FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

LuSiTa System's concept

Systems Engineering

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March 10, 2023

Contents

List of Figures

Abbreviatures used on table columns

F	Functional
MR	Marketing Requirements
NF	Non-Functional
P	Priority

Chapter 1

Introduction

1.1 Document Introduction

This document provides an overview of the system's concept for LuSiTa, a smart lamp designed to track the market cost of electricity. The purpose of this document is to explain the system and its subsystems, and to demonstrate how our team plans to develop the system to meet the defined requirements.

The document begins by describing the project's overall goal and what our team aims to achieve upon completion of the system. We will also list the functional and non-functional requirements that were defined for the project to provide an understanding of the system's scope and constraints.

We will then explain the system's design and hardware components to demonstrate the features of LuSiTa. We will highlight the benefits of LuSiTa, such as real-time monitoring of energy consumption and the ability to adjust energy usage to reduce costs.

Overall, this document provides a concise overview of the LuSiTa system and its subsystems, providing insight into the project's objectives and the system's features. We hope that this document demonstrates how LuSiTa meets the requirements defined for the project and provides a clear understanding of its functionality.

1.2 Description of the Project

LuSiTa is a highly portable lamp, able to change its light colour depending on the cost of electricity, being configurable by the user.

The lamp offers the possibility of tracking the electricity market price, depending on the tariff of the user.

This is done with the possibility of using a smartphone app or by directly accessing the database that provides all the information.

This lamp is useful to keep track of electrical consumption and to help to adjust your energy habits in a world where energy security is ever more important. Coupled with the fast track towards green energies, LuSiTa can be a great ally in this transition.

Chapter 2

Market Survey

With the intent of furthering our requirement list, it was made a preliminary market survey to investigate the market and what components are available to use in this project. It was decided that the components should be divided into the following main categories.

2.1 Light

For the light components, it was decided that it should be a light made from scratch. With that in mind, the market survey was focused on finding LEDs suitable for a programming environment.

Pursuant to this, the WS2812B LEDs were the best option found in this research. The WS2812B is an intelligent control RGB LED light source that can be individually addressable and dimmable. Furthermore, it is compatible with Arduino, Raspberry Pi, ESP32 and smart WIFI controllers, which allows you to have a wide range of options when it comes to controllers.

On the other hand, a simple RGB led could also contribute to this project since they are simpler to program and are compatible with many controllers connected with a PCB where it can be soldered.

Some other information about the research for these components can be found in the following table:

Name	Link	Advantages	Disadvantages
WS2812B LED strip	https://tinyurl.com/jjtcc87b	• Compatible with many controllers. • It doesn't need to be soldered to a PCB. • Can be cut or bent and still be usable. • Higher Brightness.	• More expensive than the other options. • It can be hard to program the LEDs individually.
WS2812B LEDs (individual format)	https://tinyurl.com/ywfw7y4x	• Compatible with many controllers. • More affordable. • Higher Brightness.	• Needs to be soldered to a PCB or similar.
Simple RGB LEDs	https://tinyurl.com/4k6jt6cx	• Compatible with many controllers. • More affordable.	• Lower Brightness • Need to be soldered to a PCB or similar.

2.2 PCB

The PCB market survey was focused on finding companies that provide affordable and flexible products that would still maintain their quality and that could be designed specifically for the

needs the project requires.
With that in mind, the following options were chosen:

Name	Link	Advantages	Disadvantages
Aluminum round PCB	https://tinyurl.com/5y8p3m33	• Can be customized. • More affordable.	• Inflexible at component choosing
RGB LED Controller Circuit	https://tinyurl.com/bdzy9hzv	• Could facilitate the design since it already has LEDs.	• Doesn't have enough LEDs. • Designed only for Arduino AVR Arm
Pierced Circuit Board	https://tinyurl.com/bdda4p8t	• Can work with any type of components. • More affordable. • Flexibility in size. • Facilitates the fixing to the lamp structure.	• It needs to have wire welded to it.

