Contribution report for project HAPPY-HOME

Development of a Context-Aware System for Happy-Home Applications

Shaikh Zaka Tabish Shaikh Zaka Tabish, s.shaikh-zaka-tabish@oth-aw.de[1]

[1]*OTH Amberg-Weiden, Masters in Artificial Intelligence For Industrial Applications"*
"

Report written on June 30, 2025

Abstract

The project HAPPY-HOME aims to simulate a pro-active system using tools like python and its libraries to make stress free home called "Happy Home" that can change the environment without direct user involvement. The main purpose behind the project is to develop smart stand-alone privacy oriented system that can adjust the home setting in a way that reduces stress on the user. The working is very simple and robust, the systems gathers user data like external temperature, light, noise and location and movement and updates sound, temperature and light intensity in the house that suites user needs.
this report explains the simulation of the stress-free proactive Happy home system. My personal contribution to the project was to write code and develop the logic of the simulation. For that I used several libraries in python like tkinter to make GUI, Simpy to create simulation environemnt and Matplotlib to create graphs. I also integrated Pandas to perform read operation from the mappings csv file that contains all essential logically arranged possible combinations for every situation of the environment in the simulation. The system is completely stand-alone that means the system is not connected to internet for privacy and cyber security reasons.

Keywords: *CSV, stand-alone, simulation,GUI*

1. Material

We implemented a waterfall model for the project development because it was straigh forward and linear in nature. As the projected did not have any user feedback system we did not selected any cyclic software development model like agile or scrum. We used figma and plantuml for diagram creation. Also we use google docs for project management and Git and Github for creating distributed version control system for the project. Apart from that we extensively used IEEE explore website to do deep research and get inspiration for project implementation.

2. Method

The project was aimed at reducing the stress in homes using proactive systems, creating a happy, stress-less environment.

To solve the problem we searched research papers from the year 2022 to 2025 on IEEE Explore. Although there were many research papers published around the topic but one of them by V. K. Patil, O. Hadawale, V. R. Pawar and M. Gijre, (see[1]) "Emotion Linked AIoT Based Cognitive Home Automation System with Senso-visual Method," became our inspiration. Their project aims to take control of all appliance of a household and automate them using the input from the sensor based on the mood using AI. The project was good but not proactive.We did further research on "How to comprehend state of human emotions through parameters such as the movement of the person in the house. So I found another research work "Understanding occupants' behaviour, engagement, emotion, and comfort indoors with heterogeneous sensors and wearables" by Nan Gao, Max Marschall, Jane Burry, Simon Watkins, Flora D. Salim (see[2]) that was posted on arxiv.org suggested how location can be a key to recognize state of human mind.

After gathering the requirements we started designing. First step of designing was to select input and output parameters in a household so we select 4 input parameters(External temperature,External Noise levels, External light levels, Persons Location in the house) and 3 Output parameters(Music, Lighting in house, Ambient temperature). Next step of designing was to map the data. We used CSV for mapping as it was the best suited for read-only purpose as compared to traditional database systems like MongoDB and SQL that are optimized or other complex operations. After mapping the data in csv, I wrote a program in python that simulated a home with 3 rooms namely Bedroom, Workout area and Lounge using Tkinter library in a GUI. I used random function to generate random input simulating user movement and random nature or climate. The program first scanned the input generated from random function then utilized the CSV performing linear search on 81 parameters and then simulated it on the GUI interface.

