CS4001 Report

Fuzzy Wakeup System

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Contents

1 Introduction

This report details a Fuzzy Logic Controller we have designed to provide users with an intelligent alarm. This was done as a proof of concept to show how the future of highly connected devices (phones, lights, thermostats etc.) in an Internet of Things (IoT) type configuration could contribute to more personal, useful technology - in this case by helping the user wake up feeling more ready for their day whether they've had a 10-hour sleep-in, or have been working all night and only got 3 hours sleep.

To an extent the fuzzy system implemented has worked - in our test cases the fuzzy system adjusted the user's wakeup times in ways which intuitively made sense.

I believe it was appropriate to use fuzzy logic for this problem, as sleep is a vastly complex process with many contributing factors - in order to capture the heuristic knowledge of what constitutes "a good night's sleep", fuzzy logic is well suited.

The theory behind the methods applied are mainly sourced from CS4001's course notes [1], and supplemented by [4].

2 Background

Sleep is a complex and necessary activity undertaken by everyone, but it is not fully understood scientifically - it's not clear why we need to spend about a third of our lives unconcious; however as anyone who has had a bad night's sleep will know, it's effects are clear, and many rules of thumb exist on how to get a good night of sleep.

Knowing the importance of sleep, and the effect it can have on our ability to function throughout the day, we have attempted to create a fuzzy logic system which can help people better manage what we think is the hardest part of sleeping - waking up - while also improving how rested they feel after through control of alarm timing, alarm volume and an (imagined) networked coffee machine.

I believe a fuzzy logic controller (FLC) is well suited to this task, given the complex, subjective nature of sleep and what exactly defines "a good night's rest". We have approached this from the point of view of capturing expert knowledge by utilizing our own heuristic knowledge of what we feel contributes to a good or poor night's sleep.

A Mamdani system was developed, which was defuzzieified with the Centroid method, as the application does not need to respond within a tight control time period, and requires an accurate response for small changes in inputs.

While it may seem that some of the inputs may be unusual or inaccessible to a (for example) smartphone, my personal view on this system would be that it could act as the decision system working in a highly connected Internet of Things (IoT) style system; where your coffee machine could be as aware of your next meeting as your phone's calender. With increasing connectivity in our everyday devices, a wealth of personal data and tools is becoming available to developers to help create highly intelligent systems which are deeply rooted into our daily activities, such as the intelligent wakeup system proposed here.

When it is considered that a common method for determining quality of sleep is a highly subjective test called the Pittsburgh Sleep Quality Index (PSQI) [2], developed in the late 80's and still in use (e.g. [3]), which produces an output after a month of self-assessed questionnaires - I believe that Fuzzy systems which can collect large amounts of user data over a duration of time could provide great improvements in sleep analysis with much reduced cost and effort for widespread use.

3 Simulation / Model

When we first set out to develop our model, we spent time considering as many potential factors which could influence sleep, and the types of inputs which would contribute to them.

This step resulted in 25 factors, each with their own term set, which could influence the sleeping process. Analysing these further, it could be seen that these factors could be grouped into 3 catagories - factors external to the user (e.g. the time of their first meeting
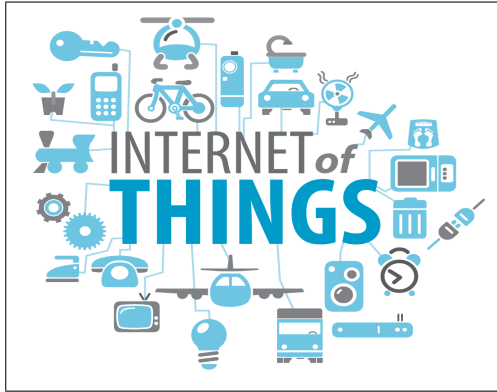
1

Figure 1: Internet of Things: Present and near future technologies consisting of networked sensors and devices. (*From: blog.surveyanalytics.com - Jan' 2015)*

the next day, or their commute time) - Factors internal to the user (e.g. the time since their last meal before bed or the amount of exercise they had that day) - and then factors which influence the ease of waking up (e.g. the amount of light that's in the room, or the user's current sleep cycle).

We determined 25 factors was far too many to attempt to model for this project, and acknowledged it was unlikely to even be an exhaustive list of factors which contribute to sleep, so instead agreed to develop a proof-of-concept by selecting some key factors from the 3 catagories and making reasonable assumptions where required.

We decided to split our control system into 3 subsystems to help deal with the complexity, and these 3 categories helped to define the fuzzy subsystems implemented.

A fuzzy subsystem was made for determining how easy it is for the user to fall asleep, a fuzzy subsystem was made for determining how long the user should sleep for, and finally a fuzzy subsystem for determing how the user should be woken up by the alarm system such that they start the day feeling alert.

System Architecture

In Figure 2, 3 fuzzy subsystems can be seen. As mentioned, these subsystems operate in a somewhat chronological order, with the 1st subsystem determining the user's ease of falling asleep, the 2nd subsystem determing how long the user is able to sleep for, and the 3rd subsystem determining how the user should be woken up.

