# Smart-Pillow: An IoT-based Device for Stress Detection Considering Sleeping Habits

L. Rachakonda[1], S. P. Mohanty[2], E. Kougianos[3],
K. Karunakaran[4] and M. K. Ganapathiraju[5]

University of North Texas, Denton, TX 76203, USA.[1,2,3]
IISc, Bangalore, India.[4] University of Pittsburgh, Pittsburgh, PA, USA.[5]

Email: rl0286@unt.edu[1], saraju.mohanty@unt.edu[2], elias.kougianos@unt.edu[3],
kalyanithepebble@gmail.com[4] and madhavi@pitt.edu[5]

# Outline of the Talk

- Introduction
- Motivation
- Proposed Solution
- Novel Contributions
- A Broad Perspective of Smart-Pillow
- System Level Modeling of Smart-Pillow
- Implementation and Validation
- Conclusions and Future Research

# Introduction

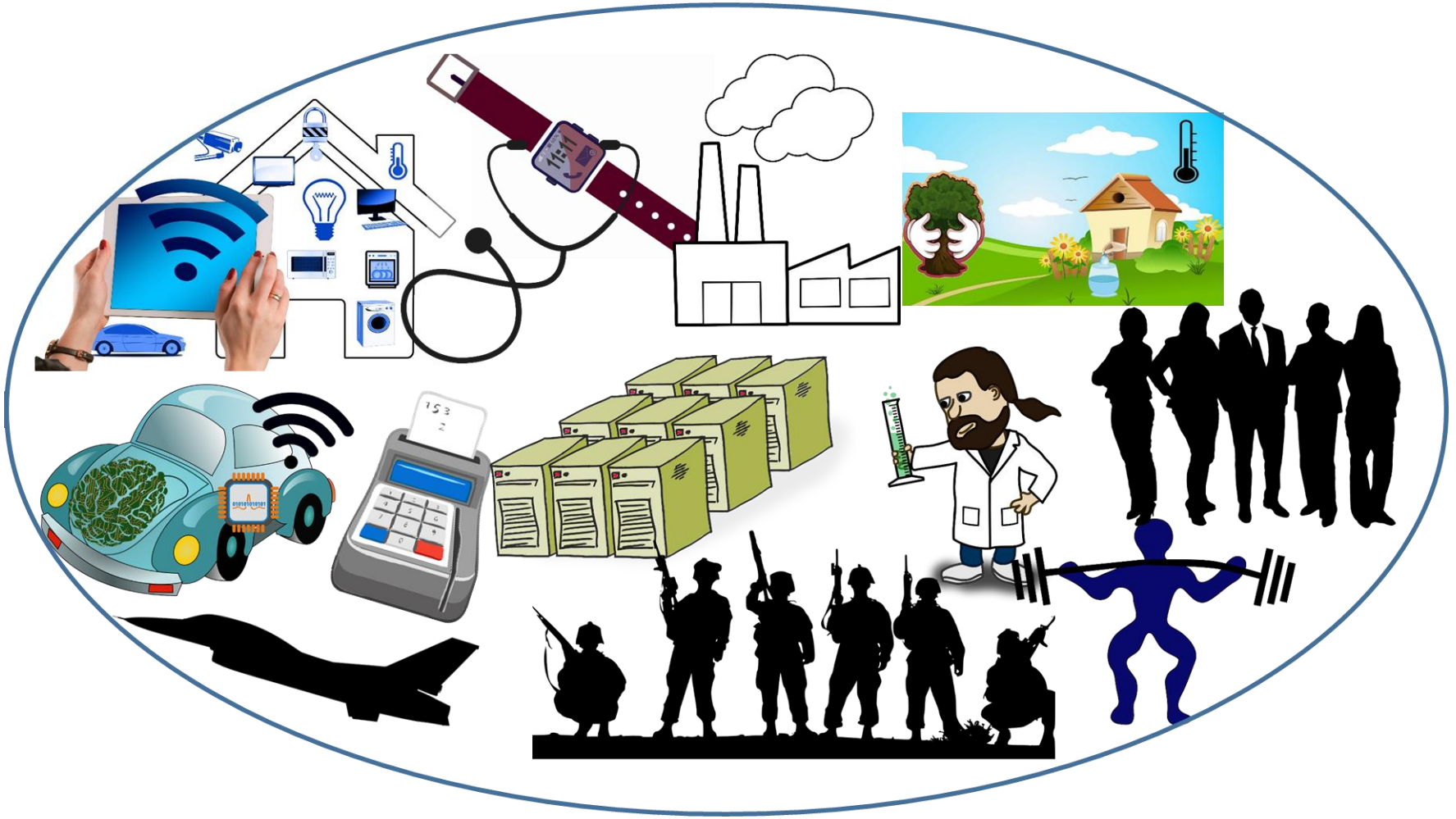
## ✓Internet of Things

## ✓Definition

- The Internet of Things is a network of devices where each device in the network is recognizable and connected.
- It can be thought of as the interconnection of uniquely identifiable smart objects and devices.

