SENSOR SOLUTIONS

Wearable Detection Device for UV And Polluted Air Exposure

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- **Background**
- **Details of Devices and Apps**
- **Damage Model behind it**
- **What We Have Learnt During**

Objective of the Project

- To define a problem and propose a sensor-based design solution.
- The result of three quarters will be a paper to be submitted to an IEEE VCACS conference.
- IEEE VCACS: A new virtual conference series targeted for students and young professionals who are using sensors and microprocessors to build working prototypes in senior design and graduate level engineering courses.

Objective of the Project

Wearable Detection Device for UV And Polluted Air Exposure

- To develop a wearable device to detect people’s exposure to the UV and polluted air;

- Detection, Alert, Data Display and Analysis

Background

1. Ultraviolet radiation from sun exposure is the primary environmental cause of skin cancer

2. The noisome components in the air would impair the health of people's respiration system.

So it is necessary to alert people who are doing outdoor activities when they have been exposed to these for a dangerous time.

Current Products

- SunFriend®
- Detection and Alert
- Waterproof and Small size
- But it cannot record or transmit the data so that the detection data cannot be analysed.

- CliMate is a Bluetooth tracker for HUT
- Data Accessible through Apps
- NO Alert

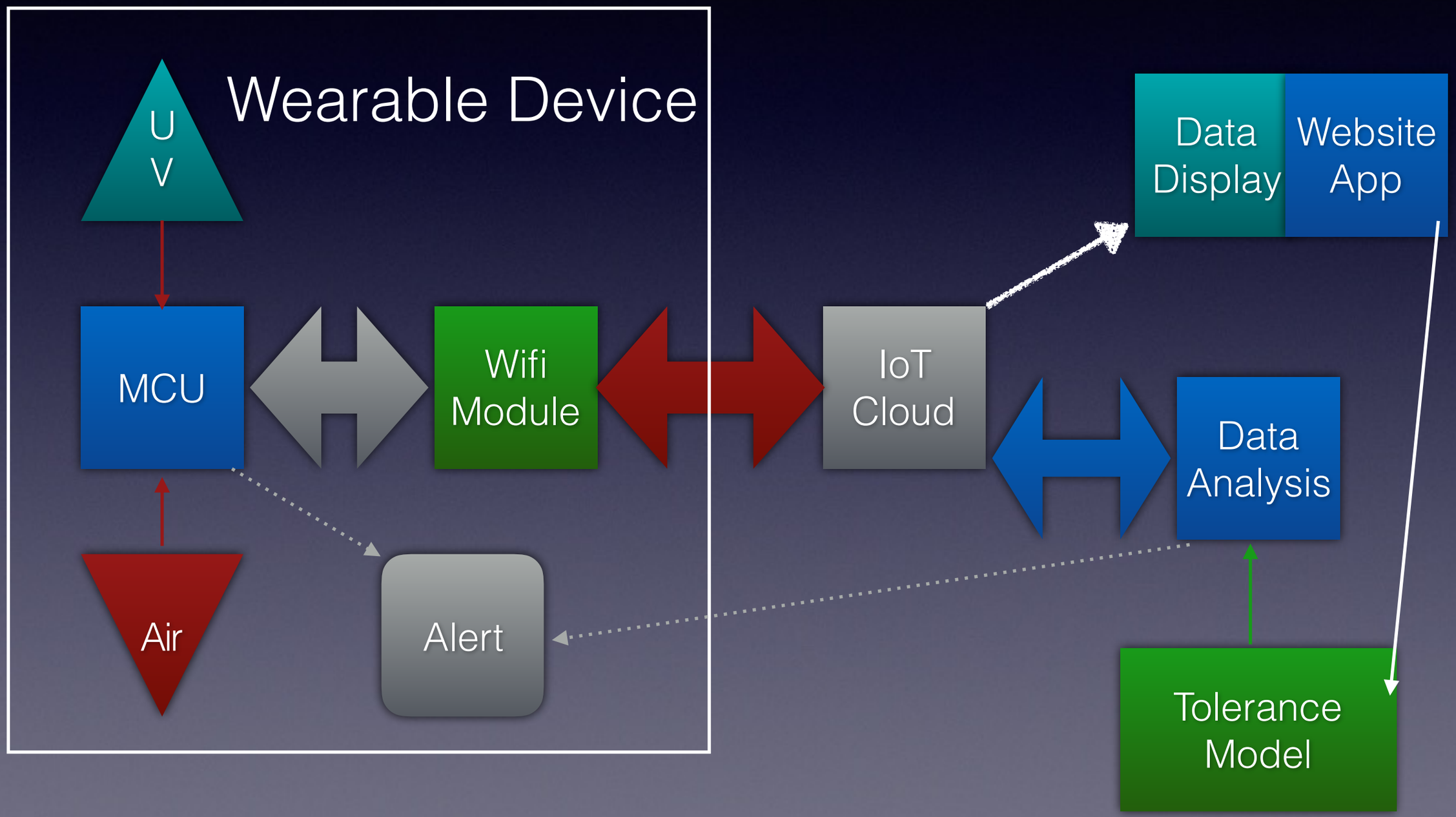
Current Products

- Air Six D1-V
- Environment Detection including air pollution, UV, and temperature, etc.
- Still in under development
- Lack data display and analysis through wireless communication
- Not waterproof
- large size

System Standards

- System must support accurate and continuous real-time data collection.
- System needs to store the data and provide access to a Internet interface.
- System needs to support mobility.
- System must use minimum power.
- System must be accessible from the wireless communication 24/7.
- System must mostly use off-the-shelf devices, components, and standards.
- System must support two-way communication between the user and the device.

System Structure

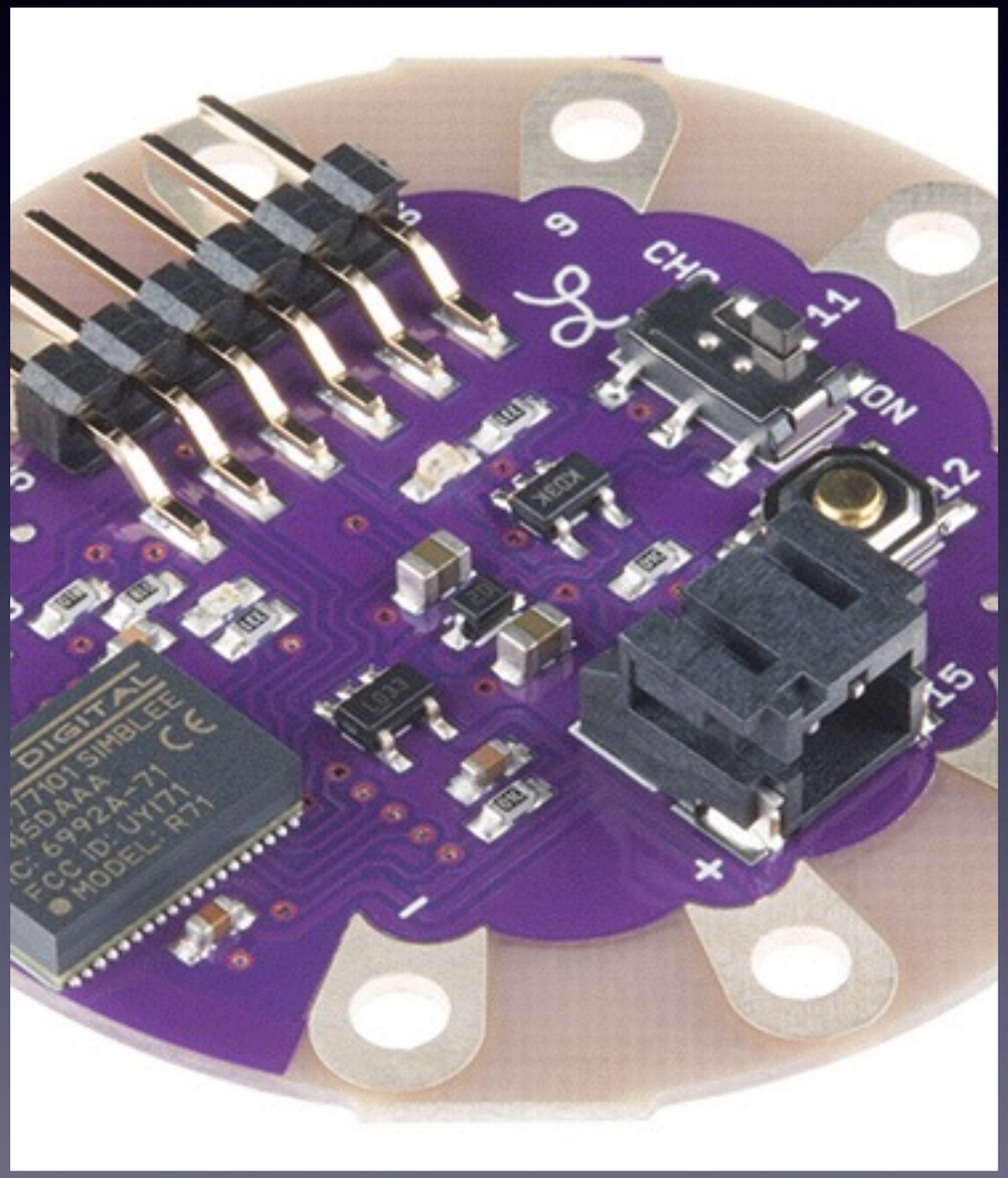


MCU

- Arduino MKR1000
- Arduino MKR1000 has been designed to offer a practical and cost effective solution for makers seeking to add WiFi connectivity to their projects with minimal previous experience in networking.