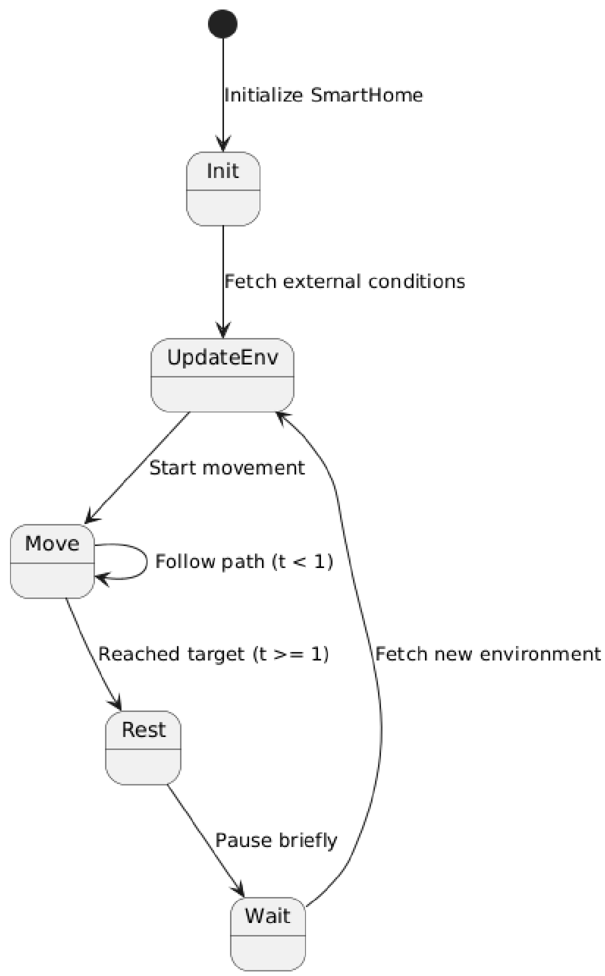

Figure 1. Simulation State Diagram

This state diagram shows the behavioral lifecycle of the smart home system. The process begins with an initialization phase "init", where the user's starting location and a movement target are set. The system then enters the environment update state UpdateEnv, getting internal parameters (temperature, lighting, music) by querying a dataset based on external conditions. Once configured, the system transitions to the movement state Move, where the user progresses toward the target room along a generated path. Upon reaching the destination, it enters a resting phase Rest, simulating a pause, followed by a brief wait period. The cycle then repeats, continuously adapting to environmental inputs and dynamically adjusting the user's behavior within the smart environment.

3. Database concept

The CSV had 4 input and 3 output parameters. All input parameters can hold either of 3 values except the location variable that can hold 5 different values. So the total number of possible variations for input was calculated to by $3^3 * 5 = 135$ (3 Input parameters with 3 distinct values + 1 Input with 5 possible values) then we accordingly added the output parameters for 135 conditions. In every line first 4 parameters are Input and remaining 3 are output separated by commas.

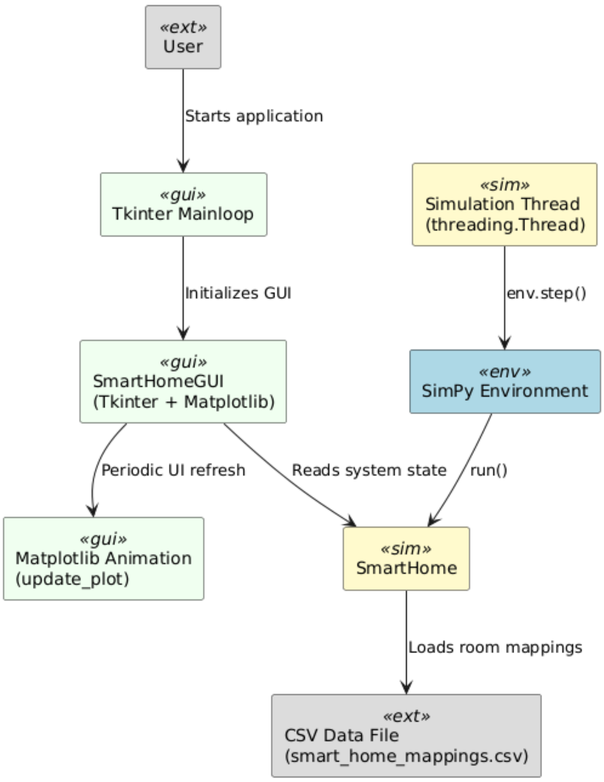

Figure 2. System Architecture Diagram

The system architecture is distributed between three different parts that is the GUI, Simulation and the Data management. I have also implemented multi-threading in python to allow simultanious UI operation like play/pause simulation without hindering the state of the simulation

A sample equation below shows the total number of possible inputs given three parameters with three different values and one location parameter with five values.

$$\text{Total Variations} = 3^n \times 5 = 3^3 \times 5 = 27 \times 5 = 135 \qquad (1)$$

So in conclusion there are total 135 lines in the mappings csv file.

4. Implementation aspects

4.1. Aspect number 1: Simulation Engine and Environmental Mapping:

The simulation is completly build using python programming langauge and it's libraries to make simple and practical. I used SimPy discrete event simulation framework to model the movement and behavior of a user within a smart home environment. Each room is defined with a fixed position, and the user navigates between rooms via randomized Bezier paths. The environmental internal state like temperature, lighting, and music level is mapped using a preprocessed CSV file that contains combinations of external conditions and their corresponding internal responses. These mappings are updated only when the user enters a new room, ensuring efficient data handling and minimal computational overhead.

4.2. Aspect number 2: GUI Visualization and Performance Optimization:

The GUI is developed using Tkinter and Matplotlib for real-time visualization of the smart home. It features a floor plan containing five rooms, dynamic path with trails, and line graphs representing temperature, lighting, and music levels. To maintain performance, the visualization only displays the latest variation instead of full historical data, and the trail length is limited to 100 points. The music level graph also translates numeric values into genre labels for better interpretability. Overall, the interface is designed to be lightweight.

