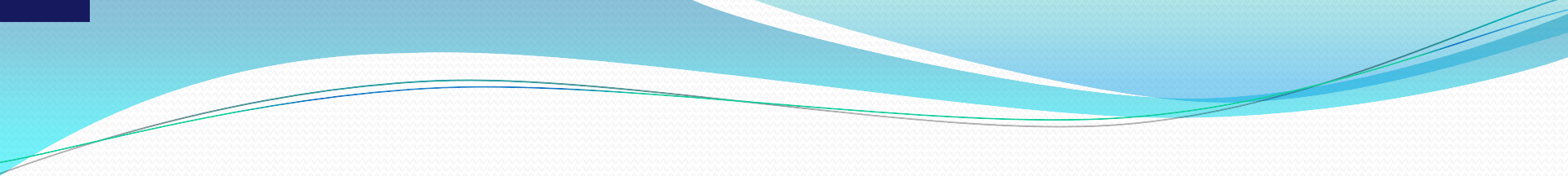


Smart Mattress System

Domain : Fuzzy Logic System

By Akshay Uppal

- 
1. Motivation
 2. Characteristics of System
 3. System Details
 4. Working of System/ Demo
 5. Benefits
 6. Future Scope

Motivation





Traditional Mattress



Mattress of Future

Characteristics of Smart Mattress



© Can Stock Photo - csp27203998



Temperature Control

- Calibrates temperature based on outside temperature
- **Pressure sensitive** temperature control
- Energy Efficient





Body Surface Area Calculation

Du Bois Formula

Calculation [\[edit \]](#)

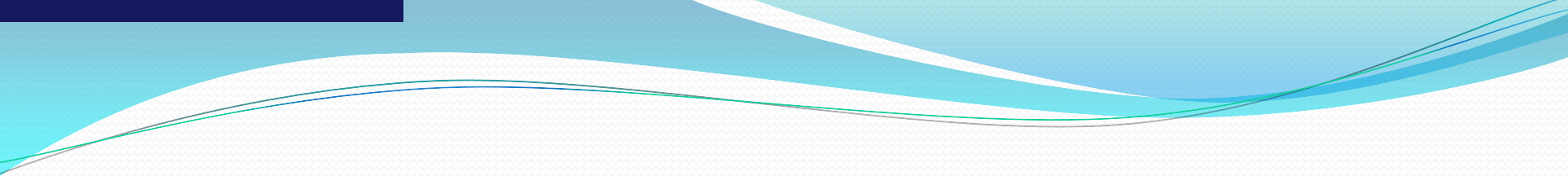
Various calculations have been published to arrive at the BSA without direct measurement. In the following formulae, BSA is in m^2 , W is mass in kg , and H is height in cm .

The most widely used is the Du Bois, Du Bois formula,^{[4][5]} which has been shown to be equally as effective in estimating body fat in obese and non-obese patients, something the [Body mass index](#) fails to do.^[6]

$$BSA = 0.007184 \times W^{0.425} \times H^{0.725}$$

A commonly used and simple one is the Mosteller formula:^[7]

$$BSA = \sqrt{\frac{W \times H}{3600}} = 0.016667 \times W^{0.5} \times H^{0.5} \text{ or even simpler: } BSA = \sqrt{W \times H} / 60 \text{ or if Ht is height in m: } BSA = \sqrt{W \times Ht} / 6$$



