Fuzzy logic based model for monitoring air quality index

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Abstract

This paper describes a fuzzy logic based monitoring system able to calculate Air Quality Index (AQI). The Air Quality Index is a simple and generalized way to describe the air quality in U.S, China, Hong Kong, Malaysia and now in India. U.S. Air Quality Index is mainly a health related index with the descriptor words: "Good (0-50)", "Moderate (51-100)", "Unhealthy for sensitive groups (101-150)", "Unhealthy (151-200)", "Very Unhealthy (201-300)", "Hazardous (301-400)", "Hazardous (401-500)". U.S. Environmental Protection Agency responsible for measuring the level of air pollution in U.S. In U.S the AQI is based on the level of 5 atmospheric pollutants, namely sulferdioxide (SO_2), nitrogen dioxide (NO_2), suspended particulates (PM), carbon monoxide (CO), and ozone (O_3) measured at the monitoring stations throughout each city. An individual score is assigned to the level of each pollutant and the final AQI is the Highest of those scores. Air quality measurement is commonly reported in terms of micrograms per cubic meter (µgm/m^3) or parts per million (ppm). 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.
Keywords: Fuzzy logic control system, air quality index, linear Interpolation.

Introduction

The U.S. environmental protection agency (EPA or sometimes USEPA) is an agency of the federal government of the united states charged with protecting human health and the environment, by writing and enforcing regulations based on laws passed by Congress. The agency conducts environmental assessment, research, and education. It has the primary responsibility for setting and enforcing national standards under a variety of environmental laws, in consultation with state, tribal, and local governments. The pollutants included for the proposed Fuzzy-AQI are O_3, PM, CO, SO_2 and NO_2. *Conventional method:* Suppose we have SO_2 value of 0.150 ppm. Then we refer to the SO_2 in the table for the values that fall above and below value (0.145-0.224) ppm. In this case, the 0.150 ppm value falls within the index values of 101 to 150. The Conventional method used Linear Interpolation for calculating AQI in the following way.

[(150-101)/(0.224-0.145)] x (0.150-0.145) + 101= 104.101≈ 104 (1)

So AQI value of 0.150 corresponds to an index value is 104. Table 1 presents the summary of the break point concentrations and AQI values

If we have the values for more pollutants

Suppose we have SO_2 value of 0.150 ppm and PM10 value of 265 µgm/m^3 and an ozone value 0.30 ppm. We apply the equation 3 times as follows:

SO_2: AQI for SO_2 is 104 (from equation 1)

PM: [(200-151)/(354-255)] x (265-255) + 151= 155.9≈156

O_3: [(300-201)/(0.404-0.125)] x (0.30-0.125) +201= 263.14≈263

Final value for AQI is 263 which is the maximum of

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 pollutants as input variables to calculate air quality index

(i) SO_2: Air pollution level and health implication for measured SO_2 are shown in Table 2.

(ii)NO_2: Air pollution level and health implication for measured NO_2 are shown in Table 3.

(iii) PM: Air pollution level and health implication for measured particulates (PM) are shown in Table 4.

(iv) CO: Air pollution level and health implication for measured CO are shown in Table 5.

(v) O_3: Air pollution level and health implication for measured O_3 are shown in Table 6.

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 *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 (Fig. 1.1-1.5).

1. Linguistic variable for SO_2: 7 types of linguistic variables are used as the inputs of the pollutant SO_2.
2. Linguistic variable for NO_2: 4 types of linguistic variables are used as the inputs of the pollutant NO_2.
3. Linguistic variable for particulates (PM): 7 types of linguistic variables are used as the inputs of the pollutant particulates (PM).

Fig. 1.1. Membership function for SO_2 (by using MATLAB software).

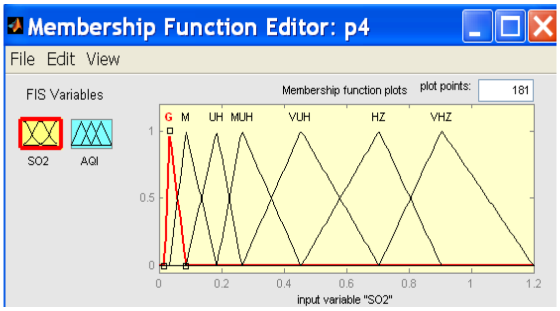


Fig. 1.2. Membership function for NO_2 (by using MATLAB software).

