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Présenté et soutenu publiquement par :

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I would like to acknowledge the Instrumentation Maintenace Department for providing the necessary resources, facilities, and access to relevant literature, which have been essential in conducting my research. The support of the faculty and staff at IMSI has played a crucial role in my academic growth and the completion of this thesis.

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Thank you.

Ferras Faiza

Abstract

Intitulé de recherche en Anglais ici

Abstract:

This study explores the convergence of Smart Parkings, Artificial Intelligence (AI), Internet of Things (IoT), and the development of a Self-Powered System (SPS) as a solution to the challenges faced in urban parking management. In Chapter 1, the current landscape of parking management is examined, highlighting the need for innovative approaches to optimize resource utilization, improve efficiency, and enhance user experience. Chapter 2 delves into the transformative potential of AI and IoT in smart parkings, showcasing how AI algorithms and IoT sensors can optimize parking spaces, improve traffic flow, and enhance user convenience. Chapter 3 focuses on the Conception & Results of the developed Self-Powered System. Through meticulous simulation, planning, and evaluation, a robust and sustainable self-powered system is realized, with presented results validating its efficacy. The study underscores the importance of collaboration with stakeholders and emphasizes ongoing research, innovation, and interdisciplinary partnerships. Overall, this research contributes to the knowledge in Smart Parkings, AI, IoT, and self-powered systems, showcasing their potential in revolutionizing parking management and paving the way for improved mobility, sustainability, and user-centric experiences.

Key words*: Smart Parkings, AI, IoT, Optimization, Self-Powered System, Simulation, Conception, Results.*

Intitulé de recherche en Français ici

Résumé :

Cette recherche explore la convergence des Smart Parkings, de l'Intelligence Artificielle (IA), de l'Internet des Objets (IdO) et du développement d'un Système Auto-alimenté (SA) comme solution aux défis rencontrés dans la gestion des parkings urbains. Dans le chapitre 1, le paysage actuel de la gestion des parkings est examiné, mettant en évidence le besoin d'approches innovantes pour optimiser l'utilisation des ressources, améliorer l'efficacité et améliorer l'expérience utilisateur. Le chapitre 2 plonge dans le potentiel transformateur de l'IA et de l'IdO dans les smart parkings, montrant comment les algorithmes d'IA et les capteurs IdO peuvent optimiser les places de parking, améliorer la circulation et faciliter la vie des utilisateurs. Le chapitre 3 se concentre sur la Conception et les Résultats du Système Auto-alimenté développé. Grâce à une simulation minutieuse, une planification et une évaluation rigoureuses, un système auto-alimenté robuste et durable est réalisé, avec des résultats présentés validant son efficacité. L'étude souligne l'importance de la collaboration avec les parties prenantes et met l'accent sur la recherche continue, l'innovation et les partenariats interdisciplinaires. Dans l'ensemble, cette recherche contribue aux connaissances sur les Smart Parkings, l'IA, l'IdO et les systèmes auto-alimentés, en montrant leur potentiel dans la révolution de la gestion des parkings et en ouvrant la voie à une mobilité améliorée, à la durabilité et à des expériences axées sur l'utilisateur..

Mots clés *: Smart Parkings, IA, IdO, Optimisation, Système Auto-alimenté, Simulation, Conception, Résultats.*

Intitulé de recherche en Arabe ici

الملخص:

تستكشف هذه الدراسة التقاء الحداثة والذكاء الاصطناعي والإنترنت من الأشياء وتطوير نظام يعمل بالطاقة الذاتية كحل للتحديات التي تواجه إدارة وقوف السيارات في المناطق الحضرية. في الفصل الأول، يتم استعراض المشهد الحالي لإدارة وقوف السيارات، مما يبرز الحاجة إلى نهج مبتكر لتحسين استغلال الموارد وزيادة الكفاءة وتعزيز تجربة المستخدم. يتعمق الفصل الثاني في الإمكانات المحولة للذكاء الاصطناعي والإنترنت من الأشياء في وقوف السيارات الذكية، حيث يُعرض كيف يمكن لخوارزميات الذكاء الاصطناعي وأجهزة استشعار الإنترنت من الأشياء تحسين مساحات وقوف السيارات وتحسين تدفق حركة المرور وتسهيل تجربة المستخدم. يركز الفصل الثالث على تصور ونتائج نظام الطاقة الذاتية المطور. من خلال محاكاة دقيقة وتخطيط وتقييم دقيق، يتم تحقيق نظام قوي ومستدام يعمل بالطاقة الذاتية، حيث يتم تقديم النتائج التي تُؤكد فعاليته. يؤكد هذا البحث على أهمية التعاون مع أصحاب المصلحة ويشدد على أهمية البحث المستمر والابتكار والشراكات المتعددة التخصصات. بشكل عام، يسهم هذا البحث في إثراء المعرفة في مجال وقوف السيارات الذكية والذكاء الاصطناعي والإنترنت من الأشياء والنظم ذاتية الطاقة،

كلمات مفتاحية: وقوف السيارات الذكية، الذكاء الاصطناعي، إنترنت الأشياء، الأمثلة، نظام يعمل بالطاقة الذاتية، المحاكاة، التصور، النتائج.

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List Of Abbreviations

SPS *: Smart Parking System*
ALG *: application-layer gateway*
ANN *: Artificial Neural Networks*
APF*: Automated Parking Facilities*
API *: applications programmer interfaces*
APS *: Automated parking system*
AVM. *: Around View Monitor*
CNN *: Convolutional Neural Network*
CPF *: Car Parking Framework*
CPU *: central processing unit*
CT *: Communication Terminals*
DL *: Deep learning*
ES *: Expert systems*
FL *: Fuzzy Logic*
GPS*: Global Positioning System*
GSM. *: Global System for Mobile*
GUI *: Graphical User Interface*
HTTP. *: Hyper Text Transfer Protocol*
IAB *: Internet Architecture Board*
IDE *: Integrated Development Environments*
IOT : *Internet of Things*
IP *: Internet Protocol*
IPS *: In-Plane Switching*
IR *: Infrared sensor*
ITS *: Intelligent Transportation System*
LCD *: Liquid Crystal Display*
LPR *: license plate recognition*
M2M *: machine–to–machine*
MANET *: Mobile Ad Hoc Network*
MAS :*Multi-Agent System*
MILP *: Mixed Integer Linear Programming*
ML *: Machine learning*
MR*: Magneto-Resistive sensor*
NFC *: Near Field Communication*
NFD *: NDN Forwarding Daemon*
NLP *: Natural Language Processing*
NN : *Neural Network*
OBU *: On-Board Unit*
PaaS :*Platform as a Service*
PDR *: Position Dead Reckoning*
PGIS *: Parking guidance and information system*
PIaaS *: Parking information as a Service*
PLC *: Programmable Logic Controllers*
PMV *: Parking Mobility Vectors*
PnR *: park-and-ride*
PSU *: Parking Side Unit*

PSU *: Park Side Units*
RFID *: Radio Frequency Identification*
RSU *: Road Side Unit*
RSU *: Road Side Units*
SMS*: Short Message Service*
TCP. *: Transmission Control Protocol*
TN *: Twisted Nematic*
UID *: unique identifier*
VANET *: Vehicle Ad Hoc Network*
VICS *: Vehicle information and communication*
WSN *:Wireless Sensor Networks*

General Introduction

Throughout the following chapters, we embark on a journey into the realm of Smart Parkings, AI, IoT, and the development of a cutting-edge Self-Powered System (SPS). This multi-faceted exploration delves into the challenges of urban parking management and seeks innovative solutions to optimize resource utilization, improve efficiency, and enhance user experience.

Chapter 1 sets the stage by providing an overview of the current landscape of parking management. We delve into the complexities and pain points associated with traditional parking systems, highlighting the need for transformative approaches. This chapter establishes the significance of Smart Parkings and paves the way for the subsequent chapters.

Chapter 2 focuses on the intersection of AI, IoT, and smart parkings. We delve into the transformative potential of AI algorithms and IoT sensors in revolutionizing parking management. Through insightful discussions, we explore how these technologies can optimize parking spaces, improve traffic flow, and enhance user convenience. This chapter highlights the opportunities that arise from leveraging intelligent systems in reimagining parking infrastructure.

Chapter 3 marks a pivotal phase in our study as we delve into the Conception & Results of our Self-Powered System. This chapter provides a comprehensive exploration of the objectives, motivations, simulation, conception, and outcomes of our SPS. We delve into the meticulous planning, design considerations, and empirical evaluations that contribute to the realization of an efficient and sustainable self-powered system. By showcasing the performance metrics and real-world scenarios, this chapter demonstrates the transformative potential of our system in addressing the challenges of parking management.

In each chapter, we aim to shed light on different facets of the Smart Parkings, AI, IoT, and Self-Powered Systems paradigm. Through our comprehensive exploration, we hope to inspire future research, innovation, and collaboration in the field. By harnessing the power of technology, intelligence, and sustainable solutions, we strive to pave the way for a future where parking facilities are optimized, efficient, and seamlessly integrated into urban environments.

As we delve into the following chapters, we invite you to join us on this transformative journey. Together, we can reimagine parking management, improve urban mobility, and create a more sustainable and user-centric future.

Chapter 1 : Smart Parking System

1.1 Introduction

This chapter serves as a comprehensive exploration of smart parking systems (SPSs), aiming to provide a deep understanding of their significance and the various facets associated with their implementation. By delving into the realm of smart parking, we can uncover innovative solutions that enhance convenience, optimize resource utilization, and contribute to sustainable urban environments.

First and foremost, we will lay the foundation by providing a clear definition of SPSs. Understanding what constitutes a smart parking system is essential to grasp the breadth and depth of its capabilities. We will explore the underlying principles and technologies that enable these systems to operate intelligently and efficiently.

To gain insights into the current state of SPSs, we will delve into survey researches conducted in this field. By examining existing literature and studies, we can identify trends, challenges, and opportunities that researchers and practitioners have encountered. This knowledge will equip us with a valuable understanding of the real-world implications and potential of smart parking systems.

Moreover, we will delve into the diverse approaches employed in designing and implementing SPSs. From sensor-based solutions to data-driven algorithms, we will explore the multitude of strategies used to create intelligent parking environments. By examining these approaches, we can uncover best practices and lessons learned from successful implementations, as well as the considerations and trade-offs associated with different methodologies.

Lastly, we will explore the classification of reviewed SPSs, organizing them based on their functionalities, technologies employed, and user experiences. This categorization will provide a structured framework for understanding the range of smart parking solutions available today, and how they cater to specific requirements and contexts.

Through this comprehensive exploration, we aim to unlock the transformative potential of smart parking systems. By embracing technology, harnessing data, and reimagining parking management, we can not only alleviate the burdens of urban parking but also pave the way for more sustainable, efficient, and user-centric urban environments. So let us embark on this journey into the world of smart parking systems, where innovation meets the everyday need for seamless parking experiences.

1.2 Literature review

1.2.1 Definitions

Smart parking is a revolutionary technology that utilizes advanced sensors, algorithms, and data analytics to optimize the use of parking spaces.

This technology enables drivers to find available parking spots quickly and easily, reducing traffic congestion, improving air quality, and enhancing overall urban mobility.

Smart parking offers numerous benefits to drivers, cities, and the environment. By reducing the time spent searching for parking, it helps alleviate traffic congestion and improve air quality.

It also provides valuable data insights to city planners, enabling them to make informed decisions about parking management and infrastructure development.

1.2.2 Smart parking system Survey researches

Many large cities face the dire problem of providing available parking spaces to their citizens at the peak hours of a day. As a result, citizens spend a massive amount of time searching for the perfect parking space or waiting in line to get one. This, in turn, creates traffic congestions. Considering the problems, many researchers have suggested different SPS approaches and technologies to mitigate this problem :

In [1] the author suggested the adaptation of a cloud-based platform as a Service (PaaS) to develop an Internet of Things (IoT) based SPS. PaaS can be divided into two parts: a back-end dashboard platform and a front-end data platform. The back-end data platform provides data storage, management, and processing facility. On the other hand, the front-end dashboard platform deals with reporting and visualization of data.

[2], a Multi-Agent System (MAS) based SPS has been designed. The system uses agent networks that coordinate between the driver and the SPS. It utilizes a negotiation algorithm that provides a negotiable parking fee depending upon different criteria. Moreover, the system offers vehicle guidance for the shortest path to the parking space and parking reservation facility.

[3] A Car Parking Framework (CPF) based on IoT has been proposed in [3]. the framework combines an automatic car parking management system with the integration of networked sensors and actuators along with Radio Frequency Identification (RFID). The CPF provides vehicle guidance, payment facilities, parking lot retrieval, and security. The system uses a hybrid

communication method instead of regular nodal communication. Due to that, the system has a low energy consumption rate with low implementation costs.

In [4] the authors developed a Wireless Sensor Networks (WSN) based SPS. The system utilizes a hybrid self-organization algorithm for WSN technology. The system has been designed to be more energy efficient during wireless communication. As a result, it enhances the life expectancy of WSN nodes and overall WSN. This sort of SPS aids the users by guiding them to the nearest parking lot and the facility to reserve it. The system utilizes both web and smartphone applications to provide SPS facilities to the users.

[5] Using Global System for Mobile (GSM), Rahayu and Mustapa proposed a secured parking reservation system . The system is comprised of a security reservation module and a parking space monitoring module. The security reservation module handles the reservation of specific parking lot. The user needs to send a Short Message Service (SMS) with provides specific instructions to reserve the parking lot. The parking lot monitoring module provides the user with a layout animation of parking space occupancy status, enabling the user to choose a parking lot for reservation. The system generates a password, which is required during enter and exit points.

In [6] Research conducted proposed a visual vehicle parking space occupancy detection method via deep Convolutional Neural Network (CNN). The system uses a decentralized approach and can detect parking lot occupancy in real-time via smart cameras. The solution datasets are compared with visual datasets.

In [7]Vacant parking space detection and tracking system based on sensor fusion have been proposed. The system uses a sensor fusion technique to fuse the data produced by the Around View Monitor (AVM) system's sensors. The data generated by ultrasonic sensors are used to monitor parking space occupancy. The system has three stages: detection of parking lot markings, classification of parking lot occupancy, tracking of parking lot markings.

In [8], an SPS based on WSN and an Ultrasonic sensor has been proposed. The system has utilized the shortest path algorithm to provide the user with the shortest route towards the vacant space. Moreover, parking lot occupancy information is provided to the users.

In [9] A cloud-based SPS was proposed . The system used WSN approach to monitor parking lots of a parking area. The parking lot status is then wirelessly transmitted to the cloud server. The user can see real-time parking lot status via an android application on a smartphone.

In [10] The authors proposed an IoT-based SPS. The SPS can monitor and indicate parking lot availability to the user via IoT applications. The system has three parts: On-field Network, Cloud platform, User side platform. The on-filed network consists of vehicle detection sensors, which detect parking lot occupancy. Then, the data from the sensors are transferred to the User side platform via a cloud platform. From the user side platform, any user can easily see the parking lot status of the particular parking area.

[11]Bagula et al. implemented an SPS using IoT and WSN. The system utilizes an ultrasonic sensor to detect parking lot occupancy and uses Radio Frequency Identification (RFID) tags for vehicle identification and payment facilities. The system implements three kinds of sensor nodes, such as slave nodes or receivers, master nodes or transmitters, and anchor nodes or repeaters. The slave nodes are placed on parking spaces to detect parking lot occupancy. The master nodes gather data of slave nodes and transmit data to the cloud. The repeaters are placed strategically inside the parking facility to increase the coverage area of WSN. The sensor nodes utilize both wired and wireless connectivity.

In [12] The authors proposed a WSN based low-cost, and energy-efficient SPS. The SPS is designed to monitor the number of vehicles entering and exiting a parking area rather than detecting vehicle occupancy in every parking lot. The system uses 6LoWPAN over IEEE802.15.4 for communication, which requires less power; thus, the system's energy efficiency increases.

In [13]The authors built An automated SPS based on Bluetooth connectivity has been developed. The system uses an automatic mechanical system-based valet parking service that transports vehicles to the unoccupied parking space and retrieves vehicles from the specific parking space without any human intervention. In this system, user authentication to process initiation is done by using Bluetooth connectivity.

In [14]The authors built a prototype for parking space vacancy monitoring based on wireless technologies. The system can be divided into two modules : a master module and a parking lot occupancy checking module. The master module comprises a Laptop Graphical User Interface (GUI), which shows the infrared sensor data. The data is transferred to the laptop via the Zigbee transceiver interface with a PIC microcontroller. The parking space occupancy checking module consists of digital Infrared sensors, which senses if a parking space is occupied or not. The user can see the information on an Liquid Crystal Display (LCD) installed at the entrance of the parking area.

In [15] Al-Kharusi et al. presented an SPS based on image processing to detect unoccupied parking spaces. The system uses cameras as sensors to detect parking lot occupancy. The system uses RF communication to send the camera's data to the system's central processing unit.

In [16]An SPS based on WSN, IoT, and RFID technology has been developed. Considering the cybersecurity of the IoT devices, the system utilizes a lightweight cryptographic algorithm.

Moreover, the system implements fog or edge computing techniques to manipulate and process the sensitive sensor node data within the network edge. Fog or edge computing techniques reduce computational stress on the central server and decrease the system's energy consumption. The system can provide real-time information on parking space occupancy to the user. Besides, a user can reserve a parking lot and has the option to pay parking fees via online transactions.

In [17] A mobile application-based SPS using embedded sensors of a smartphone (such as accelerator, gyroscope) and Bluetooth connectivity has been described . After initiating vehicle parking at the parking lot, the information disseminates over the target scenario using a combination of internet connectivity to a remote server and Device-to-Device connectivity via WiFi.

In [18]The authors presented an SPS which provides pricing, reservation, and dynamic resource allocation. The system ensures a parking guarantee for the user at the lowest possible rate in the shortest amount of time. Moreover, maximum utilization of parking resources is ensured, which provides the highest possible revenue to the parking space owners. The system implements Mixed Integer Linear Programming (MILP) to minimize monetary cost and maximize resource utilization.

In [19]An SPS based on Artificial Intelligence (AI) and image processing were designed The system deploys ultrasonic sensors for parking lot occupancy detection and uses cameras for number plate recognition which is used for billing and vehicle security. Also, the system provides parking recommendations based on parking fees and parking area distance from the user's location.

In [20] An affordable and adaptable smart parking platform using distributed camera networks, advanced deep learning algorithms, and fog computing techniques has been proposed. The cameras of the system are equipped with motorized heads and zooming lens, which provide vehicle efficient and accurate tracking facility. The system also captures the vehicle number plate image, which calculates precise parking fees for the user and ensures vehicular security.

In [21], the authors proposed a Vehicle Ad Hoc Network (VANET) based cloud framework to provide security and privacy-conscious service termed as Parking information as a Service (PIaaS). PIaaS provides SPS details from VANET oriented cloud infrastructure to vehicular nodes in a secure and privacy concerned manner. VANET enabled vehicles along with the Park Side Units (PSUs) communicate parking information known as Parking Mobility Vectors (PMVs) with the Road Side Units (RSUs) via cloud infrastructures. The RSUs are also termed Communication Terminals (CTs). The SPSs implement a geo-location-oriented parking lock encryption, which provides location privacy. The system also includes traffic congestion reports of different routes, vehicle theft protection facilities, and detection of malicious vehicles.

In [22] The authors suggested a prediction scheme of parking lot availability based on sample parking spaces. The prediction scheme uses Fuzzy logic to predict available parking spaces. The system is dedicated to the park-and-ride (PnR) commuters, which infers that the sample parking spaces are located near public transportation facilities.

In [23] The researchers proposed a crowdsourcing-based SPS solution that uses embedded smartphone sensors to detect real-time parking lot availability. The system tracks the driver's trajectory to detect parking lot occupancy. The system applies a waist-mounted Position Dead Reckoning (PDR) method to follow the driver's trajectory. Besides, the SPS implements a map-matching algorithm to calibrate the directional errors in an indoor environment.

1.2.3 Approaches to smart parking system

Detailed analysis and comparison of the technology methods or approaches used by various SPSs have been provided in this section. Based on the approaches, SPS is divided into 12 different which are covered in:

1.2.3.1 Wireless Sensor Network (WSN) based SPS

WSN can be defined as a network of wirelessly connected sensor nodes that are spatially dispersed and are dedicated to monitoring different environmental aspects such as sound, temperature, pressure, etc. WSN based sensor node comprises various sensors connected to monitor different aspects of the environment. In WSN, all the sensor nodes are connected to a sink node via wireless connection [24, 25]. Nowadays, WSN has received outstanding traction among the SPS developers for flexibility, scalability, and low deployment cost.

many of researchers utilized WSN as the primary approach towards building SPS.

1.2.3.2 Multi-agent system (MAS) based SPS

MAS is a self-organizing computer-based system accumulating multiple intelligent agents to solve problems that are pretty difficult for any single system to solve [26, 27, 28] . To develop SPS, various researchers have deployed MAS due to its effectiveness in both closed or indoor and outdoor or open parking lot areas. A significant portion of MAS-based SPS provides computing facilities to the agents, which reduces the data transmission head of the whole system. As a result, the power consumption rate decreases.

1.2.3.3 Computer vision/image processing based SPS

Computer vision/Image processing based SPS uses different types of camera networks to use image data to extract different information such as parking lot occupancy status [29], license plate recognition (LPR) and face recognition for billing, security issues, and to provide road traffic congestion report. The systems based on computer vision/image processing technologies usually have a high data transmission rate from the camera network to the processing units because these systems are dependent on real-time parking lot video data for feature extraction. These sorts of SPSs are usually suitable for open parking areas because a single camera can capture a significant area in the parking lot. However, these systems are prone to occlusion, shadow effects, distortion, and changing of light.

