Monitoring Of Air Polution By Using Fuzzy Logic

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ABSTRACT

The Air Quality Index is a simple and generalized way to describe the air quality in China, Hong Kong, Malaysia and now in India. Indian Air Quality Index (IND-AQI) is mainly a health related index with the descriptor words: "Good (0-100)", "Moderate (101-200)", "Poor (201-300)", "Very Poor (301-400)", "Severe (401-500)". State Environment Protection Agency (SEPA) is responsible for measuring the level of air pollution in China . In China the AQI is based on the level of 5 atmospheric pollutants, namely sulferdioxide(SO_2), nitrogen dioxide (NO_2), suspended particulates (PM10), carbon monoxide (CO), and ozone (O_3) measured at the monitoring stations throughout each city (USEPA et al. 1998). An individual score is assigned to the level of each pollutant and the final AQI is the Highest of those scores. Air quality measurement are commonly reported in terms of micrograms per cubic meter ($\mu gm/m^3$) or parts per million (ppm) (http://en.wikipedia.org).

The Conventional method used Linear Interpolation for calculating AQI . We applied a real time Fuzzy Logic System with Simulink to calculate AQI. This method gives satisfactory result and it is efficient to work under continuous working mode .

INTRODUCTION

IIT Kanpur has proposed the Indian Air Quality Index (IND - AQI) through a sponsored project from the Central Pollution Control Board, Delhi in simple terms. A segmented linear function is used relating the actual air pollution concentrations (of each pollutant) to a normalized number. The pollutants included for the proposed IND - AQI are SO_2, NO_2, PM10, CO and O_3. The following table presents the summary of the break point concentrations and AQI values for India (proposed) for all pollutants.

TABLE1.1 BREAK POINT CONCENTRATIONS AND AQI VALUES FOR INDIA

Index	Category	*SO_2* (24 hr avg) ($\mu gm/m^3$)	*NO_2* (1-hr avg) ($\mu gm/m^3$)	*CO* (8-hr avg) ($\mu gm/m^3$)	*O_3* (1-hr avg.) ($\mu gm/m^3$)	*PM_{10}* (24-hr avg.) ($\mu gm/m^3$)
0-100	Good	0-80	0-80	0-2	0-180	0-100
101-200	Moderate	81-367	81-180	2.1-12	180-225	101-150
201-300	Poor	368-786	181-564	12.1-17	225-300	151-350
301-400	Very poor	787-1572	565-1272	17.1-35	301-800	351-420
401-500	Severe	>1572	>1272	>35	>800	>420

Conventional method

Suppose we have an 24-hours (avg) SO_2 value of 90 $\mu gm/m^3$. Then we refer to the 24-hour SO_2 in the table for the values that fall above and below value (81-367) $\mu gm/m^3$. In this case, the 90 $\mu gm/m^3$ value falls within the index values of 101 to 200. The Conventional method used Linear Interpolation for calculating AQI in the following way.

$[(200-101)/(367-81)] \times (90-81) + 101= 104.115 \approx 104$

So an 24-hours (avg) value of 90 $\mu gm/m^3$ corresponds to an index value of 104.

If we have the values for more pollutants

Suppose we have an 24-hrs avg SO_2 value of 90 $\mu gm/m^3$, a PM10 value of 125 $\mu gm/m^3$, and a O_3 value of 190 $\mu gm/m^3$. We apply the equation 3 times:

Index value for SO_2 corresponds to 90 µgm/m3 ≈104

PM: $[(200-101)/(150-101)] \times (125-101) +101 = 149.48 \approx 149$

O3:$[(200-101)/(225-180)] \times (190-180) + 101 = 123$

The AQI is 149, with PM as the responsible pollutant.

A Fuzzy approach for calculating AQI

Fuzzy logic control process :- Control process consist of the following steps

1. Defining the input variables- We use 5 pollutant as input variables to calculate Air Quality Index

(i) SO_2: Air pollution level and health implication for measured SO_2 are as follows:

TABLE 1.2 AIR POLLUTION INDEX FOR SO_2

Index	*Category*	*SO_2* *(24 hr avg)* *(μgm/m³)*
0-100	Good	0-80
101-200	Moderate	81-367
201-300	Poor	368-786
301-400	Very poor	787-1572
401-500	Severe	>1572

(ii)NO_2 : Air pollution level and health implication for measured NO_2 are as follows:

TABLE 1.3 AIR POLLUTION INDEX FOR NO_2

Index	*Category*	*NO_2* *(1-hr avg)* *(μgm/m³)*
0-100	Good	0-80
101-200	Moderate	81-180
201-300	Poor	181-564
301-400	Very poor	565-1272

(iii) PM10: Air pollution level and health implication for measured particulates(PM10) are as follows:

TABLE 1.4 AIR POLLUTION INDEX FOR PM_{10}

Index	*Category*	*PM_{10}* *(24-hr avg.)* *(μgm/m³)*
0-100	Good	0-100
101-200	Moderate	101-150
201-300	Poor	151-350
301-400	Very poor	351-420
401-500	Severe	>420

(iv) CO: Air pollution level and health implication for measured CO are as follows:

TABLE 1.5 AIR POLLUTION INDEX FOR CO

Index	*Category*	*CO* *(8-hr avg)* *(μgm/m³)*
0-100	Good	0-2
101-200	Moderate	2.1-12
201-300	Poor	12.1-17
301-400	Very poor	17.1-35
401-500	Severe	>35

(v) O_3: Air pollution level and health implication for measured O_3 are as follows:

TABLE 1.6 AIR POLLUTION INDEX FOR O3

Index	*Category*	*O_3* *(1-hr avg.)* *(μgm/m³)*
0-100	Good	0-180
101-200	Moderate	180-225
201-300	Poor	225-300
301-400	Very poor	301-800
401-500	Severe	>800

2.Fuzzyfication **-** Comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. The fuzzification is the first step in fuzzy logic processing involves a domain transformation where the crisp inputs are transformed into fuzzy inputs(Nilesh and Gopal et. al 2009). To transform crisp inputs into fuzzy inputs, membership function must first be determined for each point. For our model purpose we defined following linguistic variables and membership function for each input and output variables.

(i) Linguistic variable for SO_2: 5 type of linguistic variables are used as the inputs of the pollutant SO_2

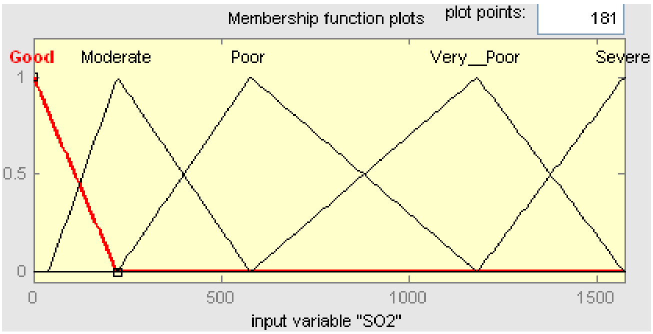

Fig1.1 Membership function plots for SO_2

(ii) Linguistic variable for NO_2 : 5 type of linguistic variables are used as the inputs of the pollutant NO_2 .

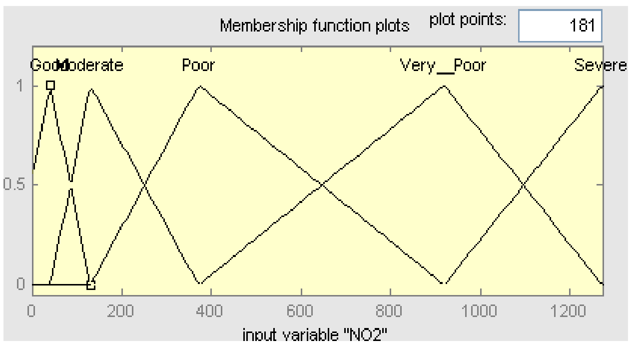

Fig1.2 Membership function plots for NO2

(iii) Linguistic variable for particulates(PM10): 5 type of linguistic variables are used as the inputs of the pollutant particulates(PM_{10}) .

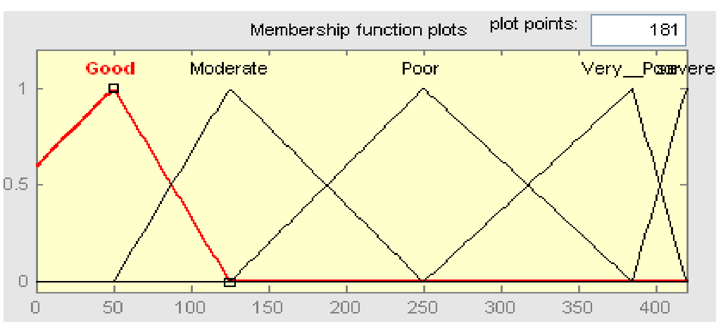

Fig1.3 Membership function plots for PM_{10}

(iv) Linguistic variable for CO: 5 type of linguistic variables are used as the inputs of the pollutant CO.

