University of Trento
Department of Computer Science
Autonomous Software Agents

UNIVERSITÀ DI TRENTO

Assignment 3 — Final Report

Marcel Pascal Stolin
marcelpascal.stolin@studenti.unitn.it

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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 project's multi-agent environment is responsible to regulate the illuminance of all rooms of the house to provide better sleep. This is done by controlling the light bulbs of a room to adjust the artificial light and controlling the shutters of a room to adjust 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 of the light on 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. A possible level of adjustment is the following:

- 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.

In the evening, the residents are transitioning to bedtime, with 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 (moonlight) 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 are 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 and sensors used in this project.

3.1 Light Bulbs

Light bulbs 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.

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

The reference model of a light bulb for this project is the *Yeelight Smart LED Light Bulb 1S*[1]. As described in Table 1, a light bulb has a power state that can be on or off, a brightness, and a temperature. These states can be changed using the actions described in Table 2.

State	Possible Values	Description
`deviceState`	`ON`, `OFF`	The power state of the device
`brightness`	*Numerical Value*	The brightness value of the light
`temperature`	*Numerical Value*	The temperature value of the light

Table 1: Light bulb device states

Action	Argument	Effect
`turnOn`		Powers the device on (set `deviceState` to `On`)
`turnOff`		Powers the device off (set `deviceState` to `Off`)
`setBrightness`	*Numerical Value*	Sets the brightness state to the given numerical value
`setTemperature`	*Numerical Value*	Sets the temperature state to the given numerical value

Table 2: Light bulb device actions

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

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: An exterior shutter on the outside of a window

Figure 2 provides an example of an exterior rolling shutter, that is used in the scenario in this project. The example also shows the state of a shutter that is half closed.
The possible states of a shutter are described in Table 3. In this scenario, a shutter can be opened completely, opened half, or closed completely. The states can be adjusted, through the actions stated in Table 4.

State	Possible Values	Description
`deviceState`	`ON`, `OFF`	The power state of the device
`state`	`OPEN`, `OPEN_HALF`, `CLOSED`	Open level

Table 3: Shutter device states

Action	Argument	Effect
turnOn		Powers the device on
turnOff		Powers the device off
open		Opens the shutter completely
openHalf		Opens the shutter half
close		Closes the shutter completely

Table 4: Shutter device actions

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. Using a

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

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

2in1 device is a good decision to save money and space and to reduce the setup complexity. However, in this project, a light sensor is not included.
The possible states of a motion sensor are described in Table 5. The `isOccupied` state presents if one or more persons are present in the room or not. To interact with this device, an agent might observe the `isOccupied` state and take actions based on that. Furthermore, actions are described in Table 6.

State	Possible Values	Description
`deviceState`	`ON`, `OFF`	The power state of the device
`isOccupied`	`TRUE`, `FALSE`	Represents if a room is occupied or not

Table 5: Motion sensor device states

Action	Argument	Effect
`turnOn`		Powers the device on
`turnOff`		Powers the device off

Table 6: Motion sensor device actions

3.4 Outdoor Light Sensor

An outdoor light sensor is responsible to measure the outdoor illuminance. Its states are described in Table 7. The `illuminance` state stores the measured outdoor illuminance. An agent will observe the `illumance` state and react to changes by performing actions based on it. Further actions are described in Table 8.

State	Possible Values	Description
`deviceState`	`ON`, `OFF`	The power state of the device
`illuminance`	*Numerical Value*	The measured outdoor illuminance value

Table 7: Outdoor light sensor states

Action	Argument	Effect
`turnOn`		Powers the device on
`turnOff`		Powers the device off

Table 8: Outdoor light sensor device actions

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) to observe the movement in the room. The house includes a single outdoor illuminance sensor (see Section 3.4).

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.