1.2.3.4 Vehicular Ad-Hoc network (VANET) based SPS

VANET is based on the Mobile Ad Hoc Network (MANET), where a wireless network of mobile devices is used. SPS utilizing VANET has three main components: Parking Side Unit (PSU), Road Side Unit (RSU), and On-Board Unit (OBU) [30, 31, 32]. The OBUs are installed on the vehicles, PSUs are installed on parking areas, and RSU's are installed beside the roads near the parking areas. This type of system requires a trusted authentication authority that authorizes the vehicle's OBU. If a vehicle is parked inside of a smart parking facility, the OBU of the vehicle provides information to the PSU that the parking lot is booked. Then, this information is transferred to the RSU from the PSU. The vehicles traveling by that road where the RSU is placed can get the information of parking lot occupancy through their OBUs. VANET based smart parking systems are deployable in both closed and open parking lots. But the system is costly and provides erroneous information when a vehicle without an OBU gets inside the smart parking facility.

1.2.3.5 Internet of Things (IoT) based SPS

IoT is the buzzing technology of the current era, where all devices are interconnected with one another through the internet. Every device interconnected with the internet possesses an unique identifier (UID). These devices can be computational devices, mechanical devices, and digital devices. They can transfer data to without human-to-human or human-to-computer interaction [33, 34, 35]. IoT technology acts as one of the primary key technologies that developers use for SPS.

In IoT-based SPS, all the sensors and computational devices are connected through the internet and can transfer data without any human intervention. The internet connection among sensors, computational devices, and storage units can be either through a wired connection or through a wireless connection.

1.2.3.6 Machine learning (ML) based SPS

ML is a subset of AI that provides a system the ability to learn and improve on a particular task from the datasets or experiences without explicitly programming the system [36]. A machine learning-based SPS analyses the parking lot of data to extract the parking lot status. Moreover, ML and AI-based SPS can predict parking lot occupancy status of the upcoming days, weeks, or even months and provide a dynamic pricing scheme. ML-based systems can monitor traffic congestion of particular roads and offer a smart solution to smart parking spaces [37].

1.2.3.7 Deep learning (DL) based SPS

DL is a subset of ML and a function of AI which mimics the human brain in terms of data processing and feature extraction to make decisions [38, 39]. DL algorithms detect vacantly occupied and special parking lots in an SPS instead of regular sensors, which reduces the number of sensors and cameras required by the system. DL is also used to predict parking lot occupancy.

1.2.3.8 Neural Network (NN) based SPS

NN is a combination of algorithms that extracts features and underlying relationships from sets of data through a process that mimics human brain function [40]. In SPS, NN is used for license plate recognition using real-time video data. Convolutional Neural Network (CNN) and machine vision are implemented to detect parking lot occupancy status. CNN's are also capable of providing road traffic conditions of different routes [41].

1.2.3.9 Fuzzy logic based SPS

Fuzzy logic is a reasoning method that resembles human reasoning. It uses multi-valued logic, which means there is no absolute truth or absolute false value in fuzzy logic [42]. Fuzzy logic is used in SPS for predicting parking lot occupancy status [43]. But the accuracy of the prediction model based on Fuzzy logic would not be that high without validating the prediction result with the real-time data [44]. Therefore, Fuzzy logic, along with machine vision or sensors, improves the accuracy of the overall system.

1.2.3.10 Global Positioning System (GPS) based SPS

GPS is an essential component of different smart parking approaches. But GPS alone is unable to gather parking lot occupancy status and provide other smart parking facilities. However, GPS can provide a vehicle guidance facility for the user to drive towards vacant parking lots. From GPS data, many systems can forecast parking lot occupancy and road traffic congestion using CNN or DL algorithms [45]. The accuracy of GPS depends on the number of receivers it has. For a single frequency receiver GPS, the accuracy is around 7.8 m. On the other hand, a two-frequency receiver provides around 0.715 m of accuracy. The GPS data is also prone to error if operated inside of a closed parking area. Thus, smart parking systems that use GPS are suitable for open parking lots [46, 47].

1.2.3.11 Global System for Mobile (GSM) based SPS

GSM is a standard for second-generation (2G) digital cellular networks. GSM standard provides a subsidiary service called SMS. SPS, based on GSM, uses SMS service to reserve parking spots at different parking spaces. Some system also generates unique codes for the users during the reservation process, which are used to authenticate the reservation and ensure that only the designated persons get to park [48].

1.2.3.12 Bluetooth based SPS

Bluetooth is a wireless communication technology standard that enables data transfer within a short-range. A smart parking system that is wholly based on Bluetooth technology usually has automated valet parking installed. Regular SPS, which does not deploy an automated valet parking facility, requires additional sensors and approaches to get different smart parking facilities [49, 50, 51]. Many smart parking systems use the Crowd-sensing method to gather information about available parking spots in an area. The method uses smartphone sensors (such as Accelerometer, Gyroscope, Magnetometer, and GPS) and applications to gather parking lot information [52].

1.2.4 Classification of reviewed SPSs according to approaches

A summary of the technological approaches used in different research works to develop SPSs and system suitability under different parking lots is given in **Table 1**.

Papers / APrOACHES	1	2	3	4	5	6	7	8	9	10	11	12	Close Space /Indoor Parking Lot Type	Open Space /Outdoor Parking Lot type
[1]	+				+								+	
[2]		+			+								+	+
[3]	+				+								+	
[4]	+													+
[5]									+				+	+
[6]			+			+							+	+
[7]			+										+	+
[8]	+												+	+
[9]	+				+								+	
[10]					+								+	
[11]	+				+									
[12]	+													+
[13]										+			+	
[14]	+												+	
[15]			+										+	+
[16]	+				+								+	
[17]					+					+				
[18]													+	+
[19]	+				+						+			
[20]												+	+	+
[21]				+									+	+
[22]							+						+	+
[23]								+						
Total	10	1	3	1	9	1	1	1	1	2	1	1	17	12

Table 1 *Classification of SPSs according to technological approaches and parking lot suitability*

From Table 1, it can be seen that WSN and IoT are the most popular approaches for implementing SPS. Computer vision/image processing can also be considered as a frequently used approach in SPS. The utilization of the remaining technological approaches in SPS is almost the same. SPS can be divided into two major groups based on parking lot suitability: open space and closed parking space. As per parking lot suitability, 9 SPSs are suitable for both open and closed parking lots. While compared individually, 17 SPSs are suitable for indoor/closed parking lots, whereas 12 SPSs are suitable for open space. [53]

1.2.5 SPS classification based on services

In current times, there are many SPS available throughout the globe. Based on the systems' services, the SPSs can be categorized into five services:

- **Parking guidance and information system (PGIS)**

PGIS provides real-time parking lot information on controlled parking areas. It is an important part of the Intelligent Transportation System (ITS) and a supplement of the vehicle guidance system [54]. In PGIS, sensors are placed at the entrances and exits to detect and count the number of vehicles entering or exiting the parking area. By detecting the number of vehicles entering and exiting available parking, number of remaining parking lots is calculated. Different computational technologies (ML, CNN, etc.) are used to determine the parking lot status along with the parking lot sensors. Users can see the processed information via different interfaces. Due to the information, users can have choices in selecting suitable parking lots. PGIS system also provides vehicle guidance to the users, which leads them towards the designated parking space.

- **Transit based information system**

Transit-based smart SPS provides parking lot information near the public transportation facilities. Moreover, it presents public transportation schedules to motivate users to use public transportation services, which reduces traffic congestions, environmental pollution, and fuel consumption [55]. Transit Based Information System is implemented using vehicle detection sensors and other computational techniques to obtain information on parking lot occupancy in real-time. Furthermore, it provides vehicle guidance to the chosen parking lot via variable message signs along the highway.

➢ Smart payment system focused parking

This kind of smart parking system deploys advance payment facilities for the users instead of conventional parking meters. Due to the deployment of an advanced payment facility, the system paves the way to fast and convenient payment collection. As a result, the time required for collecting parking fees and fines reduces significantly. Moreover, quick access to upcoming users is ensured in this system. Therefore, parking lots are unoccupied for a less amount of time. The system may use contactless methods like Near Field Communication (NFC), RFID, and smart cards [56]. The system may also deploy secure online payment methods for parking fee collection via smartphones or web applications. For calculating the parking fees, the system uses the same sensors, which detect the parking lot occupancy.

➢ E-parking system

E-Parking system utilizes advanced technological features to bring different smart parking facilities under one platform [57]. E-Parking systems are based on smartphone or web applications. Anyone having the app downloaded to their smartphone may use the facilities remotely. At first, for using the smartphone application, a user needs to sign up using the required personal and vehicle information. Once after completing registration, a user can access the E-Parking facilities. E-Parking system provides various facilities to the user, such as providing information about the occupancy status of different parking lots situated in other parking stands, vehicle guidance to the nearest parking stand, reservation facility, various payment methods, vehicular security, and also lot retrieval facility.

➢ Automated parking system (APS)

APS is an automated mechanical system that automatically parks vehicles without any human intervention [58]. This system requires Automated Parking Facilities (APF), where the user checks in with the vehicle and places it in the allocated bay. From there, a mechanical system automatically parks the vehicles in a specific parking spot. To retrieve the vehicle, the user must sign in to the system and pay the parking fees. After the payment, the system brings out the vehicle from its parking spot. APS provides the user the information on the number of available parking lots inside the parking space via digital display monitors. Moreover, APS classifies vehicles and places them in different specified parking lots. Due to no human intervention in the parking process, the vehicles are less prone to damage due to parking. APS provides efficient use of parking spaces.

The services provided by various SPSs are summarized in Table 2.

SERVICEs / papers	Parking Reservation	Security	Vehicle Guidance	Online Payment	Gate Management	Parking Supervision	Lot Retrieval
[1]	+	+			+	+	+
[2]	+	+	+	+			+
[3]	+	+	+		+	+	+
[4]	+	+	+	+		+	
[5]	+	+			+		+
[6]		+				+	
[7]			+			+	
[8]	+					+	+
[9]						+	
[10]	+			+		+	
[11]	+	+				+	+
[12]						+	
[13]		+		+		+	+
[14]						+	
[15]		+				+	
[16]	+	+				+	
[17]			+				
[18]	+		+			+	
[19]		+	+			+	
[20]		+	+			+	
[21]		+	+			+	
[22]			+			+	
[23]				+			
Total	10	13	10	5	3	19	7

Table 2 *Smart Parking Systems and the services they provide*

- Parking Reservation: is the service where the user can reserve a parking lot in the designated area in advance by using the GUI provided by SPS.
- Vehicle Guidance: aims to guide the user towards the allocated/ free parking lot in a parking area.
- Online Payment: is the SPS service through which the user can pay the parking fees online.
- Gate Management: service is the management of various gates in a parking area. It provides the authority of the facility to open or close the desired gates in the parking area to control the traffic flow.
- Parking Supervision: means parking management from both user and authority points of view.
- Lot retrieval: means providing specific guidelines to the user to find the parked vehicle.[59]

1.3 Components of sps

1.3.1Sensors [60]

Details of sensors used to design, develop, and implement SPSs are expressed in the following:

1.3.1.1 Infrared (IR) sensor

IR sensor is an electrical device that detects and measures IR radiation emitted from an object. Any object that has a temperature higher than 5° or above emits IR radiation. IR sensors are mainly used for motion detection and temperature measurement purposes. IR sensors can be categorized into two types: Active Infrared Sensor and Passive Infrared Sensor.

Figure 1 *Infrared (IR) sensor*

1.3.1.2 Cellular Sensor

Cellular sensors are the sensors that are installed inside a smartphone. Although a smartphone might comprise many sensors, SPS, Accelerometer, Gyroscope, and Magnetometer are the mainly used sensors. These sensors are used for detecting the user's motion, orientation, and direction.

Figure 2 *Gyroscope*

1.3.1.3 Magneto-Resistive (MR) sensor

MR sensors are designed to detect the applied magnetic field without using any electrical contact. The principle of the MR sensor is very straightforward. When a magnetic field is applied, a change of resistance in any electrical conductor occurs that permeates. Changes in resistance depend on the orientation of the magnetic field lines. MR is mainly used for vehicle detection in parking lots.

Figure 3 *Magneto-Resistive (MR) sensor*

1.3.1.4 Acoustic array sensor

An acoustic array sensor detects sound or vibration of specific frequencies to determine the distance and direction of the sound source that created the sound or the re flector that re flected the sound. This type of localization technique is known as the passive acoustic location technique. In SPS, Acoustic Array Sensor is used to detect parking lot vacancy and for surveillance purposes.

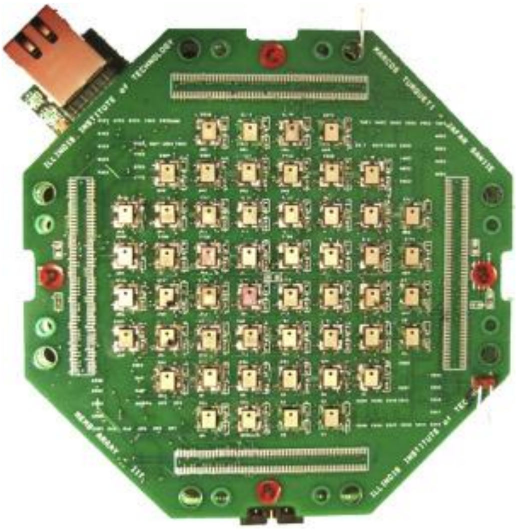

Figure 4 *Acoustic array sensor*

1.3.1.5 Ultrasonic sensor

Ultrasonic sensor uses acoustic waves in the range of 25 kHz to 50kHz to detect any nearby object that re flects the acoustic wave. This sensor is best suited for indoor applications due to not having the susceptibility to work under environmental changes such as snow and rain. Therefore, ultrasonic sensors are used for closed and indoor parking facilities where these sensors are usually mounted on the ceiling. Ultrasonic sensors can detect vehicles. Moreover, with proper implementation, this sort of sensor can segregate between a vehicle and a passer-by. Ultrasonic sensors are cheap and have a low maintenance cost.

Figure 5 *Ultrasonic sensor*

1.3.1.6 Camera

Using a camera or a network of cameras for vehicle detection and parking lot surveillance is widely adopted by many SPS researchers. Many researchers have used cameras and different computational tools (such as computer vision, image processing, etc., techniques) to detect license plates of vehicles for billing, reservation, and authentication. SPS using a camera or network of cameras provides a robust parking solution for users. However, camera-based SPS often tends to be expensive for both deployment and maintenance.

1.3.1.7 Inductive Loop detector

An inductive loop detector (also known as an Inductive loop traffic detector or Vehicle loop detector) is a vehicle detection method that utilizes the electromagnetic induction principle. This type of detector is installed under the road to detect vehicles above it. These detectors, along with some computational techniques, can classify different kinds of vehicles. Vehicle loop detectors are expensive and have a high installation cost. This sort of sensor is suitable for both open and closed parking lots.

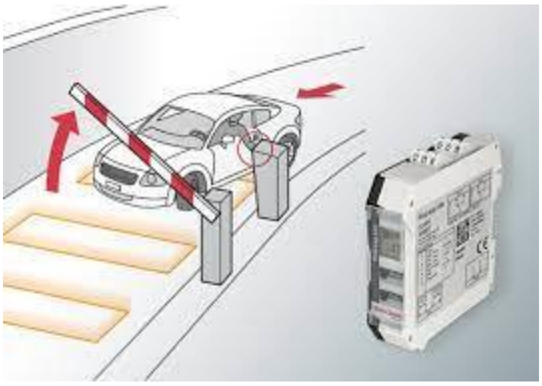

Figure 6 *Inductive Loop detector*

****** A careful study [61] shows the widespread utilization of IR Sensor, Acoustic Array Sensor, Camera, and Inductive Loop Detector in SPSs. Low implementation and maintenance cost is the main reason behind the popularity of IR Sensor, Acoustic Array Sensor, and Inductive Loop Detector in SPSs. The installation of a Camera might seem to be an expensive move towards SPS implementation. However, the Camera coverage area is relatively high compared to the other sensors, for which it becomes possible to cover a large. area with few Cameras Moreover, the Camera provides live surveillance of parking space, eliminating the need to install several other security protocols in a system. Due to the multitudinous functionalities, the Camera remains one of the frequently used sensor topologies in SPS.

1.3.2 User interfaces

To communicate with SPS, users may use different interfaces (such as web applications, smartphone applications, and Vehicle Information and Communication System). A description of various user interfaces used in SPSs is presented in the following :[62]

1.3.2.1 Web application

To provide remote access to the end-users, many SPSs use web applications based on Hyper Text Transfer Protocol (HTTP) and Transmission Control Protocol (TCP)/Internet Protocol (IP) protocols. Web applications of SPS usually provide a Graphical User Interface (GUI) to the end-user. The web application offers services such as real-time parking lot status of the parking area, guidance to the nearest parking lot or parking area, parking spot reservation facility, online payment facility, etc.

1.3.2.2 Smart phone application

A significant percentage of SPS deploys Android or IOS applications for the end-users to provide them information regarding the smart parking facilities. Like web-based applications, smartphone applications also provide a GUI for the user to interact with the system. Also, to receive information on real-time parking lot status, get vehicle guidance to the nearest parking area or a lot, reserve parking lot, retrieve parking lot information, and pay parking fees via online services or smartphones' Near Field Communication (NFC) technology.

1.3.2.3 Vehicle information and communication (VICS)

VICS is a technology used for delivering traffic and travel information to the driver via a monitor mounted on the vehicle's dashboard. In SPS, VICSs are used to get information on the nearest parking area and traffic congestion. In some cases, they can also be used for parking reservations.

1.3.2.4 Liquid Crystal Display (LCD) [63]

LCD stands for Liquid Crystal Display, and it is a type of flat-panel display that uses liquid crystals to produce images. The liquid crystals are sandwiched between two polarizing filters and when an electric current is applied, the crystals align to allow light to pass through or block it.

LCD displays are commonly used in televisions, computer monitors, smartphones, and other electronic devices. They are known for their low power consumption, thin profile, and sharp image quality.

There are two main types of LCD panels: Twisted Nematic (TN) and In-Plane Switching (IPS). TN panels are the most common and offer fast response times and high refresh rates, making them ideal for gaming and other applications that require quick image transitions.

IPS panels, on the other hand, offer wider viewing angles and better color reproduction, making them a popular choice for professionals who require accurate color representation, such as graphic designers and photographers.

In SPS, the user can see the information on an LCD installed at the entrance of the parking area.

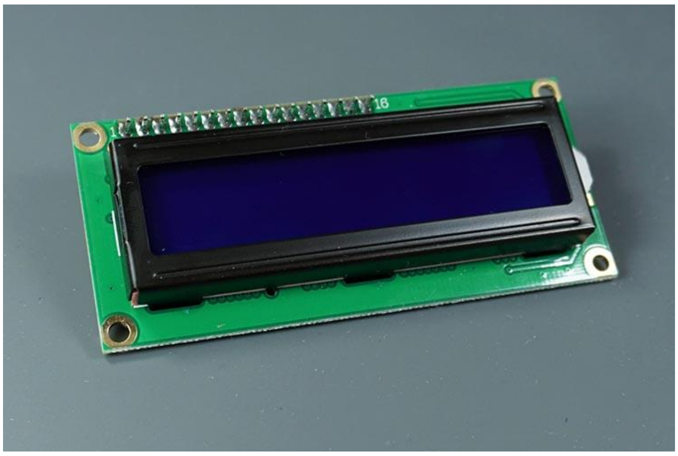

Figure 7 *Liquid Crystal Display (LCD)*

1.3.3Actuators [64]

Actuators are devices that convert electrical, hydraulic or pneumatic energy into mechanical motion. They are used in a wide range of applications, including robotics, manufacturing, aerospace, and automotive industries.

There are many different types of actuators, each with their own advantages and disadvantages. Some common types include electric actuators, hydraulic actuators, and pneumatic actuators:

1.3.3.1 Electric Actuators

Electric actuators are powered by electricity and use an electric motor to generate motion. They are commonly used in industrial automation applications, such as controlling valves, pumps, and conveyor belts.

One advantage of electric actuators is their high precision and repeatability. They can also be easily programmed and controlled using computer software, making them ideal for complex operations.

Figure 8 *Electric Actuators*

1.3.4Micro-controller [65]

A micro-controller is a small computer on a single integrated circuit that can be programmed to control various devices. It contains a processor, memory, and input/output peripherals on a single chip.

Micro-controllers are widely used in embedded systems, which are computer systems integrated into other devices such as cars, appliances, and medical equipment.

The architecture of a micro-controller consists of a central processing unit (CPU), memory, and input/output peripherals. The CPU is responsible for executing instructions and performing arithmetic and logical operations. Memory is used to store data and program code, while input/output peripherals allow the micro-controller to interact with external devices.

There are different types of micro-controllers based on their architecture, such as Harvard architecture and von Neumann architecture. Each type has its own advantages and disadvantages depending on the application.

programming a micro-controller involves writing code in a high-level language such as C or assembly language. The code is then compiled into machine code that can be executed by the micro-controller. There are also Integrated Development Environments (IDEs) that provide a graphical interface for programming and debugging micro-controllers.

Micro-controllers can be programmed to perform a wide range of tasks, from simple operations such as turning on an LED to complex operations such as controlling a robot arm.

Types of micro-controllers

1.3.4.1 PIC Microcontroller

Micro-controller PIC is a small computer on a single integrated circuit. It consists of a CPU, memory, and input/output peripherals all on a single chip. PIC stands for Peripheral Interface Controller and it was developed by Microchip Technology in the early 1980s.

