FINAL PROJECT

Autonomous Software Agents 2021/2022

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Introduction

The main target of this project is to handle in the best efficient way a house equipped with a panel system. Panels are installed on the roof and absorb solar energy generating electricity. This electric current is used for satisfying the house's consumption but can also be stocked in a battery pack installed inside the house. Based on the energy's consumption a control unit (briefly an agent) has three ways to use the panel's electricity:

1. Use for house demand (i.e. charging car, turning lights on);
2. Stock in rechargeable batteries if the house demand is totally covered;
3. Sell it to public authority;

Eventually the agent can buy (small) quantities of current from the public line if batteries are empty or not charged enough and panels disconnected.

The house presents other devices such as an electric car and other type of appliances, oven, dishwasher and tv-screen. The general idea is that devices that consume energy are controlled by the house agent, otherwise they are independent (this is the case, as we will see of the robots inside the house and the washing machine)

The agents are hierarchical structure in order to avoid conflicts and excessive consume of the house. For example, if the electric car has low charge the house agent will turn off the devices, (after being informed by the car agent of the charge mode of the car) in the building keeping the overall consume under a reasonable level. Otherwise, if the car's battery is enough charged (a threshold is chosen a priori) the house agent allows to switch or keep devices on.

House description and blueprint

The house has two floors. At the ground level, we have the garage, the laundry room, the kitchen, one of the leaving rooms and the bathroom, while on the upper floor there are the bedrooms, the second living room and a 6th room where the batteries are installed (called simply battery room).

The house presents a main entry on the north side constituted of an electronic door with ID scanner. Once entered we have the leaving room provided with a TV screen, a sofa and a table used for every type of activity.

There are a second and a third accesses consisting of French doors in the kitchen and in the living room at the ground floor that guarantee a faster way to go to the garage, avoiding residents to pass through the main doorway each time.

The garage has an electric car parked inside connected to its charge column. It is divided from the rest of the house and is located on the south side.

The laundry room has a washing machine and other devices (used mainly for scenario simulation).

In the leaving room, the stairs lead up to the upper floor and have the bathroom next to them.

As said at the beginning, the roof is equipped with solar panels connected to an inverter which allows the system to feed the house and keep the count of kWs used, produced and sold.

Rooms

1. Kitchen

The kitchen is provided with a main light and it is the most used room of the house, used both for eating and sometimes for work. In addition, there is a oven for cooking.

As mentioned before the kitchen has an independent door to get into the garage but also a door accessible from the living room.

2. Bathroom

The bathroom is on the ground floor, next to the stairs, and is provided with autonomous light for illumination.

3. Laundry Room

The laundry room has the heat pump device and the washing machine. As we will see in the device section the heat pump belongs to the appliances of the house and is considered only for its consumption while the washing machine is controlled by a planning agent and does not have a consume.

4. Garage

The garage has the electric car and the charge column where the car can obviously charge.

It is used for parking and recharging only and eventually for other activities which are not relevant to the project.

5. Battery room

This is the core of the house, right to the stairs once got to the upper floor. Batteries are fixed on the wall.

As mentioned in the general description batteries have the function of feeding the house during the night, when solar panels don’t work, allowing to spare money.

The access into this room is intended only for cleaning it up with a vacuum cleaner robot and for solving technical issues of the batteries.

