HomeSense - A Case Study On Human Activity Patterns And Air Quality For Energy Saving In Smart Homes

Niloofar Rezaei
Seyed Alireza Vaezi

Overview

- Introduction and motivation
- Hardware and software inventory
- Experiment set-up
- Results

Introduction and motivation

- Automation plays an important role in our daily lives.
- Home automation and smart houses are at our disposal today thanks to the proliferation of smaller, cheaper, and more power-efficient electronic devices (I.e. sensors, chips, etc.) that have more computational power.
- These sensors and actuators are the building blocks of smart houses, enabling processing units with the ability to interact with their environment.
- On the other hand, indoor air quality and its effect on health and comforts of the occupants is another vital aspect of our houses. HVAC units, air purifiers, dehumidifiers, and fans are among the most power-consuming devices that control and preserve the quality and comfort of the air we breathe.
- Controlling and scheduling the runtime of these electric devices can provide both the desired quality and comfort as well as saving energy.

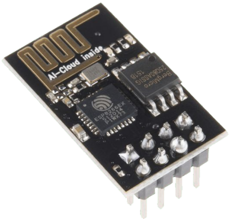
Introduction and motivation

- First step is gaining knowledge about the current status of our system.
  - Monitoring the activity of the occupants
  - Monitoring air quality and climate characteristics and properties
- Next step is finding patterns and correlations causations between the monitored features

Hardwares

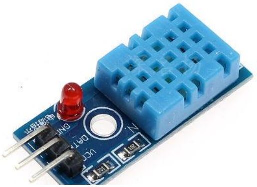
Processing units:

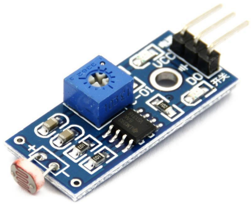
- **ESP8266** and **ESP32** Microcontrollers



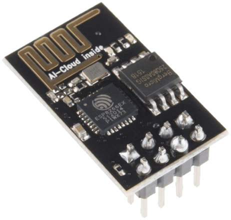
Sensors:

- Temperature and humidity: **DHT11**
- Air quality sensor: **MQ135**
- Infrared motion detection sensor: **HC-SR501**
- Light Intensity Sensor: **Photoresistor module**





ESP8266 and ESP32 microcontrollers



Espressif Systems	**Manufacturer**	Espressif Systems
160 MHz	**CPU**	240 MHz
1MB max	**Memory**	4 MB
17 GPIO pins	**Input**	30+ GPIO pins
3.3 V DC	**Power**	5 V DC
WiFi	**Connectivity**	WiFi - Bluetooth

