CS4001 Report

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# Introduction

As a part of the course Fuzzy Logic & Control Systems we have created a control system that uses fuzzy logic. This control system is based upon the notion of an alarm but has also been thought about to be extended to a fully featured “wakeup system”. The difference is that the wakeup system helps you all the way until you’re fully awake. This could include things as the amount of coffee you get, the length of the shower and so on.

We did it because the idea was interesting enough and something where we thought we could incorporate what we had learned about fuzzy systems.

The Fuzzy system we created outputs favorable results that we think gives us a certain degree of confidence that it was worth using fuzzy logic. It was definitely worth using fuzzy logic because of the learning process, and the fuzzy nature of sleep, the human day and night cycle.

# Background

## Sleep

Sleep is something we all do, we all need to do it, but we really don’t know why we do it. It is a really fuzzy concept that is perfect for a fuzzy system.

Our sleep is affected by numerous of things. Most of these are highly individual, such as how much we need to sleep or how much movement every day is normal. While some are a little bit more universal, for example is it considered that everyone should eat at least three hours before bedtime to be able to fall asleep more easily.

The concept behind this system is that it should be used in a ‘connected’ (IoT) home. This wakeup system would be integrated with the rest of the house and be able to talk to for example the coffee machine, lights, and the car to make sure everything works to make the mornings as pleasant as possible.

## Usage of fuzzy logic

This problem is a good match for a fuzzy system because of the fuzzy nature of the problem (as described in previous chapter). There are no crisp values that can be used on such a personal system and every day is different from a systems point of view.

### TSK vs. Mamdani

We have chosen to use the Mamdani system for a couple of reasons. Firstly it’s the first system we got to play with and go through during lectures so also the one we feel most comfortable with. But the strong point for TSK and why it’s mainly used is its mathematical simplicity which makes it extremely fast. Since our system is designed to work while you sleep (and will therefore have several hours for computation) this isn’t really a problem we need to solve. TSK is excellent for real-time systems. But for us, the way we model the system and the preciseness is more important.

# Simulation / Model

## Inputs

### Last meal or drink

Linguistic values: Just now, some time ago, long time ago

Scale: 0-360

Description: The input value is the number of minutes since the last meal or drink was consumed. The membership function is based on data from Joy Bauer’s article “How Food Affects Your Sleep”

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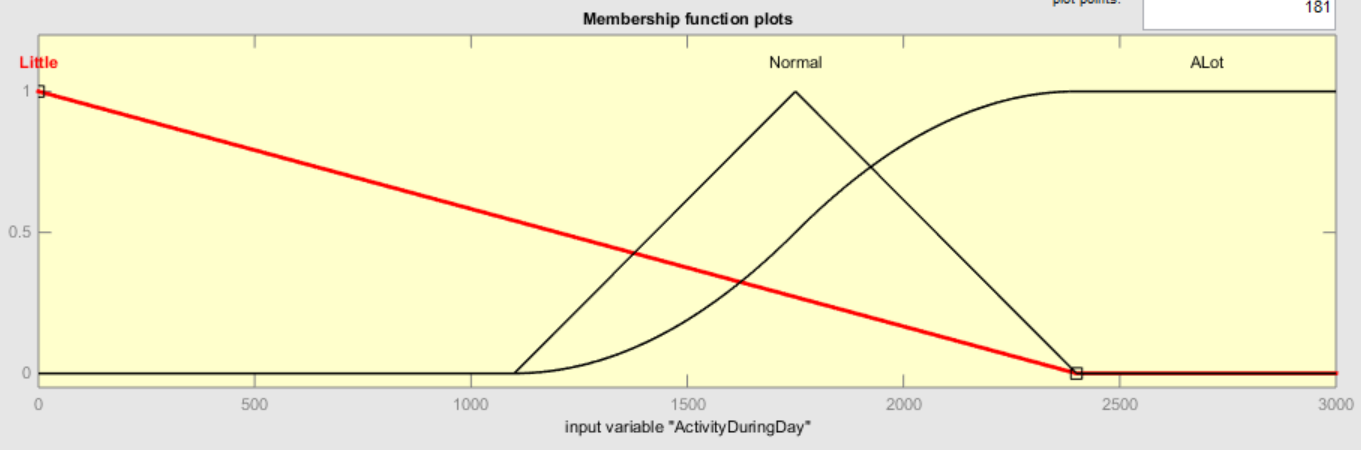
### Slept day before

Linguistic values: Little, Normal, A lot

Scale: 0 – 720

Description: The number of minutes that the ‘user’ slept the previous day. This data could possibly be from the systems logs of previous days, user input or some activity tracker. This membership function is based upon the group members own views of how much sleep is necessary for the different levels.