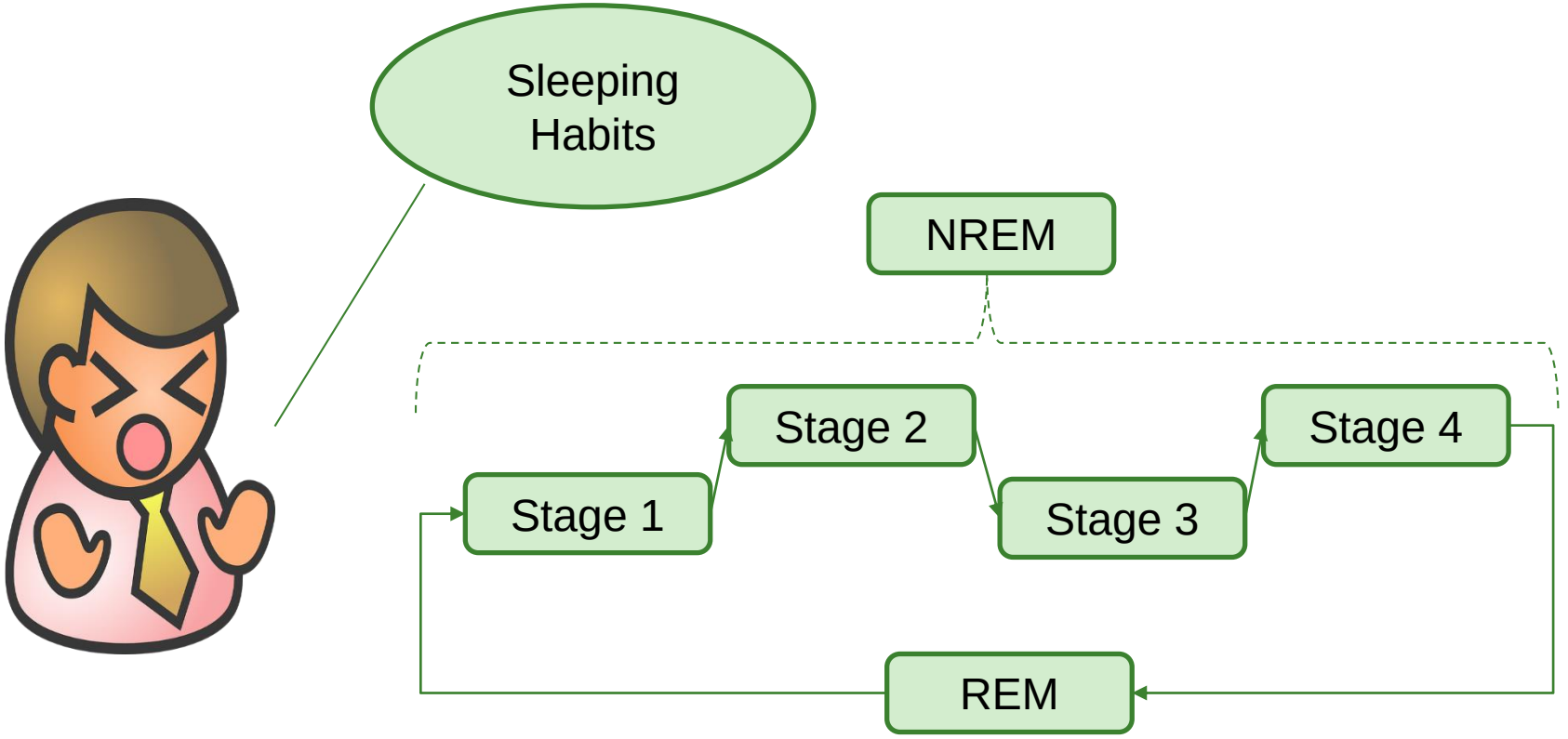
# Introduction

## ✓Applications of IoT



# Research Motivation

✓**Is sleep an important factor of Stress?**




The quality of sleep during the night reflects on productivity during the day.

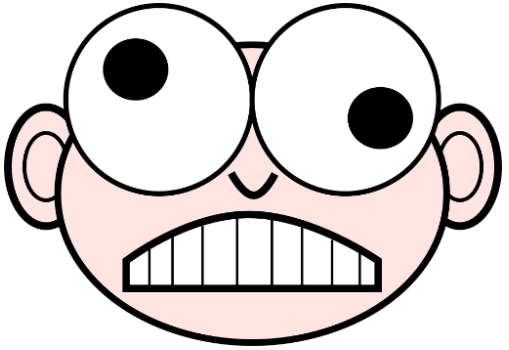
# Symptoms of Improper Sleep

Depression

Feeling Overloaded

Back Pain

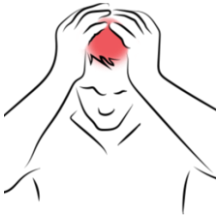
Social withdrawal and isolation



Neck Pain

Weakness

Frequent headaches



Insomnia


Weight gain

Wild Mood Swings

# How to Monitor Sleep?

# Existing Products

sleepscore labs™



EverSleep

# Related Research

| Research | Method | Drawback |
|---|---|---|
| Choi et al [6] | Wearable | Importance of sleep to stress is missing. |
| J.-M. Lee et al [10] | Survey by Wearables | Study of sleep is mentioned but couldn't establish a relationship among stress and sleep. |
| Zhenyu Chen et al [11] | Mobile Application | The accuracy of the system cannot be trusted as the user will have to manually enter the data also the relationship with stress is missing. |