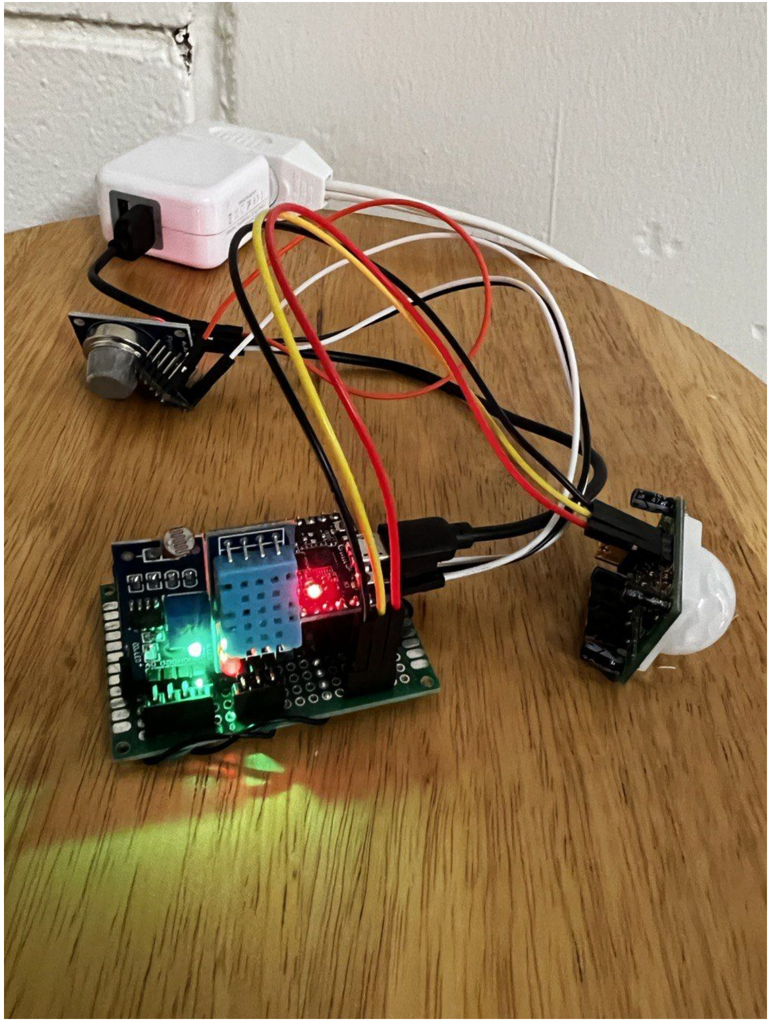
Software

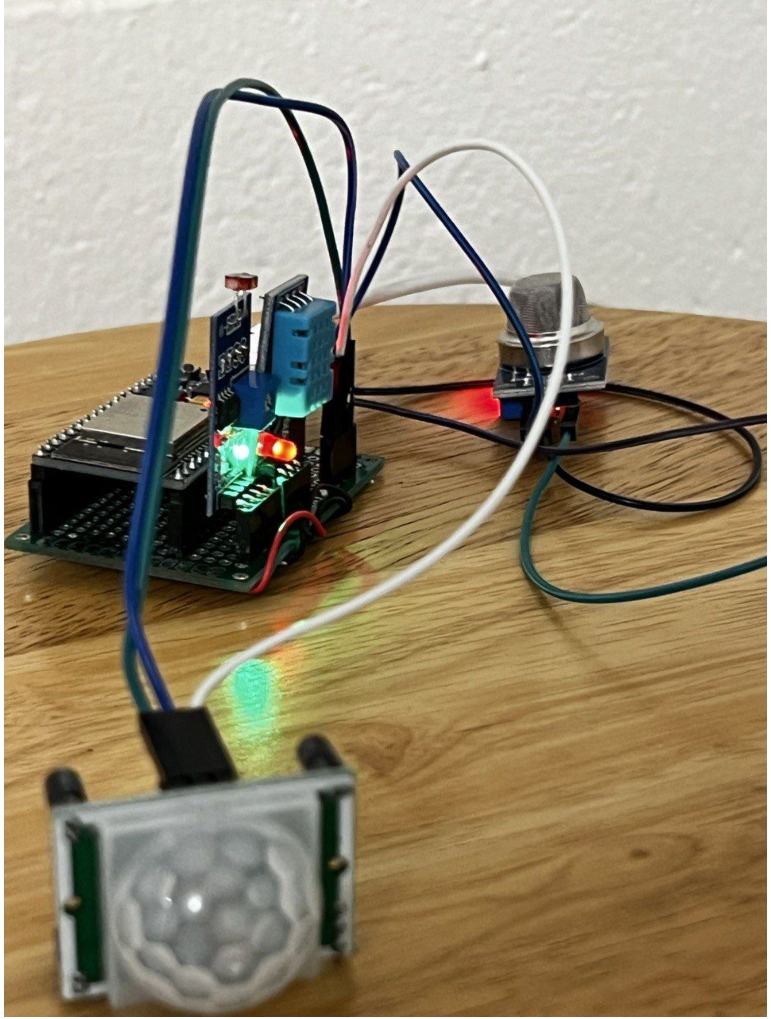
- **MicroPython** (instead of Arduino's C/C++)
  "MicroPython is a full Python compiler and runtime that runs on the bare-metal."
- Using USB serial connection to microcontrollers for programming.
- Visual Studio Code as the IDE.

Experiment

- Using three ESP32 microcontrollers.
- Each has one of the sensors connected to it. IR motion sensor , temperature/humidity, light intensity, and air quality..
- Each unit is placed in a room. One living room, and two bedrooms.
- Communication is done over WiFi.
- A laptop is used as the hub for gathering data generated by the sensors.
- An AC and a dehumidifier in each room.
- Data was gathered from devices every 60 seconds.

Data was gathered over the course of 67 hours.





Experiment

Code includes:

