University of Minho
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Project: Report

Marketing Digital Outdoor with gesture interaction — Analysis

Group 8

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List of Abbreviations

Notation	Description	First used on page nr.
CSI	Camera Serial Interface	4
DC	Direct Current	2
GPIO	General Purpose Input/Output	1
HDMI	High-Definition Multimedia Interface	1
HW	Hardware	1
mA	milliampere	2
MDO-L	MDO Local System	6
MDO-RC	MDO Remote Client	7
MDO-RS	MDO Remote Server	7
PoE	Power over Ethernet	2
SoC	System-on-a-Chip	1
SW	Software	7
TTL	Transistor-Transistor Logic	2

1. Design

In this section the theoretical foundations are used to design a viable solution, accordingly to the requirements and constraints listed. In the design phase, the product development starts, specifying the system in terms of hardware and software and its associated interfaces, the error handling required, and the design verification.

1.1. Hardware specification

The first step for system design is the HW specification. This can be pictured as a block diagram, this block diagram was already shown and mentioned in section **??** on Fig. **??**. Now, it's time to specify all the HW for each block.

1.1.1. Main Controller

The main controller was also previously mentioned because it makes part of one of the requirements of this project: use the Raspberry Pi 4B (Fig. 1.1). This System-on-a-Chip (SoC) has several of specifications [1]:

- Processor: it has the Broadcom BCM2711 processor, quad-core Cortex-A72 (ARM v8) 64-bit with 1.5GHz;
- Memory: this model has 4GB LPDDR4 with on-die ECC;
- Connectivity: it has a 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN, Bluetooth 5.0 with low energy, one Gigabit Ethernet port, four USB ports in which two are 3.0 and another two are 2.0;
- GPIO: it has a standard 40-pin General Purpose Input/Output (GPIO) header that is fully backwards-compatible with previous boards;
- Video and Sound: it has two High-Definition Multimedia Interface (HDMI) ports that support up to 4kp60, a 2-lane MIPI DSI display port, a 2-lane MIPI CSI camera port and a 4-pole stereo audio and composite video port;

- Multimedia: H.265 (4Kp60 decode), H.264(1080p60 decode and 1080p30 encode) and OpenGL ES 3.0 graphics;
- SD card support: Micro SD card slot for loading operating system and data storage;
- Input power: it has 5V Direct Current (DC) via USB-C connector (minimum 3A), a 5V DC via GPIO header (minimum 3A) and Power over Ethernet (PoE) - enabled (requires separate PoE HAT);
- Environment: it has a range of operation between 0°C and 50°C.

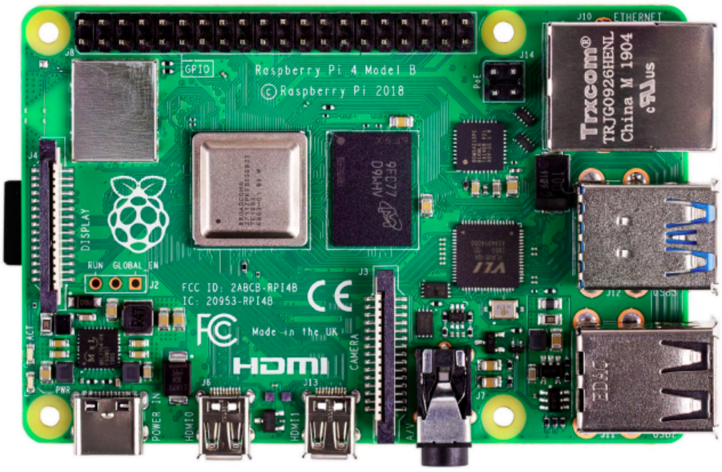

Figure 1.1.: Raspberry Pi model 4B

1.1.2. Motion Detection

For the motion detection, it was already mentioned in section **??** that the best option is to use an ultrasonic sensor. Thus, the sensor that has been chosen is the **HC-SR04 Ultrasonic Sensor**. This sensor has the following specifications [2]:

- Operating Voltage: 5V DC;
- Operating Current: 15 milliampere (mA);
- Operating Frequency: 40 KHz;
- Maximum Range: 4 meters;
- Minimum Range: 2 centimeters;
- Ranging Accuracy: 3 millimeters;
- Measuring Angle: 15 degrees;
- Trigger Input Signal: 10 microseconds Transistor-Transistor Logic (TTL) pulse;
- Dimension: 45 x 20 x 15 millimeters.

