Environment Description

Autonomous Software Agents Laboratory

1   Introduction

Rapid development of information technology has introduced a new generation of the software paradigm, named Agent Oriented Programming. In the following sections, it is proposed a system model for managing tasks in smart homes using multi-agent solutions. The proposed solution organizes work and distributes tasks to individual family members as well as to additional subject called agents. All of them will interact with each other and with the devices the house is equipped with. The document describes the application context and each relevant subject, human, software and hardware. The proposal is described with regard to the possibility of implementing a smart home project.

Intelligent agents are more and more present in our daily lives. They acquire data from the environment by using built-in sensors, such as cameras, microphones, and motion and temperature sensors. Information is processed to extract data that are then shared with the other devices on the network. Smart homes are an example of that. The agents are able to monitor the entire home in the absence of residents, analyzing and/or modifying existing conditions, like temperature and energy consumption. They make use of the house's devices in order to increase the comfort of the resident's life. In addition, in case failure such information can be shared with the tenants, with the producer of the system and with many other subjects not usually in close contact with the house (police, firefighter, etc.).

The document is divided into several sections to increase the readability. In Section 2, a description of the house is provided on different levels, with the addition of the house's blueprint. Section 3 offers an overview on the devices with which the house is equipped. Section 4 introduces some metrics used to evaluate the impact of the agents on the house. Finally, Section 5 introduces the main subjects that interact in the context of the house: the agents and the resident.
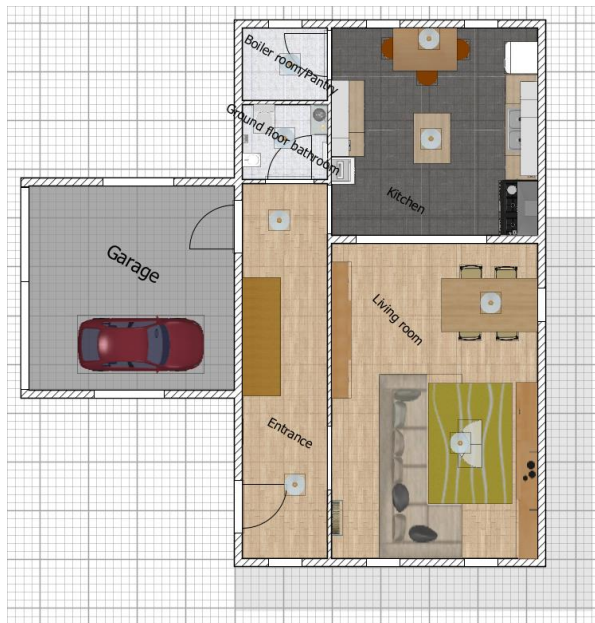
2   House description and blueprint

The house is on two floors, furnished with a minimal but essential custom-made furniture. At the ground level, there is the entrance; from here, it is possible to reach almost all the rooms located at the ground floor and, through the staircase, the rooms at the first floor.

The rooms located at the ground floor are the kitchen, the living room and the ground floor bathroom. The living room and the kitchen are connecting rooms, but in case of guests, they can be made independent. All these rooms are reachable from the entrance. In addition, the garage has an independent access to the entrance. From the kitchen, it is possible to reach the boiler room where the geo-thermal plant is installed. This last room is also used as panty (Note that, this room can be reached only through the kitchen).

As has been said, the second floor can be reached only by the staircase, which then connect the ground floor with the first floor. At the first floor, there are the study, the laundry, the bedroom and the first floor bathroom. All these rooms can be reached from the landing of the first floor. In addition, a big

balcony connects the laundry to the study, from which it can be accessed. Also in the bathroom, a glass door connects the room with the balcony.

