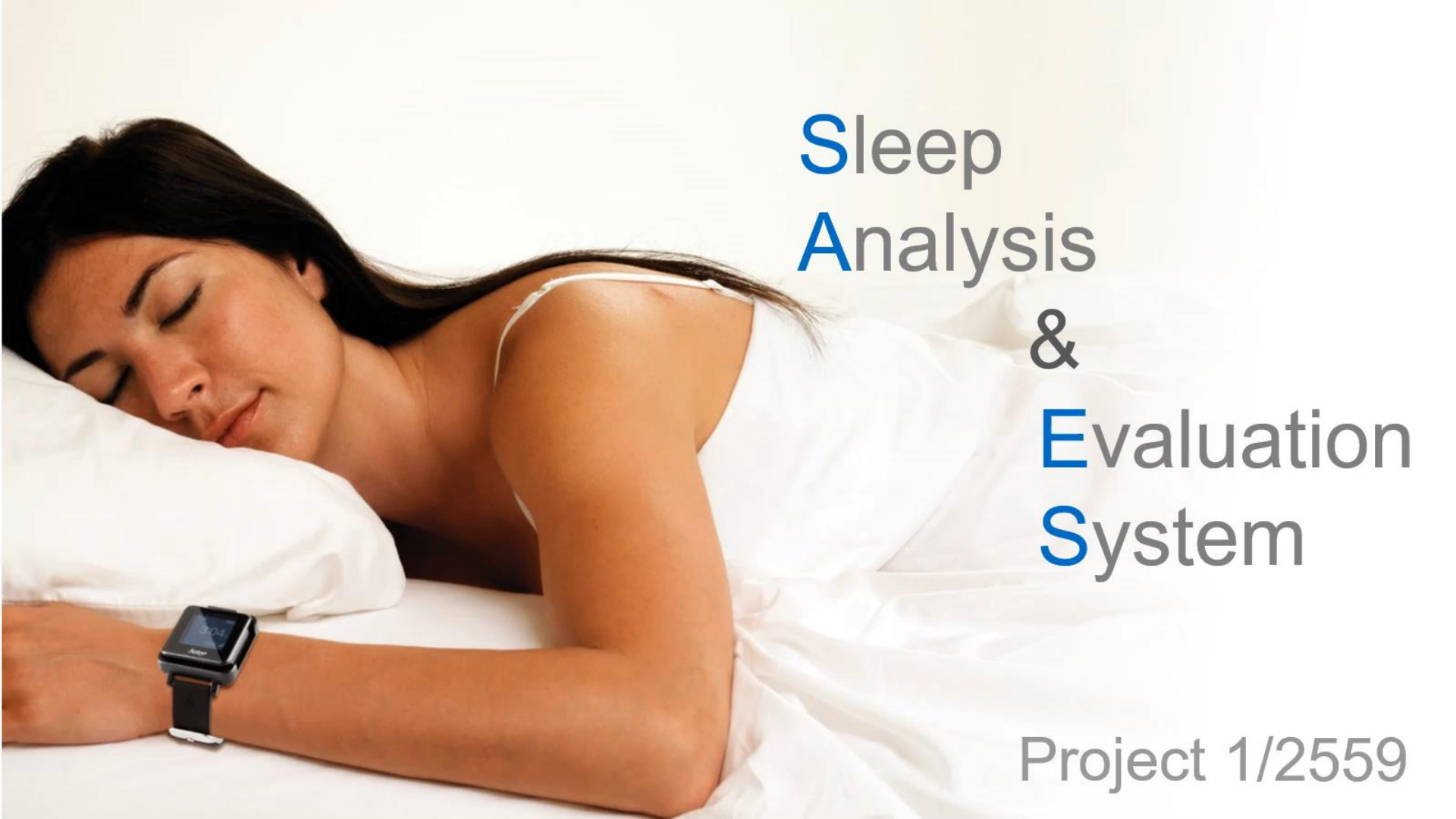

Sleep Analysis & Evaluation System

Project 1/2559

Member

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Advisor

Asst. Prof. Phongsak Keeratiwintakorn

Agenda

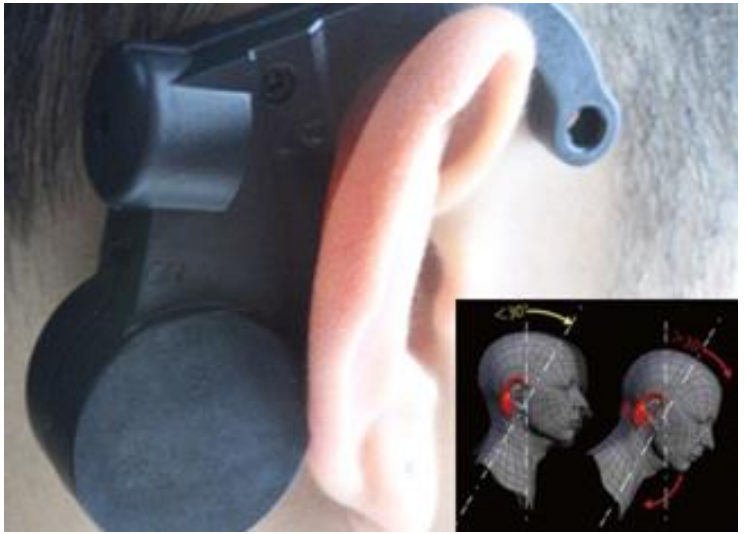
- Motivation
- How sleep work
- Wearable Devices
- Algorithm
- Conclusion


Motivation


FedEx
Ex

Current technology used in prevention

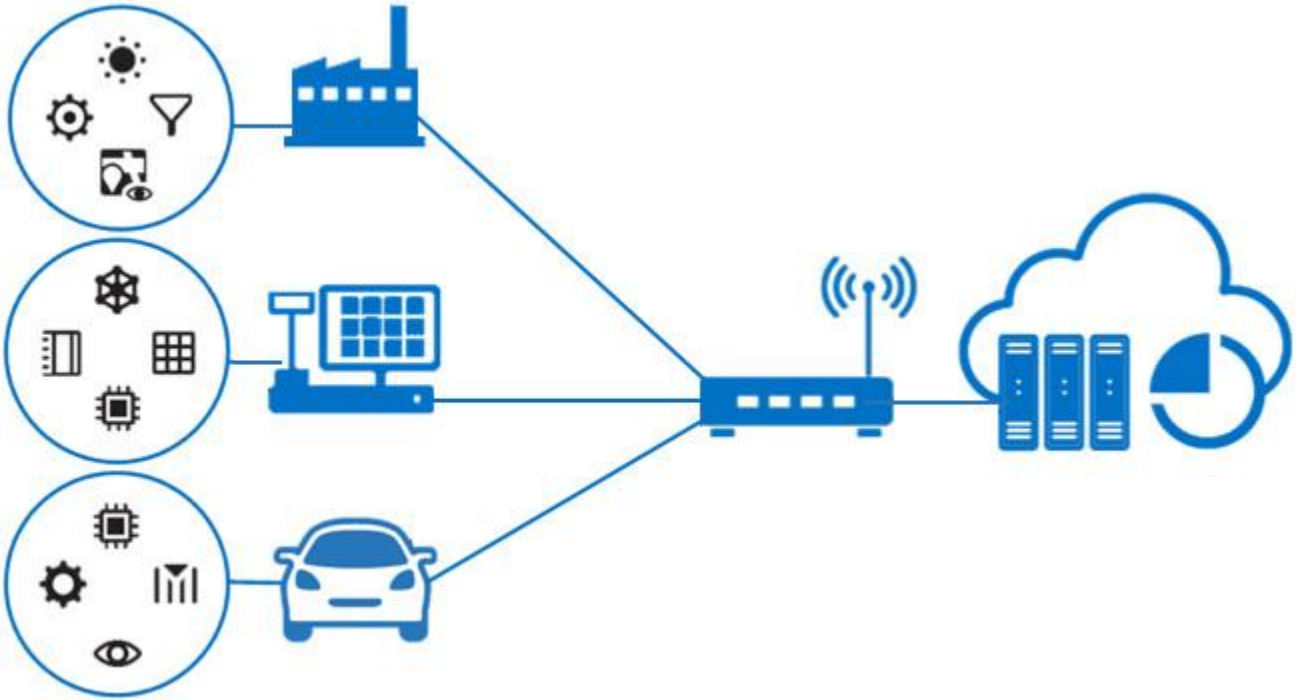
Exeros’s Sleep Watcher XR



Nap Zapper Alarm

Sleep Detection and Analysis System

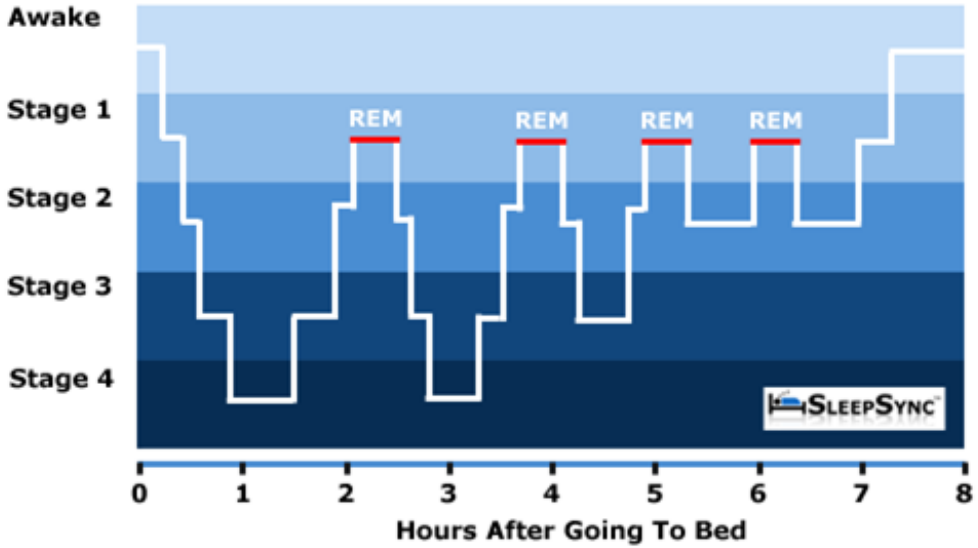
Cloud based System



How sleep work

Sleeping have 2 types:

- NREM (non-rapid eye movement) about 75% of the night
- REM (rapid eye movement) about 25% of the night



Sleep cycle

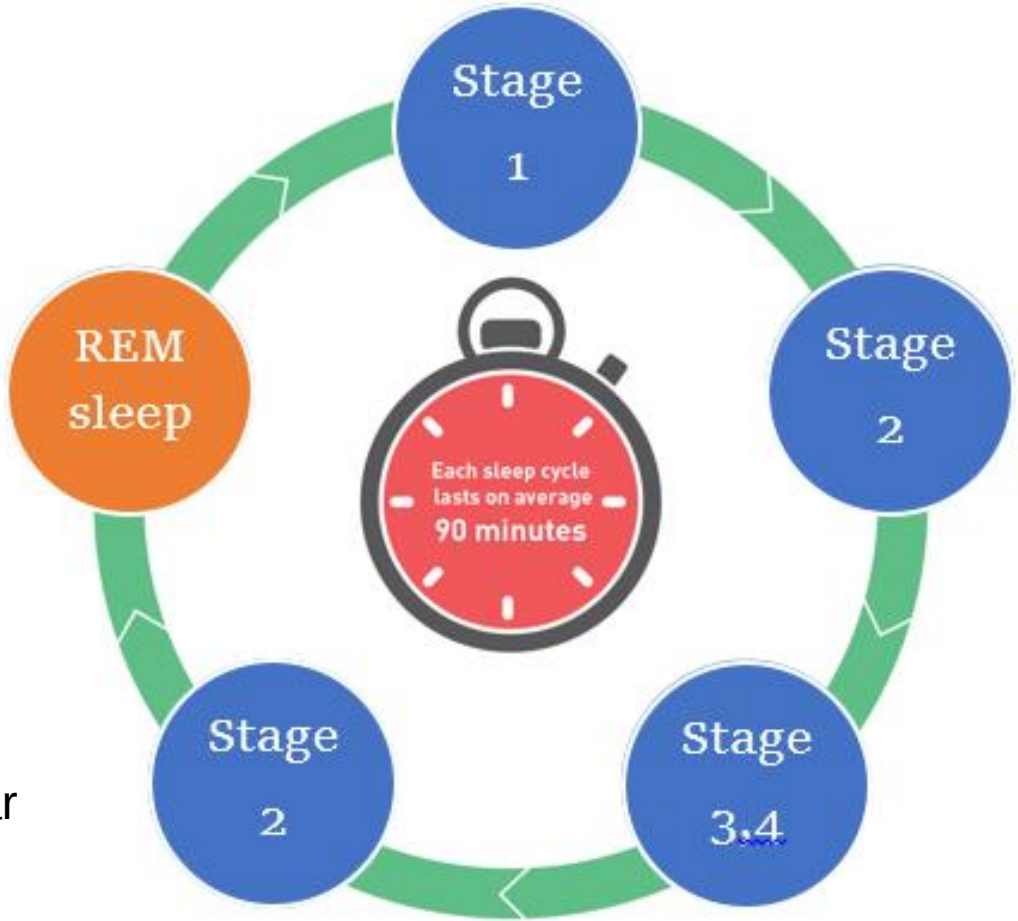
NREM sleep

Stage 1

- Between being awake and falling asleep

Stage 2

- Onset of sleep
- Breathing and heart rate are regular
- Body temperature drops

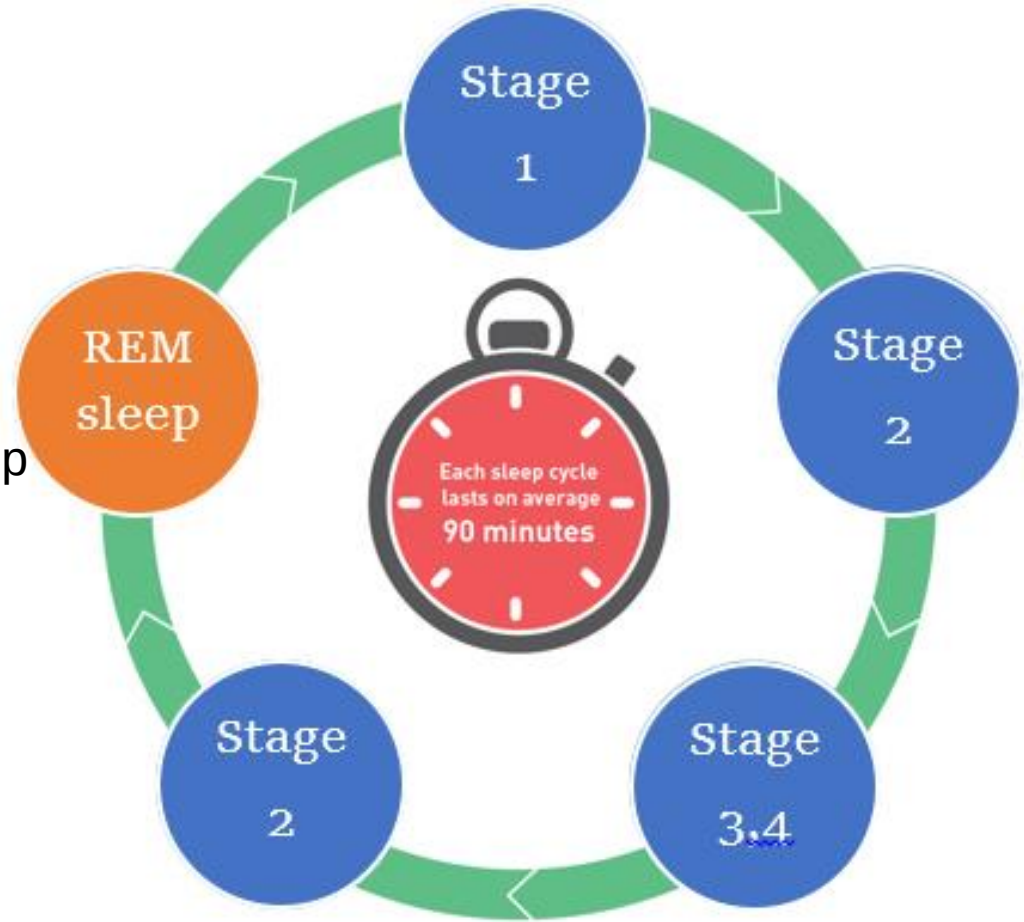


Sleep cycle

NREM sleep

Stages 3 and 4

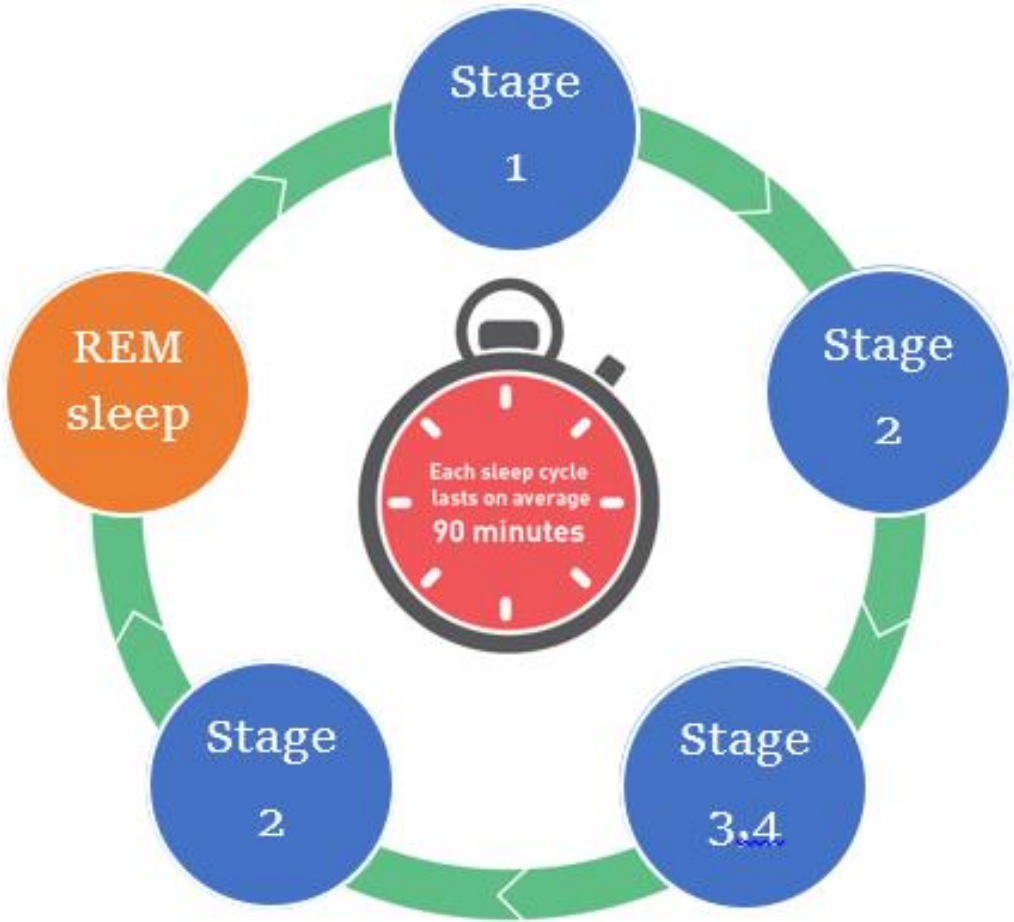
- Deepest and most restorative sleep
- Blood pressure drops
- Breathing becomes slower
- Muscles are relaxed
- Hormones are released