Sensor Pinout

In Fig. 1.2 is described the sensor pinout and each pin works as follows [2]:

1. is the power supply for HC-SR04 Ultrasonic distance sensor which we connect to a 5V supply (for example, 5V pin on Raspberry);
2. pin that is used to trigger the ultrasonic sound pulses;
3. pin that produces a pulse when the reflected signal is received. The length of the pulse is proportional to the time it took for the transmitted signal to be detected.
4. pin that should be connected to the ground (for example, GND pin of the Raspberry).

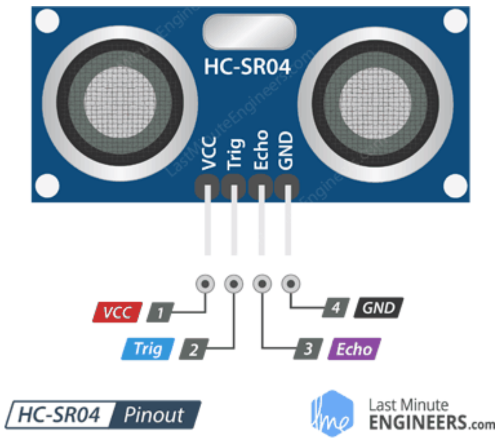

Figure 1.2.: HC-SR04 Pinout (withdrawn from [2])

For this project it will be used three sensors, one placed on the bottom, another on the middle and another one on the top of the machine. With this setup, it can be avoided some perturbations like an animal walking in front of the machine (only the bottom sensor will detect). The disposition of the middle and top sensors can't be too high, because of short people, for example.

1.1.3. Fragrance Diffusion Actuator

The chosen fragrance diffusion actuator is in Fig. 1.3 and has the following specifications [3]:

It has an operating voltage of **5V DC** and an operating current of **300 mA**. The operating power is **2 Watt**. It has a fixed frequency single-chip microcomputer with a frequency of **108 KHz**. The dimensions of the board of the module are **35 * 20 * 17 millimeters**. It has a **strong versatility**, large amount of fog, **stable performance**, the chip has an automatic timing shutdown function (4 hours of continuous work will automatically shut down protection, to turn on again, press the power on again). The 5V USB power supply mode, can be powered by MICRO charging cable. The net diameter of the atomized steel sheet is 16 millimeters, the outer diameter of the silicone ring is 20 millimeters, and the wire length is 8 centimeters.

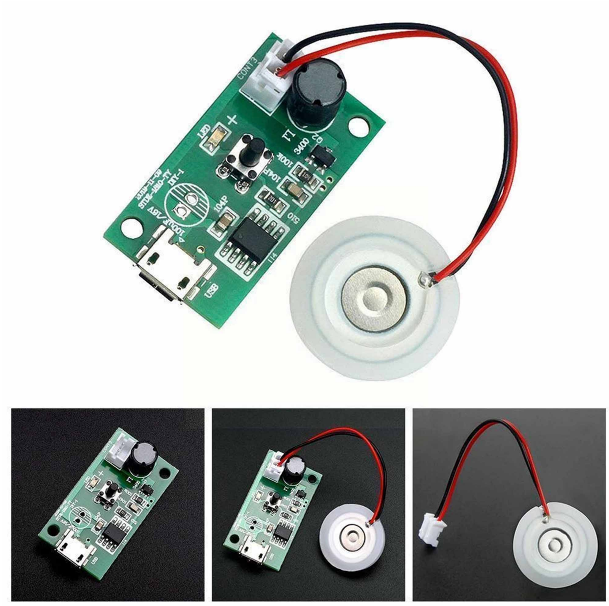

Figure 1.3.: Fragrance module (withdrawn from [3])

1.1.4. Camera

The camera to use in this project needs to be compatible with the board in use, in this case, the Raspberry Pi. Thus the camera module that is used is the **Raspberry Pi Camera Module V2** (Fig. 1.4).

