Brain-Computer Interface for Home Automation

SP2015-02

Overview

1. Introduction
2. Background
3. Analysis & Design
4. Implementation
5. Demonstration
6. Testing and Evaluation
7. Conclusion

Introduction

Motivation

Home Automation

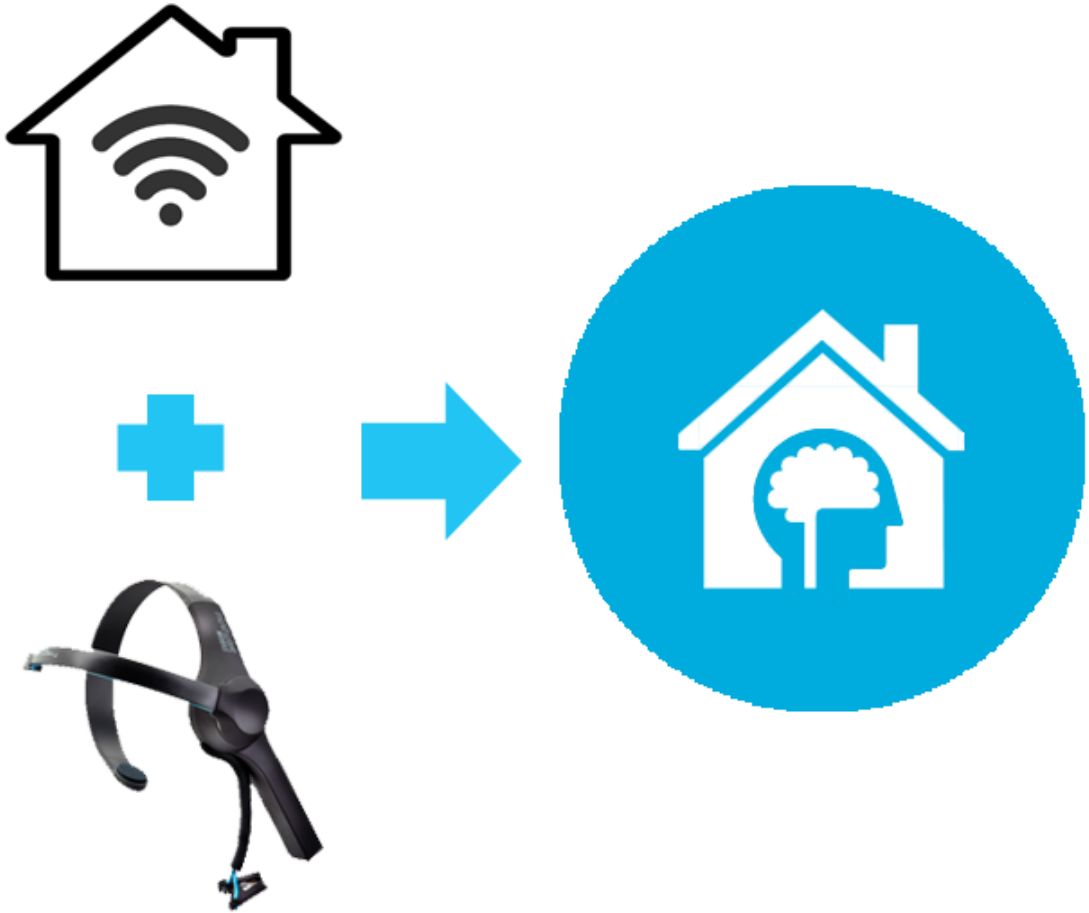
“Most home automation systems require physical interactions, which make them unable to support people with motion impairments.”

Paralysis

http://www.spinal-research.org/wp-content/uploads/2011/09/Image-0444.jpg

Amyotrophic Lateral Sclerosis (ALS)

http://vignette2.wikia.nocookie.net/epicrapbattlesofhistory/images/1/1a/Stephen_Hawking_Based_On.jpg/revision/latest?cb=20150822054937



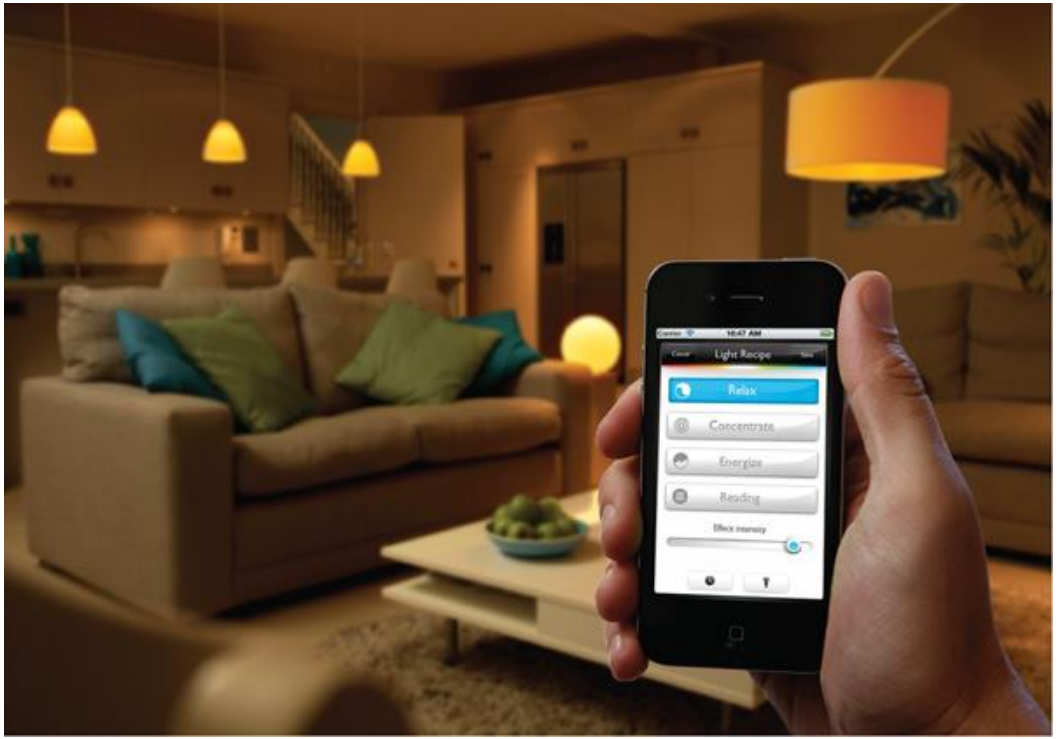
MindMagic

- **User** — Send commands to turn on/off electronic appliances in a single room by using eye-blinks.
- **System** — Control electronic appliances by using wireless connection.
- **System** — Control electronic appliances that are controlled with IR remote controls.
- **System** — Allow users to add, edit, and remove electronic appliances via the user interface.

Background

Relevant Technologies

Home Automation



https://www.pm360online.com/the-smart-home/

NeuroSky®

Body and Mind. Quantified.

Brain-Computer Interface

- EEG (Electroencephalogram) Wearable Device
- Affordable (99.99 USD)
- Easy to Use (Dry Cells, 2 Sensors)
- Bluetooth Connection
- Attention, Meditation, and Blink Detection

