TDT4137 (Cognitive Architectures) Assignment Sheet 5

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1 Emergence

1.1 Complex adaptive systems

Task 1.1: Give two examples of complex systems. Explain how this is a complex system and why you think it is interesting.

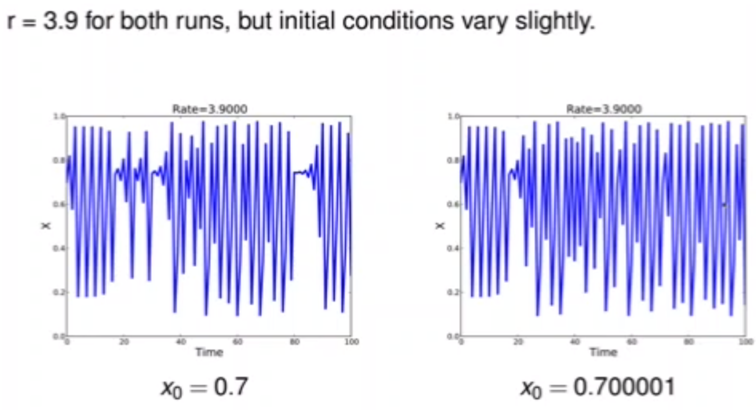
One example of a complex system is the brain. It is complex because it is comprised of a massive amount of small components, neurons, that behave quite simply (fire when excited), but due to the sheer amount of them, the brain is capable of doing basically any task it needs done. Another factor of why it is so complex is the fact that despite studying the brain for more than a century, and with all of the technological advancements that we as a species have achieved, we still don't understand fully how it works.

Another complex system is the internet. There are many many moving parts, that being the individual computers and the servers, the routers and switches and gadgets and gizmos, but they all are interconnected together, the world wide web emerges, giving people the means to contact each other and share information (among other things) almost regardless of distance.

The whole Idea of complex systems is that they comprise of a large amount of small unintelligent individuals, but highly intelligent behaviour emerges from these "societies".

Task 1.2: Plot two runs using the logistic map. Use these plots to explain sensitive dependence on initial conditions.

Didn't plot these myself, took them from Keith Downing's lecture:



Basically, the idea here is that a slight change in the initial conditions of such a system may impact the system in huge ways down the line of the systems evolution. The systems will diverge quickly from each other, and show completely different behviour in extreme examples.

Task 1.3: Explain the notion of "Edge of chaos".

A chaotic system is a system which does not exhibit any patterns or cycles in its behaviour. By changing the starting values of a system, the system may become more complex, and so by increasing the complexity of the system, the system will eventually become chaotic. Right before that happens is when the system is on the edge of chaos.

1.2 Emergence

Task 1.4: Explain Deacon's 3 orders of emergence.

1st. order of emergence: The type of emergence that's always present, such as temperature. Temperature is a property of particles moving, but it is always there, it doesn't emerge over time.

2nd. order of emergence: A typical positive feedback loop. The high level patterns that get created feed back into the lower levels, creating more constraints on the lower levels which creates more high level patterns e.g. self-organisation. After a while, the patterns die down and reach some sort of a stable pattern.

3rd. order of emergence: Involves some sort of memory which is created in the emergence process. This memory can then be used as a type of seed to recreate the emergence process. An example of this is DNA.

1.2.1 Boids

Task 1.5: optional Using the provided simulation code, implement separation, alignment, and cohesion as seen here. Add a screenshot to your delivery and add your code when you submit your assignment on blackboard.

bruh

Task 1.6: optional What happens when you have only separation, only alignment, and only cohesion? Provide screenshots and explain the phenomenon.

bruh

Task 1.7: optional Play with the parameters until you get a simulation with flocking that you think looks natural. Create a short gif and add this to the final delivery.

bruh

2 Reasoning under uncertainty

2.1 Deduction - Induction - Abduction

Task 1.8: Explain the difference between the 3 basic inference principles. Give examples for the use of each.

- **Deduction:** The process of using the rule in the knowledge base together with the cause to infer the effect.
- **Abduction:** The process of using the rule in the knowledge base together with the effect to infer the cause.
- **Induction:** The process of using the cause and the effect together to infer the rule which should be added to the knowledge base.

Deduction is often used in logic reasoning to infer some state based on percepts and what the system knows. An example would be in the Wumpus game, if there is a rule that states that a tile is smelly if it is adjacent to a tile with the Wumpus, and the system perceives that the tile it is in is smelly, then the system infers (deduces) that a Wumpus must be in one of the adjacent tiles.

An easy example of abduction is in medicine, where the doctor uses the symptoms of some disease together with their knowledge of desieses in general to infer what disease the patient has.

Induction is typically described as finding an explanation to some result from some action. This is typically used to infer rules to the knowledge base. An example might be when observing elephants, we observe that all elephants we've observed have trunks. We therefore infer that all elephants must have trunks.