The architecture of a typical PIC micro-controller consists of three main components: CPU, memory, and input/output peripherals. The CPU executes instructions stored in the memory and communicates with the input/output peripherals to perform tasks.

The memory of a PIC micro-controller is divided into two types: program memory and data memory. Program memory stores the firmware or software that controls the behavior of the micro-controller, while data memory stores variables and other data used by the program.

Programming a PIC micro-controller involves writing code in a high-level programming language such as C or assembly language. The code is then compiled and uploaded to the micro-controller using a programmer device.

Microchip provides an Integrated Development Environment (IDE) called MPLAB X IDE to develop and debug code for PIC micro-controllers. The IDE includes a compiler, debugger, and other tools to simplify the development process.

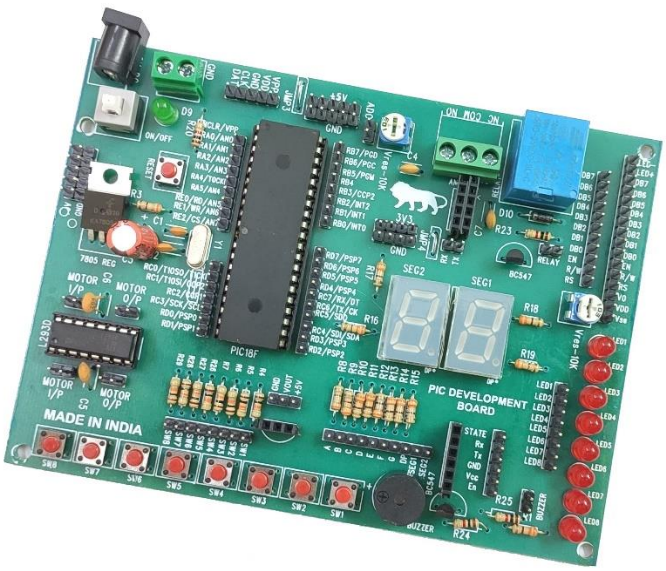

Figure 9 *PIC Microcontroller*

1.3.4.2 Programmable Logic Controllers (PLC)

Programmable Logic Controllers (PLC) are digital computers that are designed to control industrial processes and machines. They are used in a wide range of applications, from manufacturing and production lines to complex machinery and automation systems.

PLCs are capable of executing complex logic operations, making them an essential component of modern industrial automation systems. They are highly reliable and can operate in harsh environments, making them ideal for use in factories and other industrial settings.

A typical PLC system consists of several components, including a processor unit, input/output modules, power supply, and programming software. The processor unit is the brain of the system and executes the program instructions. Input/output modules are used to interface with sensors and actuators in the industrial process.

The power supply provides the necessary voltage and current to operate the system. Programming software is used to create and edit the program instructions that are executed by the processor unit. These components work together to form a complete PLC system that can be tailored to meet the specific needs of an industrial process.

PLCs can be programmed using several different languages, including ladder logic, function block diagrams, structured text, and sequential function charts. Ladder logic is the most commonly used language and is based on the graphical representation of electrical circuits.

Function block diagrams use blocks to represent functions and their relationships, while structured text is a high-level programming language similar to C or Pascal. Sequential function charts use graphical representations to show the flow of a process. Each language has its own strengths and weaknesses, and the choice of language depends on the specific requirements of the industrial process.

There are several advantages to using PLCs in industrial automation systems. One of the main advantages is their ability to execute complex logic operations quickly and reliably. They are also highly flexible and can be easily reprogrammed to adapt to changes in the industrial process.

Figure 10 *Programmable Logic Controllers (PLC)*

1.3.4.3 Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's designed for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.

The platform consists of a programmable microcontroller board and a development environment that runs on your computer. You write code using the Arduino programming language, which is based on Wiring, and upload it to the board. The board then executes the code and interacts with sensors, motors, and other electronic components.

To get started with Arduino, we'll need to purchase an Arduino board and some basic components like LEDs, resistors, and sensors.

Once we have our components, we'll need to download the Arduino software and install it on your computer. From there, we can start writing code and uploading it to our board to create projects.

Arduino can be used in a wide range of applications, from simple LED displays to complex robotics projects. Some common uses include home automation, environmental monitoring, and wearable technology.

Figure 11 *Arduino Uno*

1.4 Conclusion

In conclusion, this chapter has provided a comprehensive exploration of the world of smart parking systems (SPSs), shedding light on their significance and the various aspects associated with their implementation.

We delved into the definition of SPSs, establishing a clear understanding of their purpose and functionality. This foundation enabled us to explore the realm of smart parking system survey researches, where we examined the existing literature and studies conducted in this field. By reviewing and analyzing these researches, we gained valuable insights into the current state of SPSs and the challenges they aim to address.

Furthermore, we discussed different approaches to designing and implementing smart parking systems. By exploring various technological solutions and methodologies, we highlighted the diversity of strategies used in creating efficient and intelligent parking systems. This examination emphasized the importance of customization and adaptability to meet the specific needs of different urban areas.

Lastly, we explored the classification of reviewed SPSs, categorizing them based on their functionalities, technologies, and user experiences. This categorization allowed us to gain a deeper understanding of the range of smart parking systems available today and the unique benefits they offer.

In dissecting the components of smart parking systems, we have unveiled the intricate machinery that powers these intelligent infrastructures. From sensors that detect occupancy to microcontrollers that orchestrate operations, each component plays a crucial role in creating a seamless and efficient parking experience.

In conclusion, this chapter has provided a comprehensive overview of smart parking systems, from their definition and survey researches to the approaches and classifications associated with their implementation. The knowledge gained through this exploration serves as a solid foundation for further understanding the potential of smart parking systems and their integration into future urban environments. As we continue to innovate in the field of transportation and urban planning, the insights from this chapter will be valuable in developing more efficient, sustainable, and user-friendly parking solutions.

Chapter 2 AI, Iot & Smart parkings

2.1 Introduction

In an era defined by technological advancements, artificial intelligence (AI), the Internet of Things (IoT), and the concept of smart parking have emerged as pivotal forces shaping our modern world. This chapter delves into the fascinating realm where these domains intersect, providing an in-depth exploration of AI, IoT, and their transformative influence on the realm of parking systems.

The chapter begins by elucidating the fundamental definitions of AI, IoT, and smart parking. AI, as a multidisciplinary field, encompasses the development of intelligent systems capable of learning, reasoning, and problem-solving, often mimicking human cognitive processes. IoT, on the other hand, revolves around the network of interconnected devices, enabling them to communicate and share data seamlessly, leading to a convergence of physical and digital worlds. Within this context, smart parking emerges as a concrete application of AI and IoT, revolutionizing the traditional parking infrastructure by employing cutting-edge technologies.

To grasp the significance of AI and its application in smart parking, the chapter navigates through the rich tapestry of AI's history. Tracing its roots back to the mid-20th century, we explore key milestones and breakthroughs that have propelled AI to its current state, highlighting how this field has evolved and matured over time.

Furthermore, the chapter sheds light on the diverse research areas within AI, encompassing machine learning, natural language processing, computer vision, and robotics. By understanding these research domains, we gain insight into the vast possibilities offered by AI in developing smart parking systems that enhance efficiency, optimize resource allocation, and improve user experience.

Transitioning into the realm of IoT, the chapter unravels the history of this interconnected ecosystem. We delve into the origins of IoT and trace its evolution from a concept to a pervasive force driving the digital transformation of various industries. Moreover, we provide a comprehensive definition of IoT, establishing a common understanding of its core principles and capabilities.

The discussion then shifts towards exploring the diverse communication models within IoT. We examine the different ways devices and systems communicate, be it through local area networks (LANs), wide area networks (WANs), or wireless protocols. By unraveling the intricacies of IoT's communication landscape, we lay the foundation for comprehending its role in enabling smart parking systems.

Examining the advantages and disadvantages of IoT, the chapter delves into the potential benefits and challenges associated with implementing IoT in smart parking solutions. We explore the enhanced convenience, optimized resource utilization, and improved sustainability that IoT offers while acknowledging concerns such as data security, privacy, and the potential for system vulnerabilities.

Finally, the chapter dissects the components that form the backbone of smart parking systems. From sensors that detect parking space occupancy to user interfaces that provide real-time information, from actuators that enable automated processes to microcontrollers that orchestrate system operations, we delve into the intricate machinery that powers smart parking infrastructure.

In this chapter, we embark on a captivating journey through the realms of AI, IoT, and smart parking. By understanding their definitions, historical contexts, research areas, communication models, advantages, disadvantages, and key components, we lay the groundwork for unraveling the immense potential and impact of this transformative convergence. Let us embark on this exploration of the technological frontier, where AI, IoT, and smart parking intertwine to shape the cities of tomorrow.

2.2 Literature review

2.2.1 Artificial Intelligence AI

2.2.1.1 Definition

According to the father of Artificial Intelligence John McCarthy, it is “The science and engineering of making intelligent machines, especially intelligent computer programs”. Artificial Intelligence is a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think. AI is accomplished by studying how human brain thinks, and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems. [66]

2.2.1.2 History of AI

The following table represent the history of AI during 20th century: [67]

Year	Milestone / Innovation
1923	Karel Čapek's play named "Rossum's Universal Robots" (RUR) opens in London, first use of the word "robot" in English.
1943	Foundations for neural networks laid.
1945	Isaac Asimov, a Columbia University alumni, coined the term Robotics.
1950	Alan Turing introduced Turing Test for evaluation of intelligence and published Computing Machinery and Intelligence. Claude Shannon published Detailed Analysis of Chess Playing as a search.
1956	John McCarthy coined the term Artificial Intelligence. Demonstration of the first running AI program at Carnegie Mellon University.
1958	John McCarthy invents LISP programming language for AI.
1964	Danny Bobrow's dissertation at MIT showed that computers can understand natural language well enough to solve algebra word problems correctly.
1965	Joseph Weizenbaum at MIT built ELIZA, an interactive problem that carries on a dialogue in English.
1969	Scientists at Stanford Research Institute Developed Shakey, a robot, equipped with locomotion, perception, and problem solving
1973	The Assembly Robotics group at Edinburgh University built Freddy, the Famous Scottish Robot, capable of using vision to locate and assemble models.
1979	The first computer-controlled autonomous vehicle, Stanford Cart, was built.
1985	Harold Cohen created and demonstrated the drawing program, Aaron.
1990	Major advances in all areas of AI: • Significant demonstrations in machine learning • Case-based reasoning • Multi-agent planning • Scheduling • Data mining, Web Crawler • natural language understanding and translation • Vision, Virtual Reality • Games
1997	The Deep Blue Chess Program beats the then world chess champion, Garry Kasparov.
2000	Interactive robot pets become commercially available. MIT displays Kismet, a robot with a face that expresses emotions. The robot Nomad explores remote regions of Antarctica and locates meteorites.

***Table 3** History of AI*

2.2.1.3 Research Areas of AI

The domain of artificial intelligence is huge in breadth and width. While proceeding, we consider the broadly common and prospering research areas in the domain of AI:

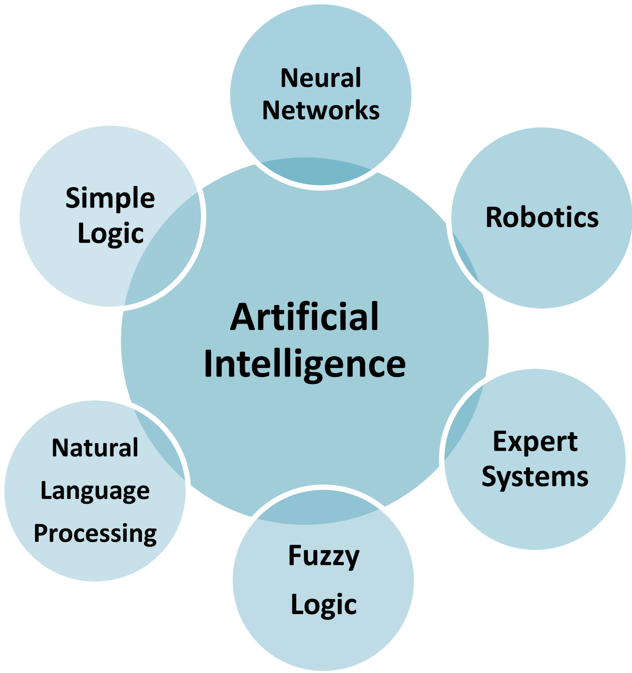

Figure 12 *Domain of artificial intelligence*

2.2.1.3.1 Simple logic

Simple logic is the foundation of reasoning and critical thinking. It involves evaluating arguments and drawing conclusions based on evidence and sound reasoning. Simple logic is an essential tool for decision-making, problem-solving, and understanding complex issues.

In its simplest form, logic is the study of truth and falsehood. It is concerned with the principles of reasoning and inference, and how we can use these principles to determine whether a statement or argument is true or false.

There are three basic principles of simple logic: deduction, induction, and abduction.

- Deduction is the process of reasoning from general principles to specific conclusions.
- Induction is the process of reasoning from specific observations to general conclusions.
- Abduction is the process of reasoning to the best explanation of a given set of facts.

Another important principle of simple logic is the distinction between validity and soundness. A valid argument is one in which the conclusion necessarily follows from the premises, while a sound argument is both valid and has true premises.[68]

A simple logic program is a computer program that utilizes formal logic to perform reasoning and computation. It is typically written in a logical programming language, such as Prolog or Datalog. These languages are based on mathematical logic, which allows for the representation and manipulation of complex relationships and structures.

A logical program consists of a set of rules, which describe the relationships between different pieces of information or data. These rules are expressed in terms of logical predicates, which represent propositions or statements that can be true or false. The program uses these rules to derive new facts and to make decisions based on the input data.

In a logical program, the process of computation involves searching for a solution to a problem by applying the rules of logic. The program uses a set of inference rules to deduce new facts from the existing data and to eliminate contradictions. The inference rules are based on logical principles, such as modus ponens and resolution, which allow for the derivation of new knowledge from existing knowledge.

Logical programming languages have applications in a wide range of fields, including artificial intelligence, knowledge representation and management, and database systems. They are particularly useful in expert systems, where they can be used to represent and reason about complex domains of knowledge, and in natural language processing, where they can be used to analyze and interpret text.

2.2.1.3.2 Fuzzy Logic Systems [69]

- **What is Fuzzy Logic ?**

Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO. The conventional logic block that a computer can understand takes precise input and produces a definite output as TRUE or FALSE, which is equivalent to human's YES or NO. The inventor of fuzzy logic, Lotfi Zadeh, observed that unlike computers, the human decision making includes a range of possibilities between YES and NO, such as:

CERTAINLY YES
POSSIBLY YES
CANNOT SAY
POSSIBLY NO
CERTAINLY NO

The fuzzy logic works on the levels of possibilities of input to achieve the definite output.

Briefly Fuzzy Logic Systems (FLS) produce acceptable but definite output in response to incomplete, ambiguous, distorted, or inaccurate (fuzzy) input.

- It can be implemented in systems with various sizes and capabilities ranging from small micro-controllers to large, networked, workstation-based control systems.
- It can be implemented in hardware, software, or a combination of both.

Fuzzy Logic Systems Architecture

It has four main parts as shown:

➢ Fuzzification Module: transforms the system inputs, which are crisp numbers, into fuzzy sets. It splits the input signal into five steps such as:

LP	x is Large Positive
MP	x is Medium Positive
S	x is Small
MN	x is Medium Negative
LN	x is Large Negative

➢ Knowledge Base: It stores IF-THEN rules provided by experts.

➢ Inference Engine: It simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.

➢ Defuzzification Module: It transforms the fuzzy set obtained by the inference engine into a crisp value.

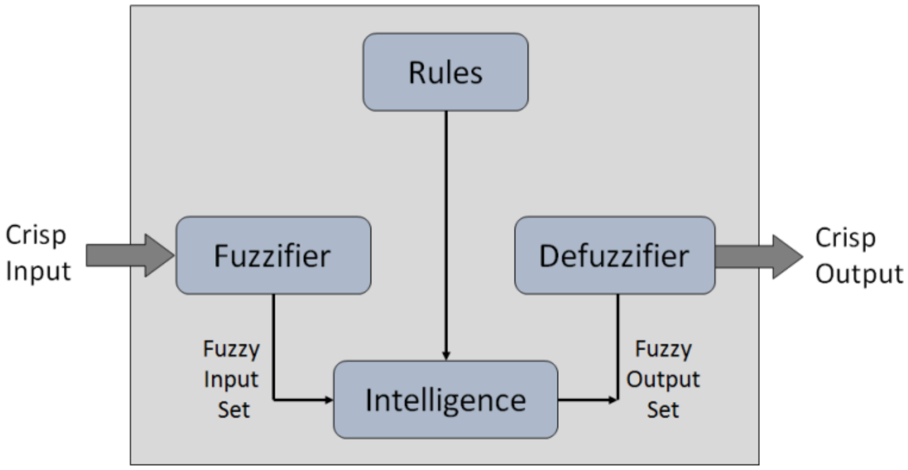

Figure 13 *Fuzzy Logic Systems Architecture*

Application Areas of Fuzzy Logic

The key application areas of fuzzy logic are as given:

- Automotive Systems (Automatic Gearboxes, Four-Wheel Steering, Vehicle environment control…)
- Consumer Electronics (Hi-Fi Systems, Photocopiers, Still and Video Cameras, Television…)
- Domestic Goods (Microwave Ovens, Refrigerators, Toasters, Vacuum Cleaners…)
- Environment Control (Air Conditioners/Dryers/Heaters, Humidifiers..)

Advantages of FLSs

- Mathematical concepts within fuzzy reasoning are very simple.
- You can modify a FIS by just adding or deleting rules due to flexibility of fuzzy logic.
- Fuzzy logic Systems can take imprecise, distorted, noisy input information.
- FLSs are easy to construct and understand.
- Fuzzy logic is a solution to complex problems in all fields of life, including medicine, as it resembles human reasoning and decision making.

Disadvantages of FLSs

- There is no systematic approach to fuzzy system designing.
- They are understandable only when simple.
- They are suitable for the problems which do not need high accuracy.

2.2.1.3.3 Natural Language Processing [70]

Natural Language Processing (NLP) refers to AI method of communicating with an intelligent system using a natural language such as English.

Processing of Natural Language is required when you want an intelligent system like robot to perform as per your instructions, when you want to hear decision from a dialogue based clinical expert system, etc.

The field of NLP involves making computers to perform useful tasks with the natural languages humans use. The input and output of an NLP system can be:

- Speech
- Written Text

2.2.1.3.4 Expert Systems [71]

Expert systems (ES) are one of the prominent research domains of AI. It is introduced by the researchers at Stanford University, Computer Science Department.

The expert systems are the computer applications developed to solve complex problems in a particular domain, at the level of extra-ordinary human intelligence and expertise.

Some of their characteristics are: high performance, understandable, reliable, highly responsive.

2.2.1.3.5 Robotics [72]

- **What are Robots ?**

Robots are aimed at manipulating the objects by perceiving, picking, moving, modifying the physical properties of object, destroying it, or to have an effect thereby freeing manpower from doing repetitive functions without getting bored, distracted, or exhausted.

Robotics is a domain in artificial intelligence that deals with the study of creating intelligent and efficient robots.

Robotics is a branch of AI, which is composed of Electrical Engineering, Mechanical Engineering, and Computer Science (computer program) for designing, construction, and application of robots.

- **Components of a Robot**

Robots are constructed with the following:

- Power Supply: The robots are powered by batteries, solar power, hydraulic, or pneumatic power sources.

- Actuators: They convert energy into movement.
- Electric motors (AC/DC): They are required for rotational movement.
- Pneumatic Air Muscles: They contract almost 40% when air is sucked in them.
- Muscle Wires: They contract by 5% when electric current is passed through them.
- Piezo Motors and Ultrasonic Motors: Best for industrial robots.
- Sensors: They provide knowledge of real time information on the task environment. Robots are equipped with vision sensors to be to compute the depth in the environment. A tactile sensor imitates the mechanical properties of touch receptors of human fingertips.

2.2.1.3.6 Neural Networks [73]

What are Artificial Neural Networks (ANNs)?

Yet another research area in AI, neural networks, is inspired from the natural neural network of human nervous system.

The inventor of the first neurocomputer, Dr. Robert Hecht-Nielsen, defines a neural network as:

"...a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs."

The idea of ANNs is based on the belief that working of human brain by making the right connections, can be imitated using silicon and wires as living neurons and dendrites.

The human brain is composed of 100 billion nerve cells called neurons. They are connected to other thousand cells by Axons. Stimuli from external environment or inputs from sensory organs are accepted by dendrites. These inputs create electric impulses, which quickly travel through the neural network. A neuron can then send the message to other neuron to handle the issue or does not send it forward.

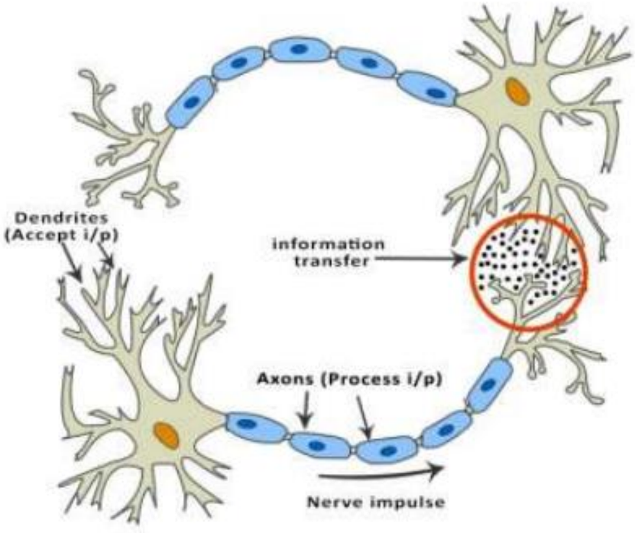

Figure 14 *Illustration of Neural Networks*

ANNs are composed of multiple nodes, which imitate biological neurons of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its activation or node value.

