João Anastácio da Rocha Almeida

Júlia Stutz Souza Carneiro de Campos

**Introduction:**

For our smart hardware project, our main goal in the winter is to use a base temperature choose by the house owner, for example 15 °C, in each room and then, predict by Markov Chain where and when the person is going to be during the day and in that way, the room temperature is going to be sensed by a TMP126 sensor and raised by an actuator (smart valve to turn on the heather) to put the temperature in a comfortable value, around 22 °C. We are also tracking the person’s position using Bluetooth Low Energy connected to a smart band and when someone enters the room, the lights will turn on depending on the LDR sensor to measure light level. That way, we decided to create a PCB (printed circuit board) with an ESP microcontroller, and our aim when talking about the user, is to decrease the gas and electricity consumption while being comfortable.

**Project Bases:**

The Markov chain is a mathematical model used to predict a next state based only on the current state, it is built upon the probability observed in a set of previous states used as training. In our research, we managed to find Markov chain implemented in use cases in microcontrollers, so it’s possible to used it in our routine prediction.

Each room is going to have a PCB (printed circuit board) with an ESP32-WROOM-32, 3 LDR sensors, 1 TMP126 sensor and 1 Low Power 2.4GHz Transceiver for ZigBee for the connections between all the ESPs in the house and a main server having the Markov Chain AI. We’ll be using 3 batteries to supply each PCB.

The ESP is perfect for this application, because it has a Bluetooth Low Energy, it is easy to configure and program, consequently, is easier to provide assistance and maintenance. It would be possible to add more features in the future, like a hydraulic system or safety project. During the design, we chose the ESP32-WROOM-32, because of the easiness, there is a lot of material for it, schematics, example, debug board, but in the real development it is not recommended since it’s.

TMP126 Low-Power is a temperature sensor, it has a configurable precision that defines the maximum and minimum range, we chose the excellent precision of -+0.4°C, which was the key factor, is very cheap, low power, is a different solution in the market and already has the SPI interface. Also, the LDR photoresistor is the most known way of sense the presence of light, is very easy to implement and is cheap, in conclusion, meets all needs.

For the transceiver communication between the microcontrollers, we are using the IC 2.4GHz Transceiver for ZigBee, and we chose the ZigBee/IEEE 802.15.4 protocol, because of the short distance reach, unlike LoRa that could have further interference, but still has a bigger range than Bluetooth, the delay is around 15ms-30ms which is low compared to Wi-Fi, is cheap, easy to configure and maintain compared to a Cellular IoT, and the low-power consumption, that usually works with 3.3V. Two AA batteries usually last 5 months and 2 years.

The installation is available and not that hard, after configuring the devices and the communication between them, the PCB is going to be added in the middle of the room, ideally attached to the ceiling. We chose this spot especially thinking of being far from heathers, the windows and the possibility of putting away from air conditioning. Since the project is about comfortable and, saving more money and energy, we thought in keep even more battery life by using sleep mode, so the price of energy spent is very low.

**Cost:**

The total cost of the PCB is 19.38 euros (€) per board to develop 1000 considering the manufacture and the components.

**Gas Consumption Calculation:**

We defined a house with an area of 100m2 and 2.5m of height, so the total volume is 250m3. If we consider a big room in this house having 30m2 (30 m2\*2.5m = 75 m3) the volume is 30% of the total.

1 person/house:

Considering that the person stays in the biggest room for most of the time, the table of consumption is:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Gas Consumption (m^3/h) | Heat load (KW/h) | Efficiency of gas boiler (%) | Calorific Value of Gas (KW/m^3) | Volume (m^3) | Heat loss | Delta T (°C) |
| 1,155990752 | 9,8837209 | 90 | 9,5 | 250 | 1 | 34 |
| 0,917992656 | 7,8488372 | 90 | 9,5 | 250 | 1 | 27 |

|  |  |  |  |
| --- | --- | --- | --- |
| Expected Average Temp (°C) | Day Average Temp (°C) | Gas Cons. Per day (m^3) | Solution: Gas Cons. Per day (m^3) |
| 22 | -12 | 27,74378 | 23,74541004 |
| 15 | -12 | 22,03182 |  |