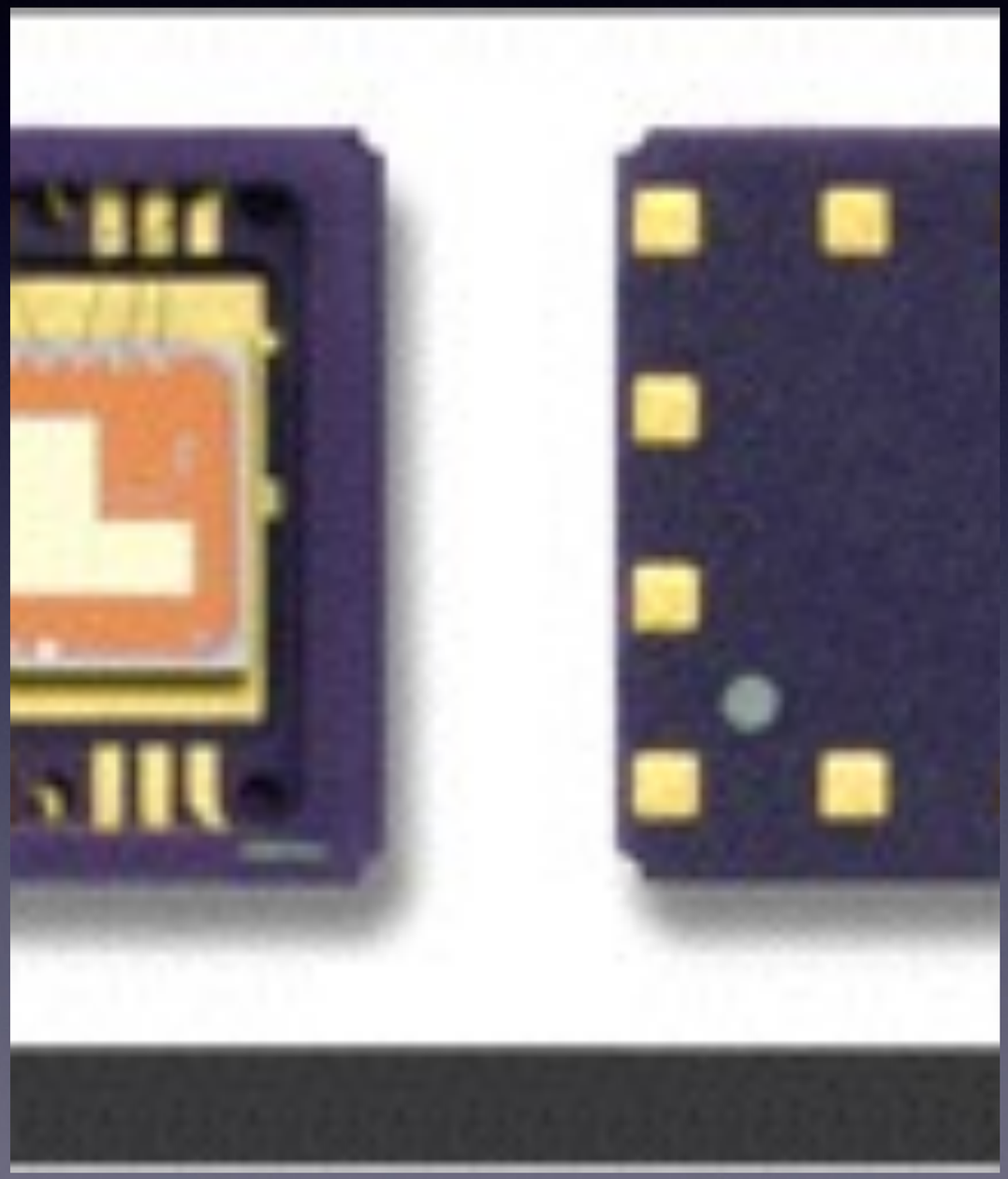
MCU

The LilyPad Simblee BLE Board is a wearable development board that allows users to add mobile application functionality via Bluetooth Low Energy (BLE, or Bluetooth 4.0) to e-textile projects. The Simblee RFD77101 module, equipped to this board, is intended to make embedded devices using Bluetooth Low Energy connections.



Sensors

- **UV sensor (ML8511A)**
  - Optical sensor to UV-A and UV-B
  - Realize equalization of an output voltage by trimming
  - The analog voltage output proportional to UV light intensity
  - Low current operation (300μA Typ.)
  - and low standby current (0.1μA Typ.)
  - Compact QFN package (4.0mm × 3.7mm × 0.73mm)
  - The TSV-CSP version is under development
  - for the further small size package(2.1 × 1.8mm)



Sensors

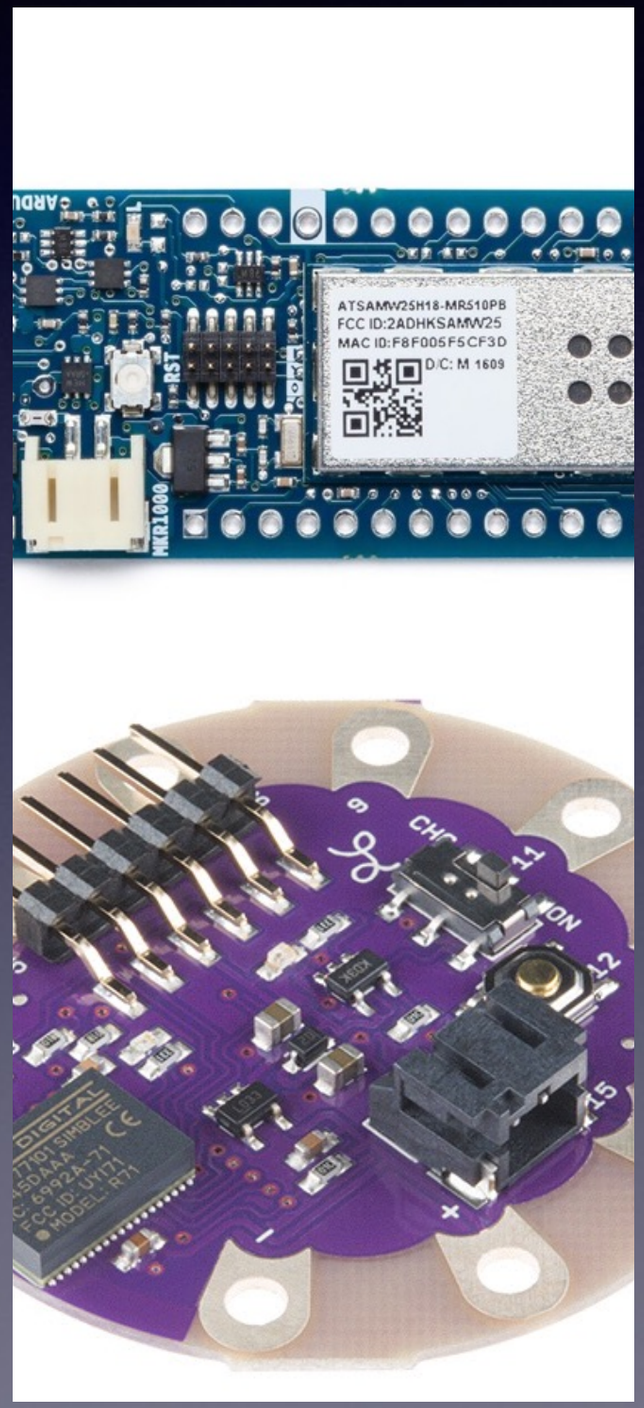
- **MQ2 Gas sensor**
- **Power supply needs: 5V**
- **Interface type: Analog**
- **Wide detecting scope**
- **Fast response and High sensitivity**
- **Simple drive circuit**
- **Stable and long life**
- **Size:36.4x26.6mm (1.4x1")**

Data Display and Analysis

Samsung ARTIK™ Cloud | developers JIENENG

Blynk: Platform with iOs and Android apps to control Arduino, Raspberry Pi and similar microcontroller boards over Internet.