2.3 Microcontroller

The microcontroller is an essential part of the project, as it is responsible for commanding the LED's according to the data received, switching the lamp's modes and presenting information on the display.

Considering this, two options were found: a Raspberry Pi Pico W and an ESP32-C3-32S.

Name	Link	Advantages	Disadvantages
Raspberry Pi Pico W	https://tinyurl.com/3mkszpxw	• Wifi protocol • Has own SDK • Slightly more affordable • Has low power mode	• Less flash memory (2Mb) • No Bluetooth
ESP32-C3-32S	https://tinyurl.com/yc5xc2vf	• Wifi and Bluetooth protocol • Has low power and sleep mode	• Has no SDK

2.4 Power supply

The power supply market survey was done with one major goal: to have the most long-lasting (but still affordable) battery that could maintain the lamp on, while respecting the portable requisite. Two scenarios were considered, a power supply of 5V, and another of 12V, in case LEDs with this voltage were chosen.

The options found are stated in the following table:

Name	Advantages	Disadvantages
Power bank	• Can be used as 5V or 12V voltage supplier. • Has 10000mA of capacity, being the most long-lasting option for the lamp.	• Needs a power transistor to increase the current flowing to the LEDs.
Rechargeable lithium battery	• More environmentally friendly. • Cheaper than power bank.	• Lasts less than power bank • Needs soldering • Smaller current capacity than the power bank
Lithium battery	• Easy to manage as people are costumed to this option.	• Lasts less than previous options • Needs a case to house the battery, which means more costs • Lowest capacity of all options (1100mA)
12V supplier with lithium batteries	• Can supply to 12V LED's	• The cable needs to be altered to fit the circuit • The most expensive option • Requires a voltage stabilizer to power the microcontroller

2.5 Competitor products

For this project, a market analysis was made in order to know other competitors and similar products.

A lengthy investigation was made, in order to ascertain said competitors and to create awareness in the team about what kind of product already exists, its features, design and applications in real life. After long research, it was concluded that there are no similar products, where a lamp changes colours based on the price of energy. Therefore, LuSiTa is a unique and innovative product in the market.

Chapter 3

System requirements

3.1 Market requirements

1. LED signal lamp with multicoloured control with high portability.
2. Built-in clock control for viewing future price signals.
3. Wireless communication, to update the price.
4. Remote platform, for generating price signals with various possibilities and saving previous values. (Configurable multi-hour tariffs, dynamic MIBEL market prices, price signals with photovoltaic self-consumption optimization, price signals generated by local markets of renewable energy communities).
5. Lusita's commercial cost must not exceed €50.
6. Budget for the prototype of 250€.
7. Enough brightness.
8. Compatibility: The lamp should be designed to work with standard electrical outlets.
9. Energy Efficiency.
10. Low Maintenance.
11. A user interface that is easy to navigate and capable of showing the level of battery, the tariffs for multiple time rates, and set thresholds defined by the user, as well as customized notifications and colour of the lamp for each price.
12. The material of the lamp should be resistant to damage.
13. Switch to turn on and off.