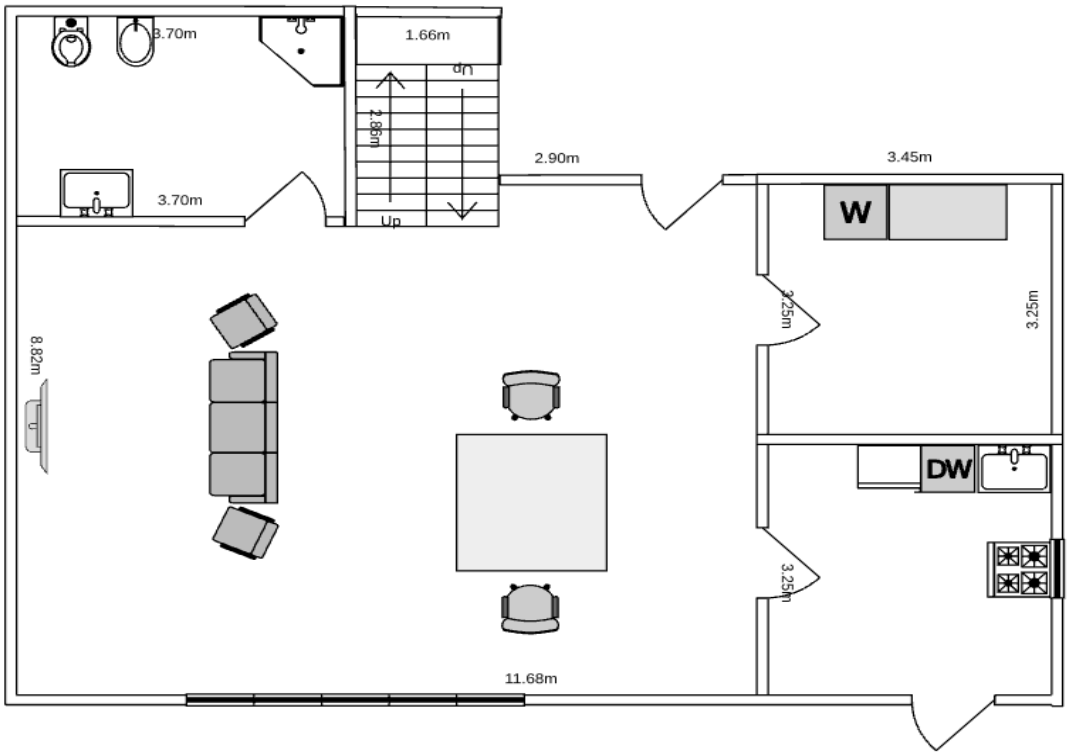
6. Bedroom(s)

Bedrooms have own lights. Based on the presence of people and time the agent will turn lights on/off (as for the other lights in the house). Bedrooms are used mainly for sleeping and eventually for studying (these activities are not distinguished in the final code).

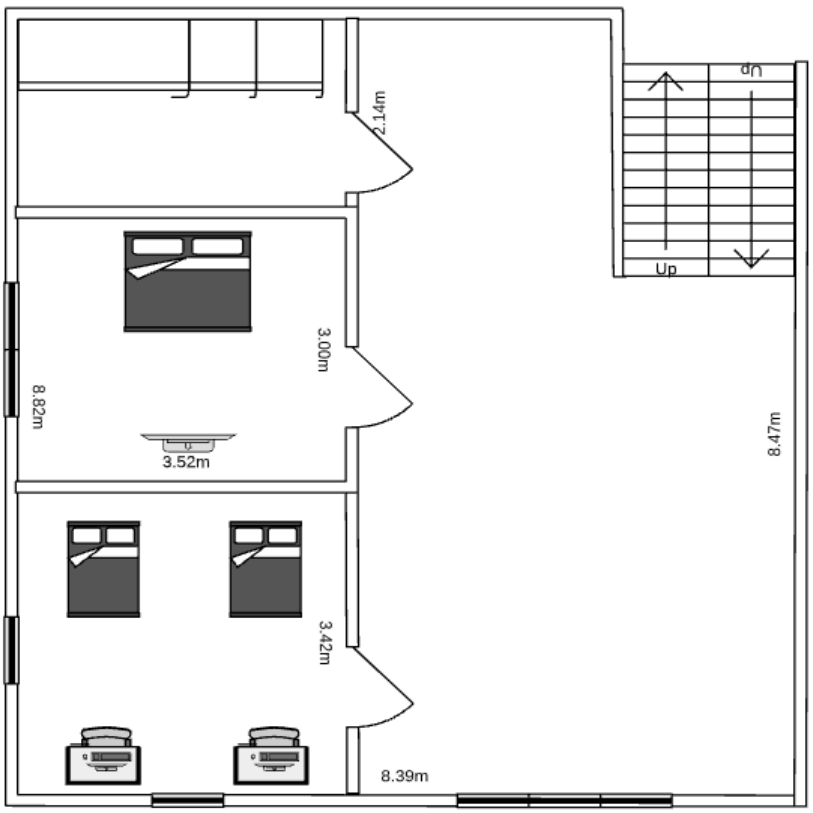
7. Living Rooms

The living rooms connect the two floors of the house, and have independent and autonomous lights. They are called living room “0” and “1” that is a reference to the floor they belong to. As we can see from the blueprint, the living room on the ground floor has a tv-screen, used in the scenario for the computation of the consumption of the house.