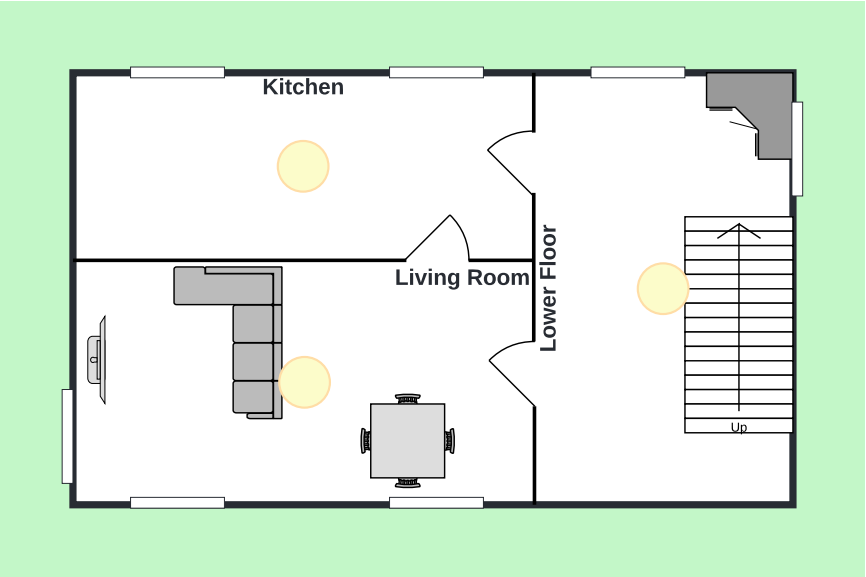

Figure 4: First-floor blueprint

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 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. 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 to provide illuminance. 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.

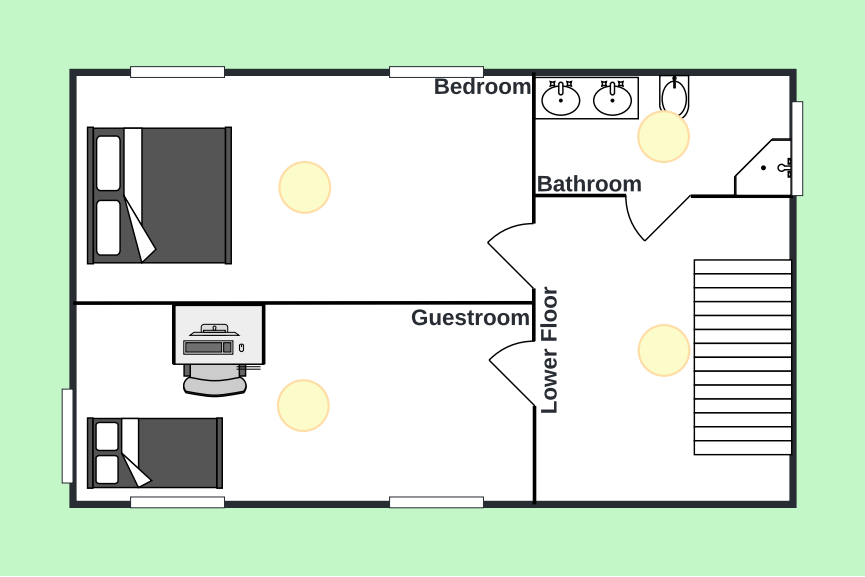

Figure 5: Second-floor blueprint

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. The bedroom is used for sleeping, in the morning and the 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. 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 People

The people who live in the house are Sandra and Bob. They wake up at 07:00 in the morning and after that, wash and have breakfast together. Then, they have to work from 08:00. Sandra has to leave the house and drive to the office, Bob prefers to work from home. They both work until 18:00 and have dinner together after that. In the evening, they like to watch TV until 22:00. Lastly, they read in bed until 23:00 when they go to sleep.

6 Agents

In the project multi-agent environment, three different types of agents exist; the House-Agent, Light-Agent, and Shutter-Agent. This section explains the details and purpose of each.

6.1 House-Agent

The House-Agent is responsible to assist the device-specific agents of the multi-agent environment. Only a single House-Agent exists in the environment. It observes the Motion Sensor states (see Section 3.3) of each room and the Outdoor Light Sensor (see Section 3.4) to decide further actions, by coordinating the device-specific agents. The House-Agent does not perform any PDDL intentions, which is further explained in Section 7.