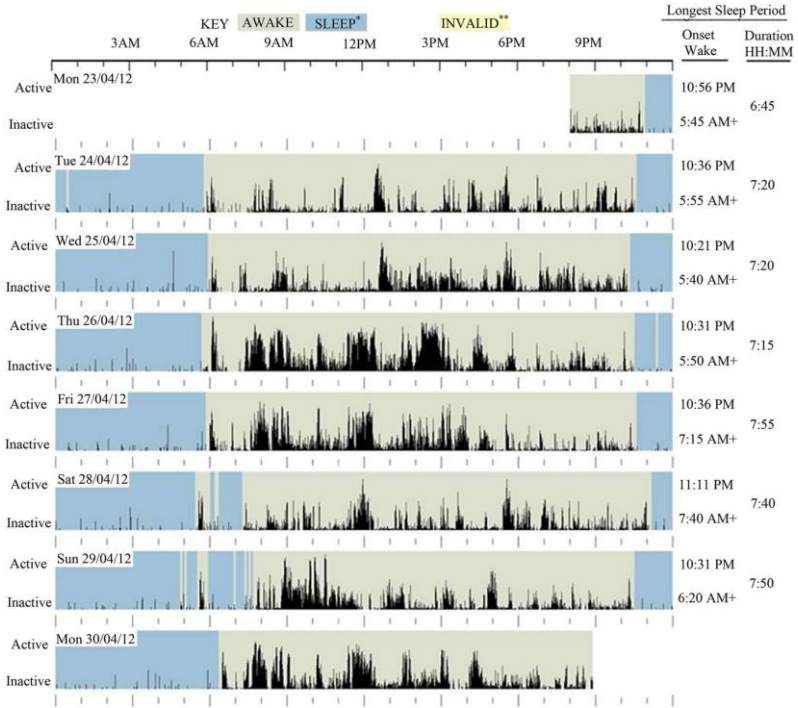
Sleep cycle

REM sleep

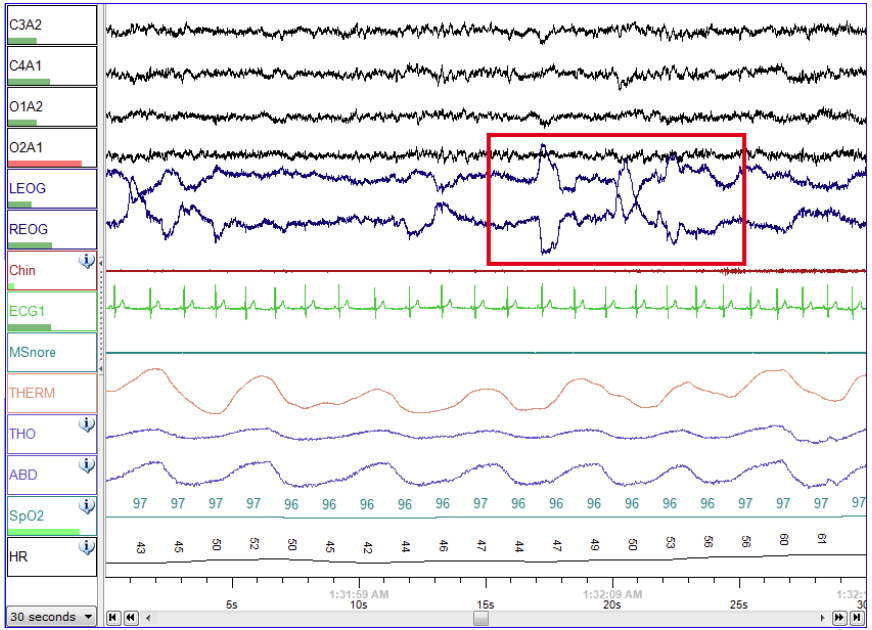
- Heart rate and blood pressure Increase.
- Core temperature is not well regulated during this time and tends towards the ambient temperature
- last for 10-11 minutes



Sleeping analysis method



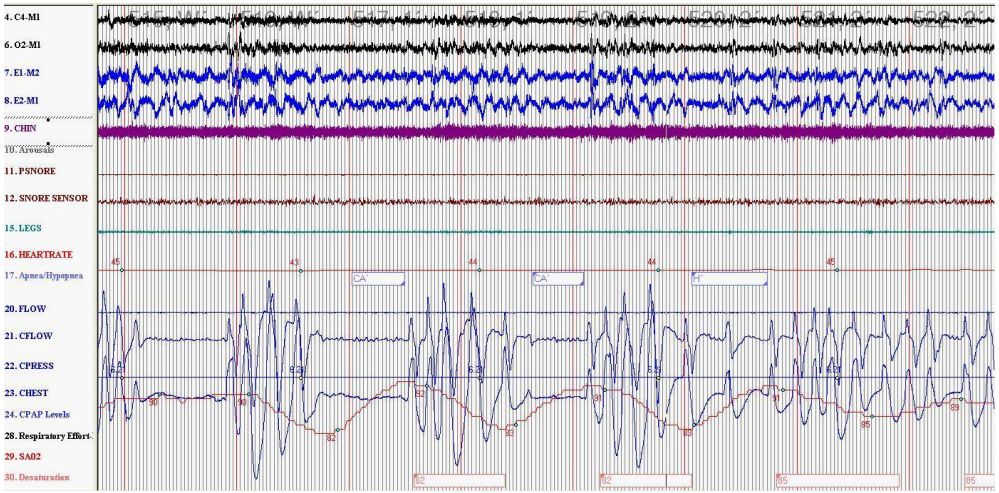
Actigraphy



Polysomnography (PSG)

Polysomnography

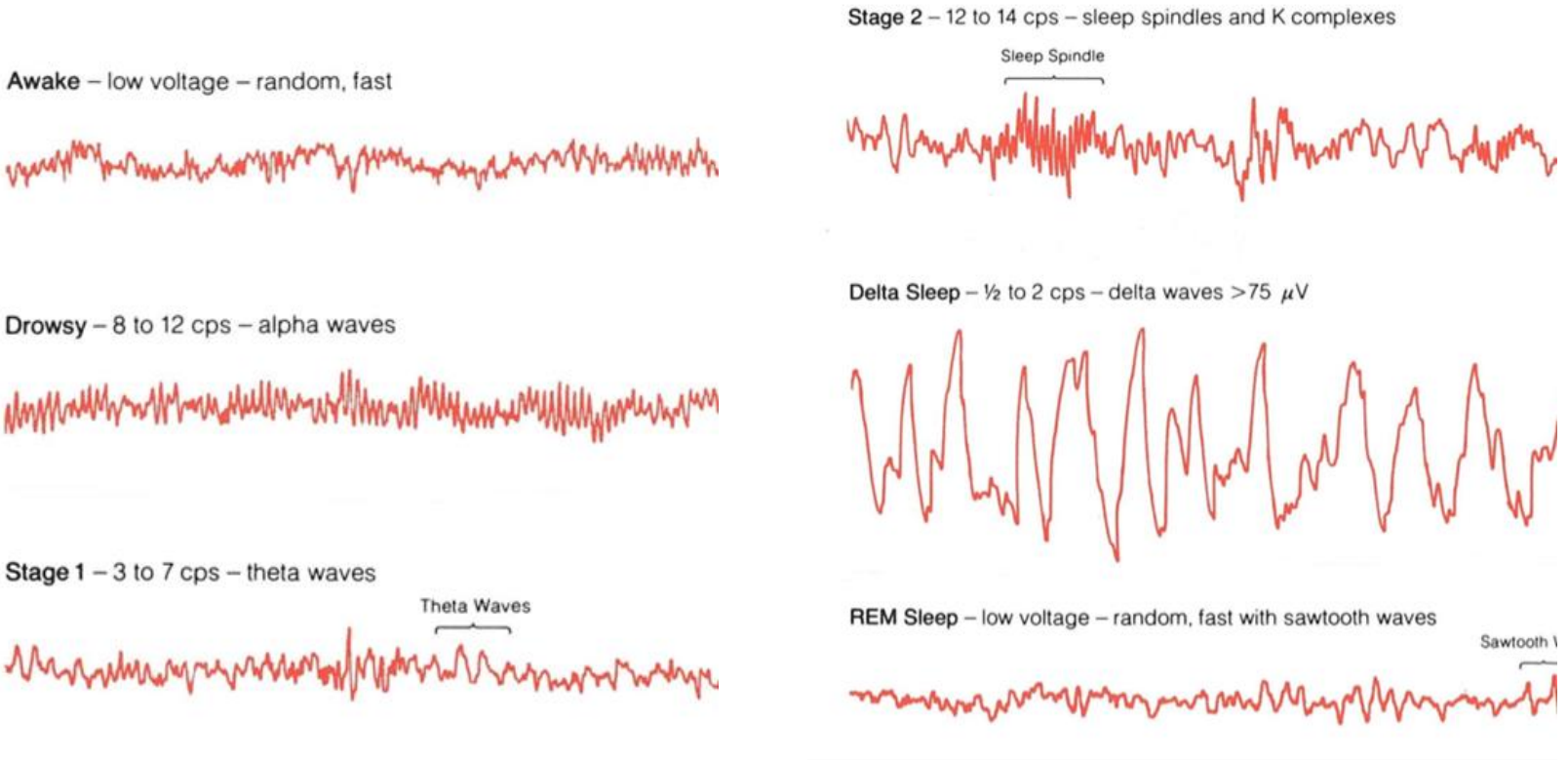
Polysomnography is a test used to diagnose sleep disorders. Polysomnography records your brain waves, the oxygen level in your blood, heart rate and breathing, as well as eye and leg movements during the study.



various ECG signal from Polysomnography

Polysomnography performed on male patient

Polysomnography

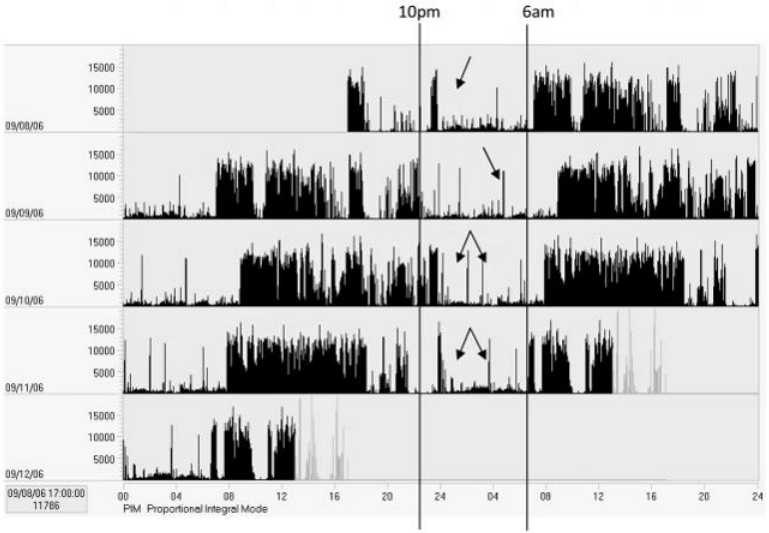


Characteristic electroencephalogram(EEG) patterns of human sleep stages.