Embedded Systems

Arduino Uno

- Microcontroller
- Easy to Use
- Open Source
- Inexpensive

ARDUINO

Universal Windows Platform

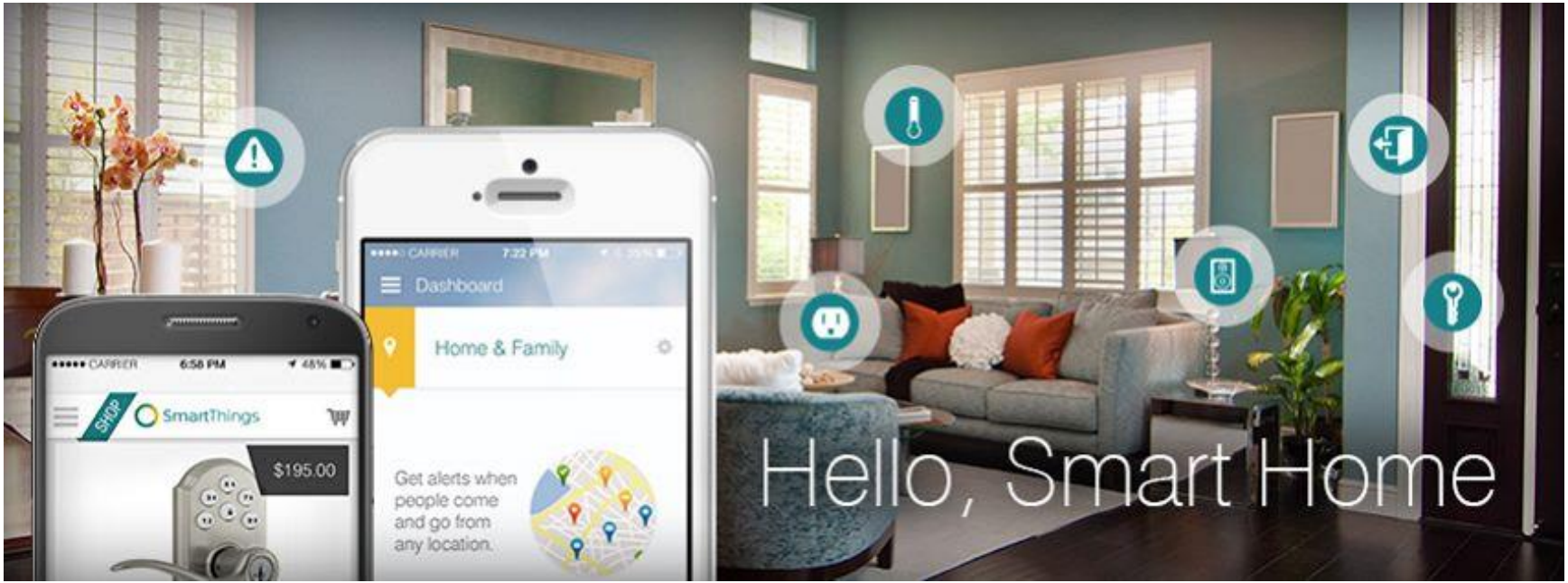
Windows 10

One Windows Platform

https://www.blognone.com/node/66491

Existing Systems

Samsung SmartThings



http://thetechportal.in/tag/samsung-smart-things/

A Brain Computer Interface for Smart Home Control

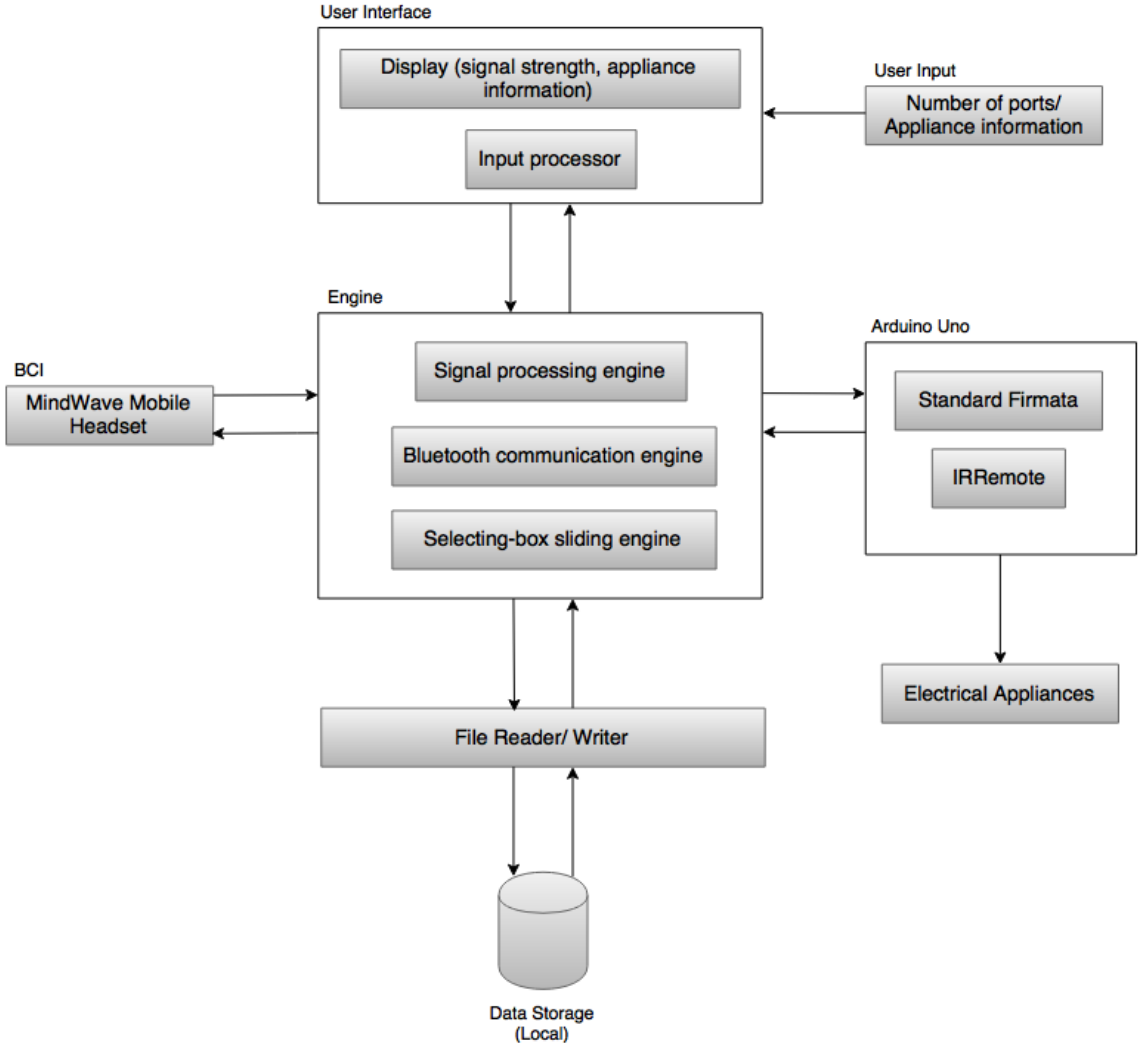
by Wei Tuck Lee, Humaira Nisar, Aamir S. Malik, and Kim Ho Yeap

- Home automation system controlled with brain-computer interface
- Users interacting with GUI (Virtual Home Environment)
- Gyroscope sensor used for controlling a mouse
- Raising eyebrows, blinking, or both for doing a mouse-click

Emotiv EPOC

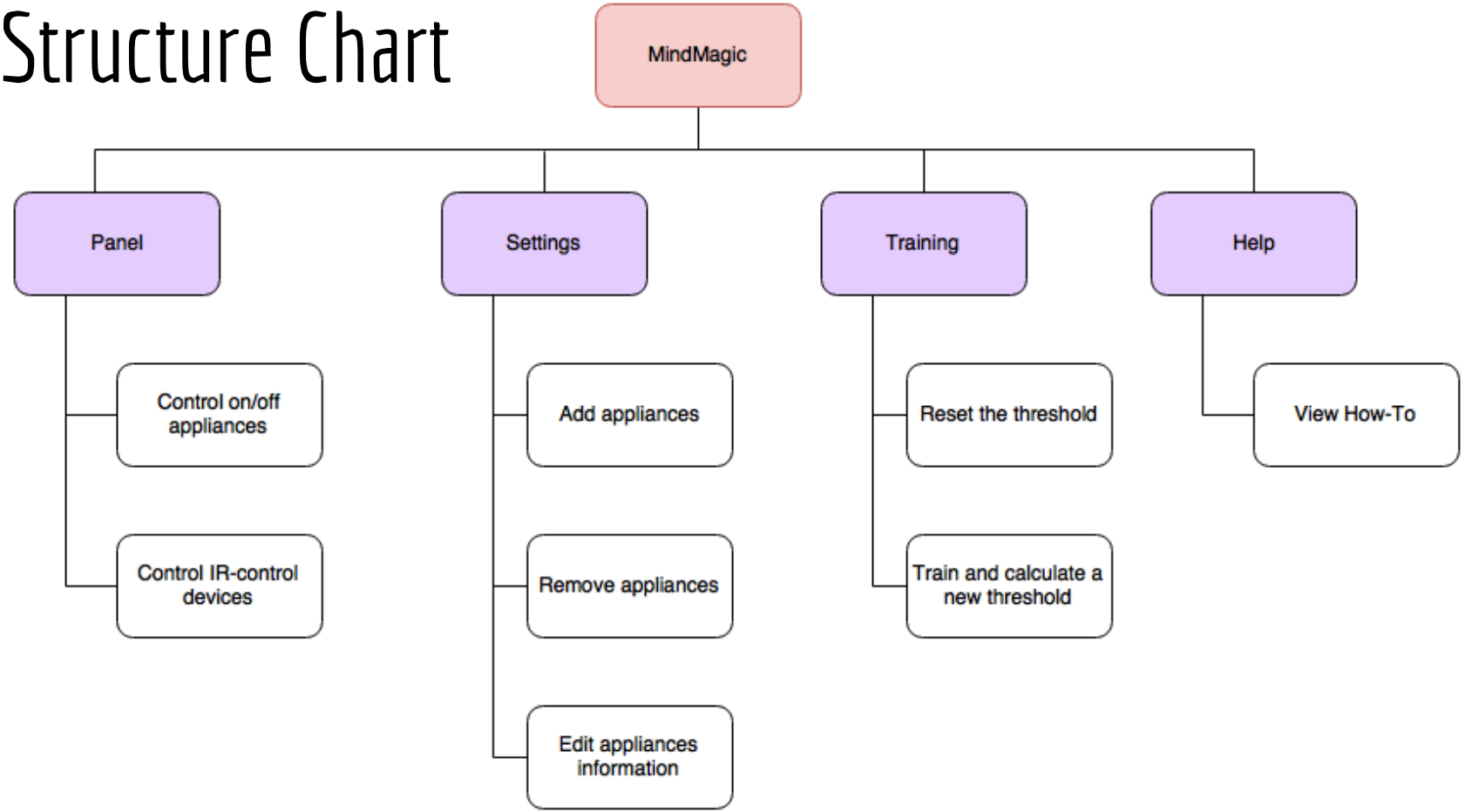
Analysis & Design

System Architecture

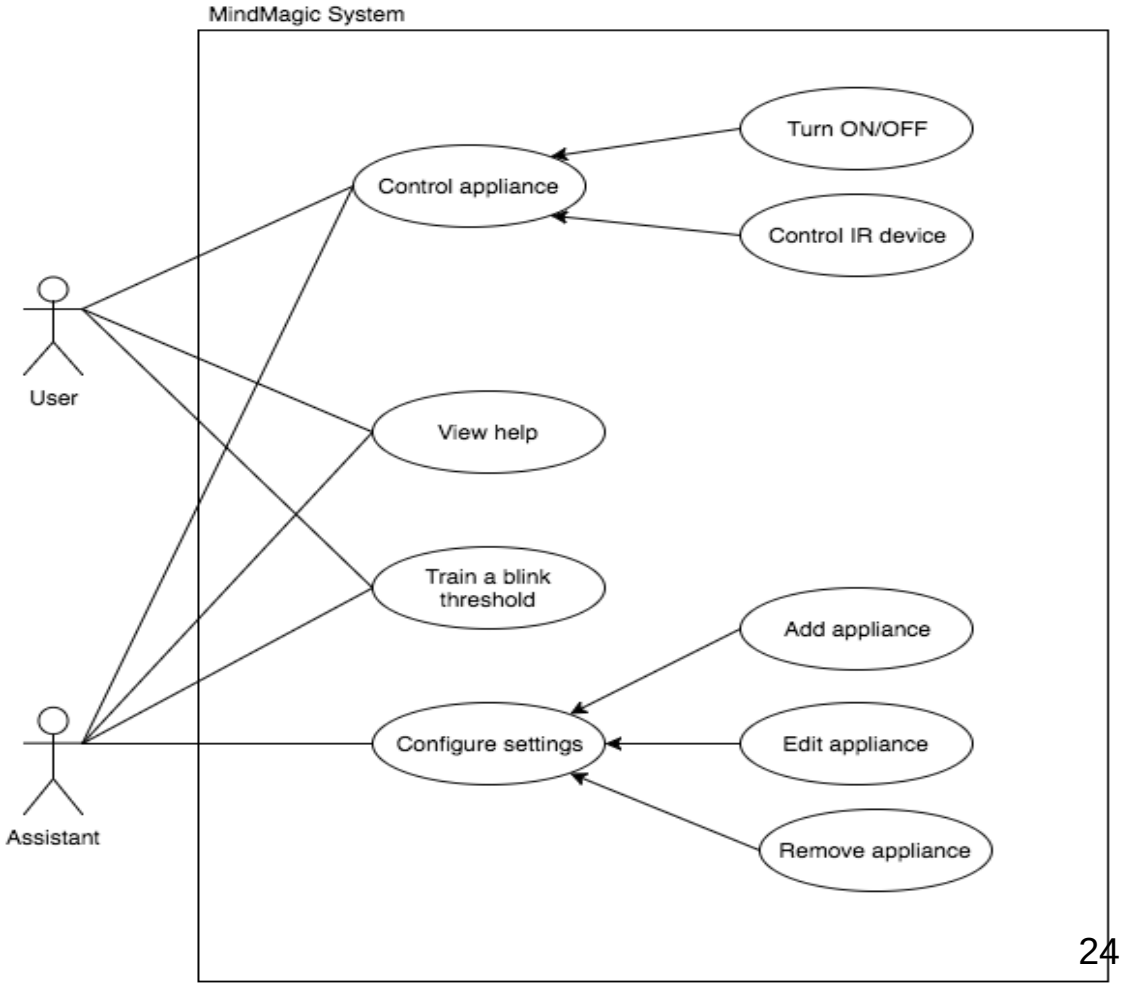

User Interface
Display (signal strength, appliance information)
Input processor
User Input
Number of ports/ Appliance information
Engine
Signal processing engine
Bluetooth communication engine
Selecting-box sliding engine
BCI
MindWave Mobile Headset
Arduino Uno
Standard Firmata
IRRemote
Electrical Appliances
File Reader/ Writer
Data Storage (Local)