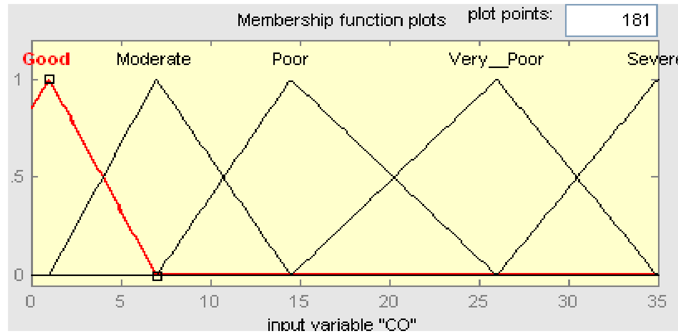

Fig1.4 Membership function plots for CO

(v) Linguistic variable for O_3: 5 type of linguistic variables are used as the inputs of the pollutant O_3 .

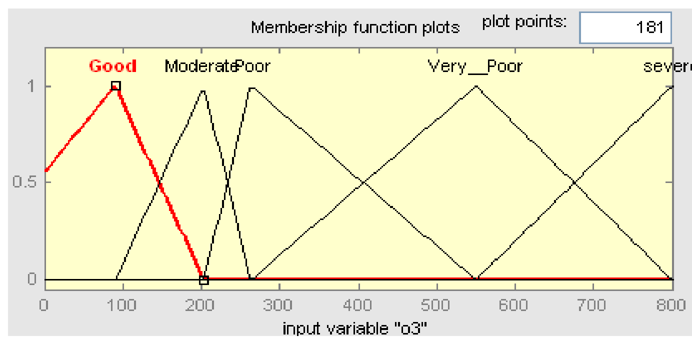

Fig1.5 Membership function plots for O_3

3.Fuzzy inference rules – In this step the knowledge pertaining to the the given control problem is formulated in terms of a set of fuzzy inference rules(Mohammad Abdul Azim and Abbas Jamlipour et al(2006). Fuzzy inference rule for the given problem are as follows.

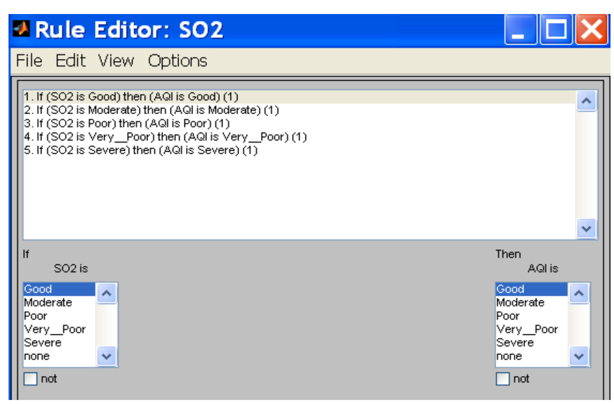

Fig1.6 Fuzzy inference rule for SO_2

4.Defuzzification- In our MATLAB FLC module, the centre of gravity method is used to get a crisp output. This method calculates the weighted average of a fuzzy set (John Yen ,Reza Langari et al. 2007).The result of applying COA defuzzification to a fuzzy conclusion "Y is A" can be expressed by the formula

$$y = \frac{\sum \mu A(yi) \times yi}{\sum \mu A(yi)}$$

If y is discrete and by the formula

$$y = \frac{\int \mu A(yi) \times yi \, dy}{\int \mu A(yi) \, dy}$$

If y is continous.

Simulation Result- We applied our suggested model to calculate Air Quality Index and found that our model gives satisfactory simulation results.