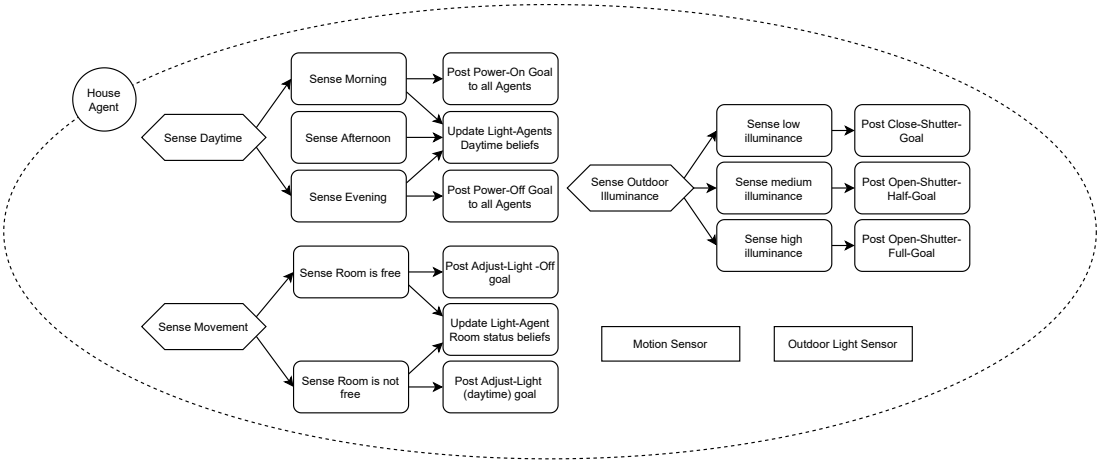

Figure 6: House-Agent actor model

Figure 6 illustrates the House-Agent's actor model. The House-Agent has three tasks; sense the daytime, sense the people's movement, and sense the outdoor illuminance. Whenever, the agents senses a change of the daytime, it is supposed to update the corresponding Light-Agent's (see Section 6.2) beliefs and post a power-on or power-off goal to all agents. When a person moves around, the House-Agent posts a goal to adjust the room lights accordingly. Additionally, it updates the Light-Agent's beliefs according to the occupation status of the room. If the outdoor illuminance has changed, the House-Agent posts a goal to all Shutter-Agents (see Section 6.3) to adjust the shutters accordingly.

6.2 Light-Agent

A single Light-Agent is associated with each room. It is a device-specific agent and controls the lightning devices (Light bulbs Section 3.1) of its room. It is assisted by the House-Agent (as explained previously in Section 6.1), and is responsible to adjust the ambient light of a room in accordance with the daytime, and 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. The value on how to adjust the brightness and temperature is defined in Section 2.1 and Section 2.2.

The Light-Agent's actor model is illustrated in Figure 7. It is supposed to power lights on and off, as well as to adjust the light off, which means that the light's brightness and temperature is set to 0. In addition, a Light-Agent has to adjust the light's brightness and temperature according to the current daytime (see Section 2.2 for the desired values).

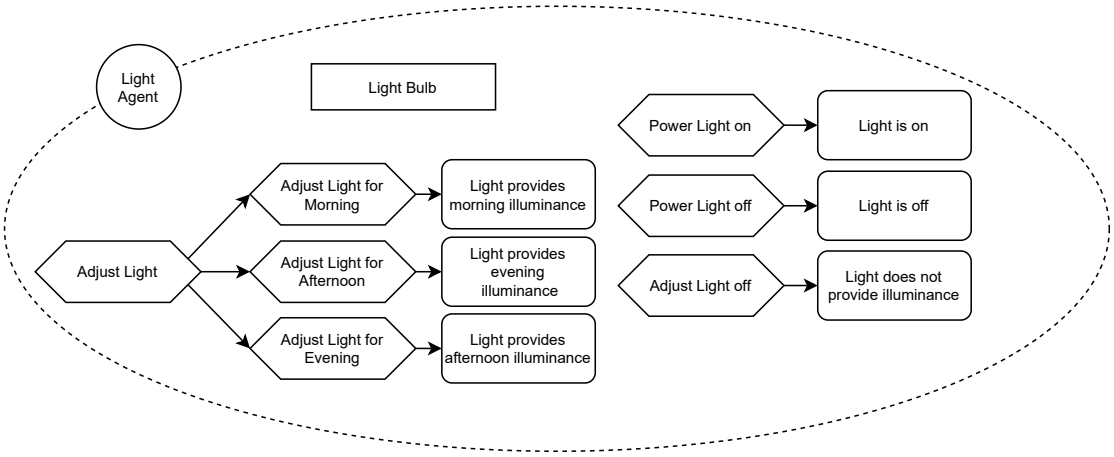

Figure 7: Light-Agent actor model

6.3 Shutter-Agent

A Shutter-Agent is another device-specific agent associated with each room. It guarantees to properly open or close the shutters (see Section 3.2) of its room according to the outdoor illuminance, to prevent ambient light going out during low outdoor illuminance, and to promote outdoor light coming in during medium and high outdoor illuminance.