4.3. Code Review

This code block shown below is responsible for updating the internal smart home environment based on randomly selected external conditions such as temperature, lighting, and noise. It uses a CSV file to find the corresponding internal settings (temperature, lighting level, and music type) for the current room and applies them.

This demonstrates how a smart home can automatically and proactively adapt to its surroundings using predefined mappings.

```
def _update_env(self):
    self.ext_temp = random.choice(['low', 'medium', 'high'])
    self.ext_light = random.choice(['low', 'medium', 'high'])
    self.ext_noise = random.choice(['low', 'medium', 'high'])

    row = df.query(
        f"Room == '{self.loc}' and "
        f"External_Temperature == '{self.ext_temp}' and "
        f"External_Lighting == '{self.ext_light}' and "
        f"External_Noise == '{self.ext_noise}'"
    ).iloc[0]

    self.temp, self.light, self.music = row['Internal_Temperature'], row['Internal_Lighting'], row['Internal_Music']
```

Code 1. Simulation code (source: `file.ipynb`)

In this code, the function that updates the environment parameters such as external temperature, lighting, user location, and noise using randomly generated values is given. It then creates a query using the query function to retrieve the row in the CSV file that matches the current conditions and extracts the corresponding output.

5. Testing

To make sure the Smart Home simulation works correctly, testing was done in two parts, that is first GUI was tested to check for inconsistencies and arrangements in the UI components and the second part was the logic that handled data and simulation to find any anomalies we ran simulation for several hours and found no mistakes in the CSV or the code. We also reduced the refresh rate of all graphs to make the program less resource intense. Apart from that some individual components like input parameters in the CSV were logically tested for research-oriented mappings. Also verifying that the simulated user followed Bézier curves between rooms with proper rest states and pauses was completed in the end to ensure animation and play/pause operation are running on different threads.

5.1. Testing Results:

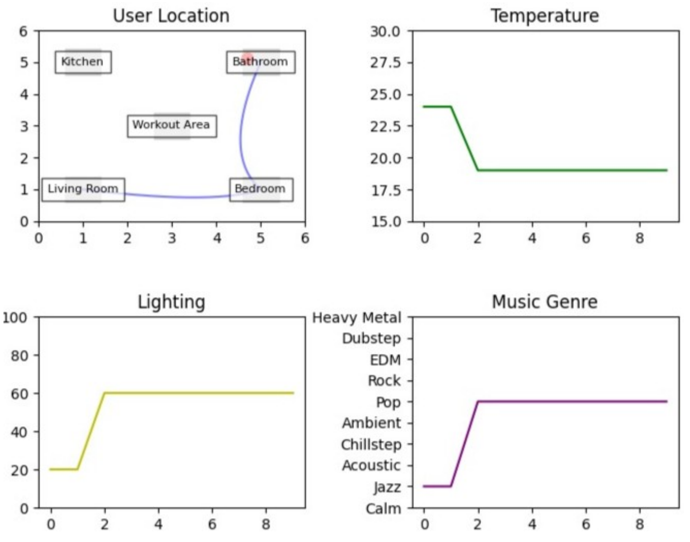

Figure 3. Result of simulation

The first graphs from the above figure shows the motion of the user in the house that is randomly generated using Bézier curves algorithms simulating random nature of the person the trail show path coverd by the person. In the second graph the temperature is of the house set by the system according to the the mappings csv file is shown. It shows current variation in temperature after user changes its location. The third graph show the lighting in the house set by the system according the to external condition and user movements. The fourth graph shows 10 different music genre set from calm to heavy music that varies with the location of the person and external conditions.

6. Appendix

The following files are provided as part of this submission:

1. Jupyter Notebook file
2. Mappings CSV file
3. Report PDF file

References

[1] Y. Li, Z. Wang, W. Zhang, *et al.*, "Smart home for elderly care: Development and evaluation of a context-aware system", in *2021 IEEE International Conference on Consumer Electronics (ICCE)*, IEEE, 2021, pp. 1–6. DOI: 10.1109/ICCE50685.2021.9686498. [Online]. Available: https://ieeexplore.ieee.org/document/9686498.

[2] N. Gao, M. Marschall, J. Burry, S. Watkins, and F. D. Salim, "Understanding occupants' behaviour, engagement, emotion, and comfort indoors with heterogeneous sensors and wearables", *arXiv preprint arXiv:2105.06637*, 2022. DOI: 10.48550/arXiv.2105.06637. [Online]. Available: https://arxiv.org/abs/2105.06637.