2.2 Uncertainty

Task 1.9: Explain the main principles of Mycin's certainty factor

The certainty factor was a metric which showed how certain the system was of a certain outcome. All possible outcomes (based on input information and the rules in the knowledge base) would get a certainty factor, and if there were multiple certainty factors for the same outcome, they would be added together using this formula:

$$CF(x, y) = \begin{cases} X + Y - XY & \text{if } X, Y > 0 \\ X + Y + XY & \text{if } X, Y < 0 \\ \dfrac{X + Y}{1 \quad min(|X|, |Y|)} & \text{otherwise} \end{cases}$$

The certainty factors could have been negative as well, meaning that they would go against the belief that the outcome was correct. This addition is comutative, meaning that it doesn't matter which order the CF's were added together in.

Task 1.10: optional State and explain Bayes theorem. Why do you think this is widely used in artificial intelligence?

Bayes theorem states that the probability of some event happening given prior relevant knowledge can be calculated. I think it's widely used because it's accurate and empirical, and also because the math is not very complicated.

2.3 Fuzzy logic

Task 1.11: Explain in your own words the main idea of fuzzy sets, and the difference from traditional set theory.

Fuzzy sets replace probability with vague human language terms. This allows for some element to "partially" belong to a set, as opposed to traditional set theory where an element is either a member of the set, or not.

”*Everything is a matter of degree*” - The ”father” of Fuzzy Sets Lotfi Zadeh, 1994

Task 1.12: optional Give examples of domains where fuzzy sets can be useful, and explain why.

Can be useful in categorising some objects which don't have a clear distinction between them, f.ex, peoples' definitions of short vs average hight vs tall. Since all people have some subjective sence of what tall or short or average means, the classifications between all people surveied will differ drastically.

Task 1.13: Explain the concept of hedges in the world of fuzzy logic?

Hedges are used to finetune the vagueness of the variable in a sence. By squaring or cubing the value of some category, the category graph will change, becoming more "round" or "sharp". This means that some elements that were included into the category might not be included in that category as strongly anymore. Take a quick look at the lecture 9 recording 3 to see exactly what I mean with this (timestamp 25:27).

Task 1.14: Briefly explain the difference between mamdani-style and sugeno-style reasoning. When would you prefer one over the other?

Mandani style reasoning finds the space under each membership function in the set by using integration. Then the center of mass in that area is found, which denotes then the average level of membership between all parts that the element is a member of, thereby deducing where the member actually belongs.

Sugeno style reasoning does the same as mandani style reasoning, but instead of using integrals to calculate the area under the graphs it uses some constants that it calculates the weighted average between.

The mandani method is a lot more mathematically robust and more accurate, but also more computationally expensive, as integration is hard to do for computers. Sugeno method is a lot quicker and easier to compute, but also less precise.

2.3.1 Practical Fuzzy logic

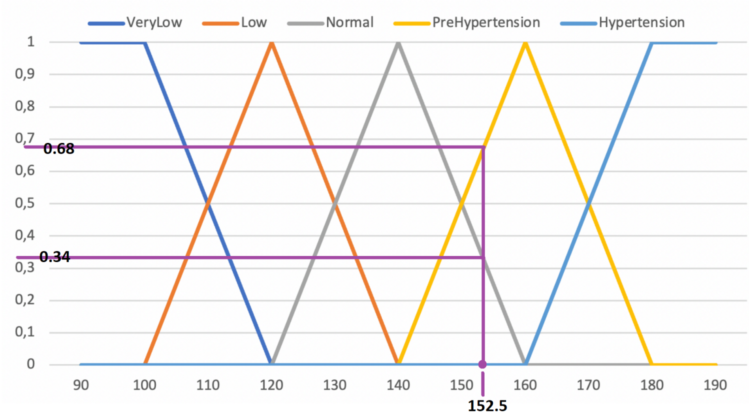
For simplicity, we assume the risk level is determined using the 5 rules shown below:

1. IF BloodPressure is Low AND RestingHeartRate is Excellent THEN RiskLevel is VeryLow
2. IF (BloodPressure is VeryLow OR BloodPressure is Low) AND RestingHeartRate is NOT Poor THEN RiskLevel is Low
3. IF BloodPressure is Normal AND RestingHeartRate is Average THEN RiskLevel is Medium
4. IF BloodPressure is PreHypertension OR RestingHeartRate is Poor THEN RiskLevel is High
5. IF BloodPressure is Hypertension THEN RiskLevel is Critical

Task 1.15: Using Mamdani reasoning, find out the risk level of a patient with BloodPressure = 152.5 and RestingHeartRate = 62.5. Show the steps and your reasoning.

I first fuzzify BloodPressure.