The output from the 1st subsystem is used as an input for the 2nd subsystem, the 2nd subsystem's output determines the user's wake up time, and the 3rd subsystem determines the volume of the alarm and the strength of coffee which should be prepared for the user.

Each subsystem is a fuzzy logic system with 3 inputs. The 1st and 2nd subsystem produce one output. The 3rd subsystem produces 2 outputs.
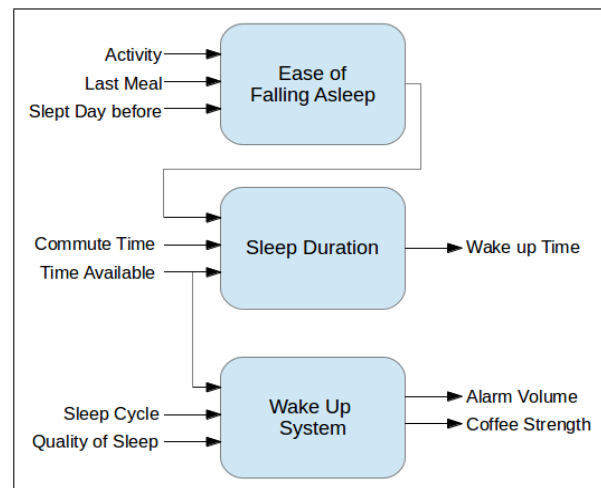

Figure 2: Fuzzy Wakeup System Architecture

Subsystems

Below are lists of the subsystems' inputs and outputs, with their term set and the reasoning behind the input.

Images of these subsystem's membership functions can be found in the appendix.

Subsystem 1

Inputs

- Activity during the day
    - *Little, Normal, A lot*

– Scale: 0 - 3000 calories, based on average guidelines as seen on food packets.

– Assumption: A person who has had a lot of physical activity throughout the day will find it easier to fall asleep.

– There is smart technology available now and being further developed to estimate activity, so we feel this is reasonable information to assume we can access.

- Last meal or drink

  – *Just Now, Some Time Ago, Long Time Ago*

  – Scale: 0-300 minutes, heuristic estimate

  – Assumption: This is a rather complex input, as different foods may affect people in different ways relating to sleep; however we have assumed here that it is difficult to fall asleep if you have gone to sleep hungry.

- Slept day before

  – *Little, Normal, A Lot*

  – Scale: 0 - 720 minutes, based on heuristic estimate.

  – Assumption: Someone who has slept little the night before will find it easier to fall asleep the following night.

Output

- Easiness of Falling Asleep

  – *Easy, Normal, Hard*

  – Scale: Unit Interval [0, 1]

  – Assumption: This output attempts to quantify the user's ease of falling asleep as a percentage, for use in other systems.

  – This output is a highly complex concept, for which there would be many other contributing factors, such as the user's mental or physical health.

Subsystem 2

Inputs

- Ease of Sleep

  – *Easy, Normal, Hard*

  – Scale: 0 - 1

  – Assumption: If it is likely the user will find it difficult to fall asleep, then less of the available time will actually be used for sleeping.

- Commute Time

  – *Very Short, Short, Average, Long, Very Long*

  – Scale: 0 - 120 minutes, heuristic estimate

  – Assumption: The longer the commute time, the less sleep the user will be able to have. Additional terms were used here to provide more intuitive responses.

- Time Available to Sleep

  – *Very Little, Little, Average, More, Lots*

  – Scale: 0 - 600 minutes, based on heuristic estimate.

  – Assumption: This input is the amount of time the user has available from when they go to bed, up to when their first meeting/appointment must happen (i.e it includes the time for getting dressed, commuting, etc.).

  – It is also assumed that the time the user went to bed can be inferred from a sufficiently intelligent connected device, or the user indicating that this is the case.

  – This is a **key input** for determining how long the user will be able to sleep and acts as a theoretical maximum - the other factors act to reduce the time available.

Output

- Sleep Duration

    - *Very Little, Little, Less Normal, Normal, More Normal, Lots*
    - Scale: Unit Interval [0, 1]
    - Assumption: This output is used to determine what percentage of the Time to Sleep can actually be used for sleep (i.e. an application would multiply this output by the Time Available to Sleep input to get a final value).
    - It is intended that the output from this stage would set the time of alarm to allow the user time to get dressed, and time to commute to their first meeting.

Subsystem 3

Inputs

- Time Available to Sleep

    - *Little, Normal, A Lot*
    - Scale: 0 - 720 minutes
    - Assumption: If the user does not have a lot of time to sleep, they may need a strong coffee to make them feel alert in the morning.

- Current Sleep Cycle

    - *Awake, Lightly Asleep, Fast Asleep*
    - Scale: Unit interval [0,1], heuristic estimate
    - Assumption: When describing sleep intuitively, it can broken into roughly these 3 stages, and it is assumed that a person who is fast asleep will require a louder alarm to wake them up.
    - Many current technologies have implemented smart alarms which attempt to estimate the user's current sleep cycle by measuring how much they are moving (e.g. by using a smart phone's accelerometer), so we feel it is not unfeasible to assume we could get access to this information.