# Issues of Existing Solutions

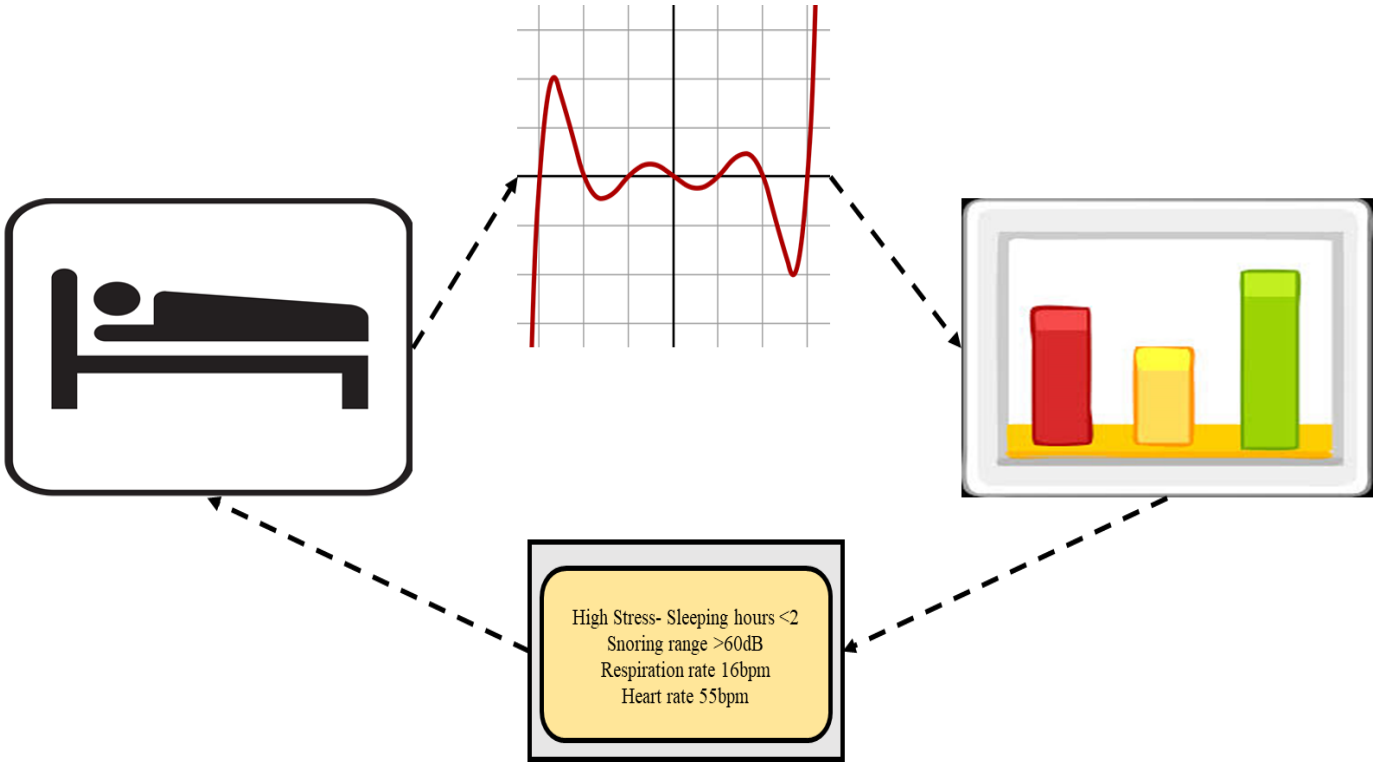
- Lack of Detection Accuracy of Sleep.
- Lack of having multiple stressors for effective sleep analysis.
- No Unified detection of the problem.
- Storage availability of the detected parameters for future usage.
- Self-Aware systems.
- Lack of knowledge on the relationship among stress and sleep.

# The Research Question Addressed in this Paper

- How to have a non-invasive, optimized, IoT enabled system which detects the stress level variations based on the sleeping parameters, analyses the data at the user end (at *IoT-Edge*) and stores the data at the cloud end (at *IoT-Cloud*)?

# Proposed Solution: Smart-Pillow

## ✓ Schematic Representation of Smart-Pillow.




- This research proposes the idea of a Smart-Pillow connected to a wireless tracker as a device to help monitor sleeping habits and let the user know using a wearable.