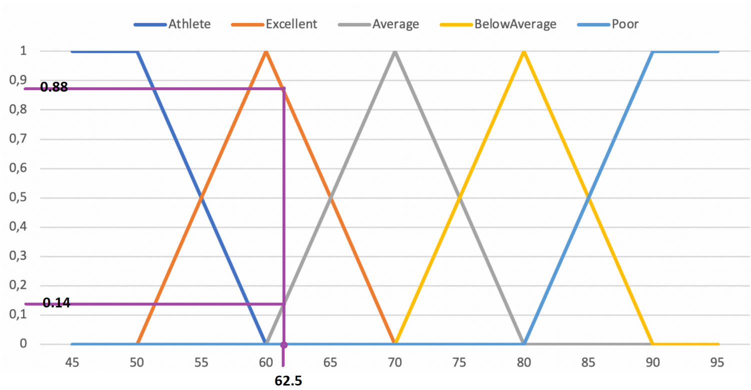
Blood Pressure:



I find that $\mu_{(BloodPressure=PreHypertension)} = 0.68$ and $\mu_{(BloodPressure=Normal)} = 0.34$

Then I fuzzify RestingHeartRate.

Resting hart rate:



I find that $\mu_{(RestingHeartRate=Excellent)} = 0.88$ and $\mu_{(RestingHeartRate=Average)} = 0.14$

Then I evaluate the rules.

IF BloodPressure is Low AND RestingHeartRare is Excllent THEN RiskLevel is VeryLow. Since this uses the AND, we have to take the least of the two values BloodPressure and RestingHeartRate. Since BloodPressure is not a member of Low, it's value is 0, meaning that the value for RiskLevel VeryLow is also 0.

IF (BloodPressure is VeryLow OR BloodPressure is Low) AND RestingHeartRate is NOT Poor THEN RiskLevel is Low. Here, the same is applied, since BloodPressure is not in either VeryLow or Low, the value for RiskLevel Low is 0.

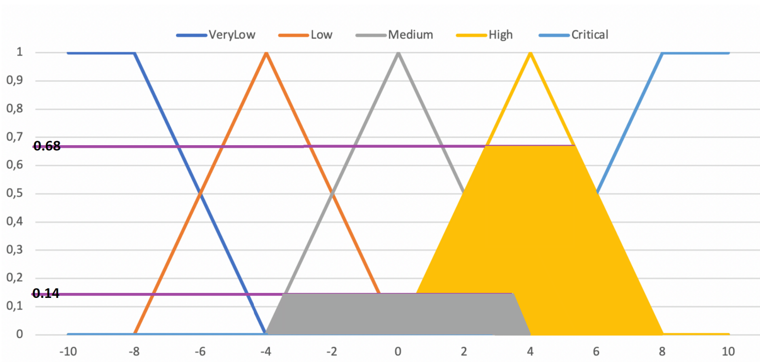
IF BloodPressure is Normal AND RestingHeartRate is Average THEN RiskLevel is Medium. BloodPressure is 0.34 in Normal and RestingHeartRate is 0.14 in Average. Since this rule uses AND, the lesser of the two values is assigned to RiskLevel Medium, which is 0.14.

IF BloodPressure is PreHypertension OR RestingHeartRate is Poor THEN RiskLevel is High. BloodPressure PreHypertention is 0.68 while RestingHeartRate is not a member of Poor, meaning it's 0. This rule uses the OR however, meaning the bigger of the two values is assigned to RiskLevel High, that being 0.68.

IF BloodPressure is Hypertension THEN RiskLevel is Critical. BloodPressure is not a member of Hypertension, meaning RiskLevel Critical is assigned to 0.

After aggregating the rule outputs, the chart looks like this:

<u>Risk level:</u>

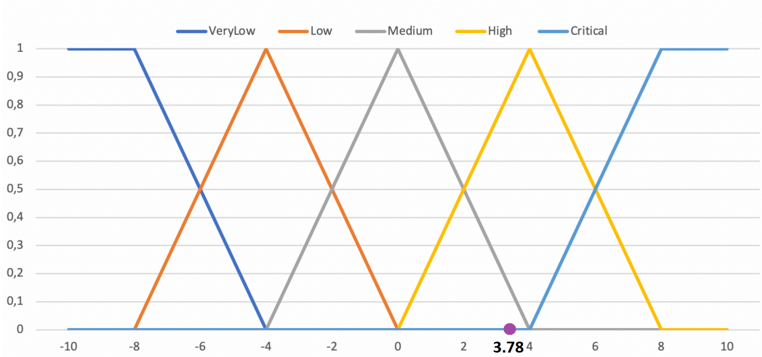


Computing the center of gravity:

$$COG = \frac{(-4 + (-2) + 0 + 2 + 4) * 0.14(0 + 2 + 4 + 6 + 8) * 0.68}{5 * 0.14 + 5 * 0.68} = 3.78$$

Putting the center of gravity value into the chart gives me the risk level of 3.78:

Risk level:



Task 1.16: Implement Mamdani reasoning using your favourite programming language.

I don't have a favorite programming language, so I cannot do this task.