2.1.1   Ground Floor

2.1.2   First Floor
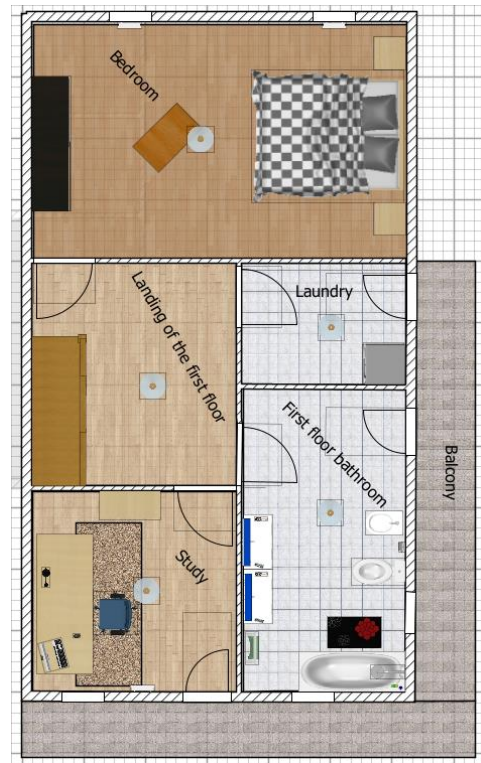
2.2   House description and blueprint

The whole house is heated and cooled by using a geo-thermal plant and the underfloor heating, with an exception for the garage. In general, the temperature is set in between 19°C and 21°C during the winter and in between 21°C and 23°C during the summer. However, each room has its own independent thermostat to control the temperature and different rooms can have different temperatures at the same time. For example, in the winter, the garage has a temperature in between 16°C and 18°C, because the tenants do not spend much time in there. While in the same period, the bathrooms have a temperature in between 20°C and 22°C when the tenants wake up.

All the rooms, with the exception of the bathrooms, are equipped with cameras, at least one for every room. While, for obvious reasons, the bathrooms are equipped with motion sensors. Some cameras are then installed outside, along the house's perimeter, plus in front of the front door and the garage entrance. Those cameras are used to identify people and objects, their presence and their position.

All the rooms then are equipped with ambient mics, which allow collecting sound information. The front door is instead equipped with a directional microphone. The outside of the house in also equipped with the ambient mics, but because of the environmental sound, they are usually unused and turned off.

Every floor is then equipped with a tablet to control the house's functionalities. The tables are usually located at the entrance for the ground floor and at the landing of the first floor. Of course the tables

can be carried around the house. Every room has at least a wireless charging point for those devices that are equipped with.

In addition, every room is also equipped with a charged point for the vacuum cleaner, which is not forced to return to it's main station if it has to be recharged.

The rest of the section will provided more details about each room of the house.

2.2.1   Entrance

The entrance represents the first room in which people can come across where they come from the outside of the house or they come from the garage. Through this room, it is possible to reach all the rooms at the ground floor, except for the boiler room/panty, and the second floor.

As has been said before, usually the tablet of the ground floor can be found here. The room is very simple and it is furnished with the essentials: coat-rack and typical furniture.

The illumination can come either from the window located in the wall near the front door and from the living room or from the lights located on the roof. The room is long enough to be required to install to lights.

The entrance is usually a crossing point, it is one of the most used room as a function of its own location.

2.2.2   Kitchen

The kitchen is located at the ground floor and from there it is possible to reach the living room, the boiler room/panty and the entrance. The kitchen has also a wall in common with the bathroom, but it is necessarily to go through the entrance in order to reach the bathroom from the kitchen, and vice versa.

The kitchen is equipped with typical instruments and devices. Near the small electrical appliances (toaster, blender, etc.), it is possible to find more interesting large household appliances: dishwasher, fridge, induction hob, oven and microwave and food processor. While the small electrical appliances can be plugged and unplugged easily, the large household appliances are always plugged, assuming that everting works as it should.

It is interesting to highlight that together with the typical kitchen's furniture, the room is equipped with a kitchen island, located in the center of the room, and with a table on the other side of the room with the respect to the living room.