- Quality of Sleep

    - *Bad, Normal, Good*
    - Scale: 0 - 1, heuristic estimate.
    - Assumption: This input is the vaguest of all inputs to our system, and estimation of it's value would ideally use a fuzzy subsystem of it's own; however we have chosen to use an assumed input for this to constrain the complexity of our project.
    - In an ideal system, this would indicate the user believing they did (or didn't) have "a good night's sleep", and help us craft actions to help them when they wake up (e.g. adjustment of lighting in the room).
    - This information could also relayed to the user to help identify good sleep related behaviours.

Outputs

- Volume of Alarm

    - *Low, Medium, High*
    - Scale: 0 - 100, arbitrary scale as found on radios with 0 being no sound and 100 being maximum volume.
    - Assumption: This output's goal is to ensure the user is woken by the alarm, without causing excessive distress (i.e. someone in a deep sleep may require a loud alarm, but someoneon in a light state of sleep would not).

- Strength of Coffee

    - *Weak, Regular, Strong*
    - Scale: 0 - 3 spoons of coffee/shots of espresso
    - Assumption: This output's goal is to help ensure the user is awake and alert after they wake - someone who has had a poor night of sleep may require an additional "boost" in the morning compared to someone who is well rested.

Fuzzy Rulebase

The general effects of each input was described in the previous section; however selected key rules are provided in the appendix.

The rules for subsystems 1 and 2 were constructed by determinging the appropriate output for each permutation of their 3 inputs, resulting in 27 rules each.

The rules for subsystem 2 were constructed by determining the appropriate output when pairs of inputs were consider, i.e. what would the appropriate output of Input 1 + Input 2 be, and what would be the appropriate output of Input 1 + Input 3 be? This approach, combined with the additional terms in some of the inputs' term sets resulted in 3 fuzzy patched relationships, with 54 rules. Tables which detail these rules are shown in the appendix. It was found that some rules relating to the commute time needed weighting to reduce the consequent effects on the subsystems outputs, as small changes were having too large effects. An alternative approach could have been attempting to term set subnormal. It is believed that further system tuning could reduce this effect.

As mentioned, there was no significant timing requiements, but there was a requirement for accuracy so the defuzzification for each subsystem was achieved with the Centroid method. No defuzzification was required for the overall output of the system, as the subsystems interacted by providing inputs to other subsystems, rather than aggregating to an overall output.

Key rules are described in the appendix, with the descriptions of key rules provided by their creators (Subsystem 1: Miiro, Subsystem 2: Sena, Subsystem 2: Ruder).

The resulting Fuzzy surfaces can also be found in the appendix.

4   Results/Analysis

Testing involved the creation of some imaginary test users, each with a particular type of persona.

The 3 users lifestyles could be described as: An average student (AS), A "work-hard-play-hard" (WHPH) buisnessperson, and finally a sedate commuter (SC).

The full results table is shown in the appendix, but let us discuss the Work-Hard-Play-Hard lifestyle case for an example of the results.

This case attempts to simulate the type of user who could be described as a workaholic, centering their lives around their job by living close to the office and working late into the night before an early start the next day.

For subsystem one, our inputs are:

- Last meal: 15 minutes - a late meal after work.

- Slept day before: 4 hours

- Activity during day: 3000 calories - a lot of walking around

This results in an output "easiness of falling asleep" of 0.166 (the lower, the easier). This intuitively makes sense, it is easy to imagine how working at this pace could result in falling asleep very quickly when you eventually made it to bed.

For substem two, our inputs are:

- Commute time: 20 minutes - living close to work

- Ease of Sleep: This input is the output of subsystem 1

- Time Available to Sleep: Assuming a 7AM start, and a bed time of 2AM, this person has a theoretical maximum of 5 hours (300 minutes) available to sleep (ignoring other activities such as commuting, getting dressed, etc.).

This results in an output "Sleep Duration Modifier" of 0.867, meaning they can only sleep for about 87% of the theoretical maximum time available. This indicates they will get roughly 4 hrs 20 mins of sleep, leaving them with 20 mins to get ready before their 20 min commute. Intuitively this result appears to make sense.

For subsystem three, our inputs are:

- Current sleep cycle: 0.9 - Due to exhaustion, it is assumed the body will be in a deep sleep

- Time available to sleep: As before, we take the theoretical maximum of 300 minutes

- Quality of sleep: 0.4 - Somewhat normal due to exhaustion; however not great due to lifestyle.

This results in an output alarm volume of 83 (Medium-High), and a coffee strength of 2.34 shots of espresso. Again, this intuitively makes sense given their deep sleep state, and the short low quality rest they are getting.

One issue encountered was that in an attempt to limit the number of rules implemented, we limited the number of fuzzy subsets implemented for each linguistic primary term; which in some cases resulted in un-smooth responses, or overcompensation for changes in the input.

5 Conclusions

Overall, our Fuzzy wake up system appears to be able to provide reasonable wake up times, as seen in the results table.

I believe that our results demonstrate the potential for fuzzy logic systems to be highly useful in the near-future technological landscape of highly-connected devices, where technology will be able to help us in our day-to-day lives in more ways.