Each link is associated with weight. ANNs are capable of learning, which takes place by altering weight values. The following illustration shows a simple ANN:

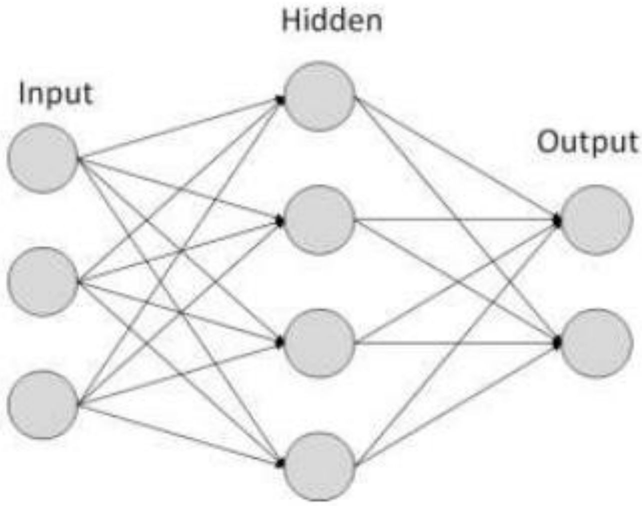

Figure 15 *Illustration of a simple ANN*

Types of Artificial Neural Networks

There are two Artificial Neural Network topologies: FeedForward and Feedback.

➢ FeedForward ANN

In this ANN, the information flow is unidirectional. A unit sends information to other unit from which it does not receive any information. There are no feedback loops. They are used in pattern generation/recognition/classification. They have fixed inputs and outputs.

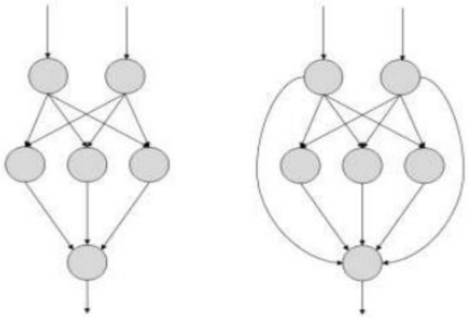

Figure 16 *Illustration of a FeedForward ANN*

➢ Feedback ANN

Here, feedback loops are allowed. They are used in content addressable memories.

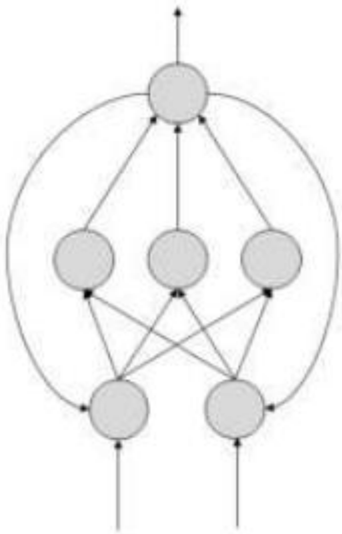

Figure 17 *Illustration of a Feedback ANN*

In the topology diagrams shown, each arrow represents a connection between two neurons and indicates the pathway for the flow of information. Each connection has a weight, an integer number that controls the signal between the two neurons.

If the network generates a “good or desired” output, there is no need to adjust the weights. However, if the network generates a “poor or undesired” output or an error, then the system alters the weights in order to improve subsequent results.

Applications of Neural Networks

- Aerospace.
- Automotive
- Military.
- Electronics
- Financial
- Industrial Medical
- Telecommunications
- Transportation

2.2.2Internet of things IoT

2.2.2.1 History of IoT

The term “Internet of Things” (IoT) was first used in 1999 by British technology pioneer Kevin Ashton to describe a system in which objects in the physical world could be connected to the Internet by sensors. Ashton coined the term to illustrate the power of connecting Radio-Frequency Identification (RFID) tags used in corporate supply chains to the Internet in order to count and track goods without the need for human intervention. Today, the Internet of Things has become a popular term for describing scenarios in which Internet connectivity and computing capability extend to a variety of objects, devices, sensors, and everyday items.

While the term “Internet of Things” is relatively new, the concept of combining computers and networks to monitor and control devices has been around for decades. By the late 1970s, for example, systems for remotely monitoring meters on the electrical grid via telephone lines were already in commercial use. In the 1990s, advances in wireless technology allowed “machine–to–machine” (M2M) enterprise and industrial solutions for equipment monitoring and operation to become widespread. Many of these early M2M solutions, however, were based on closed purpose–

built networks and proprietary or industry–specific standards, rather than on Internet Protocol (IP)–based networks and Internet standards.

Using IP to connect devices other than computers to the Internet is not a new idea. The first Internet "device"—an IP–enabled toaster that could be turned on and off over the Internet—was featured at an Internet conference in 1990. Over the next several years, other "things" were IP–enabled, including a soda machine at Carnegie Mellon University in the US and a coffee pot in the Trojan Room at the University of Cambridge in the UK (which remained Internet–connected until 2001). From these whimsical beginnings, a robust field of research and development into "smart object networking" helped create the foundation for today's Internet of Things. [74]

2.2.2.2 Definition

Despite the global buzz around the Internet of Things, there is no single, universally accepted definition for the term. Different definitions are used by various groups to describe or promote a particular view of what IoT means and its most important attributes.

All of the definitions describe scenarios in which network connectivity and computing capability extends to a constellation of objects, devices, sensors, and everyday items that are not ordinarily considered to be "computers''; this allows the devices to generate, exchange, and consume data, often with minimal human intervention. The various definitions of IoT do not necessarily disagree – rather they emphasize different aspects of the IoT phenomenon from different focal points and use cases.[75]

2.2.2.3 **Internet of Things Communications Models** [76]

From an operational perspective, it is useful to think about how IoT devices connect and communicate in terms of their technical communication models. In March 2015, the Internet Architecture Board (IAB) released a guiding architectural document for networking of smart objects (RFC 7452), which outlines a framework of four common communication models used by IoT devices. The discussion below presents this framework and explains key characteristics of each model in the framework.

- **Device-to-Device Communications**

The device-to-device communication model represents two or more devices that directly connect and communicate between one another, rather than through an intermediary application server. These devices communicate over many types of networks, including IP networks or the Internet.

Often, however these devices use protocols like Bluetooth,Z-Wave, or ZigBee to establish direct device-to-device communications, as shown in Figure 18 .

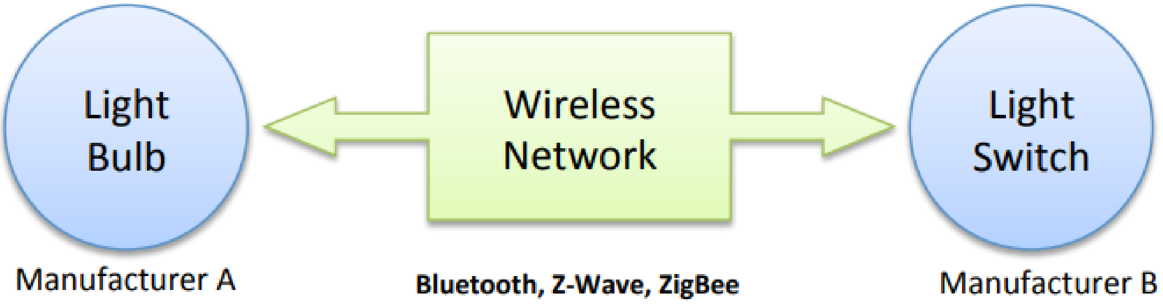

Figure 18 *Example of device-to-device communication model*

These device-to-device networks allow devices that adhere to a particular communication protocol to communicate and exchange messages to achieve their function. This communication model is commonly used in applications like home automation systems, which typically use small data packets of information to communicate between devices with relatively low data rate requirements. Residential IoT devices like light bulbs, light switches, thermostats, and door locks normally send small amounts of information to each other (e.g. a door lock status message or turn on light command) in a home automation scenario.

Device-to-Cloud Communications

In a device-to-cloud communication model, the IoT device connects directly to an Internet cloud service like an application service provider to exchange data and control message traffic. This approach frequently takes advantage of existing communications mechanisms like traditional wired Ethernet or Wi-Fi connections
to establish a connection between the device and the IP network, which ultimately connects to the cloud service. This is shown in Figure19 .

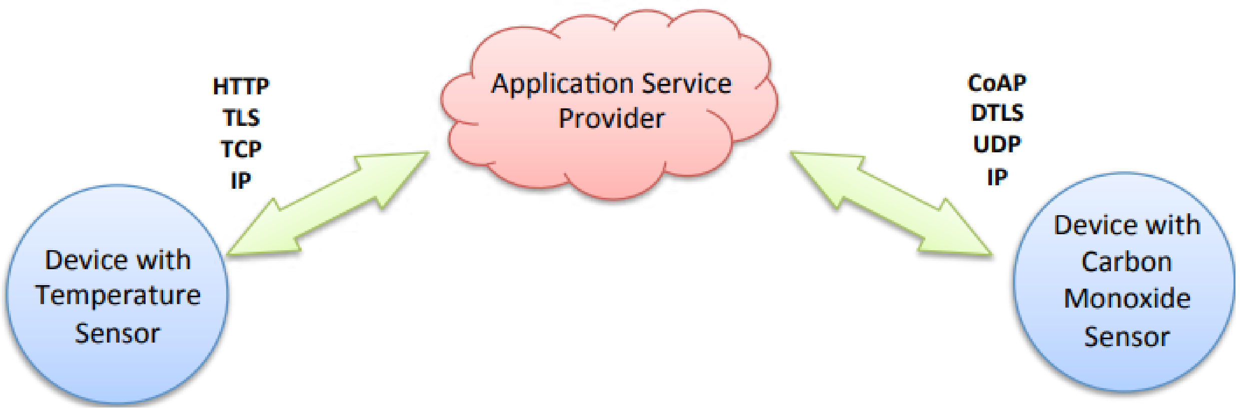

Figure 19 *Device-to-cloud communication model diagram*

Device-to-Gateway Model

In the device-to-gateway model, or more typically, the device-to-application-layer gateway (ALG) model, the IoT device connects through an ALG service as a conduit to reach a cloud service. In simpler terms, this means that there is application software operating on a local gateway device, which acts as an intermediary between the device and the cloud service and provides security and other functionality such as data or protocol translation. The model is shown in Figure 20 .

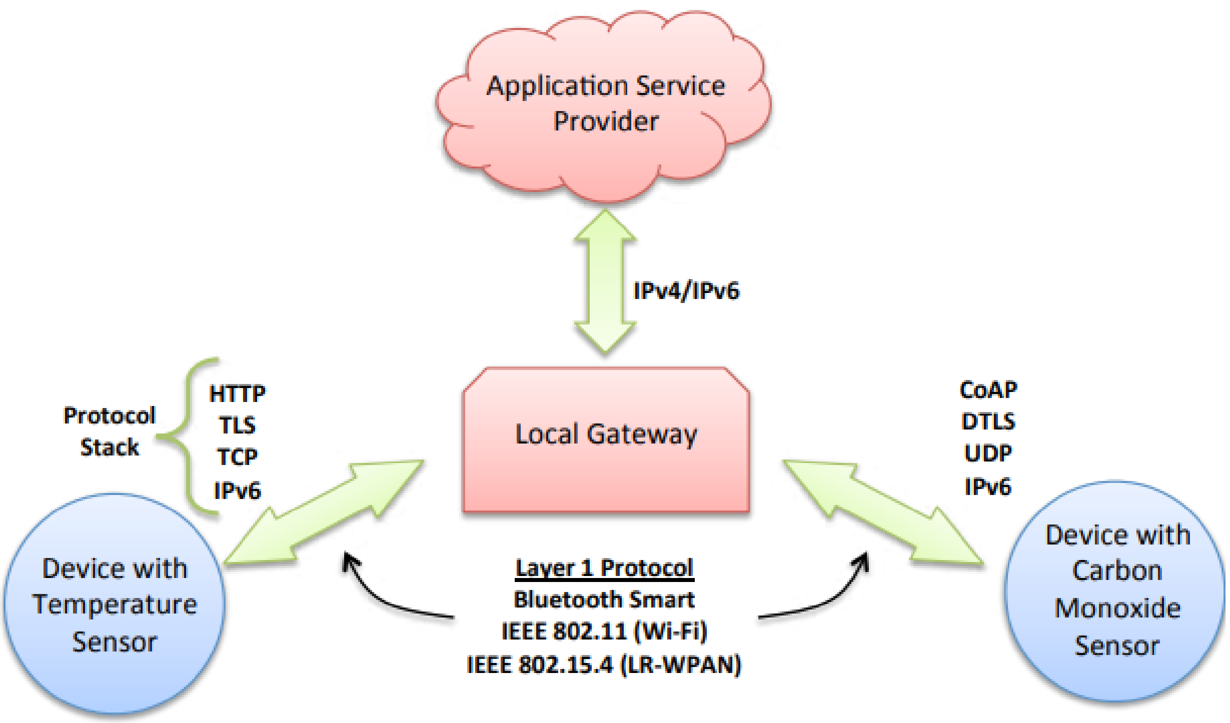

Figure 20 *Device-to-gateway communication model diagram.*

Several forms of this model are found in consumer devices. In many cases, the local gateway device is a smartphone running an app to communicate with a device and relay data to a cloud service. This is often the model employed with popular consumer items like personal fitness trackers. These devices do not have the native ability to connect directly to a cloud service, so they frequently rely on smartphone app software to serve as an intermediary gateway to connect the fitness device to the cloud.

Back-End Data-Sharing Model

The back-end data-sharing model refers to a communication architecture that enables users to export and analyze smart object data from a cloud service in combination with data from other sources. This architecture supports "the [user's] desire for granting access to the uploaded sensor data to third parties". This approach is an extension of the single device-to-cloud communication model, which can lead to data silos where "IoT devices upload data only to a single application service provider''. A back-end sharing architecture allows the data collected from single IoT device data streams to be aggregated and analyzed.

The back-end data-sharing model suggests a federated cloud services approach or cloud applications programmer interfaces (APIs) are needed to achieve interoperability of smart device data hosted in the cloud. A graphical representation of this design is shown in Figure 21.

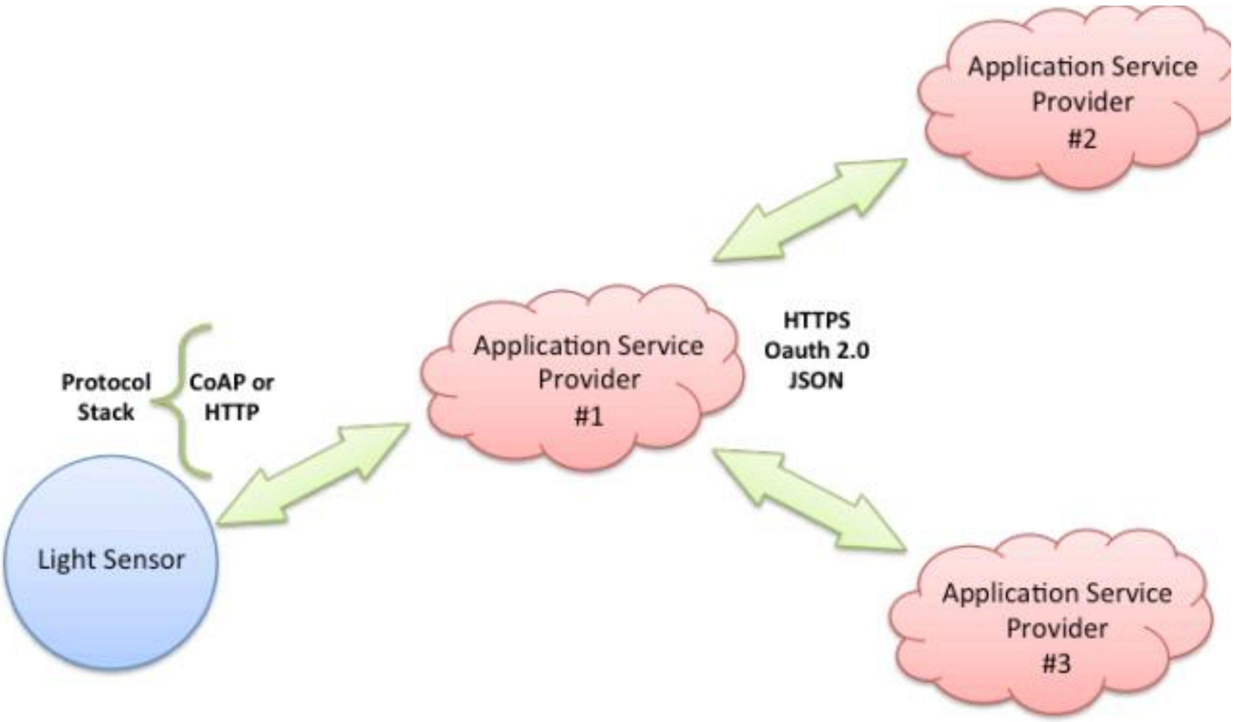

Figure 21 *Back-end data sharing model diagram*

2.2.2.4 IoT – Advantages

The advantages of IoT span across every area of lifestyle and business. Here is a list of some of the advantages that IoT has to offer:[77]

- Improved Customer Engagement :Current analytics suffer from blind-spots and significant flaws in accuracy; and as noted, engagement remains passive. IoT completely transforms this to achieve richer and more effective engagement with audiences.
- Technology Optimization : The same technologies and data which improve the customer experience also improve device use, and aid in more potent improvements to technology. IoT unlocks a world of critical functional and field data.
- Reduced Waste :IoT makes areas of improvement clear. Current analytics give us superficial insight, but IoT provides real-world information leading to more effective management of resources.
- Enhanced Data Collection :Modern data collection suffers from its limitations and its design for passive use. IoT breaks it out of those spaces, and places it exactly where humans really want to go to analyze our world. It allows an accurate picture of everything.

2.2.2.5 IoT Disadvantage

Though IoT delivers an impressive set of benefits, it also presents a significant set of challenges. Here is a list of some its major issues:[78]

- Security :IoT creates an ecosystem of constantly connected devices communicating over networks. The system offers little control despite any security measures. This leaves users exposed to various kinds of attackers.
- Privacy :The sophistication of IoT provides substantial personal data in extreme detail without the user's active participation.
- Complexity : Some find IoT systems complicated in terms of design, deployment, and maintenance given their use of multiple technologies and a large set of new enabling technologies.
- Flexibility : Many are concerned about the flexibility of an IoT system to integrate easily with another. They worry about finding themselves with several conflicting or locked systems.
- Compliance : IoT, like any other technology in the realm of business, must comply with regulations. Its complexity makes the issue of compliance seem incredibly challenging when many consider standard software compliance a battle.

2.3 AI , IOT & SPSs

Smart parking system can be build using IoT platform, where all stakeholders can part of the smart system. The problem much focused on parking slot allocation based on user given priority with IoT platform to make parking location smart system operated with help of automation explained flow of different layers in Figure 22 [79], The mobile application helps users to access available parking slot booking . Internet of Things is an emergent subject as per including, computing and sensing device systems, with sensing devices, immense data collections and generating to apply in that with AI model is to give complete entrenched system for application usage. Hence IoT model are highly flexible, trustworthy, effectual and simple to use and handle, in the way deep utilization in various applications. With help of IoT information can be gathered more efficaciously, system operations can be finished in highly precise with connectivity. Internet of things platform used in wide range of application to automat model with edge computing [80,81]. The sensors and actuators are useful to collect data from real time inputs. The networking model based on NFD (NDN Forwarding Daemon)(NFD is a network forwarder which is used to implements the Named Data Networking working protocol), Wi-Fi, Bluetooth and Zigbee, the sensing device are utilized with network for communicating purpose. These sensing devices connecting with wide range of network models like GSM, GPRS, 3G and LTE. [82]

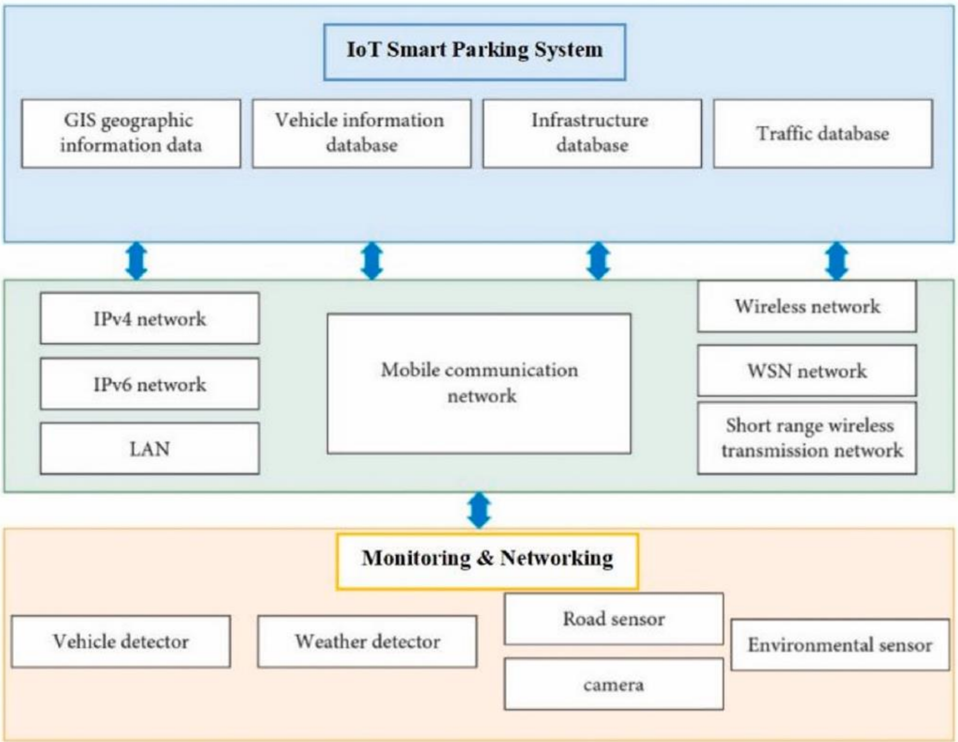

Figure 22 *IoT based Smart Parking System Operational and Communication Framework.*

2.4 Conclusion

The chapter has delved into the enthralling intersection of artificial intelligence (AI), the Internet of Things (IoT), and smart parking, unearthing the transformative power of these technologies in revolutionizing our urban landscapes. By exploring the definitions, historical contexts, research areas, communication models, advantages, disadvantages, and key components within these domains, we have gained a comprehensive understanding of their significance.