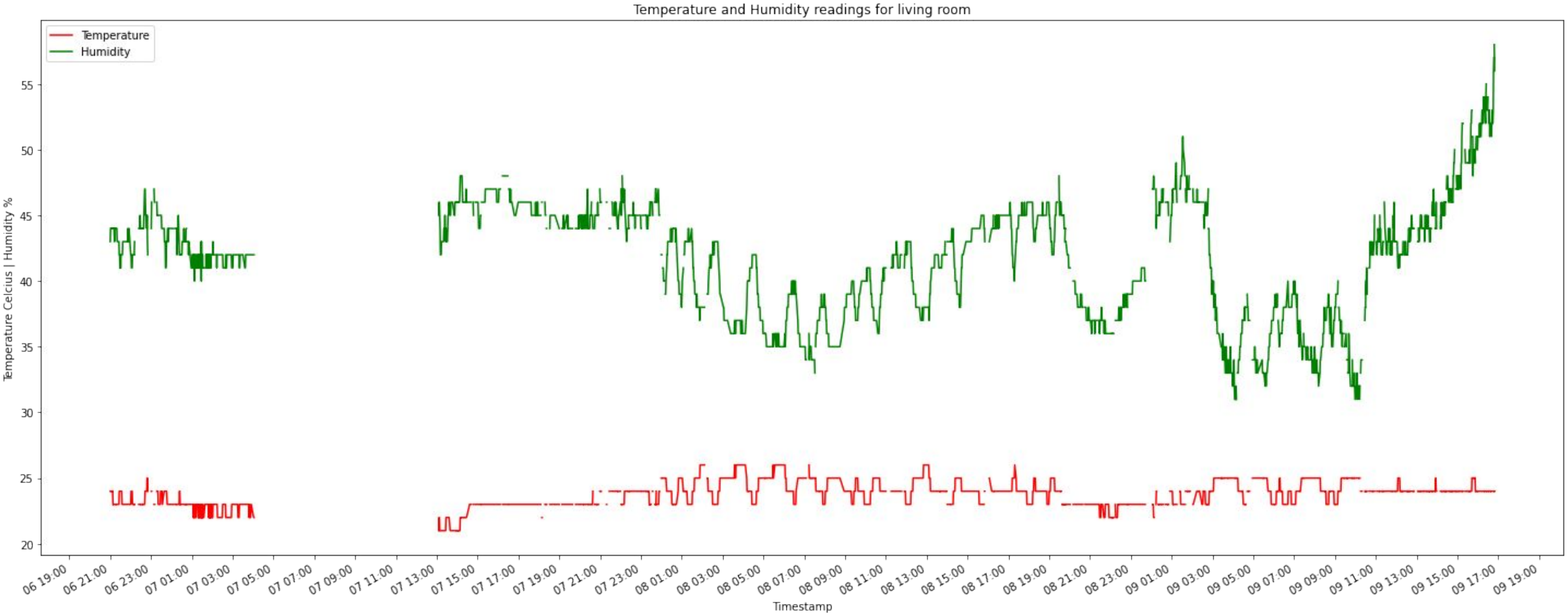
- WiFi connection to home router.
- Socket programming for sending readings and events to laptop.
- Saving captured data in a time-series format
- Python, pandas, pyplot for data visualization and representation.

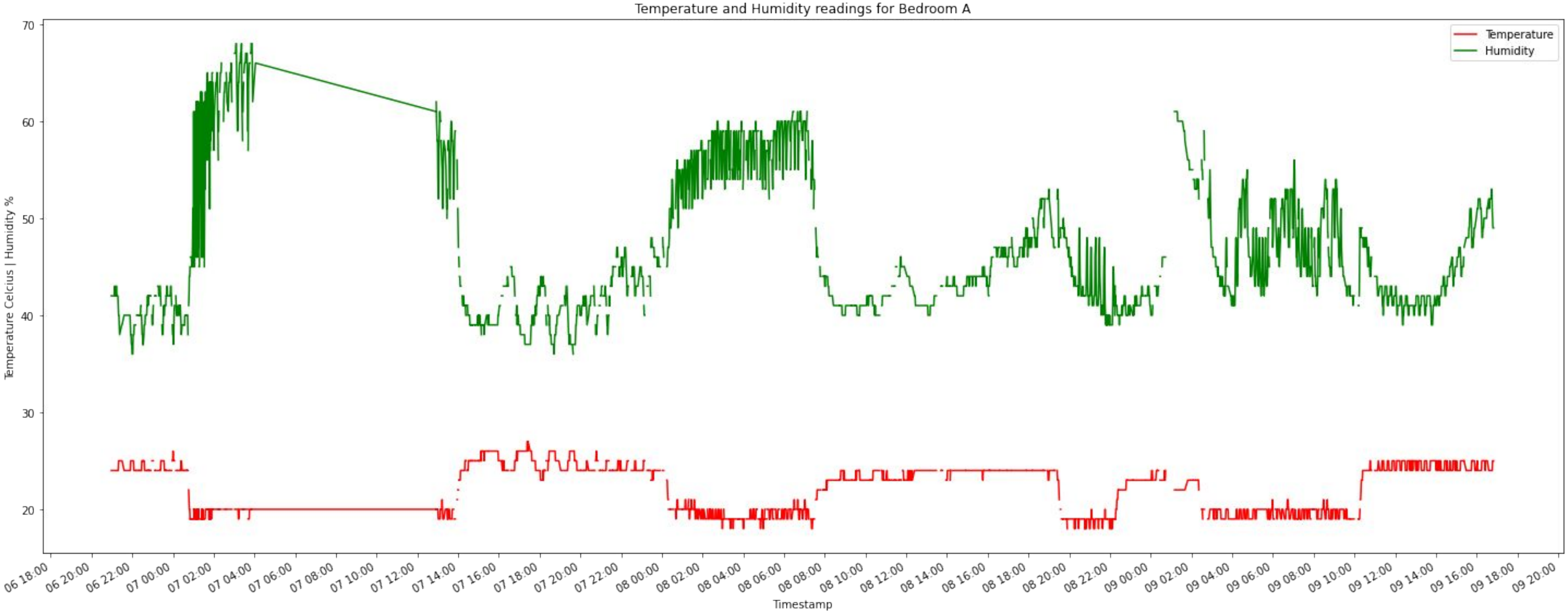
Features:

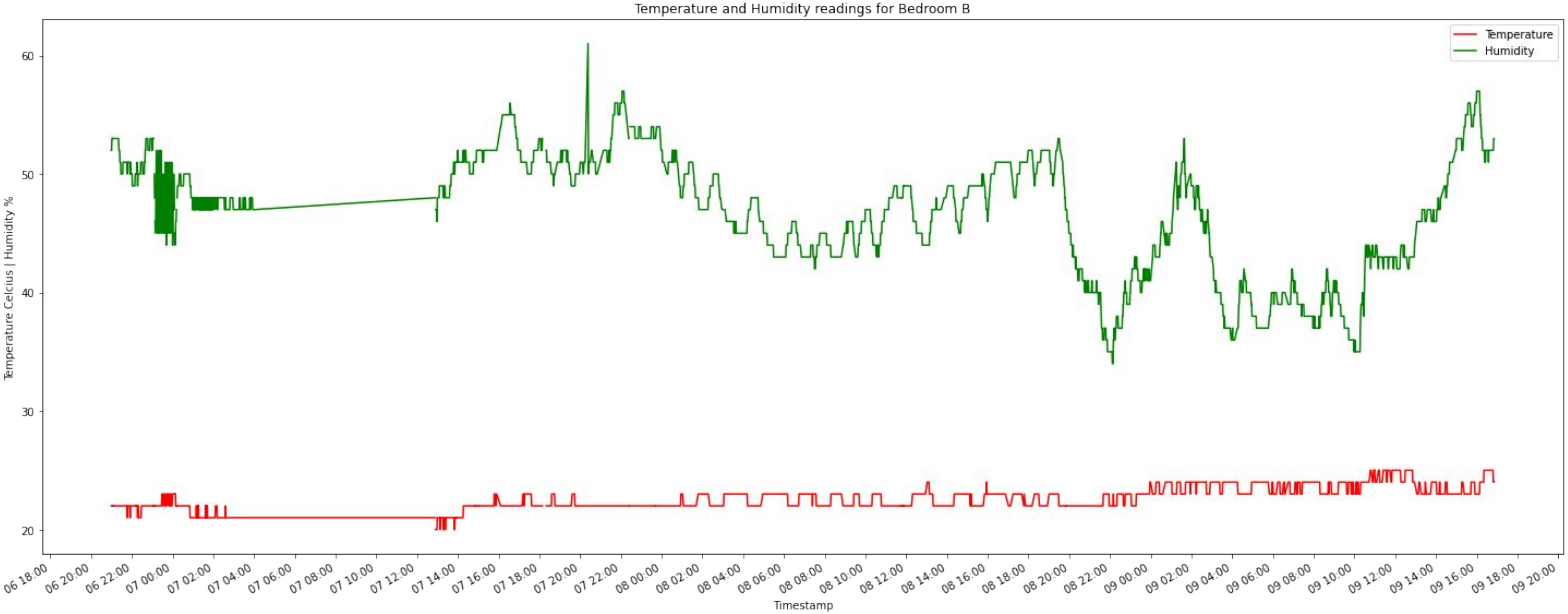
- Motion detection is event-based. As soon as motion is detected a message is sent to the laptop over WiFi via socket programming.
- Very cheap sensors and microcontrollers