System Design

Structure Chart

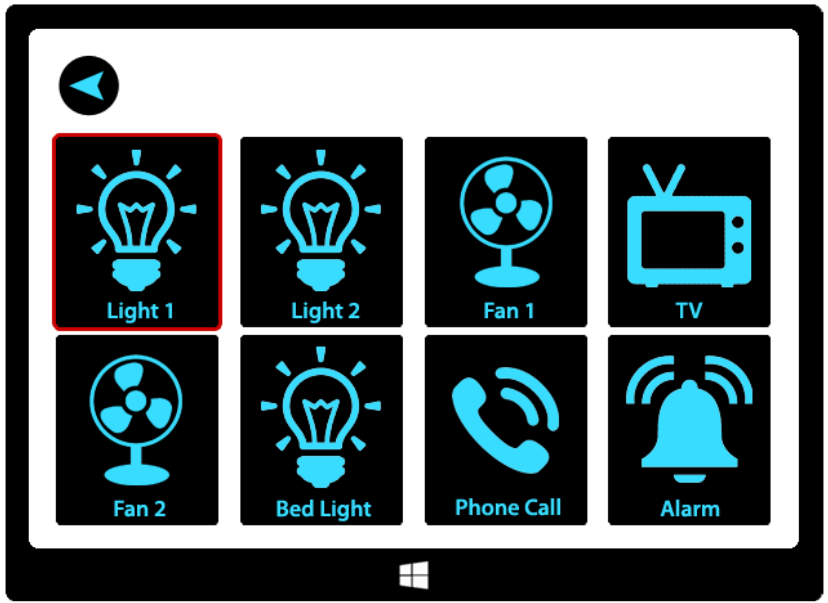


Use Case Diagram



I/O Design

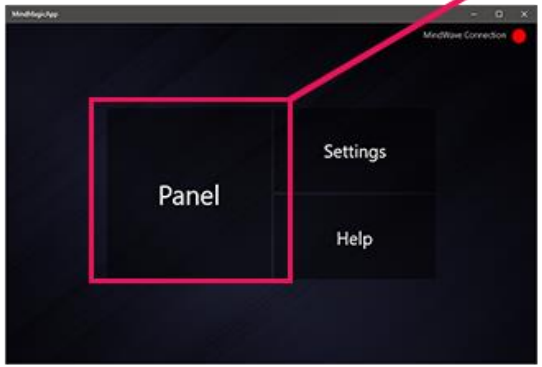
UI Design

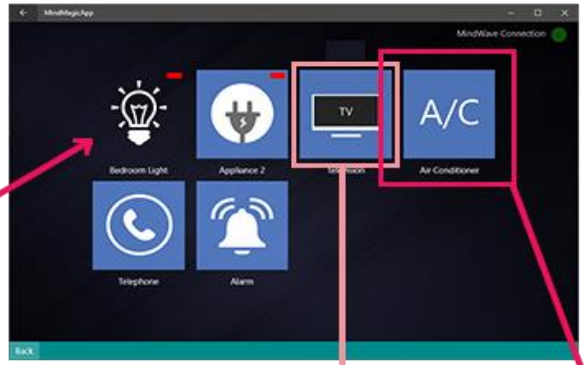


Panel UI Design

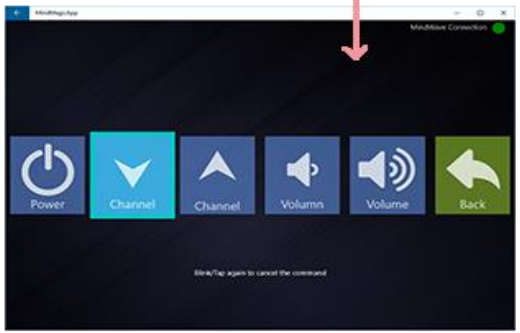
Transition - Panel

Main page

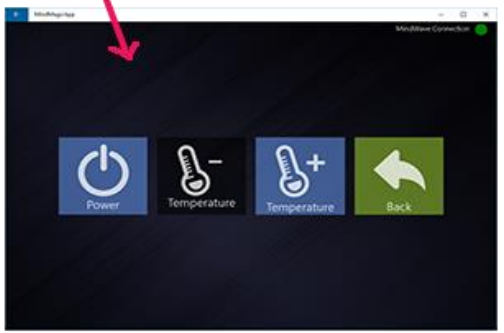




Panel page



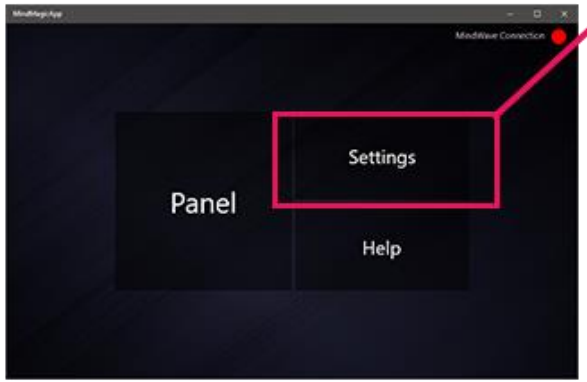
TV control options page



AC control options page

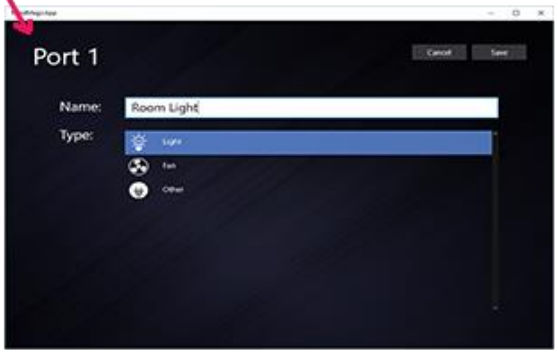
Transition - Setting

Main Page



Settings Page

Edit Page



Implementation

Hardware $ System Environment

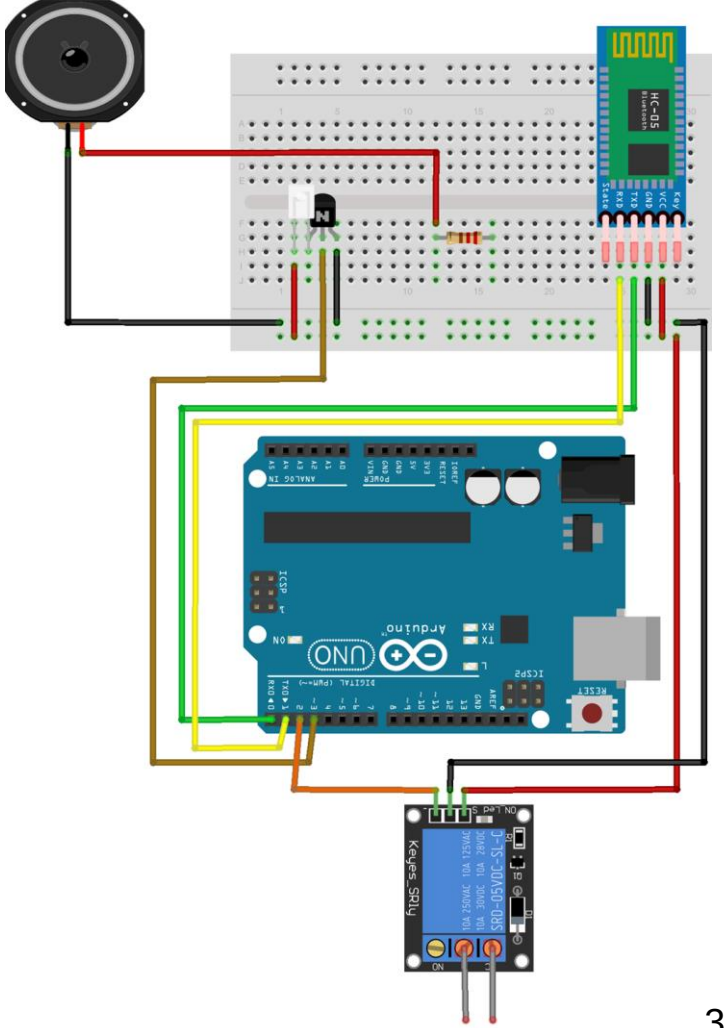
Hardware & Software

Hardware

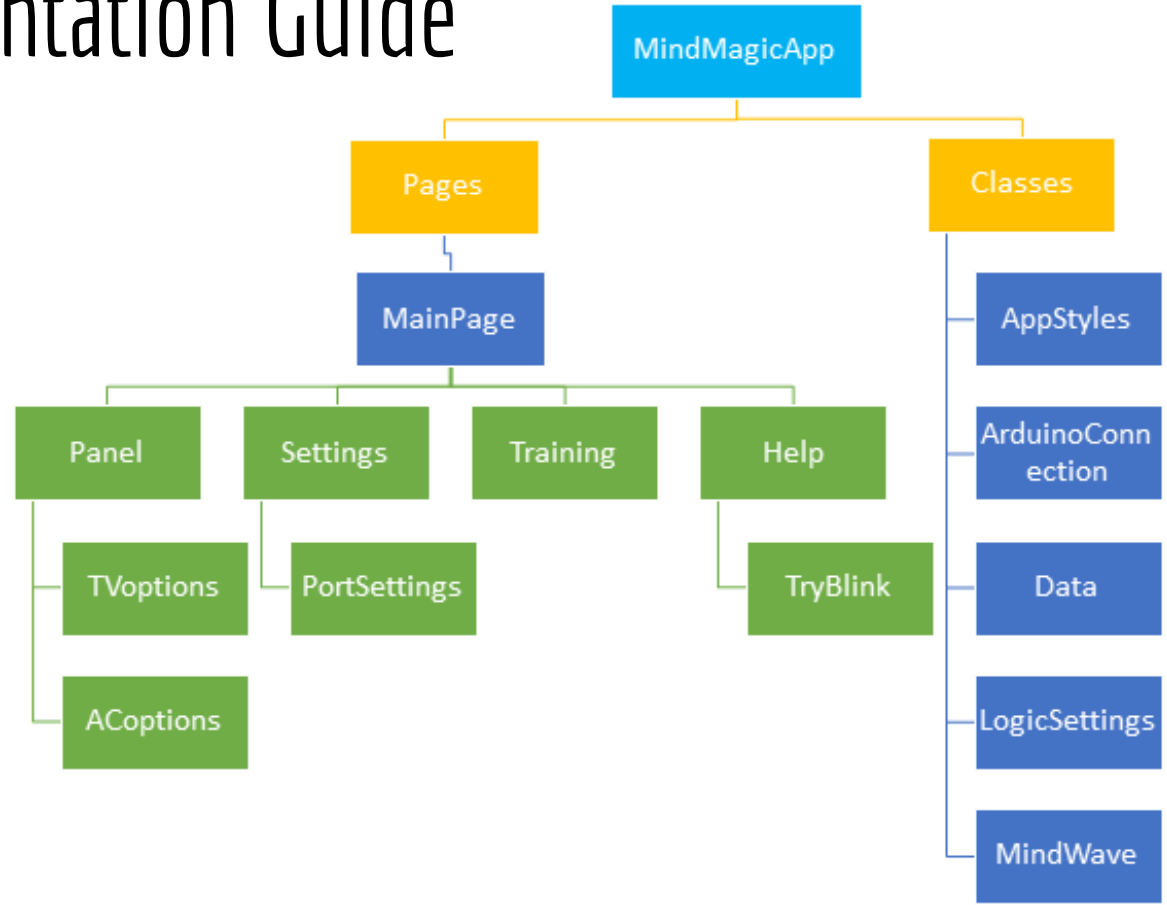
1. MindWave Mobile Headset
2. Arduino Board
3. USB cable (for uploading arduino program)
4. HC-05 Bluetooth Module
5. IR LED
6. Speaker
7. Relay board
8. Connecting wires
9. Bread board
10. Resistor (100E)
11. Device running on Universal Windows Platform