User Interface

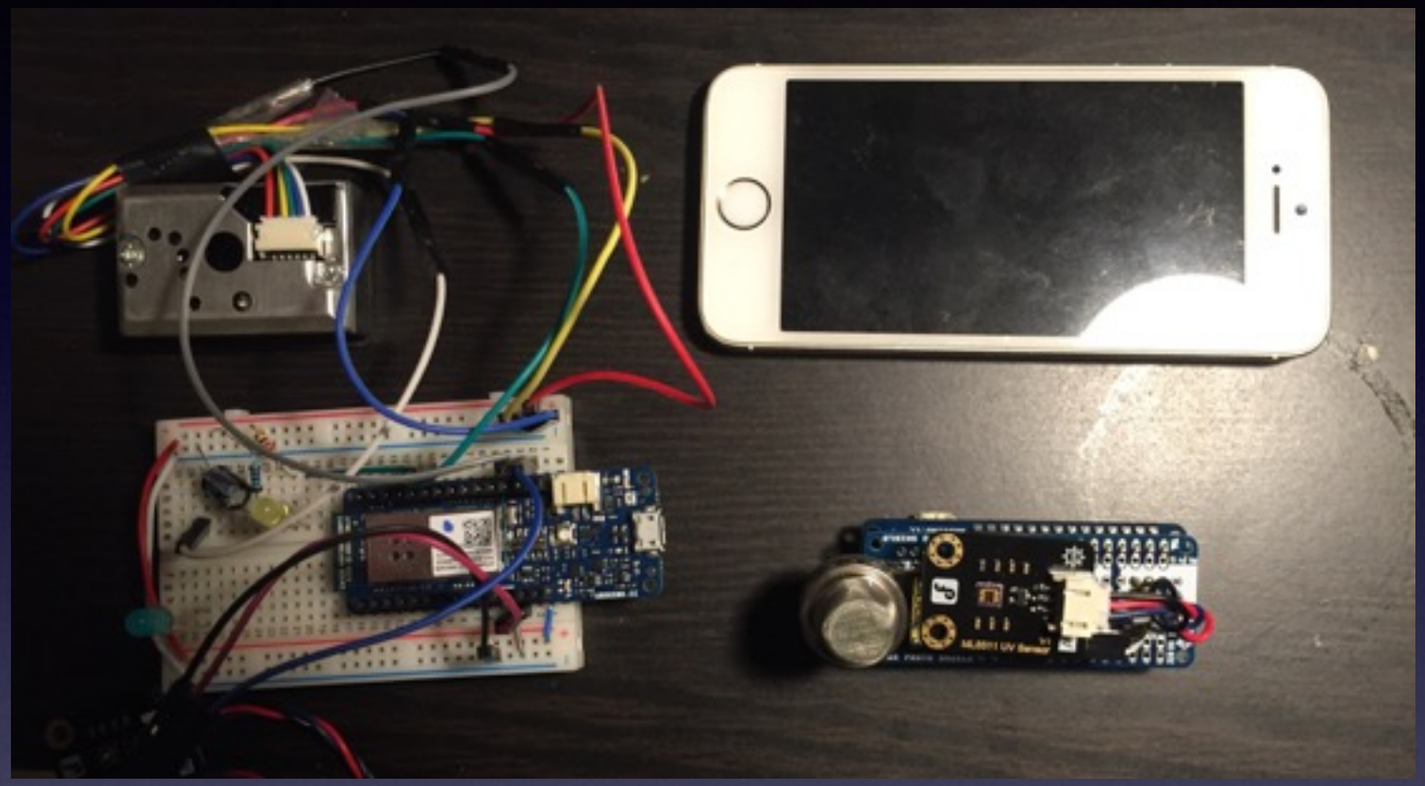


Simblee™

A subsidiary of HEPTAGON™

IoT for connecting
Everyone and Everything
IoT4EE

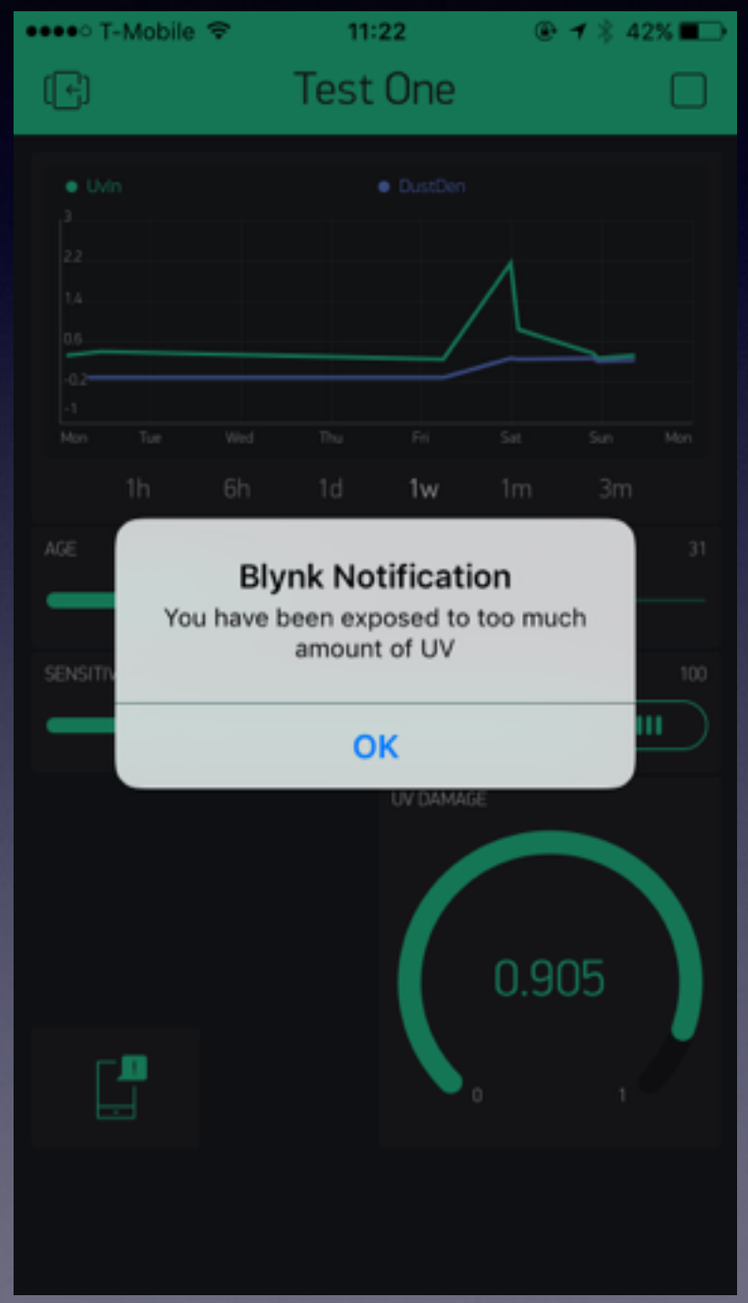
Progress - Prototype - WIFI

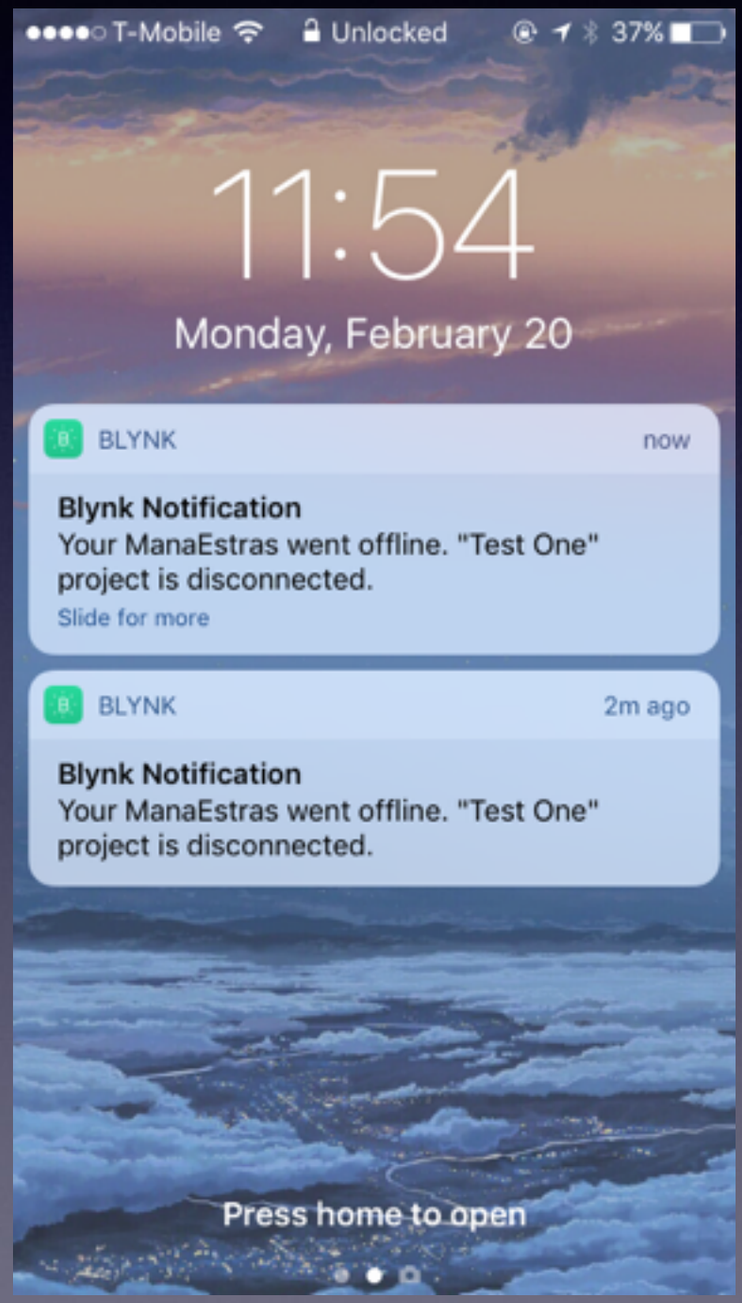


- First Prototype
- UV Sensing and Alert
- Dust Sensing and Alert
- Wifi Communication
- Data Display on Artik Cloud
- Wireless Charing with LiPo Battery

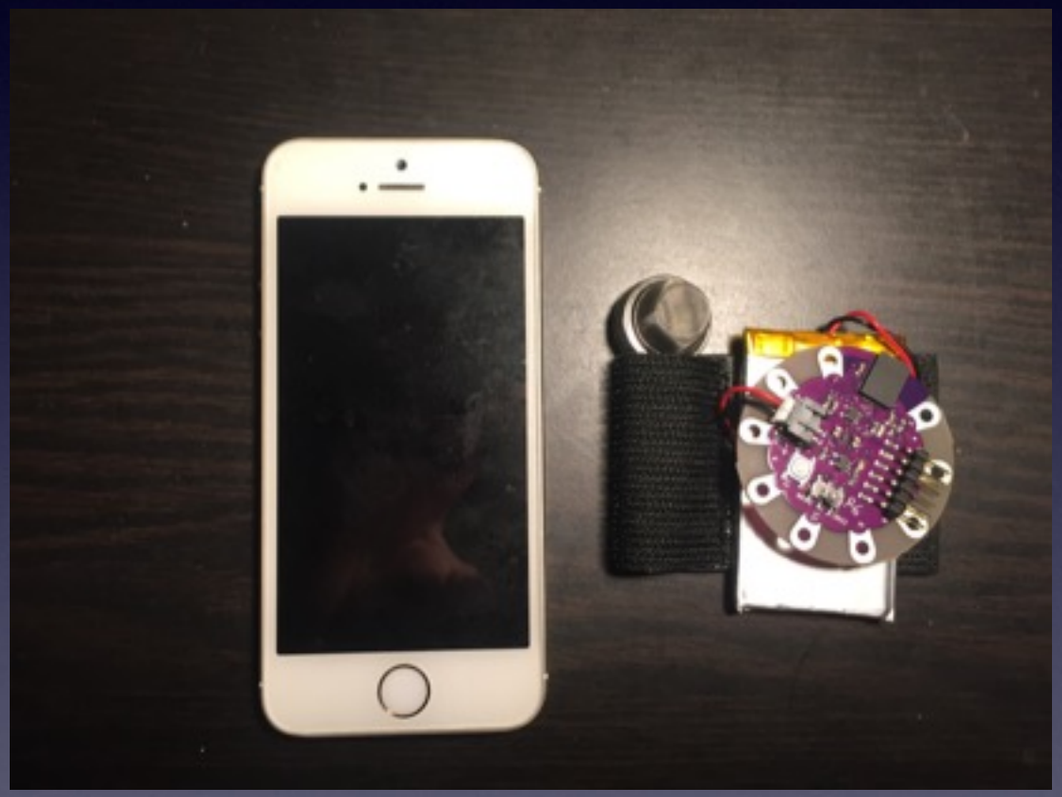
- **Second Prototype**
- **Size minimised**
- **UV Sensing and Alert with New model**
- **Gas Sensing and Alert**
- **Wifi Communication with Disconnect Failsafe**
- **Data Display on Artik Cloud and Blynk Phone App**
- **Wireless Charing with LiPo Battery**