The key advantage gained in using an application based on our fuzzy logic system, over a traditional alarm, is that it evolves from being a simple clock tool to being more like a personal assistant which attempts to understand the user's lifestyle, in order to ensure appointments are kept (the user would not necessarily need to manually set alarm times and factor in things like commute times) and to try help the user feel alert when they wake (intelligent alarm functions like adaptive volume control, and household intelligence such as automated coffee).

Given the complexity and subjectivity of the factors which affect the whole sleeping process, I believe that the approach of applying fuzzy logic was highly justified. Given the size of the problem being addressed, I believe it is also true to say that further expansion and improvement of this system is possible using fuzzy systems.

References

[1] Khurshid Ahmad. CS4001. *Trinity College Dublin*, 2014.

[2] D.J. Buysse, D.J., Reynolds, C.F., Monk, T.H., Berman, S.R., & Kupfer. Pittsburgh Sleep Quality Index (PSQI). *Psychiatry Research*, 28(2):193–213, 1989.

[3] S Lemma, Y Berhane, A Worku, B Gelaye, and M A Williams. Good quality sleep is associated with better academic performance among university students in Ethiopia, 2014.

[4] Michael Negnevitsky. *Artificial Intelligence: A Guide to Intelligent Systems*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 1st edition, 2001.

6 Appendix

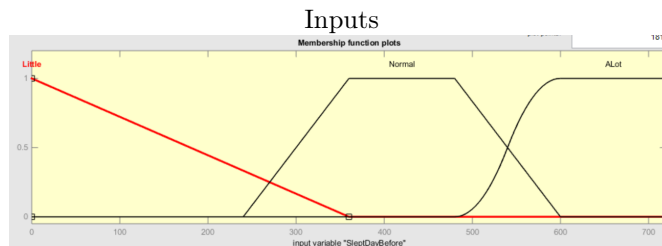## 6.1 Membership Functions

Subsystem 1

Inputs
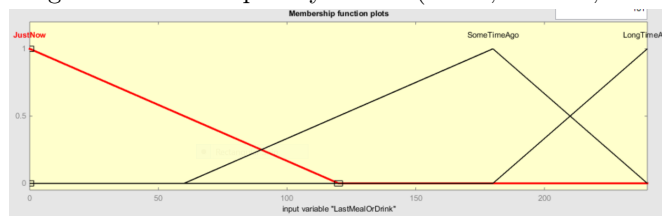

Figure 3: Time Slept Day Before (Little, Normal, Alot

Figure 4: Time Since Last Meal (Just Now, Some Time Ago, Long Time Ago)

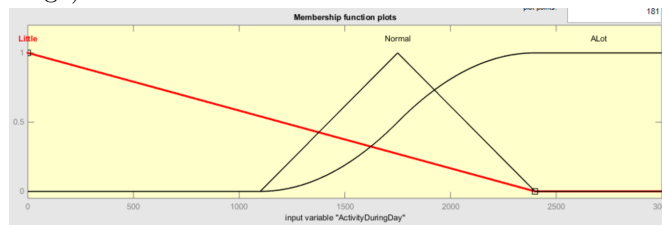Figure 5: Amount of Activity During the Day (Little, Normal, A lot)
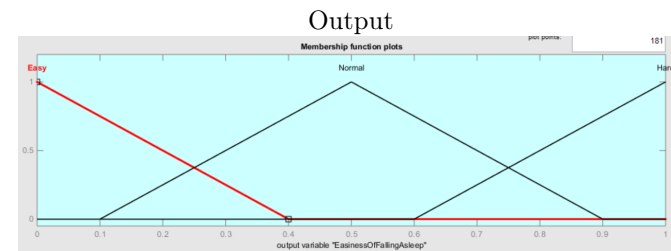
Output

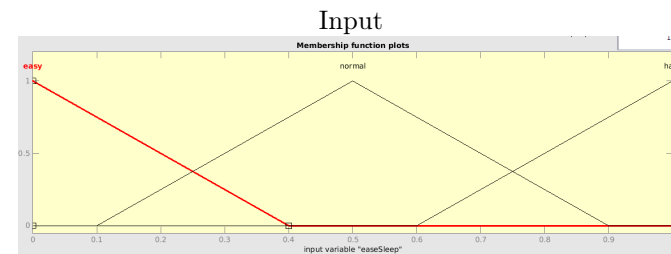Figure 6: User's Ease of Falling Asleep (Easy, Normal, Hard)

Subsystem 2

Input

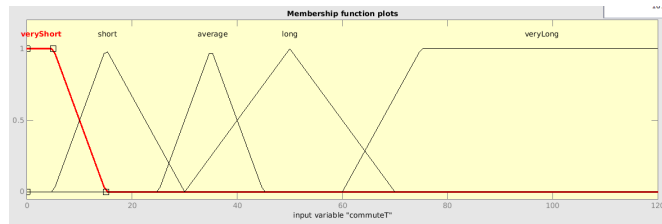Figure 7: Ease of Sleep (output from Subsystem 1) (Easy, Normal, Hard)

