required for the movement of the signals, and maximum jumps of the gradients to identify discontinuity were acquired from experts.

The second step uses four separate fuzzy logic modules to combine interrelated signals :

A. Road moisture module

This module combines all data, which indicates anything about moisture or water on the road. The fuzzy logic module consists of 5 rule blocks that implement:

1. A compensation rule block for the hygroscopical behavior of the road moisture sensors.
2. A cross check rule block between detected road surface moisture, the sensors that detect a water film on the road, and the amount of precipitation ions detected during the last 30 minutes.
3. A cross check rule block of the humidity sensor using dew point, road temperature, and a moisture sensor.
4. A cross check rule block to the precipitation sensor.

B. Road temperature module

This fuzzy logic controller contains two rule blocks to compute :

1. A verified value of the road surface temperature by cross check of the temperature signal, the gradient of this signal, and the precipitation.
2. A verified value of the freezing point, taking into account salt content and road surface moisture. Because the salt content sensor does not work with dry road conditions, a salt content forecast is used when the signal is not available.
3. A diagnosis rule block to derive an error message from the given signal situation.

C. Precipitation type module

This fuzzy logic controller verifies the existing sensor's that indicate the precipitation type by a cross check with the verified signals of road moisture, precipitation quantity, visual range, and other environmental conditions. If the sensor delivers implausible results or is not available, a substitute value is computed. The module consists of a number of rule blocks that :

1. Indicate if the weather conditions allow for hail or snow.
2. Compare the visual range with the precipitation quantity.
3. Aggregate the information with the precipitation quantity and visual range.

D. Visual range module

The visual range fuzzy logic module computes a verified value of the visual range by using two rule blocks that:

1. Cross check the visual range with the precipitation quantity. For example, there is no fog during heavy rain.
2. Cross check the visual range with air humidity. For example, fog only occurs during very high humidity.

Module	Variables	Rule Blocks	Rules	MBFs
Road Moisture	16	5	489	70
Road Temperature	10	2	130	39
Precipitation Type	15	6	204	60
Visual rage	7	2	142	36
Analysis road condition	7	3	60	33
Analysis visual range	3	1	35	17
Complete unit	58	19	1060	255

VII. MATHEMATICAL MODELLING

In order to calculate the required information, following mathematical formulas are used applicable for both theoretical and simulated problems [5,6] :

Paired algorithms

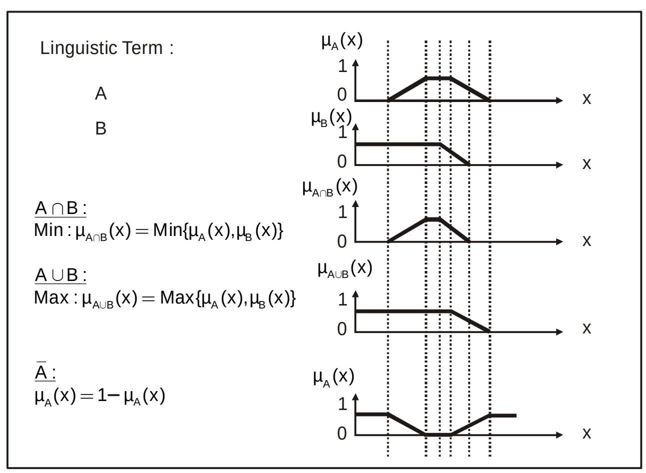
Operator OR keyword for	Algorithm	Operator AND keyword for	Algorithm
MAX	Max $(\mu_1(x), \mu_2(x))$	MIN	Min $(\mu_1(x), \mu_2(x))$
ASUM	$\mu_1(x) + \mu_2(x) - \mu_1(x).\mu_2(x)$	PROD	$\mu_1(x).\mu_2(x)$
BSUM	Min $(1, \mu_1(x) + \mu_2(x))$	BDIF	Max $(0, \mu_1(x) + \mu_2(x) - 1)$

