DESIGNING A FUZZY MODEL FOR RISK FACTORS OF AIR POLLUTION

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Abstract:
Air Pollution has been the major reason for many diseases worldwide today. The most common diseases due to Air Pollution are Stroke, Lung Cancer and Chronic Obstructive Pulmonary Disease (COPD). In this paper an attempt has been made to study the range of risks for each disease and the corresponding exposure to Air Pollution based on the level of risks. The aim of this study is to frame a model for main risk factors of air pollution and import rules in Fuzzy Inference System based on the observations. The aim is to find out which age group of people is most affected by Air Pollution.

Key Words: Air Pollution, Trapezoidal Membership Functions, Risk Factors & Exposure

Introduction:
Modernisation has lead to various changes in the life style of people. This includes increase in the number of industries and factories. This drastic increase however has lead to various hazardous effects rather than proving beneficial to people. Among these effects the most dangerous one is Air Pollution which has been increasing at a rapid rate during the recent years. Urbanisation has been the prime factor for the increase of toxic pollutants in the atmosphere. These pollutants are fatal to people and they are affected by many diseases.

Study Area:
The study has been carried out in the district of Salem, Tamilnadu. Based on the Ambient Air Quality prescribed by The Central Pollution Control Board, New Delhi, it is found that the annual average of respirable suspended particulate matter exceeds the prescribed standards. This is due to the increase in the usage of vehicles and also due to the considerable growth of industrial sectors.

Methods:
We describe the designing of the Fuzzy Inference System (FIS) for finding age group who are exposed to Air Pollution. The type of fuzzy model used in this study is Mamdani (or linguistic) model. In this model, the antecedent (if – part of the rule) and the consequent (then-part of the rule) are fuzzy propositions:

$$R_i : \text{if x is } A_i \text{ then y is } B_i, i = 1,2,\ldots,K$$

Here A_i and B_i are linguistic terms represented by fuzzy sets and K denotes the number of rules in the model.

Defining Linguistic Variables:

Table 1: Linguistic variable for Input variables

S.No	Input Variables	Linguistic Variables
1.	Stroke	SK
2.	Lung Cancer	LC
3.	Chronic Obstructive Pulmonary Disease	COPD

Table 2: Linguistic variable for Output variables

S.No	Output Variable	Linguistic Variable
1	Air Pollution	Exposure to Air Pollution

Membership Function for all Input Variables:
We scale the range based on the types of input variables and then we calculate the membership function based on the risk level of each disease and the range for all the Input Variables and their corresponding Membership functions are given.

Values for Stroke:
The main reason for Stroke is the increase in Blood Pressure. Systolic Pressure is taken into consideration while determining the risk of Stroke and the Membership Function for Systolic Pressureare given below.

Systolic Pressure:

Table 3: Values for Systolic Blood Pressure

Input Variable	Range	Risk Level
Systolic Pressure	< 120 mm Hg	Low risk (L)
	120 mm Hg – 139 mm Hg	Medium Risk (M)
	140 mm Hg– 159 mm Hg	High Risk (H)
	>160 mm Hg	Very High Risk (VH)

$$\mu_l(x) = \begin{cases} 0 & x \le 30 \\ \dfrac{x-30}{30} & 30 \le x \le 60 \\ 1 & x = 60 \\ \dfrac{120-x}{60} & 60 < x \le 120 \\ 0 & x \ge 120 \end{cases}$$

$$\mu_m(x) = \begin{cases} 0 & x \le 120 \\ \dfrac{x-120}{10} & 120 < x < 130 \\ 1 & 130 \le x \le 131 \\ \dfrac{139-x}{8} & 131 < x < 139 \\ 0 & x \ge 139 \end{cases}$$

$$\mu_h(x) = \begin{cases} 0 & x \le 140 \\ \dfrac{x-140}{10} & 140 < x < 150 \\ 1 & 150 \le x \le 151 \\ \dfrac{159-x}{8} & 151 < x < 159 \\ 0 & x \ge 159 \end{cases}$$

$$\mu_{vh}(x) = \begin{cases} 0 & x \le 160 \\ \dfrac{x-160}{20} & 160 \le x \le 180 \\ 1 & x = 180 \\ \dfrac{200-x}{20} & 180 < x \le 200 \\ 0 & x \ge 200 \end{cases}$$
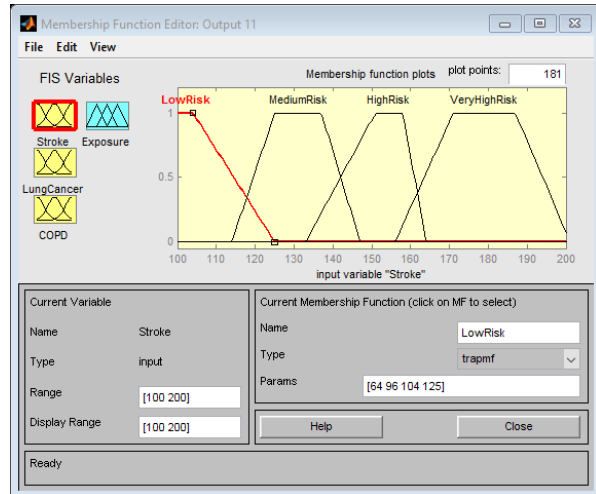
Values for Lung Cancer:

Staging is important for determining how a particular tumor should be treated. Stages are assigned as I to IV based on their severity.
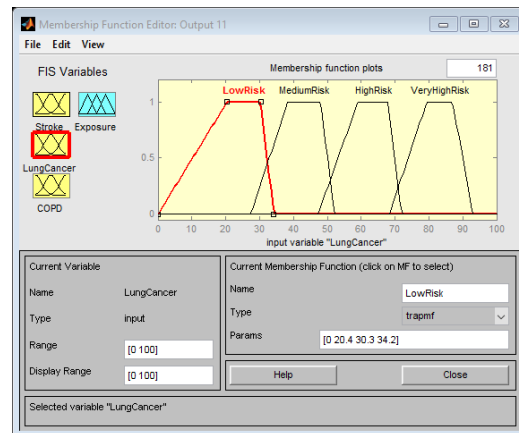
Table 4: Values for Lung Cancer

Input Variable	Range	Risk Level
Length of Tumour	< 30 mm	Low risk (L)
	30 mm – 50 mm	Medium Risk (M)
	50 mm – 70 mm	High Risk (H)
	>70 mm	Very High Risk (VH)

$$\mu_l(x) = \begin{cases} 0 & x \le 10 \\ \dfrac{x-10}{5} & 10 \le x \le 15 \\ 1 & x = 15 \\ \dfrac{30-x}{15} & 15 < x \le 30 \\ 0 & x \ge 30 \end{cases}$$

$$\mu_m(x) = \begin{cases} 0 & x < 30 \\ \dfrac{x-30}{10} & 30 < x < 40 \\ 1 & 40 \le x \le 41 \\ \dfrac{50-x}{9} & 41 < x < 50 \\ 0 & x \ge 50 \end{cases}$$

$$\mu_h(x) = \begin{cases} 0 & x \le 50 \\ \dfrac{x-50}{10} & 50 < x < 60 \\ 1 & 60 \le x \le 61 \\ \dfrac{70-x}{9} & 61 < x < 70 \\ 0 & x \ge 70 \end{cases}$$

$$\mu_{vh}(x) = \begin{cases} 0 & x \le 70 \\ \dfrac{x-70}{20} & 70 \le x \le 90 \\ 1 & x = 90 \\ \dfrac{110-x}{20} & 90 < x \le 110 \\ 0 & x \ge 110 \end{cases}$$

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Values for COPD:

The diagnosis for COPD comprises of a Lung function test known as the Forced Expiratory Volume (FEV_1) test. This test measures the amount of air exhaled on the first second of a forced breath. The severity depends on how difficult it is to exhale during the extreme stages of COPD.

Table 5: Values for COPD

Input Variable	Range	Risk Level
Forced Expiratory Volume	< 30 (per second)	Very High risk (VH)
	30 – 49 (per second)	High Risk (H)
	50 – 79 (per second)	Meduim Risk (M)
	≥80 (per second)	Low Risk (L)

$$\mu_{vh}(x)=\begin{cases} 0 & x \le 10 \\ \dfrac{x-10}{5} & 10 \le x \le 15 \\ 1 & x=15 \\ \dfrac{30-x}{15} & 15 < x \le 30 \\ 0 & x \ge 30 \end{cases}$$

$$\mu_{h}(x)=\begin{cases} 0 & x < 30 \\ \dfrac{x-30}{9} & 30 < x < 39 \\ 1 & 39 \le x \le 40 \\ \dfrac{49-x}{9} & 40 < x < 49 \\ 0 & x \ge 49 \end{cases}$$

$$\mu_{m}(x)=\begin{cases} 0 & x < 50 \\ \dfrac{x-50}{15} & 50 < x < 65 \\ 1 & 65 \le x \le 66 \\ \dfrac{79-x}{13} & 66 < x < 79 \\ 0 & x \ge 79 \end{cases}$$