Actigraphy

Actigraphy is a non-invasive method of monitoring human rest/activity cycles. Usually worn for a week or more to measure gross motion activity. The unit is usually, in a watch-like package, worn on the wrist. The movements the actigraph unit undergoes are continually recorded

The data can be later read to a computer and analysed

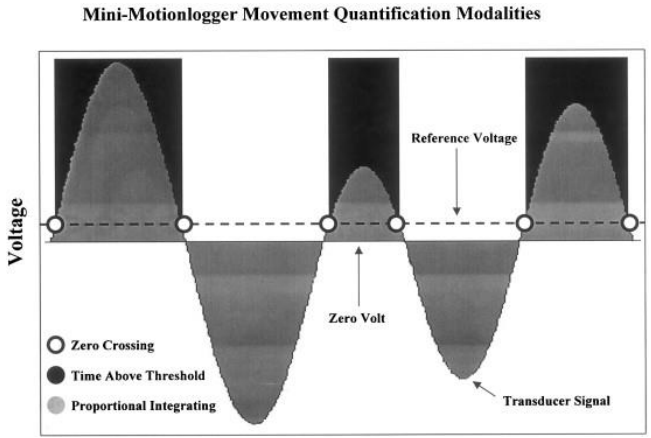


Actigraphy recorded using PIM method

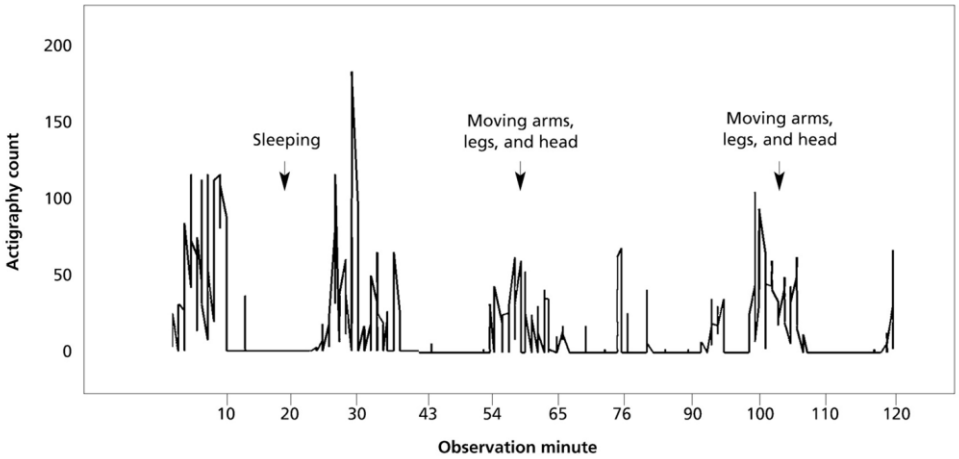
Actigraphy device worn over wrist

Actigraphy

Actigraphy can be measured by
- calculating magnitude of motion from 3-axis accelerometer using low-pass filter (0.25 hz - 3hz)
- calculating activity data by accumulating the values of magnitude data using difference approach (eg ZCM,PIM) in a period of time (called epochs)



motion magnitude measured by type



actigraphy measured by ZCM method

Wearable platform

fitbit FLEX

Hexiwear

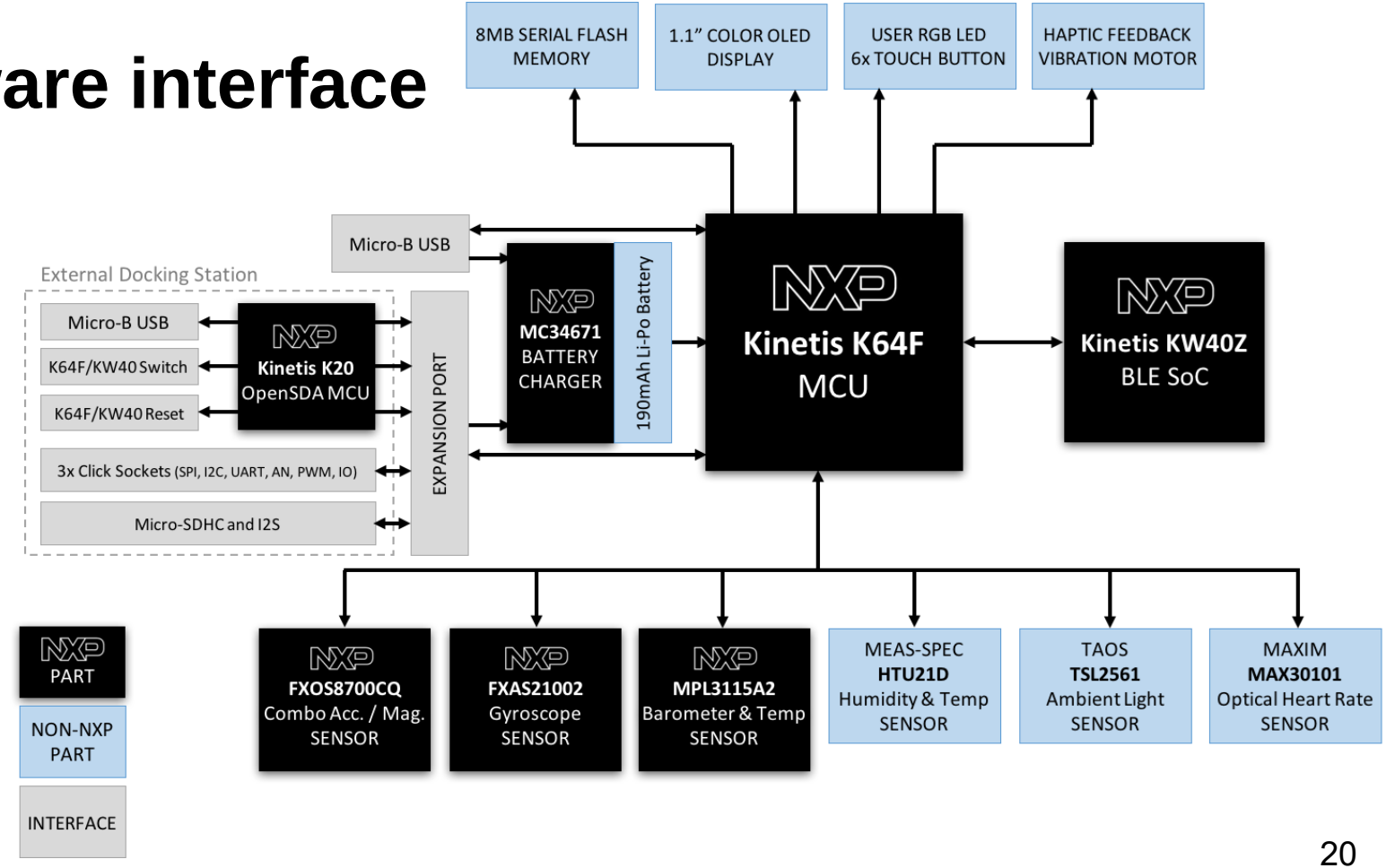
Pebble HR

Hexiwear

Hexiwear is a wearable development kit for the Internet of Things era. A low-power device packed with many sensors. Open sources both hardware and software.