Floor “0”



Floor “1”



Devices

Vacuum cleaner

The house is provided of a vacuum cleaner robot. It knows the map of the entire house, both floor-0, and floor-1 and can move around to clean the rooms.

Status: -

Actions: the actions that it can perform are Clean and moveTo with their obvious meaning

Consume: not relevant

Prerequisites: -

Roller Shutter Robot

The roller shutter robot rolls up and down the shutter in the house. It knows the map of the entire house and it is able to move around the rooms and roll up and down the shutters.

The robot rolls up the shutters in the morning and then, once the residents are in the bedroom, rolls them down.

Status: -

Actions: the actions that it can perform are Roll Up and Roll Down and moveTo with their obvious meaning.

Consume: not relevant

Washing Machine

The washing machine is installed in the laundry room and wash the clothes put in its basket by residents.

Status: -

Actions: the actions that it can perform are Fill Water that puts the water just as the clothes are in the washing machine, Set Program that prepares the device to wash and Wash_cycle with its obvious meaning.

Consume: not relevant

Lights

Lights provide illumination to the rooms at every time of the day and are autonomous.

Status: Light status can be on or off.

Methods:

1. **switchOnLight**: turns light on and updates consume of the house (+1)
2. **switchOffLight**: turns light off and updates consume of the house (-1)

Consume: not relevant

Electric car

The electric car has a battery of 54Kw, but its capacity is reported through a percentage parameter (10%,20%...) and has to be connected to the charge column every time it is parked in the garage, The connection and disconnection of the car is intended as performed by the This is a sort of security system in order to know always the charge status.

Status:

- 0% < charge < 40% need to be recharged in DC_mode (Direct Current);
- 40% < charge < 100 % charge mode switches to AC_mode (Alternate Current) where the recharge process is slower in terms of time and consume;

Methods:

1. **switchOncharge**: switch the charge status to on
2. **switchOffcharge**: switch the charge status to off
3. **get_charge**: verifies the status of the charge and calls methods charge_AC_mode or charge_DC_mode
4. **decrease_charge**: decreases the charge of a battery in order to simulate its use during a day (i.e. there might be days where the car is used less and for that reason its battery decreases less)
5. **charge_DC_mode:** charges the car faster than AC_mode. When the charge reaches level 40% it calls method charge_AC_mode that keep charging the car
6. **charge_AC_mode:** invoked if the battery of the car is more of 40% or called by the method above. It keeps charging the car till 100% then calls switchOffCharge.

Consume: 5kW if DC_mode on, 3 kW otherwise.

Prerequisites: car connected to the charge point. DC_mode and AC_mode are chosen based on its current capacity. DC_mode or AC_mode are automatically selected by the agent.

Solar panels

The entire system has a capacity of 10 kWh and it changes based on the time. In the evening and the night it is set to 0. As described at the beginning the electricity is primarily used for feeding the house. Only if panels produce a surplus is stored in the batteries and eventually sold.

Status

- Capacity which indicates the current production of the panels

Methods:

1. **Production_during_time:** simulates the production of current based on the clock. From 00.00 to 6.00 it is considered 0 (panels disconnected) then the average production is 4 till 18.00 and then set to 0 again
2. **Start_store_energy(diff):** starts storing the surplus of energy produced into the battery system

Battery system

When the night has come the solar panels stop working. The feeding of the house swaps to the batteries and the pack has a capacity of 5kW. When they are full the surplus of the panels is sold to the public authority.

The devices is controlled by the same agent of the panels and has a series of parameters that indicate some features as the current charge, current sold and bought.

Methods:

1. **Use_batteries**: decreases the capacity of the battery system basing on the parameter given as input
2. **Is_full():** returns true if the batteries are full (15 kWs)
3. **Is_empty():** returns false if the capacity is 0
4. **Start_store(diff):** method invoked by the solar panels, starts increasing capacity of the system of an amount depending on the parameter given as input

Devices

For a better simulation of the scenario, the house has been equipped with some devices (memorized in an array in the class House), which are used for increasing and decreasing the consumption of the house. They are automatically switched on when a person enters the room they are installed in and switched off when the room is free.