# Novel Contributions

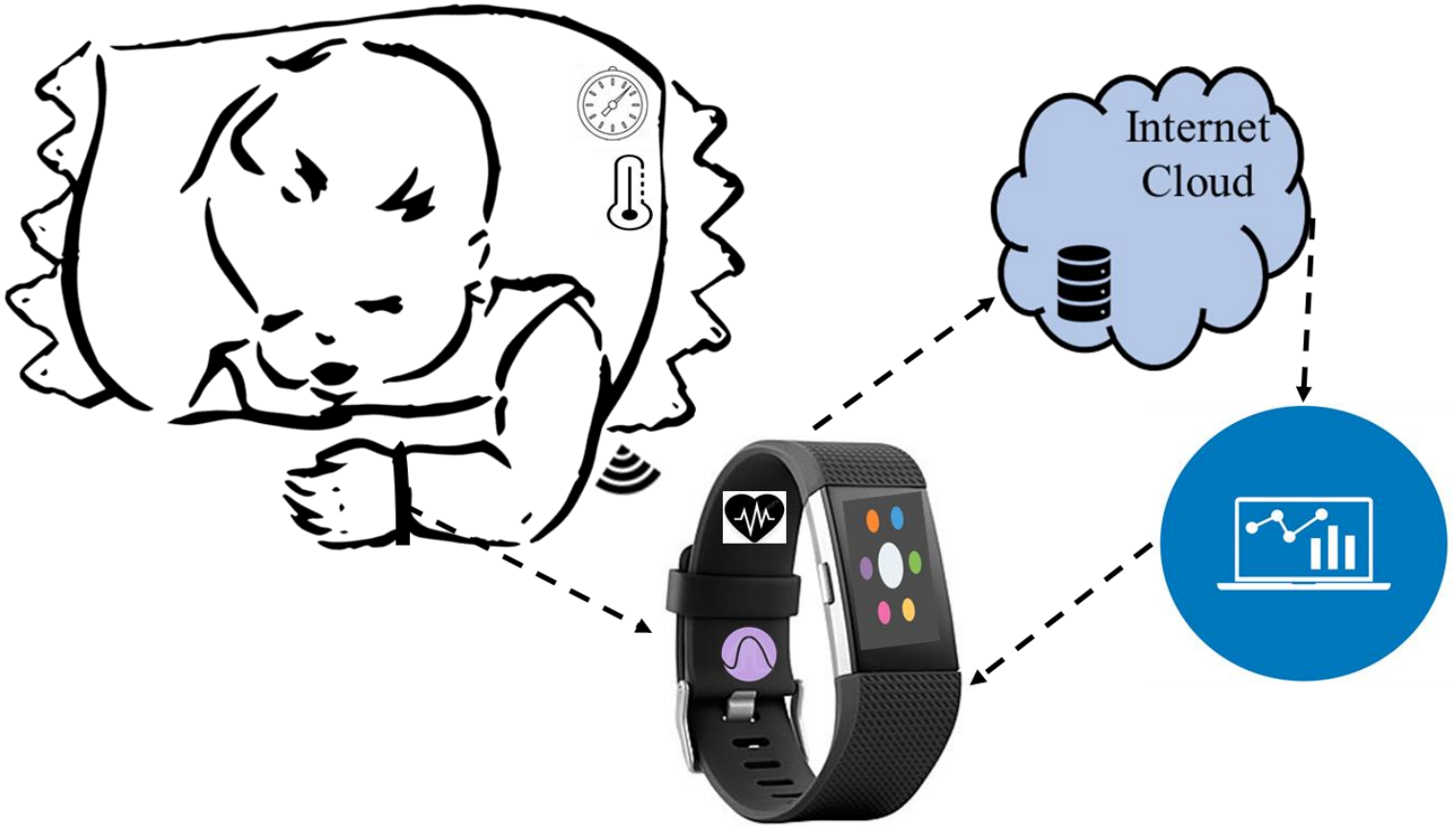
- A continuously monitoring battery optimized device which gets activated only when a person is lying on a bed.
- A non-invasive technique which allows the person to analyze behavior considering sleeping habits.
- Determining the stress state of a person based on the sleeping pattern through out the night.
- Providing diagnostic results and home remedies in order to maintain or control the stress variations based on their characteristics for future improvement.
- Allowing the user to detect the exact level of stress variation by classifying stress states into five levels based on their sleeping habits.

# Issues Addressed in this Research

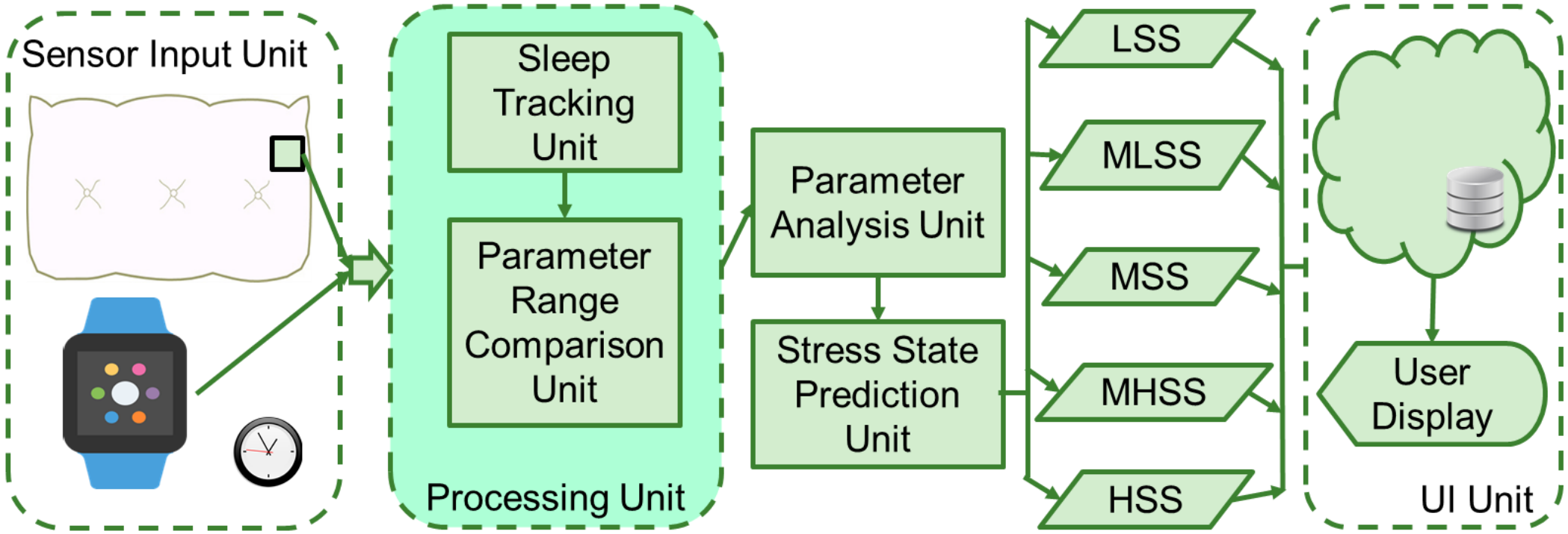
- Advancement through this paper in Electronics.
- Significant Improvement in the Accuracy of Sleep Analyses
- Considered Multiple Stressors for the assessment.
- Provided cloud storage access for future purposes.
- Proposed a self-aware system which is intelligent enough to establish a relationship between stress and the sleeping habits.
- An edge level system is presented with which the performance, accuracy and stabilization of the system can be maintained.