Hexiwear

Hardware interface



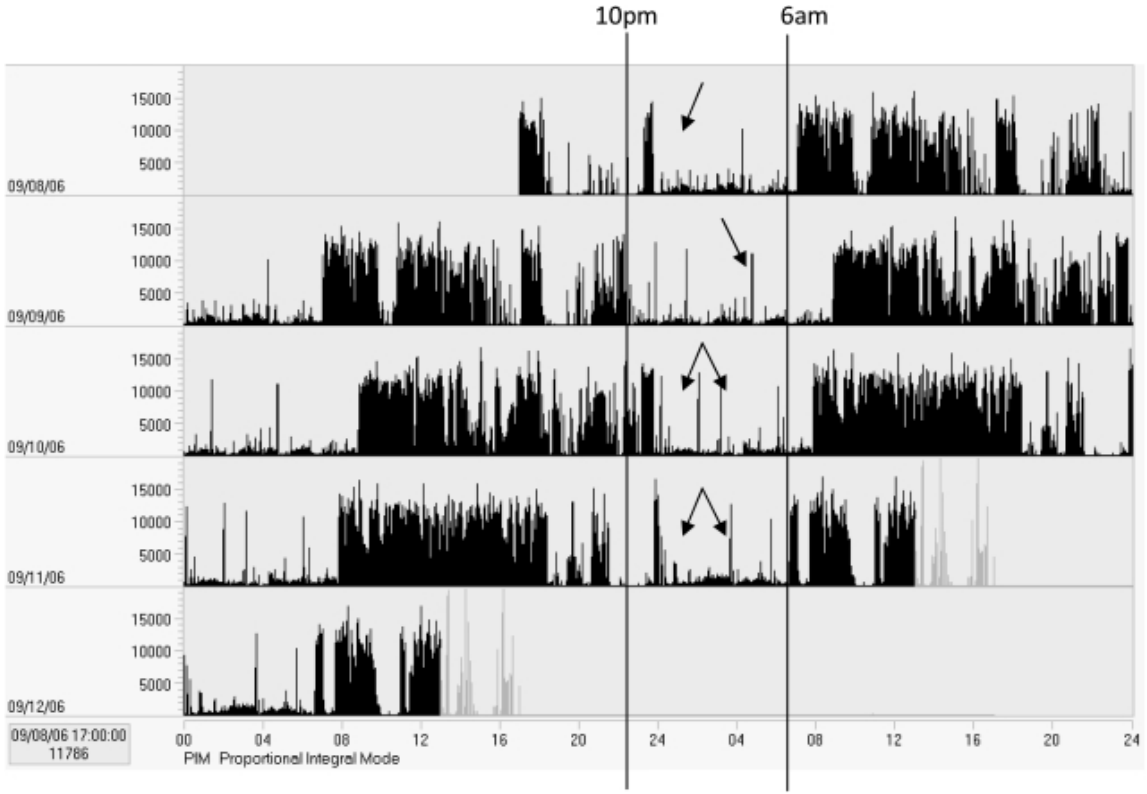
Software interface

ARMmbed

Algorithm

- Sleep-Wake Identification Algorithm
- Sleep Quality Evaluation Algorithm

Sleep-Wake Identification Algorithm



Pattern Recognition Method Using MLP

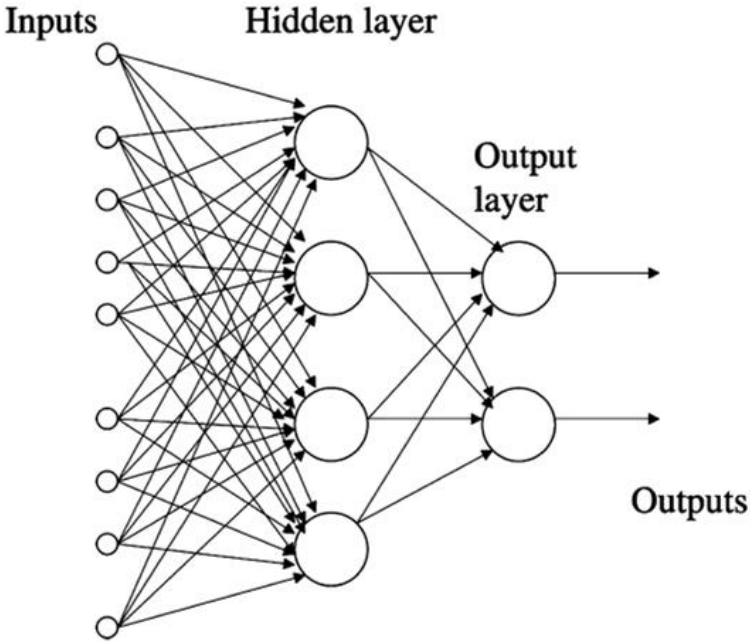


Figure 3. Multilayer perceptron with one hidden layer: each circle is one artificial neuron.

Artificial Neuron Function

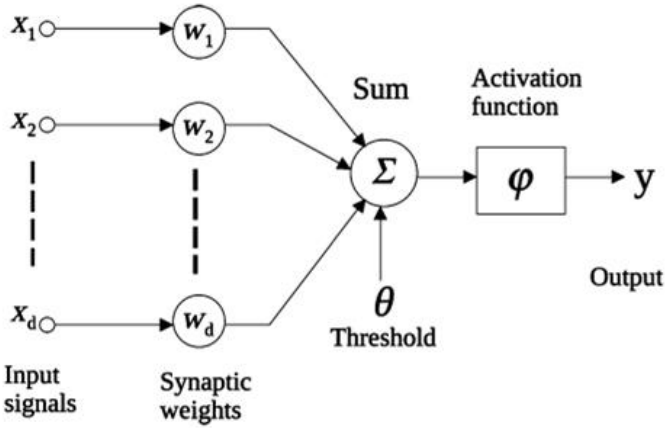


Figure 2. Structure of an artificial neuron.

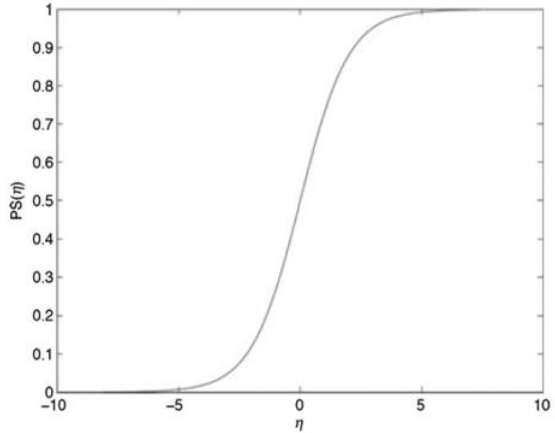


Figure 1. Sigmoid function.

Activation Function, $A = sigmoid\left(\sum_{i=1}^{m} X_i W_i\right)$

Function Explanation

Activation j,

$$A_j = sigmoid\left(\sum_{i=0}^{m} X_i W_{ji}^{(l)}\right)$$

Output j,

$$O_j = sigmoid\left(\sum_{i=0}^{n} A_i W_{ji}^{(l)}\right)$$

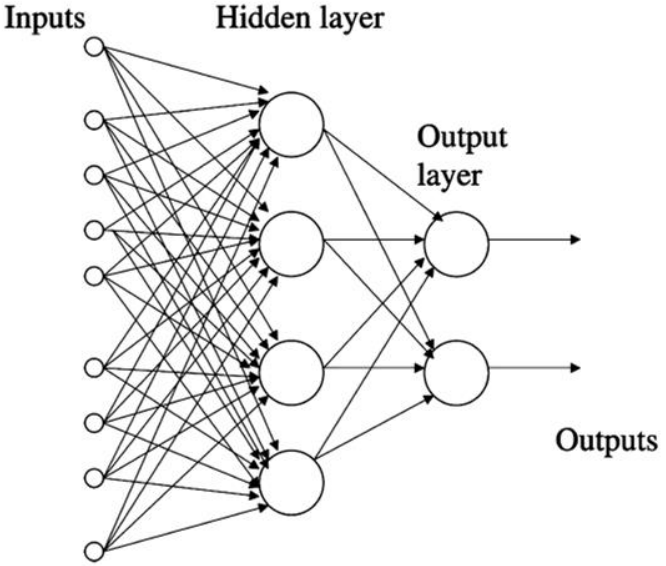


Figure 3. Multilayer perceptron with one hidden layer: each circle is one artificial neuron.

m = total numbers of Input
n = total numbers of Weight
l = layer level

*X_0 , A_0 = 1 (as a bias or threshold)

25 Relevant Feature list

Table 4 Proposed actigraphy features with their discriminant power *D*

N	*Feature*	*D*
1	Activity of current epoch	0.1381
2	Sum of activities in a 10.5-min centered window	0.2212
3	Activity of current minus previous epoch	0.00001
4	Activity of current minus next epoch	0.0006
5	Mean activity of the file	0.005
6	Activity of current epoch divided by the number of periods of successive one-value signal in this epoch	0.0698
7	Same as feature 6 in a 5.5-min centered window	0.0998
8	Standard deviation of activity in a 10.5-min centered window	0.2289
9	Number of epochs in centered window with an activity ≥9 and ≤16	0.0688
10–14	Activity of epoch located respectively 5, 4, 3, 2, 1 epochs before the current one	0.0988, 0.1047, 0.113, 0.126, 0.136
15–19	Activity of epoch located respectively 1, 2, 3, 4, 5 epochs after the current one	0.1215, 0.101, 0.083, 0.0714, 0.064
20,21	Max, min epoch activity in a 10.5-min centered window	0.2333, 0.0158
22	Number of epochs in a 10.5-min centered window with activity value greater than five times the mean activity	0.2167
23	Longer one-period in epoch	0.1049
24	Number of one values in actigraphic signal in a 5.5-min centered window that are not between 2 zeros	0.0987
25	Natural logarithm of the activity of current epoch, incremented by 1	0.1762

*

Tilmanne, J, Urbain, J, Kothare, MV, Wouwer, AV & Kothare, SV 2009, 'Algorithms for sleep-wake identification using actigraphy: A comparative study and new results' *Journal of Sleep Research*, vol 18, no. 1, pp. 85-98. DOI: 10.1111/j.1365-2869.2008.00706.x