The appliances chosen are the following

a) **Oven**: installed in the kitchen, consume of 2 kWs;
b) **TV-screen**: installed in one of the bedrooms, consume 1 kW;
c) **Heatpump**: installed in the laundry room, consume 1 kW;
d) **Dishwasher**: installed in the kitchen, consume 2 kWs

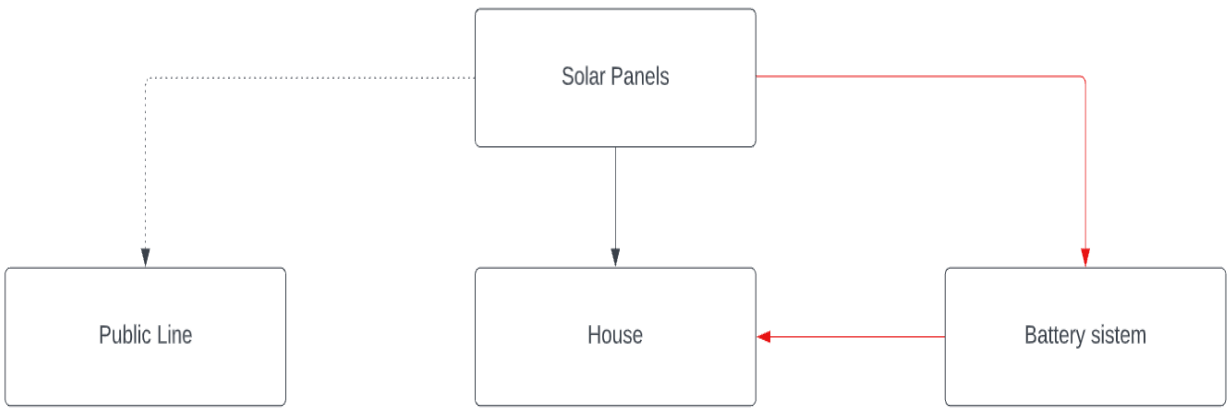
Status: device status can be on or off

Methods:

1) **Switch_ON_device**: turns the device on and increase consume of the house
2) **Switch_OFF_device**: turns the device off and decrease the consume of the house

Summary of the entire system

In the figure below there is a simple scheme of the devices. The arrow in black indicates the primary function while the arrows in red explains the alternative way to feed the house.



Metrics

Sell cost of electricity

Selling electricity is paid 0.20 €/kWh while buying it costs 0.10 €/kWh. The house is intended for selling electricity only or buy small quantities. At the end of the day a final report of current bought and sold is showed on the console.

People and agents

People

Residents in the house include two people, Stefano and Elisabetta. Stefano is out from 8.00 am to 19.00 pm and goes to work by car, it is perhaps important that at least 40% of the battery capacity is stored. Elisabetta works in a smart modality and has to take care of the house, so in her daily schedule movements in the house are considered.

The action they can perform is MoveTo that allows residents to move through the rooms. Each action or method in the daily schedule (called **brutal force**) is intended as “taken by a human action”. For example at 8.00 Stefano is going to work by car. He needs to switch off the charge so in the schedule it is performed the action switch_off_charge, method of car class, but it is formally performed by Stefano and not by the agent.

House agent

The house agent controls panels and battery system.

In particular it has to choose when to stock the energy and when to sell it. The idea is that solar energy and battery resources are enough for the agent to not buy electricity (or buy small quantities) and so try to minimize the costs of the house. Its work is summarized in the four bullet points below:

1. The current is **primarily** used for feeding the house;
2. If the panels produce **more energy** than the demand it is stored in the batteries;
3. When the batteries are **full** (invoking the method is_full()) the eventual surplus is sold to the public authority, which obviously pay the owner for the service (0.20 €/kWh);
4. If batteries are empty then the agent buys electricity.

The four actions above are chosen by a sensor that looks at the production of the panels

The consume of the house is tracked by a sensor and is computed as the sum of the consumptions of lights and car plus an additional consume of 0.5 kWs and/or other random consumes in the daily schedule

Lights Agent

Lights agent helps people in the house to switch on and off lights automatically. The behavoiur of the agent is the following:

1. Switch on lights of a room if a person is in there
2. Switch off lights of a room if a person is no more in there

At the end of the day every light is in the ‘off’ status, otherwise residents would sleep during night with the light on.

