Autonomous Software Agents

Assignment 1

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1. Introduction

This assignment aims at describing the **domain** for a **smart home** implementation. In this specific case, the problem domain corresponds to the actual layout of the house—broadly described in Section 2 (*House Description and Blueprints*) of this deliverable, and then with a particular focus on each and every room in the following subsections.

To efficiently implement a smart home environment, smart devices become a requirement. Smart devices can range from core and central devices—also referred to as actuators—such as communication *hubs* and *agents*, to peripheral devices taking care of the actual execution of the action.
A more detailed description of how hubs and actuators will be implemented is covered in Section 3.1 (*Hubs and Smart Agents*).

The house layout proposed in this deliverable is inspired by a real household located in Cupertino, Ca. (see *Figure 3* at the very last page of the deliverable), to which some feasibility-driven modifications have been made.
For simplification purposes, each room has smart internal illumination and each outdoor room has smart outdoor illumination.

2. House Description and Blueprints

This section aims at describing the house plan. Two blueprints are provided in the next page to best explain the household layout. The house develops on two floors: namely the *ground floor* and the *first floor*.

The ground floor features a **kitchen**, connected to the **living room** (no door separates the two spaces). The living room, in turn, is connected to the **entrance hall** which faces two more rooms and the entrance door. Connected to the entrance hall is a **washroom** and the **garage** (both separated by a door).
A stairhead—followed by a staircase ending with a small landing—connects the ground floor with the first floor.

The first floor features a **bedroom** and a **bathroom**, both accessible from the staircase landing through regular doors (see blueprint in *Figure 2*). A sliding door allows the bedroom to communicate with a small terrace.
A room-wise description of furniture and their arrangement is provided in the following sections.

2.1. Kitchen

The kitchen room is placed to the far left side of the house. It features essential furniture such as a fridge, a refrigerator, a smart coffee machine, and a two-level island kitchen with cookers and a sink on the lower level, and a raised table on the other. At the bottom of the room lies a four seats dining table. The room features smart lights and smart blinds (see *Figure 1*).

