University of Trento
Department of Computer Science
Autonomous Software Agents

UNIVERSITÀ DI TRENTO

Assignment 1

Marcel Pascal Stolin

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1 Introduction

Physical and psychological health does significantly benefit from good sleep. What mostly affects sleep, is light. It controls the body's internal clock when to sleep, regulates the circadian rhythm, and additionally influences the production of melatonin, a sleep-promoting hormone. However, in modern times, it is possible to provide 24/7 artificial illumination to brighten homes. When people are exposed to artificial light most of the day, especially in the evening, it negatively affects the quality of sleep [1].
This project's goal is to provide a multi-agent solution, that can control the lights in the house autonomously in a way, that will increase the quality of sleep of the residents and promote concentrating tasks during the day.
The sources of light in a standard house are light bulbs, and light that comes from the outside through the windows (sunlight and moonlight).
The multi-agent is responsible for regulating the lightning in a room, by controlling the light bulbs of a room and eliminating the influence of the outside light. When transitioning from day to evening, warm color temperatures and low illuminance help the human to relax. At night, the bedroom needs to be as dark as possible to promote the best possible quality of sleep, therefore all sources of light need to be shut down. Additionally, the electrically powered lights in a room are supposed to be off, if no resident is present.

2 Metrics

Light is measured in lux, lumen, and wavelength and all three influence the quality of sleep. In this project, we are not interested in the wavelength metric. Lumen is a measurement of brightness, and lux is a metric, that measures the impact on the light to the surrounding space (illuminance). As an example, a light bulb has a specific value of lumen, but the brightness of this bulb in the room is lux.
In addition, a color is associated with a certain range of temperature, which is measured using the Kelvin scale.

2.1 Illuminance

A clear day provides an illuminance of 10,000 lux outdoors. In a room, this illuminance can break down to 25 - 50 lux. Therefore, artificial indoor lightning is still required during the day. What level of lux to provide during the day, depends on the tasks done by the residents in that room. Overall, an illuminance level of 300 to 500 lux during the day is reasonable, if no task, that requires concentration, is performed in that room. For basic tasks like reading, a value of 500 - 800 lux is required. Tasks that require high concentration require a higher illuminance of 800 - 1,700 lux.
When it comes to the evening and the residents are transitioning from evening to bedtime, an overall illuminance of 100 - 200 lux should be present.

When the residents start to sleep, all lightning devices are supposed to be off, and the windows need to be closed so that no outside light can come in.
It is important to mention, that the lux level differs between adults and children. However, no children are involved, therefore the values are based on adults [2, 3].

2.2 Color Temperature

The following common color temperatures [4]:

- Candlelight (lower than 2000K)
- Incandescent light (2000K - 3000K)
- Neutral light (3000K - 3500K)
- Cool white light (3600K - 4500K)
- Bright white light (4600K - 6500K)
- Clear sunlight (greater than 6500K)

In the morning and evening, a yellow color in the range of 2000K - 2700K (Incandescent light) should be present. Before going to bed, an ideal temperature is 1900k (candlelight.)
During the day, to increase productivity, a cool white in the range of 4000K - 6000k (Cool white light or bright white light) should be set [5].

3 Devices

This section provides details of the devices used in this scenario.

3.1 Lights

Lights provide artificial illuminations to the ambient light of the room. Each single light bulb is a LED bulb and has a rated power consumption of 8.5W when powered on, and consumes a minimum of 0.5W on standby. It provides a range of 16 million different colors and the color temperature can be adjusted between 1700K-6500K. Additionally, it provides 800 lumens. The light bulb can only be fully turned off when disconnecting from the power source.
The reference model of a light bulb for this project is the *Yeelight Smart LED Light Bulb 1S*[1], as shown in Figure 1.

3.1.1 States

- `ON` — The light bulb is connected to electricity and connected to the agent.
- `OFF` — The light bulb is not connected to electricity.
- `STANDBY` — The light bulb is connected to electricity but does not provide light.
- `DISCONNECTED` — The light bulb is connected to a power source but not connected to the agent.

[1] `https://us.yeelight.com/shop/yeelight-smart-led-light-bulb-1s-color/` (Accessed: 07-04-2022)

Figure 1: Yeelight Smart LED Light Bulb 1S (Color)

3.1.2 Actions

- `TURN_ON` — Turn the device on, and connect to the agent.
- `TURN_OFF` — Turn the light bulb into a `STANDBY` state.
- `SET_BRIGHTNESS` — Set the brightness in lumens of the light bulb.
- `SET_TEMP` — Set the temperature in kelvin of the light bulb.

