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REMOTE MONITORING AND CONTROL OF A RESERVATION-BASED PUBLIC PARKING SYSTEM

Dissertation under the Integrated Master's in Mechanical Engineering at Production and Project Specialty supervised by Professor Doctor Fernando Jorge Ventura Antunes and presented to the Department of Mechanical Engineering.

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REMOTE MONITORING AND CONTROL OF A RESERVATION-BASED PUBLIC PARKING SYSTEM

Submitted in Partial Fulfilment of the Requirements for the Degree of Master in Mechanical Engineering in the specialty of Production and Project

Monitorização e Controlo Remoto de um Parque de Estacionamento Publico com Base em Reserva

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“Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away.”

Antoine de Saint-Exupery

To the family.

ACKNOWLEDGEMENTS

The work presented here would not be possible without the support of my girlfriend and my family. The experience of Erasmus+ Exchange Program gave me the chance of developing new skills, needed to conclude this project.

Abstract

Nowadays, time is one of the most precious resources that people have. Thanks to the evolution of technology and living on the revolution of the industry 4.0, searching for an available parking place represents wasted time and a challenge for the developers to find a solution for it. Problems such as traffic congestion, air pollution, limited parking spaces and safety on the roads are few of the most important challenges of the actual century.

This project proposes a smart parking system, implemented on each slot of a parking facility. Composed by a circuit, designed to gain real time information regarding availability of the slot, and a future mobile application for the customer to use and be able to reserve a chosen slot. Using a Cyber-Physical System, in which a mechanism is controlled and monitored by a software, changing the status of the mechanism according with the need and context, it will be possible to concretize the purpose of blocking and unblocking a car slot through a simple press of a button.

The strategy for developing this research is to separate the project in three main parts, mechanical, electronic and informatic, and in the end of it, to make the connection between the three of them. All the steps mentioned will be developed for having the initial stage of a system that is intended to facilitate the process of finding and reserving a free parking space for a limited period of time.

Keywords Parking, Smart System, Reservation, Arduino IoT Cloud, Arduino RP2040 Connect,

Resumo

Hoje em dia, o tempo tornou-se um dos recursos mais preciosos na vida das pessoas. Graças à evolução da tecnologia combinada com a revolução industrial 4.0, vivida no momento, a procura de um lugar de estacionamento livre representa tempo perdido e um desafio para os engenheiros encontrarem uma solução.

Problemas como congestionamento de tráfego, poluição do ar, lugares de estacionamento limitados e a segurança nas estradas, são alguns dos desafios mais importantes da atualidade.

Este projeto propõe um sistema de estacionamento inteligente, implementado em cada um dos lugares dos parques de estacionamento públicos. Composto por um circuito, projetado para obter informações em tempo real sobre a disponibilidade de cada lugar, e um futuro aplicativo móvel para o cliente usar e ser capaz de reservar um lugar disponível. O objetivo do projeto passa por desenvolver um sistema Cyber-Físico, no qual um mecanismo é controlado e monitorizado por um *software*, onde é possível alterar o estado do mecanismo de acordo com a necessidade e contexto. Será possível concretizar a finalidade de bloqueio e desbloqueio de um lugar de estacionamento através de um simples pressionar de botão.

A estratégia de desenvolvimento desta pesquisa será separar o projeto em três sistemas principais, mecânico, eletrónico e informático, e no final fazer a interligação entre cada um deles. Todas as etapas mencionadas irão ser desenvolvidas e constituem a fase inicial de um sistema que visa facilitar o processo de encontrar um lugar de estacionamento disponível dentro de um período de tempo limitado.

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E_c – Kinetic energy [J]

W^{int} – Internal work [J]

W^{ext} – External work [J]

M_m – Motor torque $[N.m]$

ω_m – Motor angular velocity $[rad/s]$

v_y, v_x – Structure speed in x and y$[m/s]$

$\theta_{min}, \theta_{max}$ – Minimum and maximum angle [°]

n_m – DC Motor speed $[rpm]$

P_{out}, P_{in} – Output and input power $[W]$

V – Voltage $[V]$

I – Current $[A]$

Abbreviations

IoT – Internet of Things

FAST– Functional Analysis Systems Technique

CAD – Computer-aided design

DC – Direct Current

PLC – Programmable Logic Controller

1. INTRODUCTION

The industrial growth of the world is reflected also by the increase in the number of cars on the streets all over the world, which has caused a lot of parking related issues and the city planning on a slow rhythm has increased the problem even more. The search for an available parking slot is a time-wasting process which not only affects the economic activities' efficiency, but also the environment and cost. This was one of the reasons that led to a lot of attention on the development of smart parking technologies and a consistent increase in correlative research.