Pressure of
body lying
down

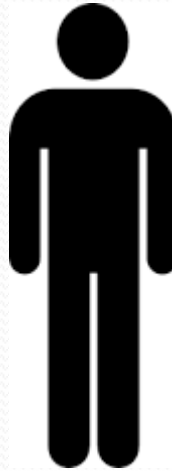
$$P_{\text{lying}} = \frac{F}{A}$$

Weight of the body
Body Surface Area

Ground pressure variations



~3.5 kPa



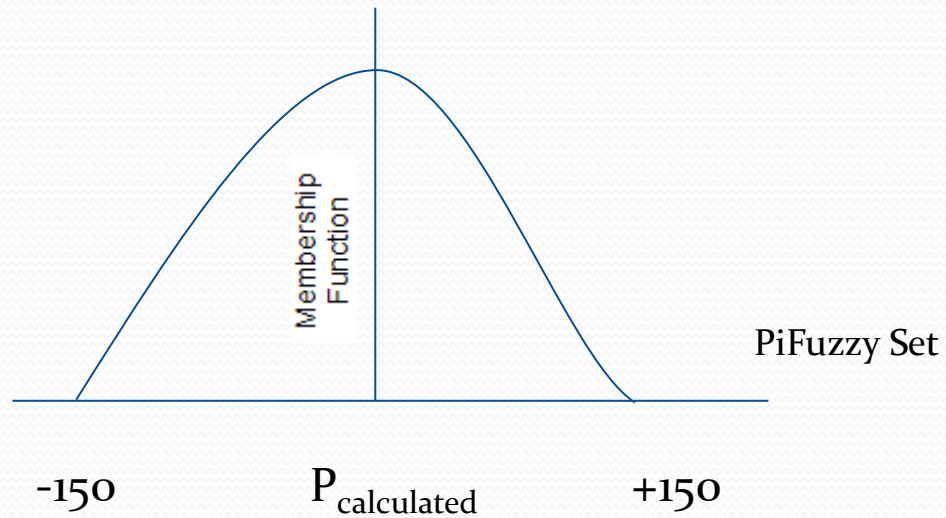
~55kPa



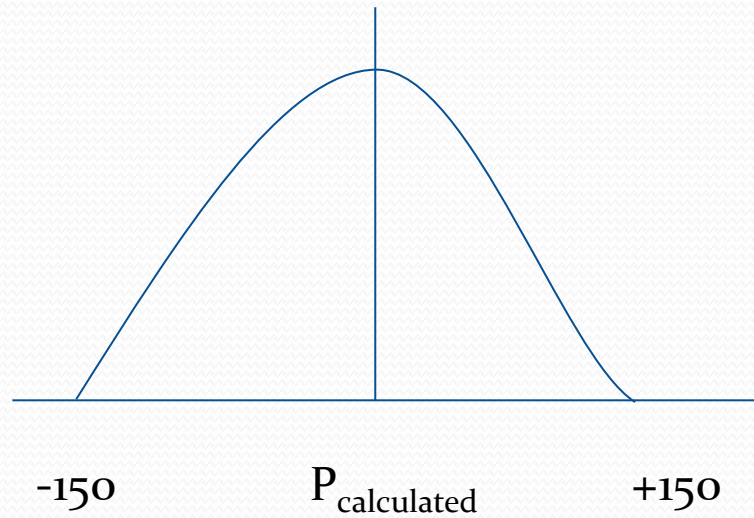
~300-500Pa

Pressure Fuzzy Set

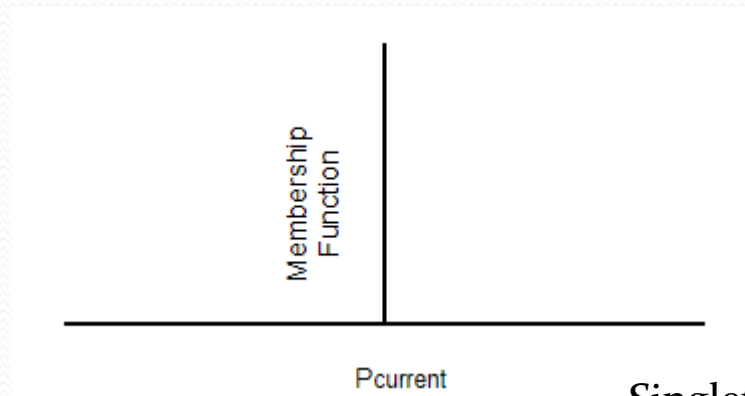
Pressure_{Global} : 0 -5000 Pa



Pressure Fuzzy Set

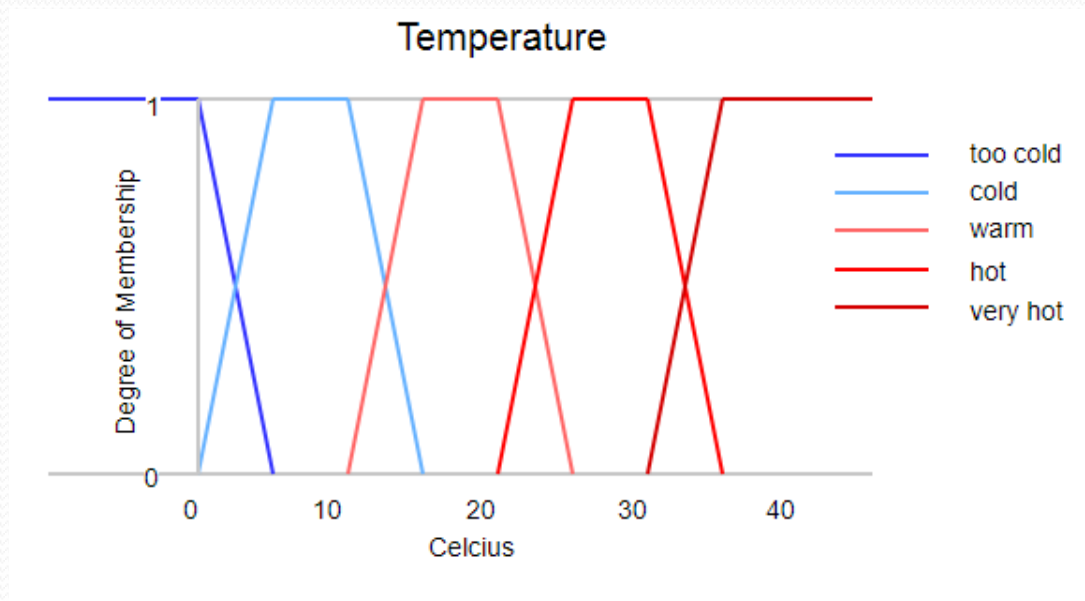


Fuzzy Match

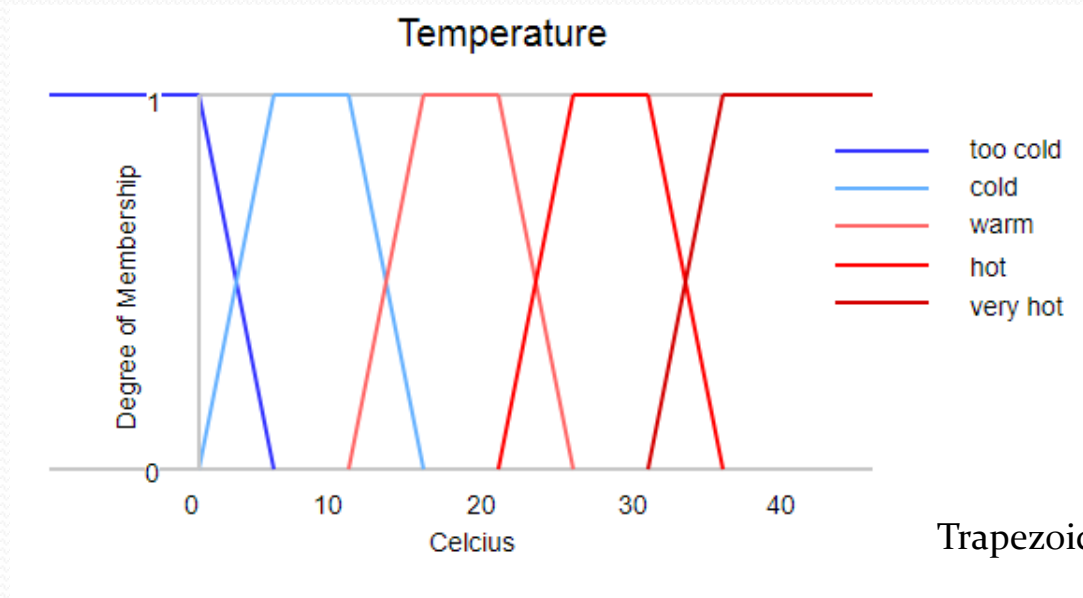


Singleton set