AI, with its rich history and evolving research areas, has emerged as a driving force behind the development of intelligent systems. From machine learning algorithms to computer vision techniques, AI offers a vast array of tools that can be harnessed to create efficient and user-centric smart parking solutions.

The advent of IoT has reshaped the way devices communicate and interact, creating a seamlessly interconnected ecosystem. By leveraging IoT's capabilities, smart parking systems can achieve real-time data collection, analysis, and decision-making, resulting in optimized parking resource management and enhanced user experiences.

Throughout our exploration, we have recognized the advantages offered by AI, IoT, and smart parking. These include improved efficiency, reduced congestion, enhanced sustainability, and enhanced convenience for drivers. However, we must also remain cognizant of the potential challenges and risks, such as data security, privacy concerns, and system vulnerabilities, which demand careful attention and mitigation strategies.

As we conclude this chapter, we are left with a profound appreciation for the convergence of AI, IoT, and smart parking. These technologies hold immense potential to reshape our urban environments, addressing the pressing challenges of parking congestion, resource allocation, and sustainability. By harnessing the power of AI and IoT, we can create intelligent parking ecosystems that optimize space utilization, improve user convenience, and contribute to a more sustainable future.

With ongoing advancements and research in these fields, the trajectory of AI, IoT, and smart parking continues to evolve. As cities strive to become smarter and more connected, it is imperative for researchers, policymakers, and stakeholders to collaborate and navigate the ethical, social, and technical implications that arise. Together, we can shape a future where AI, IoT, and smart parking converge to create intelligent, sustainable, and user-centric urban spaces for generations to come.

Chapter 3 : Conception & Results

3.1 Introduction

Chapter 3 marks a pivotal phase in our study as we delve into the intricate details of the Conception & Results of our project. Building upon the foundation established in the preceding chapters, this chapter serves as a gateway to the core of our work, where we present the culmination of our efforts and unveil the outcomes we have achieved.

In this chapter, we embark on a comprehensive exploration of the objectives, motivations, and the Self-Powered System (SPS) we have developed. We will shed light on the accurate planning, simulation, and conception processes that went into creating our system. Furthermore, we will showcase the tangible results and scenarios that emerged from our study, providing empirical evidence of its efficacy and real-world implications.

By delving into the Conception & Results of our project, we aim to provide a deep understanding of the technical aspects, practical implementation, and the impact of our Self-Powered System. This chapter serves as a crucial point where we bridge the gap between theory and practice, presenting the peak of our research journey.

Through the subsequent sections, we will unravel the complexities of our SPS, including the simulation and conception processes. We will highlight the objectives and motivations that fueled our efforts, providing a context for the development of our system. Furthermore, we will present the results and scenarios, offering a comprehensive assessment of the system's performance and its potential implications in various contexts.

3.2 Objectives & motivations

3.2.1First objective: Conception of Smart Parking system

In the development of our smart parking system, our primary objective is to address the growing challenges associated with traditional parking solutions. We aim to leverage cutting-edge technology to create an intelligent and efficient parking management system.

To simulate the conception of our Smart parking we will use:

- LCD display: a display that will show how many free and full spots in our parking using our IR sensors in every slot
- Barriers: a fully automatic barriers both in entry and exit they will open and close based on the availability of the spots, that way we can have a human-free working parking

- Create Android and iOS applications for end-users to provide them with information about smart parking facilities. The applications should include a user-friendly graphical user interface (GUI) for easy interaction with the system. Additionally, the apps should enable users to receive real-time updates on parking slot availability, receive vehicle guidance to the nearest parking area or slot, reserve parking slots, retrieve parking slot information, and make online payments for parking fees using smartphone's Near Field Communication (NFC) technology.

Our goals from this are:

- Enhance efficiency and convenience of parking for users
- Streamline the parking experience through advanced technologies
- Provide real-time information about parking availability using LCD display
- Optimize parking resource utilization
- Reduce traffic congestion by directing the driver to the available slot.
- Enhance overall user satisfaction.

3.2.2 Second objective: Programming Robot Parking Assistant

To simulate our SPS, we have developed a robot parking assistant that interacts with the infrastructure using IoT based of SPS using the Arduino Uno Wi-Fi model, so that the robot can receive the commands wirelessly from the SPSs parking Arduino. Also, we want to develop a dedicated mobile application for controlling the robot parking assistant.

The goals of the robot parking assistant are as follows:

- Serve as prototype representing automatic cars in the SPS
- Execute SPS commands received from the Arduino
- Navigate autonomously to designated parking spots
- Contribute to the seamless operation of the smart parking system
- Seamless Control: Provide a user-friendly interface for effortlessly commanding the robot parking assistant to navigate to selected parking slots.

3.3 Sps simulation & conception

3.3.1 Simulation

we will explore several simulation tools available:

- Proteus: Proteus is a comprehensive simulation tool that supports Arduino development. It provides a virtual environment for designing, simulating, and testing Arduino-based circuits.
- Autodesk EAGLE: EAGLE is a powerful PCB design software that also includes a simulation feature. It allows you to design Arduino circuits and simulate their behavior.
- Virtual Breadboard (VBB): VBB is a simulation and development environment for embedded systems. It supports Arduino simulation and offers a realistic virtual prototyping experience.
- CircuitLab: CircuitLab is an online platform that enables circuit design and simulation. It supports Arduino components and allows you to test your Arduino circuits virtually.
- SimulIDE: SimulIDE is an open-source simulator that provides a graphical environment for designing and simulating Arduino circuits. It includes a library of Arduino components.
- 123D Circuits: 123D Circuits is an online platform that offers a virtual Arduino environment for designing and testing circuits. It includes an extensive library of components.
- EasyEDA: EasyEDA is a web-based PCB design and simulation tool. It supports Arduino simulation and offers collaborative features for team projects.
- Fritzing: Fritzing is an open-source software for designing electronics projects. It includes a breadboard view where you can simulate Arduino circuits.
- Virtual Serial Port Emulator (VSPE): VSPE is a software tool that emulates virtual serial ports on your computer. It can be useful for simulating communication between Arduino and other devices.
- RoboDK: RoboDK is a simulation and offline programming software for industrial robots. While primarily focused on robotics, it can also be used to simulate Arduino-based robotic systems.
- QUCS (Quite Universal Circuit Simulator): QUCS is an open-source circuit simulator that supports Arduino simulation. It offers a wide range of analysis capabilities for circuit design.

Simulation tools for Arduino play a crucial role in the development and testing of projects, offering a cost-effective and time-efficient way to validate designs before physical implementation. Among the multiple simulation tools available, Proteus has been chosen as the preferred option for our project.

By selecting Proteus for our project, we have leveraged its intuitive interface and rich feature set to design, simulate, and debug our Arduino circuits effectively. The availability of Proteus's extensive component library has allowed us to accurately represent the physical hardware and ensure the reliability of our simulation results. Moreover, Proteus's robust debugging capabilities have enabled us to validate our Arduino code and fine-tune our project's behavior before deployment.

While other simulation tools offer their own unique features and benefits, Proteus emerged as the most suitable choice for our specific project requirements. Its versatility, extensive library, and advanced debugging capabilities have proven to be instrumental in our development process.

In conjunction with the chosen simulation tool, Proteus, we utilized the Arduino software to compile and upload our code onto the Arduino chip. The Arduino is a user-friendly software that provides a simple and intuitive interface for writing, compiling, and uploading code to the Arduino board. With its extensive library of pre-defined functions and examples, the Arduino simplifies the programming process, allowing us to focus on developing the desired functionality for our project. Once the code was written and tested in Proteus, we seamlessly transferred it to the Arduino , which efficiently compiled it into a format that could be understood by the Arduino board. Finally, using the IDE's upload functionality, we effortlessly deployed our code onto the physical Arduino chip, bringing our simulated project to life.

By utilizing the Arduino in conjunction with Proteus, we benefited from a cohesive development workflow that encompassed simulation, code development, and chip programming. This integration allowed us to seamlessly transition from simulating and validating our project's behavior in Proteus to uploading and executing the code on real hardware. The combination of Proteus for simulation and the Arduino for code compilation and deployment provided us with a comprehensive development ecosystem that accelerated our project's progress and ensured its successful implementation.

In summary, the Arduino serves as a vital tool in the development process by enabling the compilation and uploading of code onto the Arduino chip. When used in conjunction with Proteus, it facilitates a seamless transition from simulation to physical implementation, ensuring the efficient realization of our project's functionality.

3.3.1.1 SPS simulation:

In this research endeavor, a comprehensive simulation was conducted to explore and analyze the operational efficacy of a smart parking system. Leveraging the capabilities of the Proteus application, a virtual environment was created to design, implement, and evaluate the proposed parking system. The primary objective of the simulation was to assess the functionality and effectiveness of various hardware components employed in the system.

The simulation incorporated several essential elements:

- Arduino Uno Microcontroller: The Arduino Uno is a popular microcontroller board renowned for its versatility and ease of use. It served as the central control unit of the smart parking system, responsible for processing data, executing logic, and coordinating the various components.
- Liquid Crystal I2C Display: The Liquid Crystal I2C display module was utilized to provide a user-friendly interface for the smart parking system. It offered real-time information regarding parking availability, slot status, and relevant messages to guide users.
- Infrared (IR) Sensors at Parking Slots: These IR sensors were strategically placed at each parking slot to detect the presence or absence of vehicles. By emitting and receiving infrared signals, they accurately determined whether a slot was occupied or vacant, enabling the system to monitor parking availability.

- Infrared (IR) Sensors at Entry and Exit Points: Two additional IR sensors were installed at the entry and exit points of the parking facility. Their purpose was to detect vehicles approaching or departing the parking area. These sensors played a crucial role in managing incoming and outgoing traffic, triggering actions such as barrier control and access control.
- Servo Motors for Barrier Control: Two servo motors were employed to control the barriers at both the entry and exit points of the parking facility. These motors were responsible for opening and closing the barriers in response to signals received from the IR sensors. They ensured smooth vehicle entry and exit while maintaining security and controlled access.

Figure 23 depicts a screenshot of the simulated circuit, providing a visual representation of the arrangement and connection. The circuit diagram serves as a valuable reference point for comprehending the system's intricate design and component interactions.

Through this simulation, valuable insights were gained into the performance and potential enhancements of the proposed smart parking system. The comprehensive evaluation of the hardware components within a controlled virtual environment paves the way for informed decision-making and further refinement of the system's design before its physical implementation.

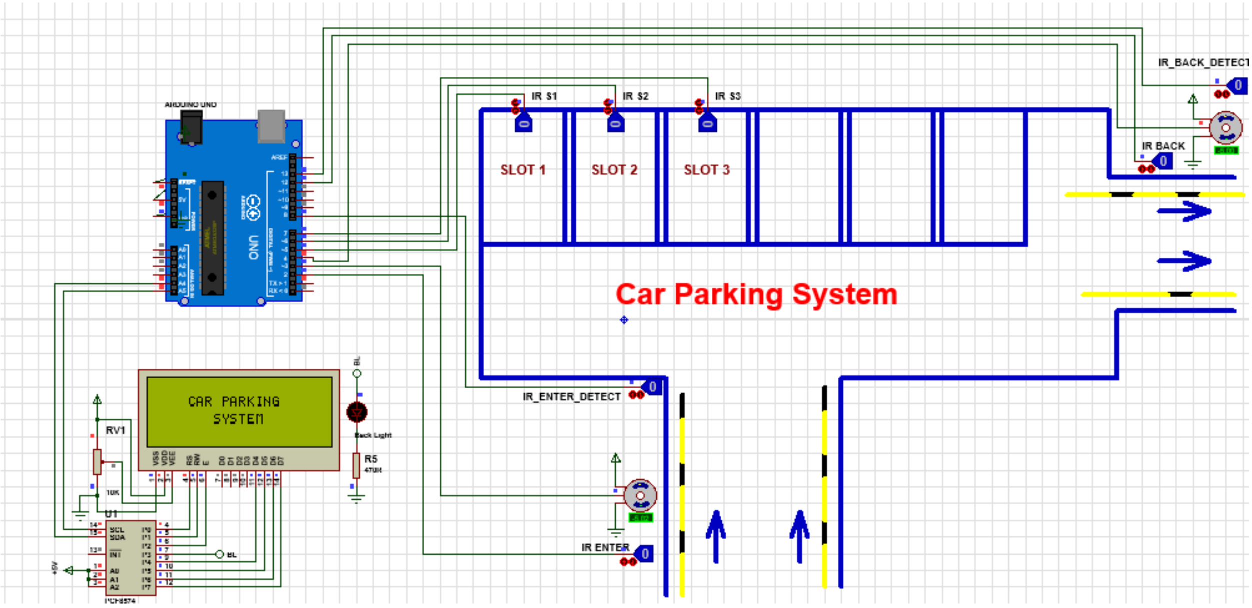

Figure 23 *Simulation for Smart Parking System*

3.3.1.2 SPS and Robot Assistant simulation:

The smart parking system (SPS) simulation incorporates a robot assistant Created by our colleagues Loucif Mohamed & Moumen Moncef to enhance the parking experience. The robot assistant utilizes its own Arduino chip, and the SPS Arduino communicates with it wirelessly through a WiFi connection. However, it is important to note that the physical robot assistant is not available at the current stage of the research. Therefore, in place of the robot, the simulation employs three LEDs to represent the robot's actions based on the commands sent by the SPS Arduino.

In the simulation, the SPS Arduino wirelessly sends commands to the robot assistant, directing it to the designated parking slot. These commands are transmitted through the WiFi connection, indicating which specific slot the robot should proceed to for assisting incoming vehicles. However, as the physical robot is not present, the simulation replicates its actions by activating LEDs corresponding to each command.

For example, when a parking slot is available, such as Slot 1 (S1), the SPS Arduino sends the command to the robot or LED1 to illuminate. This visual indication mimics the robot assistant moving towards the designated slot. Similarly, for Slot 2 (S2) and Slot 3 (S3), LED2 and LED3 would light up, respectively, as a representation of the robot's response to the commands received.

While the physical implementation of the robot assistant is pending, the simulation effectively demonstrates the communication capabilities of the SPS Arduino and the concept of a robotic system supporting the parking process. The utilization of LEDs allows for a visual representation of the robot's actions, creating a tangible and observable simulation outcome despite the absence of the physical robot assistant.

Figure 24 displays the simulated circuitry, featuring the SPS Arduino, ESP module, and three LEDs representing the robot assistant's actions. The LEDs are strategically positioned to correspond with the parking slots, with LED1 indicating Slot 1 (S1), LED2 representing Slot 2 (S2), and LED3 denoting Slot 3 (S3).

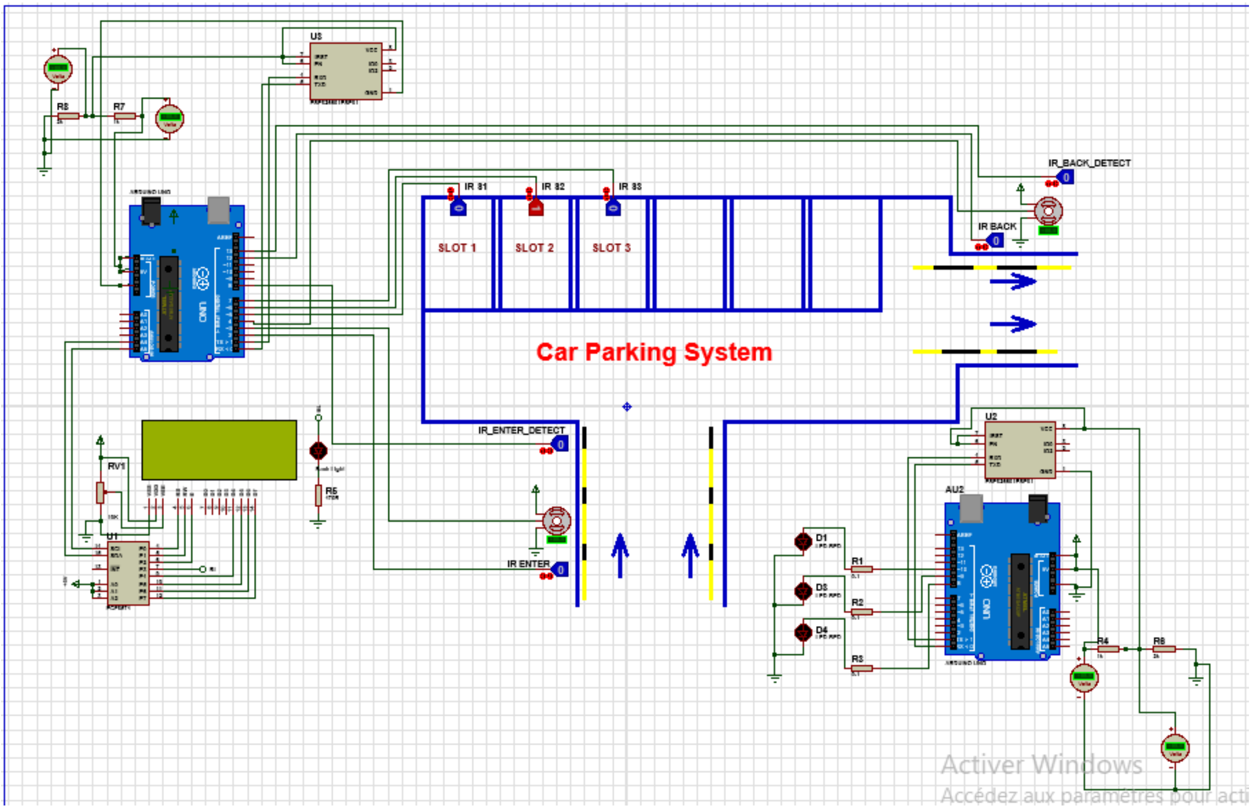

Figure 24 *Simulation of SPS with Robot prototype*

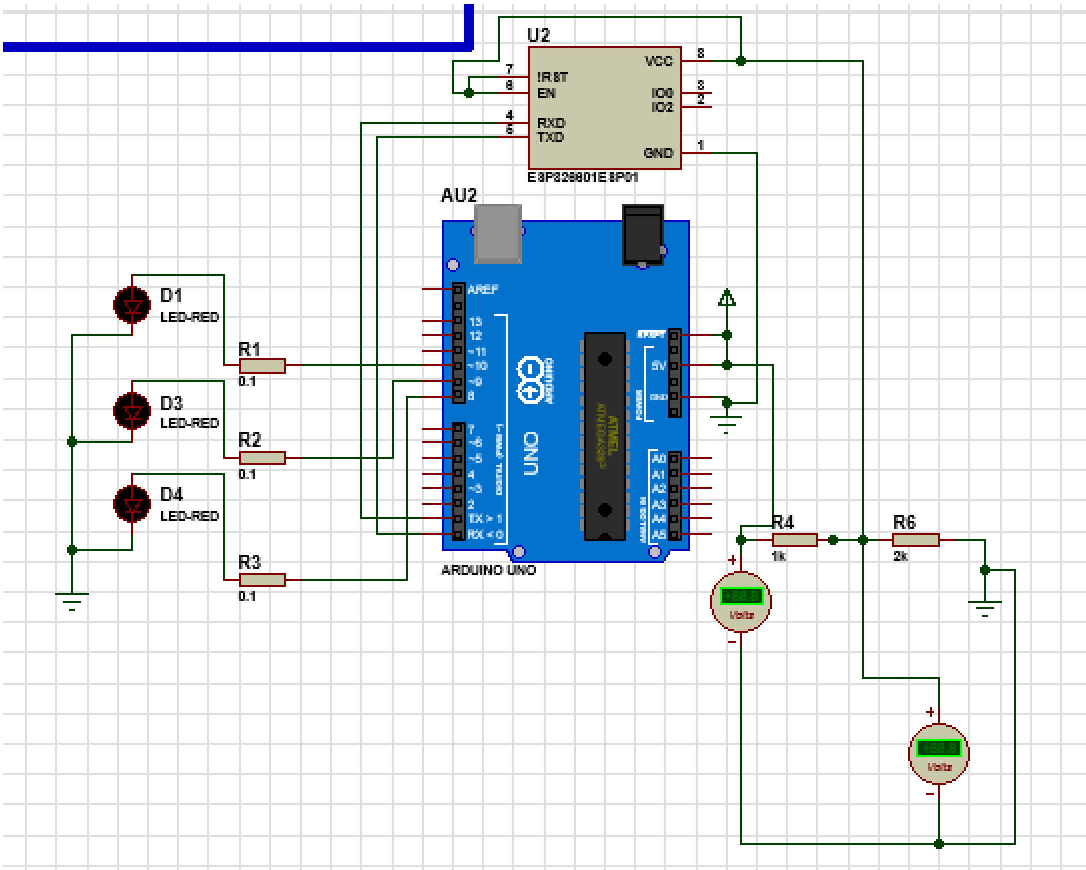

Figure 25 *Close up simulation of Robot Assistant Arduino*

3.3.2Conception :