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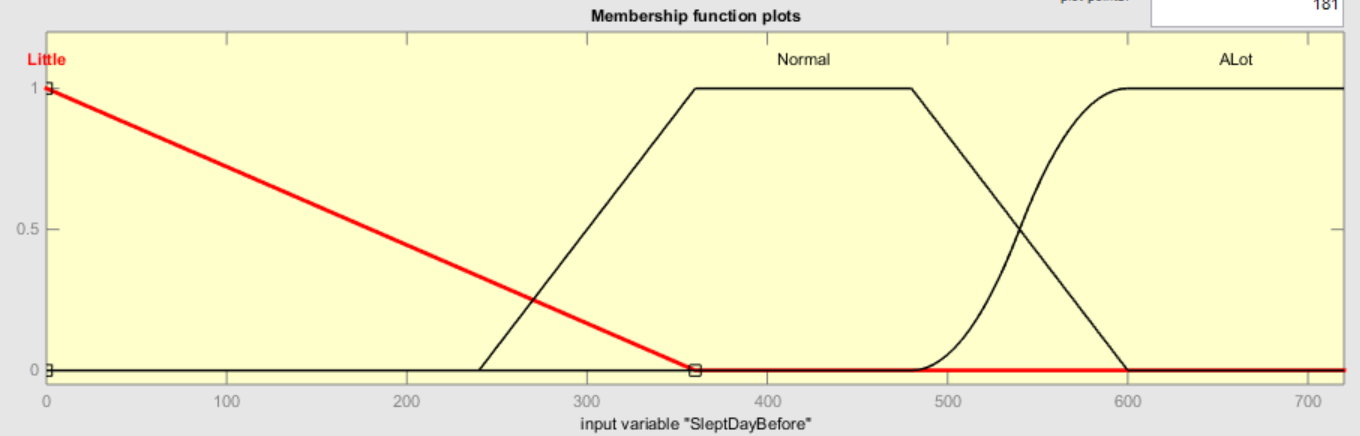
### Activity during the day

Linguistic values: Little, Nromal, A Lot

Scale: 0 – 3000

Description: How many calories were burnt during the day. (data from wearables). The membership function here is based upon the article by TODO!!!!

MF



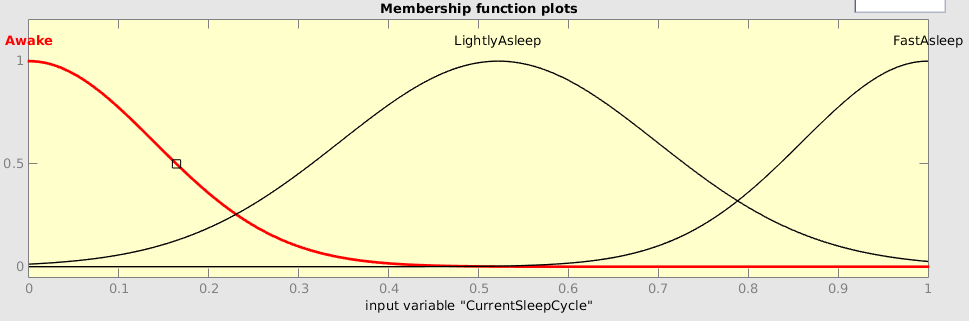
### Current sleep cycle

Linguistic values: Awake, Lightly asleep, Fast asleep

Scale: 0 – 1

Description: In which sleep cycle is the user currently? This data can be obtained using a number of methods. For once it could be extracted using some kind of wearable that could track heartrate and movement. But since sleep cycles are often very similar it could be calculated based upon when the user fell asleep.