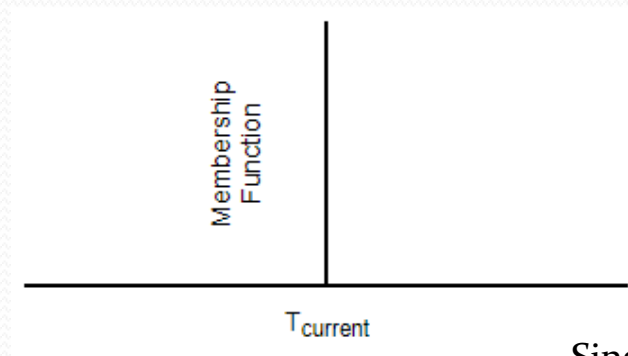
Fuzzy sets



Fuzzy sets



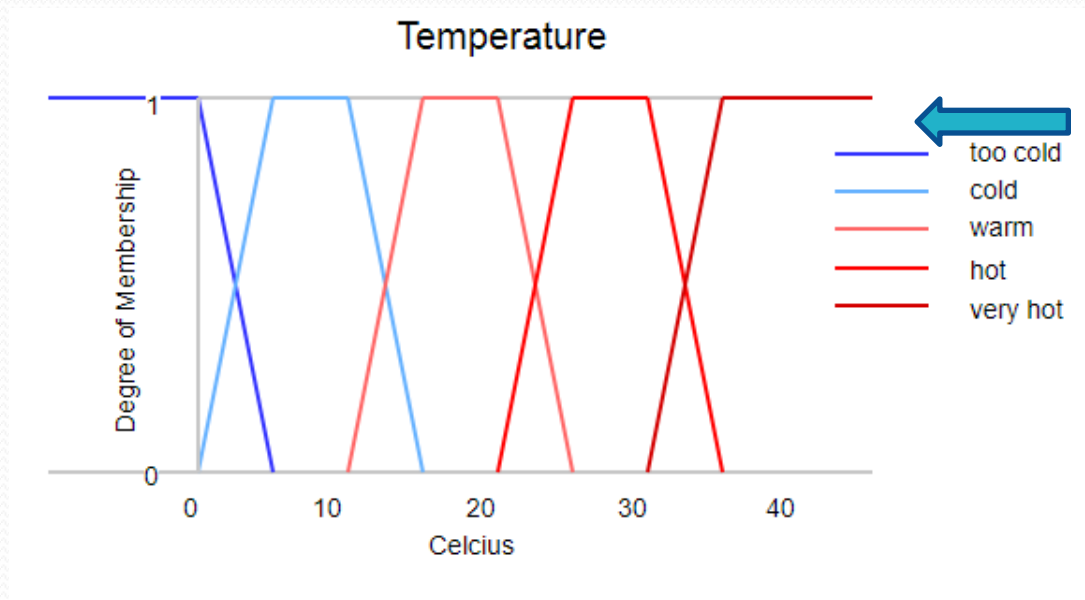
Trapezoid Fuzzy Set



Singleton Fuzzy Set

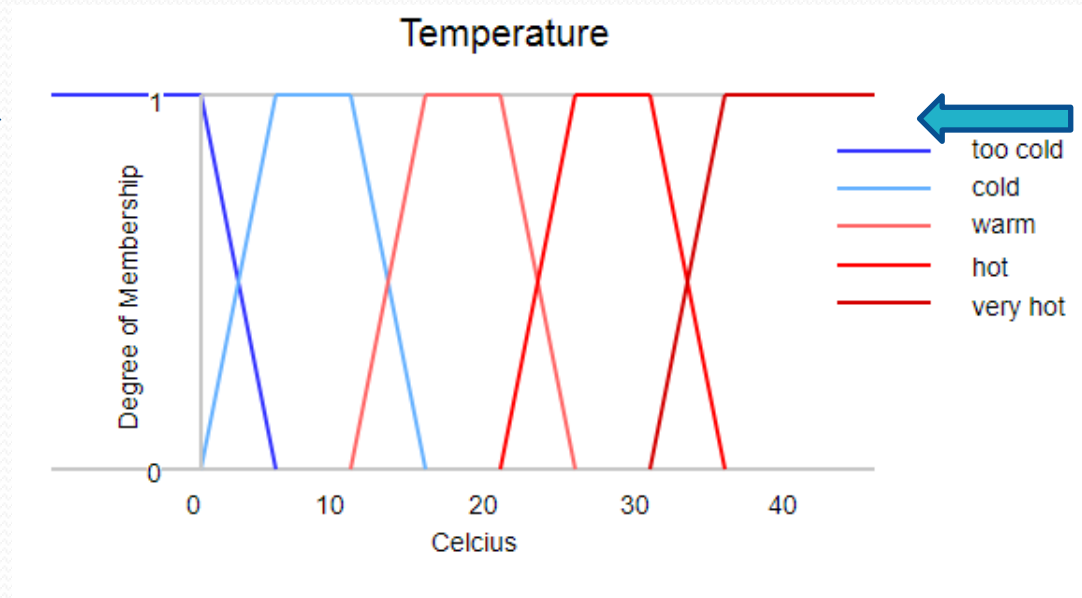
Fuzzy Match

More Heat



More Cool

More Heat



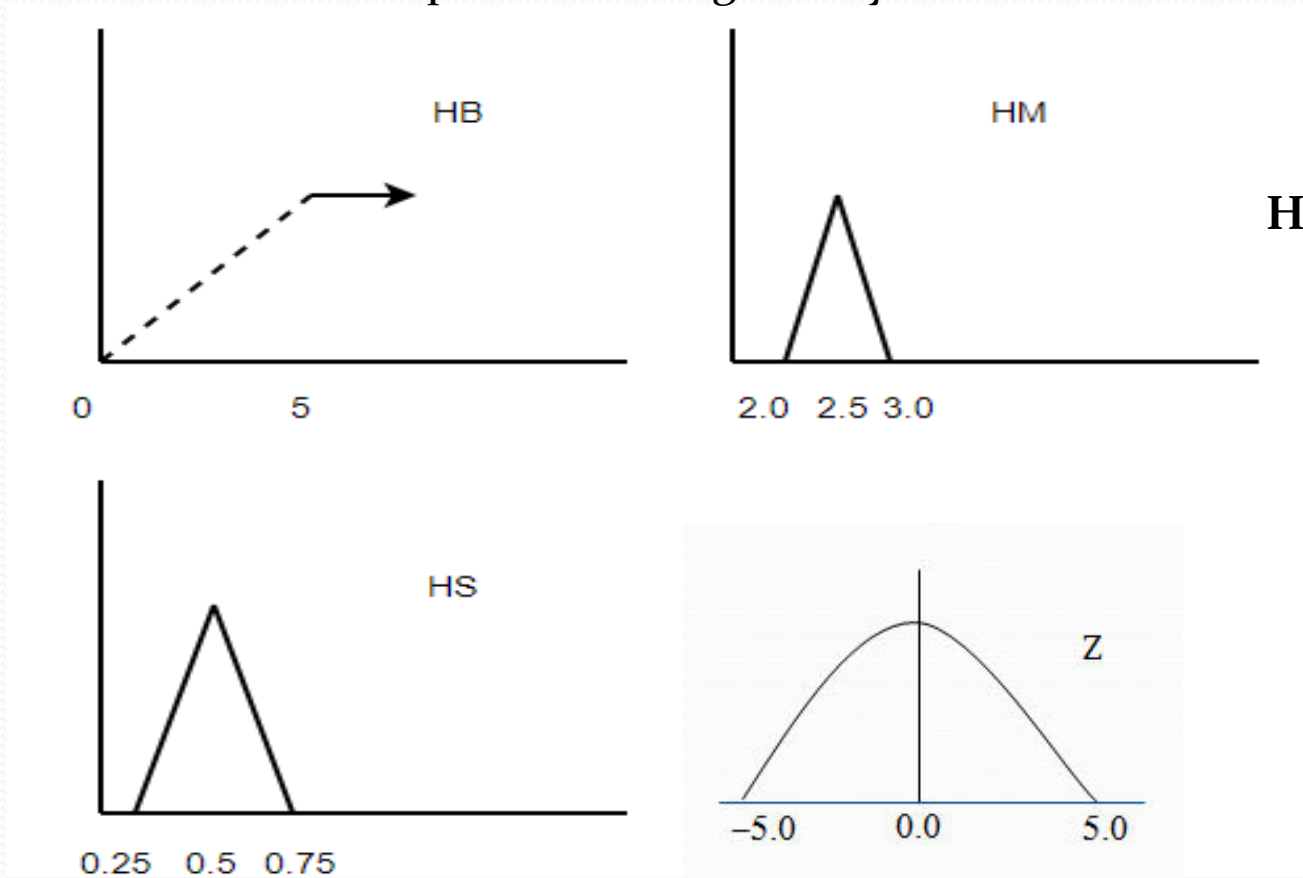
More Cool

Heat Change

Cold Change

Fuzzy sets

Temperature change Fuzzy Sets



Heat Change

Heat and Cold Change Rule

Fuzzy Match	Change Heat	Change cool
Too cold	HB	Zero
Cold + Too cold	HM	Z
Cold	HM	Z
Warm + Cold	HS	Z
Warm	Z	Z
Warm + Hot	Z	CS
Hot	Z	CM
Hot + too Hot	Z	CM
Too Hot	Z	CB

Pressure matched
with calculated pressure



Current Temperature
Readings received



Change Temperature

Intelligent Posture Control

- Measure sleepiness index to adjust the posture for the mattress
- Calibrates postures based on sleepiness of the person
- Angle varies from 120 to 180
- Measures sleep based on PERCLOS

PERCLOS

(Percentage of eye closure)

Eyelid Closure (PERCLOS)

PERCLOS: the proportion of total time that the eyelids are closed 80% or more.