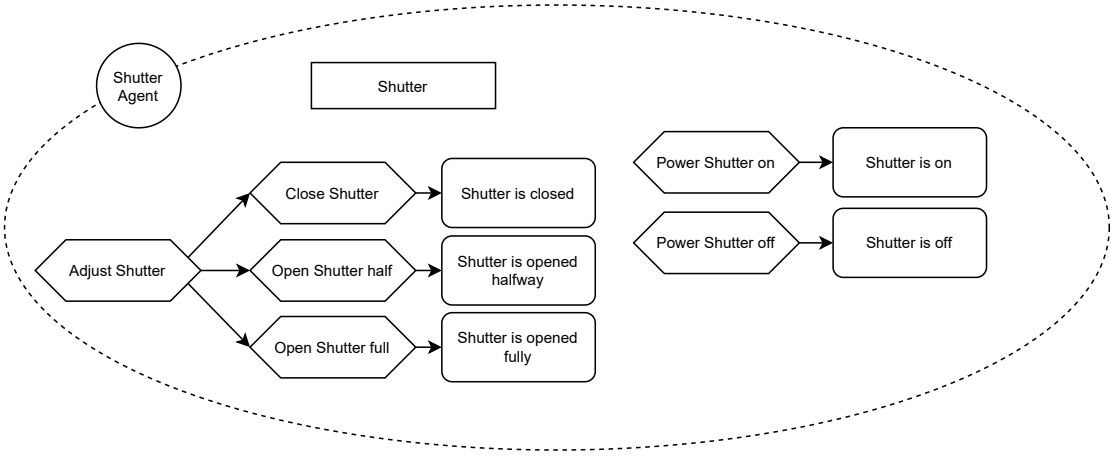

Figure 8: Shutter-Agent actor model

In Figure 8, the Shutter-Agent actor model is illustrated. As a device-specific agent, it is responsible to power on and power of its devices. Furthermore, it adjusts the shutters of its room according to the outdoor illuminance, as described previously.

7 Implementation

This section describes the implementation details. Section 7.1 explains how the agents interact with the world through sensor devices, Section 7.2 explains how agents interact and coordinate between each other in the multi-agent environment, and Section 7.3 explains how the agents affect the world through their actions.

7.1 Sensors and Agent Perception

The House-Agent is the only agent that interacts with the motion sensor (see Section 3.3), and outdoor light sensor (see Section 3.4). It observes it states and instructs the corresponding agent to take further actions if needed (explained in more detail in Section 7.2). The three sensor intentions are *SenseMovementIntention*, *SenseIlluminanceIntention*, and *SenseDaytimeIntention*.

7.1.1 SenseMovementIntention

The *SenseMovementIntention* is used to sense any movement between the rooms. If a resident enters or leaves a room, the House-Agent instructs the Light-Agent of the room to adjust the light accordingly.

7.1.2 SenseIlluminanceIntention

Using the *SenseIlluminanceIntention*, the House-Agent percepts any changes in the outdoor illuminance. Then, it instructs all Shutter-Agents on how to take further actions.

7.1.3 SenseDaytimeIntention

The House-Agent maintains the *SenseDaytimeIntention* to observe any changes in the global clock. Whenever the current hour changes, it assists the Light-Agents to take further actions.

7.2 Agents Interaction and Coordination

The Light-Agents and Shutter-Agents work independently from each other because both have different use-cases and control different devices as explained in Section 6. As mentioned in Section 7.1, the House-Agent interacts with the world by observing the states of the sensor devices. If a state has changed, it will take further actions by instructing either a Light-Agent or a Shutter-Agent. It instructs both agents through posting new goals and updating their beliefs.