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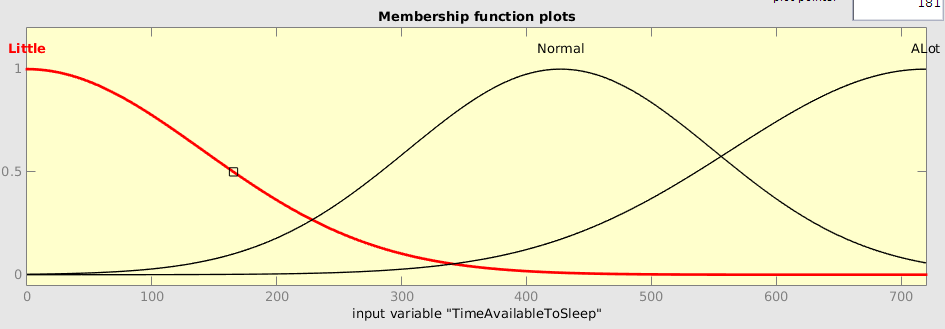
### Time to sleep

Linguistic values: Very little, Little, Avarage, More, Lots

Scale: 0 – 600

Description: In minutes, how long time there is available to sleep. This should be the number of minutes from that the user goes to bed to when the first meeting is about to start. This value is used as an absolute maximum in the system. A user can NEVER sleep more than the available time, what the system does is reduce this theoretical maximum so that the user will have time to eat and commute while still getting the proper amount of sleep.

MF



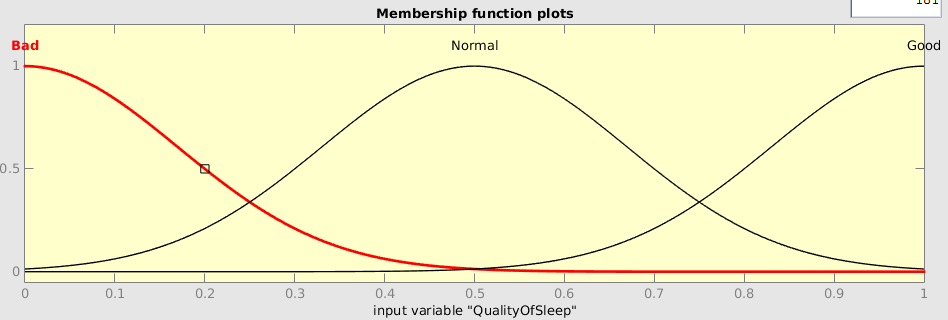
### Quality

Linguistic values: Bad, Normal, Good

Scale: 0 – 1

Description: What is the quality of the sleep? (Calculated by an external system). This is also a very fuzzy thing and should in real life be calculated by another fuzzy system, but since this isn’t real life we just assume a value for how good the sleep is.

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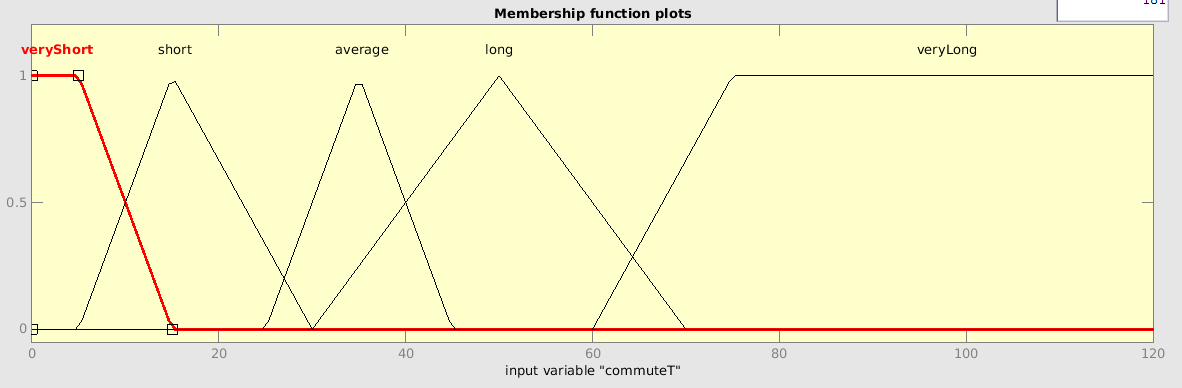
## Commute time

Linguistic values: Very short, short, average, long, very long

Scale: 0 – 120

Description: This is the commute time in minutes, aka how long it takes to get from door to door.

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## Rules

See appendix for full rule list. But here are some interesting rules:

TODO!

## Defuzzification methods

We used the Centroid method to defuzzify the output from the different systems. No aggregation was required since all outputs where either used as input to a new system or as the final output.