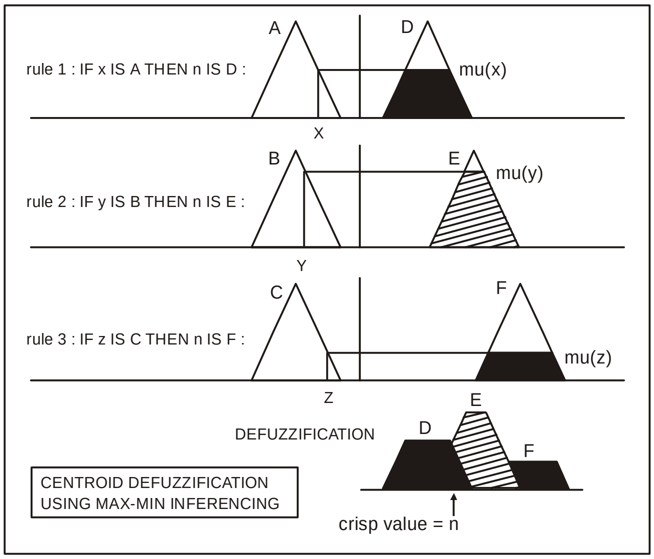
Activation methods

Name	keyword	Algorithm
Product	PROD	$\mu_1(x)\ \mu_2(x)$
Minimum	MIN	Min $(\mu_1(x), \mu_2(x))$

Accumulation methods

Maximum	MAX	Max $(\mu_1(x), \mu_2(x))$
Bounded Sum	BSUM	Min $(1, \mu_1(x) + \mu_2(x))$
Normalised Sum	NSUM	Max $\frac{\mu_1(x), \mu_2(x)}{\text{Max}(1, \text{MAX}(\mu_1(x') + \mu_2(x')))}$





COG	$U = \dfrac{\int_{Min}^{Max} u\,\mu(u)\,du}{\int_{Min}^{Max} \mu(u)\,du}$
COGS	$U = \dfrac{\sum_{l-1}^{P}[u_1\mu_1]}{\sum_{l-1}^{P}[\mu_1]}$
COA	$U = u', \int_{Min}^{u'} \mu(u)\,du = \int_{u'}^{Max'} \mu(u)\,du$
RM	$U = \sup(u'),\ \mu(u') = \sup_{u \in [Min, Max]} \mu(u)$
LM	$U = \inf(u'),\ \mu(u') = \sup_{u \in [Min, Max]} \mu(u)$

Where :

U : result of defuzzification

u : output variable

p : number of singletons

m : membership function after accumulation

i : index

Min : lower limit for defuzzification

Max : upper limit for defuzzification

sup : largest value

inf : smallest value

VIII. CONCLUSION

Conventional traffic systems are susceptible to faulty weather sensor signals. The fuzzy logic approach presented delivers more reliable results using meteorological expertise. The solution discussed was implemented using the fuzzy logic development software *fuzzy*TECH.

In day to day operation, the fuzzy logic solution has shown that it can prevent traffic control system malfunction in most sensor breakdown situations. In addition "biological attack" situations were detected and misleading rain or fog detection was avoided.

In a complete traffic control system, analysis of environmental conditions is only one component of its functionality. However, faulty weather detection can cause the entire traffic control system to malfunction. Thus, the enhancement of traffic control systems by fuzzy logic greatly improves the reliability of traffic control.

REFERENCES

[1] G. Hill, E. Horstkotte, and J. Teichrow, *FUZZY-C Development, User's Manual Togai* Infralogic, 30 Corporate Park, Irvine, USA, (1990).

[2] N.N., System Description of Traffic Management System, Landesamt für Straßenwesen Baden-Württemberg, (1994).

[3] M. Mangold, K. Träger, A. Lindenbach, Wirksamkeit von Streckenbeeinflussungsanlagen unter besonderer Berücksichtigung der Umfelddatenerfassung *(Efficiency of traffic control systems focusing on the Detection of Environmental Data)*.

[4] B. Krause, C. von Altrock, M. Pozybill, Intelligent Highway by Fuzzy Logic: Congestion Detection and Traffic Control on Multi-Lane Roads with Variable Road Signs. Proceedings of EUFIT'96, Aachen, Germany, (1996).

[5] C.C. Lee, "Fuzzy Logic in Control System: Fuzzy Logic Controller-Part I and II", *IEEE Trans. On Systems, Man and Cybernetics*, **20**(2)**:** 404-435(1990).

[6] R.L. Kelsey and K.R. Bisset, "A Simulation Environment For Fuzzy Control of Traffic Systems", *12th IFAC-World Congress*, Sydney, Austria, **5**(18-23)**:** 553-556(1993).