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University Degree in Data Science and Engineering and Telecommunication Technologies Engineering
2024 – 2025

Bachelor thesis

Building a Scalable and Decentralized Parking Management Solution for Multi-Community Deployment

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Leganés, 2025

ABSTRACT

this is an abstract

Keywords: keyword1, keyword2, keyword3

ACKNOWLEDGMENTS

Thanks

AGRADECIMIENTOS

Gracias

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INCOSE	International Council on Systems Engineering.

Part I

Introduction

1. MOTIVATION

In recent years, the exponential increase in the number of vehicles has aggravated urban challenges, notably in parking management. For instance, the surge in car usage in Madrid has significantly contributed to an increase in pollution levels [1]. Despite a stable number of parking spaces in Spain between 2014 and 2020 [2], the demand has led to higher costs and greater difficulty in securing parking, thereby increasing time spent searching for spaces, traffic congestion, and urban pollution.

Parking management systems remain a critical area of research and development, even though manual parking management has been utilized for many years. Research published in [3] indicates that the type of parking management system significantly influences the parking choices of citizens. Additionally, citizens tend to prefer systems that are user-friendly, secure, and reliable.

Advancements in technology offer promising solutions to these issues. The proliferation of internet-connected devices, which have grown by 20% year-over-year [4], has facilitated the development of Internet of Things (IoT)-based parking management systems. These systems aim to mitigate traffic congestion and reduce pollution in urban areas.

PMSs provide numerous benefits in modern urban settings. They contribute to reducing traffic congestion and pollution, thereby improving urban mobility and the quality of life for residents. Additionally, PMSs enhance security by monitoring vehicle movements within parking areas, which aids in crime prevention.

These systems share several common features:

- Automation of parking space management.
- Application in various areas such as cities, communities, or buildings.
- Documentation of vehicle transit within parking spaces.

Currently, parking management systems in Spain largely rely on human intervention, leading to several issues such as delays in availability, lack of information, and insufficient control of parking spaces. Continuous human presence is required to maintain the functionality of these systems throughout the day, which increases operational costs.

To address these issues, recent technological advancements have emerged. For instance:

- RFID-based smart parking management systems [5] have been developed to manage the transit of vehicles within parking spaces.
- IoT-based smart parking management systems [6] have been designed to manage parking spaces within a community.
- Intelligent parking systems utilizing image processing [7] have been proposed to recognize license plates of parked vehicles.

Despite these advancements, several challenges persist. Current parking management systems are typically centralized, which presents scalability and reliability issues in the event of service interruptions. Additionally, these systems often lack customization options, making it difficult to adapt to user-specific needs.

Given these challenges, the primary objective of this project is to design and implement a fully distributed parking management system that addresses the limitations of current systems, focusing on enhancing scalability, reliability, and user adaptability.

2. STATEMENT OF THE PROBLEM

TODO: write the statementof the problem

3. OBJECTIVES

The primary objective of this bachelor thesis is to design and implement a fully distributed parking management system tailored for the next generation of smart cities. This project aims to address the inefficiencies and challenges inherent in current parking management systems through a distributed approach that leverages modern technologies.

Specifically, the objectives of this project are as follows:

1. **Research Current Systems**: Conduct a comprehensive study of existing parking management systems, identifying their main problems. This involves understanding user requirements, analyzing the technologies employed, and evaluating system effectiveness.
2. **Technology Analysis**: Analyze the technologies currently used in parking management systems to determine their suitability for a distributed architecture. This includes examining sensors, Internet of Things (IoT) devices, communication protocols, and data processing methods.
3. **System Infrastructure Design**: Design the overall infrastructure of the distributed parking management system. This encompasses defining the system architecture, selecting appropriate technologies, and developing detailed design specifications.
4. **System Development**: Develop the system by adhering to a structured methodology that includes phases of planning, design, implementation, testing, deployment, and maintenance. Each phase will follow best practices to ensure the system's robustness and efficiency.
5. **Performance Analysis**: Evaluate the implemented system based on various criteria such as performance, scalability, security, usability, reliability, availability, and cost. This comprehensive analysis will help in assessing the effectiveness of the system and identifying areas for improvement.

Throughthese objectives, the thesis aims to contribute to the advancement of smart city technologies by providing a scalable, secure, and user-friendly parking management solution. The distributed nature of the proposed system is expected to enhance its performance and reliability, making it a viable option for modern urban environments.