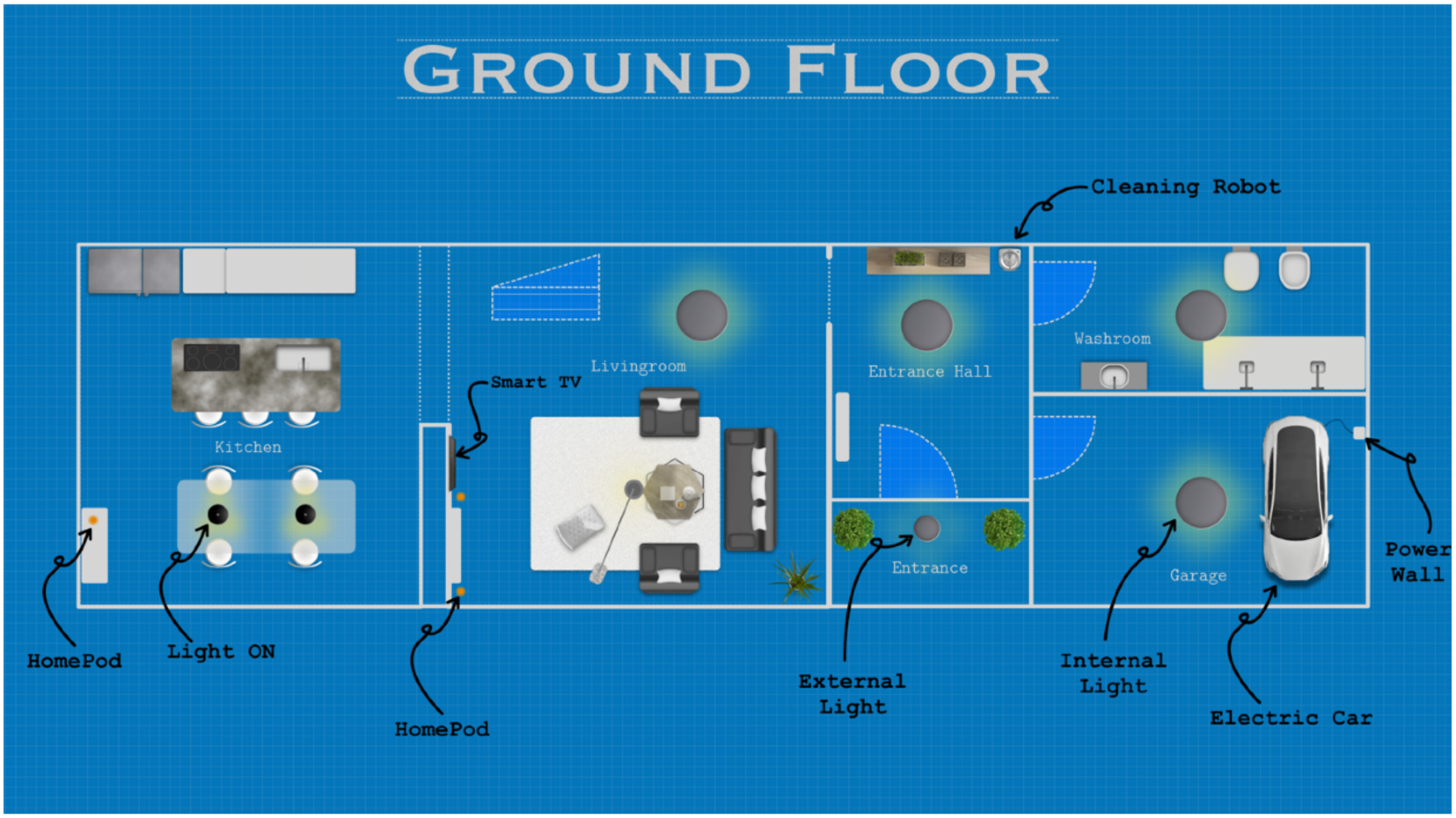

Figure 1: Ground Floor Blueprint

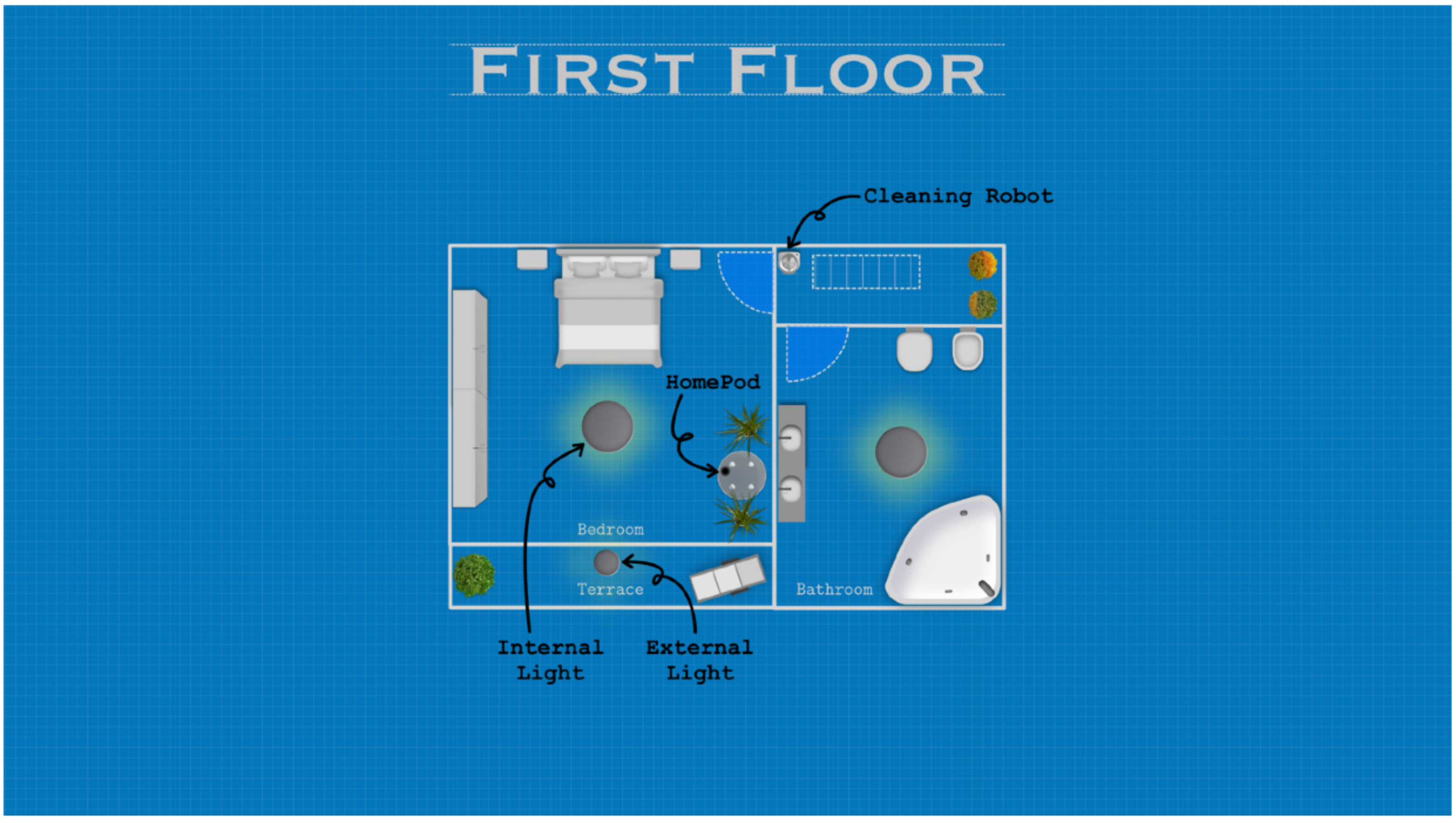

Figure 2: First Floor Blueprint

2.2. Living Room

The living room is usually the space where residents spend the most time in. It features a smart tv attached to the wall, right next to a fireplace. In the center of the room—facing the fireplace and the smart tv—lies a couch, with two large armchairs and an upholstered chair. Providing light to the relax area is a large lamp together with the usual lighting coming from the ceiling. All lights in this room are smart and can be controlled by any hub which, especially for this room, also serve as stereo speakers for entertainment. The fireplace is also smart, and can as well be switched on and off through a hub. There are two large windows on each side of the living room to let natural light in. Each window features a smart blind to limit (or block completely) the amount of light in. At the top left side of the living room there is a stairhead, and then a staircase allowing for residents to reach the upper floor.

2.3. Entrance Hall

Entrance hall is probably the least complex room from the furniture point of view. In fact, the only piece of furniture is a wall element placed right beneath the staircase. However, this room is central for reaching almost any other room in the ground floor. In fact, the entrance hall is connected—through doors—to both the washroom and the garage.

2.4. Washroom

The ground floor washroom is only reachable from the entrance hall through a door. Inside the ground floor washroom are a shower, a toilet, a bidet, a single basin, and a double shower. As well as in any other room of the house, smart lighting (coming from the ceiling) is available for the washroom.

2.5. Garage

Similarly to the washroom, the garage is connected to the entrance hall through a (fire-resistant) door. However, the garage can be accessed through a motorized tilting gate. The latter is also a smart device and can be controlled by any hub. The garage features a wall box to charge an electric car. The garage features smart lights.

2.6. Bedroom

Climbing up the staircase from the living room, there happens to be a landing which gives access to the bedroom and to the bathroom through doors. The bedroom features a kingsize bed with two sided tables, one on each side of the bed. On the lefthand side of the room is a double wardrobe, and opposite to it is a glass table. The bedroom gives access to a small terrace through a sliding glass door. Because also functions as window, it features one of the aforementioned smart roller blinds. The lighting of this room is provided by one of the usual smart lights on the ceiling.

2.7. Bathroom