TABLE 1.7 CONCENTRATION AND INDEX VALUE FOR PLLUTANTS

SO2		*NO2*		*CO*		*O3*		*PM10*		*Air Quality Index*
Index	*Conc. (μgm/m^3)*	*Index*	*Conc. (μgm/m^3)*	*Index*	*Conc. (μgm/m^3)*	*Index*	*Conc. (μgm/m^3)*	*Index*	*Conc. (μgm/m^3)*	*AQI*
144	203	228	328	59	01	309	439	254	254	309
248	573	352	928	357	27	295	390	294	307	357
339	1132	287	560	311	22	416	749	183	162	416

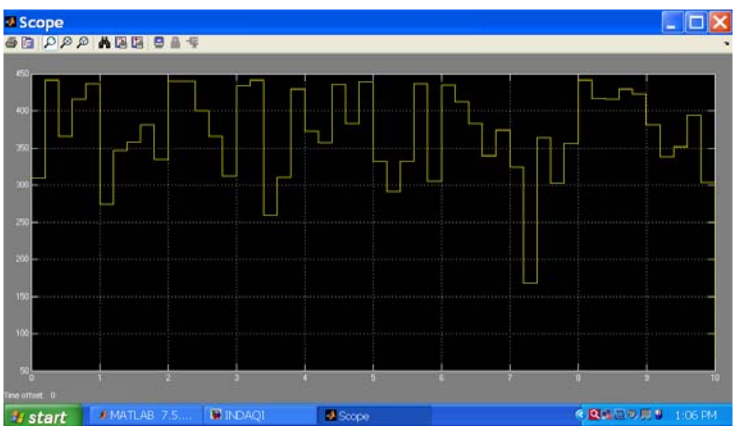

Fig 1.7 MATLAB® Simulation graph for final AQI

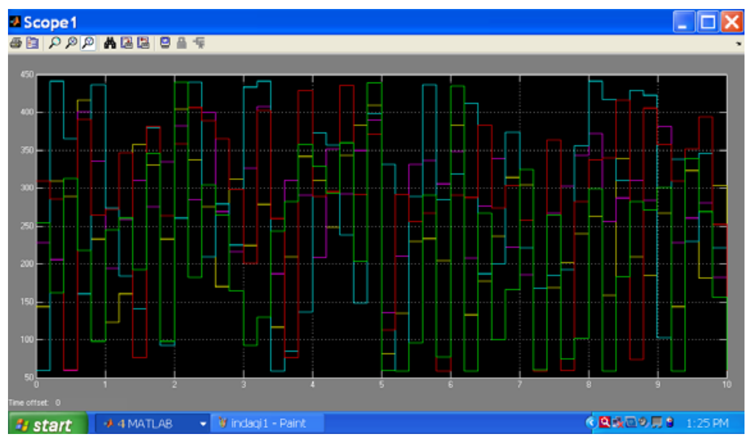

Fig 1.8 MATLAB® Simulation graph containing AQI for all pollutant

Comprative Analysis for SO2

Linear Interpolation for calculating AQI

(i) If SO2 value 203 (μgm/m3)

AQI= [(200-101)/(367-81)]x (203-81) + 101= 143.212 ≈ 143

(ii) If SO2 value 573 (μgm/m3)

AQI= [(300-201)/(786-368)]x (573-368) + 201 = 249.54 ≈250

(iii) If SO2 value 1132 (µgm/m3)

AQI= [(400-301)/(1572-787)]x (1132-787) + 301= 344.5045 ≈ 345

TABLE 1.8 CONCENTRATION AND INDEX VALUE FOR SO_2

Concentration (µgm/m^3)	AQI (Using Fuzzy Approach)	AQI (Using Linear Interpolation Approach)
203	144	143
573	248	250
1132	339	345

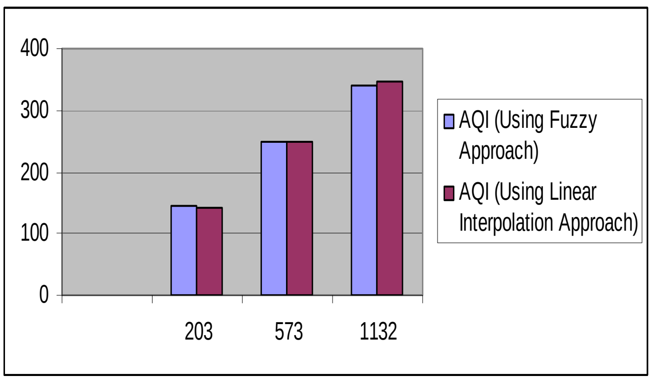

Fig 1.9 Graph showing comparison of Fuzzy and Linear Interpolation approach

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