

Fuzzy Inference System for Emergency Investigation

Coursework Report

Wenxuan Zhu (20379163)
alywz30@nottingham.ac.uk

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1. Model description and justification

The aim of this coursework is to design a fuzzy inference system for advising doctors whether to refer patients to hospital for urgent investigation. It has three inputs and one output. The three inputs are the patient's temperature, severity of the headache and age, and the output is the urgency of the patient. Given the different input requirements of the two fuzzy systems that need to be designed, this means that two different models need to be chosen to build the fuzzy system. Therefore, the model selection and descriptions for the two cases are shown below:

1.1 Case1

All inputs are numeric, i.e. Temperature, Headache and Age are all provided as numbers. Based on this, I choose Type-1 fuzzy sets and systems to build this fuzzy inference system. Type-1 fuzzy system is a mathematical framework that uses type 1 fuzzy sets to model complex systems. It usually consists of three main parts: fuzzification, rule evaluation, and defuzzification. Fuzzification consists of using member functions to transform clear input into fuzzy input. Rule evaluation applies fuzzy logic, using fuzzy rules to combine fuzzy inputs to obtain fuzzy outputs. Deblurring converts blurred output into sharp output. This meets the needs of this design and is easy and fast to calculate, so in case1 I have chosen Type-1 fuzzy sets and systems.

1.2 Case2

All inputs are interval-values, i.e. Temperature, Headache and Age are provided as intervals. Based on this, Type-1 fuzzy sets and systems has clearly failed to meet the need for the input to be an interval, and in terms of input complexity, it does not achieve what is needed in this case. Hence, I choose non-singleton type-1 fuzzy system.

Non-monadic Type-1 fuzzy systems are a variant of Type 1 fuzzy systems whose membership functions are not restricted to monads (i.e., brittle values), but allow them to have fuzzy values. This means that the membership functions of non-monadic type 1 fuzzy systems can have a range of values, rather than being restricted to binary or flat membership values. In non-monadic type-1 fuzzy systems, membership functions are represented as fuzzy sets, usually defined by fuzzy numbers or fuzzy intervals. Fuzzy numbers are used to represent fuzzy values, where the value of a member changes gradually from one value to another within a specified range. On the other hand, a fuzzy

interval represents a range of values whose fuzzy member values are associated with each value in the range. Member functions in non-monadic-1 fuzzy systems can be represented by various mathematical models, such as fuzzy sets, fuzzy numbers, fuzzy intervals, or other suitable representation methods. Non-monadic type-1 fuzzy systems generally follow the same structure as type-1 fuzzy systems, including fuzzification, rule evaluation, and defuzzification steps. However, the membership functions used in non-monadic-1 fuzzy systems have greater flexibility in capturing the uncertainty and variability of the input data, since membership values can vary gradually within a certain range, rather than being restricted to crisp numerically. This meets the needs of this design very well, so in case2 I have chosen non-singleton type-1 fuzzy system.

2. Specific descriptions of final models

Before describing the final model in detail, we need to consider a fuzzy set of three inputs: temperature, headache, and age.

Regarding the patient's body temperature, I found that the normal body temperature of a person is between 36.5 and 37.5 degrees Celsius by consulting Wikipedia. When the human body temperature is higher than 37.7 degrees Celsius, the human body is in a state of fever. The state of hypothermia. So, in the temperature input, I used three fuzzy sets, namely low, normal, and high.

For the patient's headache level, migraine is generally divided into ten levels. Level 0-3 is Mild Pain Level, Level 4-6 is Uncomfortable Pain Level, Level 7-10 is Severe Pain Level (Sajobi, 2019). So, in the headache grade input, I used two fuzzy sets named uncomfortable and heavy.

Regarding the age of the patients, the general age range for young people is 18-35 years old, the age range for middle-aged people is 36-55 years old, and the age range for elderly people is greater than 55 years old (Nancy, 2002). So, in the age input, I used two fuzzy sets as young and old. In today's situation where people's physical health is generally improved, I prefer to combine middle-aged people and young people into one category.

As mentioned above, after the criteria for dividing the values of the three inputs have

been determined, the name and number of fuzzy sets for each input function are also determined. Therefore, the next step is to plot the final three input functions and one output function for the inputs. It should be added that since Type-1 fuzzy sets and systems and non-singleton type-1 fuzzy system were chosen for Case 1 and Case 2, the input and output functions can be the same for both cases, provided that the conditions are the same and only the input values are of different types. The final input and output functions described below are the functions used jointly by the two cases.