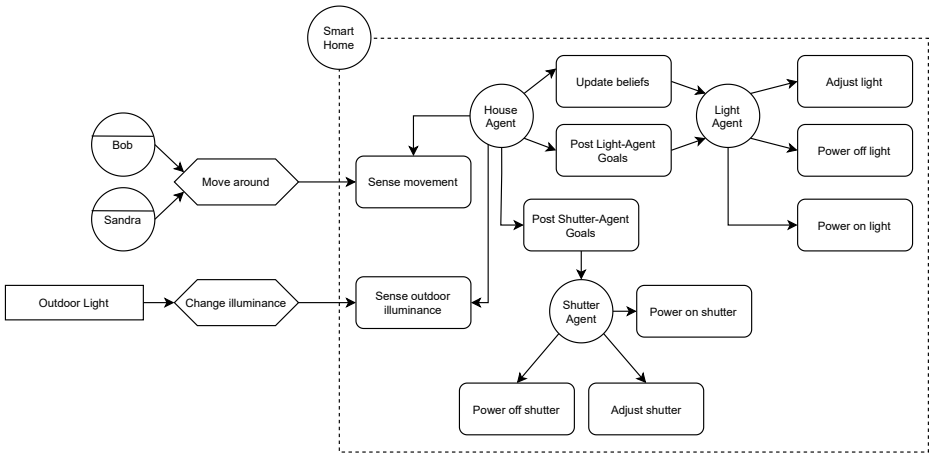

Figure 9: Multi-Agent Environment Architectural Design

The architectural design of the environment in which the agents are interacting is illustrated in Figure 9. It is based on the actor models introduced in Section 6.
Whenever the House-Agent percepts any changes in the daytime (see Section 7.1.3) it will update all Light-Agents beliefs to the current daytime (e.g. `(MORNING time)` and `(not (EVENING time))`). The Light-Agents require these beliefs to adjust the light according to the daytime (see Section 7.3.2 for details).
As explained in Section 7.1.1, the House-Agent observes the movement of all residents through the motion sensors. Then, whenever a resident enters a room, the light needs to be adjusted according to the daytime. Therefore, the House-Agent updates the specific Light-Agent beliefs (e.g. `(not (free bathroom))`) and posts a `PlanningGoal` to adjust the light accordingly (see Section 7.3.2 for details). In contrast, when a resident leaves a room, and the room is empty, its Light-Agent is supposed to adjust the brightness and temperature to 0. Therefore, the House-Agent posts a simple goal to the corresponding Light-Agent, that triggers an intention to adjust the light. To adjust the shutters accordingly, the House-Agent posts a `PlanningGoal` to all Shutter-Agents, whenever the outdoor illuminance has changed. This triggers a specific intention to adjust the shutter accordingly (see Section 7.3.3 for implementation details).

7.3 Agents acting in a shared Environment

The agents that interact and have a direct effect on the world are the Light-Agents and Shutter-Agents. In that context, each agent can only interact with the devices of its room, i.e. the Bedroom-Light-Agent only interacts with the light of the Bedroom, and the Kitchen-Shutter-Agent only interacts with the Kitchen shutters. The agents interact with devices through their actions (see Section 3), which change the device state and have a direct effect on the world.

7.3.1 Power on Devices

Both Light-Agents and the Shutter-Agents have to power on their devices in the morning and power them off in the evening. They maintain a simple intention to achieve this. It is executed, whenever the House-Agents post a goal to the agents in the *SenseDaytimeIntention* (introduced in Section 7.1.3).

7.3.2 Adjust Lights

As mentioned in Section 6.2, a Light-Agent is responsible to adjust the light whenever a resident enters a room, or when no resident is present in its room, and as mentioned in Section 7.2, the House-Agent posts a `PlanningGoal` to a Light-Agent to adjust its light device, when a resident enters, according to the daytime. Therefore, each Light-Agent maintains three different PDDL intentions (a single one for each daytime — Morning, afternoon, and evening) each to adjust the brightness and the temperature based on its beliefs. To adjust the light off, a Light-Agent maintains a simple intention called *AdjustLightOffIntention* that simply sets the light's brightness and temperature to 0.

7.3.3 Adjust Shutters

The Shutter-Agent is responsible to adjust the shutter of its room according to the current outdoor illuminance. As mentioned in Section 7.1.2, the House-Agent assists all Shutter-Agents in posting a `PlanningGoal`. Therefore, a Shutter-Agents maintains three different PDDL intentions, one for each setting (*CloseShuttersIntention*, *OpenShuttersFullIntention*, and *OpenShuttersHalfIntention*), to adjust the shutter according to the beliefs of the current daytime.

8 Scenarios

For this project, a single scenario exists. During that scenario the two residents Sandra and Bob move around the house to simulate a normal workday. Section 8.1 describes the routine of the scenario and Section 8.2 explains the details of its log output.

8.1 Routine

Some examples are: Bob walks into the Guest Room to work on the computer, Sandra walks into the Living Room to eat or watch TV, Sandra or Bob walk into the Bathroom to take a shower or use the toilet.
The events that happened during that scenario are described in Table 9.