3.2 System requirements

MR	Requirements	Justification	P	F/NF
1, 3	1. System will implement colour-changing functionality: The lamp will change its colour based on the current price of electricity.	This functionality will give users information on the current price of electricity by associating the price to the colours.	H	F
2, 3, 4	2. System will provide data display: The lamp will have a display that shows data about electricity prices, pricing schedules and lamp function modes.	This functionality provides an interface that shows the user lots of relevant data.	H	F
1, 7	3. System can adjust brightness: The lamp should have adjustable brightness settings that allow users to customize the level of illumination.	Users can adjust the brightness as they wish.	M	F
8	4. Compatibility: The lamp should be designed to work with standard electrical outlets.	Compatibility is essential to let the system work correctly.	H	NF
1, 9	5. Energy Efficiency: The lamp should use low-power LED technology to reduce energy consumption.	Reducing energy consumption is important to help users save money, resulting in a longer-lasting battery.	H	NF
3	6. Wireless Connectivity: The lamp should be able to receive data and be configured wirelessly	This would improve user friendliness and configurability of the lamp.	H	F
2, 4	7. Automated Scheduling: The lamp should have an automated scheduling feature, allowing users to set it to turn on and off at specific times.	An automated scheduling can help users to save energy consumption.	M	F
10	8. Low Maintenance: The lamp should be designed for low maintenance, with minimal cleaning and maintenance required to keep it working properly.	Low maintenance helps users to save some work.	M	NF
2, 4, 11	9. Intuitive User Interface: The lamp should have an intuitive user interface that is easy to navigate and use, even for those with limited technical knowledge.	User interface should be intuitive so everybody can use it easily.	H	NF

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Table 3.0: (Continued)

3, 4	10. Connectable to a configurable database with information about the electricity cost with data from previous and future prices.	This would let the user prepare for future prices and compare them with past values.	H	NF
3, 4	11. Access point connectivity to configure the lamp's wifi with the support of a third-party app.	This functionality provides users with an app to configure the lamp.	M	F
1	12. The lamp should be highly portable, lightweight and small.	Users can move the lamp to wherever they want.	H	NF
2	13. A countdown timer to show the next update.	System will provide a countdown timer so users can know when the next update will be.	L	F
5	14. The commercial price can not exceed 50 euros (counting profit).	The commercial price can not exceed 50 euros so it is accessible to anyone.	H	NF
11	15. Alert the user of low battery level.	The system will alert the user that the battery is low, so the user can charge it beforehand.	M	F
4, 11	16. The system should have different tariffs and configurable time schedules.	This makes the system compatible with any type of standard tariff, with little user input.	H	F
8	17. The lamp should be rechargeable. The process to recharge should be to simply connect a charger to the lamp.	No rechargeable system can help the user to save money.	M	NF
1, 12	18. The lamp shell should not be made out of any brittle material (glass, for example) that could be easily damaged in transport.	Brittle material can break easily and be dangerous for the user.	H	NF
3, 13	19. The lamp should have a simple, mechanical on-off switch.	This improves user friendliness and allows for long periods without usage and consumption.	M	NF

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Table 3.0: (Continued)

11	20. User-defined thresholds: Allow users to set their own price thresholds for when the lamp should change color. This gives users more control over the lamp's response to electricity prices.	This functionality will allow users to associate the colour to the price as they prefer.	M	F
11	21. The lamp should have a mode that shows what sources the energy is coming from. Each energy source would have a colour associated with it.	The user will be informed of what sources the energy is coming from, so the user can decide to use it or not.	L	F
4, 11	22. Customizable notifications: Allows users to set up custom notifications for electricity price changes when prices exceed a certain threshold.	The notifications can alert the user of price changes in electricity.	L	F
1	23. The system could have different colour gradients. There are different colours of grid consumption in a day: peak time, standard consumption time, and lower-priced time (which is the best time for using high-consumption devices).	This functionality will inform users which period of grid consumption of the day is.	L	F
4	24. The database should store previous (or following) energy prices so the user can check the actual values at will.	If the user wants to check previous energy prices, it can be checked in the database.	L	F
3, 4	25. Depending on the mode (tariff) of the lamp, there will be a different refresh rate, different resolution and different prediction time span.	This functionality will provide the user with the price of the moment, according to the tariff.	H	F
1	26. To provide mobility the lamp should function without being connected to an outlet for 6 hours.	The lamp should last for 6 hours without being recharged, to provide mobility without worrying that the battery will run out.	H	NF

Chapter 4

System's structure breakdown

Our system's main sections, level 0, are the lamp and the Database. Both are part of the overall product that LuSiTa offers. The database can be considered part of the product while its subcomponents are better defined as a process.