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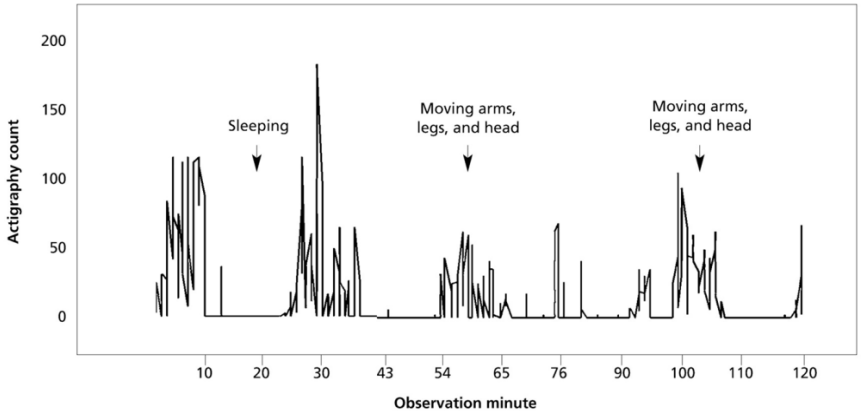
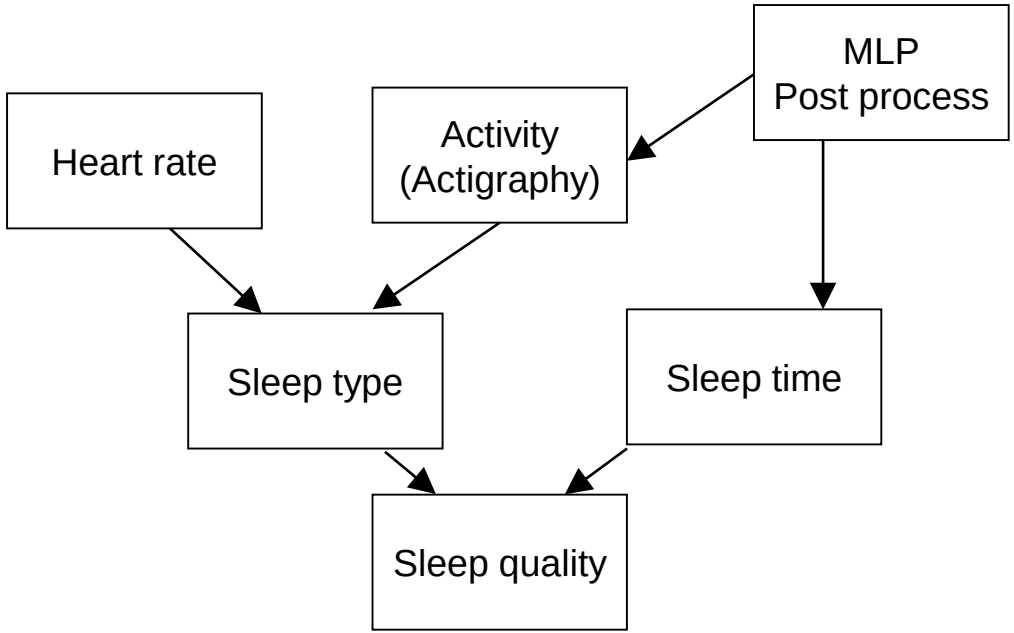
5 Most significant features

#2. Sum of activities in a 10.5-min centered window
#8. Standard deviation of activity in a 10.5-min centered window
#20. Maximum epoch activity in a 10.5-min centered window
#22. Number of epochs in a 10.5-min centered window with activity value greater than fivetimes the mean activity
#25. Natural logarithm of the activity of current epoch, incremented by 1
(May be change due to input epoch values)



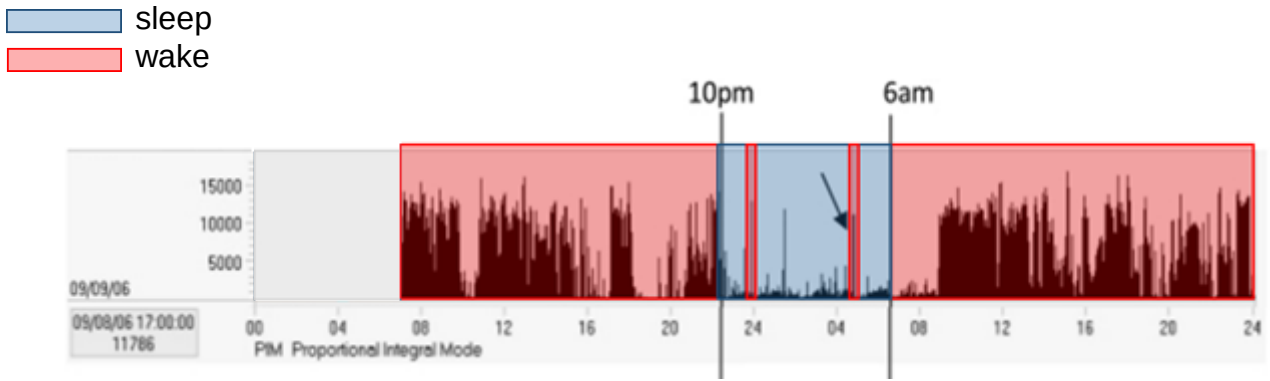
Sleep Quality Evaluation Algorithm



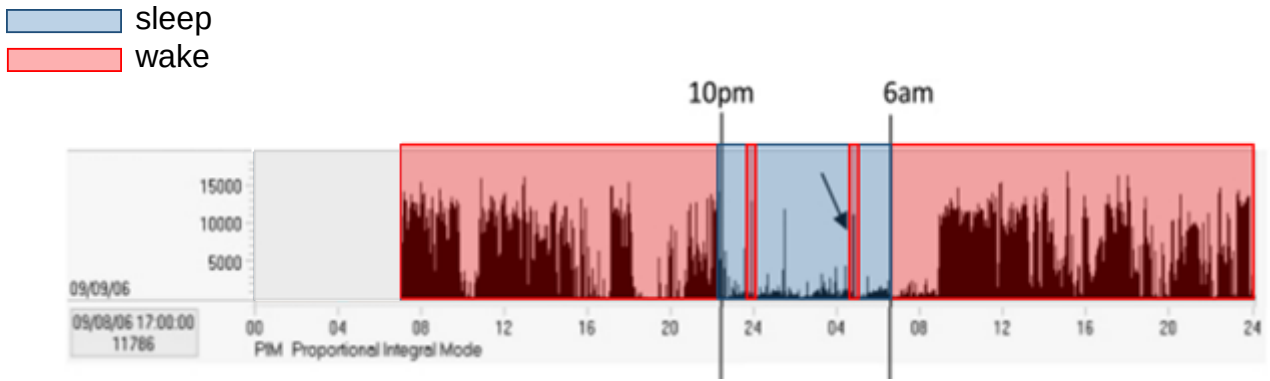
MLP Post Process Algorithm

- Total sleep time
- Sleep activity

MLP Post Process Algorithm



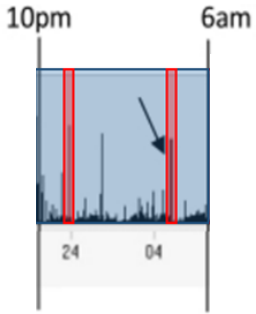
Total sleep time



$$Total\ time\ (S_t) = time_{wase} - time_{sawe}$$

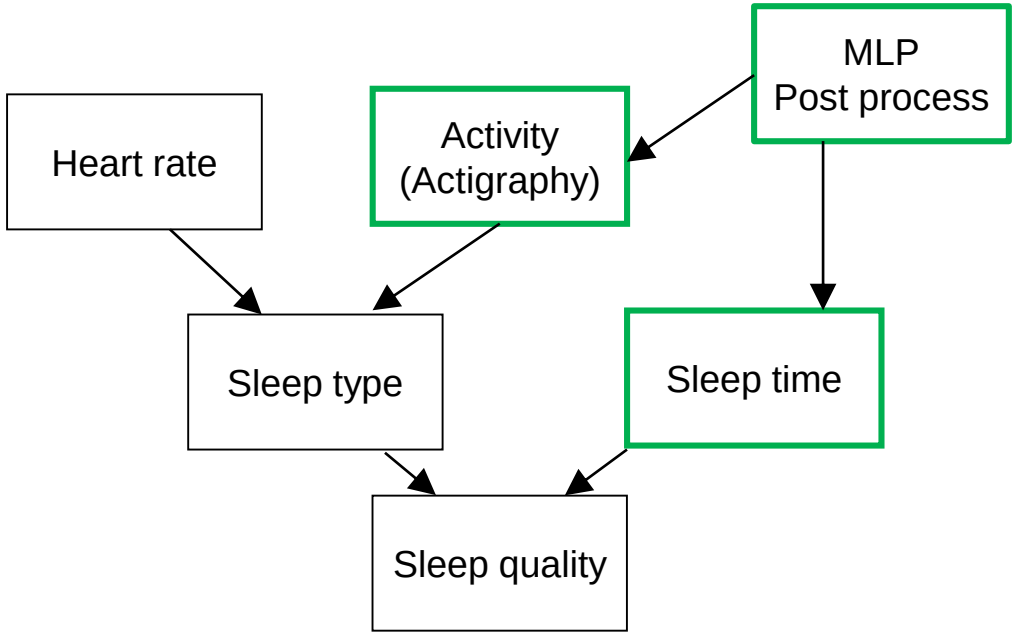
$$time_e = \begin{Bmatrix} time_{sawe}\ , if\ AvgState_{e-1\ \ldots e-10} = wake\ \ and AvgState_{e+1\ldots e+10} = sleep \\ time_{wase}\ , if\ AvgState_{e-1\ \ldots e-10} = sleep\ \ and\ AvgState_{e+1\ldots e+10} = wake \end{Bmatrix}$$

