COMP4033 Fuzzy Sets and Systems Assignment Report

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Section 1: Model Design Choices

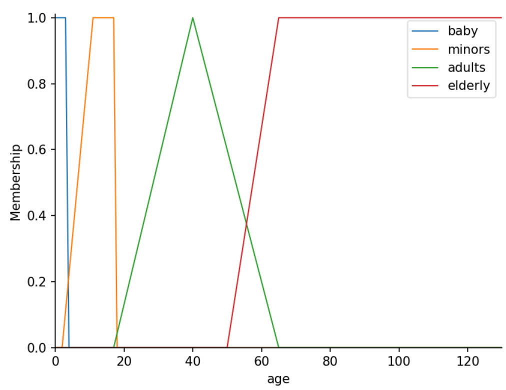
After reviewing the assignment brief, we made several key assumptions that helped guide the design of our fuzzy systems. These assumptions were further validated and refined through research, as outlined below.

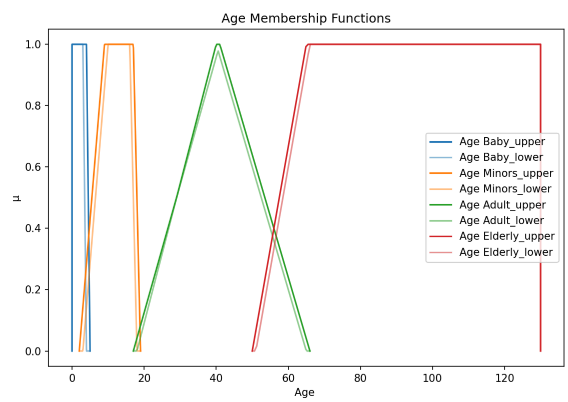
Input Models

Shown below are the MFs for our Type-1 and Type-2 systems. We kept the graph structures as similar as possible, adding appropriate margins between the UMF and LMFs to allow for interval inputs. We chose a safe margin of 0.5 to 1 between most of the UMF and LMFs, to try and make the data as accurate as possible whilst still remaining fuzzy. In some cases, we had to increase this margin in order to scale the system to handle larger intervals.

For all models, Left: Case/Type-1, Right: Case/Type-2

Age:





For age, we used the 4 MFs Baby, Minors, Adults and Elder as we felt that these groups were easily distinguishable and had varying levels of vulnerability to symptoms and illnesses. Babies and elders are more susceptible due to weaker immune systems, whereas minors and adults are generally stronger, differing in their tolerances slightly due to stages of development.

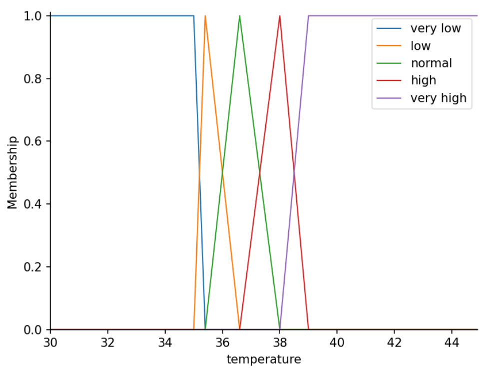
We used a half-trapezoidal MF to define ‘Baby’ with $\mu = 1$ at birth. Using NHS research, we set the age range for babies from 0-3, with μ gradually decreasing between 3 and 4 to ensure proper overlap with the "Minor" MF.

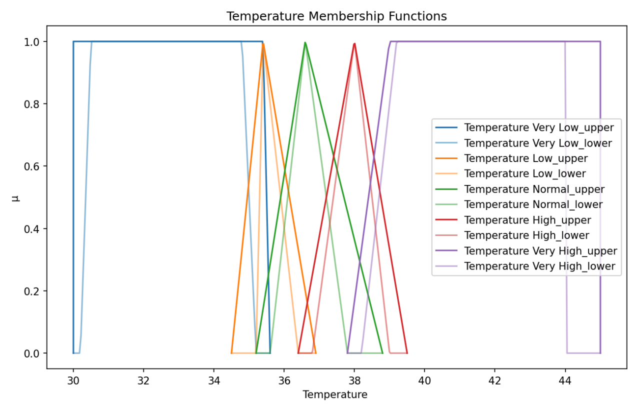
‘Minors’ is also trapezoidal, as we followed the UK legal adult age limit being 18 and over. Therefore ages between 3 and 18 have $\mu = 1$, with appropriate declines on either side to overlap with ‘Baby’ and ‘Adult’.