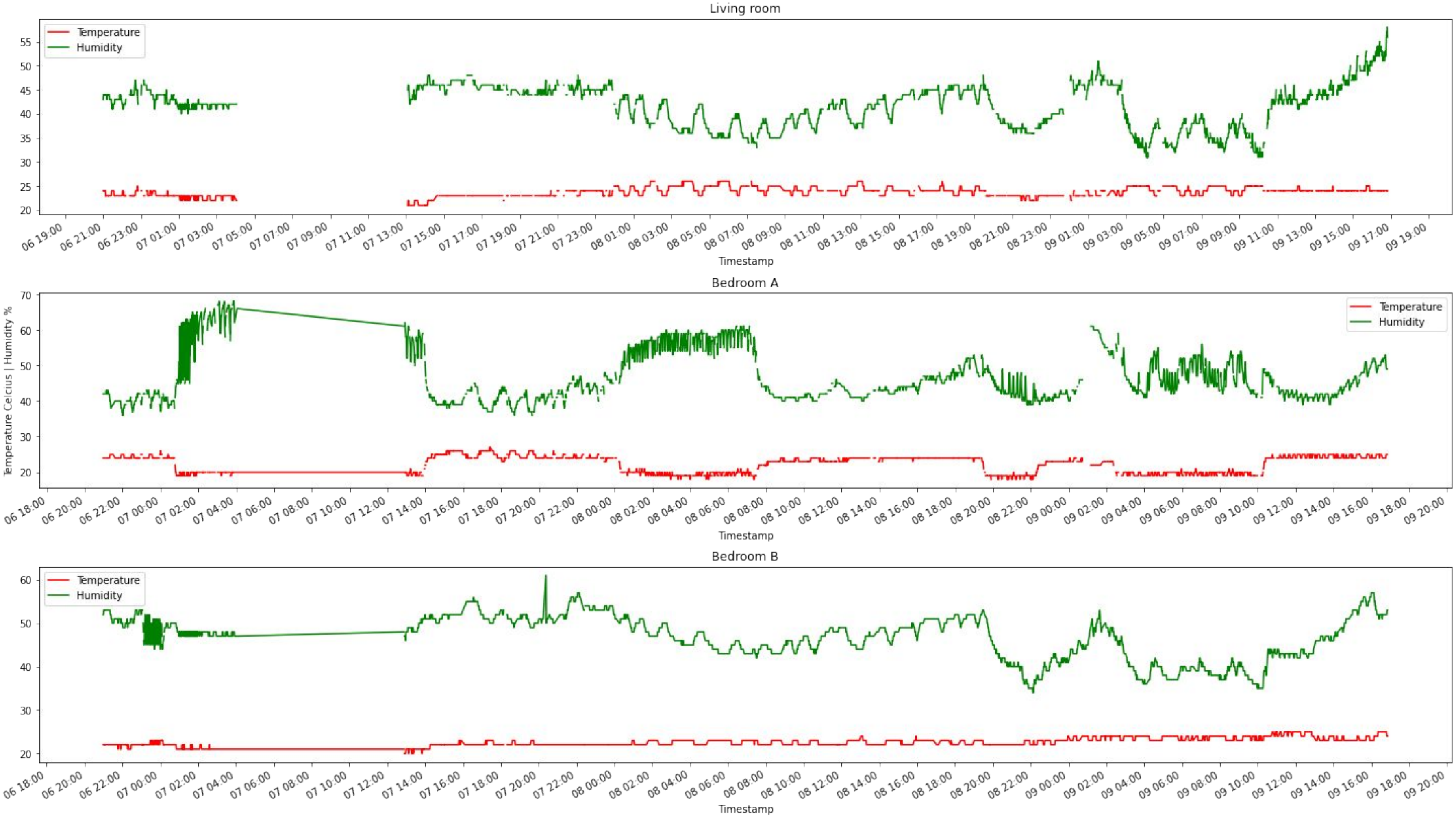
Drawbacks:

- Sensors have lots of errors and are sometimes unreliable. Not up par with industrial standards