Progress - Wifi App



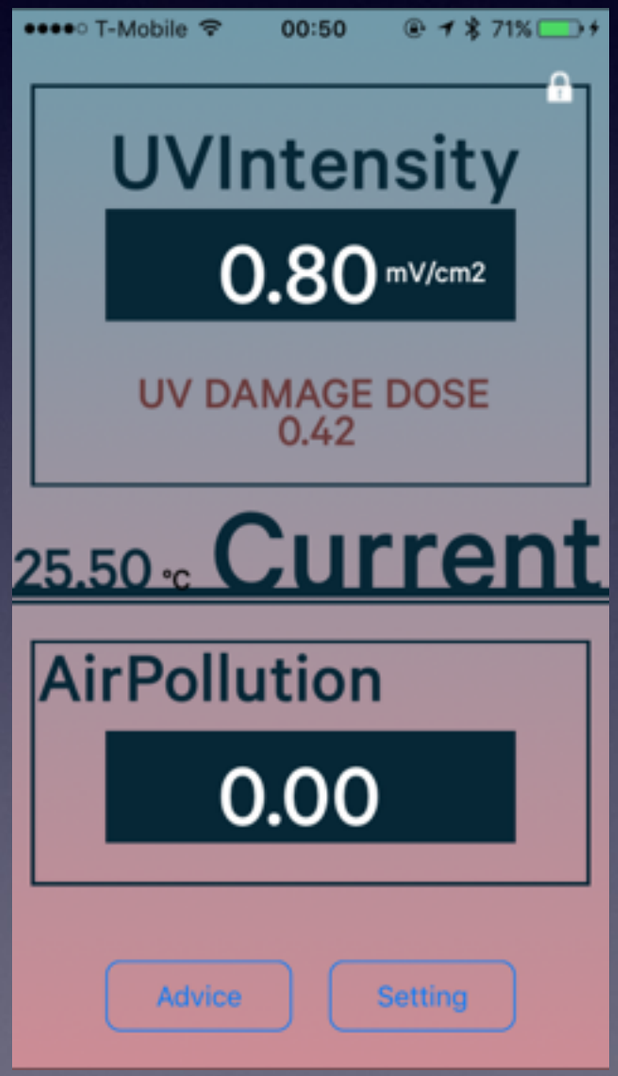


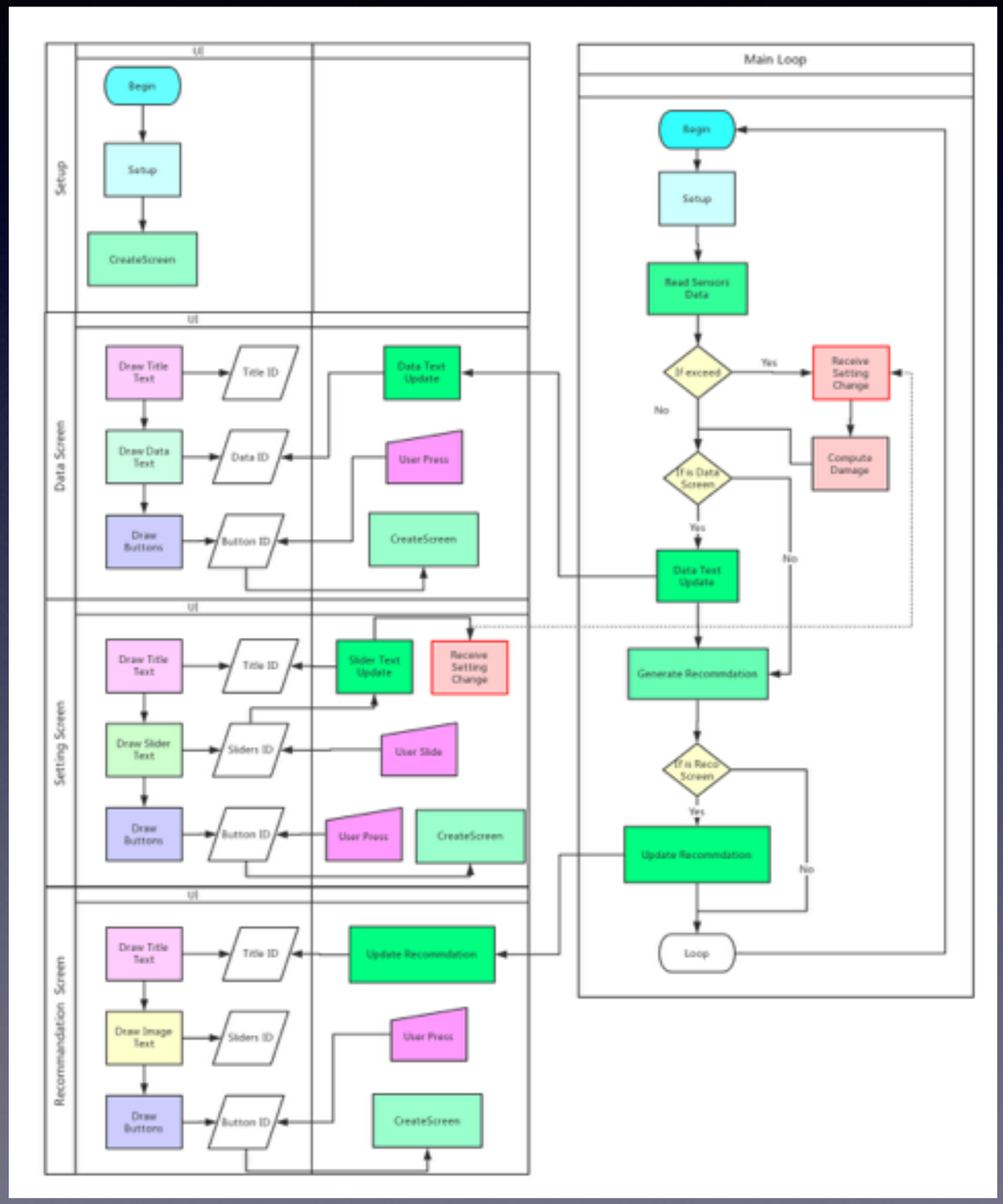
Progress - BLE Prototype



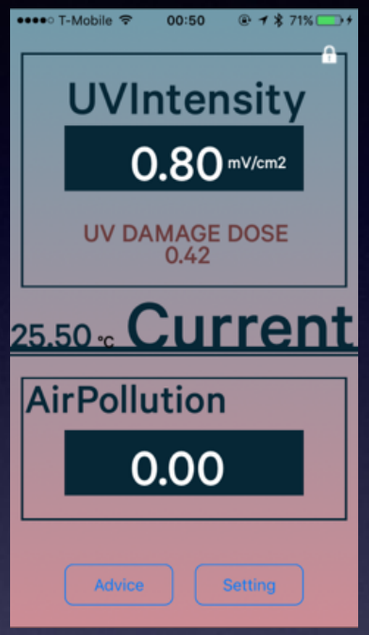
- **Third Prototype**
- **Size minimised**
- **UV Sensing and Alert with New model**
- **Temperature Sensing**
- **Gas Sensing and Alert**
- **BLE Communication**
- **Data Display Simblee Phone App**
- **Charing with LiPo Battery**

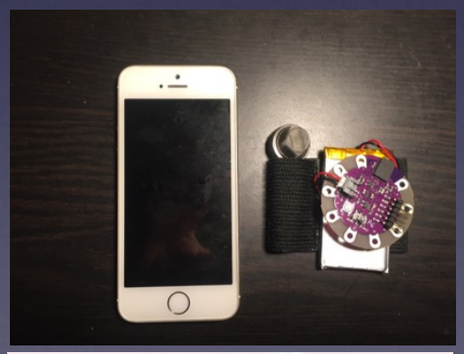
Progress - BLE Prototype



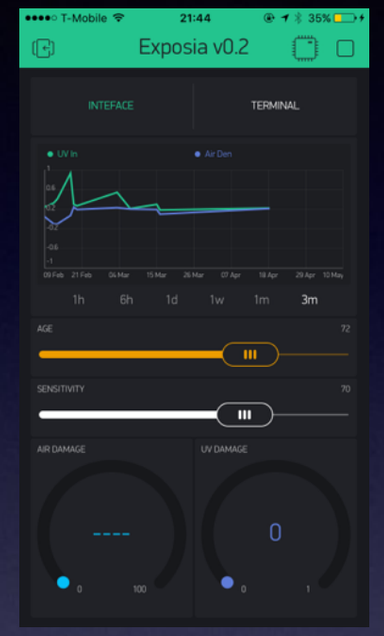


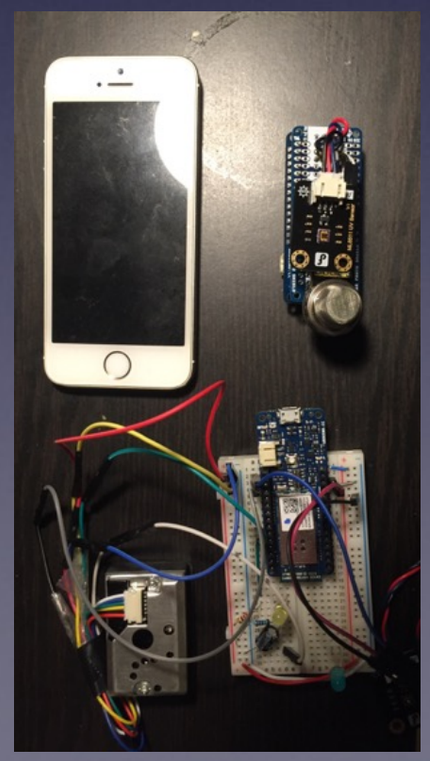
Compare: BLE vs Wifi





Y	**Size minimised**	Y
Y	**UV Sensing and Alert**	Y
Y	**Temperature Sensing**	N
Y	**Gas Sensing and Alert**	Y
Y	**Personalised Alert and Recommendation**	Y
Y	**Wireless Communication**	Y
Y	**Data Display on Phone App**	Y
N	**Data Analysis on IoT Cloud**	Y
Y	**Charing with LiPo Battery**	Y
Y	**Mobility**	Y
N	**Internet Interface**	Y
Y	Cost Less than 50 $	Y





1.Air pollution Model

- Using International standard index AQI(Air Quality Index) to measure the degree of the air pollution.