Software

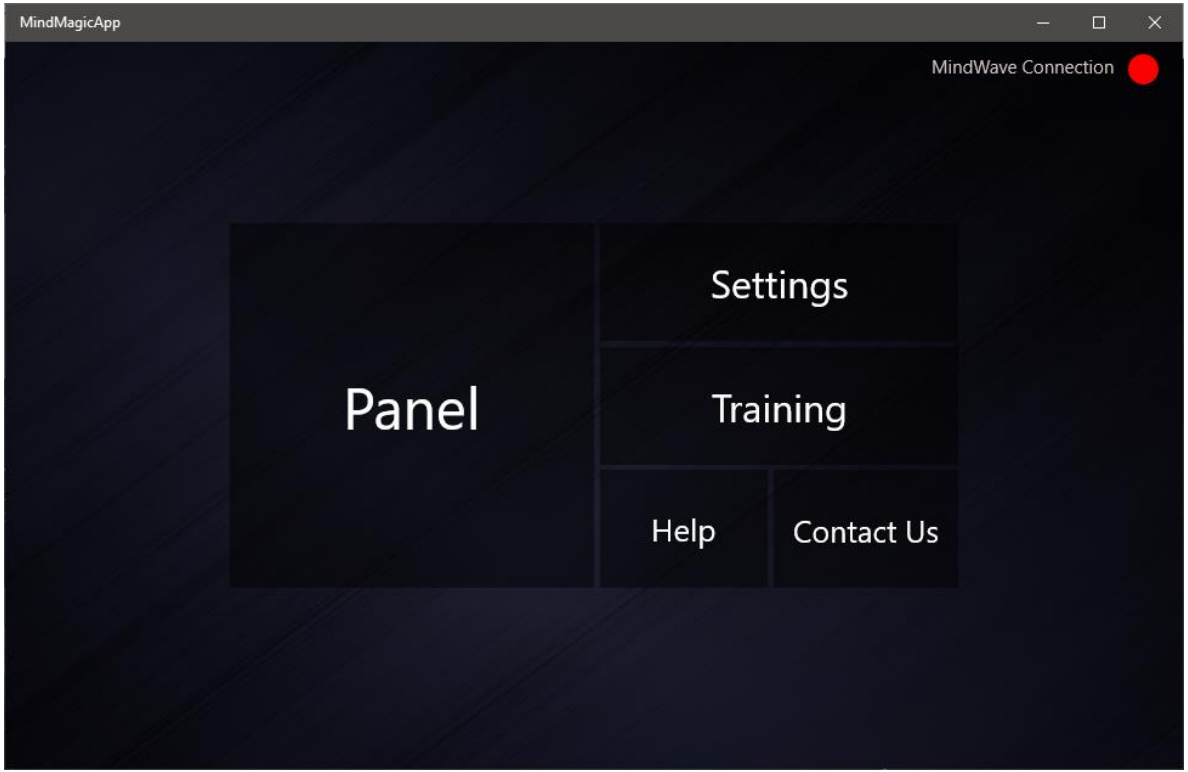
1. Arduino 1.6.5
2. Visual Studios 2015



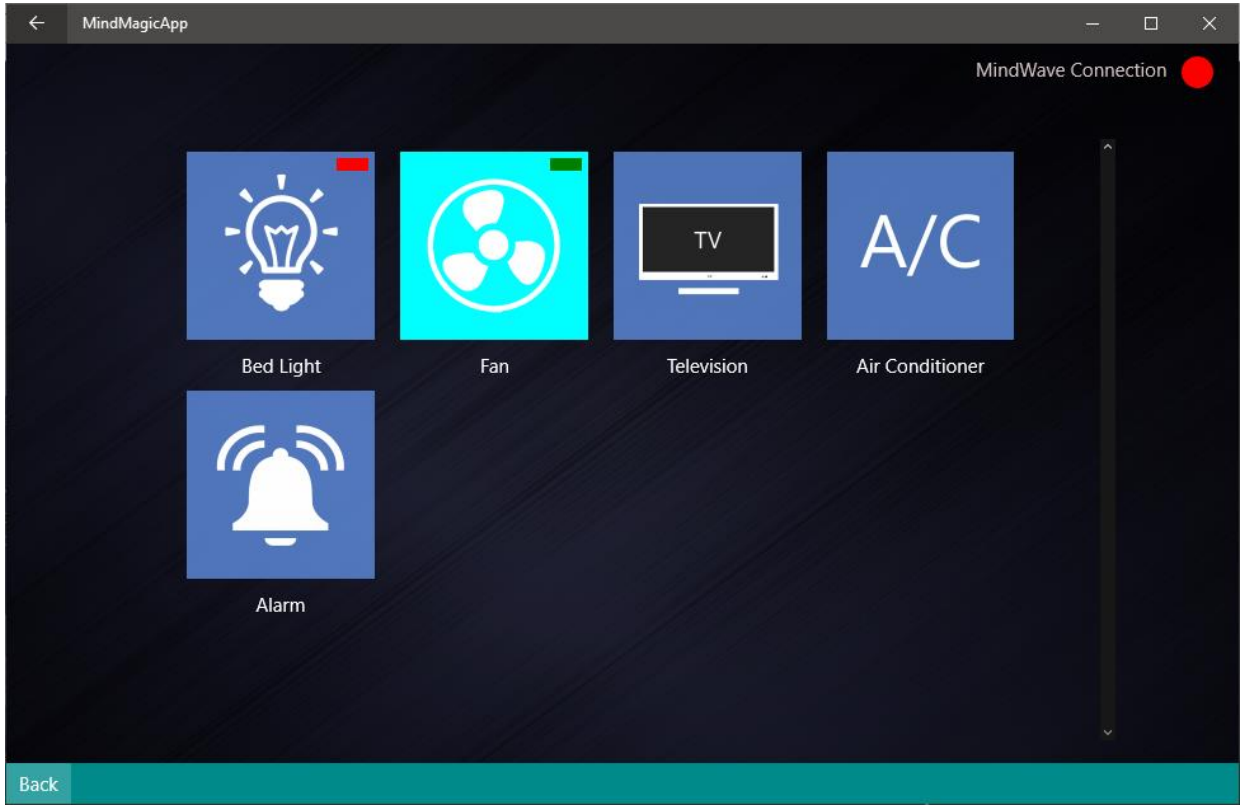
Implementation Guide



Pages » MainPage

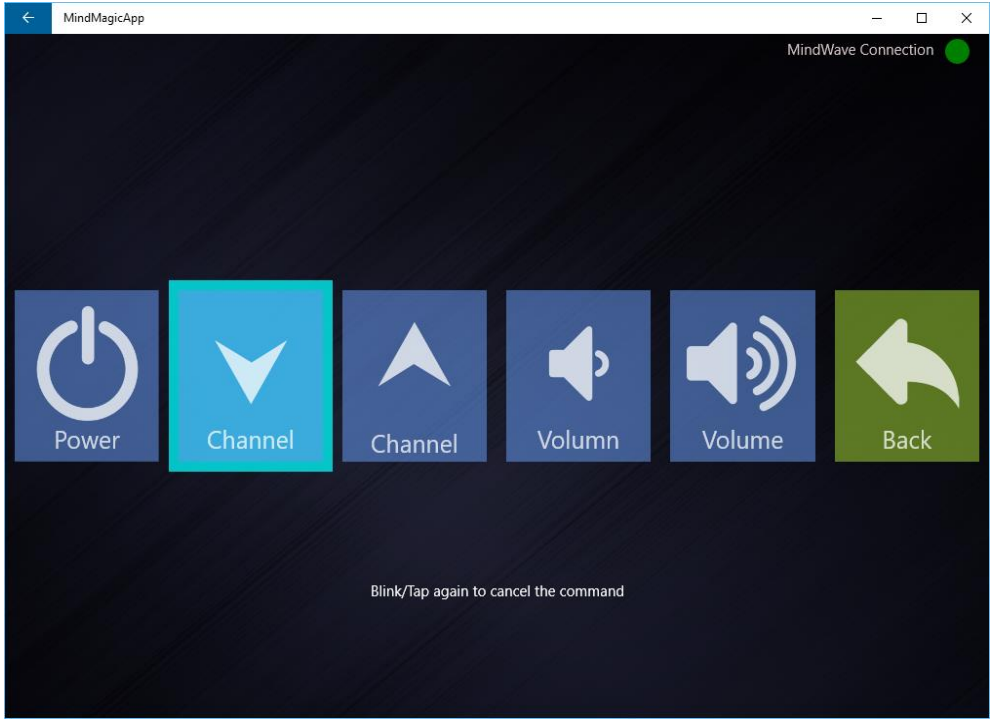


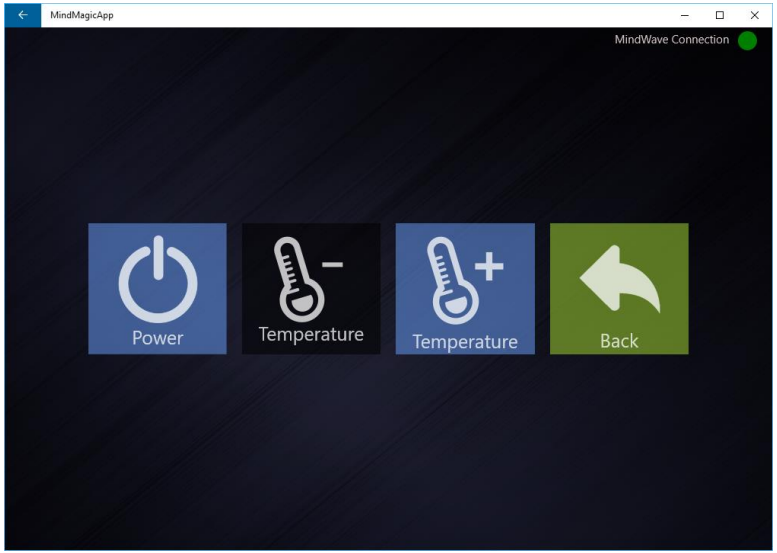
Pages » MainPage » Panel



Two event handlers:
HandleUpdate()
HandleBlink()