3.2 Shutters

Shutters are used to preventing sunlight from going into the rooms. They are attached to the outside of each window and can be closed using a built-in motor. A shutter can be closed by rolling the shutter down from the top of the window to the bottom.
Figure 2 shows an example of an exterior rolling shutter, that is used in the scenario in this project.

3.2.1 States

- `CONNECTED` — The shutter is powered on and connected to the agent.
- `DISCONNECTED` — The shutter is powered on, but not connected to the agent.
- `OFF` — The shutter is not connected to a power source.

3.2.2 Actions

- `TURN_DOWN` — Turn the shutter down.
- `TURN_UP` — Turn the shutter up.

Figure 2: A rolling exterior shutter on the outside of a window

Figure 3: Philips Hue Motion Sensor, suitable as a light and motion sensor

3.3 Motion Sensor

The motion sensor triggers when a person enters a room. Additionally, the motion sensor is able to detect if no person is present in a room.
A reference model for a motion sensor is the *Philips Hue Motion Sensor*[2], as shown in Figure 3. It is important to mention, that this device includes a motion and light sensor (for light sensor see section Section 3.4). Using a 2in1 device is a good decision to save money and space and to reduce the setup complexity. However, in this project, both sensors are threatened as a single device.

3.3.1 States

- `ON` — The motion sensor is powered on and connected to the agent.
- `OFF` — The motion sensor is not connected to a power source.
- `DISCONNECTED` — The motion sensor is powered on, but not connected to the agent.

3.3.2 Actions

- `NOTIFY` — Notifies the agent that a person has entered/left the room.

3.4 Light Sensor

The light sensor is a device, that observes and measures the ambient light of a room in lux. When the illuminance of a room change, it notifies the corresponding light agent of that room. Reference models can either be the *Philips Hue Motion Sensor*(see Section 3.3 for details about this device) or the *Xiaomi Mi Light Detection Sensor Zigbee 3.0*[3].

3.4.1 States

- `ON` — The light sensor is powered on and connected to the agent.
- `OFF` — The light sensor is not connected to a power source.
- `DISCONNECTED` — The light sensor is powered on, but not connected to the agent.

3.4.2 Actions

- `ILLUMINANCE_CHANGED` — Notify the specific agent, that the illuminance of the room has changed.

3.5 Room Controller

The room controller is a device that provides the residents to control the profile of a room. Overall, the residents can choose between three different profiles:

- No-concentration — Lightning between 300 - 500 lux is sufficient.
- Low-concentration — Lightning between 500 - 800 lux is sufficient.
- High-concentration — Lightning between 800 - 1,700 lux is sufficient.

By default, the no-concentration profile is active. In addition to the physical device, which is located in each room, a resident can also change the profile with a smartphone.

[2] `https://www.philips-hue.com/en-us/p/hue-motion-sensor/046677570972` (Accessed: 07-04-2022)

[3] `https://xiaomi-mi.com/sockets-and-sensors/xiaomi-mi-light-detection-sensor-zigbee-30/` (Accessed: 07-04-2022)