In this Chapter we provide insights into the real-life implementation of the smart parking system (SPS) and discuss each component's significance. The following is a brief overview of the key components utilized in the SPS:

- **Arduino Uno WiFi**

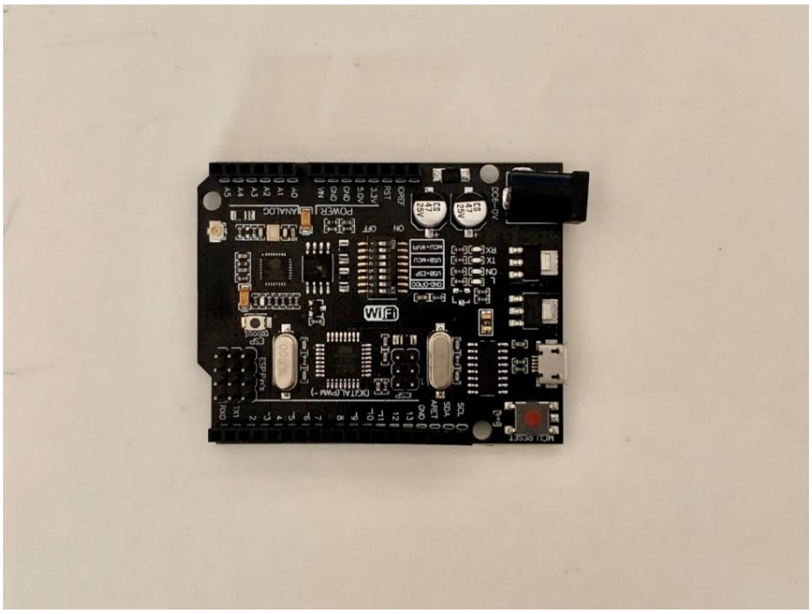

Figure 26 *Arduino Uno WiFi real life*

- **LCD 20x3**

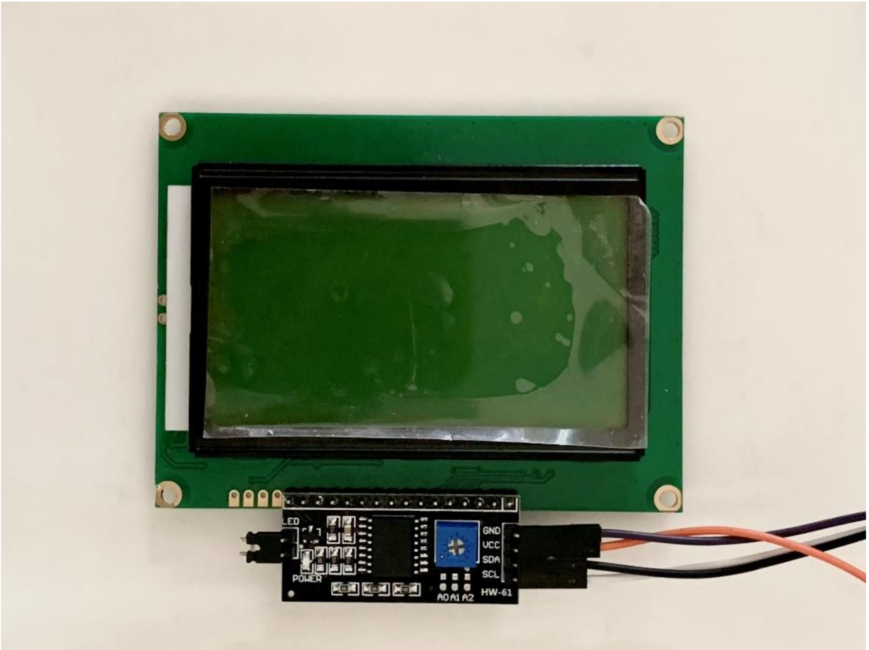

Figure 27 LCD 20x3 real life

- **IR Sensors**

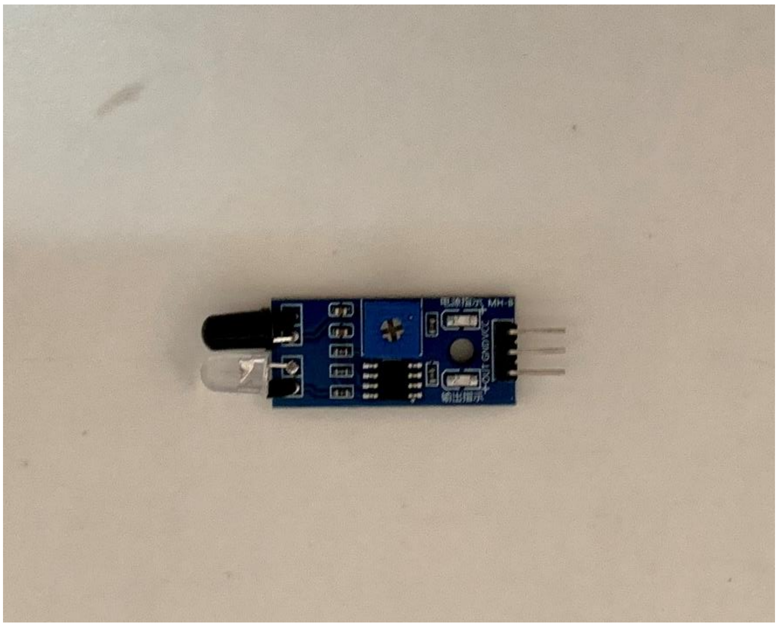

Figure 28 *IR sensor real life*

- **Servo Motor for Barriers**

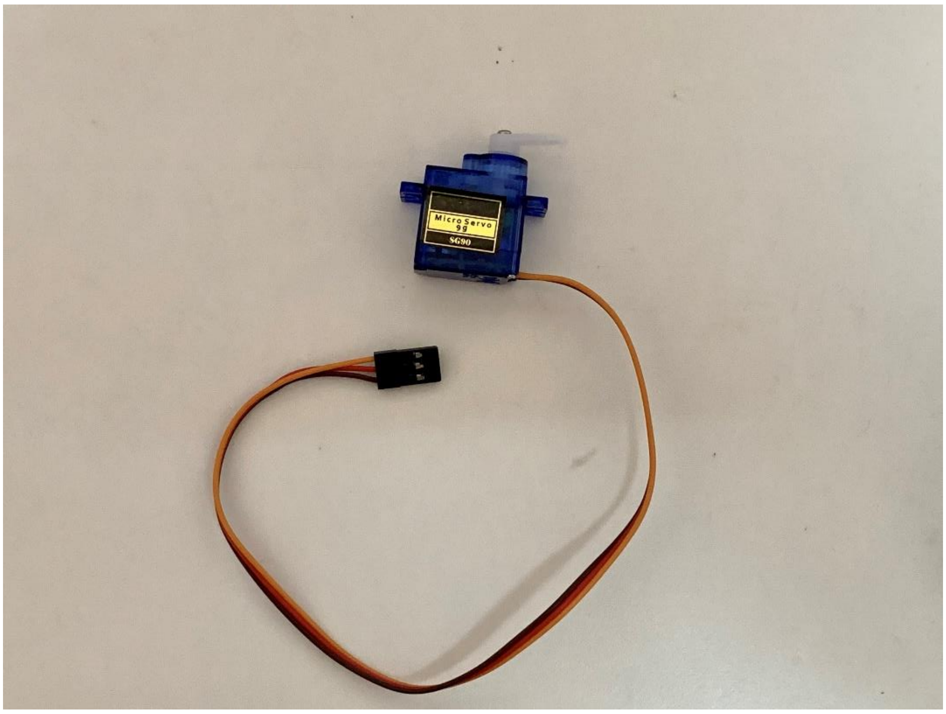

Figure 29 *Servo Motor real life*

Each of these components contributes to the overall functionality and effectiveness of the SPS. The Arduino Uno WiFi board serves as the brain of the system, while the LCD module provides a user-friendly interface. The IR sensors enable accurate vehicle detection, and the servo motors automate the barrier control process.

The successful integration of these components, along with other supporting elements, enables the SPS to optimize parking management, improve user experience, and streamline parking operations in real-life scenarios. The conception of the SPS involves careful consideration of the functionalities and interconnections of these components to ensure a robust and efficient system.

The process of making the smart parking system (SPS) involved several key steps and considerations to ensure a successful implementation. Here is an overview of the process:

a) Planning and Design: The first step in creating the SPS was to plan and design the system architecture. This involved defining the objectives, functionality, and requirements of the system. The placement of components, such as the Arduino Uno WiFi, LCD, IR sensors, and servo motors, was determined during this phase to ensure optimal performance and usability.

b) Circuit Design and Assembly: With the components in hand, the circuit design was created, taking into account the interconnections and power requirements of each component. The Arduino board served as the central hub, with cables used to establish the necessary connections between the Arduino, LCD, IR sensors, and servo motors. The circuit was then assembled and tested for proper functionality.

c) Programming and Code Development: The SPS required programming to control and coordinate the various components. The Arduino programming language, based on C, was used to write the code. The code encompassed tasks such as reading inputs from the IR sensors, controlling the servo motors, managing the LCD display, and handling wireless communication using the Arduino Uno WiFi capabilities (see Annex).

d) Testing and Debugging: Once the code was developed, thorough testing and debugging were performed to ensure the SPS operated as intended. This involved simulating various scenarios, such as vehicle detection, barrier control, display updates, and wireless communication. Any issues or errors encountered during testing were identified and addressed to ensure the system's reliability and performance.

e) Integration and Deployment: After successful testing, the SPS was integrated into the desired environment, such as a parking facility. This involved setting up the IR sensors at the parking slots, positioning the servo motors for barrier control, and installing the LCD display in a suitable location. The system was then ready for deployment and use.

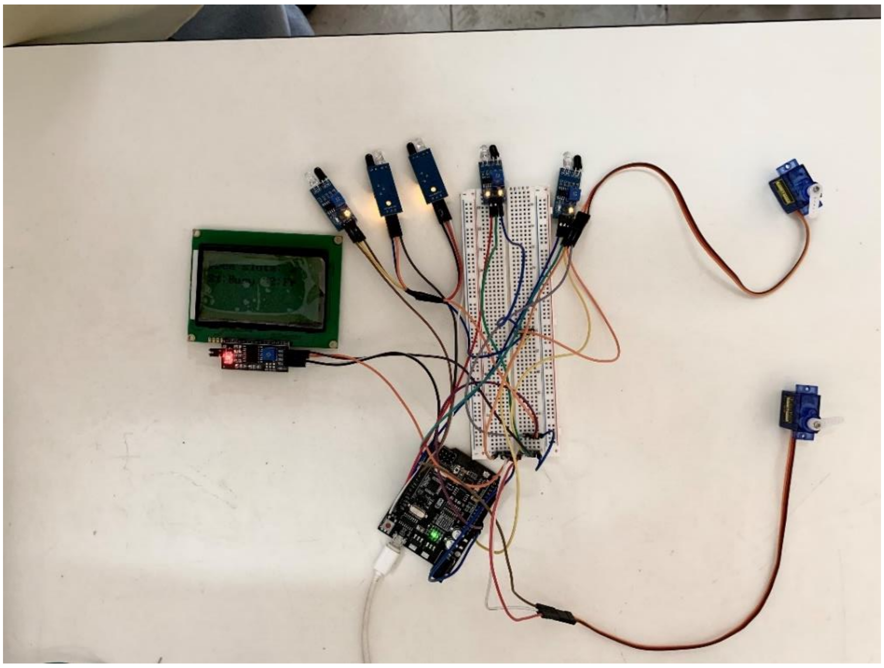

Figure 30 *Integration and Deployment of our SP*

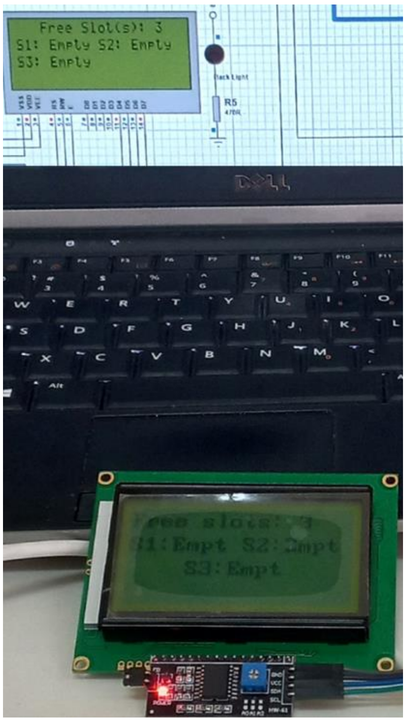

Figure 31 *LCD display*

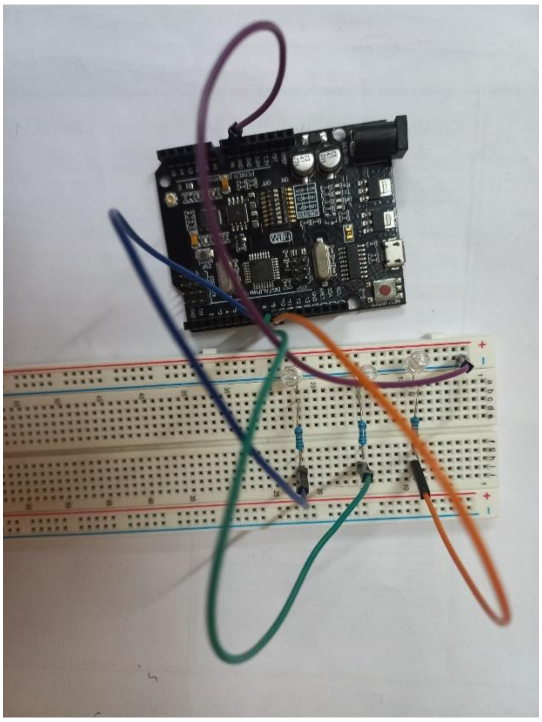

Figure 32 *Leds representing the robot mouvment*

Figure 33 *Desired environment integration*

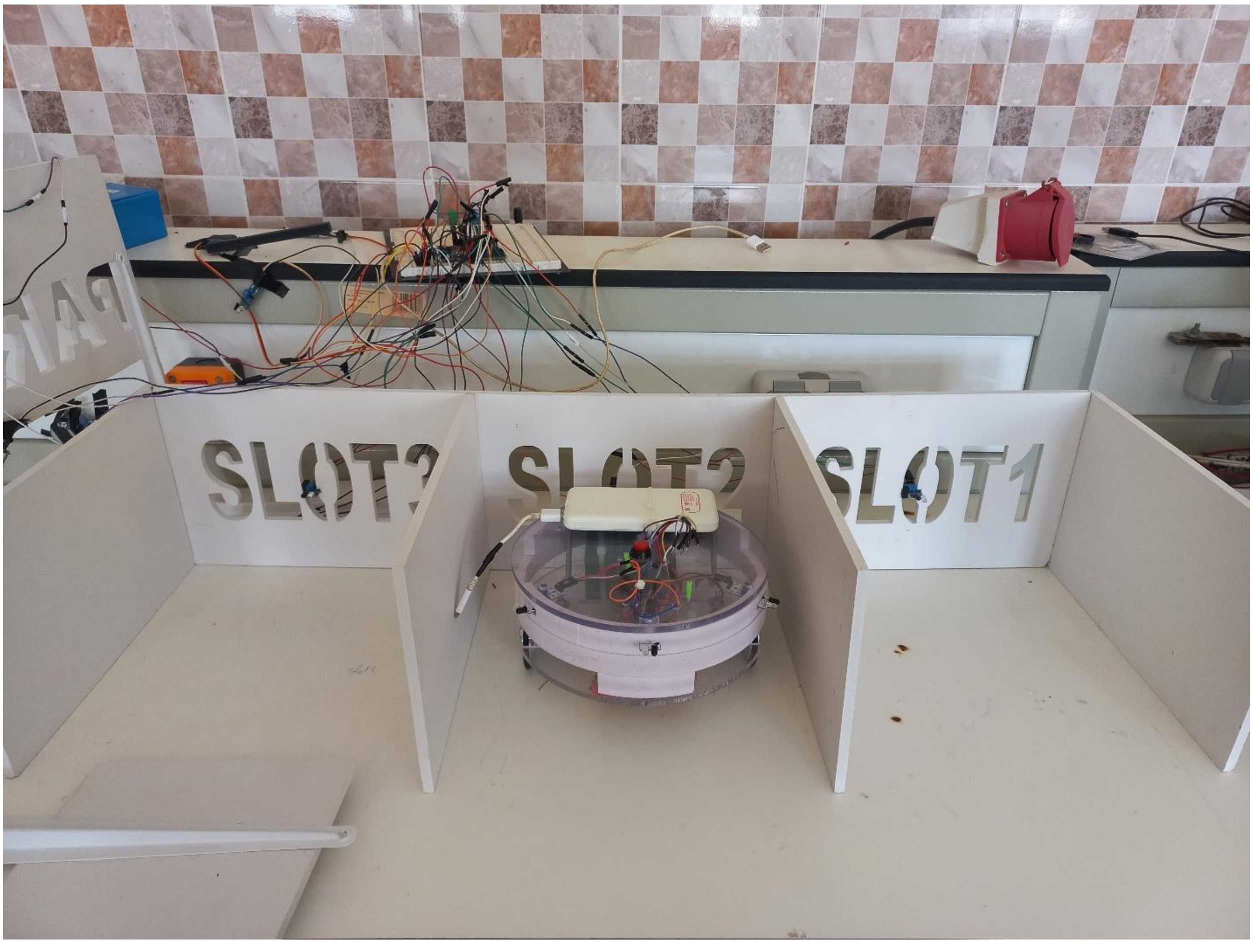

Figure 34 *Desired environment integration*

3.4 Scenarios & results:

3.4.1 Scenarios of SPS simulation:

The simulation showcases the step-by-step working of the smart parking system through screenshots. The following scenarios depict the functioning of the system:

- **Car Entry scenario:** The first step illustrates a car entering the smart parking facility. The IR sensors at the entrance detect the presence of the vehicle, prompting the entry servo motor to open the barrier. Once the car has passed under the barrier, the second IR sensor confirms its safe passage and triggers the closure of the barrier. The display then indicates the status of the parking slots. It will show "S1: Full, S2: Empty, S3: Empty" along with the number of free slots, which would be "Free Slots: 2"