# A Broad Perspective of Smart-Pillow

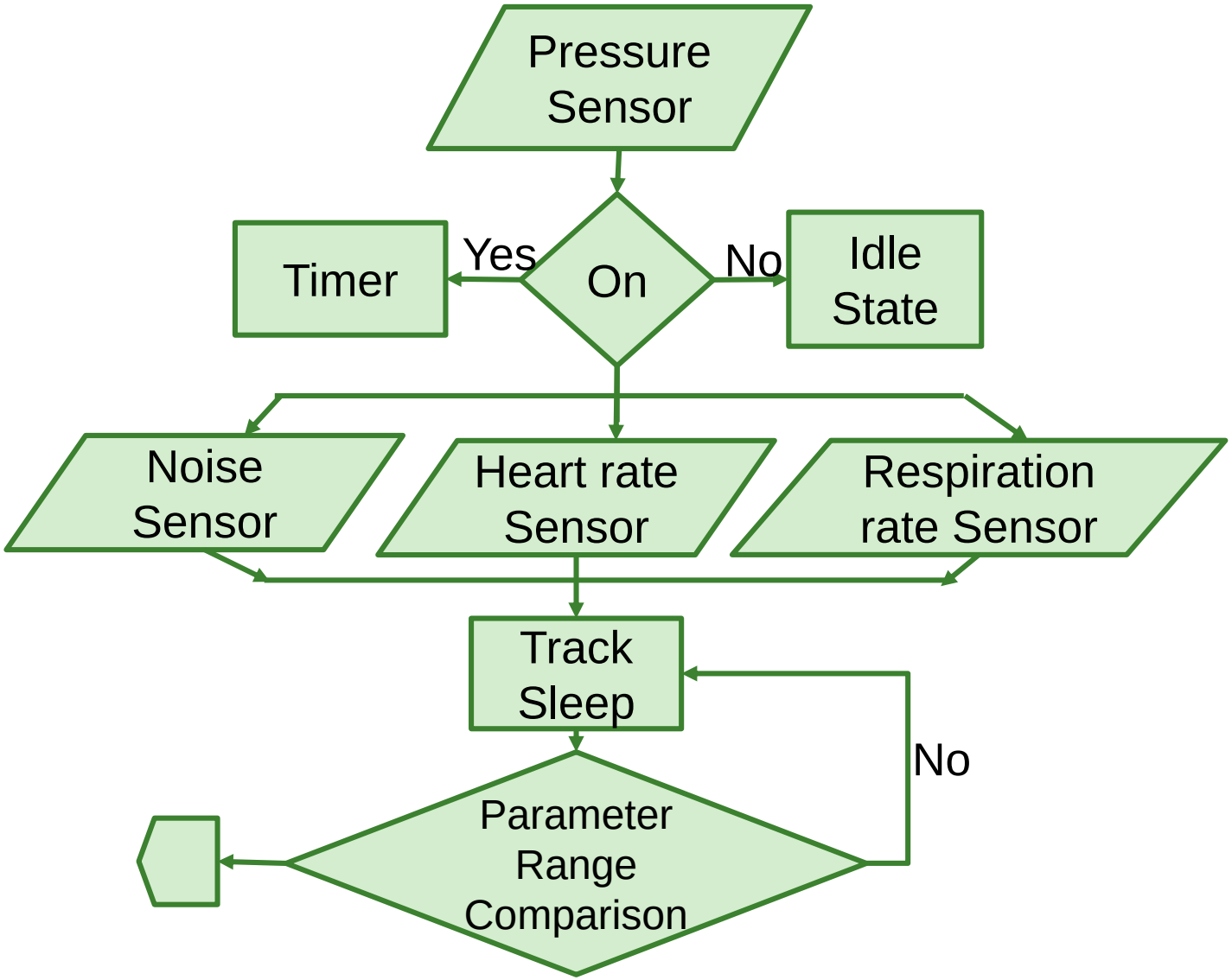
- ✓ **Broad Conceptual View of Smart-Pillow.**