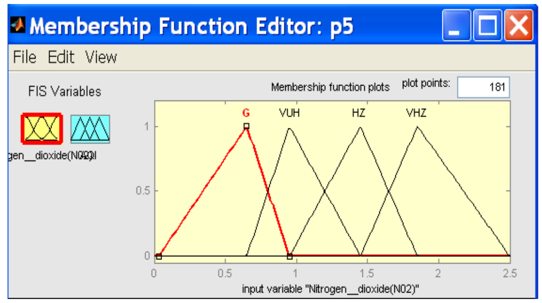


Fig. 1.3. Membership function for PM (by using MATLAB software).

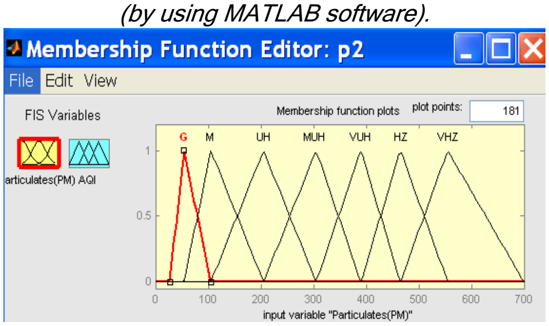


Fig. 1.4. Membership function for CO (by using MATLAB software).

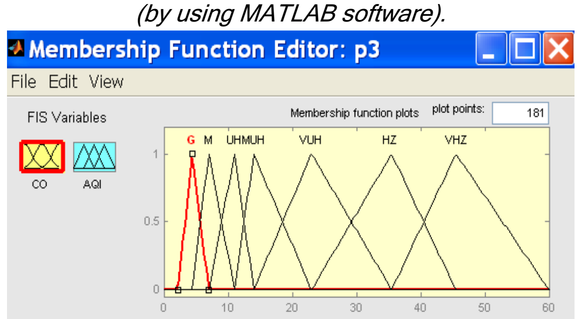


Fig. 1.5. Membership function for O_3 (by using MATLAB software).

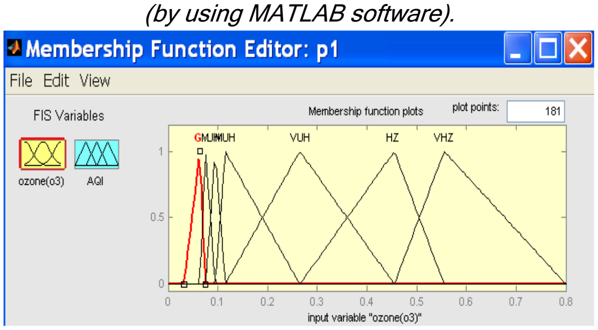


Fig. 1.6. Fuzzy inference rule.

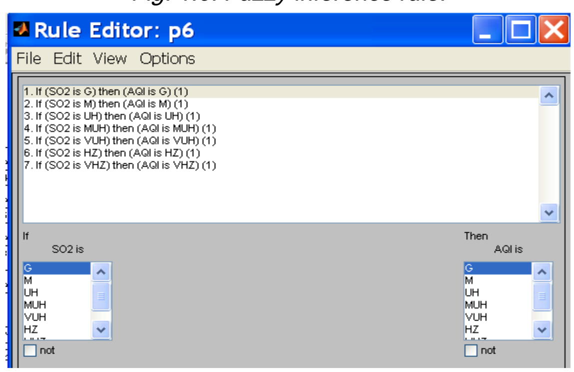
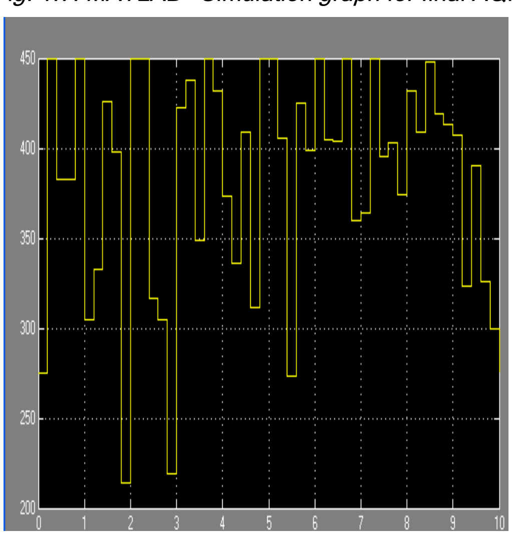


Fig. 1.7. MATLAB® Simulation graph for final AQI.