Car agent

Depending on the status of the battery the agent has to choose the type of the charge. The car is plugged in the charge column as soon it gets parked in the garage. The two types of modes are:

1. DC mode (fast mode) and consumes 5 kWs;
2. AC mode (normal mode) and consumes 3 kWs;
3. The overall consume is communicated to the house through a specific parameter.

A sensor is thought to verify the charge of the battery and to inform the agent which will perform the best action invoking he right method.

The DC mode has a double speed with respect to the AC mode and it applied when the charge is less than 40%. The house agent helps the car agent to charge the car using primarly the current coming from panels, otherwise batteries have to charge the car (this is the case where house might buy electricity).

When the DC mode is activated the house agent is informed and set a parameter called “**intensity**” to true, indicating that the operative devices in the house have to be switched off.

Consumption Agent

As the panels, through the house agent, communicate the beliefs “intensity true” the consumption agent turns off the devices.

Device Agent

It controls the devices of the rooms, switching them on as a person enters the room.

Planning agents

Vacuum Cleaner Agent

The vacuum cleaner has to clean all the rooms in the house. The rooms become dirty every evening, and the vacuum cleaner move towards the rooms using the doors connecting them and clean the floor. It can be go to the upper floor using the stairs between the two living rooms.

It is provided of the map of the environment and it knows how rooms and floors are connected. Its position in the house and the status of a room are detected by its own sensors that inform it where it is and if the room is clean or not.

Roller Shutter Agent:

Very similar to the Vacuum Cleaner Agent it is thought as a robot moving in the house. It has to roll up and down the roller shutters during the day. As for the vacuum cleaner it is provided of the map of the house and using its sensors it can open or close roller shutters.

Washing Machine Agent

This agent uses the washing machine installed in the laundry room and wash the clothes. It waits that its basket is full (in the scenario “clothes_in”) and starts its plan to wash the clothes. At the end

of the plan, it is ready for another iteration if necessary, otherwise it waits till the next day or till the basket is full again.

Implementation

Sensors and agent perception

Each agent perceives the environment through a sensor that updates its beliefs. The house is provided by the following sensors

Sensor	Agent
PersonSensor	LightAgent
LightSensor	LightAgent
CarSensor	CarAgent
PanelSensor	HouseAgent
DeviceSensor	DeviceAgent (integrated in House Agent)
ConsSensor	ConsAgent (integrated in House Agent)
VacCleanSensor	VacuumCleanerAgent
VacPresSensor	VacuumCleanerAgent
RSPresSensor	RollerShutterAgent
RollerShutterSensor	RollerShutterAgent
WashingMachineSensor	WashingMachineAgent

Sensor and implementation for planning agent

Vacuum Cleaner Agent perceives the environment as a set of rooms where they can move and can perceive the room in one of the two status, clean or dirty. The movements between rooms are allowed thanks to the doors connecting them and for that reason agents can move only between communicating rooms.

Roller Shutter Agent perceives the environment as a set of rooms where they can move and can perceive the room in one of the two status, up or down. The movements between rooms are allowed thanks to the doors connecting them and for that reason agents can move only between communicating rooms.

Washing Machine Agent perceives the presence of clothes to wash in its basket. They are put into it by a person in the house and starts a plan to wash them using its 3 actions Fill_Water Set_Program and Wash.

Sensor and implementation for other agents

Light Agent perceives the presence of a person in a room through PersonPersSensor and turns on the light of that room and switches off the light of the room left by the person.

Example: Stefano goes from living room to kitchen, light agent turns on the light of the kitchen and switches off the light of the living room.

Furthermore, the agent can rely on the LightSensor which is used in cases lights are switched on/off by residents (brutal force) in order to updates its beliefs.

I have assumed that at the beginning of the day all lights are off. Once the residents start moving in rooms the lightAgent activates

House Agent controls solar panels, battery system and the other devices with its sensors PanelSensor, Consumption Sensor and Device Sensor.