- Because our dust sensor can only detect the dust with the diameter over 0.8um and could not tell apart the specific dust(Over or below 2.5um or 10um), we will treat all the dust as the pm2.5(the most harmful dust to human beings) in this model

AQI

United States [edit]

The United States Environmental Protection Agency (EPA) has developed an Air Quality Index that is used to report air quality. This AQI is divided into six categories indicating increasing levels of health concern. An AQI value over 300 represents hazardous air quality and below 50 the air quality is good.[10]

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

AQI Calculation

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

where:

I = the (Air Quality) index,

C = the pollutant concentration,

C_{low} = the concentration breakpoint that is $\leqslant C$,

C_{high} = the concentration breakpoint that is $\geqslant C$,

I_{low} = the index breakpoint corresponding to C_{low},

I_{high} = the index breakpoint corresponding to C_{high}.

2.UV damage Model

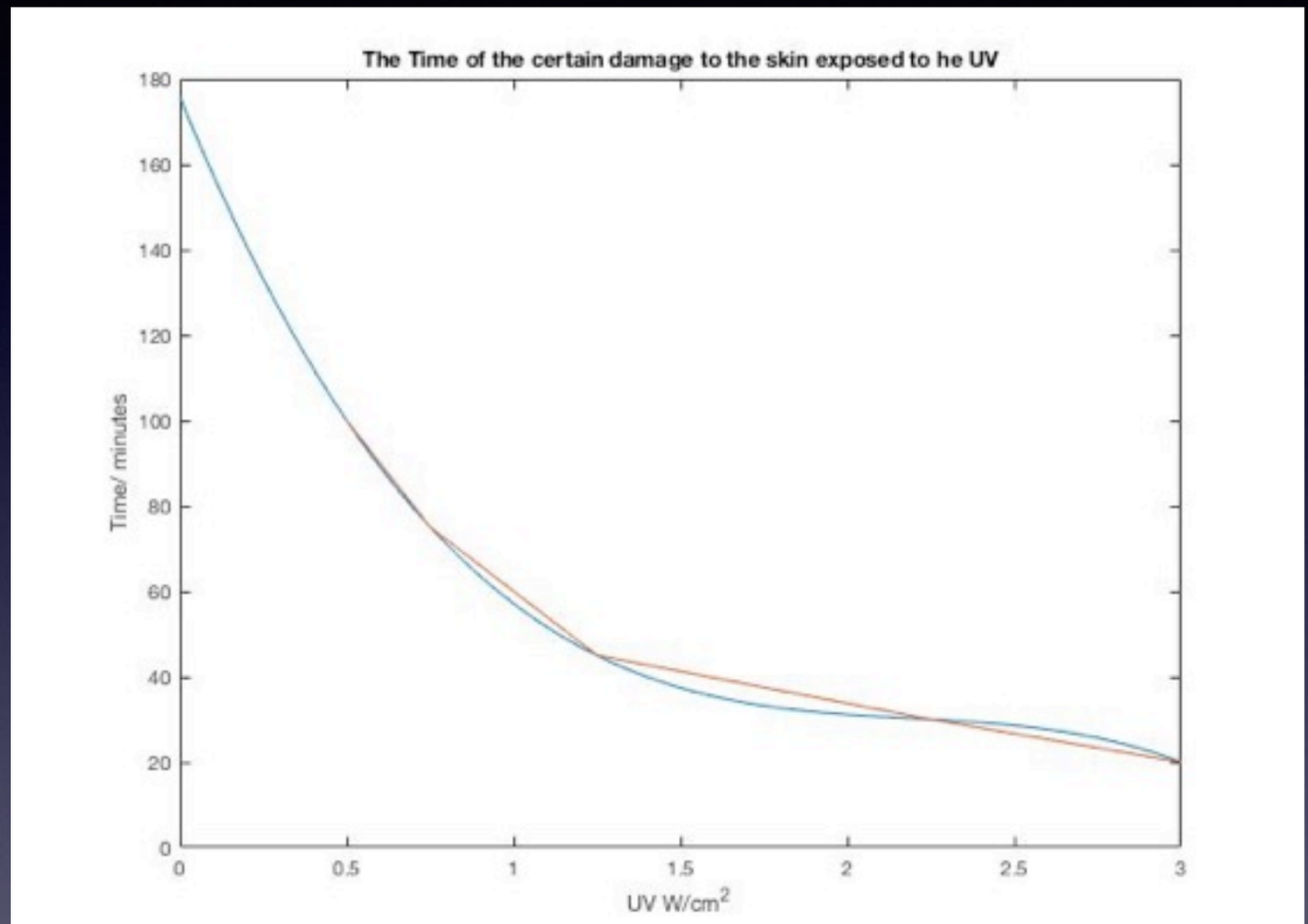
- There is not a appropriate index to measure the damage of UV so we have to build a damage model based on some known data.