The first floor bathroom is accessible from the staircase landing through a door. Similarly to the washroom in the ground floor, there is a toilet and a bidet. What is different with respect to the ground floor washroom is that there is a hot tub and a double basin. As well as any other room in the house, the bathroom has smart lights which can be controlled by hubs.

3. Smart Devices

In the following sections we cover each and every smart device installed in the household. Each device has a specific role in the ecosystem, some have central roles (like hubs), and some others have marginal roles (like lightbulbs). All devices are properly configured to communicate with the core device: a hub—in this particular case there is more than one, and are HomePods **[1]**—which is able to interact with peripheral devices. A hub can be thought as a mean for the house agent to tell what actions peripheral devices should take based on the state the current environment is in. In turn, each state is determined by sensors, or a time variable. For example, the hub will send a `turn_off` signal to the entrance light (peripheral device) whenever the clock (time variable) says it is between 8am and 6pm. Actions and states for each smart device are summed up in *Table 1*.

Device	State
Light	`light_on` `light_off`

Shutter	`shutter_open`
	`shutter_close`
	`shutter_dim`

Anti-intrusion System	`all_inside`
	`all_outside`
	`alarm_off`

Table 1 — Possible States for lighting smart devices.

3.1. Hub and House Agent

HomePods and are placed strategically around the house making it easy for the residents to call on the vocal assistant from anywhere. Specifically—in the ground floor—one hub is placed in the kitchen, two more are placed in the living room (they also serve as stereo speakers for entertainment purposes). As for the first floor, one HomePod is placed in the bedroom to conveniently control smart accessories also from the upper floor .

Taking decisions based on given scenes is a **house agent**. The house agent aims at **minimizing total costs**, meaning that the agent is able to keep track of consumption of each peripheral smart device's consumption, and smartly schedule scenes based on such consumption. Decisions that the house agent can take in order to minimize total costs might be of two different natures: *dynamic* (based on the situation the household is currently in), and *systematic* (commands that recurrently happen based on some time window)—also referred to as *scenes*. An example of a dynamic decision is: if no residents are detected in the surroundings of the house during the day, the agent will turn on the anti-intrusion alarm, turn off all lights, reduce the house temperature, and close all shutters.