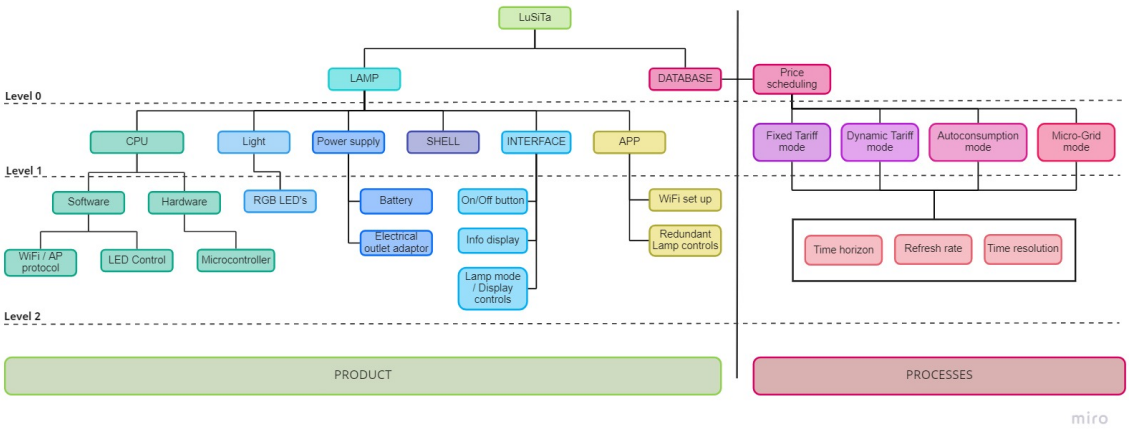

Figure 4.1: System's structure diagram

Regarding level 1 subsystems, most are self-explanatory. The shell is just the physical casing for the lamp. While the app (smartphone app) is an external feature (on the user's smartphone) that allows him/her/they to interact with the lamp. This component does not exist without the lamp, so although it is not part of the lamp itself, it is a subsystem of it. This app will not be constructed by us, but it will most likely be a third-party app, designed for IoT purposes.

With respect to level 2 subsystems, again most are self-explanatory in the case of the product. However, looking at the processes, we can elucidate on the 3 boxed sub-components. These are 3 aspects we must consider and model for each of the level 1 processes. Time horizon refers to the length of time a pricing prediction for a tariff is made. So, the pricing is set for 1 week, one-month etc... This sets the limit for how further in the future the user can look for energy prices. Refresh rate refers to the frequency at which the tariff prices change, so the price might not be fixed, and change every day around midday. This means that, if we want to provide the current price, we

need to know when the change occurs. Finally, the time resolution refers to the smallest interval a prediction is made for, so if the price is defined in 15-minute intervals, 30 minutes, 1-hour, and so on.

Chapter 5

Functional Architecture

The LuSiTa table lamp is an intelligent solution for optimizing energy consumption and enhancing the user experience. It consists of several sub-components that work together to provide a range of features and functionalities, including colour-changing capabilities, real-time electricity price display, and time display. This chapter describes the functional architecture of the LuSiTa table lamp, including the product's modes, components and interfaces, and how they operate and communicate.

5.1 Modes of Operation

The LuSiTa table lamp has two modes of operation: manual and automatic. In manual mode, the user can control the lamp's colour and brightness settings manually, using the lamp's control panel. In automatic mode, the lamp adjusts its colour and brightness settings automatically based on real-time electricity prices, as well as ambient lighting conditions.