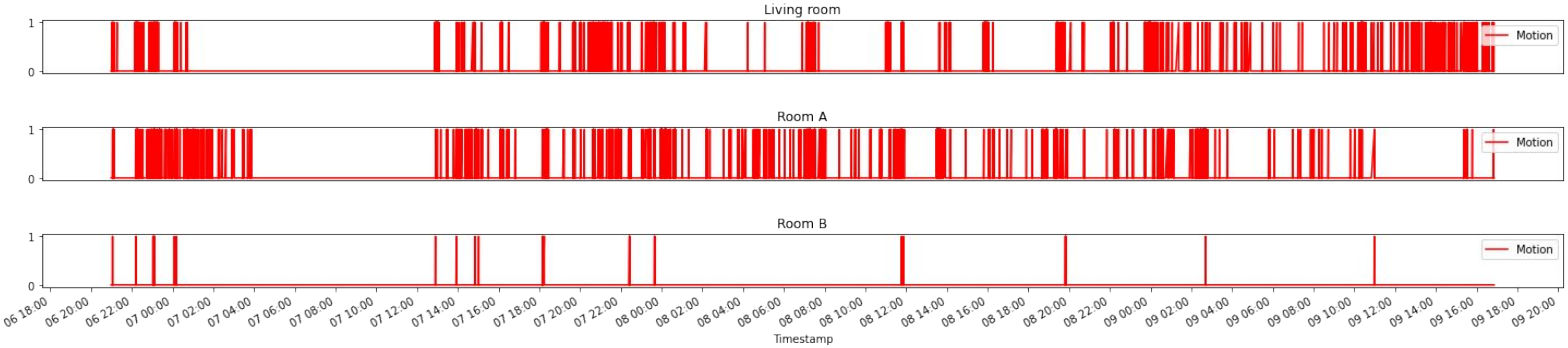

Temperature and Humidity readings for living room
Temperature
Humidity
Temperature Celcius | Humidity %
55
50
45
40
35
30
25
20
06 19:00
06 21:00
06 23:00
07 01:00
07 03:00
07 05:00
07 07:00
07 09:00
07 11:00
07 13:00
07 15:00
07 17:00
07 19:00
07 21:00
07 23:00
08 01:00
08 03:00
08 05:00
08 07:00
08 09:00
08 11:00
08 13:00
08 15:00
08 17:00
08 19:00
08 21:00
08 23:00
09 01:00
09 03:00
09 05:00
09 07:00
09 09:00
09 11:00
09 13:00
09 15:00
09 17:00
09 19:00
Timestamp

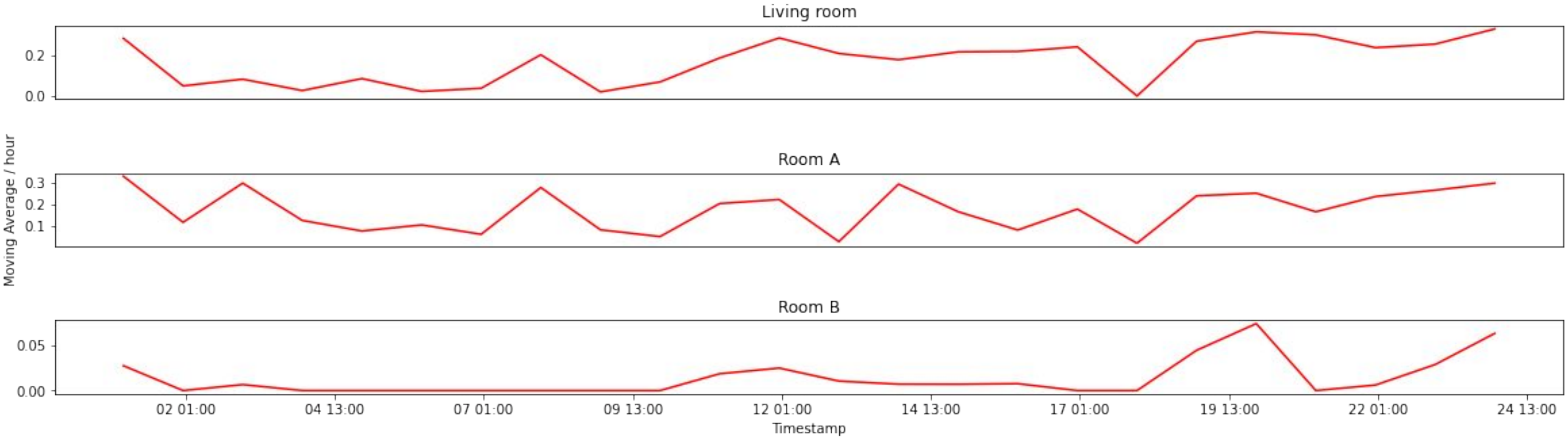

Temperature and Humidity readings for Bedroom A
Temperature
Humidity
Temperature Celcius | Humidity %
70
60
50
40
30
20
Timestamp
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00