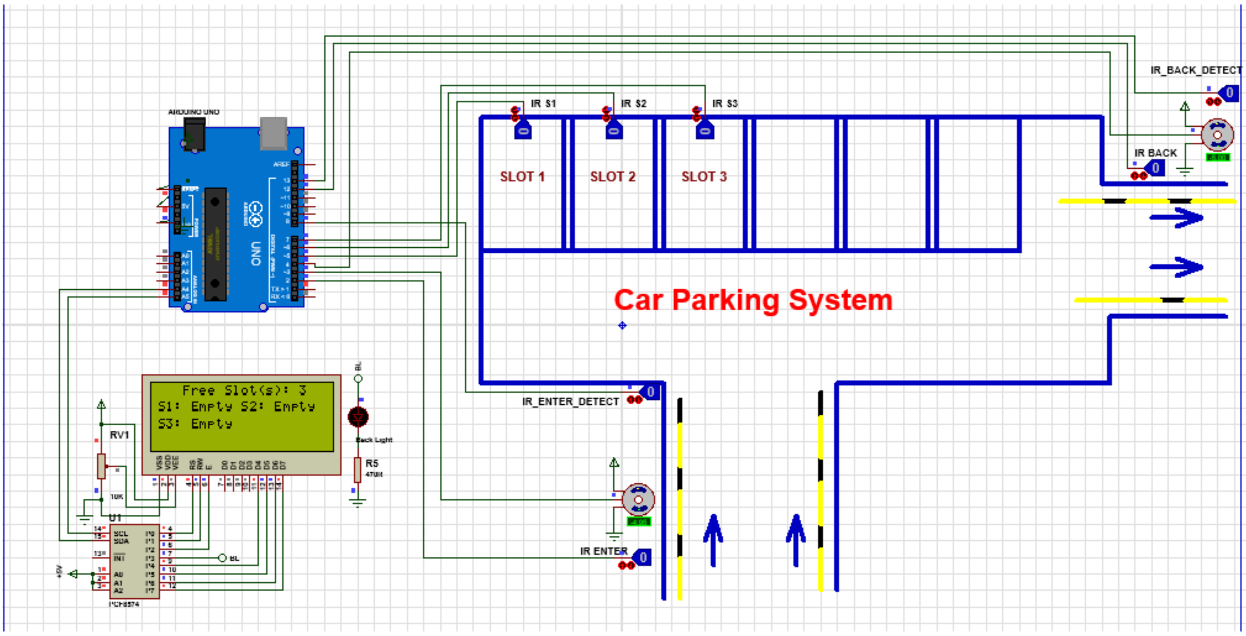

Figure 35 *Our SPS with 3 free slots*

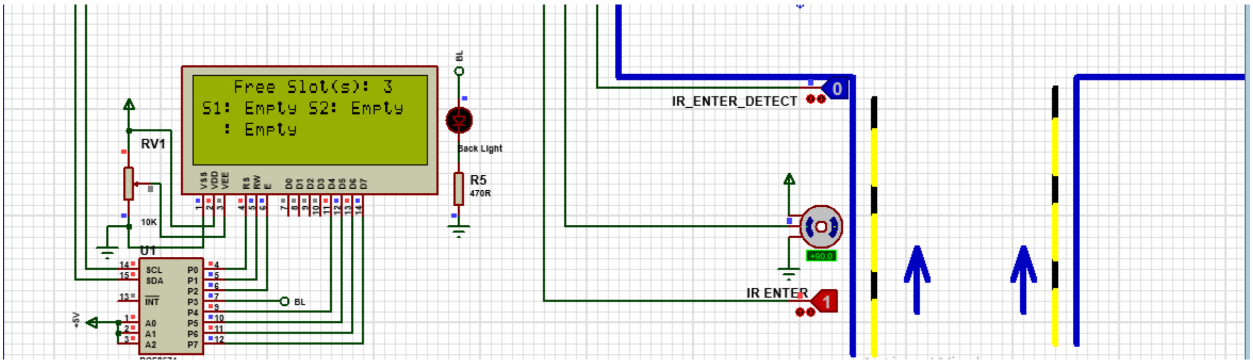

Figure 36 IR sensor detect the presence of the car in the entry gate and open it

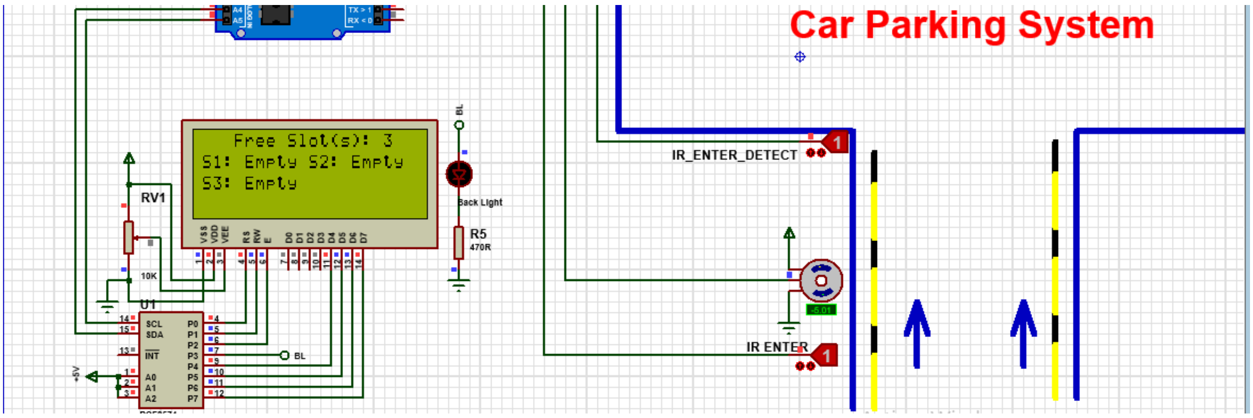

Figure 37 *the second IR sensor confirms the car passage and close the gate*

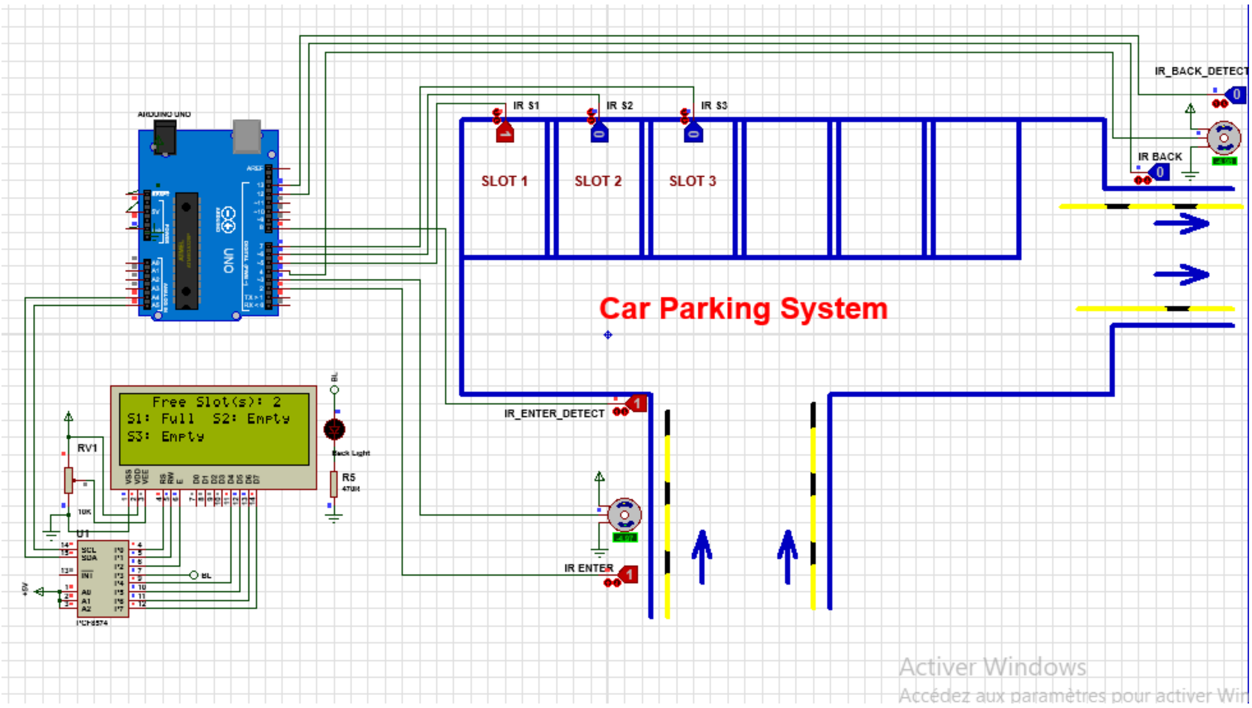

Figure 38 *car parks in slot 1& the lcd display S1= full*

➢ **Subsequent Car Entries scenario:** In subsequent steps, additional cars enter the parking facility following the same process. The IR sensors detect the cars, the entry servo motor opens the barrier, and the system ensures the safe passage of vehicles. The display updates to reflect the changing occupancy status and the number of available slots.

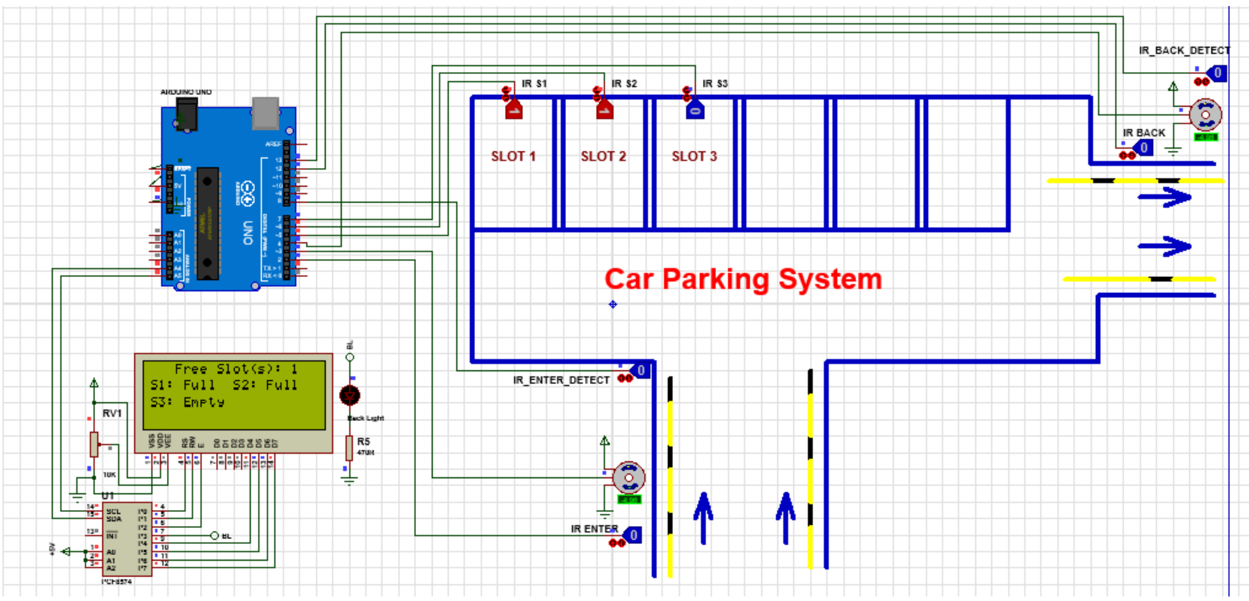

Figure 39 *Subsequent Car Entries Scenario*

➢ **Parking Full scenario:** As the parking slots become fully occupied, a scenario arises where the display shows "Sorry Parking Full" Along with the text "S1: Full, S2: Full, S3: Full" The entry servo motor does not open the barrier for incoming cars, indicating that the parking facility has reached maximum capacity.

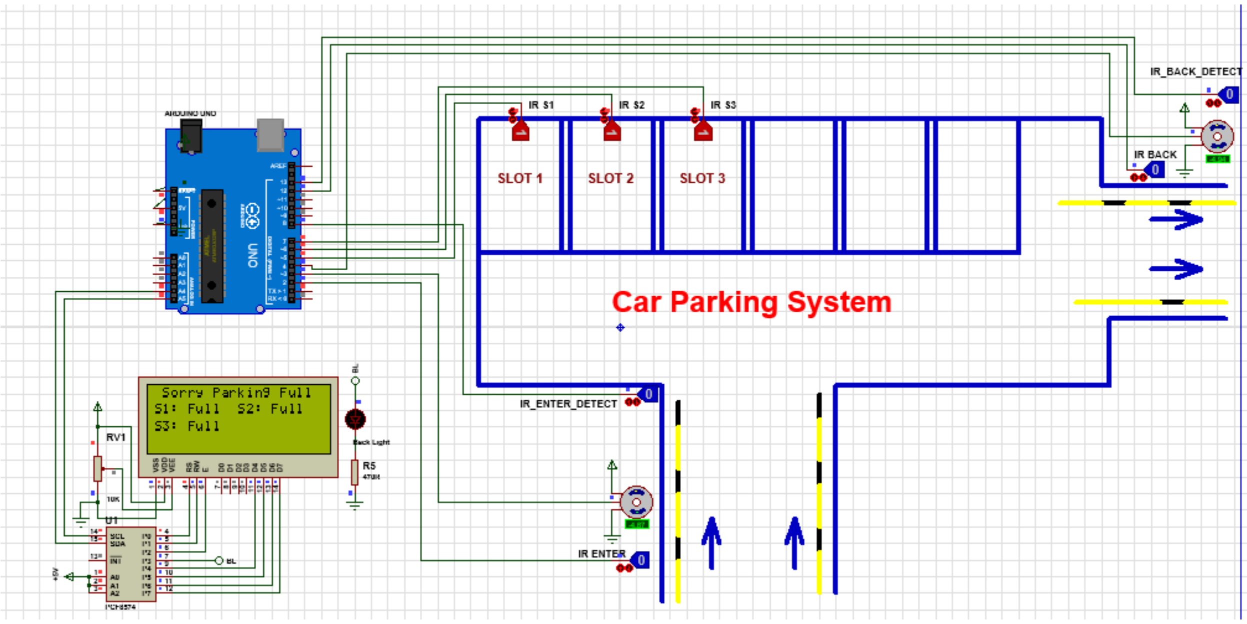

Figure 40 Parking Full Scenario

And the Barrier won't open as we can see in the Figure 40.

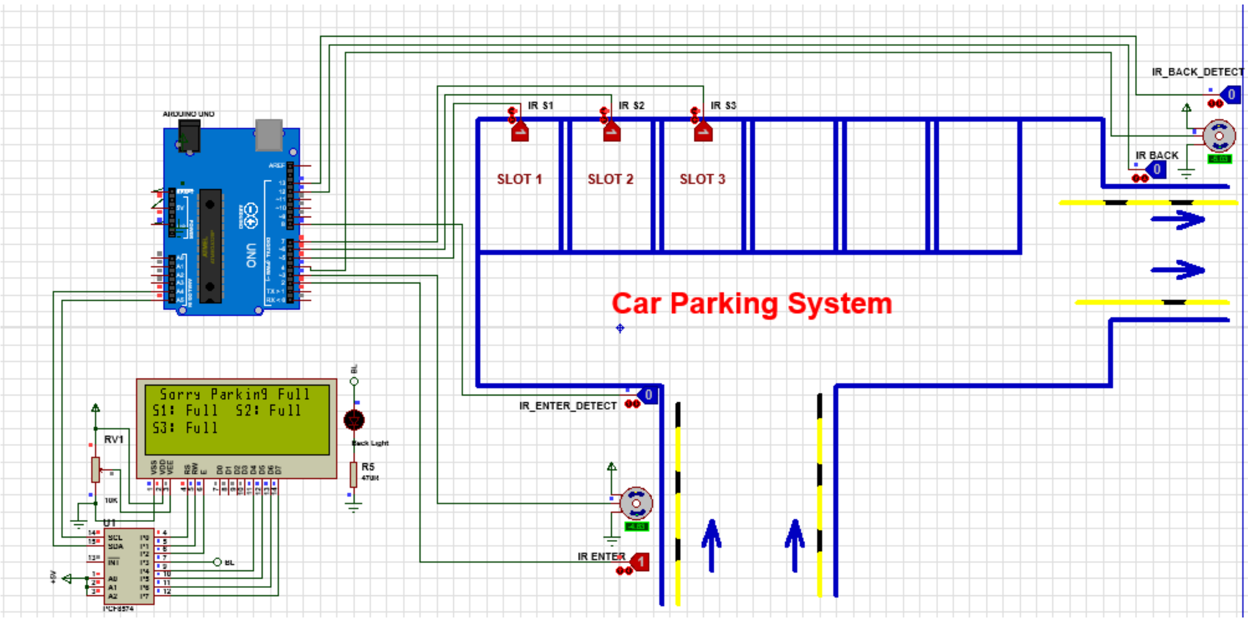

Figure 41 *Barrier not opening when park is full*

➢ **Car Exit scenario:** In the final scenario, a car that was already parked leaves the smart parking facility. The display updates to show "S1: Empty, S2: Full, S3: Full" along with the number of free slots, which would be "Free Slots: 1", which has increased due to the car's departure. The exiting vehicle is detected by the exit IR sensors, prompting the exit servo motor to open the barrier. Once the car has safely passed, the second exit IR sensor confirms its passage, leading to the closure of the barrier.

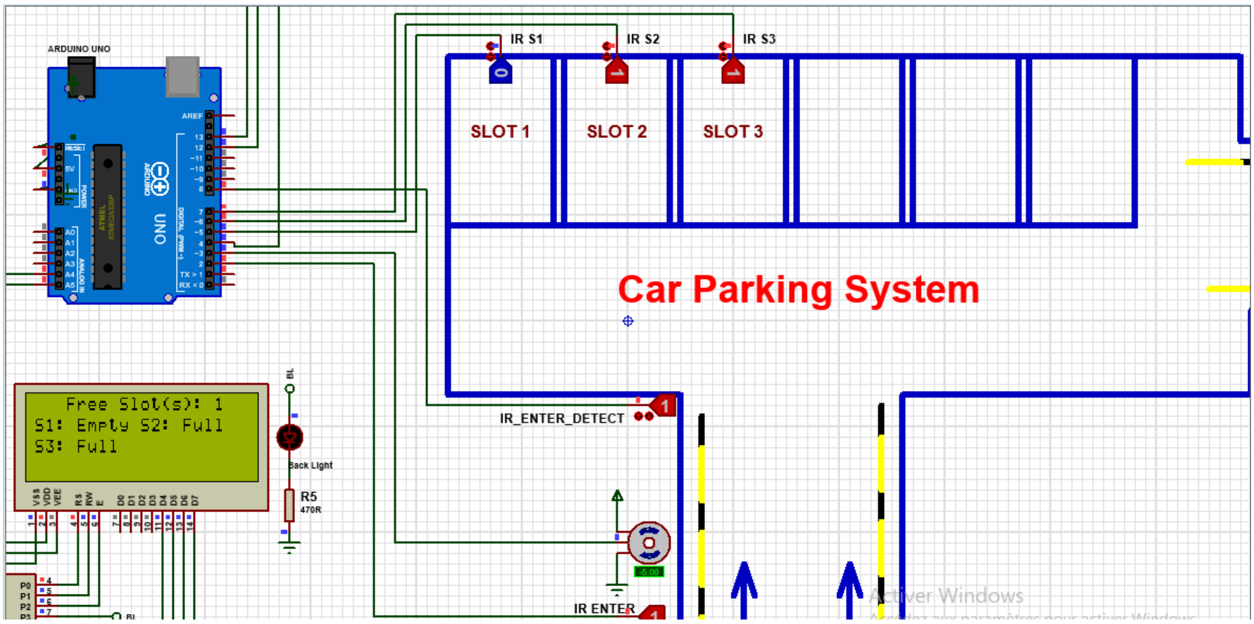

Figure 42 *Car Exit Scenario*

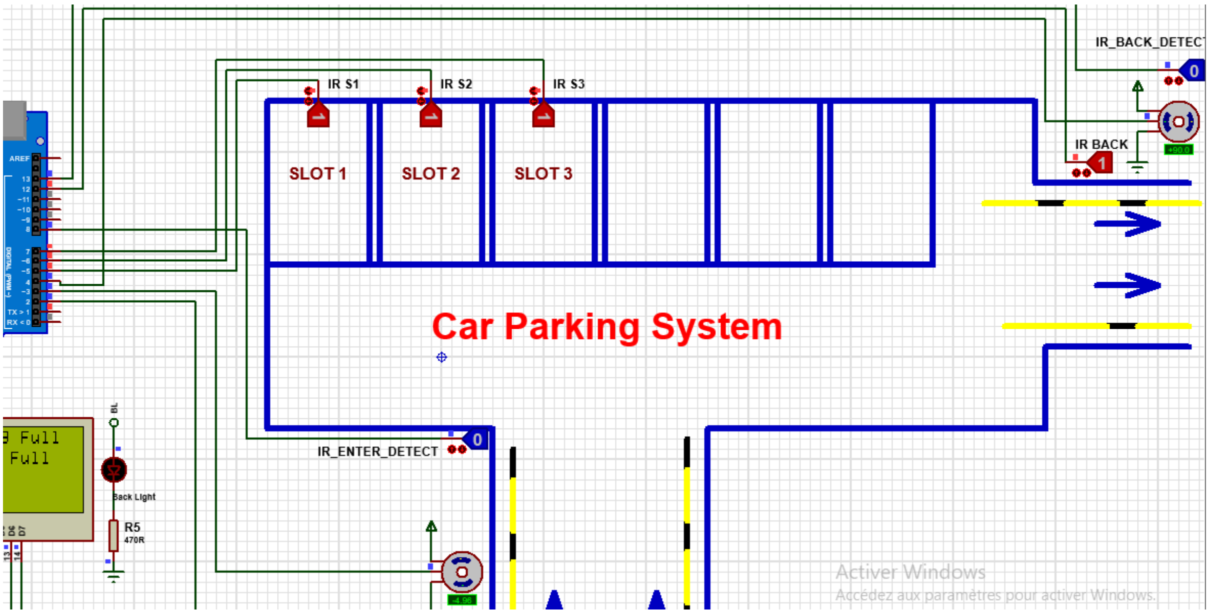

Figure 43 *IR sensor detect the presence of the car in the exit barrier and open it*

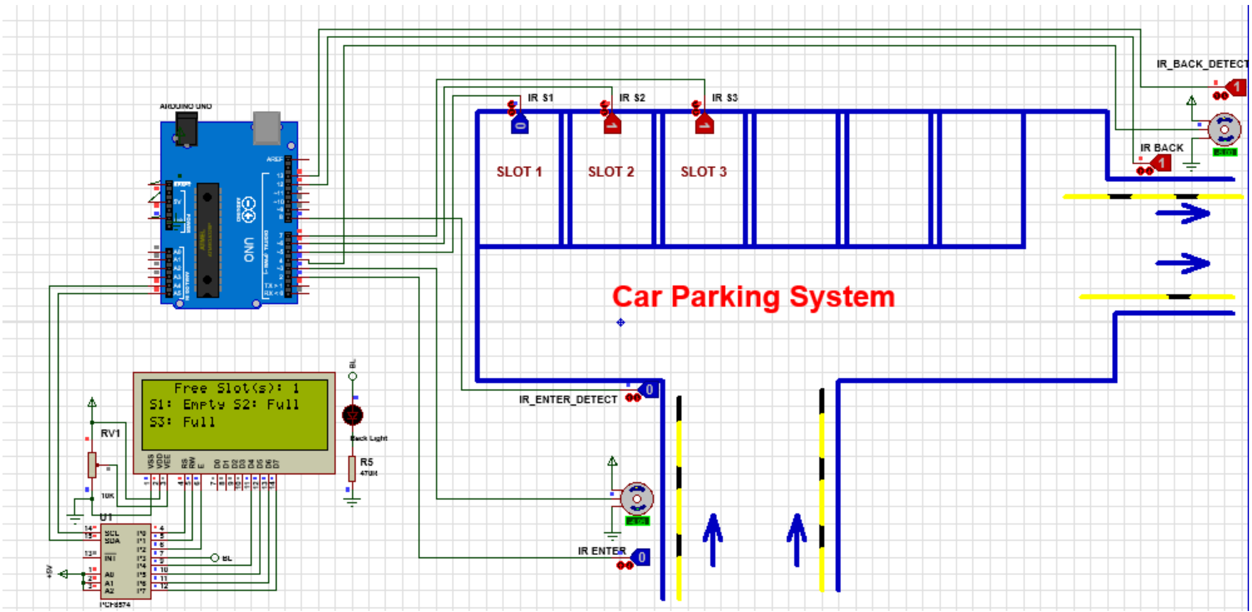

Figure 44 *The second IR sensor confirms the car passage and close the barrier*

- **Another Car Entry:** Following the car exit scenario, a new car arrives at the smart parking facility. The display indicates the updated number of available slots after the previous car's departure. And the entry barrier will open now since there's free spots .