Time	Event
07:00	Sandra and Bob wake up in the Bedroom
07:02	Sandra and Bob walk into Second Floor
07:03	Sandra walks into Bathroom and Bob walks into First Floor
07:05	Bob walks into Kitchen
07:20	Sandra walks into Second Floor and Bob walks into Living Room
07:22	Sandra walks into First Floor
07:24	Sandra walks into Living Rooms
07:45	Sandra walks into First Floor and Bob walks into First Floor
07:47	Sandra leaves the house and Bob walks into Second Floor
07:49	Bob walks into Bathroom
08:00	Bob walks into Second Floor
08:02	Bob walks into Guestroom
12:00	Bob walks into Second Floor
12:02	Bob walks into First Floor
12:04	Bob walks into Kitchen
12:10	Bob walks into Living Room
12:50	Bob walks into Kitchen
12:55	Bob walks into First Floor
12:57	Bob walks into Second Floor
12:59	Bob walks into Guestroom
14:00	Bob walks into Second Floor
14:03	Bob walks into Bathroom
14:10	Bob walks into Second Floor
14:13	Bob walks into Guestroom
18:00	Sandra enters the house and Bob walks into Second Floor
18:02	Sandra walks into Living Room and Bob walks into First Floor
18:04	Bob walks into Kitchen
18:30	Bob walks into Living Room
22:00	Sandra and Bob walk into First Floor
22:02	Sandra and Bob walk into Second Floor
22:04	Sandra and Bob walk into Bedroom

Table 9: Scenario routine

8.2 Log Example

This section explains the output of the log. A full log can be found at `assignment-3/fullLog.txt`.

8.2.1 Power on Devices

Both Listing 1 and Listing 2 show an example output, of how the light and the shutters of a room are being powered on using a simple intention. After the intentions have been successful, the `deviceState` state has been set to on. In addition, the agent beliefs have been updated as well.

```
LightAgent-bathroom            Trying to use intention TurnLightOnIntention to
    achieve goal TurnLightOnGoal#11[object Object]
LightAgent-bathroom>TurnLightOnIntention#11 Intention started
(0:07:00:00) [BATHROOM-MAIN_LIGHT] Has changed deviceState to on
LightAgent-bathroom            Belief changed: on bathroom-main_light
LightAgent-bathroom>TurnLightOnIntention#11 Intention success
LightAgent-bathroom            Succesfully used intention TurnLightOnIntention
    to achieve goal TurnLightOnGoal#11[object Object]
```

Listing 1: Example output of *TurnOnLightIntention*

```
ShutterAgent-lower_floor       Trying to use intention TurnOnShuttersIntention
    to achieve goal TurnOnShuttersGoal#4[object Object]
ShutterAgent-lower_floor>TurnOnShuttersIntention#4 Intention started
(0:07:00:00) [LOWER_FLOOR-SHUTTER_1] Has changed deviceState to on
ShutterAgent-lower_floor       Belief changed: on shutters
(0:07:00:00) [LOWER_FLOOR-SHUTTER_2] Has changed deviceState to on
ShutterAgent-lower_floor>TurnOnShuttersIntention#4 Intention success
ShutterAgent-lower_floor       Succesfully used intention
   TurnOnShuttersIntention to achieve goal TurnOnShuttersGoal#4[object Object
   ]
```