Pages » MainPage » Panel » TVoptions & ACoptions



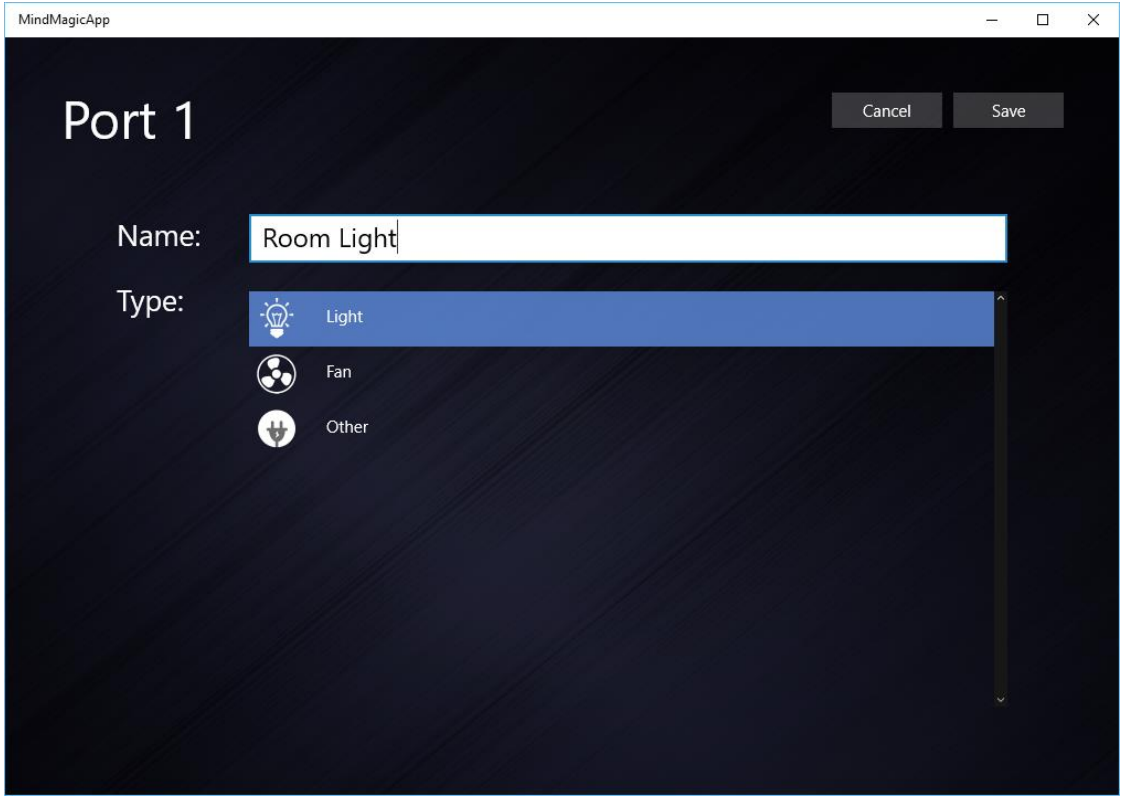


Pages » MainPage » Settings

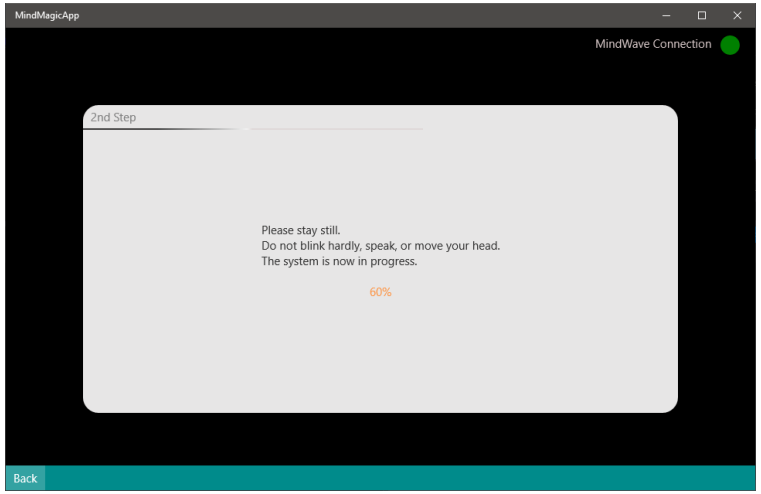
Three functions:

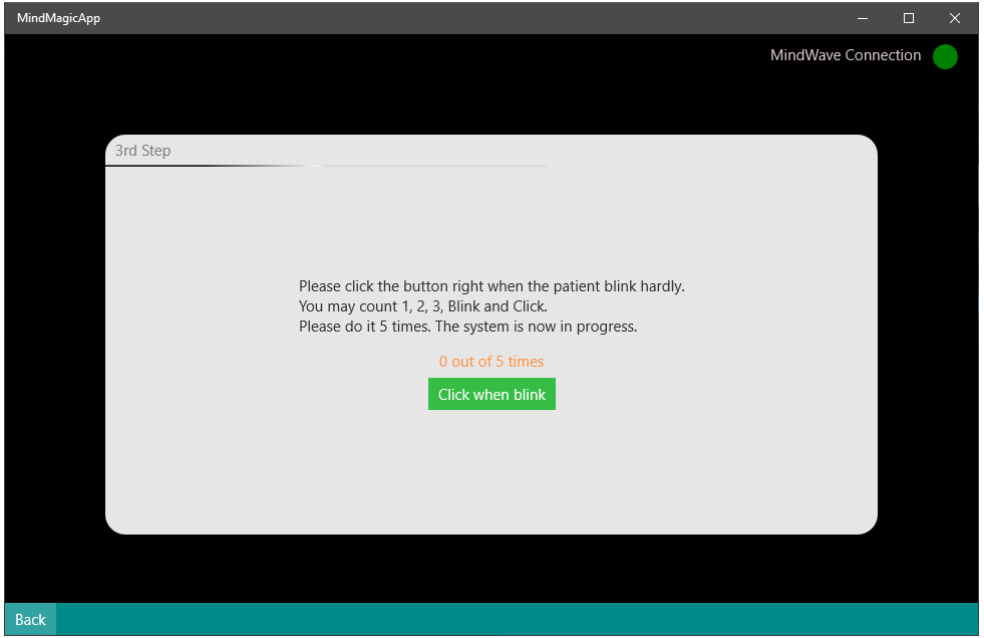
- Add
- Edit
- Delete

Pages » MainPage » Settings » PortSettings



Pages » MainPage » Training

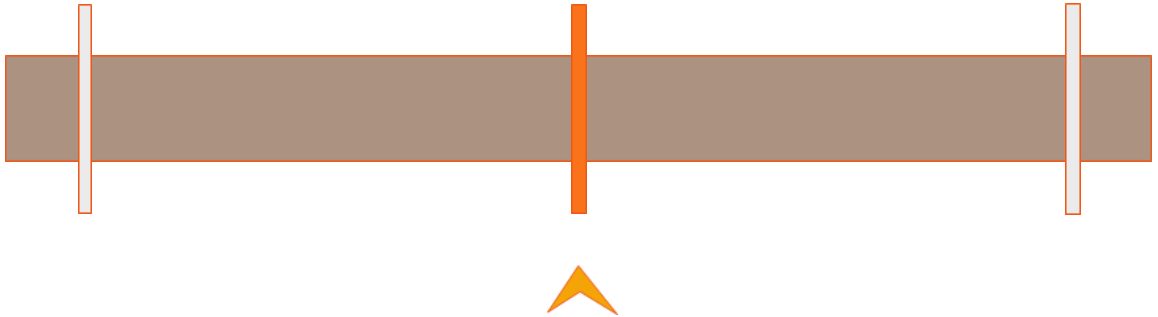




Pages » MainPage » Training

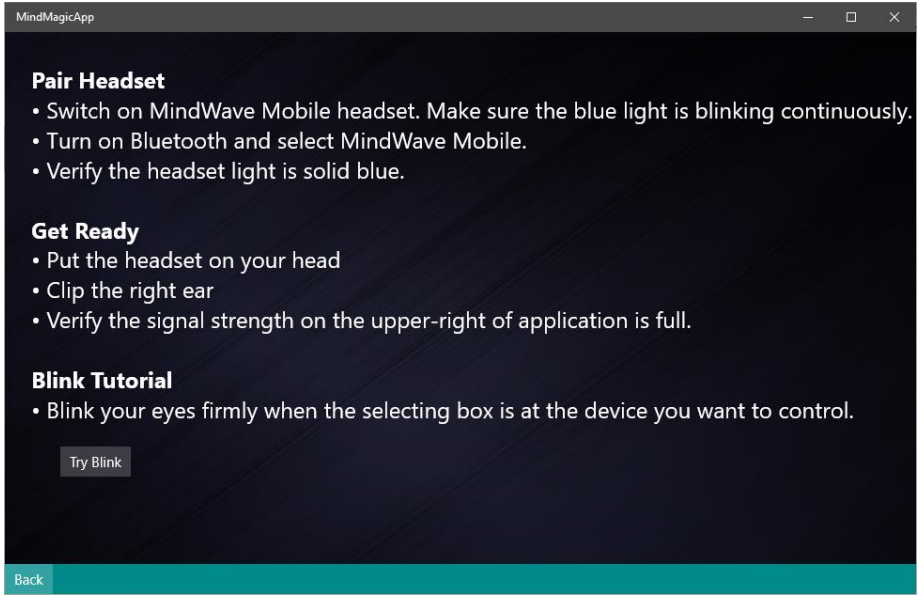
Average brainwave value
in normal state

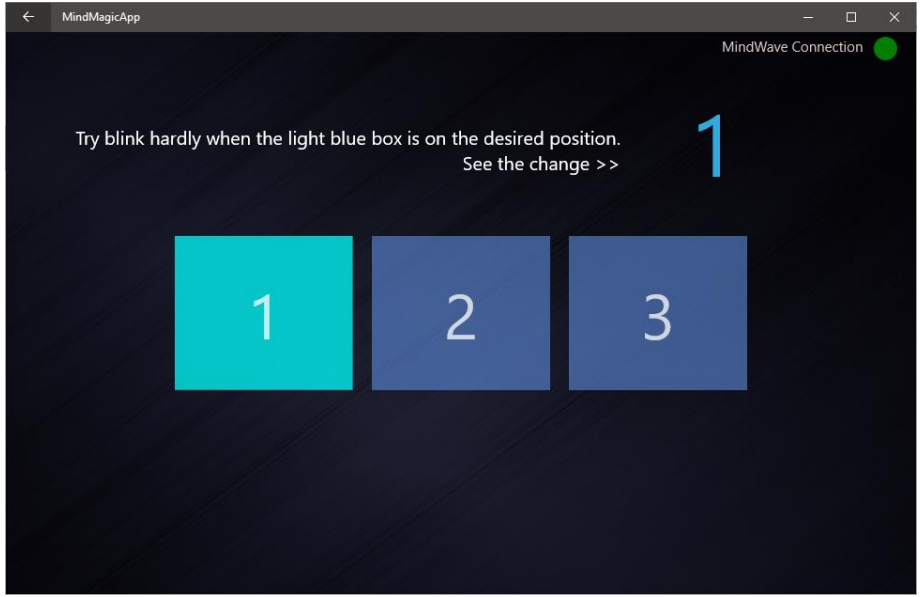
Average brainwave value
when blinks



Eye-blink
Threshold

Pages » MainPage » Help › TryBlink





Classes

1. AppStyle

Contain read-only variables used in the user interface for customizing the look and style.

Classes

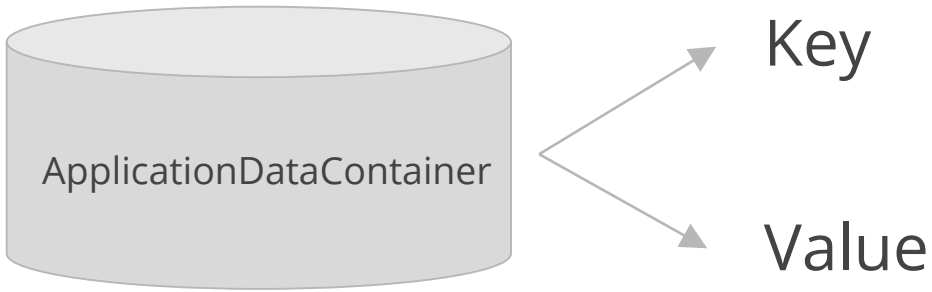
2. ArduinoConnection

Handle the communication between the application and the Arduino board.

Classes

3. Data

Handle everything involved with application data.



Classes

4. LogicSettings

- Work with Settings page and PortSettings page.

- Contain constant variables and helper methods.