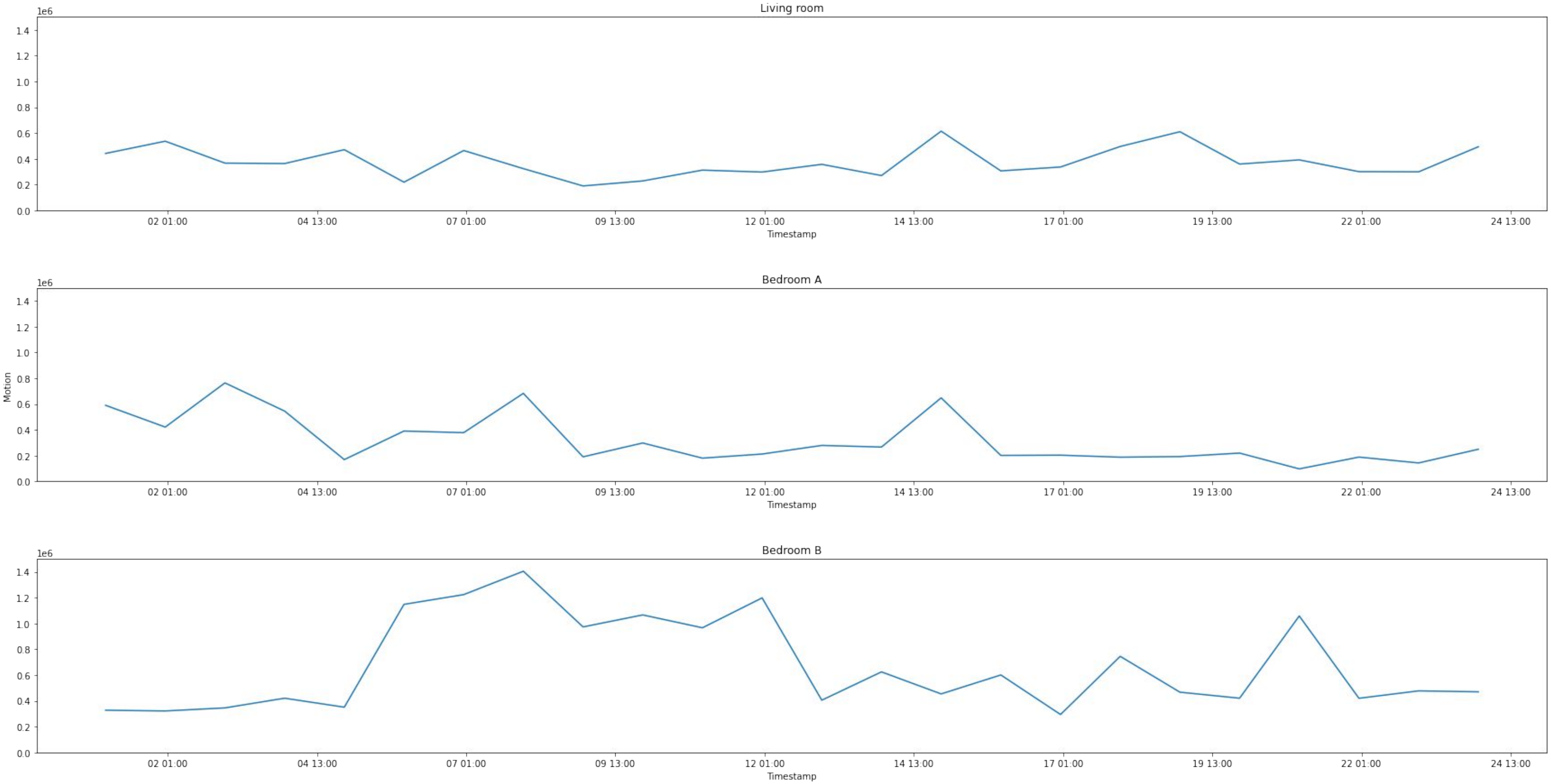

Temperature and Humidity readings for Bedroom B
Temperature
Humidity
Temperature Celcius | Humidity %
60
50
40
30
20
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00
Timestamp