The agent waits one of the three following beliefs: capacity (PanelSensor), intensity(Consumption Sensor) or pers_in_room (Device Sensor).

The capacity beliefs indicates to the agent that the panel system is producing current and indicates the number of kWs produced per hour. Once the panels are producing the agent decides how to split the energy between the house and the batteries

The intensity belief comes from the Consumption Sensor. When it is true it means that the car in the garage is getting charge in DC mode, increasing the consumption of the house of 5 kWs. The House Agent turns off the devices in the house in order to spare energy.

The pers_in_room belief informs that a person is in a room and if a device is installed into it the agent switches on the device.

Car agent uses the sensor CarSensor to know if the car is in charge or not. As mentioned few rows above if the charge is under 40% the agent activates the DC mode and the intensity parameter is set to true, forcing the house agent to switch the devices off.

Furthermore, when the charge has overtaken the 40% it activated the AC mode, which consumes less energy. As consequence the intensity belief is change into false as we will see in the Simulated Scenario section.

Its knowledge is perhaps limited to the garage and the car and has no need to know the house blueprint, which is fundamental for the vacuum cleaner.

Agents acting in a shared environment

As said before **House Agent** governs the panels, batteries and the overall consumption of the house. At the beginning of the day panels are disconnected and the Agent uses eventually the batteries to feed the house. As the time proceeds the panels start producing and the Agent receives information about the consumption of the house, which can increase if a device turns on or the car gets in charge. The actions of this agent are summarized in the following:

00.00 <= time < 07.00

The sun does not have raised yet, House Agent use batteries through the method use_batteries() or waits till the capacity increases or the consumption of the house changes. If batteries are empty a message is logged out on the console and the Agent starts buying current (prize 0.10 €/kWh).

07.00 <= time < 12.00

Panels produce 3 kWs, and the sensor of consumption of the house tracks each consume of the devices. Based on the consumption of the house, logged on the console each hour the agent covers the energy's request and eventually stores buys some electricity.

13.00 <= time < 18.00

Panels increase their production to 6 kWs, and the consume is computed by the agent tracking movements of the residents. If the consumption is less than 6 kW, most of the cases, the agent keep storing energy in the batteries.

19.00 <= time < 00.00

This is the period, along with the first hours of the morning, where the batteries feed the house, because the production of the panes decreases to 0.

time = 23.30

The house agent prints the daily report of the current sold and bought

(This is the general schedule of the house agent, but in the "Simulated Scenario" section and in the log files it is better explained)

The car Agent simply disconnects the car if it is enough charged using the method Switch_OFF_charge(). The idea is that Stefano, who is the main user of the car puts it in charge once he is back to home. The Agent is informed that the car is plugged in and verifies its charge deciding what type of modality to use (AC mode or DC mode explained in the device section).

The other agents have independent behaviour and do not have constraints on their actions.

Vacuum Cleaner Agent moves between rooms and clean them with clean action. The rooms are considered dirty every morning and the Vacuum Cleaner moves through the rooms of its floor cleaning them up.

Light Agent turns on and off lights through its methods turn_on(), turn_off() and works in the both floors (no distinction between ground floor and upper floor as for the cleaning agents)

Agent interaction and coordination

The **house agent** manages the most part of the devices in the house. It waits that the beliefs change and then takes the best decision to manage the consumption of the house.

It tracks the consume of the house, communicated by the Consumption Sensor and choose where to take the energy to satisfy the current's request.

But the most important decision it has to take is when the car agent informs the house agent that the car is put into charge. The consume of the house increases of 5 kWs if the DC mode is activated and the "intensity" parameter is set to true (a sort of alarm state). The house switches off the devices (oven, tv-screen, heat pump) in order to use less energy as it can. If the car is charged in AC mode the house agent allow the devices to keep working because the consume of the car is only 3 kWs.

Light Agent has to turn on and off light depending on the presence or not of people in a room **but doesn't have to take into account the presence of the robots.**

In the house there are the two robots, the vacuum cleaner and the roller shutter that move in the rooms trying to reach their goal.