- Simple Ultra Violet Model only need to concern about the intensity and the exposed time.

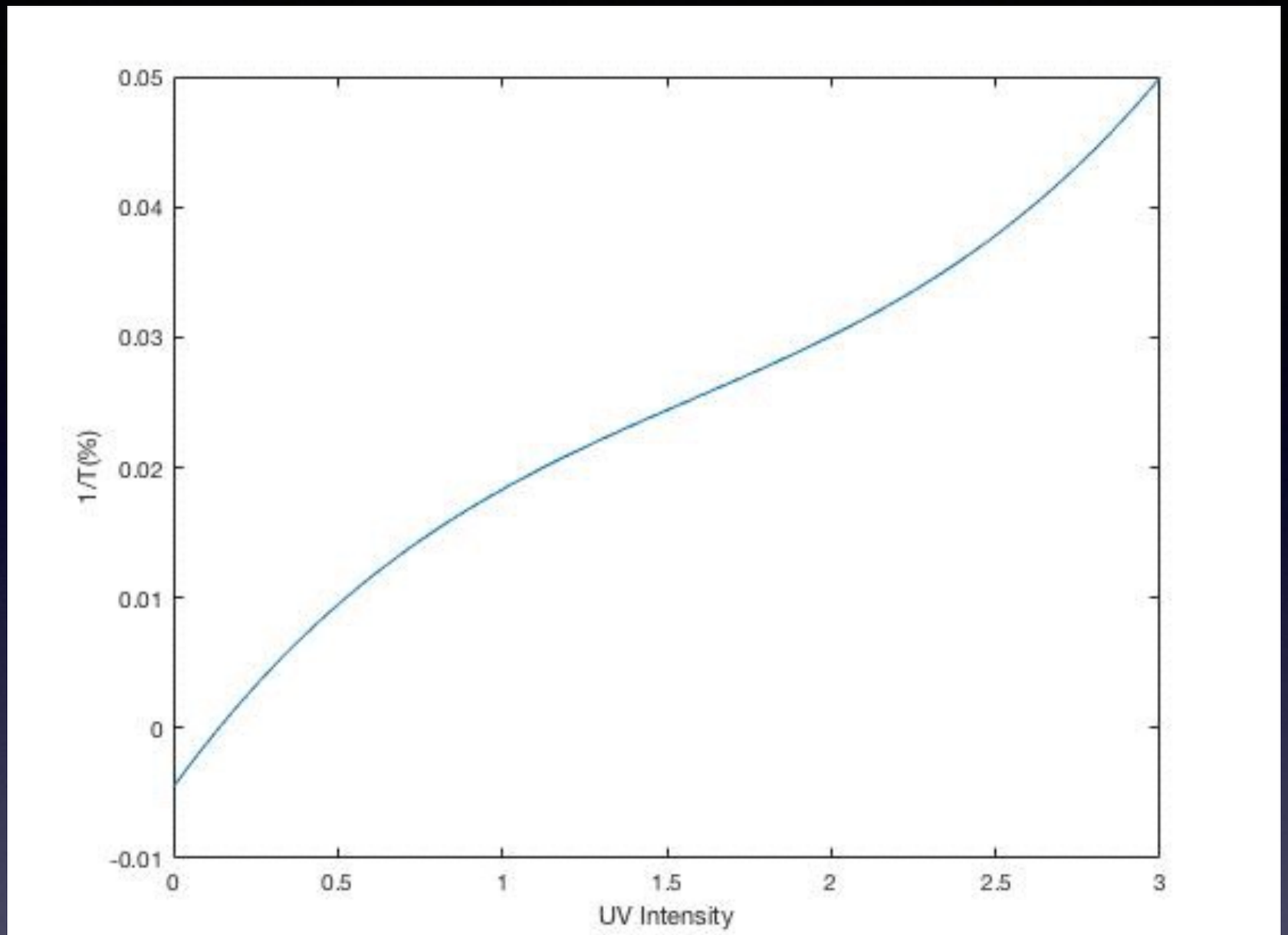
- The degree of damage can be different and in this model we chose the damage that cause slight sunburn.

We use Matlab to find the fitted curve of the data

So the 3-order polynomial is quite sufficient to describe the damage time based on different level of UV



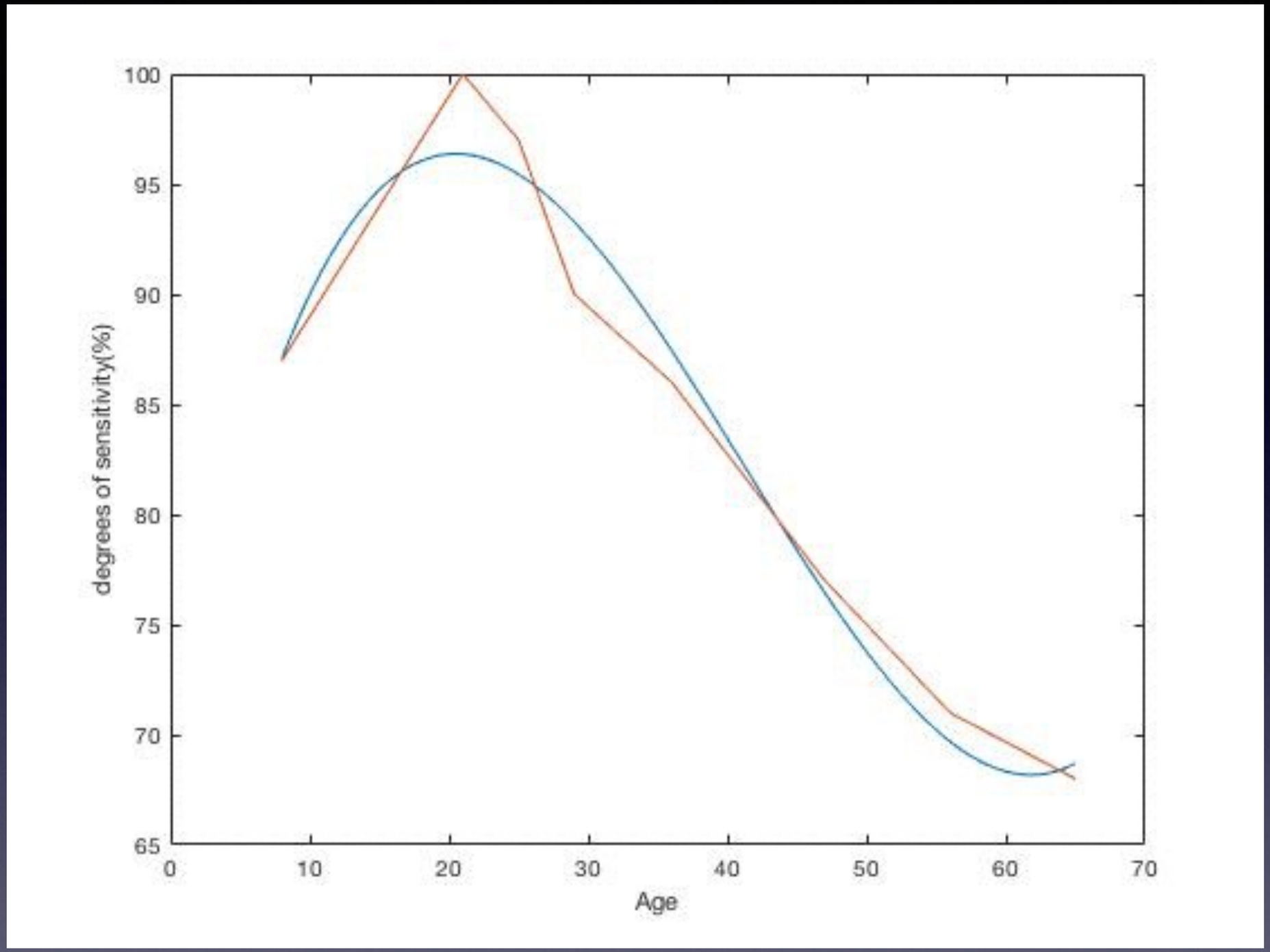
And the polynomial of curve is T(x)=-12.9736*x^3+85.2522*x^2-190.9085*x+175.7416