In the kitchen there are two windows by which the room is illuminated by natural light during the day, some other light comes from the living room thanks to the communication between the two rooms. There is then a main light located in the middle of the room, over the kitchen island, plus additional separated lights, one over the table, and others over the kitchen surfaces and cooktop.

This is one of the most used room. Usually the tenants consume here their main daily meals.

2.2.3   Boiler room and Pantry (pantry)

This room is located at the ground floor and it can be reached only from the kitchen. Here there is the geo-thermal plant and some shelves because the room is used also as panty. In this room it is possible to find the main station of the vacuum cleaner that is responsible for the cleaning of the entire ground floor.

Illumination is provided by one window that allows the sunrays to penetrate during the day, and one main light located in the middle of the room.

This is one of the lesser used rooms. Usually residents go there if they have to take or place objects placed there, or if they have to take care of the status of the vacuum cleaner, ore ever in case of maintenance of the geo-thermal plant.

2.2.4 Living room

The living room is located at the ground floor and from there it is possible to reach the kitchen, and the entrance, instead to reach the bathroom, it is necessarily to go through the entrance, and vice versa.

The room can be subdivided in two macro areas. The first, the bigger one, is the one in which can be found the sofa and most of the furniture, among them there also the TV stand and a little bookcase behind the sofa. The other area is closest to the kitchen and it is occupied by a table.

In the living room there are three windows by which the room is illuminated by natural light during the day, some other light comes from the kitchen and the entrance, thanks to the communication between the rooms. There is then a light located over the table, and another one over the sofa. Another light is located behind the sofa near the door between the entrance and the living room.

Usually the resident spend many time in the living room over the weekend. This room in equipped with a smart TV and a bed-sofa, and sometime they watched the television and then spend the night on the bed-sofa. Because of the bed-sofa, if the tenants have guests, the living room becomes the guest room.

2.2.5 Ground floor bathroom (gf_bathroom)

The ground floor bathroom is a very simple room, provided by the typical bathroom's supplies.
In this bathroom is also present the shower. Although in the room there is the underfloor heating, the ground floor bathroom is also provided of a towel warmer.

The illumination is provided by one window and a main light located in the middle of the room. Over the washbasin there is a mirror which has its own light.

The ground floor bathroom is a normal used room. In case of guests this becomes the guests' bathroom and the residence will use just the one on the first floor.

2.2.6 Garage

Garage is located at the ground floor and it has an independent access to the entrance of the house.

The garage is large enough for two cars, but the resident possess just one car. This last therefore occupies one park area of the garage, while the other is uses as a warehouse, with shelves, a worktable with tools and things like that. In between the two, there is a charging station for electric cars. The same charging station can be used to recharge the electric bicycle.

Illumination is provided by two windows, one for each side, that allow the sunrays to penetrate during the day, and two main lights, located in the middle of each park area.

During the winter this is one of the lesser used rooms, while during the summer the tenants use it form many different activities.

2.2.7 Landing of the first floor (l_first_floor)

The landing of the first floor allows the access to all the rooms situated at the first floor. It is connected to the entrance by a staircase.

As has been said before, usually the tablet of the first floor can be found here. The room is very simple and it is furnished with the essentials: coat-rack and typical furniture.

The illumination can come either from the windows located in the wall near the staircase and from the light located on the roof.

As for the entrance, the landing is usually a crossing point; it is one of the most used room as a function of its own location.

2.2.8 Study

This room is locate at the first floor and it is reachable by the landing of the first floor.

Over the desk placed in the room it is possible to find a laptop with an external monitor and a desk light. On the wall in front of the desk, there is hung a very large monitor that is connected with the main system of the house, with which it is possible to interact. The same monitor can be also connected with other devices and used for other reasons. The room is then completed by the typical office's furniture.

The illumination can come either from two windows located in the wall near the desk, but also from the light located in the middle of the room, as well as from the desk light.

One of the resident is a software developer and he works three days per week from home. Because of that the room is mainly used by him, although it can represent a useful workspace for all the residents.