An example of a scene is the following: knowing that in working days residents are away from 8am to 6pm, the house agent will turn off the lights, close the shutters, activate the anti-intrusion system, and—if sunny—run household appliances in a smart way to best exploit the energy produced by solar panels.

3.2. Lighting System

House lighting is under control at any hour of the day. In fact, the house features a smart lighting system for darker hours as well as a twofold **electric blinds** system. By 'twofold' I mean that electric blinds can be used either as actual *blinds* (letting partial natural light in) or as roller *shutters* (letting no natural light in at all). Blinds' `open`, `close`, and `dim` state for each room is controlled through set scenes that are triggered under specific conditions or—alternatively—by using vocal commands through HomePods. The artificial lighting system can take two states: `light_on` and `light_off`. Each internal artificial light consumes up to 7W, whereas outdoor artificial lights consume up to 5W each. If all lights are turned on, the total energy consumption ascribable to lighting is 66W, which can be round up to 70W to ease out calculations.

3.3. Wall Box

As mentioned in Section 2.5 (*Garage*), inside the garage a wall box for charging an electric car is installed. Let us suppose the car has a 75kWh battery **[2]**, and the maximum power coming out of the wall box outlet is 7kW **[3]**. This means that the car can be charged from 20% to 100% in roughly eight hours and a half.

3.4. Solar Panels

A set of three solar panels are installed on the roof. The amount of electricity each panel can produce is 3kWh **[4]**, allowing for the household to produce a total of 9kWh from 8am to 6pm. Such an amount of electricity makes it possible for the car to charge at a power of 7kWh, leaving 2kWh to keep all other services (such as fridge, washing machine, tv, etc.) running. If household appliances required more than 2kWh of power, then should the house agent take care of it by limiting the electric car charging speed.

3.5. Anti-intrusion System

An anti-intrusion system is installed in the house. It can communicate and interact with the hub as well as any other smart device the household owns. There are two types of sensors: **motion** sensors—installed in each and every room—and lock sensors—installed in every perimetrical door and window. The system takes three states in total (see *Table 1*), namely `all_inside`, `all_outside`, and `alarm_off`. The first state activates all the perimetrical sensors leaving only the motion sensors inside deactivated. The second state activates all the sensors (both the internal and the external ones). The latter state implies that all sensors are turned off.

3.6. Cleaning Robot

The household owns two cleaning robots in total: one takes care of the ground floor, and the other is meant to clean the first floor. The choice of having two separate robots is somewhat related to the fact that cleaning robots are yet not able to climb stairs. Each robot has its own charging point conveniently placed at the entrance hall (for the ground floor) and at the stair landing of the first floor. Both robots have built-in sensors to prevent falling down the stairs, and are able to avoid getting stuck in cramped spaces. Furthermore, each robot can autonomously perceive its battery life and go back to base whenever needed. The vacuum cleaner undergoes classic physics limitations, meaning it cannot pass through a closed door—hence will not be able to clean that specific room.
We assume that each vacuum cleaner can clean an entire floor on a single charge.¶

Table 2 contains the amount of time the vacuum robot requires to clean each room.

Floor	Room	Time
Ground Floor	Kitchen	10m
	Living Room	25m
	Entrance Hall	4m
	Washroom	3m
	Garage	20m
Total		1h 2m
First Floor	Bedroom	10m
	Bathroom	8m
Total		18m

Table 2 — Time required for each room to be cleaned.

4. Residents

Intuitively, the household takes two residents—a couple for instance. On weekdays (Mondays to Fridays) both residents are away for work, the woman leaves home at 7am and gets back at 3pm, whereas the man leaves home one hour later but gets back home at 6pm. Both residents have one car each, the man's car is electric whereas the woman's car is a gas one. Because the man's car is electric, he needs it charged at at least 80% by 7am. On the weekends (Saturdays and Sundays) both residents are in the house, but occasionally go on vacation on Sundays. For this reason the electric car needs to be fully charged by Sunday morning.

5. Metrics

Table 3 shows what are the metrics considered in this project:

Supply	Cost
Electricity	0.30 €/kWh
Gas	0.90 €/ssm

Table 3 — Cost of supplies. Data have been averaged over the last 3 years to best reflect the behavior of prices in the near future.

Price of electricity and gas supplies come from LuceGas **[5]** and Mercato Libero **[6]** respectively.

All appliances are thought to be electric (induction cookers included), apart from the smart fireplace which needs to be fed with gas. Because the heating (and cooling) system is a heat pump, no gas-fired boiler is needed.

6. Bibliography

[1] AppleStore
[2] Ev-database
[3] Tesla
[4] EnergySolutions
[5] LuceGas.it
[6] Mercato Libero

Figure 3: The house in the blueprints is actually inspired by a real one. This photo shows one of the real houses used by Apple Inc. to demonstrate their products.