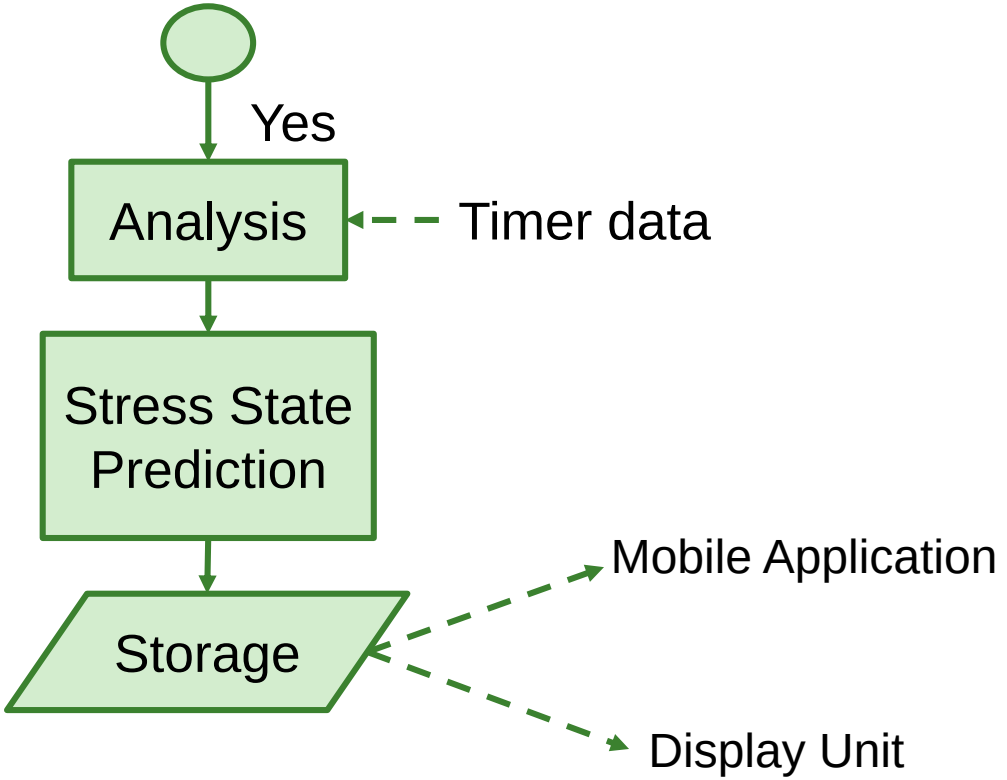
# Architecture of Smart-Pillow



# Flow of Smart-Pillow



# Flow of Smart-Pillow



# Dataset Acquisition

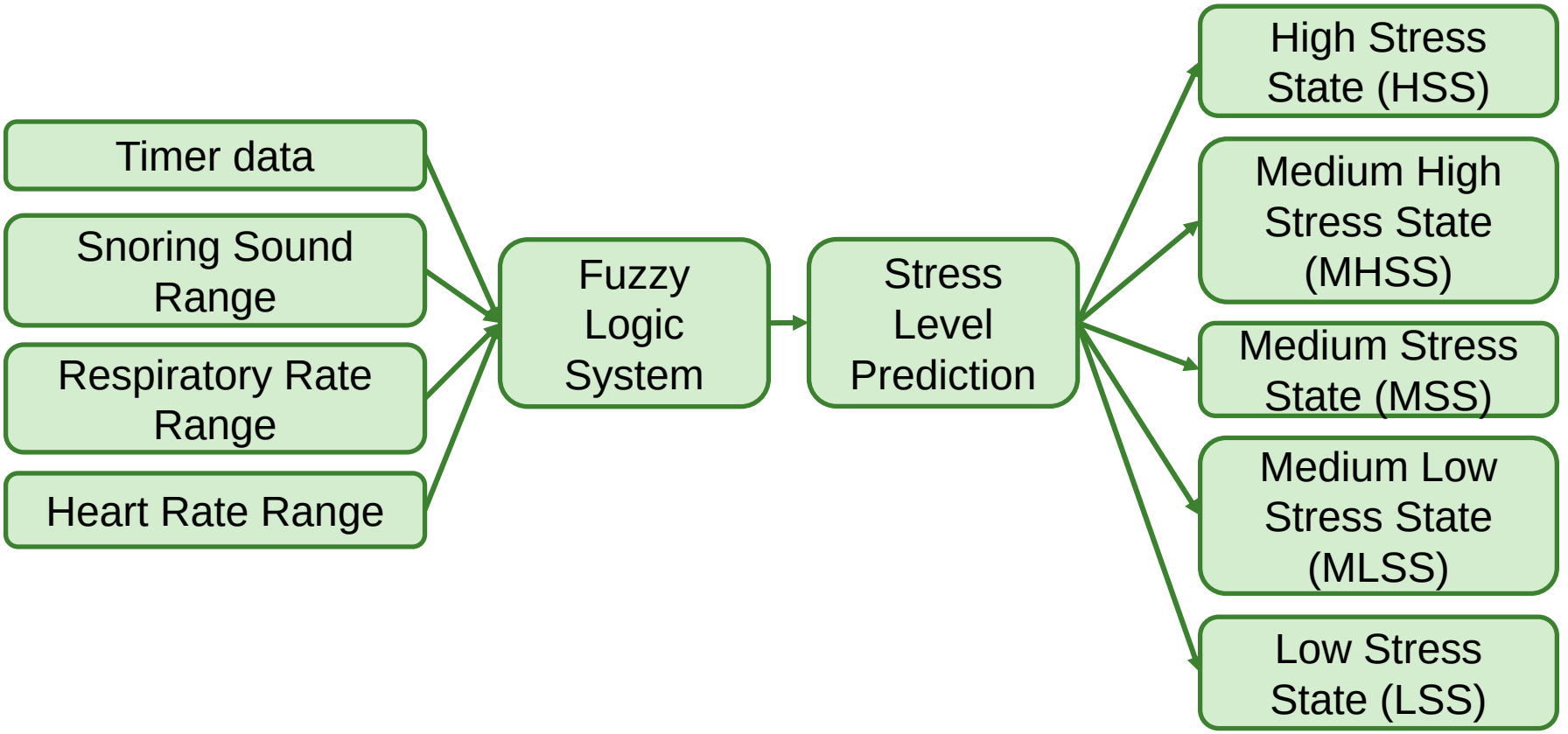
The Data at the sensor units are:

- Snoring Rate- When Snoring level exceeds 50dB, the chances of having stress is high
- Respiration Rate- Number of breathes per minute (bpm) when exceeds 15-17, can cause stress
- Heart Rate- If there is an observed heartrate more than 54-64 beats per minute (bpm), the chances of stress are high.
- Number of hours of Sleep- Minimum of 7 hours of sleep is required to maintain a healthy life.