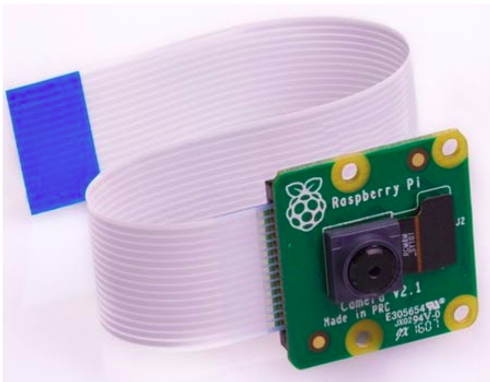

Figure 1.4.: Camera module (withdrawn from [4])

This camera module has a **Sony IMX219 8-megapixel sensor** and can be used to take high-definition video, as well as stills photographs. It supports 1080p30, 720p60 and VGA90 video modes, as well as still capture. It attaches via a 15 centimeters ribbon cable to the Camera Serial Interface (CSI) port on the Raspberry Pi. The camera works with all models of Raspberry Pi 1, 2, 3 and 4. It can be accessed through the MMAL and V4L APIs, and there are numerous third-party libraries built for it, including the Picamera

Python library. [4].

1.1.5. LCD Display

In Fig. 1.5 is the display that is used in this project. One advantage on this display is that it has **audio drivers**, which means that it is only necessary to plug a speaker and the board can handle the rest. It is also important to refer that the display isn't touch because there is no need to it and also this was the chosen one because it was the bigger and best on market considering quality and price.

As it can be seen, the display has **10.1 inches** and it is supplied with **5V DC** and with a current of **2 A** via a micro USB port. Fig. 1.6 show all the interfaces that the board module of the display provides. That was also one more reason for the choice of this display: it has an **HDMI interface** to connect to the Raspberry, the **50Pin TTL Screen Interface** that will connect to the display and two options to plug audio - the **Speaker Interface** and the **3.5mm audio interface**.

Figure 1.5.: Display (withdrawn from [5])

It can also be seen in this figure that the display has also a remote and a board to handle the remote controls, but in this implementation, it will probably not be in use.

1.1.6. Speakers

When playing video ads, it is not only necessary a display, but also a speaker to playback the sound of the ads. As it can be seen in Fig. 1.6, the screen board has two different interfaces of audio: the speaker

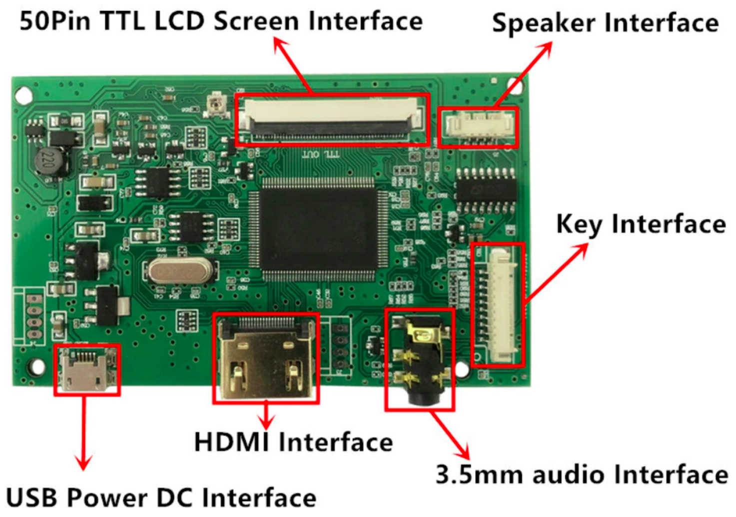

Figure 1.6.: Display Interfaces (withdrawn from [5])

interface and the audio interface. For this project it will be used speakers that uses the speaker interface, because that type of speakers with that interface are passive speakers and don't need a DC power supply, which is an advantage [6].

Thus, the speakers that will be used have an impedance of 8 Ohm and a power of 5 Watts and are displayed on Fig 1.7.

Figure 1.7.: Speakers (withdrawn from [7])

1.1.7. Power Supply

The MDO Local System (MDO-L) will be a plugged in system, so it will be needed a plugged in power supply to supply all the components of the system. In total, the power consumption will not overtake 20 Watts and all the supplies necessary are plugged by USB (Raspberry Pi, Fragrance Diffusion Actuator, and screen). So, it will be used the power supply in Fig. 1.8, that has 4 outputs of 5 V DC and 2.4 A DC each.