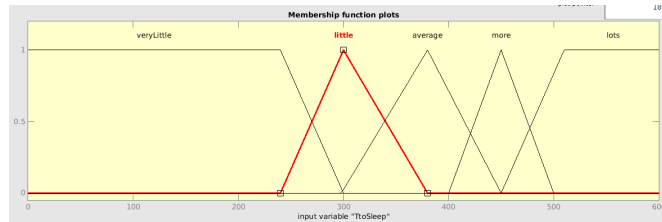Figure 8: Expected Commute Time in the Morning (Very Short, Short, Average, Long, Very Long)

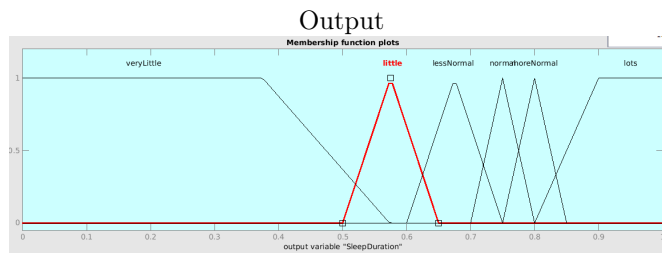Figure 9: Theoretical Maximum Time Available to Sleep (Very Little, Little, Average, More, Lots

Output

Figure 10: Sleep Duration (as a percentage of the theoretical maximum) (Very Little, Little, Less Normal, Normal, More Normal, Lots)
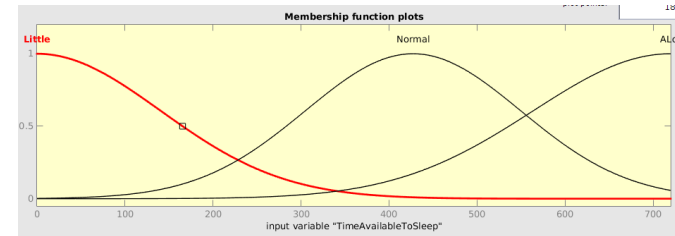
Figure 11: Theoretical maximum time available to sleep (Little, Normal, A Lot)
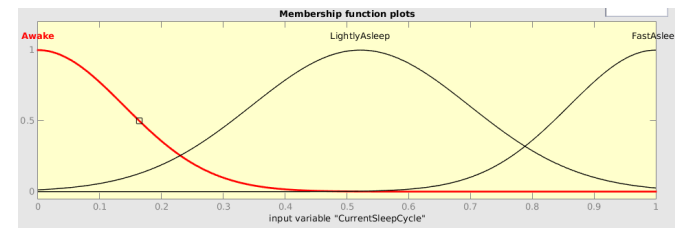

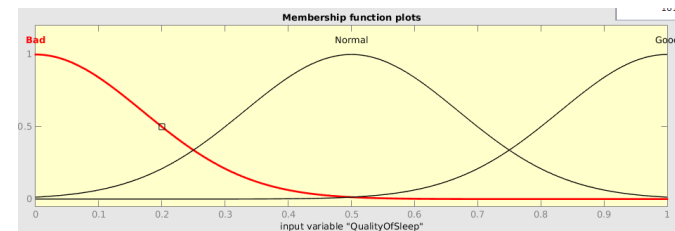Figure 12: Current Sleep Cycle (Awake, Lightly Asleep, Fast Asleep)

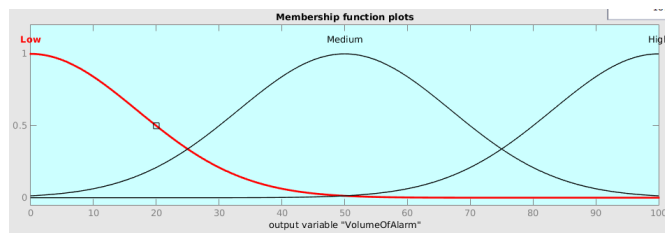Figure 13: Quality of Sleep (Bad, Normal, Good)

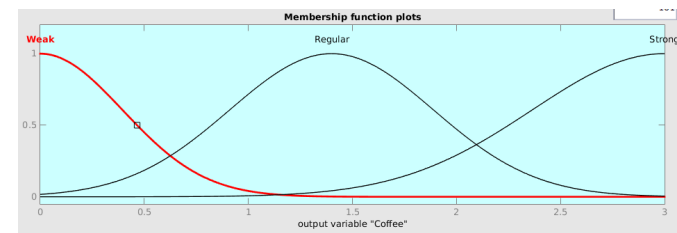Figure 14: Alarm Volume (Low, Medium, High)

Figure 15: Strength of Coffee (Weak, Regular, Strong)

6.2 Key Rules

Below is a selection of the key rules for each subsystem.

Subsystem 1
—Rules which heavily influence easiness of falling asleep—

Assumption: We will more easily fall asleep if we have slept little the day before (all rules except one that include slept little day before have easy as output).