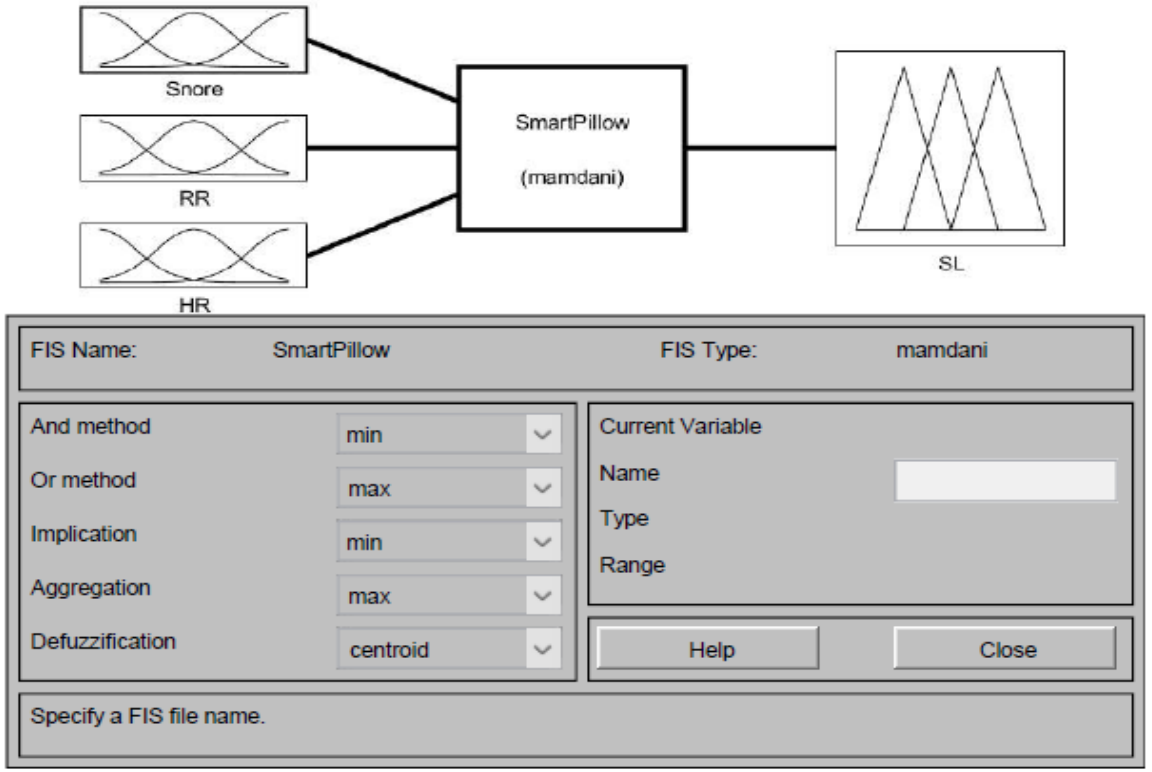
# Parameter Ranges

| Snoring Range (dB) | Respiration Rate (bpm) | Heart Rate (bpm) | Stress State |
|---|---|---|---|
| 50-60 | 17-19 | 54-57 | LSS |
| 60-70 | 19-21 | 57-60 | MLSS |
| 70-80 | 21-22 | 60-64 | MSS |
| 80-89 | 23-25 | 65-70 | MHSS |
| 90+ | 25+ | 70+ | HSS |