By this room, through the glass door, it is possible to reach the balcony.

2.2.9 First floor bathroom (ff_bathroom)

The first floor bathroom is bigger than the ground floor bathroom, it is provided by the typical bathroom's supplies, but this time there are two washbasins, one for each residents, and it has a whirlpool bath. As for the ground floor bathroom, in this room there is the underfloor heating but also two towel warmers.

Two windows and one glass door provide the illumination. One main light is located in the middle of the room. Each washbasin has its own mirror, which one in turn has its own light. Also the whirlpool bath has a colorful light that can illuminates the water and another light over the whirlpool bath.

The first floor bathroom is a normal used room; only the tenants and no one else usually use it.

By this room, through the glass door, it is possible to reach the balcony.

2.2.10 Laundry

This room is located at the first floor and it can be reached by the landing of the first floor.

Here there are the typical furniture of a laundry, some tools (iron, laundry basket, clothes peg, etc.) and devices. The main interesting devices are the washing machine and the tumble dryer. Being they large household appliances, they are always plugged. In this room, it is possible to find the main station of the vacuum cleaner that is responsible for the cleaning of the entire first floor.

Illumination is provided by one glass door that allows the sunrays to penetrate during the day, and one main light located in the middle of the room.

This is one of the lesser used rooms. Usually residents go there if they have to take care of the status of the vacuum cleaner or for clean their clothes.

By this room, through the glass door, it is possible to reach the balcony.

2.2.11 Bedroom

The bedroom is locate at the first floor and it is reachable by the landing of the first floor.

Whit the living room and the kitchen this is one of the largest rooms of the house. The room is equipped with the typical bedroom's furniture (wardrobe, bed, bedside tables, etc.). At the center of the room there is then a little table and in front of the door, on the other side of the room, there is a small bedroom desk. On the right side of the wardrobe, in the corner of the room, is located a bedroom mirror.

The illumination is provided by two windows, located perpendicular with the respect to the bed. There is then a main illumination in the middle of the room. In addition, each bedside table has its own bedside lam. Also the wardrobe has a light, but it is inside and in order to use that is it necessary to open at least one closet door.

Usually this room is used by the tenants only, to sleep and to change their clothes.

3 Devices

This section presents the devices available in the house. The following devices are intended as smart devices instead of agents because they are mainly performers and not decision-makers. Most of them collect information and share them with the agents present in the house or the resident (e.g. Sensor). Sometime they can also perform some kind of computation on the data before to share them. Other devices are instead used by the agents or the residents to perform some kind of activity in order to reach some goals.

Most of the devices can be put into operation in a traditional way, for example a light can be turned on/off by using the switch present on the wall, or by the house agent, for example by asking to the agent to turn on/off the light or by using the tablet's application. When you would like to interact with the devices through an agent, it is mandatory that the device is plugged and connected with the agent. This last aspect is common to all the following devices unless otherwise stated.

3.1 Light

Lights are the most widespread devices around the house. They make use of the Led technology, that makes possible to have great performances with low costs. Lights provide illuminations to the rooms when necessarily, for example at night. Each light consumes in average 5 W of electricity when turned on.

Status
• is_on – level of intensity in %
• light _status – TRUE if any anomalies

Actions
• turn_on(x) –set a new value x for intensity or restore the previous one (default behavior if x is not specified)
• turn_off – set intensity to zero

Preconditions
• turn_on(x) – NOT is_on and NOT light_status
• turn_off() – is_on

3.2 Electric car

The electric car has a capacity of 100 kWh. It can be charged at 7.4 kW (standard charge) or 11 kW (fast charge), up to 100% or 85% to preserve the battery.