From Akrouf & Mahdi, 2013.

Dingus, T. A., Hardee, H., & Wierwille, W. W. (1987). Development of models for on-board detection of driver impairment. *Accident Analysis & Prevention*, 19(4), 271-283.

$$PERCLOS = \frac{Time(ECD \geq 80\%)}{1 \text{ min}} \times 100\%$$

Driver drowsiness detection

- The Driver Monitoring System, also known as Driver Attention Monitor, is a vehicle safety system first introduced by Toyota in 2006 for its and Lexus and latest models.

Other technology being used

- Driver eye/face monitoring
- Physiological measurement
- Driver eye/face monitoring
- Physiological measurement

Applications

Rest recommendation system



Active Driving Assistant



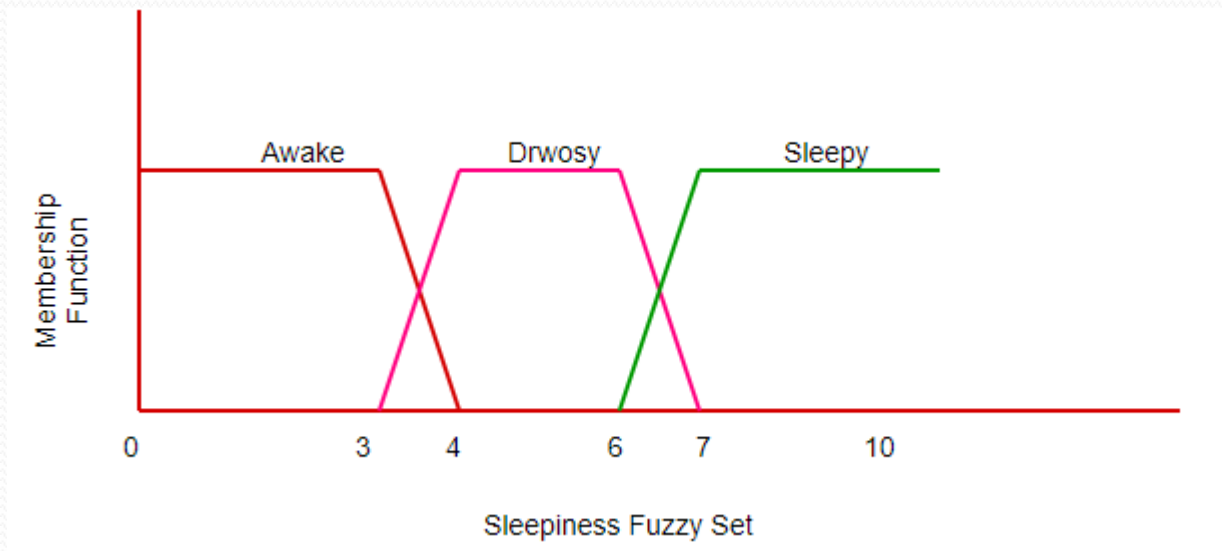
Driver Alert



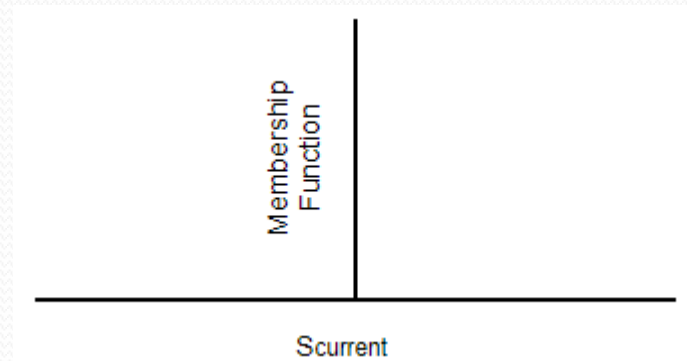
Driver Condition Monitor and
Driver Fatigue Alert