Sleep Activity



$$Activity = e_{time_{sawe}} \ldots\ldots e_{time_{wase}}$$

Sleep Quality Evaluation Algorithm



Sleep Type

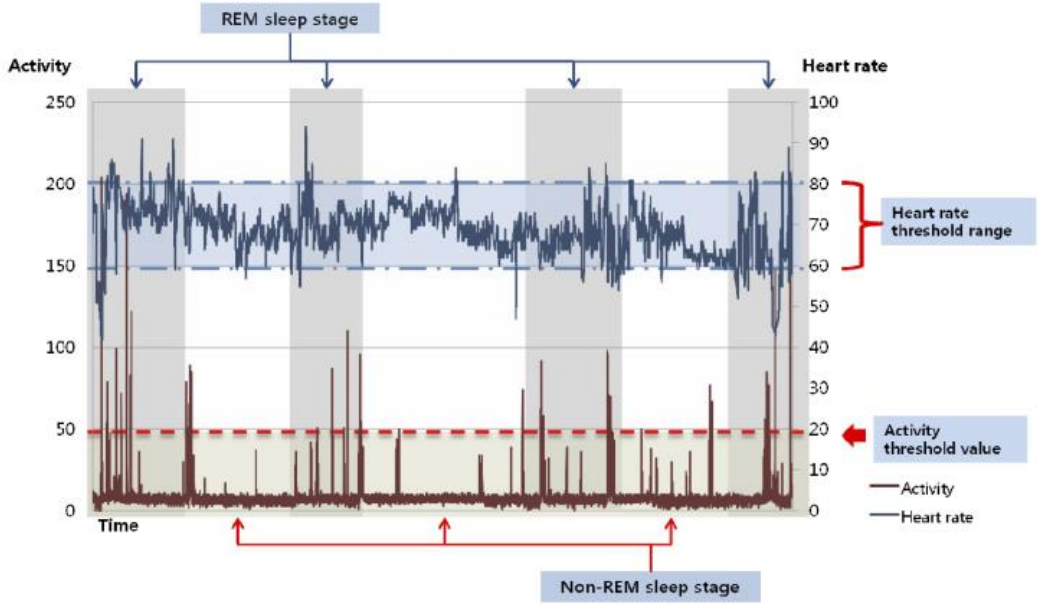
$$Type_e = \begin{cases} Type_{NREM} & ,if\ T_{A_{min}} \leq A_i \leq T_{A_{max}}\ and\ T_{HR_{min}} \leq HR_i \leq T_{HR_{max}} \\ Type_{REM} & ,otherwise \end{cases}$$

$$time_e = \begin{cases} time_{frem} & ,if\ AvgType_{e-1\ldots e-5} = Type_{NREM}\ and AvgType_{e+1\ldots e+5} = Type_{REM} \\ time_{lrem} & ,if\ AvgType_{e-1\ldots e-5} = Type_{REM}\ and\ AvgType_{e+1\ldots e+5} = Type_{NREM} \end{cases}$$

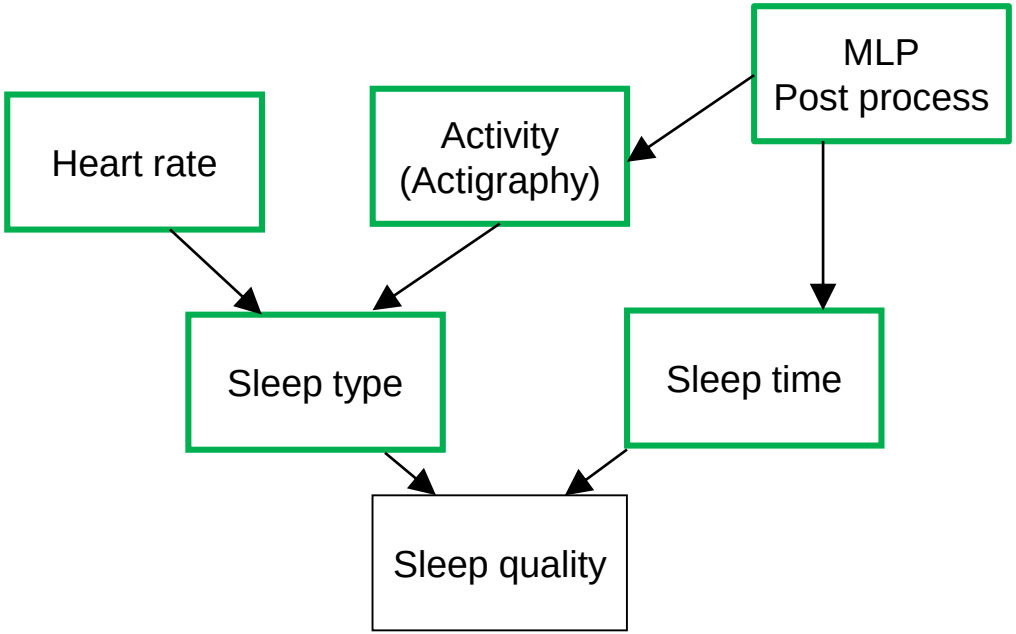
Sleep Type

$$Total\ REM\ time\ (S_{REM}) = \sum_{i=1}^{total\ rem\ times} (time_{lrem} - time_{frem})$$

$$Total\ NREM\ time\ (S_{NREM}) = S_T - S_{REM}$$



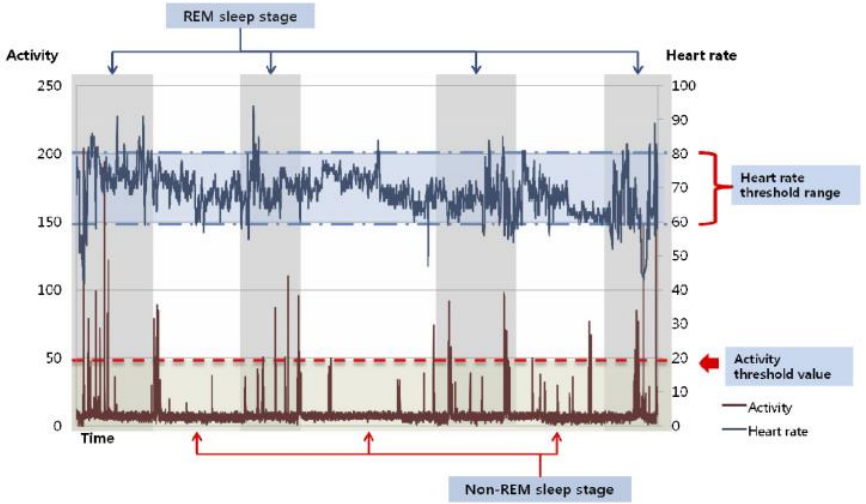
Sleep Quality Evaluation Algorithm



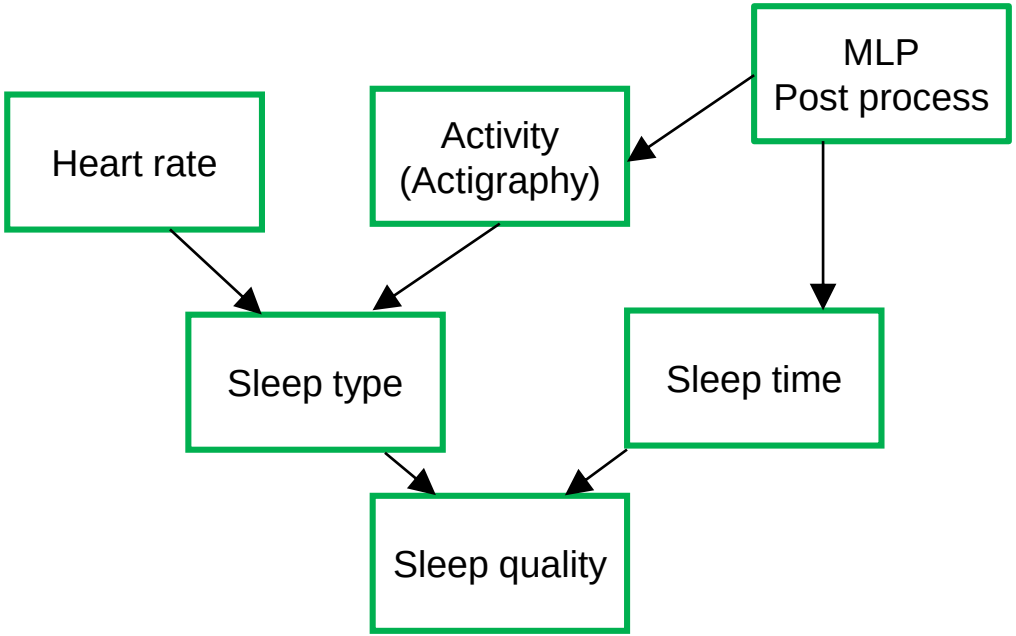
Sleep Quality Evaluation Algorithm

$$S_{quality} = \frac{S_{NREM}}{S_T + penelty}$$

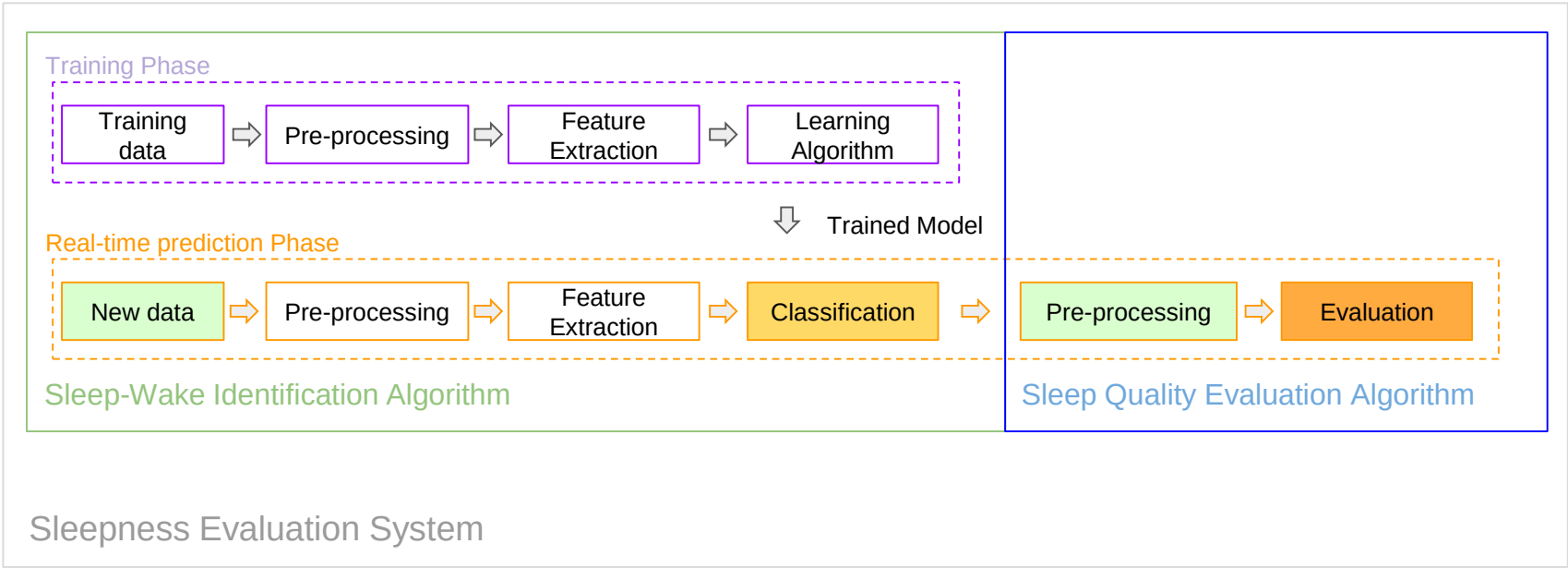
$$\text{penalty} = \begin{cases} 0 & , S_{Threshold} - S_T < 0 , \\ S_{Threshold} - S_T & , otherwise, \end{cases}$$