Status
• car_in_gare – TRUE / FALSE
• charging_status – TRUE / FALSE
• charging_type – 7.4 kW or 11 kW
• battery_level – %
• need_ charging – battery level under 83% or 97% depending on the setting –TRUE / FALSE
• car_status – TRUE if any anomalies

Actions
• start_charge(mode)
• stop_charge()
• set_charging_type(x) – 7.4 kW default

Preconditions
- start_charge() – car_in_garage AND need_ charging AND NOT car_status
- stop_charge() – charging_status

3.3   Solar panel

Solar panels produce in average 8.5 kW per day, about from 8.00 to 18.00, when it is sunny. In all the other cases, they don't produce anything.

Solar panel is a passive device; it is not possible to make any kind of actions on it.

Status
- watt_produced – returns the amount of producted watt
- panel_activity – return if the panels are producing energy – TRUE / FALSE
- panel_status() – TRUE if any anomalies

Actions

Preconditions
NOT panel_status()

3.4   Tumble dryer

Tumble dryer consumes in average 2.5 kW per cycle, in average every cycle takes 20 minutes. It is usually used 2 days per week from November to March.

Status
- is_working– TRUE / FALSE
- time_remaning – how much time before the end of the work in minutes
- timble_dryer_status – TRUE if any anomalies
- work_program – returns the active program id is_working

The real difference between stop and pause is that if the process is in pause, it can restart from a certain point, while if it is stopped, it has to restart from the beginning. In both cases is_working returns FALSE.

Actions
- start_work()
- stop_work()
- pause_work()
- set_work_program(p)

Preconditions
- start_work() –NOT timble_dryer_status AND NOT is_working
- stop_work() – is_working
- pause_work() – is_working

3.5   Washing machine

Washing machine consumes in average 1.5 kWh, in average every cycle takes 1 hour. It is usually used 2 days per week.

Status
• is_working– TRUE / FALSE
• time_remaning – how much time before the end of the work in minutes
• washing_machine_status – TRUE if any anomalies
• work_program – returns the active program id is_working

Actions
• start_work()
• stop_work()
• pause_work()
• set_work_program(p)

The real difference between stop and pause is that if the process is in pause, it can restart from a certain point, while if it is stopped, it has to restart from the beginning. In both cases is_working returns FALSE.

Preconditions
• start_work() –NOT washing_machine_status AND NOT is_working
• stop_work() – is_working
• pause_work() – is_working

3.6   Dishwasher

Dishwasher consumes in average 2.5 kWh, in average every cycle takes 1.20 hours. It is usually used 4 days per week.

Status
• is_working– TRUE / FALSE
• time_remaning – how much time before the end of the work in minutes
• dishwasher_status – TRUE if any anomalies
• work_program – returns the active program id is_working

Actions
• start_work()
• stop_work()
• pause_work()
• set_work_program(p)

The real difference between stop and pause is that if the process is in pause, it can restart from a certain point, while if it is stopped, it has to restart from the beginning. In both cases is_working returns FALSE.

Preconditions
• start_work() –NOT dishwasher_status AND NOT is_working
• stop_work() – is_working
• pause_work() – is_working

3.7 Vacuum cleaner

Vacuum cleaner consumes in average 0.85 kWh, it works in average 5 hours every day.

Status
• is_working– TRUE / FALSE
• time_remaning – how much time before the end of the work in minutes
• charging_status – TRUE / FALSE
• battery_level – %
• need_ charging – battery level under 83% or 97% depending on the setting
• vacuum_cleaner_status – TRUE if any anomalies
• work_program – returns the active program id is_working

doesn't necessarily mean that it is working. It could be in standby because it has finished is daily work.

Actions
• start_charge()
• stop_charge()
• start_work()
• stop_work()
• pause_work()
• set_work_program(p)

is_working and charging_status are pretty similar, however, if the device isn't charging it

Preconditions
• start_charge() – NOT vacuum_cleaner_status AND NOT charging_status AND need_ charging
• stop_charge() – charging_status
• start_work() – NOT vacuum_cleaner_status AND NOT is_working AND battery_level >= 30%
• stop_work() – is_working
• pause_work() – is_working

3.8 Roll-up shutter

The roll-up shutter consumes 290 W if completely opened when it is completely closed and vice versa.

