Applications of Fuzzy Logic for Tritium Sensing Technology

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Introduction

Fuzzy Logic is a mathematical method that can represent human-like decisions by analyzing vagueness. The project is a practical approach for evaluating sensors using a fuzzy group best-worst method.

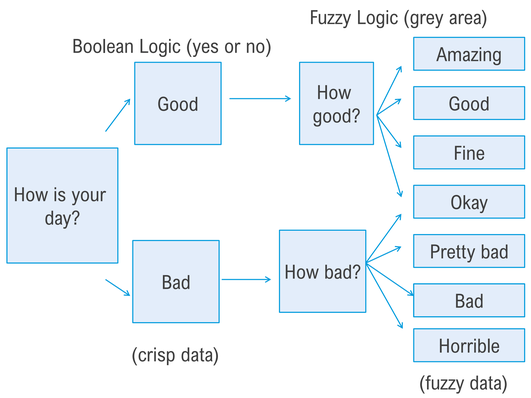


Figure 1. Diagram of Boolean logic versus fuzzy logic on a conceptual basis.

Methods

1. Determine important qualities of a sensor.
2. Rank the sensor qualities using an analytic hierarchy process to produce a weight on each quality.
3. Define membership functions.
4. Apply fuzzification methods to each quality (If-Then Rules).
5. Express output score through defuzzification.
6. Integrate expert opinion into the decision process with the best-worst method.
7. Compare many sensors with the multi-criteria decision-making technique to choose one sensor

Fuzzy Logic Process

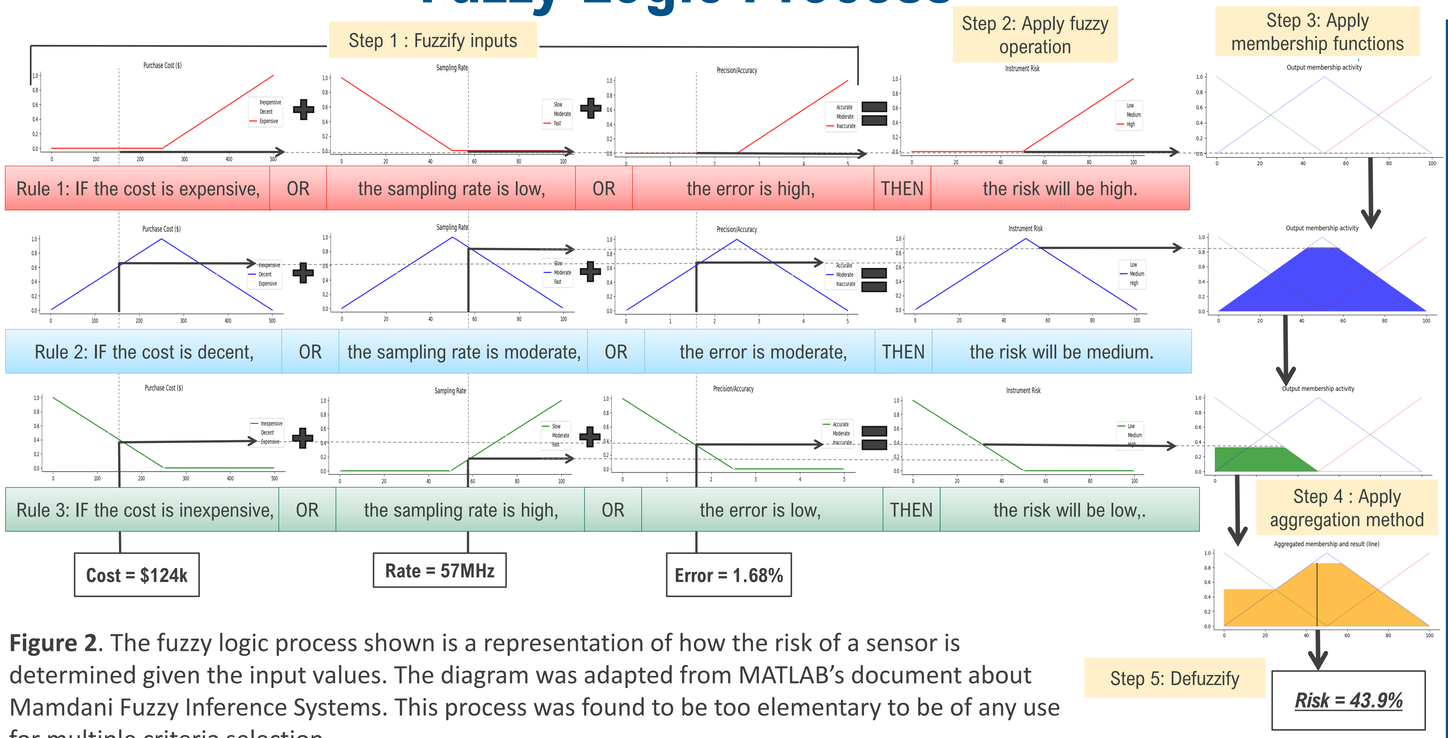
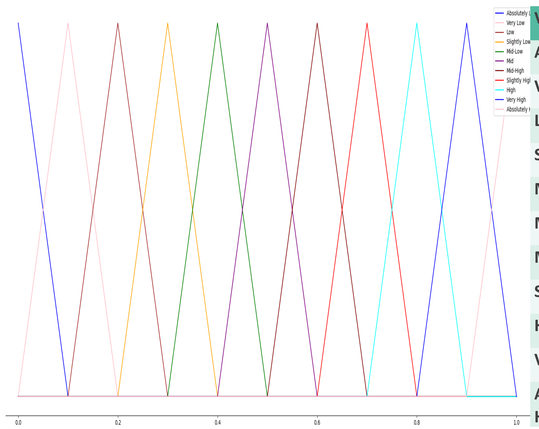