P-Intensity relation Of UV

Enhancement of Model

- More specific to different users with different genders, ages, skin types, sensitivity wishes .
- Most paper said men and women are equally likely to get sunburn under UV.
- Sensitivity can be chosen in the phone application to users' will.
- Skin type is commonly unknown to users.



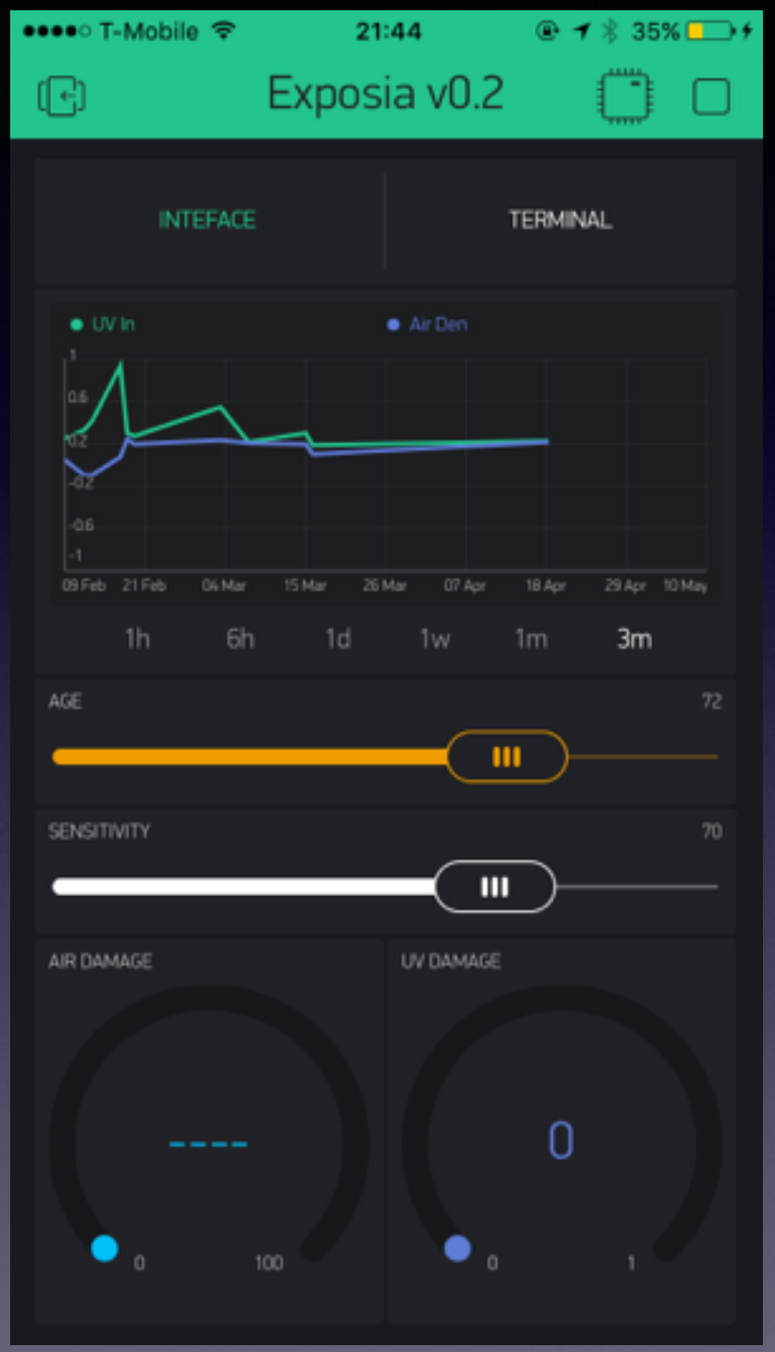
Age relations

Skin type	Description	MED $[mJ/cm^2]$
I	Always burns, never tans(pale white skin)	20-35
II	Always burns easily, tans minimally(white skin)	30-45
III	Burns moderately, tans uniformly(light brown skin)	40-55
IV	Burns minimally, always tans well(moderate brown skin)	50-80
V	Rarely burns, tans profusely(dark brown skin)	70-100
VI	Never burns(deeply pigmented dark brown to back skin)	>100

Skin type

So in this way
we can let the user modify
the
Age, Sensitivity and Skin
type in the application

Then
the app will work based on
their own individual feature



What We Have Done

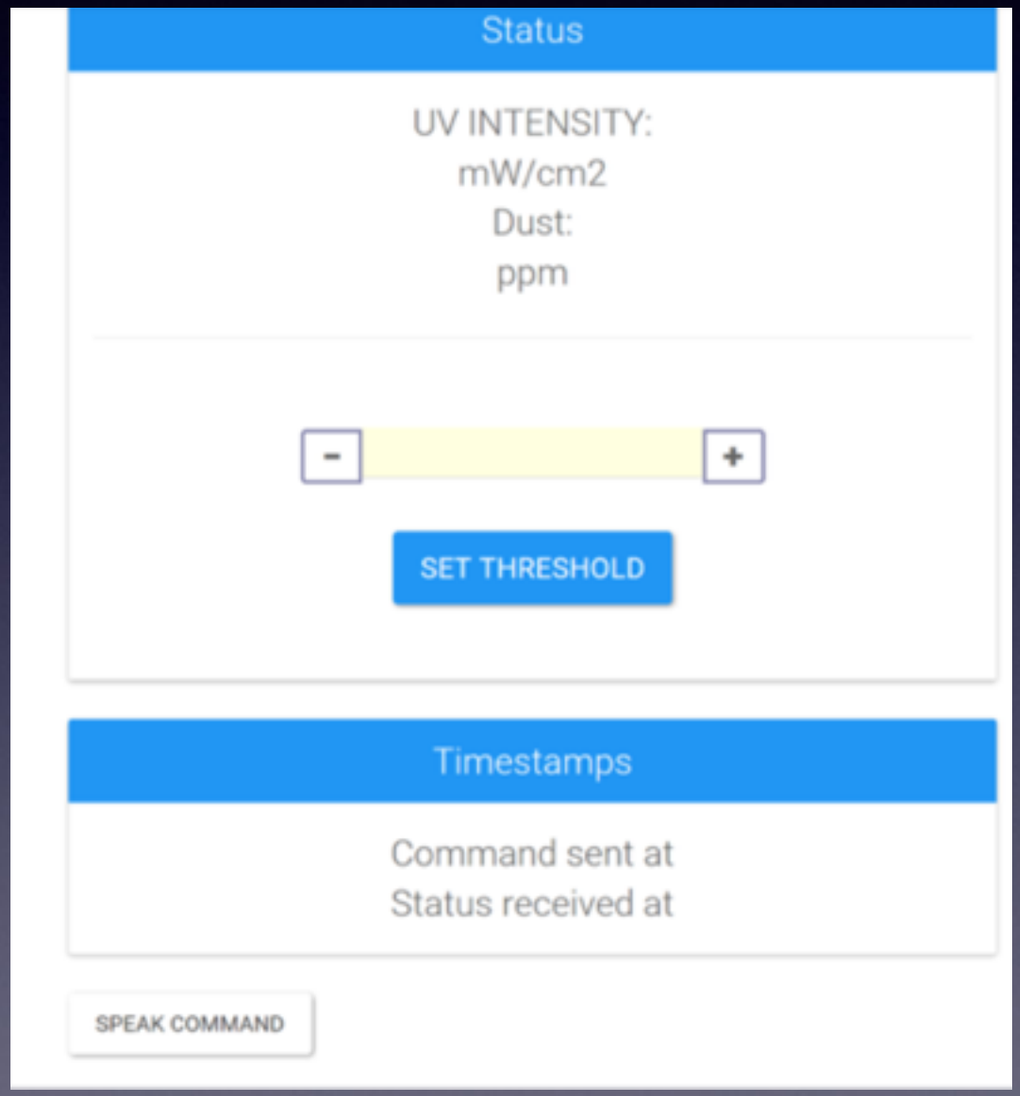
- Built 3 Prototypes of the product
- Built 2 Apps that work with the prototypes
- Built 1 Web-based Data Dashboard that works with the Wi-fi Prototype
- Did some research on UV and Air Pollution, Come up with Mathematic Model of UV Damage Dose and Air pollution Damage Dose