Temperature membership function (Input):

The temperature membership function has three fuzzy sets, low, normal, and high, and the human body temperature is defined and delineated in detail, especially at the edges, so the triangle function is used to build this function.

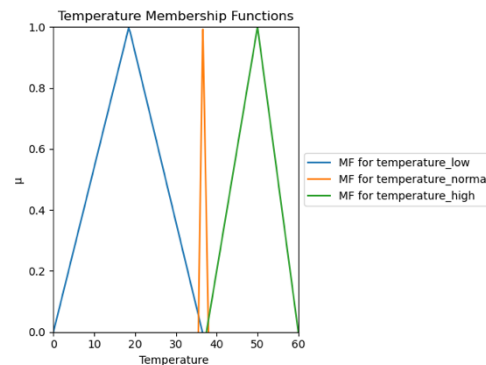


Figure 1 Temperature Membership Function

As shown in Figure 1, the two endpoints of the low fuzzy set function are 0 and 36.5 degrees C, with a vertex of 18.5 degrees C. The two endpoints of the normal fuzzy set function are 35.5 and 38.0 degrees C, with a vertex of 36.6 degrees C. The two endpoints of the high fuzzy set function are 37.5 and 60.0 degrees C, with a vertex of 50 degrees C.

Headache membership function (Input):

The headache membership function has two fuzzy sets, uncomfortable and heavy. The headache level is not strictly divided at the boundary and the higher the level, the more severe the headache, which is a gradual process, so the Gaussian function is very suitable for the construction of this function, simple and obvious, and very smooth.

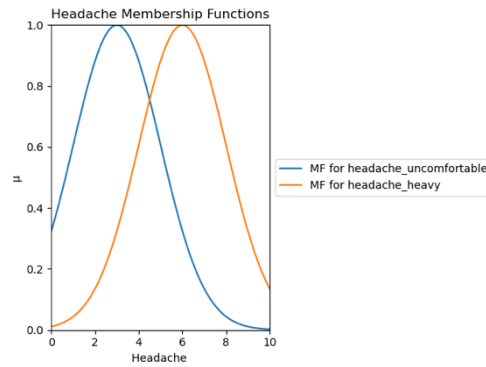


Figure 2 Headache Membership Function

As shown in Figure 2, the uncomfortable fuzzy set has a function vertex of level 3 and a spread of 2, and the heavy fuzzy set has a function vertex of level 6 and a spread of 2.

Age membership function (Input):

The age membership function has two fuzzy sets, young and old. Similar to temperature, age has clearer boundaries, but given that I have divided it into two categories, young and old, age also has a gradual change process and therefore also requires a smooth curve. I chose the Gau-angle function to plot this.

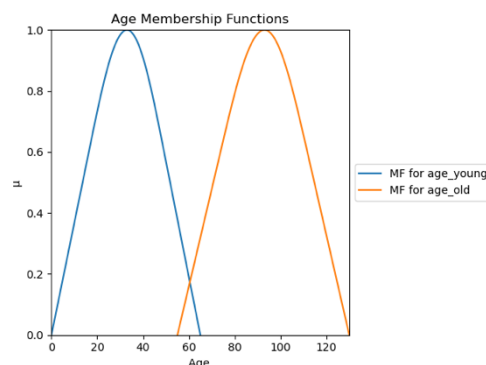


Figure 3 Age Membership Function

As shown in Figure 3, the ends of the function for the young fuzzy set are 0 and 65 years old, and the top of the function is 33 years old. the ends of the function for the old fuzzy set are 55 and 130 years old, and the top of the function is 93 years old.

Urgency (Output):

The urgency membership function has three fuzzy sets, not urgent, urgent, and very urgent. The degree of urgency is the only output function of this system, the three fuzzy sets are more evenly divided, with higher values implying a higher degree of urgency for the patient, so the Gau-angle function is more in line with the need for a hitch output

function, smooth and simple, with a relatively strong interpretation.

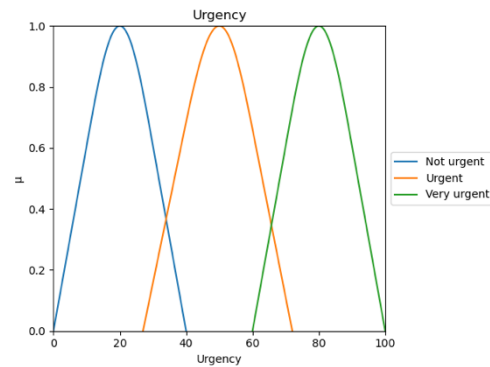


Figure 4 Urgency

As shown in Figure 4, the not urgent fuzzy set has 0 and 40 at both ends of the function and 20 at the top of the function. urgent fuzzy set has 27 and 72 at both ends of the function and 50 at the top of the function. very urgent fuzzy set has 60 and 100 at both ends of the function and 80 at the top of the function.