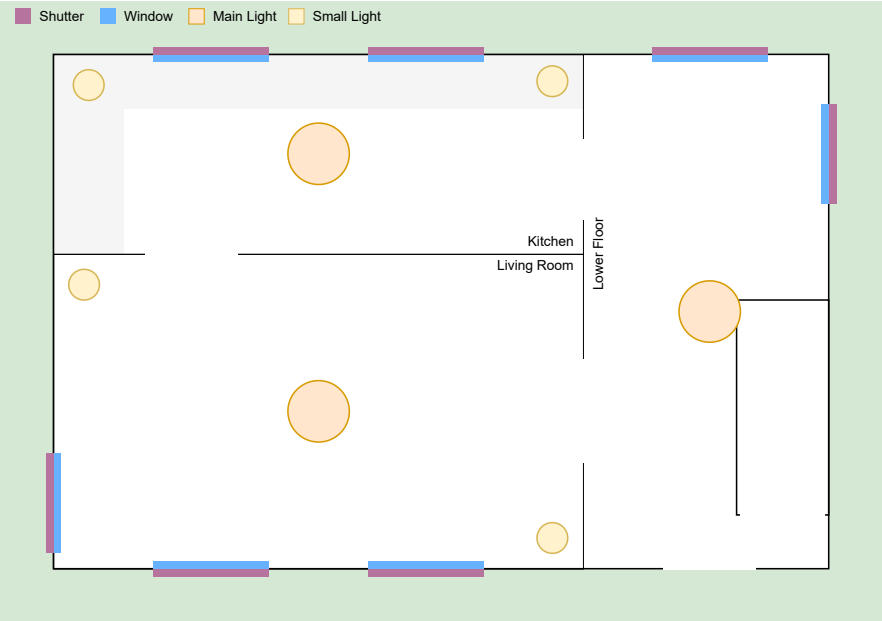

Figure 4: First-floor blueprint

3.5.1 States

- `ON` — The room controller is powered on and connected to the agent.
- `OFF` — The room controller is not connected to a power source.
- `DISCONNECTED` — The room controller is powered on, but not connected to the agent.

3.5.2 Actions

- `CHANGE_PROFILE` — Notify the specific agent that a resident changed the profile for the room.

4 House Description and Blueprint

This section describes the house of the scenario. The house has two floors, which are described in this section in detail. Each floor section provides a blueprint of the floor and a detailed description of each room.
It is important to mention, that all rooms do include a motion sensor (Section 3.3), and a light sensor (Section 3.4) to observe the movement and illuminance in the room.

4.1 First Floor

Figure 4 illustrates the blueprint of the first floor. Additionally, the blueprint also shows the location of light devices in the room. It can be entered through the main entrance in the south and has 3 rooms, the lower floor, the living room, and the kitchen.

4.1.1 Lower Floor

The lower floor on the first floor includes the main entrance to the house in the south. Two additional doors in the west of the room, lead to the living room, or the kitchen. Furthermore, the stairs to the second floor are located in this room. Light is provided by a single main

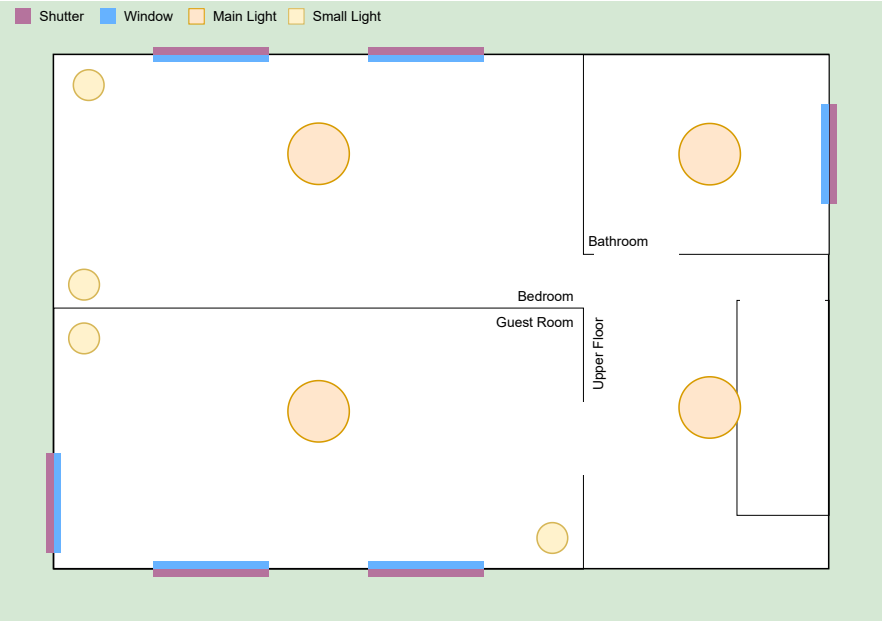

Figure 5: Second-floor blueprint

light on the ceiling in the middle of the room. In addition, two windows, in the north, and one in the northeast are located in the room. The only usage of this room is to get from one room to another or to get to the second floor. Therefore, no tasks requiring concentration are performed here.

4.1.2 Living Room

Doors include the main entrance door in the east and the door to the kitchen in the north. Windows include two in the south and one in the west. The living room has a main light in the middle of the room on the ceiling. Additional lights include two smaller lights in the north-west and southeast of the room. The living room is used by residents mostly in the morning and evening, to eat breakfast or dinner, as well as to watch TV in the evening. Therefore, only low concentration tasks, like reading or watching TV, are performed in this room.

4.1.3 Kitchen

The kitchen includes two doors, one in the south and one in the east. The door in the south leads to the living room and the door in the east leads to the lower floor. It has a main light on the ceiling, as well as two lights in the work area of the kitchen, one in the northwest, and one in the northeast. There are two windows in the north above the work area. The kitchen is used by residents to cook and prepare other foods/beverages. These tasks require high concentration.