If (LastMealOrDrink is SomeTimeAgo) and (SleptDayBefore is Little) and (ActivityDuringDay is ALot) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is SomeTimeAgo) and (SleptDayBefore is Little) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is SomeTimeAgo) and (SleptDayBefore is Little) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is JustNow) and (SleptDayBefore is Little) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is JustNow) and (SleptDayBefore is Little) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is JustNow) and (SleptDayBefore is Little) and (ActivityDuringDay is ALot) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is Little) and (ActivityDuringDay is ALot) then (EasinessOfFallingAsleep is Easy)
If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is Little) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Easy)

Normality also leads to easily falling asleep
If (LastMealOrDrink is SomeTimeAgo) and (SleptDayBefore is Normal) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Easy)

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—Rules that show it's hard to fall asleep —

Almost half of the rules (4/9) that results in it being hard to fall asleep includes that we have eaten a long time ago.

If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is ALot) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)
If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is ALot) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Hard)
If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is Normal) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Hard)
If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is Normal) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)

Off all the 'hard to fall asleep rules' 77% of them got at least two rules at their peaks (Little | ALot | LongTimeAgo | JustNow).
If (LastMealOrDrink is SomeTimeAgo) and (SleptDayBefore is ALot) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)

If (LastMealOrDrink is JustNow) and (SleptDayBefore is ALot) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)

If (LastMealOrDrink is JustNow) and (SleptDayBefore is ALot) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Hard)

If (LastMealOrDrink is JustNow) and (SleptDayBefore is Normal) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)

If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is Normal) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)

If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is ALot) and (ActivityDuringDay is Normal) then (EasinessOfFallingAsleep is Hard)

If (LastMealOrDrink is LongTimeAgo) and (SleptDayBefore is ALot) and (ActivityDuringDay is Little) then (EasinessOfFallingAsleep is Hard)

Subsystem 2
—Rules which heavily influence more sleep—

Assumption: We can sleep longer if the commute will be short and we have a decent amount of time to sleep:

if (commuteT is veryShort) and (TtoSleep is average) then (SleepDuration is lots)
if (commuteT is short) and (TtoSleep is more/lots) then (SleepDuration is lots)
if (commuteT is average) and (TtoSleep is lots) then (SleepDuration is lots)

If we can fall asleep easily, and we have a decent amount of time to sleep, we can sleep more:
if (easeSleep is normal) and (TtoSleep is lots) then (SleepDuration is lots)
if (easeSleep is easy) and (TtoSleep is more/lots) then (SleepDuration is lots)

If the commute is short, and we can sleep easily, we can sleep for more of the time available:
if (commuteT is veryShort) and (easeSleep is normal/easy) then (SleepDuration is lots)
if (commuteT is short) and (easeSleep is easy) then (SleepDuration is lots)

————————————————————————

—Rules which heavily influence less sleep—

Assumption: If we know we have long to travel, and little time to sleep, we can't use as much of the available time:

if (commuteT is average/long/verylong) and (TtoSleep is veryLittle) then (SleepDuration is veryLittle)
if (commuteT is verylong) and (TtoSleep is Little) then (SleepDuration is veryLittle)

If it is hard to sleep, and we have little time to sleep, then we can't sleep for as long:
if (easeSleep is *hard) and (TtoSleep is little/veryLittle) then (SleepDuration is veryLittle)

If the commute is long, and it's hard to fall asleep, then we can't sleep for as long:
if (commuteT is verylong) and (easeSleep is hard) then (SleepDuration is veryLittle)

————————————————————————

Subsystem 3
—Example of Rules which heavily influence stronger Coffee—

Assumptions: Current sleep cycle is awake; thus volume of alarm can be low. As the person hasn't slept a lot and the sleep he had was only of normal quality, coffee should be strong to make the person feel more awake and alert.

If Current sleep cycle is Awake and Time available to sleep is Little and Quality of sleep is normal, then Volume of alarm is Low and Coffee is Strong.

Assumptions: Lightly asleep, so alarm should be medium. User has slept alot, but quality of sleep was bad indicates user isn't fully awake on waking up, means coffee should be strong to make user feel more awake.

If Current sleep cycle is Lightly Asleep and Time available to sleep is Alot and Quality of sleep is Bad, then Volume of alarm is medium and Coffee is Strong.
_____

—Example of Rules which heavily influence louder Volume—

Assumptions: Volume of alarm is high, since user needs to be woken from deep sleep. The user has slept a lot and slept well; but because he was awoken from deep-sleep, he might not be fully awake yet, so coffee should be regular instead of weak.

If Current sleep cycle is Fast Asleep and Time available to sleep is Alot and Quality of sleep is Good, then Volume of alarm is High and Coffee is Regular.