‘Adults’ is defined as a triangular MF, peaking at 40. We chose this peak by considering the average human lifespan being around 80 years old, concluding that peak adulthood would be around half of that age. Additionally, 41 was the median between 17-65, marking transitions between the neighbouring sets.

The ‘Elder’ MF is similar to ‘Baby’ as a half-trapezoidal. The State Pension age in the UK is 66 years old, so any age past that would have μ = 1 too. It starts from age 50 and reaches μ = 1 at 65 to show the decline in health as people age, impacting their resistance to symptoms.

Temperature:



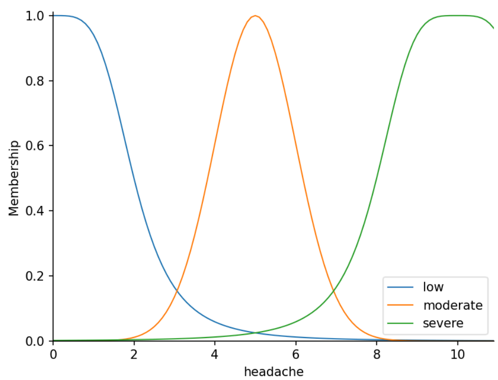


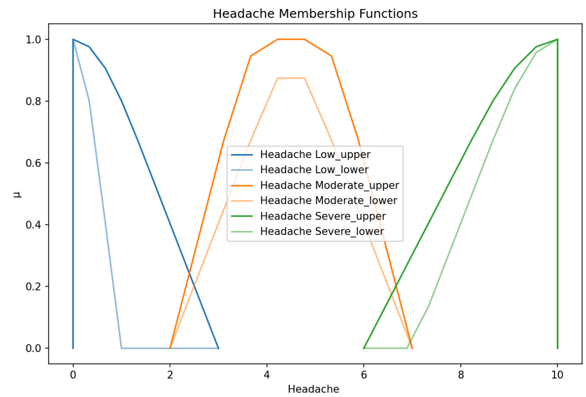
Temperature uses the 5 MFs ‘Very Low’, ‘Low’, ‘Normal’, ‘High’ and ‘Very High’. We wanted to ensure that we could differentiate between temperatures that were considered dangerous, enabling more precise rules definitions and ensuring patients with very high/low temperatures have a higher urgency than those who were more neutral.

We decided to use trapezoidal fuzzy sets to represent both ‘Very High' and ‘Very Low’, as once the temperature had passed a certain point, μ in either of these sets would remain 1.

For ‘Low’, ‘Normal’ and ‘High’, we used triangular MFs,using the NHS data to determine the peak for ‘Normal’, 36.6, and structuring the other MFs around that point. We considered using trapezoidal sets for ‘Low’ and 'High', however decided against it as the temperature intervals were not large enough to have μ plateau.

Headache





Headache Severity has 3 MFs, ‘Low’, ‘Moderate’ and ‘Severe’. We believed this input would represent the scale of pain of the headache, the length of time that they have had regular headaches for, and how often the headaches would return.