Figure 1.8.: Power Supply (withdrawn from [8])

1.1.8. Total HW cost

The total HW cost can now be precisely calculated, once that all the hardware is now specified on table 1.1, yielding about 175 EUR.

Table 1.1.: Total spending on Hardware

Item	**Quantity**	**Price (€)**
Raspberry Pi 4B	1	70.00
Ultrasonic Sensor HC-SR04	3	11.70
Fragrance Diffusion Actuator	1	3.23
Raspberry Pi Camera V2	1	20.00
LCD Display	1	51.95
Speakers	1	3.00
Power Supply	1	13.50
	Total	**173.38**

1.2. Hardware interfaces definition

1.3. Software specification

Next, the SW responsible for system operation is specified for all subsystems — **MDO Remote Client (MDO-RC)**, **MDO Remote Server (MDO-RS)**, and **mdo-l**. All these subsystems are event-driven (asynchronous), and they can be more easily specified using state-machine diagrams, previously illustrated in the analysis phase (Section **??**). Also in the analysis phase, the use case diagrams helped to identify the main features required for the system and the respective sequence diagrams helped to clarify the intervening objects and the interaction among them.

In this section, the analysis phase information is used to derive the static architecture of the system — classes diagram — and to specify algorithms for its implementation through flowcharts, keeping in mind that the several subsystems operate multiple tasks concurrently, thus requiring the tasks' specification and its priorities. The data frame formats are specified for communication between the different modules. The Entities-Relationships diagram (ERD) are depicted to design the required databases and the User Interface (UI) mock-ups are recalled. The test cases for each subsystem are listed, defining its operation and the expected result. The Commercial off-the-shelf (COTS) SW and the third-party libraries are identified and a mapping between class topics and the foreseeable implementation is presented for clarification. Finally, the SW tools are listed.

1.3.1. Software architecture

The system's SW architecture was devised using Unified Modeling Language (UML) component diagrams for **Remote Client** (Fig. 1.9), **Remote Server** (Fig. 1.10), and **Local System** (Fig. 1.11). Each component diagram illustrates all SW components for the system in analysis and the interaction between them, and its interfaces with external subsystems.

Remote client

The **Remote Client** SW architecture is comprised of the following artifacts:

- **User Interface** package:
- **Comm Manager** package:
- **DB Manager** package:

- Remote Controller package:
- RC Rx Parser component:
- Transmission Control Protocol/Internet Protocol (TCP/IP) Tx socket:
- TCP/IP Rx socket:

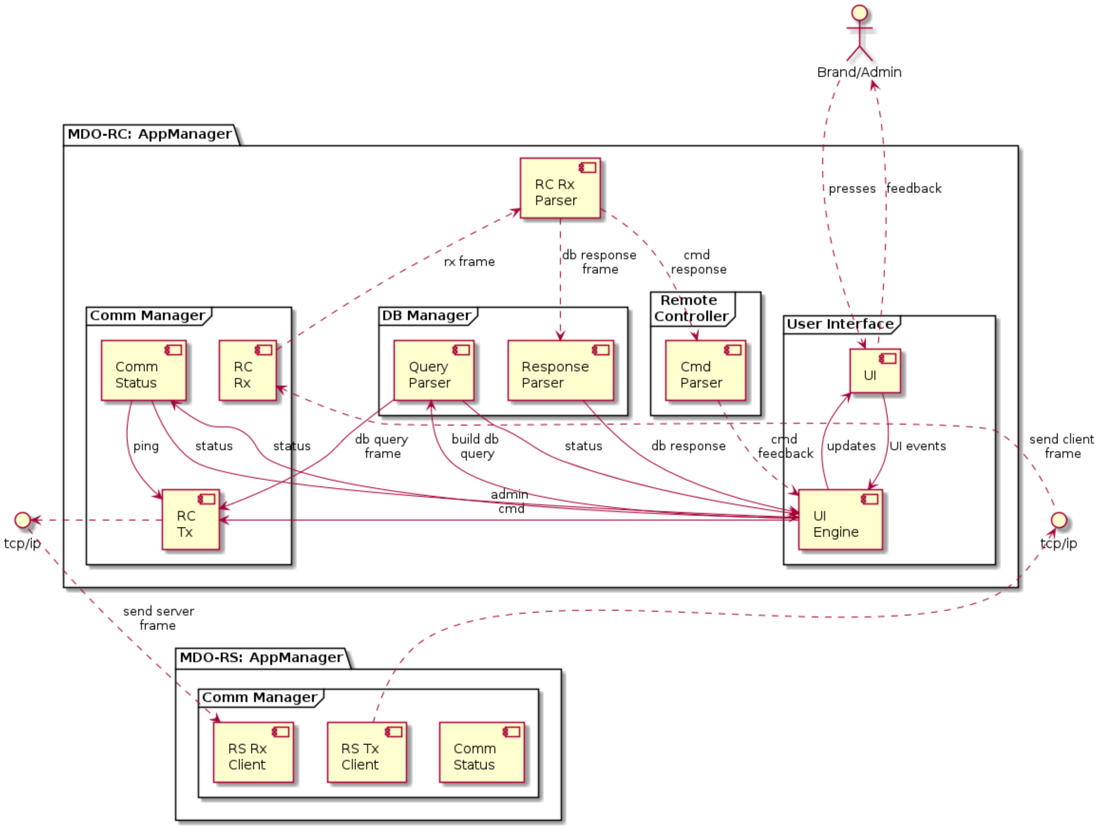

Figure 1.9.: SW architecture: component diagram — Remote Client

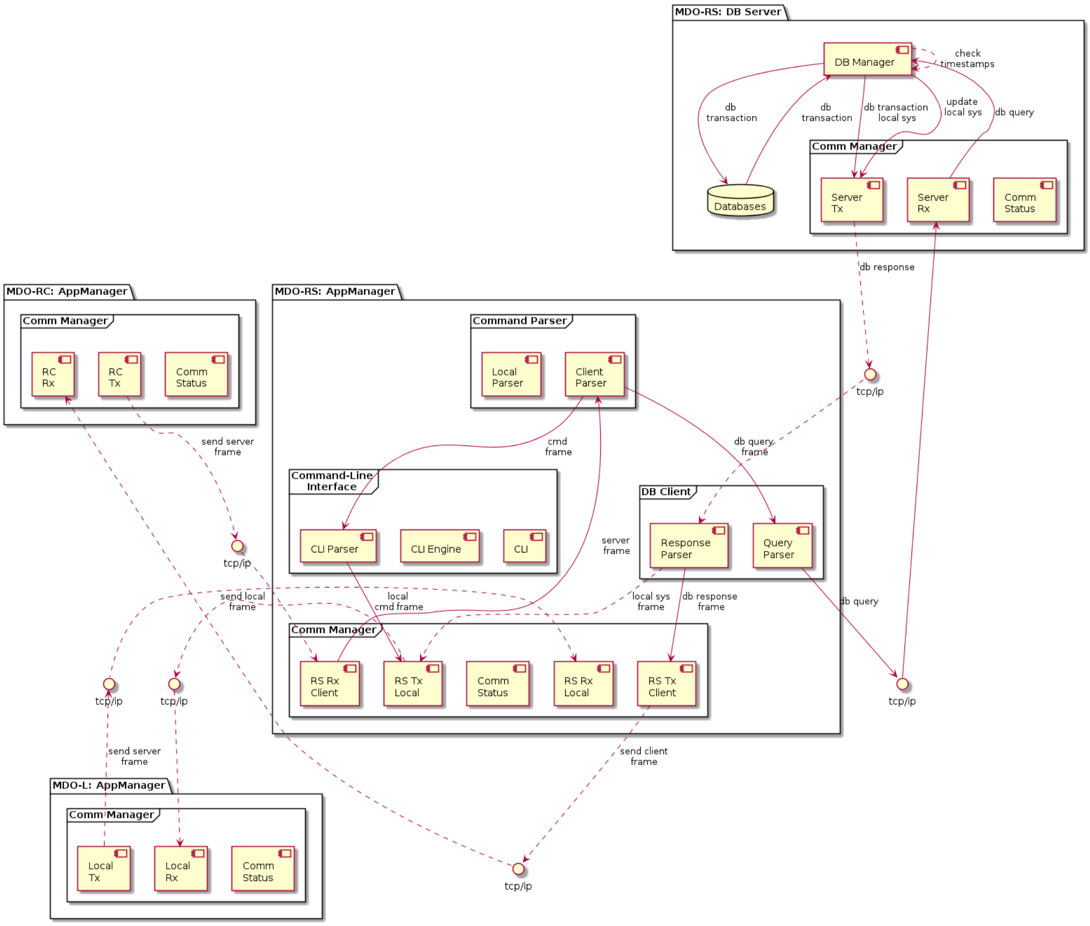

Figure 1.10.: SW architecture: component diagram — Remote Server

Remote server

Local system

1.4. Software interfaces definition

1.5. Start-up/shutdown process specification