## Outputs

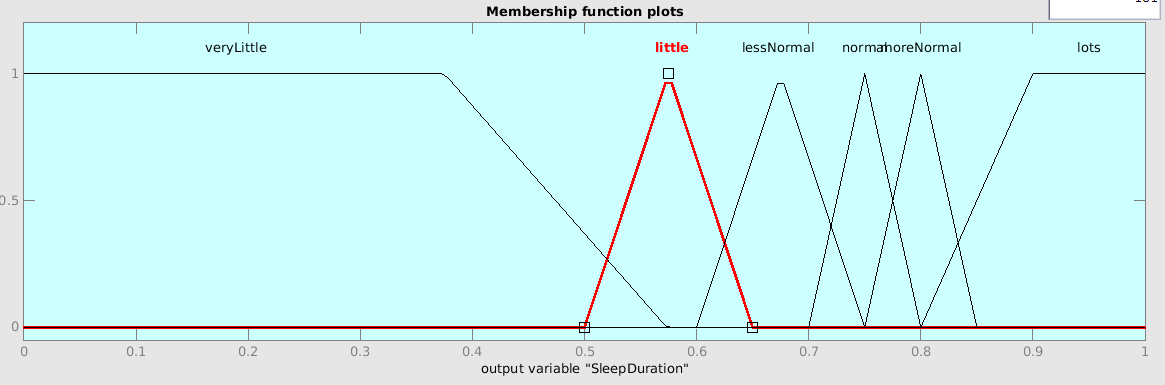
### Sleep Duration

Linguistic values: Very little, little, less normal, normal, more normal, lots

Scale: 0 – 1

Description: This output is a multiplier that should get multiplied to the time to sleep to get the total minutes that the user should sleep to still be able to have time to commute, get dressed and eat breakfast.

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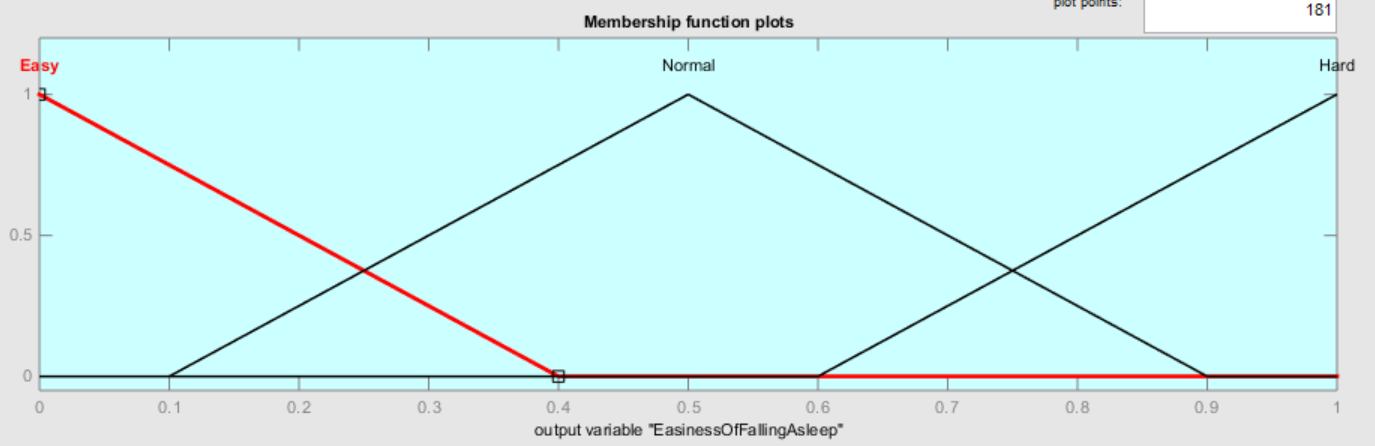
### Easiness of Falling Asleep

Linguistic values: Easy, Normal, Hard

Scale: 0 – 1

Description: This output tries to explain how easy it was to fall asleep. This will affect how soon the user fell asleep and therefore also how much time the user will be able to sleep until it’s time to wake up.