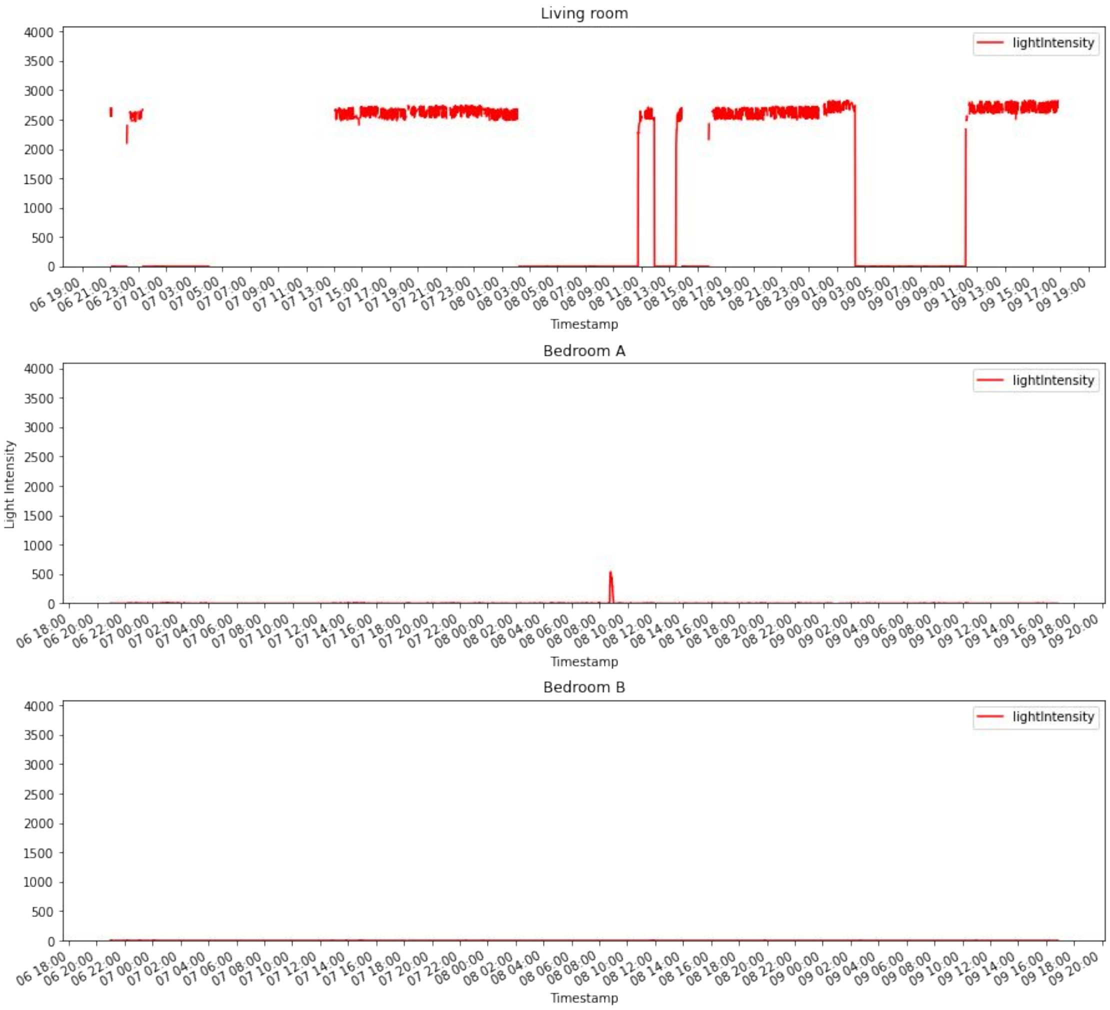


Living room
Temperature
Humidity
55
50
45
40
35
30
25
20
06 19:00
06 21:00
06 23:00
07 01:00
07 03:00
07 05:00
07 07:00
07 09:00
07 11:00
07 13:00
07 15:00
07 17:00
07 19:00
07 21:00
07 23:00
08 01:00
08 03:00
08 05:00
08 07:00
08 09:00
08 11:00
08 13:00
08 15:00
08 17:00
08 19:00
08 21:00
08 23:00
09 01:00
09 03:00
09 05:00
09 07:00
09 09:00
09 11:00
09 13:00
09 15:00
09 17:00
09 19:00
Timestamp
Bedroom A
Temperature
Humidity
Temperature Celcius | Humidity %
70
60
50
40
30
20
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00
Timestamp
Bedroom B
Temperature
Humidity
60
50
40
30
20
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00
Timestamp


Living room
1
0
Motion
Room A
1
0
Motion
Room B
1
0
Motion
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00
Timestamp


Living room
0.2
0.0
Room A
0.3
0.2
0.1
Room B
0.05
0.00
Moving Average / hour
02 01:00
04 13:00
07 01:00
09 13:00
12 01:00
14 13:00
17 01:00
19 13:00
22 01:00
24 13:00
Timestamp


Living room
1e6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
02 01:00
04 13:00
07 01:00
09 13:00
12 01:00
14 13:00
17 01:00
19 13:00
22 01:00
24 13:00
Timestamp
Bedroom A
1e6
Motion
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
02 01:00
04 13:00
07 01:00
09 13:00
12 01:00
14 13:00
17 01:00
19 13:00
22 01:00
24 13:00
Timestamp
Bedroom B
1e6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
02 01:00
04 13:00
07 01:00
09 13:00
12 01:00
14 13:00
17 01:00
19 13:00
22 01:00
24 13:00
Timestamp


Living room
lightIntensity
4000
3500
3000
2500
2000
1500
1000
500
0
06 19:00
06 21:00
06 23:00
07 01:00
07 03:00
07 05:00
07 07:00
07 09:00
07 11:00
07 13:00
07 15:00
07 17:00
07 19:00
07 21:00
07 23:00
08 01:00
08 03:00
08 05:00
08 07:00
08 09:00
08 11:00
08 13:00
08 15:00
08 17:00
08 19:00
08 21:00
08 23:00
09 01:00
09 03:00
09 05:00
09 07:00
09 09:00
09 11:00
09 13:00
09 15:00
09 17:00
09 19:00
Timestamp
Bedroom A
lightIntensity
Light Intensity
4000
3500
3000
2500
2000
1500
1000
500
0
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00
Timestamp
Bedroom B
lightIntensity
4000
3500
3000
2500
2000
1500
1000
500
0
06 18:00
06 20:00
06 22:00
07 00:00
07 02:00
07 04:00
07 06:00
07 08:00
07 10:00
07 12:00
07 14:00
07 16:00
07 18:00
07 20:00
07 22:00
08 00:00
08 02:00
08 04:00
08 06:00
08 08:00
08 10:00
08 12:00
08 14:00
08 16:00
08 18:00
08 20:00
08 22:00
09 00:00
09 02:00
09 04:00
09 06:00
09 08:00
09 10:00
09 12:00
09 14:00
09 16:00
09 18:00
09 20:00
Timestamp