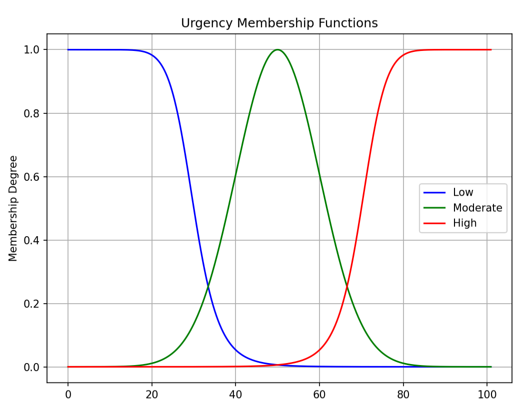
In Type-1, The ‘Low’ and ‘Severe’ MFs are generalised bell-shaped, as we felt that they handled the smooth transitions between extreme to ‘Moderate’ headache severities the best. ‘Low’ ranges from 0-3 and ‘Severe’ 6-10.

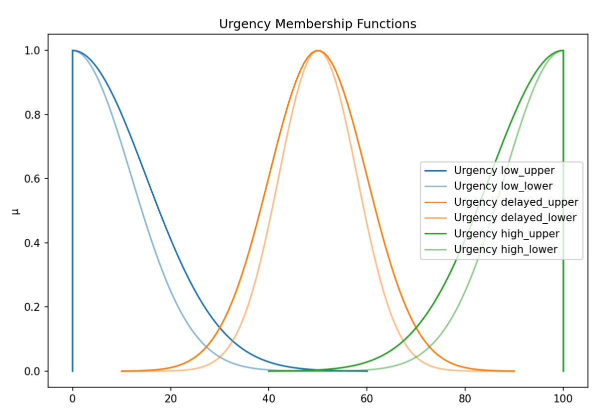
‘Moderate’ was a gaussian MF in Type-1, peaking at 5. We chose this instead of a triangular function as we again wanted the transitions between the MFs to be smooth, whilst still keeping a meaningful overlap to neighbouring MFs.

For our Type-2 system we used Gauangles for all MFs, as we believed it was better suited at handling the uncertainty of data with the inputs now being given as intervals.

<u>Output Models</u>

Urgency





Urgency uses 3 MFs ‘Low’, ‘Moderate’ and ‘High’ to determine what advice the doctor could give.

We believed ‘Low’ should be when $\mu < 33$, encouraging a user first to undergo home remedies before getting checked out professionally.

$33 <= \mu <= 66$ signifies ‘Moderate’, where advice may be to request for an appointment at a GP at a later date. It implies that the user is unwell enough to be checked out professionally, however not enough for them to be seen urgently.

‘High’ is when $\mu > 66$, and should be treated as an emergency, where patients would be advised to go to hospital as soon as possible.

Structurally, Urgency was designed similarly to Headache Severity, with two generalised bell shaped functions and one gaussian function. We believed that this again displayed smooth overlaps between the MFs.

Fuzzification/Defuzzification Approach

For Case 1, we used the ‘skfuzzy’ library to fuzzify the crisp inputs and return their degree of memberships. Case 2 used interval inputs, which required us to create Upper and Lower MFs for each input and work out the degrees of membership for both limits, accommodating the ‘uncertainty’ of the data. We learned and implemented the ‘Juzzy’ Python library to execute this approach.

To defuzzify our output in the Type-1 system, we used centroid defuzzification to calculate a center of gravity under the FS curve and return a crisp value. In Type-2, we used Center-of-Sets in defuzzifying both the outputs of the UMF and LMFs and then combined them to obtain a single crisp value that reflects the degree of membership to an urgency fuzzy set influenced by both bounds of the fuzzy intervals.

Section 2: Rulesets and Test Cases

Full Ruleset

We have applied the same ruleset across both Inference Systems in order to keep them as similar as possible for comparability. Our rules are comprehensive across all situations, and take into account real life scenarios and some brief research conducted on the vulnerability of different groups of people.

Both systems use the ruleset in similar ways, using the minimum membership between two antecedents with the AND logic rules, and maximum membership with the OR rules, however the Type-2 system has to evaluate both the UMF and LMF values against the ruleset so that it is able to capture the uncertainty of the input data. Additionally, a product is created from the UMF and LMF memberships to combine them into a crisp value.