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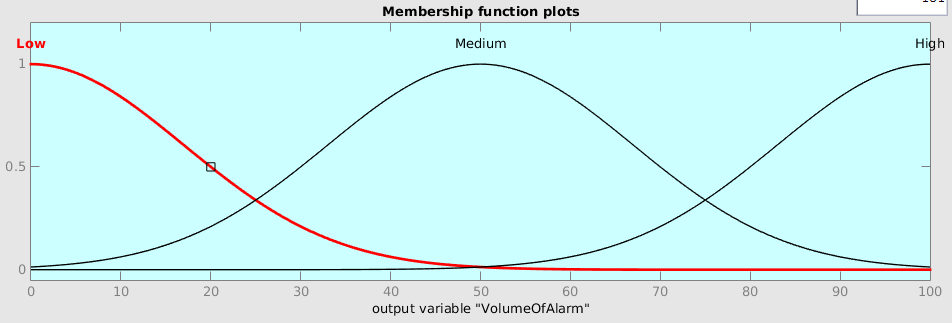
### Volume of alarm

Linguistic values: Low, Medium, High

Scale: 0 – 100

Description: This output is basically the volume knob on the alarm clock. 0 is the same as mute, 100 is the same as “ouch”.

MF



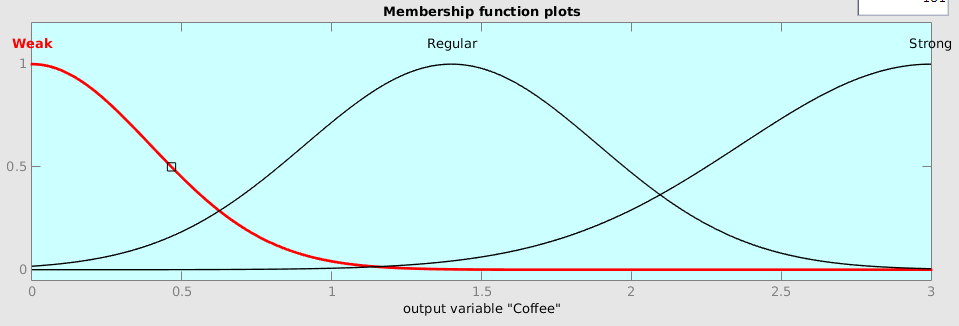
### Strength of Coffee

Linguistic values: Weak, Regular, Strong

Scale: 0 – 3

Description: This output describes how many shots of coffee the user should be given. Is used to make sure that we give the user as little coffee as possible but still let them have that feeling of alertness and energy that coffee can help with.

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# Results & Analysis

## Results

### Example runs

### Screenshots

## Evaluation

The results are actually surprisingly good. Provided input data and examining the output will in most cases provide a reasonable wakeup time. However we’ve had to jump through some loops to make it all work, distort some amplifiers to make it work more as the real world. Something that would have been a better solution would have been to instead of having the commute time as input just subtract the commute time from the output time. Since the commute time isn’t generally fuzzy but a crisp value based on how long it takes for the bus/car to get to the meeting. (you could argue it’s fuzzy because a ‘long’ commute can be different things for different people but still be different time, but I’m not going to get into that discussion right now [maybe do get into the discussion?])

Since our output “easiness of falling asleep” is an amplifier being used as a percentage value we have a very clear and consistent output membership curve. Some other data might also need a bit of an explanation.

We decided to use the value “time to sleep” instead of “time of alarm” after several discussion about the advantages with the two different kinds of values. We settled with time to sleep because it’s more easy work with and doesn’t require any extra steps to figure out if that’s a long nights sleep or not.

# Conclusions

Was a fuzzy solution justifiable?

Yes, a fuzzy solution was in this case definitely justifiable because of the fuzzy nature of the problem. A crisp system would have problems with different people and would therefore most probably be designed for a “normal” person. Since our system is fuzzy it will still be able to handle people that are outside the normal bounds in let’s say sleep pattern or calories burnt per day.

References

Engelmore, R., and Morgan, A. eds. 1986. *Blackboard Sys­tems.* Reading, Mass.: Addison-Wesley.

<http://sleepfoundation.org/how-sleep-works/how-much-sleep-do-we-really-need/>

<http://www.joybauer.com/insomnia/how-food-affects-sleep.aspx> - Summary: eat at least three hours before bedtime. Eating just before might keep you awake

<http://www.webmd.com/sleep-disorders/features/cant-sleep-adjust-the-temperature> - Summary: You should have the room a little bit colder when you sleep. But at a comfortable level ☺

<http://www.thedietchannel.com/AskTheExpert/dieting-weightloss-obesity/Calories-Whats-an-ideal-daily-intake.htm> - Summary: We should eat 3 meals and 2-3 snacks per day. 400-600 calories per meal for men, 300-500 for woman and 100-200 calories per snack. This makes the “normal” span between 1100 to 2400

# Appendix

## Rules

TODO