Failures - MS Azure IoT Hub

In the first 2 weeks in winter quarter, we tried to use the Azure IoT Hub to realize two important functions of the device:

A. Over-the-Air (OTA) programming of the Arduino MKR1000

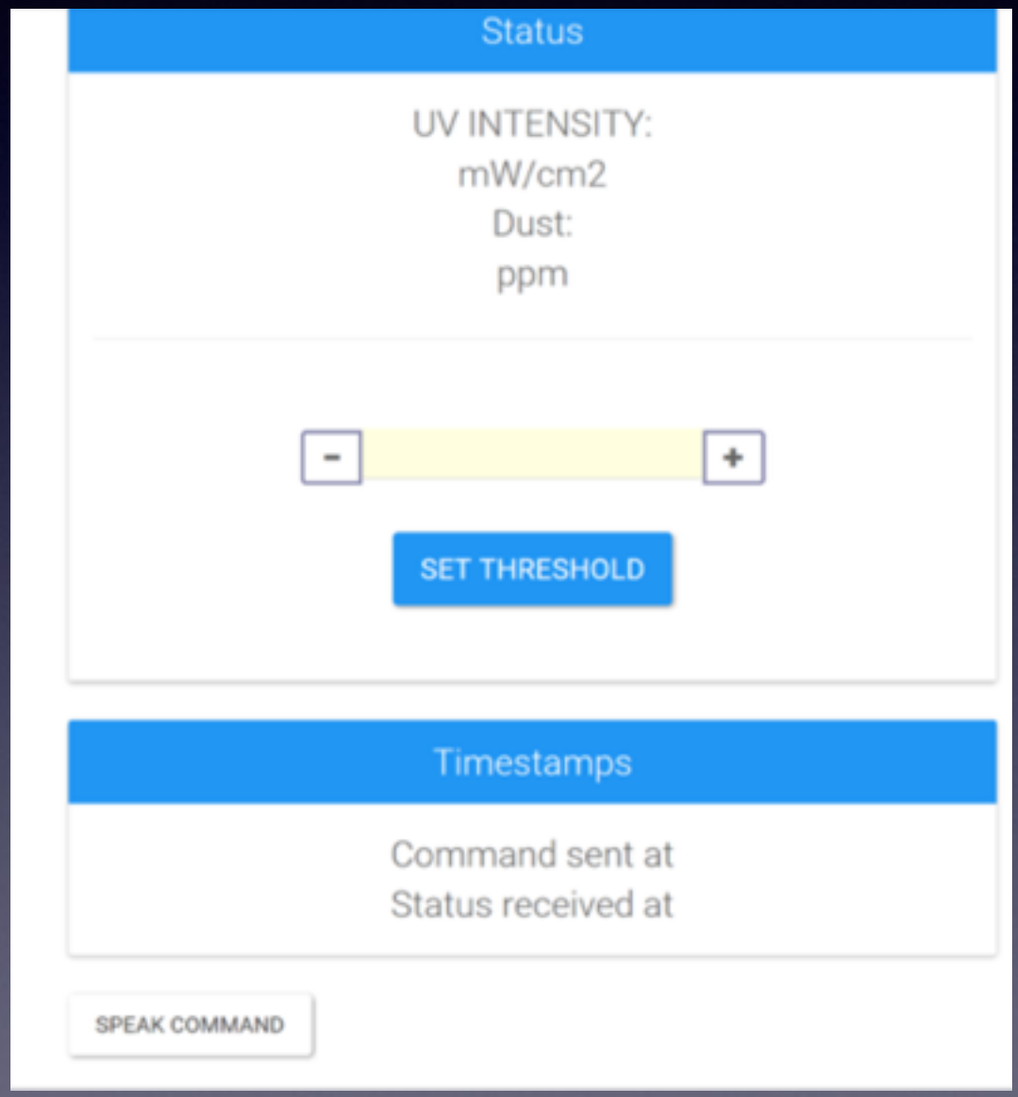
B. Universal Windows Platform (UWP) client app, with a nice user interface. It communicates securely with the board via Azure IoT Hub.



Failures - MS Azure IoT Hub

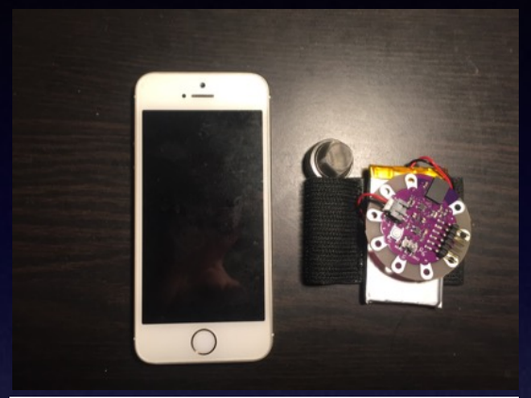
Before considering other methods, I have built a simple but applicable user interface using Microsoft VS2015 with C# and JavaScript. This interface can be run on smart devices that have Windows 10 OS, including Personal Computer and Windows Phone.

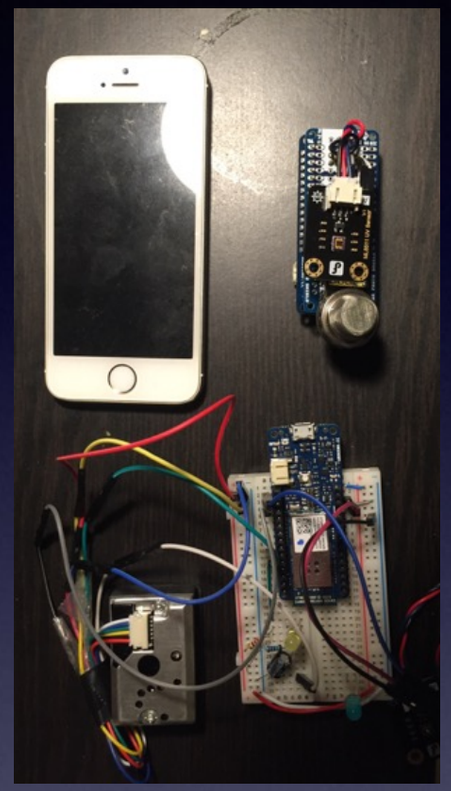
However, I met fatal problems with OTA programming and connecting Azure to the user interface. Apparently, the new version of Arduino IDE cannot support the OTA Flower Platform, as the libraries have errors on the latest version on Arduino IDE. In addition, this interface could not be run on most smart phones, which have Android or IOS. In order to build an universal app, I decided to use another platform.

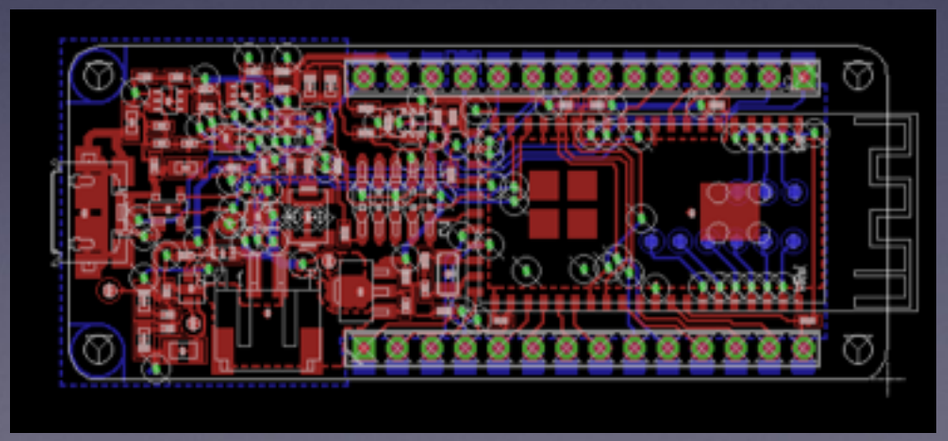


Failures - Packaging and PCB

- Cannot come up with a good idea to package the devices
- Despite PCB designed, we cannot produce the circuits boards with limited resources
- Resources needed: PCB Manufacturers, 3D Printing with CAD







What We Have learnt

- Microcontroller Programming
- Sensors Circuit Design
- Modelling Based on Previous Research
- Application Development on IoT Platform
- Reading and Writing Research Paper

Future Steps

- Involve IoT Cloud into BLE prototype
- Using Photo Recognition to Recognise User's Skin Type
- Develop Universal Package
- Complete the Paper

Thank You

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