# Parameter Analysis



# Fuzzy Logic-Designer's View



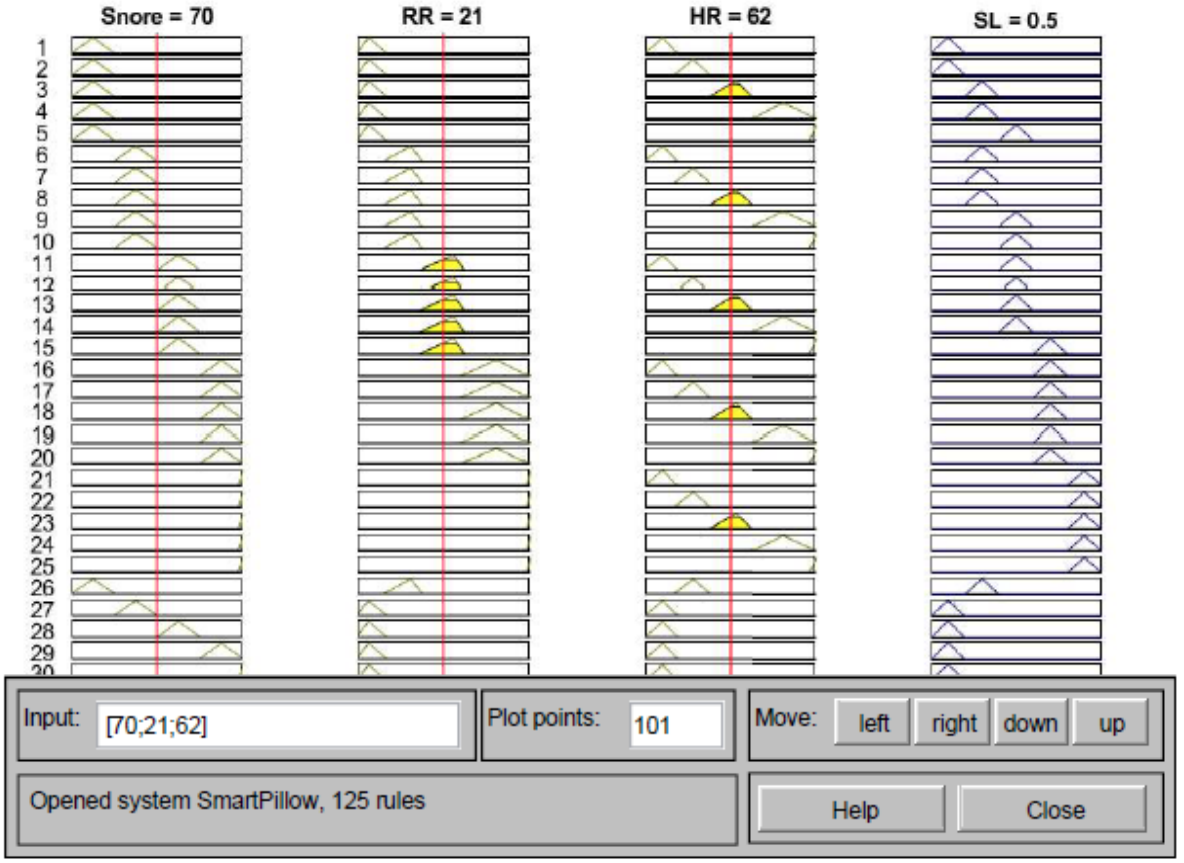

- A Mamdani Type Fuzzy Logic System is used.

- As there are 3 parameters and 5 sets of states, the total rules which can be generated are $5^3=125$.

# Fuzzy Output Range Specification

| Stress State | Output Range |
|---|---|
| Low Stress State (LSS) | 0.00-0.20 |
| Medium Low Stress State (MLSS) | 0.21-0.40 |
| Medium Stress State (MSS) | 0.41-0.60 |
| Medium High Stress State (MHSS) | 0.61-0.80 |
| High Stress State (HSS) | 0.81-1.00 |

# Rules of Fuzzy Logic Design

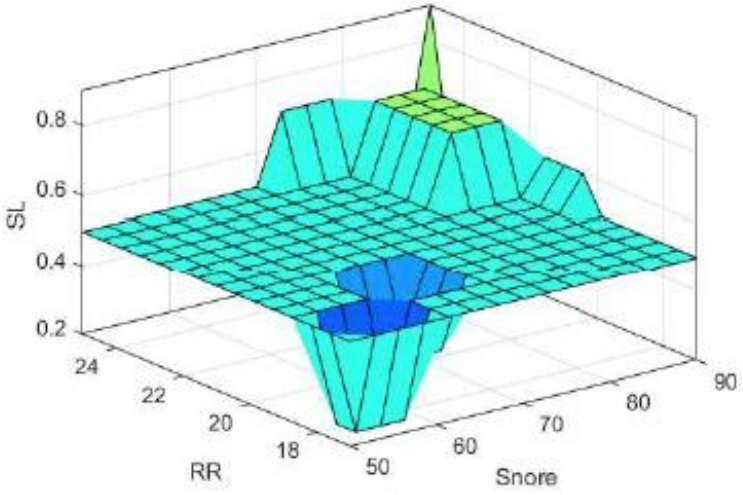


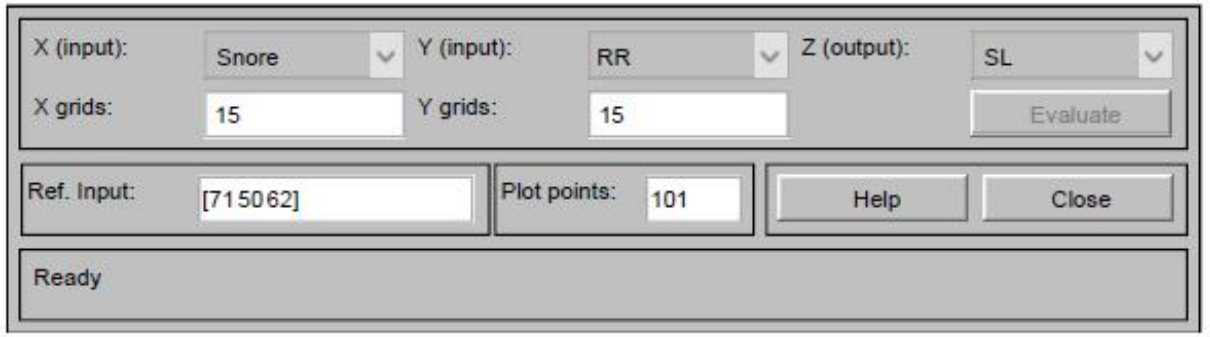

- The representation of rules and its implementation in the Fuzzy Designer is shown.

- The system is trained by a set of 125 rules and the output, i.e. the stress state, is defined in between the values 0 and 1.

# Sleep Parameters-Surface Plot

## ✓ Surface Plot of the Fuzzy System Response.




- The 3D plot of the system is Represented here.

- The values Stress Level (SL), Respiration Rate (RR) and Snoring rate are represented along with their boundaries as a validation of the system.

# Comparison with Existing Research

| Name | Approach | Features | Drawback |
|---|---|---|---|
| Fitbit [14] | Wearable | Heart rate monitor, sleep stages monitor | Does not manage stress with sleep. |
| SleepScore Max [15] | Non-wearable | Invisible radio wave sleep tracking | Does not manage stress with sleep. |
| Xiaomi Mi Band 3 [16] | Wearable | Pulse Monitor | Does not manage stress with sleep. |
| Beddit [18] | Non-wearable | Monitors snoring | Does not manage stress with sleep. |
| This Paper | Wearable | Heart rate, Snoring, Respiration rate | Establishes a relationship between sleep and stress, allows the user to have a control over the stress level variations. |

# Conclusion and Future Research

- Five different classifications of stress based on measurement of sleeping parameters is presented in this work.
- This method helps in improving and controlling the overall stress levels of a person.
- Implementation of the system incorporating machine learning or deep learning concepts are suggestions for future research.

# Thank You !!!