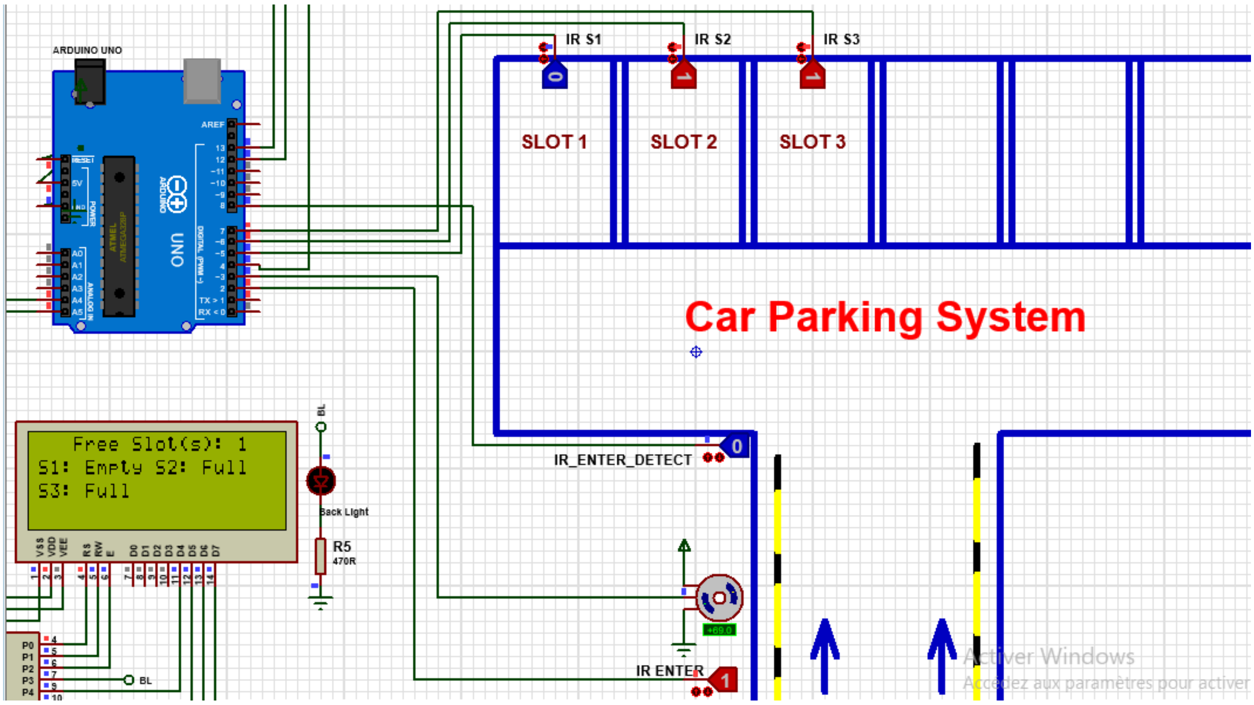

Figure 45 *Servo Motor opening again*

3.4.2 Scenarios of SPS Robot Assistant Simulation:

Here are the scenarios illustrating the actions of the robot assistant (represented by LEDs) as it navigates to each parking slot:

- **Robot Assistance to Slot 1 (S1):** In this scenario, the SPS Arduino sends a command to the robot assistant or LED1, indicating that Slot 1 (S1) is available. Consequently, LED1 lights up, simulating the robot assistant's movement towards Slot 1. The illuminated LED1 provides a visual cue to drivers, indicating the availability of the parking slot.

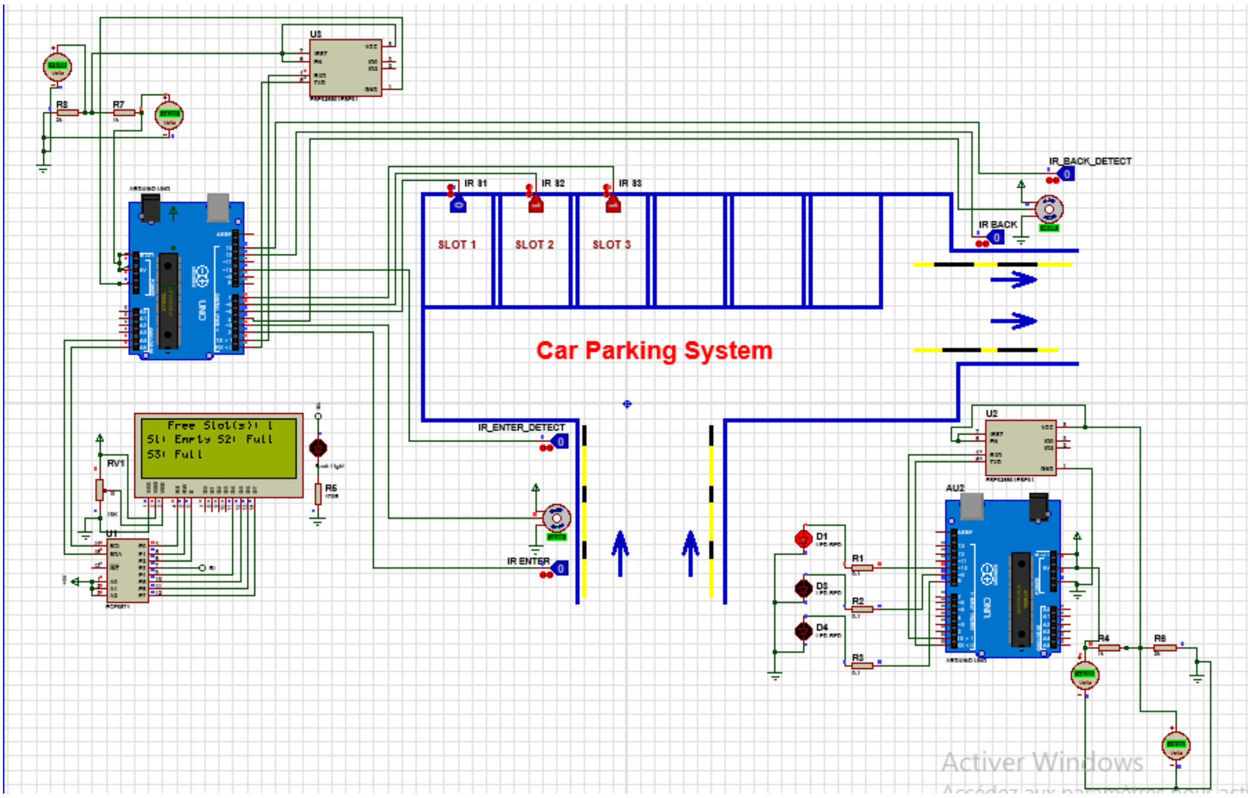

Figure 46 *LED1 lights up, simulating the robot assistant's movement towards Slot 1*

- **Robot Assistance to Slot 2 (S2):** Following the previous scenario, the SPS Arduino now directs the robot assistant or LED2 to proceed towards Slot 2 (S2) as it becomes available. Consequently, LED2 lights up, replicating the robot's action of moving towards Slot 2. This visual indication guides drivers to the designated parking spot.

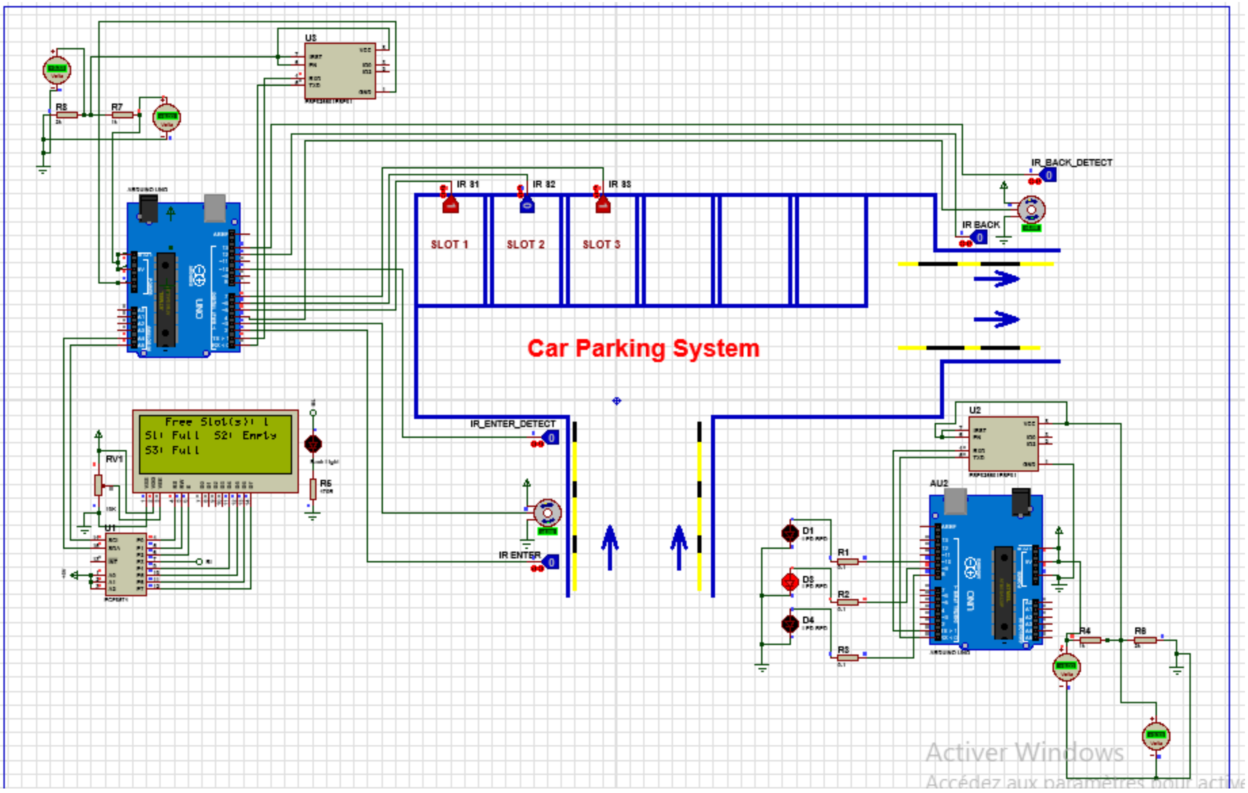

Figure 47 *LED2 lights up, replicating the robot's action of moving towards Slot*

➢ **Robot Assistance to Slot 3 (S3):** Continuing the sequence, the SPS Arduino sends a command to the robot assistant or LED3, signifying that Slot 3 (S3) is now available. As a result, LED3 lights up, representing the robot assistant's navigation towards Slot 3. The illuminated LED3 serves as a clear indicator for drivers, assisting them in locating the available parking slot.

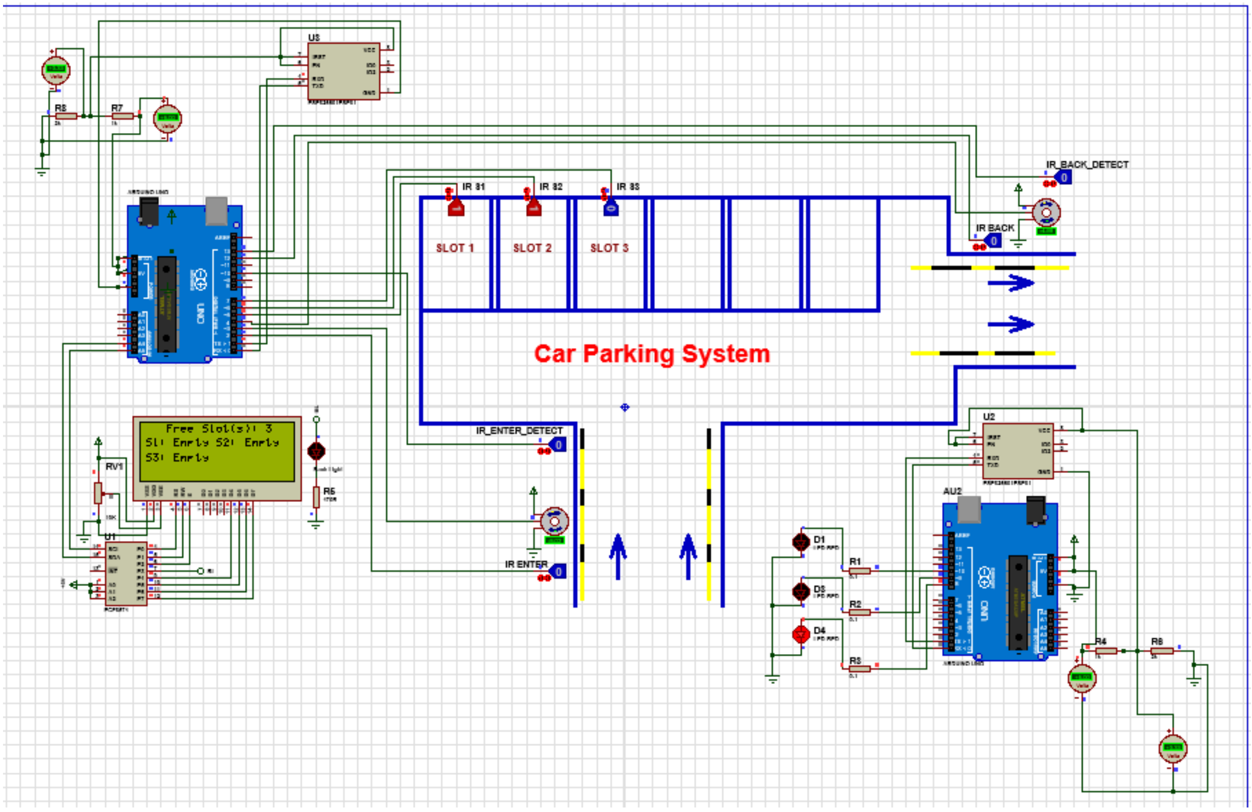

Figure 48 *LED3 lights up, representing the robot assistant's navigation towards Slot 3*

By simulating the robot assistant's actions using LEDs, these scenarios effectively demonstrate how the SPS Arduino communicates the availability of parking slots. The illuminated LEDs provide a visual representation, mimicking the movements of the physical robot, and guiding drivers to the appropriate parking spots.

3.5 Conclusion

Chapter 3 has provided a comprehensive exploration of the Conception & Results of our Self-Powered System (SPS). We began by outlining the objectives and motivations that fueled our research, highlighting the driving forces behind our project. This context set the stage for the subsequent discussions.

The simulation aspect played a crucial role in our study, allowing us to model and evaluate the performance of our SPS. Through the utilization of advanced tools and techniques, we gained valuable insights into the system's behavior and fine-tuned its parameters. This simulation-driven approach ensured that our SPS was designed to meet the desired objectives.

Building upon the simulation results, we then delved into the conception of our SPS. This phase involved meticulous planning, design considerations, and decision-making processes. By translating the simulation findings into a tangible system, we were able to establish the feasibility and practicality of our approach.

Finally, we presented the results and scenarios that emerged from our study. These outcomes served as empirical evidence of our SPS's efficacy and its potential implications in various contexts. Through comprehensive analysis and evaluations, we were able to showcase the performance metrics and validate the effectiveness of our system.

In summary, Chapter 3 has been a pivotal chapter where we have showcased the Conception & Results of our Self-Powered System. This chapter has demonstrated our ability to transform theoretical concepts into practical solutions. The meticulous simulation, conception, and evaluation processes have provided a solid foundation for the subsequent application and future development of our SPS.

Through the insights gained in this chapter, we have made significant strides towards addressing the challenges in the field of smart parkings. Our SPS offers a promising solution that can optimize parking management, enhance user experience, and contribute to a more sustainable and efficient urban environment.

As we move forward, the knowledge and outcomes presented in Chapter 3 will guide us in refining our system, exploring new applications, and fostering further innovation. By harnessing the power of simulation, accurate conception, and empirical evaluation, we can continue to drive advancements in the realm of self-powered systems and make a tangible impact in the world of smart parkings.

General Conclusion & prespectives

In this final chapter, we have delved into the Conception & Results of our project, bringing together the key elements of Smart Parkings, AI, IoT, and our Self-Powered System (SPS). Through the comprehensive exploration of these topics, we have reached the culmination of our research journey.

Chapter 1 provided an introduction to the concept of Smart Parkings, highlighting the need for innovative solutions to address the challenges of urban parking management. We explored the current landscape, identified the pain points, and set the stage for our project's significance.

In Chapter 2, we delved into the intersection of AI, IoT, and smart parkings, uncovering the potential of these technologies to revolutionize parking management. We examined how AI algorithms and IoT sensors can optimize parking spaces, improve traffic flow, and enhance user experience. This chapter laid the foundation for the development of our Self-Powered System.

Chapter 3, the focal point of our study, has been dedicated to the Conception & Results of our Self-Powered System. We embarked on a meticulous journey of simulation, conception, and implementation, translating our vision into a tangible reality. Through careful planning, consideration of technical aspects, and real-world feasibility, we have developed an innovative solution that holds promise for practical applications.

By presenting the objectives, motivations, and outcomes of our project, we have demonstrated the transformative potential of our Self-Powered System. Our simulation-driven approach and meticulous conception process have paved the way for a robust and efficient solution. The results and scenarios we have presented validate the system's efficacy and its ability to address the challenges in parking management.

Looking ahead, there are several perspectives and avenues for further exploration and advancement. Firstly, the integration of our Self-Powered System with existing parking infrastructures can be a significant area of focus. Adapting our SPS to different environments and scaling its implementation can unlock its full potential in diverse settings.

Additionally, continuous monitoring, data analysis, and machine learning techniques can further optimize the performance of smart parking systems. By leveraging real-time data and predictive analytics, we can enhance decision-making, streamline operations, and anticipate parking demand more effectively.

Furthermore, collaboration and partnerships with stakeholders such as urban planners, city authorities, and parking facility operators are crucial for successful implementation. By fostering cross-disciplinary collaborations and engaging in open dialogues, we can collectively address the challenges, capitalize on opportunities, and ensure the sustainable adoption of smart parking solutions.

In conclusion, our study has laid the groundwork for the convergence of Smart Parkings, AI, IoT, and self-powered systems. Through the exploration of these domains, we have unveiled the transformative potential of technology-driven solutions in reimagining parking management. By embracing innovation, collaboration, and ongoing research, we can shape a future where parking facilities are optimized, efficient, and user-centric, making our urban spaces more livable and sustainable.

In conclusion, our research journey has encompassed the exploration of Smart Parkings, AI, IoT, and the development of our Self-Powered System. We have witnessed the convergence of these domains, driving innovation and paving the way for a more efficient and sustainable future in parking management.

While this marks the end of our research endeavor, it also signifies the beginning of new opportunities and possibilities. The knowledge and insights gained from this study provide a strong foundation for further advancements, inspiring future researchers and practitioners to build upon our work.

We hope that our project serves as a catalyst for continued exploration, collaboration, and innovation in the field of smart parkings. Together, we can shape a future where parking management becomes seamless, sustainable, and user-centric, making urban spaces more livable and efficient.

Annexes

Annexe A

SPS code

```
#include <Servo.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 3);


Servo myservo;
Servo myservo_exit;

const int ir_enterPin = 2;
const int ir_enter_detectPin = 10;

const int ir_backPin = 12;
const int ir_back_detectPin = 13;
#define ir_car1 5
#define ir_car2 6
#define ir_car3 7

int S1, S2, S3;
int ir_enter ;
int ir_back ;
```

```
if (S1 == 1) {
  lcd.print("S1:Busy");
} else {
  lcd.print("S1:Free");
}

lcd.setCursor(0, 2);
if (S2 == 1) {
  lcd.print("S2:Busy");
} else {
  lcd.print("S2:Free");
}


lcd.setCursor(10, 0);
if (S3 == 1) {
  lcd.print("S3:Busy");
} else {
  lcd.print("S3:Free");
}
}

```

Annexe B

Code server & client

```
#include <WiFiNINA.h>
#include <WiFiUdp.h>

const char* ssid = "ESP_1E7873";
const char* password = "";

unsigned int serverPort = 8888;
WiFiUDP Udp;

const int pinSensor1 = 2;
const int pinSensor2 = 3;
const int pinSensor3 = 4;

void setup() {
Serial.begin(9600);
pinMode(pinSensor1, INPUT);
pinMode(pinSensor2, INPUT);
pinMode(pinSensor3, INPUT);

WiFi.beginAP(ssid, password);

Udp.begin(serverPort);

Serial.println("Access Point créé");
Serial.println("Adresse IP du serveur: ");
Serial.println(WiFi.localIP());
}
```

```
  if (packetSize) {
    int bytesRead = Udp.read(packetBuffer, 255);
    packetBuffer[bytesRead] = '\0';

    int sensor1 = packetBuffer[0] - '0';
    int sensor2 = packetBuffer[1] - '0';
    int sensor3 = packetBuffer[2] - '0';

    digitalWrite(pinLED1, sensor1);
    digitalWrite(pinLED2, sensor2);
    digitalWrite(pinLED3, sensor3);

    Serial.print("Sensor 1: ");
    Serial.println(sensor1);
    Serial.print("Sensor 2: ");
    Serial.println(sensor2);
    Serial.print("Sensor 3: ");
    Serial.println(sensor3);
  }
}
void printWifiStatus() {
  // print the SSID of the network you're attached to:
  Serial.print("SSID: ");
  Serial.println(WiFi.SSID());

  // print your board's IP address:
  IPAddress ip_client = WiFi.localIP();
  Serial.print("Adresse IP du client: ");
  Serial.println(ip_client);
}
```

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