Listing 2: Example output of *TurnOnShuttersIntention*

8.2.2 Adjusting Lights

This is an example of how the light gets adjusted after Bob moved from the upper floor to the lower floor.
Listing 3 shows the log of the Upper-Floor-Light-Agent using the *AdjustLightOffIntention* to set the temperature and brightness of the light to 0. It can be seen, that the motion sensors percept the correct movement, and after the temperature and brightness have been adjusted to 0, the light sensor senses an illuminance of 0. Additionally, the beliefs of the Light-Agent are getting updated.

```
(0:07:3:00) [BOB] Has entered lower_floor
(0:07:3:00) [UPPER_FLOOR-MOTION_SENSOR] Occupied status has changed to false
(0:07:3:00) [LOWER_FLOOR-MOTION_SENSOR] Occupied status has changed to true
LightAgent-upper_floor         Trying to use intention AdjustLightOffIntention
    to achieve goal AdjustLightOffGoal#39[object Object]
LightAgent-upper_floor>AdjustLightOffIntention#39 Intention started
LightAgent-upper_floor         Belief changed: free upper_floor
(0:07:3:00) [UPPER_FLOOR-MAIN_LIGHT] Has changed temperature to 0
(0:07:3:00) [UPPER_FLOOR-MAIN_LIGHT] Has changed brightness to 0
LightAgent-upper_floor         Belief changed: not morning-brightness
   upper_floor-main_light
LightAgent-upper_floor         Belief changed: not afternoon-brightness
   upper_floor-main_light
LightAgent-upper_floor         Belief changed: not evening-brightness
   upper_floor-main_light
```

```
LightAgent-upper_floor          Belief changed: not morning-temp upper_floor-
    main_light
LightAgent-upper_floor          Belief changed: not afternoon-temp upper_floor-
    main_light
LightAgent-upper_floor          Belief changed: not evening-temp upper_floor-
    main_light
(0:07:3:00) [UPPER_FLOOR-LIGHT_SENSOR] Illumince has changed to 0
0:07:3:1        LightAgent-upper_floor>AdjustLightOffIntention#39 Intention
    success
LightAgent-upper_floor          Succesfully used intention
    AdjustLightOffIntention to achieve goal AdjustLightOffGoal#39[object
    Object]
```

Listing 3: Example output of *AdjustLightOffIntention*

Next, in Listing 5 it is shown that the light on the lower floor is getting adjusted for the morning. The Light-Agent of the lower floor is using a `PlanningIntention` to adjust both the temperature and the brightness to the correct value for the morning. Then, it is seen, that the main light temperature and brightness value change, and the light sensor senses the changes. Additionally, the Upper-Floor-Light-Agent beliefs are getting updated.

```
LightAgent-lower_floor          Trying to use intention PlanningIntention to
    achieve goal PddlGoal#40 goal:morning-temp lower_floor-main_light,morning-
    brightness lower_floor-main_light
LightAgent-lower_floor>PlanningIntention#40 Intention started
LightAgent-lower_floor          Belief changed: not free lower_floor
0:07:3:2        LightAgent-lower_floor>PlanningIntention#40 Plan found:
LightAgent-lower_floor>PlanningIntention#40 1 (
    adjustmorninglighttemperaturelowerfloorintention lower-floor-main-light
    time lower-floor)
LightAgent-lower_floor>PlanningIntention#40 1 (
    adjustmorninglightbrightnesslowerfloorintention lower-floor-main-light
    time lower-floor)
LightAgent-lower_floor>PlanningIntention#40 Starting sequential step with
    Intention: (AdjustMorningLightTemperatureLowerfloorIntention lower-floor-
    main-light time lower-floor) Effect: not evening-temp lower-floor-main-
    light,morning-temp lower-floor-main-light
LightAgent-lower_floor>AdjustMorningLightTemperatureLowerfloorIntention#41
    Intention started
(0:07:3:2) [LOWER_FLOOR-MAIN_LIGHT] Has changed temperature to 2000
LightAgent-lower_floor          Belief changed: not evening-temp lower-floor-
    main-light
LightAgent-lower_floor          Belief changed: morning-temp lower-floor-main-
    light
0:07:3:3        LightAgent-lower_floor>
    AdjustMorningLightTemperatureLowerfloorIntention#41 Intention success
LightAgent-lower_floor>PlanningIntention#40 Starting sequential step with
    Intention: (AdjustMorningLightBrightnessLowerfloorIntention lower-floor-
    main-light time lower-floor) Effect: not evening-brightness lower-floor-
    main-light,morning-brightness lower-floor-main-light
LightAgent-lower_floor>AdjustMorningLightBrightnessLowerfloorIntention#42
    Intention started
(0:07:3:3) [LOWER_FLOOR-MAIN_LIGHT] Has changed brightness to 200
(0:07:3:3) [LOWER_FLOOR-LIGHT_SENSOR] Illumince has changed to 200
LightAgent-lower_floor          Belief changed: not evening-brightness lower-
    floor-main-light
LightAgent-lower_floor          Belief changed: morning-brightness lower-floor-
    main-light
LightAgent-lower_floor>AdjustMorningLightBrightnessLowerfloorIntention#42
```

```
    Intention success
LightAgent-lower_floor>PlanningIntention#40 Intention success
LightAgent-lower_floor         Succesfully used intention PlanningIntention to
     achieve goal PddlGoal#40 goal:morning-temp lower_floor-main_light,morning
    -brightness lower_floor-main_light
```