Status
• is_opened – TRUE / FALSE
• opening_level – % - 0, 25, 50, 75, 100
• rollup_shutter_status – TRUE if any anomalies

Actions
• open(x) – open at a certain % regardless the actual open level (e.g. actual = 75%, new = 25%) or open completely if it isn't already completely opened. By default, if an x value is given it will open completely
• close – close completely, if it isn't already completely closed, regardless the actual openness level

Preconditions
• open() – NOT rollup_shutter_status AND opening_level != 100
• open(x) – NOT rollup_shutter_status – if x == 100 the same as open()
• close() – NOT rollup_shutter_status AND opening level > 0

3.9   Thermostat

Usually, temperature is completely managed by the house agent. In large, if there aren't any anomalies, the residents don't interact with the device.

Status
• is_working – TRUE / FALSE
• temperature – actual temperature
• thermostat_status – TRUE if any anomalies
• work_program – returns the active program – winter, spring, summer, autumn

Actions
• start()
• stop()
• set_temperature(t)
• set_work_program(p)

Preconditions
• start () – NOT is_working AND NOT thermostat_status
• stop() – is_working

3.10 Camera

Camera is a passive device; it is not possible to make any kind of actions on it.

Status
• is_working – TRUE / FALSE
• camera_status – TRUE if any anomalies

Actions

Preconditions

3.11 Fridge

The fridge consumes 150 Wh in average.

Status
• is_working – TRUE / FALSE
• fridge_status – TRUE if any anomalies

Actions

Preconditions

3.12 Door

Doors can be opened by the house agent or manually by the residents.

Status
• is_opened – TRUE / FALSE
• is_locked() – TRUE / FALSE
• door_status – TRUE if any anomalies

Actions
• open()
• close()
• lock()
• unlock()

Preconditions
• open() – is_opened
• close() – NOT is_opened
• lock() – NOT is_locked
• unlock() – is_locked

3.13 Sensor

Sensor is a passive device; it is not possible to make any kinds of actions on it. The information below are in common to light sensors, motion sensors used in the bathrooms and audio sensor for voice control.

Status
• is_working – TRUE / FALSE
• sensors_status – TRUE if any anomalies

Actions

Preconditions

4 Metrics

4.1 Cost of electricity

Buying electricity is more expensive during the day. For that reason, when possible the one produced by the solar panel is used.

Segment	Hours	Price
F1	08.00 – 19.00	0.31612 €/kWh
F2 – F3	19.00 – 08.00	0.2519 €/kWh

Produced electricity is sold at 0.15 €/Wh. The overproduced electricity is stored into batteries, when these last are full it is sold.

4.2 Cleaning time

Room	Time (hours)
Entrance	0.25
Kitchen	0.45
Boiler room/Panty	0.15
Living room	0.35
Ground floor bathroom	0.20
Garage	0.25
Ground floor	**2.45**
Landing of the first floor	0.20
Study	0.25
First floor bathroom	0.30
Laundry	0.20
Bedroom	0.35
First floor	**2.10**

5   People and agents

In this section intelligent and autonomous entities in the house are introduced.

5.1   People

The house is inhabited by two residents: Adam and Ashley.

Adam is a software developer. In general, he spends three days per week working from home, while the other two he works in office. He wakes up at 6.45 in the morning and starts to work at 7.30 am. Lunch break is from 01.00 to 01.30 pm and then he works until 4.30 in the afternoon. It may happen that he is away for two or three weeks because of the work. When he goes to the office, he uses the car, in all the other cases the car remains available to Ashley. He does sport three times per week: Monday, Wednesday and Thursday, from 7.00 pm to 8.30 pm.

Ashley is a doctor and she works is the city's hospital. In general, she wakes up at 06.45 am and works from 07.45 am to 05.00 pm with one hour of lunch break. Sometimes she has a night shift, when it happens she spends that day resting and the same for the morning after. She does sport three times per week, but she frequents the gym and she decides week by week when going to train.