Classes

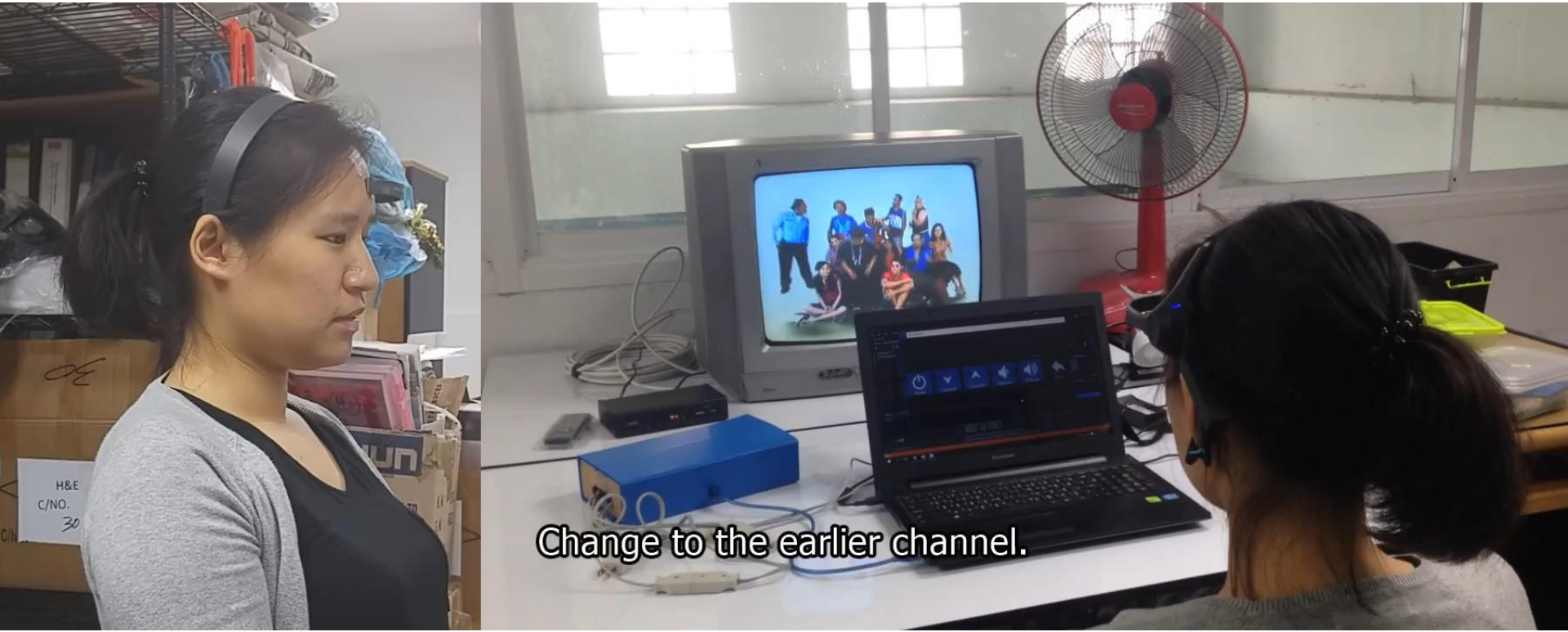
5. MindWave

- Establish the connection with the headset.
- Analyze the received packets from the headset.
- Detect eye-blinks.

Demonstration

Demonstration

1. System Configuration
2. Help
3. Turning ON/OFF Appliances
4. Turning ON/OFF Alarm
5. Training
6. Controlling Appliances with IR


H&E
C/NO.
30
Change to the earlier channel.

Testing & Evaluation

Testing & Evaluation

1. Unit test
2. Accuracy test
3. Usability test
4. User feedback

Unit Test

Test Description

Objective

A test on each part of the system to see its functionality

Testing Device

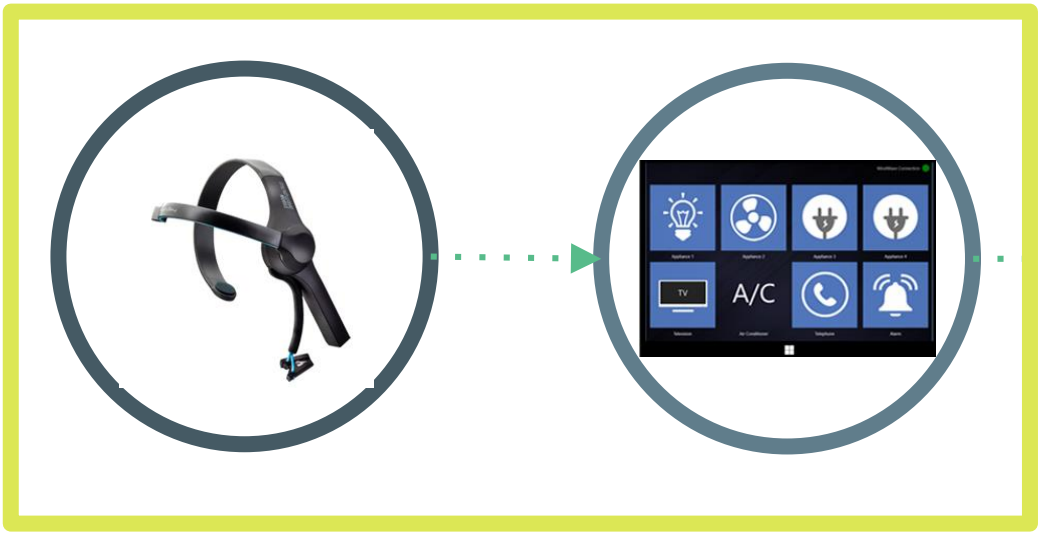
1. DELL INSPIRON N5110
   Windows 10, CPU 2.3 GHz, RAM 8 GB, Bluetooth
2. MindWave Mobile

Electronic Appliances Used

1. Light Bulb
2. Electric Fan
3. Television
4. Air Conditioner

IR Devices

ON/OFF Devices
(Plug)

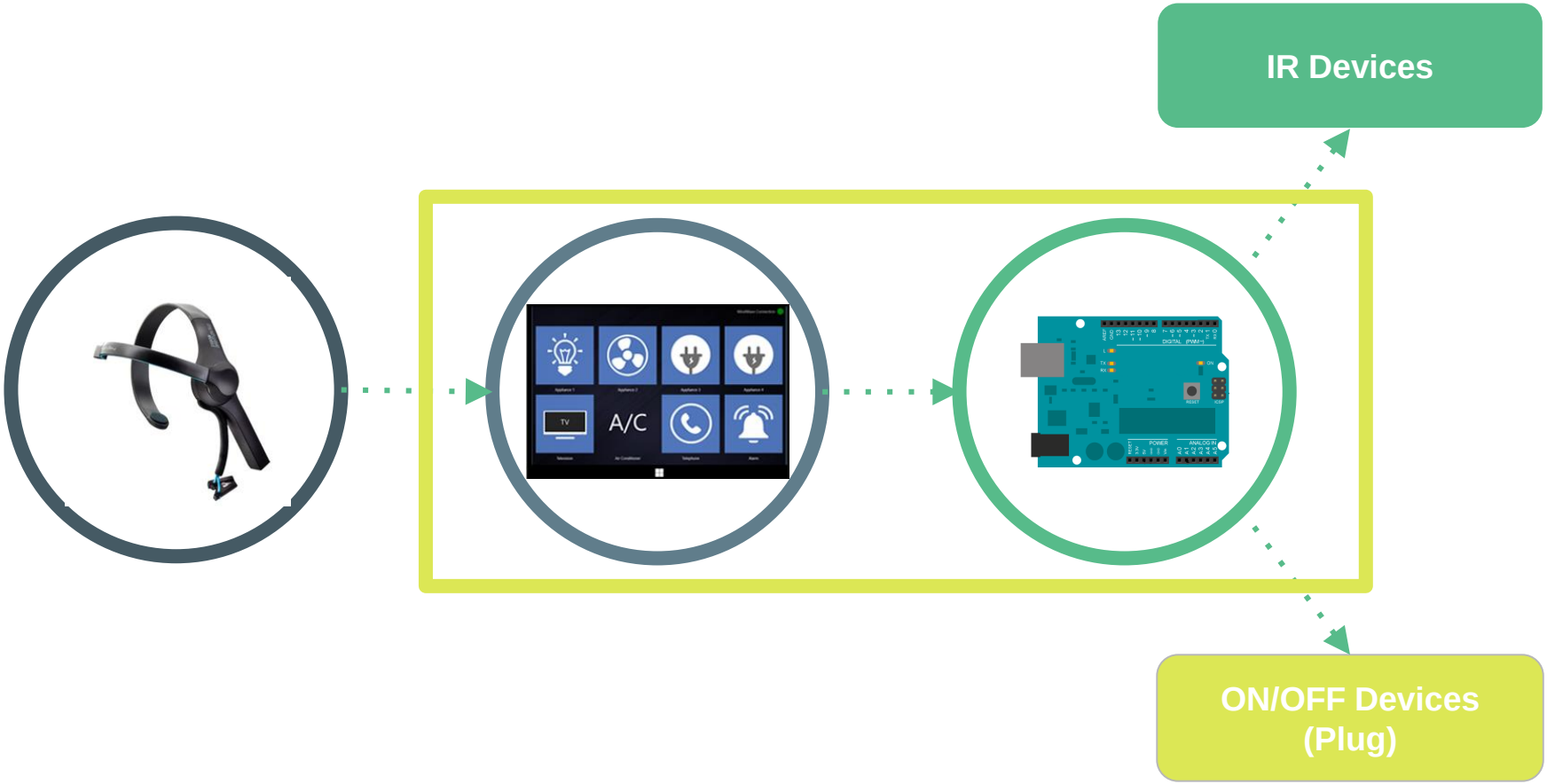


IR Devices

ON/OFF Devices
(Plug)

Result : Test MindWave Mobile connection

Testing Condition	Details	Results
Pair MindWave mobile with the device Tester wears MindWave Mobile	Test the connection establishment Test the connection status of MindWave Mobile headset: it should show at least yellow or green.	The system can detect signals from MindWave Mobile. The connection status is shown properly.

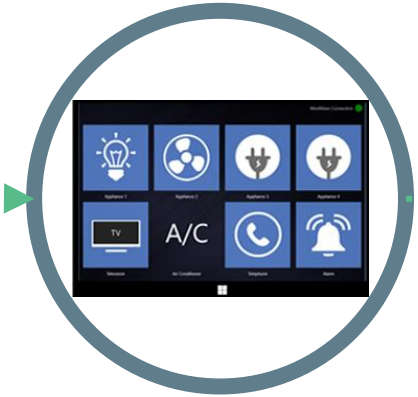

IR Devices
TV
A/C
ON/OFF Devices
(Plug)

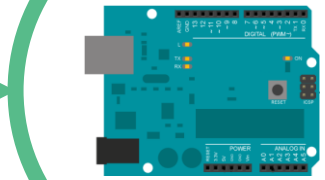
Result : Test Arduino Connection and Communication

Testing Condition	Details	Results
The device that run the application connects with Arduino’s Bluetooth module.	Test if the connection can be established properly.	The Bluetooth module works properly. The connection can be established.

Result : Test Arduino Connection and Communication

Testing Condition	Details	Results
The application sends a command message to Arduino via Bluetooth.	Check if the application can issue a command message in the form of a Bluetooth package and if Arduino can receive the command message from the application correctly.	Arduino receives the command message correctly.