High Urgency

We believed that cases where any symptoms are of an extreme nature should immediately be classed as urgent, then we considered that babies and elderly are more vulnerable and should be admitted with lower conditions. Adults and minors must have a reasonably abnormal level in both conditions to go to the hospital.

- **IF** (Temperature = VERY HIGH **OR** Temperature = VERY LOW) **OR** (Headache = SEVERE) **THEN** High Urgency

- **IF** (Age = BABY **OR** Age = OAP) **AND** **(**(Temperature **=** HIGH **OR** Temperature **=** LOW**)** **OR** (Headache = MODERATE)) **THEN** High Urgency

- **IF** (Age = MINOR **OR** Age = ADULT) **AND** (Headache = MODERATE) **AND** (Temperature = HIGH **OR** Temperature = LOW) **THEN** High Urgency

<u>Moderate Urgency</u>

Due to their vulnerability, we believe that babies and the elderly should make an appointment with the GP, regardless of condition. Minors are prioritised slightly more than adults due to their stage of development.

- **IF** (Age = BABY **OR** Age = OAP) **THEN** Moderate Urgency

- **IF** (Age = MINOR) **AND** (Headache = LOW) **AND** (Temperature = HIGH **OR** Temperature = LOW) **THEN** Moderate Urgency

- **IF** (Age = MINOR **OR** Age = ADULT) **AND** (Headache = MODERATE) **AND** (Temperature = NORMAL) **THEN** Moderate Urgency

<u>Low Urgency</u>

Adults are better equipped to deal with milder conditions than any other age category.

- **IF** (Age = MINOR **OR** Age = ADULT) **AND** (Headache = LOW) **AND** (Temperature = NORMAL) **THEN** Low Urgency

- **IF** (Age = ADULT) **AND** **(**Headache **=** LOW**)** **AND** **(**Temperature = HIGH **OR** Temperature = LOW**)** **THEN** Low Urgency

<u>Results</u>

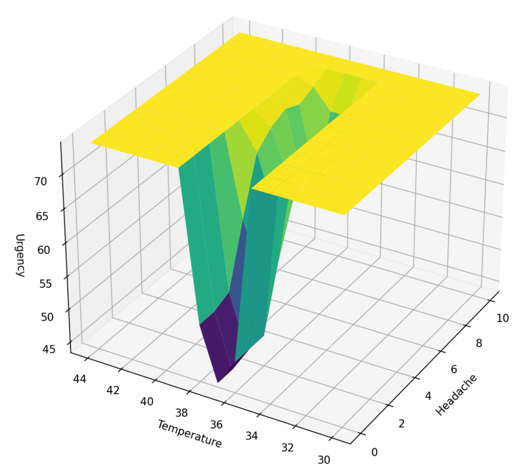
Below shows some of the test cases that we used whilst comparing the output values for the Type-1 and Type-2 systems:

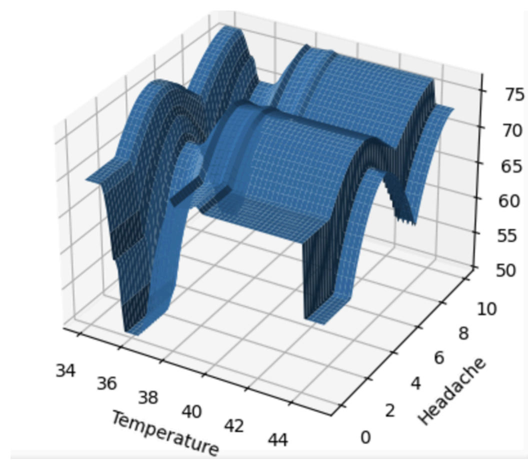
Inputs (Type-1 =	**Expected Urgency**	**Type-1 Urgency**	**Type-2 Urgency**