1.6. Error handling specification

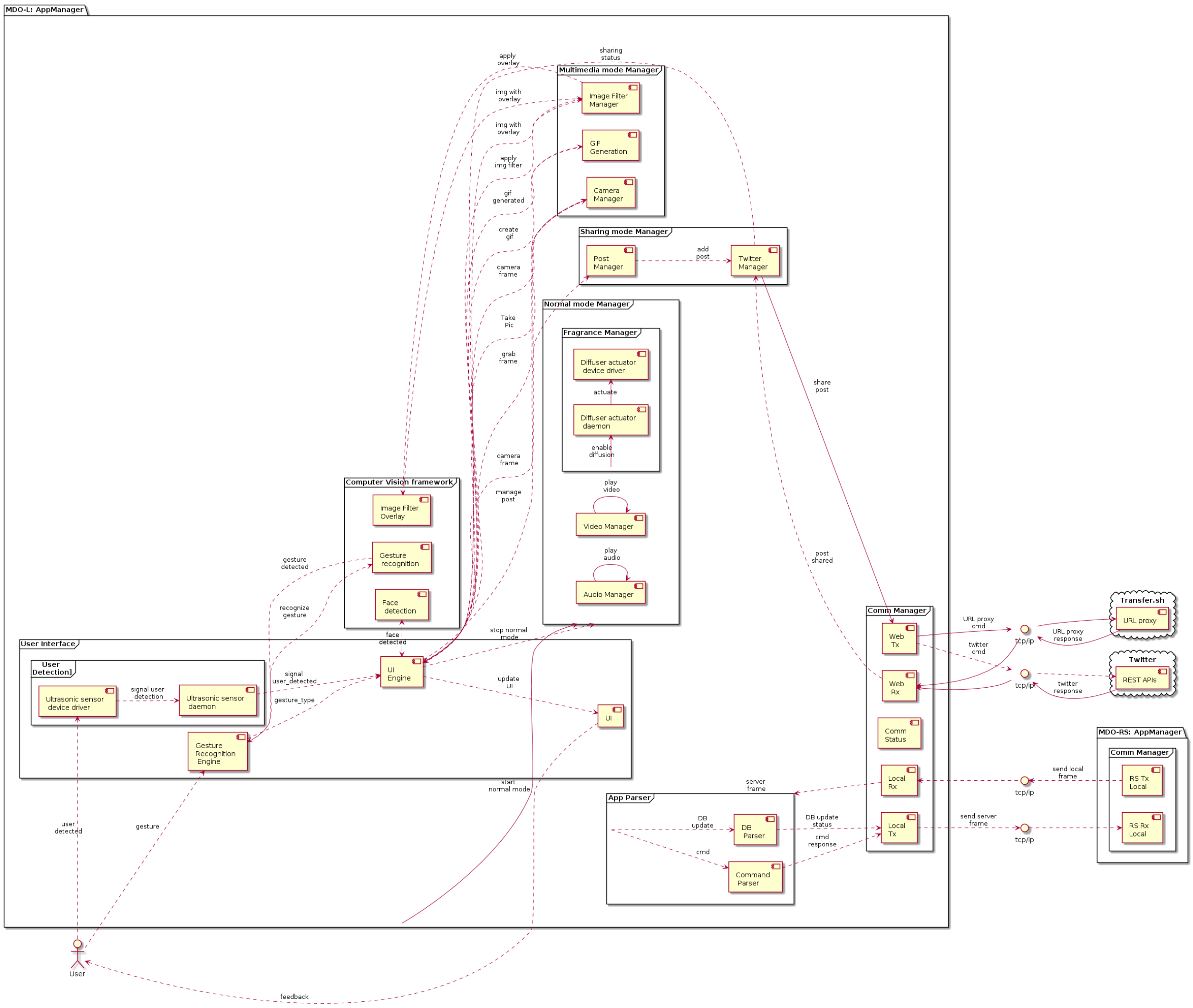

Figure 1.11.: SW architecture: component diagram — **Local system**

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Appendices

A. Project Planning — Gantt diagram

In Fig. A.1 is illustrated the Gantt chart for the project, containing the tasks' descriptions.