30% of 27,74378 + 70% 22,03182 = 23,74541004

2 person/house staying most of the time in 2 rooms of 20m2 (2\*20m2 = 40m2) the total volume of these rooms is 40% of the total:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Gas Consumption (m^3/h) | Heat load (KW/h) | Efficiency of gas boiler (%) | Calorific Value of Gas (KW/m^3) | Volume (m^3) | Heat loss | Delta T (°C) |
| 1,155990752 | 9,8837209 | 90 | 9,5 | 250 | 1 | 34 |
| 0,917992656 | 7,8488372 | 90 | 9,5 | 250 | 1 | 27 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Delta T (°C) | Expected Average Temp (°C) | Day Average Temp (°C) | Gas Cons. Per day (m^3) | Solution: Gas Cons. Per day (m^3) |
| 34 | 22 | -12 | 27,74378 | 24,31660547 |
| 27 | 15 | -12 | 22,03182 |  |

40% of 27,74378 + 60% 22,03182 = 24,31660547

3 person/house staying most of the time in 3 rooms of 18m2 (3\*18m2 = 54m2) the total volume of these rooms is 54% of the total:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Gas Consumption (m^3/h) | Heat load (KW/h) | Efficiency of gas boiler (%) | Calorific Value of Gas (KW/m^3) | Volume (m^3) | Heat loss | Delta T (°C) |
| 1,155990752 | 9,8837209 | 90 | 9,5 | 250 | 1 | 34 |
| 0,917992656 | 7,8488372 | 90 | 9,5 | 250 | 1 | 27 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Delta T (°C) | Expected Average Temp (°C) | Day Average Temp (°C) | Gas Cons. Per day (m^3) | Solution: Gas Cons. Per day (m^3) |
| 34 | 22 | -12 | 27,74378 | 25,11627907 |
| 27 | 15 | -12 | 22,03182 |  |

54% of 27,74378 + 46% 22,03182 = 25,11627907

|  |
| --- |
| Before the Solution (€) |
| 24,65202622 |

|  |  |  |
| --- | --- | --- |
| Solution: Gas Cons. Per day (kWh) | Solution: Price avarege in Eu per day (€) | Percentage of total savings (%) |
| 269,8111791 | 21,09923421 | 14,41176471 |
| 276,3014824 | 21,60677592 | 12,35294118 |
| 285,387907 | 22,31733433 | 9,470588235 |

**Electricity Consumption:**

For the electric calculation, we considered that someone forgot at night a LED lamp lighted in a room and just saw on the next day at night, so the lamp was 20 hours on. If the room had an ESP with a Bluetooth connection and a light sensor, then the light would turn off without needing someone and would be only 8 hours on.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Consumption (kWh) | Wattage of the lamp (W) | Wattage of the lamp (kW) | Hours per Day (h) | Cost per kWh ($) | Total Cost ($) |
| 0,24 | 12 | 0,012 | 20 | 0,14 | 0,0336 |
| 0,096 | 12 | 0,012 | 8 | 0,14 | 0,01344 |

|  |  |
| --- | --- |
| Total Cost in a month ($) | Percentage of total savings (%) |
| 1,008 | 60 |
| 0,4032 |  |

Applying our hardware solution, even more of this kind of case will be solved and still have the comfort of not having to turn the light on and off.

**Bibliograph:**

How IoT Devices Operates and Communicates Itself: A Brief Explanation - EE Times Asia. <https://www.eetasia.com/how-iot-devices-operates-and-communicates-itself-a-brief-explanation/>.

Top wireless standards for IoT devices - IoT Times. <https://iot.eetimes.com/top-wireless-standards-for-iot-devices/#:~:text=Similar%20to%20Zigbee%2C%20LoRaWan%20is,focuses%20on%20wide%2Darea%20networks>.

ctrfantennas. Lora vs ZigBee - C&T RF Antennas Manufacturer. <https://ctrfantennasinc.com/lora-vs-zigbee/>.

“Xbee/Zigbee Setup with Arduino and NodeMCU”. Arduino Project Hub, <https://create.arduino.cc/projecthub/Neutrino-1/xbee-zigbee-setup-with-arduino-and-nodemcu-81f7fa>.

Interfacing SX1278 Ra-02 LORA Module with Arduino. <https://how2electronics.com/interfacing-sx1278-lora-module-with-arduino/>.

Gas consumption for heating a house 100 m2: formulas and calculation example. <https://engineer.decorexpro.com/en/otoplenie/project/rashod-gaza-na-otoplenie-doma-100-m2.html>.

Natural Gas Price Statistics. <https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Natural_gas_price_statistics>.

2022 Lighting Energy Cost Calculator. <https://www.inchcalculator.com/lighting-energy-cost-calculator/>.