Integer, Type-2 = Interval)			
Headache: 5-9 (7) (Moderate - Severe) Temperature: 30-34 (32) (Very Low) Age: 45-49 (47) (Adult)	High	84.6932145785993 (High)	89.39963568889857 (High)
Headache: 8-10 (9) (Severe) Temperature: 36-37 (36.5) (Normal) Age: 13-15 (14) (Minor)	High	84.26502746342453 (High)	89.39963568889857 (High)
Headache: 0-2 (1) (Low) Temperature: 39-40 (39.5) (Very High) Age: 66-70 (68) (Elder)	High	69.40543302388423 (High)	70.79796978228102 (High)
Headache: 1-3 (2) (Low) Temperature: 37-37.5 (37.25) (Normal) Age: 3-5 (4) (Minor)	Moderate	36.80102753204957 (Moderate)	63.90032795323454 (Moderate)
Headache: 0-2 (1) (Low) Temperature: 36-37 (36.5) (Normal) Age: 67-72 (70) (Elder)	Moderate	52.90890351536238 (Moderate)	64.06351161574565 (Moderate)
Headache:0-2 (1) (Low) Temperature: 36-37 (36.5) (Normal) Age: 0-2 (1) (Baby)	Moderate	52.90890351536238 (Moderate)	56.48037361725761 (Moderate)

Headache: 0-2 (1) (Low) Temperature: 36-37 (36.5) (Normal) Age: 15-17 (16) (Minor)	Low	19.989820139409908 (Low)	27.705603869618837 (Low)
Headache: 0-2 (1) (Low) Temperature: 36-37 (36.5) (Low) Age: 45-51 (48) (Adult)	Low	17.186171621446846 (Low)	15.975631733693394 (Low)

Control Surfaces (Left: Type-1, Right: Type-2)





Section 3: Comparisons between Both Systems

Upon reviewing the control surfaces of both systems, it is reasonable to assume that the Type-1 system is not as sensitive to changes of data as the Type-2 system. This is because the surface is much more flat in comparison, implying that the output will remain the same even though the input may be changing. However, because Case 1 only takes singular inputs, it doesn't need to adopt such a volatile control surface as its crisp data allows for direct comparisons to the rule environment. In a medical context, it would not be desirable to have a system whose answers fluctuate heavily over minor input variances.

One of the most significant differences between the systems was the type of inputs used, with Type-1 taking integer inputs and Type-2 taking intervals. The advantage of using a type-2 to take interval inputs is it is capable of handling more 'fuzzy' and uncertain data, whilst the Type-1 system requires precise integer inputs in order to produce a meaningful output. Within a medical environment, accuracy is valued highly so the less noisy the input data is, the more reliable the output will be. In cases such as taking an age value, it is more likely that a patient's age will be known, taking away any need for an interval input. This can also be applied to measuring temperature, as a thermometer would be able to give an exact reading without any noise.

It could also be argued that subjective measurements such as headache severity would be better recorded as an interval variable, allowing answers to be more of a range of values. In cases where the patient has been experiencing discomfort for a period of time, their temperature could vary intermittently, leading them to provide an interval input. In this context, a Type-2 FIS may be more suited as a solution.

Another reason favouring the Type-1 FIS would be the difference in computational complexity compared to Type-2. Type-1 uses crisp MFs, which requires less calculations to compute as it will only perform membership calculations once. Type-2 uses fuzzy interval inputs, so it will have to evaluate rules against both the upper and lower MFs, doubling the computation time.

In summary, we believe that a medical environment would benefit more using a Type-1 FIS rather than a Type-2. This is because most of the measurements and data that a doctor would receive would be crisp and precise, therefore disregarding the need for interval inputs. Especially when the assessing of patients may be time-critical, it would be more reasonable to favour the solution that takes less time and resources to compute, further implying that a Type-1 system would be preferred.

Section 4: Self Reflection

During this assignment, collaborating with Akshay has been an excellent experience.We equally solved every step for both cases. Moreover, we arranged several meetings where we discussed all the issues we had throughout the coding and report parts. We compared and merged our own versions of the Type-1 and Type-2 into one clear logic which we then used to structure our approach. Generally, I would say Akshay was very supportive and was always able to help whenever I had any issues or questions.

Appendix

References

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