Usually, when it is possible, Adam and Ashley have a dinner together. They order pizza once a week, typically on Friday evening. On Saturday, they like to go around doing their hobbies, and the day finishes going out to dinner. They spend at least one weekend per month away from home, having a cultural trip or an excursion. On Sunday, they are used to spend the day with their families or their friends or simply by resting at home.

5.2   Agents

5.2.1   House agent

The House Agent (HG) receives and computes all the information received by the different sensors present in the house (light sensors, motion sensors, cameras, thermostats, etc.). On the basis of the receive data, it decides what action to take and communicates that decision to the selected performer device, or devices.

HG assists the residents in their daily life, by managing most of the processes that should be otherwise handled by them. The tenants can interact with HG simply by saying "Sophie" (the name of HG) followed by the request, by using the tablets present into the house, by using their smart-phone, in which is installed the same application that in installed into the tablets, or even by using the computer present into the study. Every activity is done by trying to minimize consumption and cost.

Some examples of activities that can be handled by HG are:

- turning on/off the heater/cooler;
- opening/closing the roll-up shutter;
- redirecting the produced electricity to the battery or selling it;
- remembering something for the resident, for example if they have an appointment, or if the dishwasher has ended its work;
- taking notes for the resident, for example the shopping list;
- starting processes that involves other devices. Some process are decided from the resident and HG is only an actuator, for example to start the washing machine;
- communicating with the other agents in the house;
- turning on/off the light.

The list could of course go on forever.

Here below a more specific description of some activities is stated.

HG regulates the house temperature based on the period of the year, the outside temperature and the habits of the resident. Although the residents can change the temperature in any moment, with the experience HG is able to satisfy the needs of the residents, which usually doesn't not intervene.

By recognizing the presence of the residents, HG turns on/off the light in the rooms following the movement of them. If one of them is between two rooms, only the nearest lights are switched on. If one resident wants to look inside a room without entering in it, he can just ask HG to switch on the light.

In addition, HG also works as anti-theft, by analyzing all the information received by the other devices. In particular, this activity is done day and night, both if the residents are at home or not. HG decides autonomously if it has to communicate the presence of possible thieves to the residents only or also to the police station.

Although there is just one HG, it is able to have different conversation in different rooms at the same time. For example if Adam is working in the study an Ashley is in the living room, they have different conversation with HG in the same moment. From outside it might seem that there are four different subjects, two for every conversation. On the contrary, if the residents are both in the kitchen and they want to talk with HG, this conversation involves three subjects only.

5.2.2   Robot vacuum agent

The vacuum cleaner (VC) is able to move around the house autonomously, it can ask to HG to open the doors and it performs its task very day. Its week schedule is different from its weekend schedule, because of the habits of the tenants. Just as an example, VC usually cleans the house in the morning but when Adam works from home, it cleans the study during the Adam's lunch break. In addition, it asks HG to close the door of the room that it is cleaning, in that way it doesn't disturb Adam.

VC doesn't receive the amount of information that has been received by HC. Because of that it usually asks the status of the room that it wants to clean before performing the task. For example, sometimes it happens that the residents spend the Saturday night sleeping on the bed-sofa. HG will inform VC about the presence of the tenant, VC then will postpone the cleaning for that room.

VC reacts to the information received by HG but also to what it perceives. For example if it gets in touch with something that is unknown, it reports that to HG and asks him more details in order to understand what could be the best action to be taken.

As mentioned, the house is equipped with two VC, one for the ground floor and another for the first floor.

5.2.3   Fridge

The fridge (F) is able to recognize what is inside itself and what is missing. By analyzing the resident habits, it automatically adds what is missing or what is about to end to the shopping list. If something that turns out to be very useful for the residents might not be early available, maybe because of the upcoming weekend, or some holyday, F will not only add the element to the list, but it will directly inform the residents by notifying it through the application or asking HG to do that.