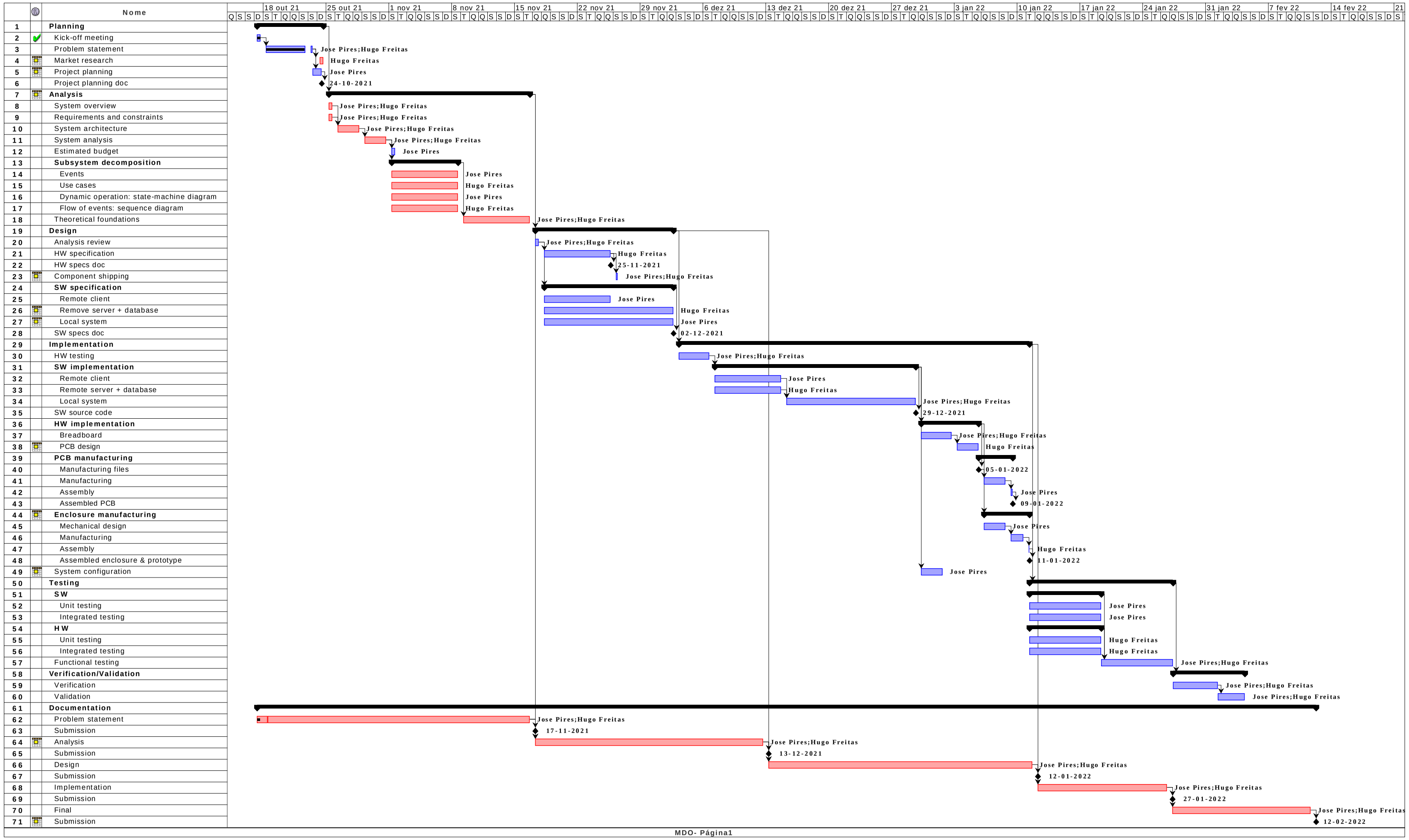

Figure A.1.: Project planning — Gantt diagram