5.2 Components and Interfaces

The LuSiTa table lamp has several sub-components, each with its interface and functionality. These sub-components are:

- Lamp Body: This is the main body of the lamp, which houses the LED lights and all the other components.
- Physical Interface: The display is located on the lamp body and allows the user to manually adjust the lamp's colour and brightness settings, while also displaying real-time electricity prices, allowing the user to easily determine the best time to use energy. The main display communicates with the processing unit via a wired interface.
- Mobile Interface: The mobile interface for LuSiTa is designed to allow the user to control and monitor the lamp's behaviour from their smartphone. The interface consists of a user-friendly app that connects to the LuSiTa lamp via an access point hosted by the LuSiTa's

processor. Once connected, the app allows the user to connect LuSiTa to WIFI, by sending the respective WIFI details to the processor, and displays the current electricity prices, as well as the lamp's current colour and time. The user can also use the app to adjust the lamp's colour and brightness manually or set up a schedule to turn it on and off based on their preferences.

- Processor: The processor is the brain of the lamp, controlling the lamp's overall functionality and communication with other sub-components. It communicates with the other sub-components via a wired interface.
- LED interface: consists of the unit that contains the hardware responsible for the illumination.
- Database: stores information about electricity prices. This information is updated regularly to ensure the lamp displays the most up-to-date electricity prices and adjusts its behaviour accordingly.

5.3 Functional Architecture Diagram

The following diagram shows the functional architecture of the LuSiTa table lamp, including the sub-components and interfaces of the product and how they operate and communicate with each other:

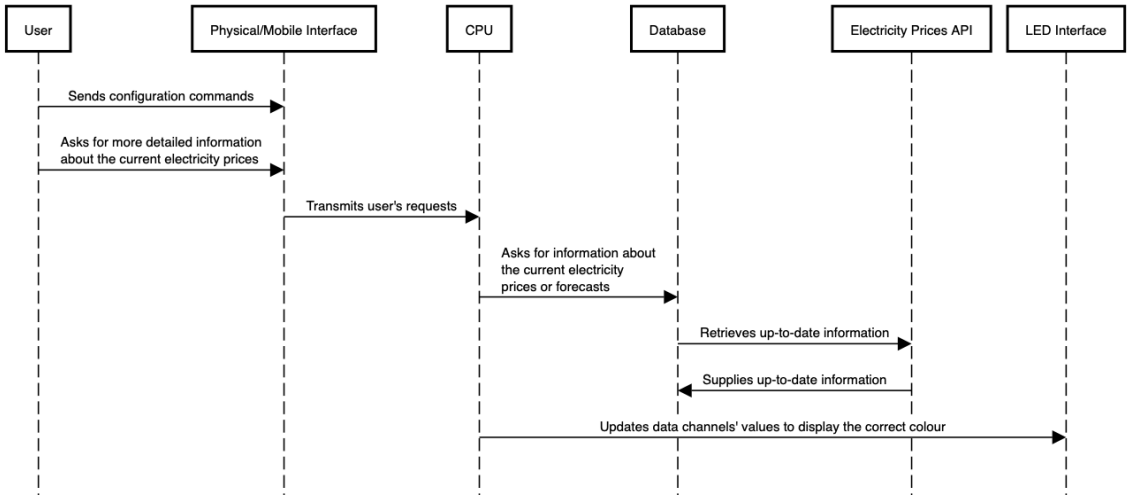

Figure 5.1: UML Sequence Diagram representing the functional architecture

Chapter 6

Conclusion

The LuSiTa table lamp is an innovative project that envisions a lamp capable of integrating different electricity tariffs in order to identify the cost of electricity through different colours in real time and in advance. The system concept helps us visualize the project as a whole and how different sub-components and interfaces should interact with each other. Understanding these concept divisions and defining the functional and non-functional requirements is essential for the successful development and implementation of our goal. Preliminary market research and the definition of the structure are imperative starting points. Moreover, the continued monitoring and evaluation of these aspects during the process helps us identify areas of improvement, so the document is likely to change.

In the end, this document should have informed us and the reader fully, as well as other involved parties, of the concept and overview of the project idea, how it is being developed and organized, and finally, what the client may expect.