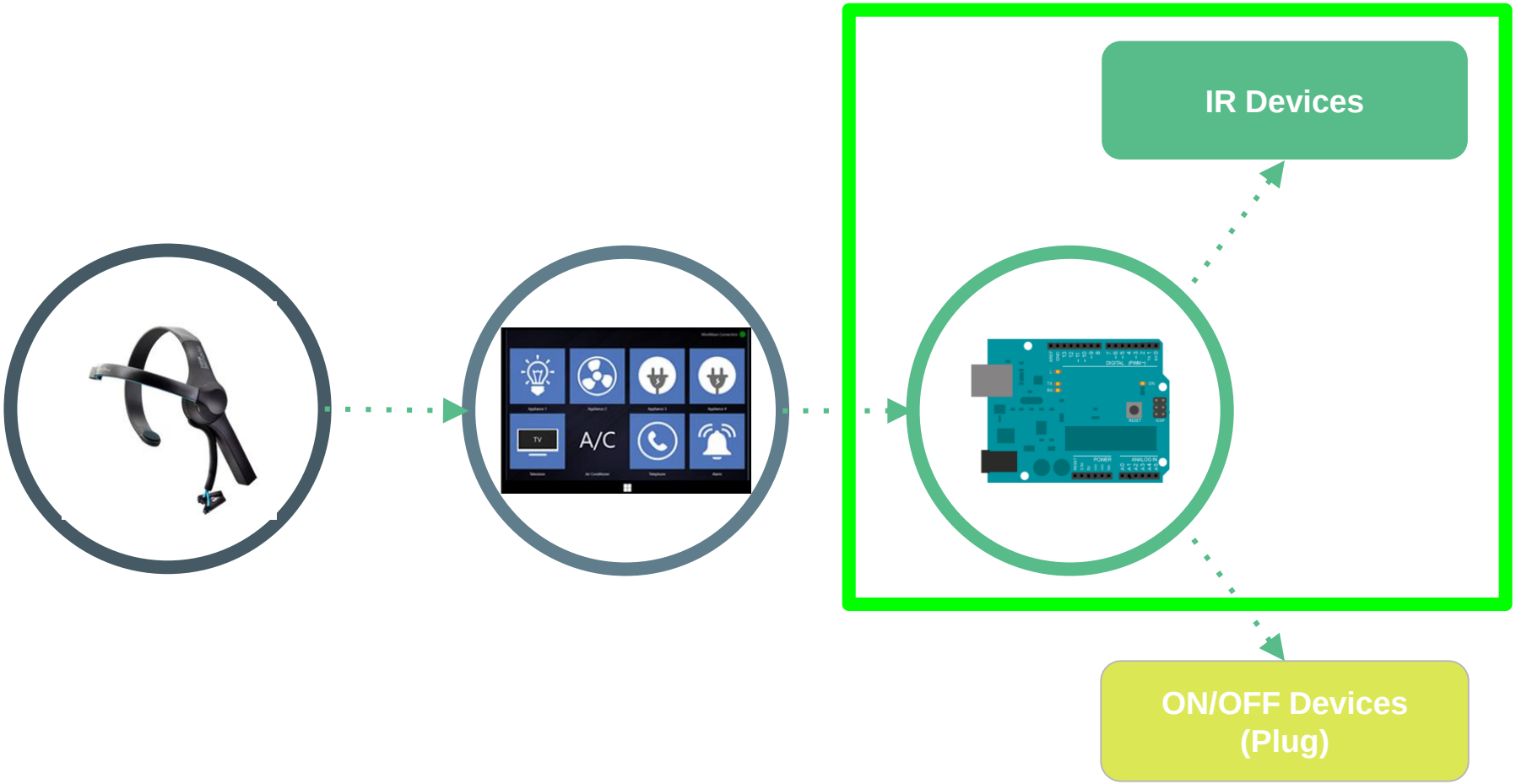


IR Devices

ON/OFF Devices
(Plug)

Result : Test controls on ON/OFF devices

Testing Condition	Details	Results
Use the application to turn on/off electronic appliances.	Test the ability to turn on/off the appliances according to the command.	The system can turn on/off electronic appliances.

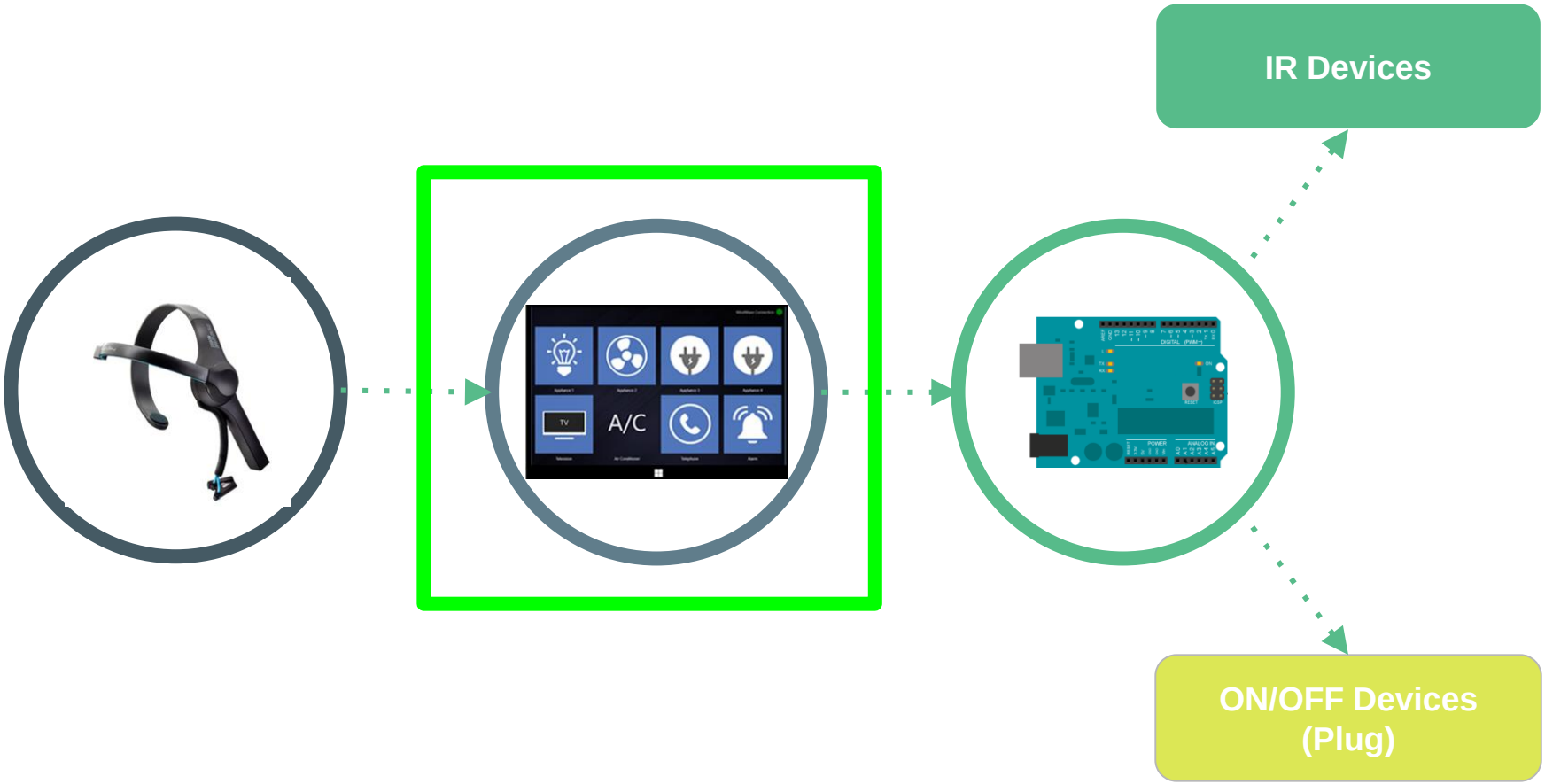

IR Devices
A/C
TV
ON/OFF Devices
(Plug)

Result : Test controls on IR devices

Testing Condition	Details	Results
Starts controlling the level of electronic appliances	Test if the application issue the command correctly	The application issues the command to Arduino properly.

Result : Test controls on IR devices

Testing Condition	Details	Results
Arduino emit IR signal to control IR device	Check if the program emit the correct IR signal code according to the command from the application Check IR transmitter functionality	The system can control IR device properly.


IR Devices
TV
A/C
ON/OFF Devices
(Plug)

Result : Test Settings function & database connection

Testing Condition	Details	Results
Add an electronic appliance to the panel.	Have a new icon of the new appliance.	The system shows the new icon of a new electronic appliance and save the data onto databases.
Remove an electronic appliance out of the panel.	The icon of the removed appliance disappears.	The system removes the icon of removed appliance and its data from database.

Result : Test Settings function & database connection

Testing Condition	Details	Results
Configure the existing electronic appliance.	Edit name and type of electronic appliance and click save.	The system shows the configure page of the electronic appliances and save the new data to the database.