Subsystem 2 Rulebase development

Commute Time		Time Available to Sleep				
		veryLittle	little	average	more	lots
	very short	lessNormal	normal	moreNormal	**lots**	**lots**
	short	little	normal	moreNormal	**lots**	**lots**
	average	**veryLittle**	lessNormal	normal	moreNormal	**lots**
	long	**veryLittle**	little	lessNormal	normal	morenormal
	very long	**veryLittle**	**veryLittle**	little	lessNormal	normal

Ease of Falling Asleep		Time available to Sleep				
		veryLittle	little	average	more	lots
	hard	veryLittle	veryLittle	little	lessNormal	Normal
	normal	little	lessNormal	Normal	moreNormal	lots
	easy	lessNormal	Normal	MoreNormal	lots	lots

Ease of Falling Asleep		Commute Time				
		very short	short	average	long	very long
	hard	moreNormal	normal	lessNormal	little	veryLittle
	normal	lots	moreNormal	normal	lessNormal	little
	easy	lots	lots	moreNormal	normal	lessNormal

Figure 16: Subsystem 2 Rulebase Tables

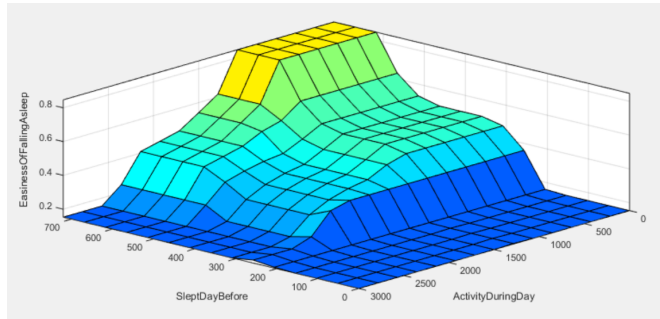## 6.3 Surfaces

Subsystem 1

Figure 17: Activity During the Day v Time Slept Day Before v Ease of Falling Asleep
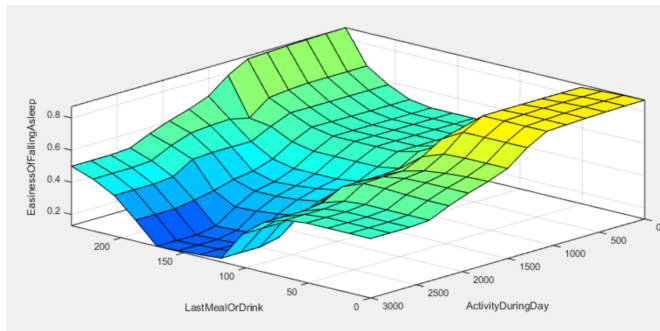

Figure 18: Last Meal Before Sleep v Activity During the Day v Ease of Falling Asleep
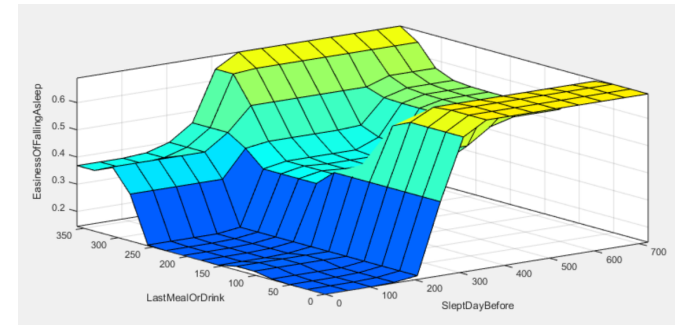

Figure 19: Last Meal Before Sleep v Time Slept Day Before v Ease of Falling Asleep
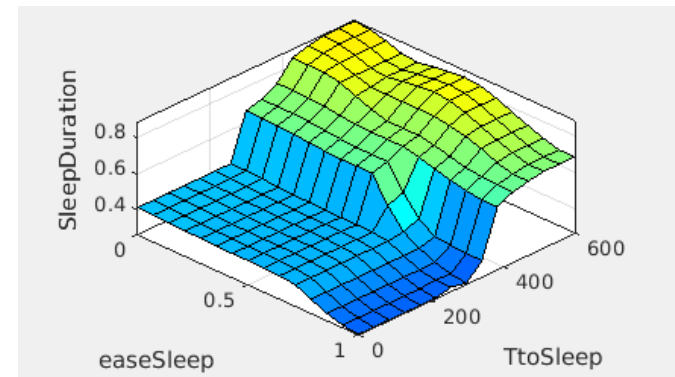
Subsystem 2

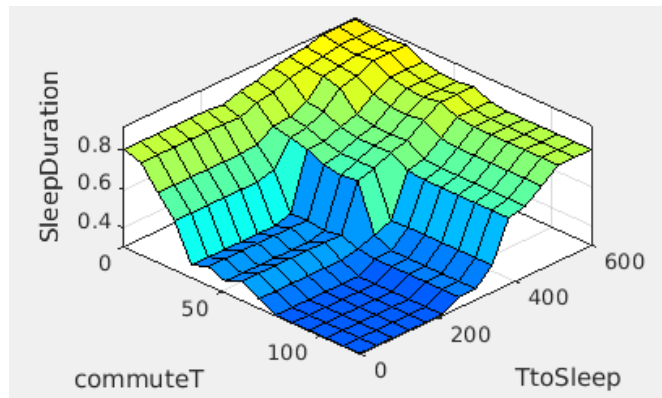Figure 20: Ease of Sleep v Time Available to Sleep v Sleep Duration