4. Linguistic variable for CO: 7 types of linguistic variables are used as the inputs of the pollutant CO.
5. Linguistic variable for O_3: 7 types of linguistic variables are used as the inputs of the pollutant O_3.

3. *Fuzzy inference rules:* In this step the knowledge pertaining to the given control problem is formulated in terms of a set of fuzzy inference rules (Azim *et al.,* 2006). Fuzzy inference rule for the given problem are given in fig. 1.6

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 (Yen *et al.,* 2007).The result of applying COA defuzzification to a fuzzy conclusion "Y is A" can be expressed by the formula:

Table 1. Break point concentrations and aqi values for -u.s. (Taken from U.S. environmental protection agency research triangle park, North Carolina).

Index	Category	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	O_3 (8-hr avg.) (ppm)	PM (μgm/m^3)
0-50	Good	0.000-0.034	-	0.0-4.4	0.000-0.064	0-54
51-100	Moderate	0.035-0.144	-	4.5-9.4	0.065-0.084	55-154
101-150	Unhealthy	0.145-0.224	-	9.5-12.4	0.085-0.104	155-254
151-200	Unhealthy	0.225-0.304	-	12.5-15.4	0.105-0.124	255-354
201-300	Very unhealthy	0.305-0.604	0.65-1.24	15.5-30.4	0.125-0.404	355-424
301-400	Hazardous	0.605-0.804	1.25-1.64	30.5-40.4	0.405-0.504	425-504
401-500	Hazardous	0.805-1.004	1.65-2.04	40.5-50.4	0.505-0.604	505-604

Table 2. Air pollution index for SO_2.

Index	Category	SO_2 (ppm)
0-50	Good	0.000-0.034
51-100	Moderate	0.035-0.144
101-150	Unhealthy for sensitive group	0.145-0.224
151-200	Unhealthy	0.225-0.304
201-300	Very unhealthy	0.305-0.604
301-400	Hazardous	0.605-0.804
401-500	Hazardous	0.805-1.004

Table 3. Air pollution index for NO_2.

Index	Category	NO_2 (ppm)
201-300	Very unhealthy	0.65-1.24
301-400	Hazardous	1.25-1.64
401-500	Hazardous	1.65-2.04

Table 4. Air pollution index for PM.

Index	Category	PM (μgm/m^3)
0-50	Good	0-54
51-100	Moderate	55-154
101-150	Unhealthy for sensitive group	155-254
151-200	Unhealthy	255-354
201-300	Very unhealthy	355-424
301-400	Hazardous	425-504
401-500	Hazardous	505-604

Table 5. Air pollution index for CO.

Index	Category	Co (ppm)
0-50	Good	0.0-4.4
51-100	Moderate	4.5-9.4
101-150	Unhealthy for sensitive group	9.5-12.4
151-200	Unhealthy	12.5-15.4
201-300	Very unhealthy	15.5-30.4
301-400	Hazardous	30.5-40.4
401-500	Hazardous	40.5-50.4

Table 6. Air pollution index for O_3.

Index	Category	O_3 (ppm)
0-50	Good	0.000-0.064
51-100	Moderate	0.065-0.084
101-150	Unhealthy for sensitive group	0.085-0.104
151-200	Unhealthy	0.105-0.124
201-300	Very unhealthy	0.125-0.404
301-400	Hazardous	0.405-0.504
401-500	Hazardous	0.505-0.604

Table 8. Simulated concentration and index value for pollutants.

Pollutant	Concentration (ppm)	(AQI) Linear interpolation	(AQI) Fuzzy logic system
NO_2	.7222	213	214
NO_2	1.7923	437	432
CO	36.2	358	360

Table 7. Simulated concentration and index value for pollutants.

SO2		NO2		CO		O3		PM		Air quality index
Index	Conc. (ppm)	Index	Conc. (ppm)	Index	Conc. (ppm)	Index	Conc. (ppm)	Index	Conc. (μgm/m3)	AQI
69	.53	214	.7222	50	3.4	49.5	.032	50	100.88	214
417	.846	432	1.7923	89	7.3	402	.508	402	518.63	432
233	.3653	301	1.1432	360	36.2	242	.2192	242	187.16	360

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

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

By applying Fuzzy approach, we observed AQI values for diverse concentration of pollutants (Table 7 & 8, Fig. 1.7). We applied our suggested model to calculate Air Quality Index and found that our model gives satisfactory simulation results.

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