$$\mu_{l}(x)=\begin{cases} 0 & x \le 80 \\ \dfrac{x-80}{20} & 80 \le x \le 100 \\ 1 & x=100 \\ \dfrac{120-x}{100} & 100 < x \le 120 \\ 0 & x \ge 120 \end{cases}$$
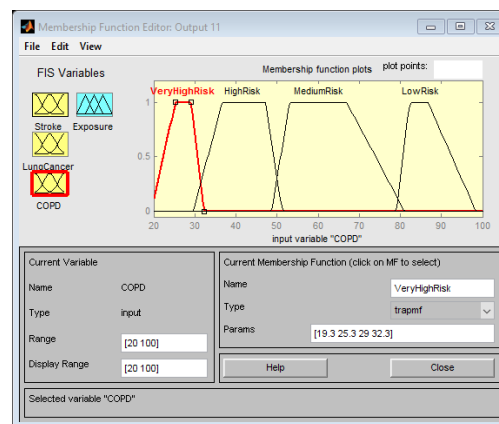
Fuzzy Rules:

The fuzzy inference rules are generated now based on the severity of each disease. The rules are formulated based on symptoms based testing.

1. If (SK is Low Risk) and (LC is Low Risk) and (COPD is Low Risk) then Exposure to air   pollution is Low.
2. If (SK is Low Risk) and (LC is Low Risk) and (COPD is Medium Risk) then Exposure to air pollution is Low.
3. If (SK is Low Risk) and (LC is Low Risk) and (COPD is High Risk) then Exposure to air pollution is Low.
4. If (SK is Low Risk) and (LC is Low Risk) and (COPD is Very High Risk) then Exposure to air pollution is Low.
5. If (SK is Low Risk) and (LC is Medium Risk) and (COPD is Low Risk) then Exposure to air pollution is Low.
6. If (SK is Low Risk) and (LC is High Risk) and (COPD is Low Risk) then Exposure to air pollution is Low.
7. If (SK is Low Risk) and (LC is Very High Risk) and (COPD is Low Risk) then Exposure to air pollution is Low.
8. If (SK is Medium Risk) and (LC is Low Risk) and (COPD is Low Risk) then Exposure to air pollution is Low.
9. If (SK is High Risk) and (LC is Low Risk) and (COPD is Low Risk) then Exposure to air pollution is Low.
10. If (SK is Very High Risk) and (LC is Low Risk) and (COPD is Low Risk) then Exposure to air pollution is Low.
11. If (SK is Low Risk) and (LC is Medium Risk) and (COPD is Medium Risk) then Exposure to air pollution is Medium.
12. If (SK is Medium Risk) and (LC is Low Risk) and (COPD is Medium Risk) then Exposure to air pollution is Medium.
13. If (SK is Medium Risk) and (LC is Medium Risk) and (COPD is Low Risk) then Exposure to air pollution is Medium.
14. If (SK is Low Risk) and (LC is Medium Risk) and (COPD is High Risk) then Exposure to air pollution is High.
15. If (SK is Low Risk) and (LC is High Risk) and (COPD is Medium Risk) then Exposure to air pollution is High.
16. If (SK is Low Risk) and (LC is High Risk) and (COPD is High Risk) then Exposure to air pollution is High.
17. If (SK is Medium Risk) and (LC is Low Risk) and (COPD is High Risk) then Exposure to air pollution is High.
18. If (SK is Medium Risk) and (LC is Medium Risk) and (COPD is Medium Risk) then Exposure to air pollution is High.
19. If (SK is Medium Risk) and (LC is Medium Risk) and (COPD is High Risk) then Exposure to air pollution is High.
20. If (SK is Medium Risk) and (LC is High Risk) and (COPD is Low Risk) then Exposure to air pollution is High.
21. If (SK is Medium Risk) and (LC is High Risk) and (COPD is Medium Risk) then Exposure to air pollution is High.

22. If (SK is High Risk) and (LC is Low Risk) and (COPD is Medium Risk) then Exposure to air pollution is High.

23. If (SK is High Risk) and (LC is Low Risk) and (COPD is High Risk) then Exposure to air pollution is High.

24. If (SK is High Risk) and (LC is Medium Risk) and (COPD is Low Risk) then Exposure to air pollution is High.

25. If (SK is High Risk) and (LC is Medium Risk) and (COPD is Medium Risk) then Exposure to air pollution is High.

26. If (SK is High Risk) and (LC is High Risk) and (COPD is Low Risk) then Exposure to air pollution is High.

27. If (SK is Low Risk) and (LC is Medium Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

28. If (SK is Low Risk) and (LC is High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

29. If (SK is Low Risk) and (LC is Very High Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

30. If (SK is Low Risk) and (LC is Very High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

31. If (SK is Low Risk) and (LC is Very High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

32. If (SK is Medium Risk) and (LC is Low Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

33. If (SK is Medium Risk) and (LC is Medium Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

34. If (SK is Medium Risk) and (LC is High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

35. If (SK is Medium Risk) and (LC is High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

36. If (SK is Medium Risk) and (LC is Very High Risk) and (COPD is Low Risk) then Exposure to air pollution is Very High.