Accuracy Test

Test Description

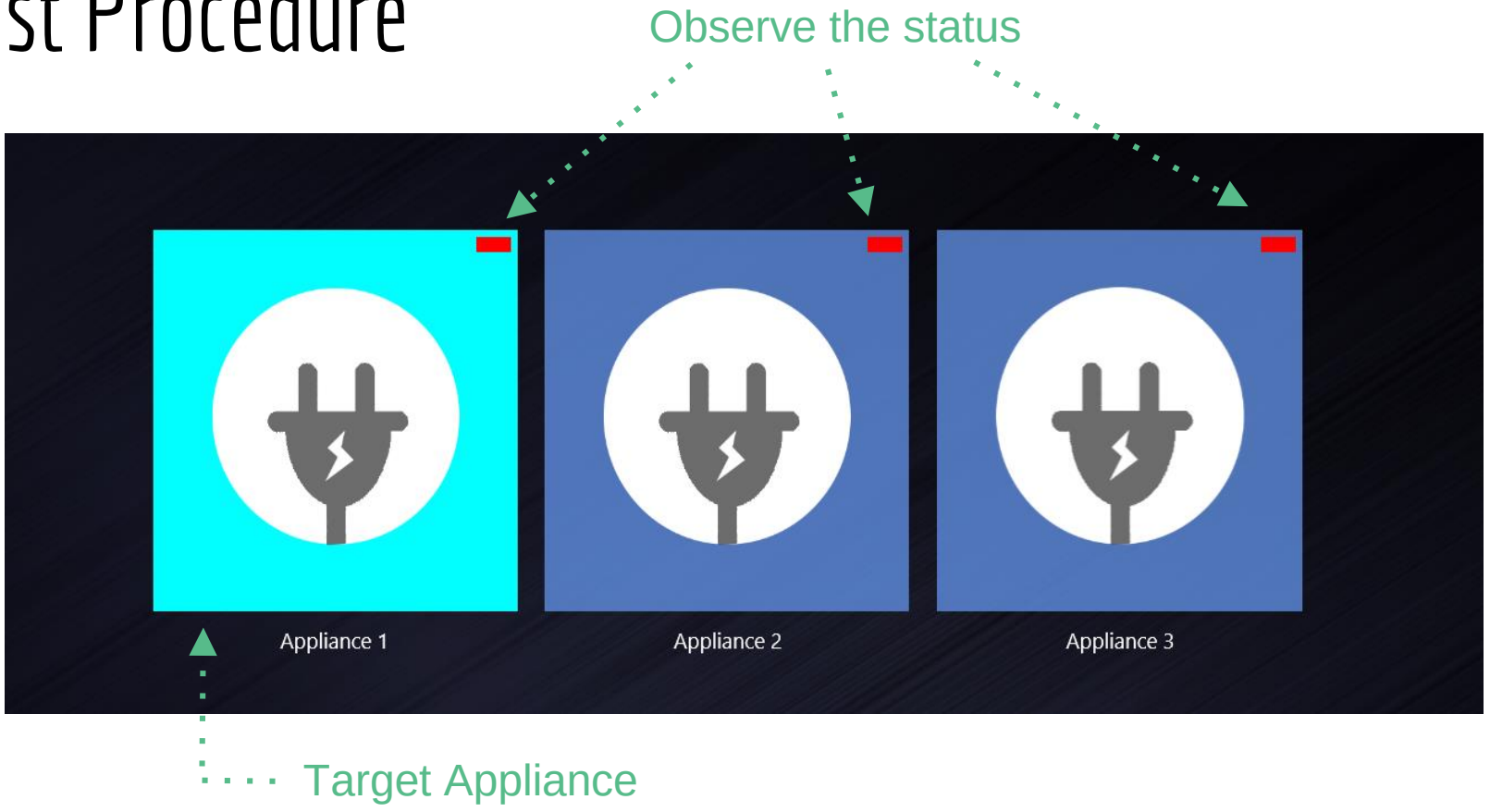
Objective

To evaluate the accuracy of the system

Testing Device

1. DELL INSPIRON N5110
   Windows 10, CPU 2.3 GHz, RAM 8 GB, Bluetooth
2. MindWave Mobile

Test Procedure



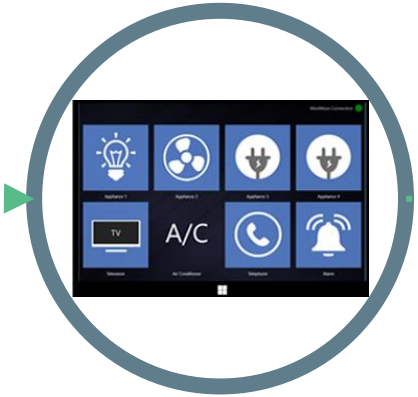
Result

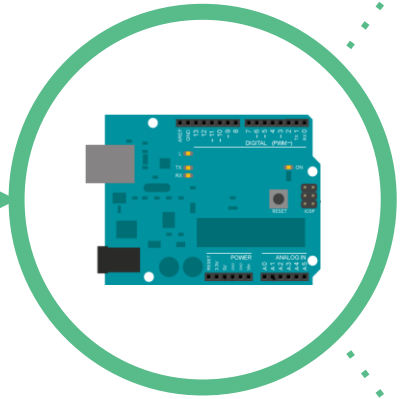
8%
Miss

1

MindWave Mobile sends data package in varied amount of time.

The selection box already moved from the desired appliance.





IR Devices

ON/OFF Devices (Plug)

2

MindWave Mobile cannot detect user's eye blinks, or brainwave values do not reach the threshold.

Result

2s per box

8%
Miss

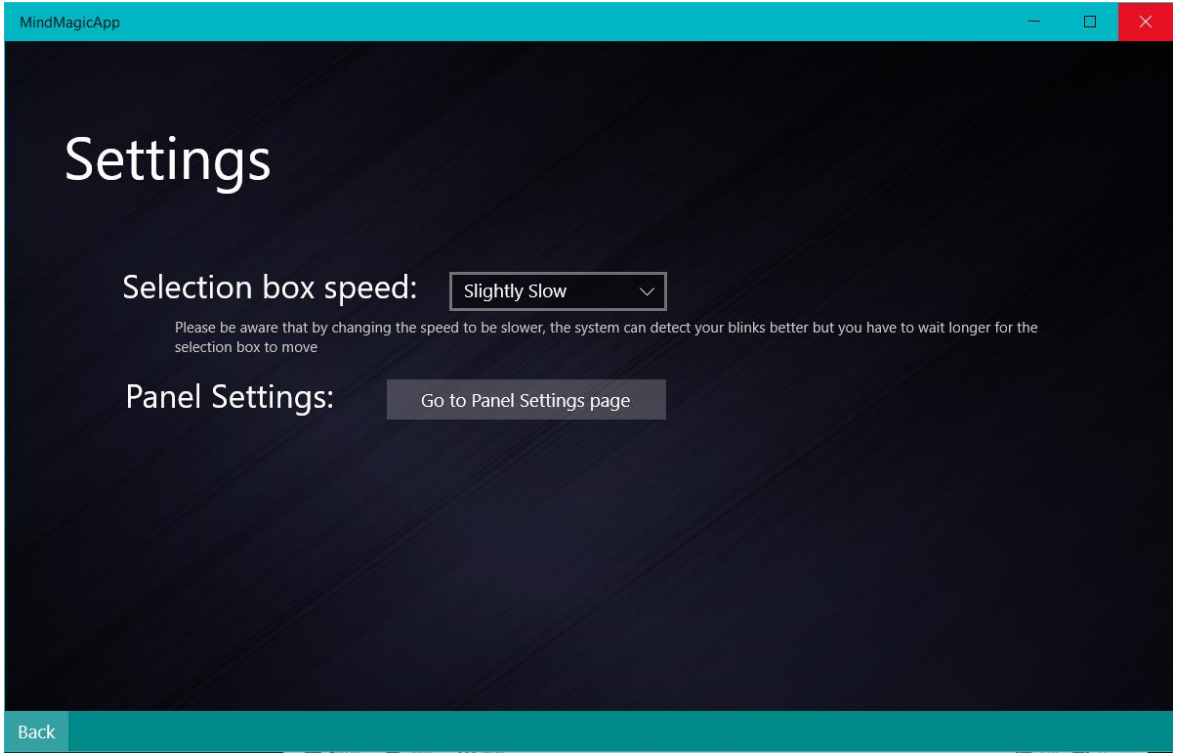
Result

3s per box

3%
Miss

Result

- Selection box speed added to Settings



Usability Test

Test Description

Objective

- To observe how well the users perform specific tasks with the current design of the application
- To observe the problems that occurred when the users use the system

Testing Device

1. Lenovo Y50-70
   Windows 10, CPU 2.5 GHz, RAM 8GB, Bluetooth
2. MindWave Mobile

Test Procedure

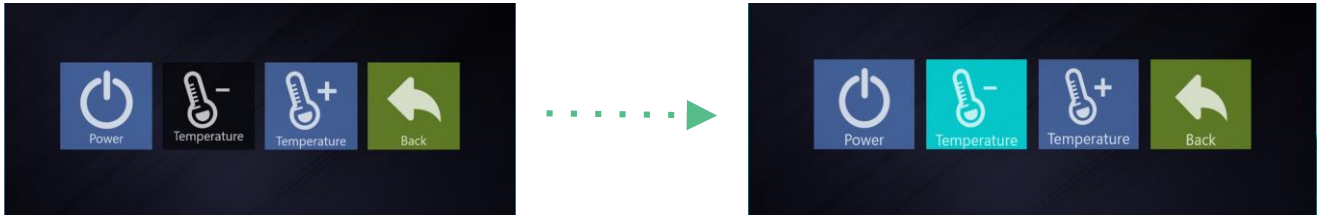
Scenario ID	Details
Scenarios #1	You want to set the control panel so that you can control a lamp, TV, phone, and alarm. Set port 1 name 'Lamp' type 'light'
Scenarios #2	You want to turn on the lamp but you can't use your hand.
Scenarios #3	You want to turn the tv on and then change the channel up but you can't use your hand.
Scenarios #4	You are an ALS patient. You can't move your body, you can only blink your eyes. You want to call your assistant to help you using the system's alarm.

Result

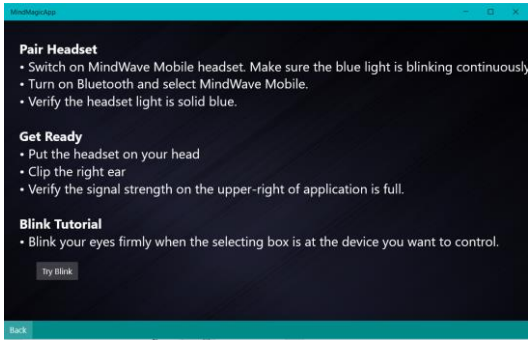
- Some UI confusion observed
- Some testers were founded **having trouble to finish Scenario#2**
- Testers can finish Scenario#3 and Scenario#4 easily after finishing Scenario#2

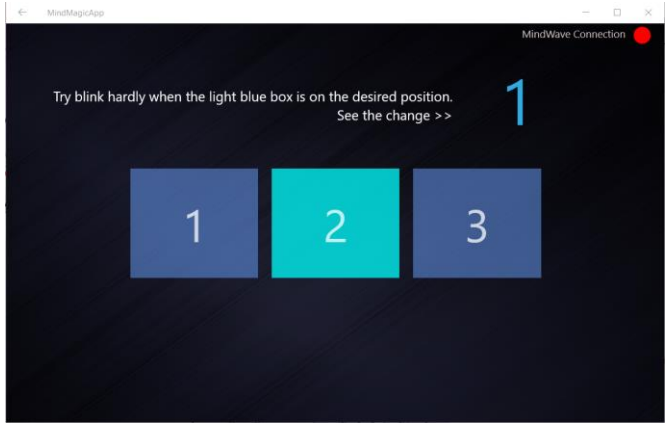
Result

- Minor changes in the UI design



- Help page and Try Blink page added





User feedback

“ This system is needed,
but more functions should be added. ”

A Physician at Karnjana Medical Center

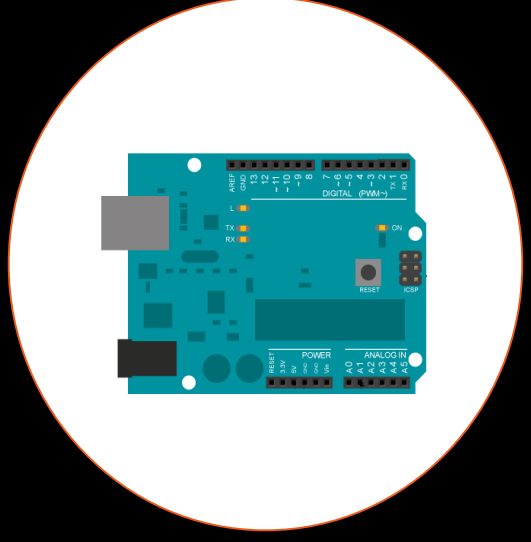

สถานสงเคราะห์คนพิการและทุพพลภาพพระประแดง
กระทรวงการพัฒนาสังคมและความมั่นคงของมนุษย์

Conclusion

Mind Magic

BCI
Headset

MindMagic
Application



Embedded
System

Benefits to...

Motion-Impaired Users

- Being able to control electronic appliances inside their houses without moving their limbs
- Being more independent

Assistants

- Having less workloads

Problems and Limitations

- Bluetooth Signal Limitation
- Blink Detection Accuracy
- Battery Life of EEG Headset
- Access to target users

Future Work

- Develop a Thai version of the application.
- Improve the accuracy of the system.
- Replace Bluetooth with WiFi
  for the connection between the *engine* and the *Arduino board*.
- Support more electronic appliances.

Acknowledgement

- BaanPhrapradaeng
- National Software Contest 2016
- Imagine Cup Thailand 2016
- Test Participants

Thank you.