Listing 4: Example output of *PDDLIntention* to adjust the lower floor main light

8.3 Adjusting Shutters

Listing 5 shows the output of the Living-Room-Shutter-Agent, which uses a `PDDLIntention` to open the shutters half. It is seen, that at 08:00 the outdoor-illuminance sensor percepts a change. Then, the House-Agent decides to open all shutters half, and a `PDDLGoal` is posted to the Shutter-Agent. The agent starts a `PDDLIntention` and finds a plan to adjust the shutters accordingly.

```
0:08:00:00      (0:08:00:00) [HOUSE-ILLUMINANCE-SENSOR] Outdoor illuminence
    has changed to 0.37747083757143196
ShutterAgent-living_room       Trying to use intention PlanningIntention to
    achieve goal PddlGoal#66 goal:openHalf shutters,not (openFull shutters),
    not (closed shutters)
ShutterAgent-living_room>PlanningIntention#66 Intention started
ShutterAgent-living_room>PlanningIntention#66 Plan found:
ShutterAgent-living_room>PlanningIntention#66 1 (openshuttershalfwayintention
    shutters)
ShutterAgent-living_room>PlanningIntention#66 Starting sequential step with
    Intention: (OpenShuttersHalfwayIntention shutters) Effect: openHalf
    shutters,not openFull shutters,not closed shutters
ShutterAgent-living_room>OpenShuttersHalfwayIntention#77 Intention started
(0:08:00:2) [LIVING_ROOM-SHUTTER_1] Has changed state to halfwayOpen
(0:08:00:2) [LIVING_ROOM-SHUTTER_2] Has changed state to halfwayOpen
ShutterAgent-living_room       Belief changed: openHalf shutters
ShutterAgent-living_room       Belief changed: not openFull shutters
ShutterAgent-living_room>OpenShuttersHalfwayIntention#77 Intention success
ShutterAgent-living_room>PlanningIntention#66 Intention success
ShutterAgent-living_room       Succesfully used intention PlanningIntention to
     achieve goal PddlGoal#66 goal:openHalf shutters,not (openFull shutters),
    not (closed shutters)
```

Listing 5: Example output on how the Living Room shutters are being adjusted

9 Source Code

This section explains the structure and organization of the source code. Furthermore, the source is publicly available at `https://github.com/mstolin/145867_Autonomous-Software-Agents`.

9.1 Structure

The root directory contains four folders. First, `assignment-1/` contains the report for the first assignment. Then `assignment-3/`, which contains the final report and a full log called `FullLog.log`. The `pddl/` folder includes `.pddl` files to test planning intentions for the agents. Lastly, the folder `better-sleep/` contains the source code of the project.
Inside `better-sleep/src/` there are two additional folders. First, `lib/` contains an extended version of *Autonode.js*. Second, `scenario/` contains the implementation of the project scenario and environment.
The *Autonode.js* library has been extended with classes for the devices mentioned in Section 3 and for the house, the rooms (see Section 4), and the Persons (see Section 5). The directory `devices/` was renamed to `world/`. Additionally, `Autonode.js` scenarios are not included.
The `scenario/` folder contains all custom implementations for this project. The implementation of all agents (see Section 6), their intentions, and goals are included at `bdi/`. Under `observers/`, the observers for all entities of the scenario (house, devices, and persons) can be found. The folder `world/` contains the definition of all previously mentioned entities.
The file `environment.js` implements all methods needed to initialize the environment and `routine.js` defines the in Section 8.1 introduced routine. The `scenario.js` serves as the application entry point to start the scenario.

9.2 Light-Agent Intentions Generation

The folder `src/utils` contains a file called `generateAdjustIntentions.js` to generate the `PDDLIntention` classes for the Light-Agents. It uses the templates defined under `src/templates/`. The intentions can be generated using the command `npm run genIntentions`.

9.3 Usage of the Application

It is important to mention, that this application was developed on Linux. Therefore, for planning the `Blackbox.js` file was altered to use the Linux executable instead of the Windows executable.
At first, the *Node.js* project has to be initialized using the command `npm install`. After that, the scenario can be started using `npm run scenario`.

10 Improvements

In this section, the improvements compared to the previous assignments are described.

- A Shutter-Agent (see Section 6.3) was added.
- Each room has its own Light-Agent and Shutter-Agent.
- The House-Agent is only responsible to sense changes in the world (see Section 7.2) and assist other agents.
- A room only has a main light instead of multiple different lights.

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