Once the final input and output functions have been designed, we also need to devise a set of rules for the inputs and outputs, which will provide the arithmetic basis and guidelines for the defuzzification that follows. The rules for Case 1 and Case 2 are shown below:

Table 1 Input and output rules

Input: temperature	Input: headache	Input: age	Output: urgency
Low	Uncomfortable	Young	Urgent
Low	Uncomfortable	Old	Urgent
Low	Heavy	Young	Urgent
Low	Heavy	Old	Very urgent
Normal	Uncomfortable	Young	Not urgent
Normal	Uncomfortable	Old	Not urgent
Normal	Heavy	Young	Urgent
Normal	Heavy	Old	Very urgent
High	Uncomfortable	Young	Urgent
High	Uncomfortable	Old	Very urgent
High	Heavy	Young	Very urgent
High	Heavy	Old	Very urgent

At this point, the fuzzy system is basically built, and the main differences between Case 1 and Case 2 are in the input value types and defuzzification. Below, I show some illustrative examples for reference:

Case1:

Input: temperature is 37, headache is 3, age is 27.

Output:

Using height defuzzification, the FLS recommends the urgency is 29.37.

Using centroid defuzzification, the FLS recommends the urgency is 31.23.

Input: temperature is 39, headache is 5, age is 65.

Output:

Using height defuzzification, the FLS recommends the urgency is 80.0.

Using centroid defuzzification, the FLS recommends the urgency is 79.99.

Case2:

Input: temperature is 37 (gaussian with a spread of: 2), headache is 3 (gaussian with a spread of: 2), age is 27 (gaussian with a spread of: 2).

Output:

Using height defuzzification, the FLS recommends the urgency is 33.80.

Using centroid defuzzification, the FLS recommends the urgency is 32.60.

Input: temperature is 39 (gaussian with a spread of: 2), headache is 5 (gaussian with a spread of: 2), age is 65 (gaussian with a spread of: 2).

Output:

Using height defuzzification, the FLS recommends the urgency is 58.37.

Using centroid defuzzification, the FLS recommends the urgency is 52.63.

3. Discussion, comparison, and reflection

By looking at the examples in Case 1 and Case 2, we can see that there are still significant differences between the two different models. Firstly, in terms of inputs, the former has three specific values entered in each of the three dimensions, while the latter has three intervals of values entered in each of the three dimensions. Even though the middle values of the numerical intervals in my control case two are the same as the

specific values in case one, the final output values of the two models are significantly different. It is not the case that the output values after their defuzzification are always smaller for the former than for the latter. Furthermore, when we take a closer look at the second example in Case 1 and Case 2, we see that the output in Case 1 seems to make a lot more sense compared to that in Case 2.

Based on these, for Type-1 fuzzy sets and systems, It is simple to implement and understand and highly interpretable, but has limited flexibility as they use single-valued membership functions that do not fully capture uncertainty, for non-singleton Type-1 fuzzy sets and systems, It allows for more flexible and dynamic membership functions, providing greater expressiveness and potentially improved performance, but they also present higher complexity and interpretability challenges.

In this design, the inputs of temperature, headache level and age are mostly presented as concrete values in real life, and together with the fact that the output values in the final case 1 seem more reasonable compared to case 2, Type-1 fuzzy sets and systems may be more suitable for this system in real life applications. In addition, I gained a deeper understanding of fuzzy logic systems in this design, which made me understand that uncertainty and fuzziness exist in many parts of life, and it was also very interesting to learn how to use uncertainty to simulate human emotions to make final decisions.

4. Reference

Sajobi, T.T., Amoozegar, F., Wang, M. et al. Global assessment of migraine severity measure: preliminary evidence of construct validity. *BMC Neurol* 19, 53 (2019).

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Nancy M. Petry, PhD, A Comparison of Young, Middle-Aged, and Older Adult Treatment-Seeking Pathological Gamblers, *The Gerontologist*, Volume 42, Issue 1, 1 February 2002, Pages 92–99, <https://doi.org/10.1093/geront/42.1.92>