4. DOCUMENT STRUCTURE

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5. METHODOLOGICAL FRAMEWORK

The methodological framework employed in this thesis is grounded in the V-model as established by the International Council on Systems Engineering (INCOSE) [8] for project development. The V-model offers a rigorous and structured method that ensures all project facets are considered, facilitating timely and budget-compliant completion. This is achieved through a comprehensive development process, enabling clear validation and verification of initial requirements at every stage.

The methodology is segmented into seven key components which can be summarized as follows:

1. **Identification of User Requirements**: A detailed analysis of the problem statement is conducted to identify the primary issues and potential solutions. Moreover, the user requirements are defined to ensure that the proposed solution aligns with the objectives of the project.

2. **System Design**: The system architecture is developed based on the user requirements, ensuring that the proposed solution is feasible and aligns with the project's objectives. This phase includes a detailed overview of the system components and their interconnections. Requirements are formulated to satisfy the previously defined solution requirements. This phase includes a high-level overview of the components of the proposed solution, the justification for their selection, and the interconnections among them.

3. **Component Design**: Building upon the high-level architecture of the solution, a more detailed approach is outlined for each component, taking into account their specific power and data transmission needs. This culminates in a comprehensive architecture of the solution. Furthermore, a detailed overview of the components is provided, including the rationale for their selection and the interconnections among them.

4. **Implementation**: The proposed solution is implemented and manufactured utilizing available tools while simultaneously integrating the necessary electrical components. This phase includes a detailed description of the implementation process, including the tools and materials used, as well as the integration of electrical components. The development of software and hardware components is also detailed.

5. **Component Testing**: The functionality of each component is verified in a standalone mode, with detailed information provided regarding the verification process.

6. **System Testing**: The methodology for conducting flight tests and subsequent analyses is elaborated. System integration is performed by assessing communication between module pairs to ensure that data can be transmitted freely and utilized effectively.

7. **Acceptance Testing**: Validation of the initial requirements is conducted to confirm that all solution requirements have been met. This phase also includes preparations for potential future enhancements.

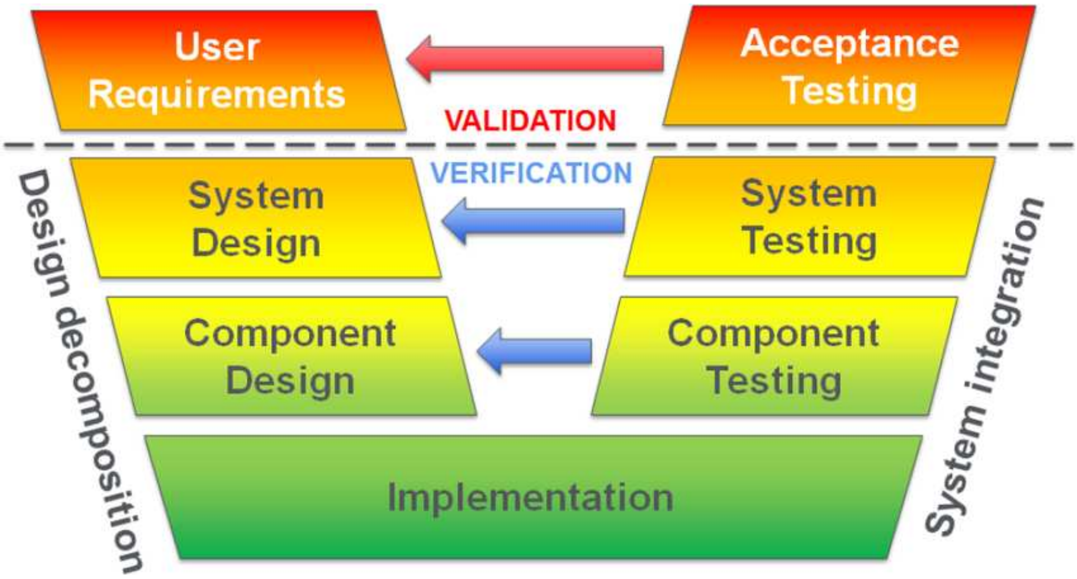

Figure 5.1. *Methodological framework based on the V-model from INCOSE with the different stages of the project development process[9]*

Moreover, a graphical representation of the V-model is provided in Figure 5.1 to illustrate the methodology's structure and the relationship between the various stages.