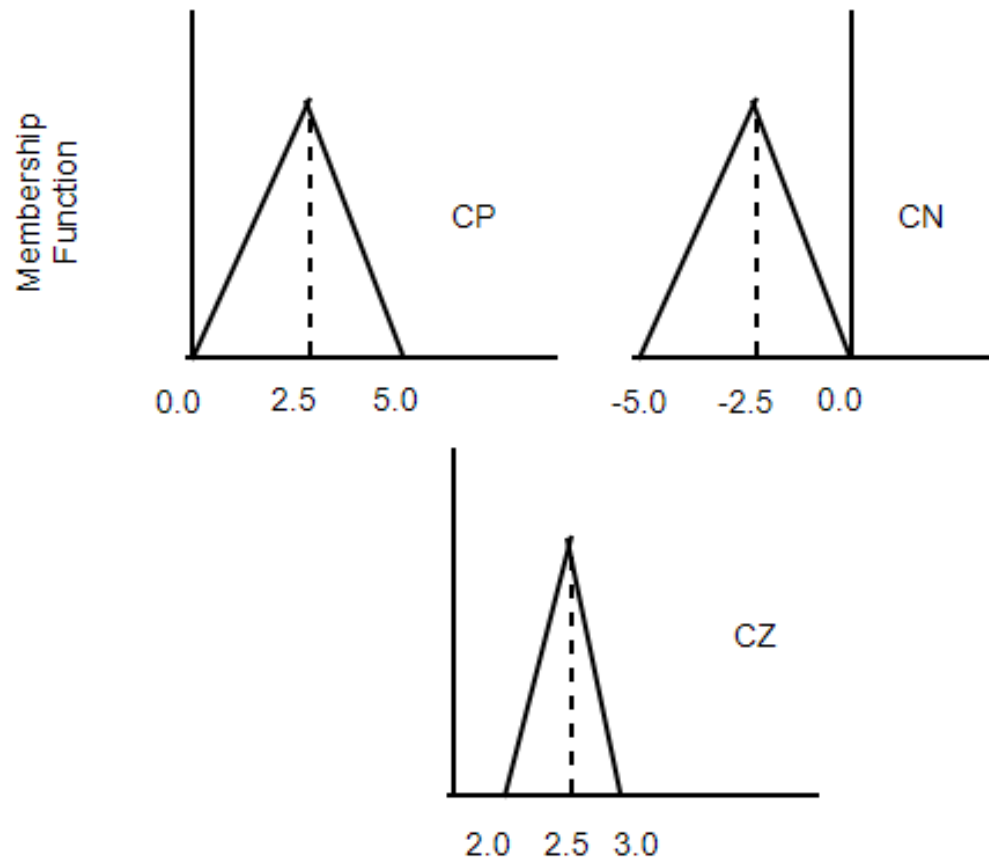
Sleepiness Index



Sleepiness Index

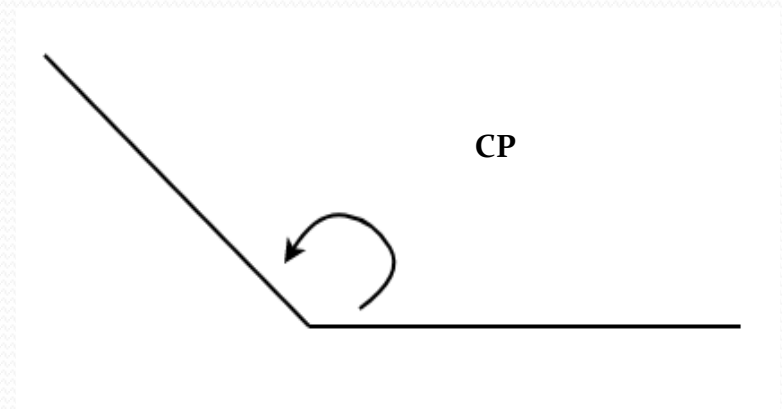
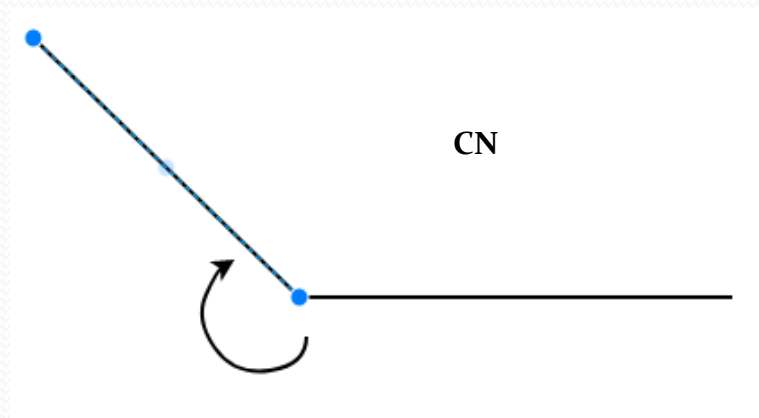


Angle Change Fuzzy Sets



Angle Change Rule

Sleepiness value	Current Angle	Change Angle
Awake	> 120	CN
Drowsy	≤ 180	CZ
Sleepy	≤ 180	CP