4.2 Second Floor

The second floor is illustrated in Figure 5. It is reachable through the stairs from the first floor. It includes the bedroom, a guest room, the bathroom, and the upper floor.

4.2.1 Upper Floor

The upper floor is the entrance to the second floor of the house. It includes the stairs from the first floor. Light is provided by a single main light on the ceiling. Three doors are included in this room. One door in the north to the bathroom, and two doors in the west, one to the guest room, and one to the bedroom. No additional windows are included in this room. The upper floor is used like the lower floor. Therefore, concentration is not required in this room.

4.2.2 Bedroom

This room includes one door in the east to the upper floor. Two windows are located in the north of the room. The main light is located in the middle of the room on the ceiling, and two additional small lights are located in the northwest and southwest. The bedroom is used for sleeping, in the morning and in evening. Sometimes, the residents like to read to relax during the day or in the evening, which is a low-concentration task.

4.2.3 Guestroom

The guest room includes one door to the floor in the east. Windows include two in the south and one in the west. It has one main light on the ceiling, two small lights in the northwest and one in the southeast. In addition, it includes a desk with a computer. The room is mostly used either for guest sleepovers or for working. Working is a high-concentration task.

4.2.4 Bathroom

The bathroom has a single door in the south of the room which leads to the upper floor. A single main light on the ceiling is provided in the middle of the room. One window is located in the east. Residents use the bathroom for their hygiene. This requires either high- or low-concentration light.

5 Agents

This section describes the agents in the multi-agent scenario, that is responsible to provide the autonomous behavior.

5.1 House Agent

The house agent is responsible to assist the device-specific agents of the multi-agent environment. It connects to the motion sensors (Section 3.3) of each room and can detect the resident's movements. Additionally, the house agent is aware of the geographical location of the house, can differentiate between different daytimes (morning, afternoon, evening, bedtime), and knows about the time of sunrise and sunset. According to the daytime, the house agents open or close the window shutters.
The following are common procedures and events, the house is responsible for:

- Observe the movement of the residents in the house.
- When a resident enters/leaves a specific room, notify the corresponding light agent of the room.
- Notify the light agents, when the daytime has changed.
- Open the window shutter during sunrise, and close the window shutter during sunset.

5.2 Light Agent

A light agent is a device-specific agent and controls the lightning devices (light bulbs, see Section 3.1) of a specific room. It is assisted by the house agent, and responsible to adjust the ambient light of a room in accordance with the daytime, if a resident is present. Overall, it is responsible to create an environment in a room, where the residents can either relax before bedtime or do concentrating tasks. To get information about the illuminance of a room, it can communicate with the light sensor of its room.
The following are the specific procedures and events, the light agent is responsible for:

- Turn light devices on/off when a resident enters/leaves the room.
- Decide which devices are not needed, to fulfill the desired state (e.g.: Prefer main light over small lights during the day).
- Adjust the illuminance and color temperature of a room (see Section 2), according to the daytime.

6 People

The residents of the house are the couple Sandra and Bob. Both can be in one room at a time, in two different rooms, or out of the home. Sandra works during the workdays from 08:00 to 17:00 Monday - Friday. Bob works from home while being self-employed, he has no specific work time. However, he does not work after 18:00. On the weekend, they both are either at home or outside. Usually, on all days, in the evening they like to watch TV from 19:00 to 21:00 and go to sleep at 22:00. Between 21:00 and 22:00, both residents like to read in the bed.

References

[1] A. Eric Suni, "Light and sleep," accessed: 12-04-2022. [Online]. Available: https://www.sleepfoundation.org/bedroom-environment/light-and-sleep

[2] SleepScore Labs, "How light and temperature mix with sleep," accessed: 12-04-2022. [Online]. Available: https://www.sleepscore.com/blog/light-temperature-and-a-good-nights-sleep/

[3] Chris Adams, "Ergonomic lighting levels by room for residential spaces," accessed: 12-04-2022. [Online]. Available: https://www.thoughtco.com/lighting-levels-by-room-1206643

[4] Mario Esposito, "Using color temperature for better sleep," accessed: 12-04-2022. [Online]. Available: https://www.goodnights.rest/the-science-of-sleep/color-temperature-for-better-sleep/

[5] "What is the best color temperature?" accessed: 12-04-2022. [Online]. Available: https://iristech.co/what-is-the-best-color-temperature/