Part II

Theoretical Background

6. DEEP LEARNING

Part III

State of the art

7. REGULATORY FRAMEWORK

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Part IV

Methodology

8. REQUIREMENTS

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The parking management system developed for this project was designed to ensure that it met the needs of drivers, parking facility managers, and city administrators. The system was designed to address the limitations of current parking management systems, focusing on enhancing scalability, reliability, and user adaptability.

For this purpose, different user requirements were identified, and system requirements were defined to meet these needs. Furthermore, the system was designed to incorporate specific technical and functional specifications to ensure its effectiveness and efficiency.

8.1 User Requirements

The user requirements for the distributed parking management system were identified through a comprehensive analysis of the needs and preferences of drivers, parking facility managers, city administrators and users with disabilities. These requirements were essential to ensure that the system was user-friendly, efficient, and aligned with the objectives of smart city initiatives [10].

The requirements of the primary users were as follows:

For drivers, the system needed to provide real-time information about available parking spaces to minimize search time. This was crucial to reduce traffic congestion and pollution in urban areas. Moreover, drivers expected an easy-to-use interface for quick navigation and more importantly, automatic functionality of the system without the need for human intervention. That way, they did not have to worry about the availability of parking spaces and could focus on other tasks.

Parking facility managers required tools to monitor and manage their facilities efficiently, as well as access to detailed reports and analytics on parking usage patterns to optimize space utilization. A notification system for intrusions such as unauthorized parking or security breaches was also essential to ensure the safety of the parking facilities. Enhanced security measures, including surveillance and access control, were a must-have for them.

On the other hand, city administrators needed a system that could provide insights into parking demand and usage trends to inform urban planning decisions. The system should support the integration of parking data with other smart city initiatives to enhance overall urban mobility and sustainability. Moreover, city administrators required tools to monitor and minimize the environmental impact of parking facilities, such as reducing emissions and energy consumption. The system should also comply with local regulations and standards for data privacy and security such as GDPR [11].

Finally, users with disabilities needed accessibility features such as voice commands, screen readers, and other assistive technologies to ensure that they could use the system effectively. These features were essential to promote inclusivity and ensure that all users could benefit from the distributed parking management system. Moreover, the system should be designed to accommodate users with different needs and preferences, ensuring a seamless user experience for everyone.

8.2 System Requirements

For the distributed parking management system to meet the user requirements, it had to incorporate specific system requirements. These requirements were defined to ensure that the system was scalable, reliable, secure, and user-friendly, aligning with the objectives of smart city initiatives as well as the needs of drivers, parking facility managers, and city administrators. The system requirements were essential to guide the design and development of the distributed parking management system, ensuring that it met the expectations of all stakeholders and delivered the desired outcomes.

The main system requirements were as follows:

For the real-time monitoring of parking space availability, the system needed to incorporate sensors and IoT devices to detect vehicle presence and occupancy. These sensors had to be accurate, reliable, and cost-effective to provide up-to-date information on parking availability.

Reservation was another key requirement, allowing drivers to be assigned a specific number of parking spaces in advance to ensure that they could secure a spot when needed. The reservation system had to be integrated with the monitoring system to ensure that drivers could find available spaces.

The system also needed to be self-sufficient, with automated gate and barrier control to regulate access to parking facilities. It had to be capable of managing multiple parking facilities simultaneously, ensuring that drivers could access the system from different locations. And it had to be able to function without human intervention, reducing the need for manual oversight.

Moreover, the system had to be scalable and flexible, with a distributed architecture that could handle large volumes of data and a growing number of users. It had to support additional number of communities and parking facilities, ensuring that it could adapt to changing requirements. For the system to be effective, modularity was essential, allowing for easy updates and integration of new features as needed.

Security and availability were critical requirements for the system, ensuring that the system was robust and resilient against cyber threats and service interruptions. Interoperability was crucial to ensure compatibility with existing and future smart city infrastructure.

Finally, the user interface had to be intuitive and user-friendly, with mobile accessibility for drivers and web-based interfaces for facility managers and city administrators. And accessibility features were needed to support users with disabilities, ensuring that the system was inclusive and accessible to all.

9. DESIGN

TODO: Write this chapter

10. IMPLEMENTATION

TODO: Write this chapter

11. TESTING

TODO: write this chapter

Part V

Results

Part VI

Conclusions

12. CONCLUSIONS

TODO: write this chapter

13. FUTURE WORK

TODO: write this chapter

14. SOCIO-ECONOMIC ENVIRONMENT

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