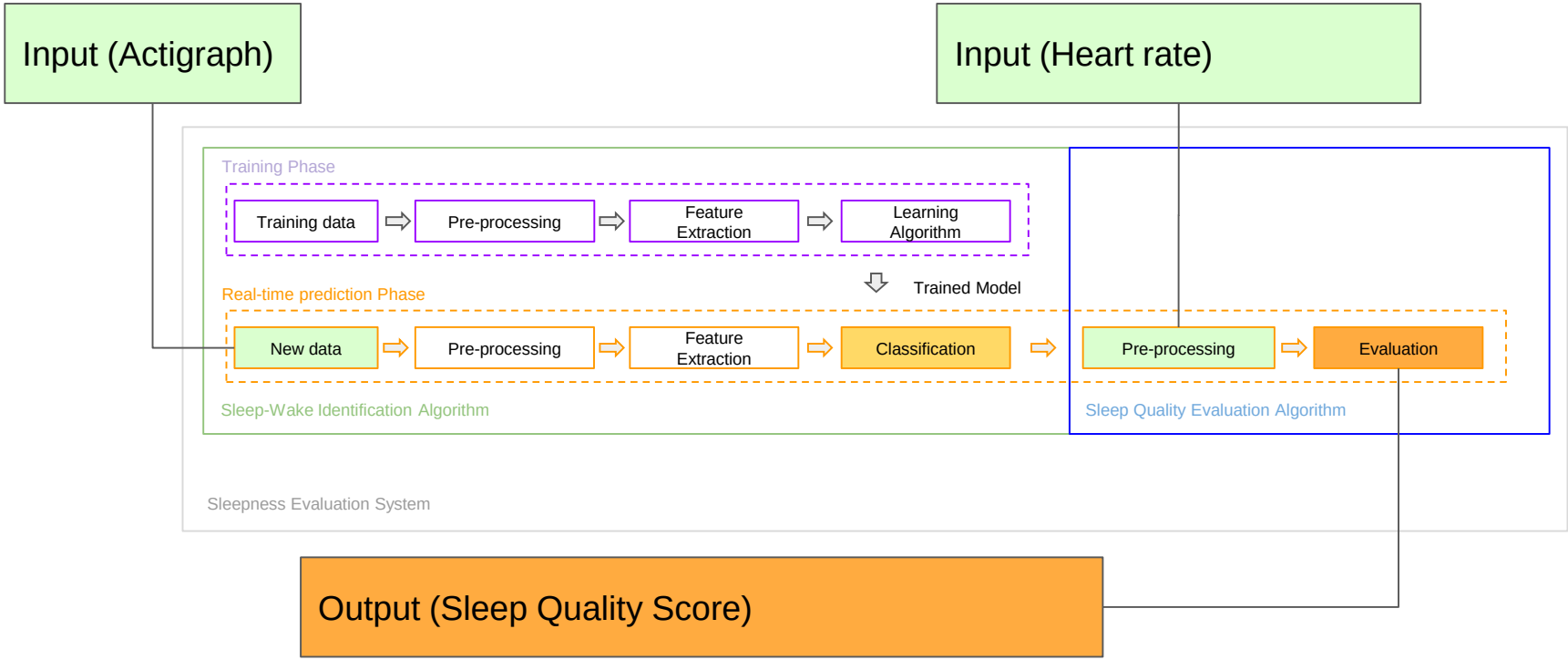
Sleep Quality Evaluation Algorithm



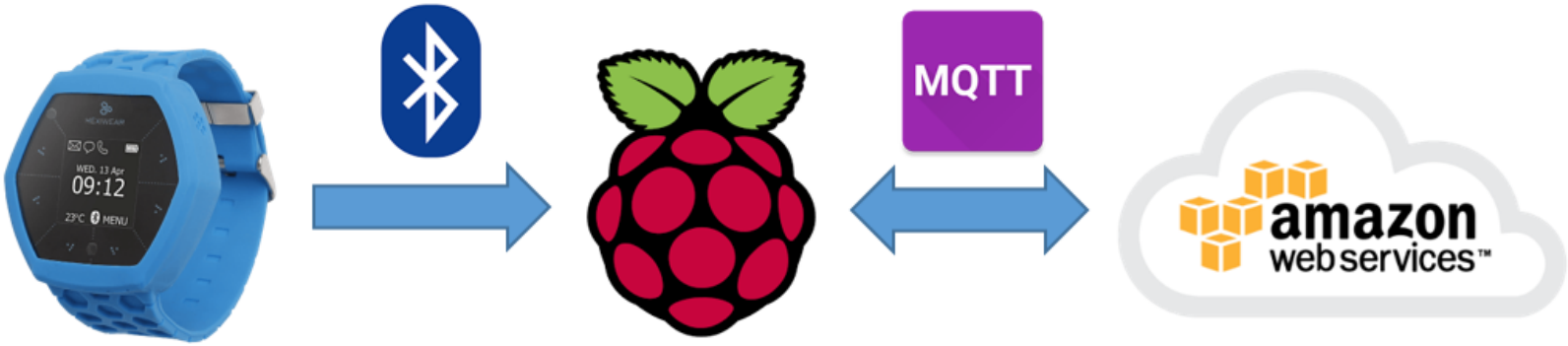
Sleepness Evaluation System Pipeline



Sleepness Evaluation System Pipeline



Block diagram



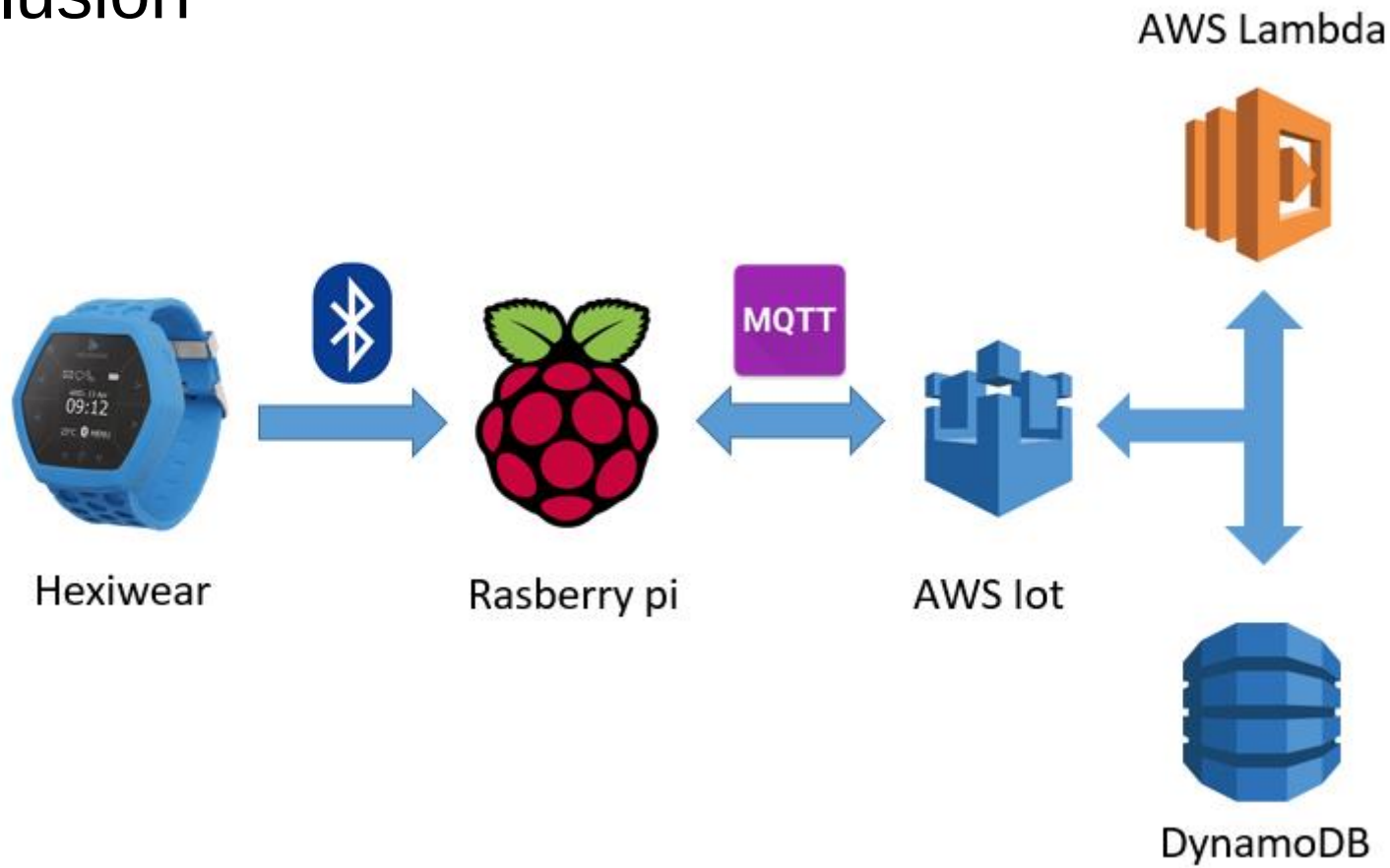
Amazon Web Services

AWS Iot

AWS Lambda

AWS DynamoDB

Conclusion



Save our Life

with Your Sleep

Project 1/2559