Figure 21: Commute Time v Time Available to Sleep v Sleep Duration

Figure 22: Commute Time v Time Available to Sleep v Sleep Duration

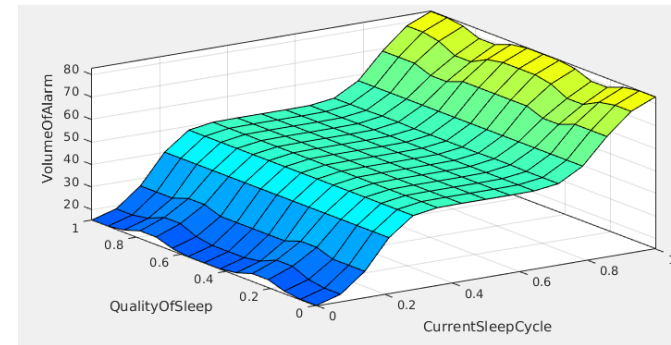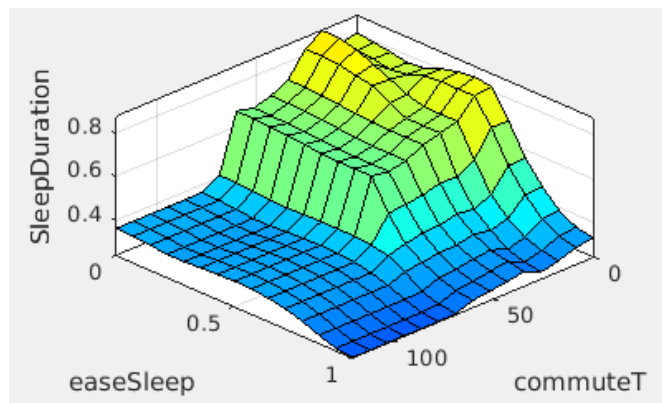Figure 23: Current Sleep Cycle v Quality of Sleep v Strength of Coffee
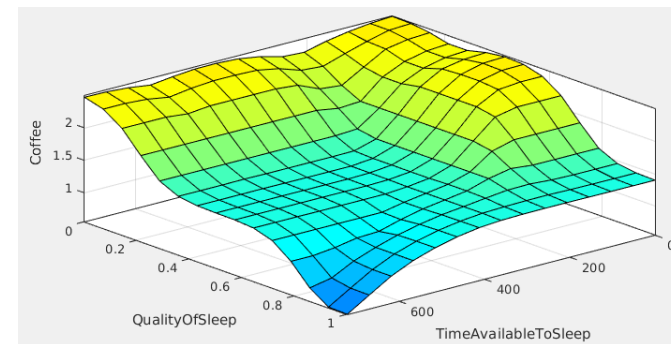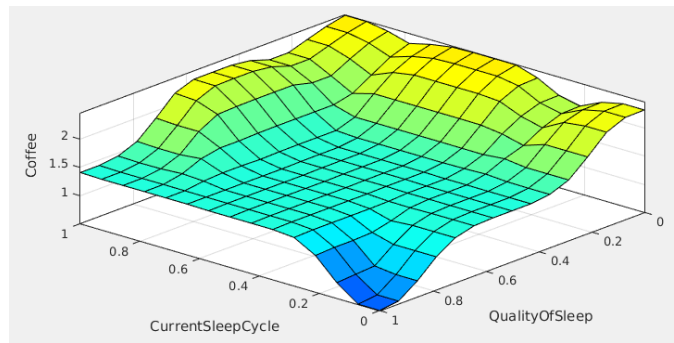

Figure 24: Current Sleep Cycle v Quality of Sleep v Strength of Coffee

15

of Coffee

Figure 25: Time Available to Sleep v Quality of Sleep v Strength

6.4 Results Tables

Results from 3 test cases: Average Student (AS), Work Hard Playhard Buisnessperson (WHPH),
Sedate Commuter (SC)

Subsystem 1

User	Last Meal	Slept Day Before	Activity	Ease of Sleep
AS	60	360	2400	0.5
WHPH	15	240	3000	0.166
SC	120	540	1500	0.476

Subsystem 2

User	Commute Time	Ease of Sleep	Time Available to Sleep	Sleep Duration	Time Sle*eping
AS	60	0.5	480	0.848	6.784^1
WHPH	20	0.166	300	0.867	4.335^2
SC	90	0.476	600	0.82	8.2^3

1: This would indicate a wake up time of about 7.30AM for a bed time of 1AM, with 30min to
get ready, a commute of 60min and an appointment at 9AM.
2: Person wakes up at around 6.15AM, has 25 mins to get ready and then commutes 20min (i.e.
assumes they live close to work, and they start work at 7AM).
3: Person wakes up around 6.58am, gets ready in 30 mins roughly, then has a long commute of
90mins for a 9AM start.

Subsystem 3

User	Current Sleep Cycle	Time Available to Sleep	Quality of Sleep	Volume of Alarm	Coffee
AS	0.8	480	0.6	78.6	1.99
WHPH	0.9	300	0.4	83	2.34
SC	0.6	600	0.9	50	1.03