Check Current Angle



Current Sleepiness
Readings received



Change Angle of mattress

Sensor Reading

Black box

Output

**Current
temperature**

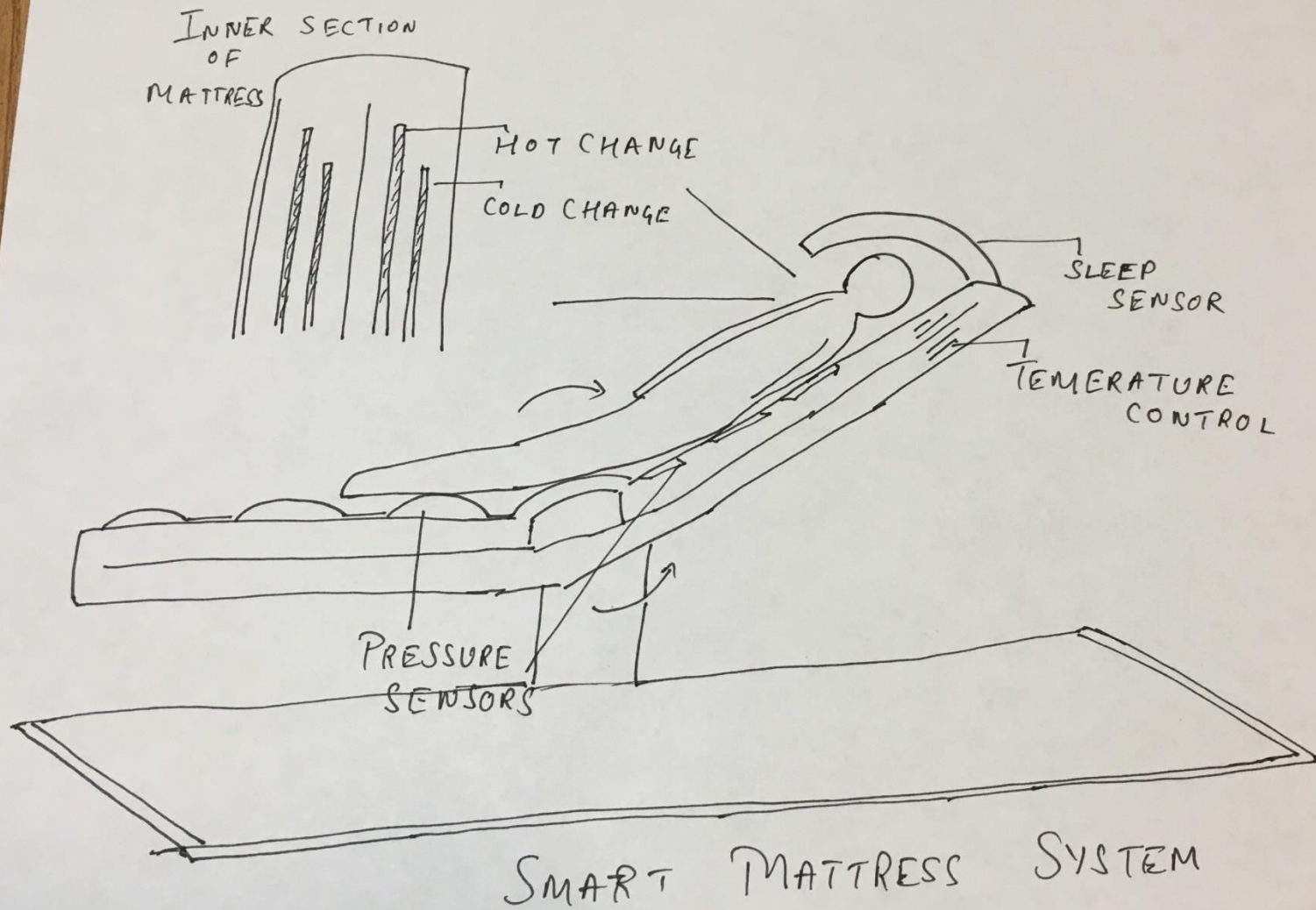
**Users body
weight and
height**

**Sleepiness
Value**

**Current
pressure**

Smart Mattress System

Temperature and
Angle Change

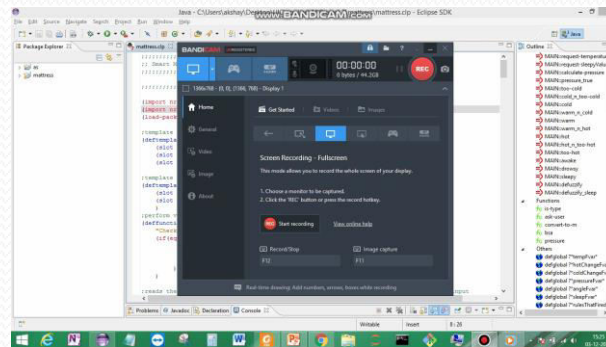


A typical rule

```
(defrule warm_n_hot
  (pressureVaid true)
  (temp ?t&:(fuzzy-match ?t "warm"))
  (temp ?t&:(fuzzy-match ?t "hot"))
=>
  (assert (change_cool(new FuzzyValue ?*coldChangeFvar* "CS")))
  (assert (change_heat(new FuzzyValue ?*hotChangeFvar* "Z")))
  (bind ?*rulesThatFired* (str-cat ?*rulesThatFired*
    "!Rule: if Temp warm & hot and Pressure Valid then change Cool CS fires%"))
  )
  (printout t "warm hot" crlf)
)
```

```
(defrule drowsy
  (currentang ?angle)
  (answer (ident sleepiness) (answer 2))
=>
  (if (<= ?angle 180) then
    (assert (change_angle(new FuzzyValue ?*angleFvar* "CZ")))
  ))
```

Demo



Sample Run- I

```
Jess, the Rule Engine for the Java Platform
Copyright (C) 2008 Sandia Corporation
Jess Version 7.1p2 11/5/2008
```

```
This copy of Jess will expire in 1817 day(s).
```

```
Please and enter your name Cyclops
```

```
*****
```

```
Hello Cyclops.
```

```
Welcome to Smart Mattress control system
```

```
Just enter your details
```

```
So that Mattress can be customised based on your preferences
```

```
The process will take less than 5min for caibration
```

```
*****
```

```
What is your height
```

```
Please enter height in inches (1 foot = 12 inches) 70
```

```
Current temperature readings
```

```
Please enter current temperature readings (-35 to 100) 45
```

```
How sleepy are you feeling
```

```
1.Awake 2.Drowsy 3.Sleepy 1
```

```
Please enter your weight (in kgs) 65
```

```
pressure matched
```

```
-----
-----
```

```
Mattress calibrated based on your readings.
```

```
Following are the calibration of readings based on the outside temperature
and your current posture that is based on pressure calculated on mattress
```

```
Hot Change 0.0
```