Figure 2. The fuzzy logic process shown is a representation of how the risk of a sensor is determined given the input values. The diagram was adapted from MATLAB's document about Mamdani Fuzzy Inference Systems. This process was found to be too elementary to be of any use for multiple criteria selection.

Multi-Criteria Decision-Making Technique

Criteria	Sub-criteria	Expert 1	Expert 2	Expert 3	Expert 4
Cost (C1)	Purchasing cost (SC11)	1	3	3	1
	Operational cost (SC12)	3	2	1	3
	Material cost (SC13)	4	4	4	4
	Labor cost (SC14)	2	1	2	2
Data Quality (C2)	Digitization rate (SC21)	2	4	6	6
	Discretization (SC22)	5	5	2	4
	Precision (SC23)	1	1	3	1
	Accuracy (SC24)	1	1	1	2
	Limit of detection (SC25)	4	3	4	5
	Sensitivity (SC26)	3	2	5	3
Physical Robustness (C3)	Size (SC31)	2	7	5	6
	Ease of use (SC32)	1	5	2	2
	Ease of maintenance (SC33)	1	3	1	3
	Life cycle/ deterioration (SC34)	3	4	4	5
	MTBF (SC35)	3	1	3	4
	Rarity (SC36)	4	6	7	7
	TRL (SC37)	4	2	6	1

Figure 3. The table lists the ranking of sensor sub-criteria per expert evaluation.



Verbal Phrases	Fuzzy Score
Absolutely Low	(0,0,0)
Very Low	(0,1/10,2/10)
Low	(1/10,2/10,3/10)
Slightly Low	(2/10,3/10,4/10)
Mid-Low	(3/10,4/10,5/10)
Mid	(4/10,5/10,6/10)
Mid-High	(5/10,6/10,7/10)
Slightly High	(6/10,7/10,8/10)
High	(7/10,8/10,9/10)
Very High	(8/10,9/10,1)
Absolutely High	(1,1,1)

Figure 4. Membership function shown above provides what percentage of the input is categorized into one of the verbal phrases (step 3).

Results

What is the best sensor?

The fuzzy logic methods give an answer to that through a selection system. The relationship between the inputs and the outputs gives consumers an understanding of how the best sensor was found through a scoring of each quality/criteria and their corresponding sub-criteria through expert opinion.

Future Work

The project will utilize the fuzzy logic methods to provide commercial powerplant owners to select a tritium sensor for any location in the fusion fuel cycle.

- Obtain a score for each sub-criteria
- Repeat process for qualities of different locations in the fusion fuel cycle
- Connect the sensor data with location qualities
- Output an applicable program for commercial use

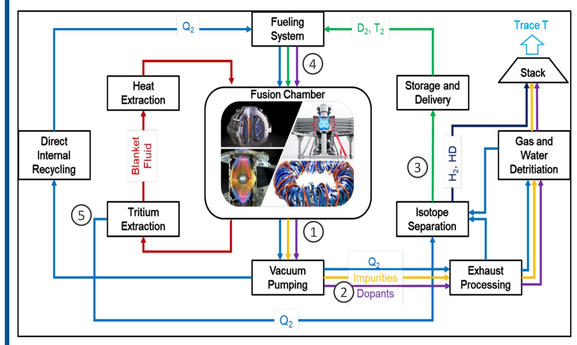


Figure 5. Diagram of the fusion fuel cycle, with possible sensor locations.

Reference

[1] Tavana, Madjid, Shahryar Sorooshian, and Hassan Mina. "An integrated group fuzzy inference and best–worst method for supplier selection in intelligent circular supply chains." *Annals of Operations Research* (2023): 1-42.

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