37. If (SK is Medium Risk) and (LC is Very High Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

38. If (SK is Medium Risk) and (LC is Very High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

39. If (SK is Medium Risk) and (LC is Very High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

40. If (SK is High Risk) and (LC is Low Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

41. If (SK is High Risk) and (LC is Medium Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

42. If (SK is High Risk) and (LC is Medium Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

43. If (SK is High Risk) and (LC is High Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

44. If (SK is High Risk) and (LC is High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

45. If (SK is High Risk) and (LC is High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

46. If (SK is High Risk) and (LC is Very High Risk) and (COPD is Low Risk) then Exposure to air pollution is Very High.

47. If (SK is High Risk) and (LC is Very High Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

48. If (SK is High Risk) and (LC is Very High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

49. If (SK is High Risk) and (LC is Very High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

50. If (SK is Very High Risk) and (LC is Low Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

51. If (SK is Very High Risk) and (LC is Low Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

52. If (SK is Very High Risk) and (LC is Low Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

53. If (SK is Very High Risk) and (LC is Medium Risk) and (COPD is Low Risk) then Exposure to air pollution is Very High.

54. If (SK is Very High Risk) and (LC is Medium Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

55. If (SK is Very High Risk) and (LC is Medium Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

56. If (SK is Very High Risk) and (LC is Medium Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

57. If (SK is Very High Risk) and (LC is High Risk) and (COPD is Low Risk) then Exposure to air pollution is Very High.

58. If (SK is Very High Risk) and (LC is High Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

59. If (SK is Very High Risk) and (LC is High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

60. If (SK is Very High Risk) and (LC is High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

61. If (SK is Very High Risk) and (LC is Very High Risk) and (COPD is Low Risk) then Exposure to air pollution is Very High.

62. If (SK is Very High Risk) and (LC is Very High Risk) and (COPD is Medium Risk) then Exposure to air pollution is Very High.

63. If (SK is Very High Risk) and (LC is Very High Risk) and (COPD is High Risk) then Exposure to air pollution is Very High.

64. If (SK is Very High Risk) and (LC is Very High Risk) and (COPD is Very High Risk) then Exposure to air pollution is Very High.

Rule Viewer for Linguistic Variables:Surface Viewer:
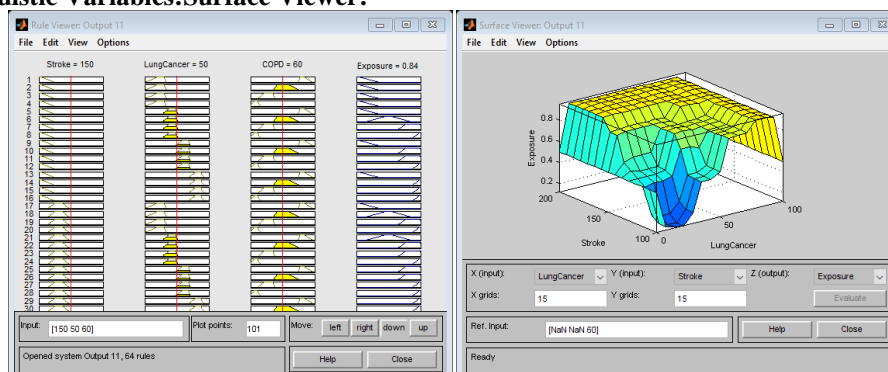
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Result based on Data:

Based on the details collected from 150 people who were susceptible to air pollution the observation is that people who are less than 18 years of age and people who are above 65 years are severely affected due to air pollution and reports from Health Organizations and American Lung Association also confirms the result.

Table 6: Result

Risk Factor of each Disease	No. of People		
	Children	**Adults**	**Old Age**
Low Risk	2	17	5
Medium Risk	1	5	1
High Risk	12	8	11
Very High Risk	35	20	33
Total	50	50	50

Conclusion:

The study has been carried out among people affected by various risk factors of Air Pollution and they can be attributed to many reasons such as development of more industrial areas, poverty, increase in fuel from vehicular emissions etc., These can be controlled if people working or residing in such areas take proper medications at the appropriate time and if proper monitoring is done at frequent intervals. People should wear masks while going out to safeguard themselves from the pollutants emitted from these gases. Reduced usage of vehicles can also lead to a decrease in fuel emission which can reduce the harmful effects in a considerable rate.

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