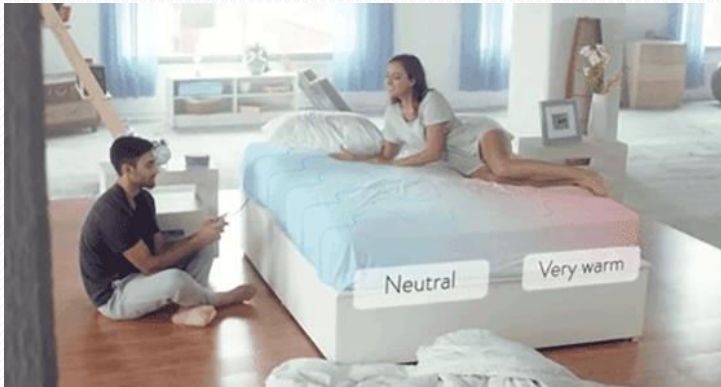
```
Cold change -3.5355339059327378
```

```
-----
-----
```

Value Proposition and Benefits

- Saves energy during temperature control
- Adjusts the posture based on user sleepiness value
- More personalised towards the user
- Humans spend $\frac{1}{3}$ of their time sleeping

Existing Market



Eight Sleep



Sleep Number 360

- Remote control based Temperature control
- Doesn't used pressure sensitive control
- Lacks detection of drowsiness

Future Scope

- In future bed will take sleep index value based on EEG-ECD model (87.5 – 70%) or by measuring brain activity.
- Make the changes in the control more smoother
- Tracks the sleep pattern of the user and give him feedback
-

Citations

1. https://www.researchgate.net/publication/260232896_Temperature_Control_using_Fuzzy_Logic
2. <https://www.seeingmachines.com/technology/>
3. <http://halls.md/formula-body-surface-area-bsa/>
4. https://en.wikipedia.org/wiki/Body_surface_area#Calculation
5. https://en.wikipedia.org/wiki/Ground_pressure
6. Sleep : https://en.wikipedia.org/wiki/Multiple_Sleep_Latency_Test
7. Sleepiness scale : <http://healthysleep.med.harvard.edu/narcolepsy/diagnosing-narcolepsy/epworth-sleepiness-scale>
8. <http://www.https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4208235/>



Questions?



Thank you

PERCLOS Today

Seven systems that have been tested and may be ready for commercial use soon (continued):

InSight™ (SensoMotoric Instruments GmbH) computer vision measures head position and orientation, gaze direction, eyelid opening, and pupil position and diameter.

Prototype (Bergasa & Nuevo; U. Alcala, Madrid) computer vision based upon PERCLOS, eye closure duration, blink frequency, nodding frequency, face position, and fixed gaze.

Prototype (Rensselaer Polytechnic Institute) computer vision system tracks PERCLOS and average eye closure speed.

Barr, L., Howarth, H., Popkin, S., & Carroll, R. J. (2005). **A review and evaluation of emerging driver fatigue detection measures and technologies**. In *Proceedings of the 2005 International Conference on Fatigue Management in Transportation Operations* (Vol. TP 14620E). Ottawa: Transport Canada.

Driver drowsiness detection

Systems [\[edit \]](#)

- **Audi: Rest recommendation system**^[5]
- **BMW: Active Driving Assistant with Attention Assistant** analyses driving behaviour and, if necessary, advises the driver to rest. The advice to take a break is provided in the form of graphic symbols shown on the Control Display.^[6]
- **Bosch:** "Driver drowsiness detection"^[7] takes input from the steering angle sensor, front-mounted lane assist camera, vehicle speed and turn signal stalk.
- **Citroën: AFIL/LDWS** uses different technologies to monitor the vehicle position on the road. Some models use sensors mounted in front of the front wheels, monitoring the lane markings. Other models use a camera mounted in top center of the windscreen for the same purpose. Both systems alert the driver by vibrations in the driver's seat, on the left or right half of the seat cushion, respectively.^[8]
- **DS:**
 - **AFIL/LDWS**:^[9] Lane Departure Warning System gives an audible reminder if you drift out of your lane.
 - **DS DRIVER ATTENTION MONITORING**^[10] identifies any reduction in driver alertness. Using an infrared camera above the steering wheel, DS DRIVER ATTENTION MONITORING continuously monitors: the eyes for signs of tiredness (blinking); the face and head movements for signs of distraction; and the course steered by the car in its road lane (deviations or steering movements by the driver).
- **Ford: Driver Alert**^[11]
- **Jaguar Land Rover: Driver Condition Monitor and Driver Fatigue Alert**, both evaluate driving technique for signs of driver fatigue. When the feature determines if the driver is fatigued, the message center displays the warning, TAKE A BREAK!, for 1 minute, accompanied by an audible chime. When driving continues for more than 15 minutes after the first warning, without taking a break, a further warning is given. The warning continues until the OK button on the steering wheel menu control is pressed.
- **Mazda: Driver Attention Alert** ^[12] Activates at speeds above 65 km/h. Learns driving behavior through steering input and position of road during the beginning of the ride and compares the learned data during later stages of the ride. A difference above a certain threshold triggers an audible and visual cue.
- **Mercedes-Benz: Attention Assist**^[13] In 2009, Mercedes-Benz unveiled a system called Attention Assist which monitors the driver's fatigue level and drowsiness based on his/her driving inputs. It issues a visual and audible alarm to alert the driver if he or she is too drowsy to continue driving. It is linked to the car's navigation system, and using that data, it can tell the driver where coffee and fuel are available.^[14]