Scenarios

hh 00.00 < hh < hh 06.00

Residents are sleeping, consume of the house as well as the production of the panels is 0.

hh 6.00

Elisabetta wakes up and plans to move from bedroom_1 to the ground floor. Panels start producing, increasing their capacity to 3 kWs and store the energy in the battery because consume of the house is still 0.

hh 6.15

Stefano wakes up and moves from bedroom_1 to kitchen going through living_room_1 and living_room_0. The car is plugged in (this is done only for simulation reasons). The house agent notices that the battery is low and set the DC mode to true. Car Agent updates its beliefs (in charge car).

hh 6.30

Residents keep moving into house. Elisabetta goes into the laundry room, heat pump and tv-screen are correctly turned on.

The washing machine agent changes its beliefs because clothes are put in its basket and starts its plan to wash them (SimulationPlanning file)

hh 7.00

The house agent is informed of the DC charge mode by the car agent and turns off both tv-screen and heat pump (they were on as consequence of the movements of the residents).

The consumption of the house is 7 kWs in total, as result of the sum of the car, heat pump and tv-screen.

(In the Simulation1day file the devices are not switched off automatically when the person leaves the room. This is done in order to show better the manage of their consumption of them)

hh 8.00

The car is taken by Stefano and the charge is switched off, consume of the house decreases if the car was charging otherwise the consume remains constant. Once the car is disconnected the consume of the house depends on the lights and some additional consumes I set in the daily schedule.

Meanwhile the vacuum cleaner of the ground floor (VacuumCleaner_0) starts cleaning

hh 8.30

Elisabetta goes in the laundry_room, heat pump is turned on.

During these first hours of the day (and in the next ones too) it is printed on the console the consume of the house, as well as the capacity of the panels, showing the difference between the two values.

If it is positive the console logs the following message:

Storing energy in the batteries

Charging batteries, capacity 8

If it is negative the message is:

Batteries are not charged enough to supply the house

kWs bought from the public line: -4 total price: 0.40

or can be

Batteries are supplying the house

Capacity of the batteries is: 8

Depending on the capacity of the batteries in that moment.

hh 9.00

The vacuumCleanerAgent starts cleaning rooms up. VaccumCleanerAgent has to clean all the two floors completely. After it finishes its planning all rooms are clean and the robot turns off until the day after. The room where it can stay is chosen in the planning.

hh 10.00 < time < hh 19.30

During this time only movements of Elisabetta are considered, because Stefano has gone to work. In the log file it can be seen that the lightAgent follows the movements switching on/off the lights of the rooms that Elisabetta visits and leaves

hh 15:15

Roller shutter starts its planning. It has to move through rooms and roll shutters up. Once it has reached the goal it stops in the last room it entered.

hh 19.30

Stefano comes back to home, the car is parked in the garage and the carAgent verifies its status.

The car gets charged in AC mode, and the House Agent does not have to switch off the devices inside the house.

hh 21.45

Residents are in the bedroom_1, all lights are turned off.

hh 22.45

Vacuum_Cleaner_1 finishes to clean rooms. It will be activate the day after, once the rooms will be dirty

hh 23.30

houseAgent prints its daily report about the electricity.

hh 1.00 Day 1

Roller shutter agent starts rolling shutters down (only shutters of floor 1 where residents sleep, this is done in order to verify that the day after it rolls up only the shutters open. It does not satisfy the goal completely).

Additional: every hour the houseAgent shows the production of the panels and what type of action is performing (charging batteries or not). Moreover, it shows the consume of the house and the amount of electricity stored in the batteries (this can be observed in the log file).

At certain times I manually increased and decreased the consumption of the house in order to make the simulation more real and dynamic.

Additional informations

As written in the README file:

In the ReportandLogs folder there are 3 files where I simulated the scenario

-) In Simulation1day and Simulation3days the simulation is between houseAgent, carAgent and LightAgent

-) In Simulation1day the scenario is simulated without turning off the devices, to better show the consumption of the house and the function of the entire system

-) In Simulation3days the scenario is simulated in its final version

In the SimulationPlanning file it is simulated the scenario only with the planning agents

In order to understand better the file it is suggest to open the it with VSCode reading it as a log file instead of using Blocco Note or similars. The comments are highlighted in RED with three reverse bars

Source code organization

In src/myworld all files are implemented

In ReportandLog log files and report are loaded

https://github.com/GiovanniAmbrosi/232252_Ambrosi_Giovanni_ASA2022/upload/main