According to a research made during the International Conference on Service Operations and Logistics, and Informatics (SOLI), the urban population is expected to significantly grow in the near future: from 3.9 billion people that already live-in cities (54% of the global population) up to 6.3 billion people by 2050 (66%). Today's cities are culpable for more than 75% of waste production, 80% of emissions, and 75% of energy utilization. About Europe, the research is identifying that road transportation produces about 20% of the total CO_2 emissions, out of which 40% is generated by urban mobility. It is estimated that the cars searching for free parking slots cause 30% of the daily traffic congestion in an urban downtown area.

The purpose of the project is to develop a smart parking system that can reduce traffic by making it easier to find empty parking slots, thus lowering the risk of distracted driving and the environmental issues. A smart parking system is an intelligent system that assists the process from the moment when the drivers decide to park in a specific place over the city until the car is being parked safely on the chosen slot. Available space in the parking slot is indicated by signs or lights with the help of implemented software and sensors. The vacant slot is notified to the driver correctly due to the proper management of the system and by the usage of a specific smart mobile application. This technology uses different types of sensors as hardware components in the parking slot to detect presence or absence of the vehicles.

Smart parking systems provide real-time data information regarding the availability of parking space and allow drivers to reserve and occupy that slot without any interference of other vehicles. One of the systems implemented on the market, in the end of 2017, belongs to INRIX, a company that created a mobile application where the users will be able to check if a specific parking space is free or not, as shown on the imageFigure 1.1. Despite of being a useful application, it does not have a blocking system on the slot that will prevent other drivers to park their cars on the free parking spaces.

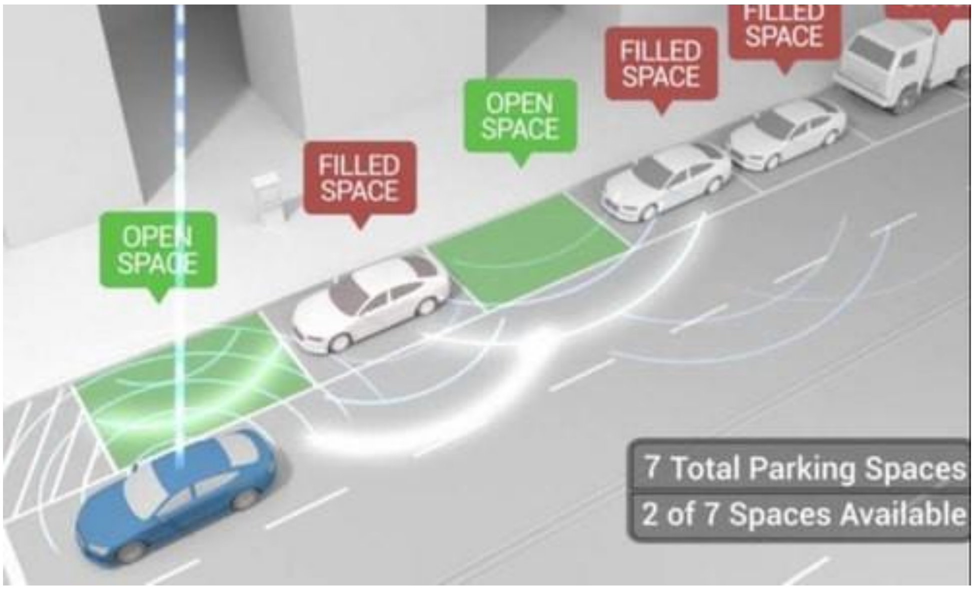


Figure 1.1-Smart Parking System (Mark, 2017, INRIX parking system)

Chapter 2 will go deeper on the analysis of some other examples implemented on the market. There, some conclusions will be taken about the way they are working and what is missing, or in other words, what can be improved. After taking some relevant results, chapter 3 will describe each concept generated that can be used in order to face all the needs of the users. The next step is to design and develop the concept that suits the best for the needs expressed. Is there, in chapter 4, that the 3D model will be presented, as well as all the components required. The last chapter of the prototype development is number 5, where all the hardware is integrated on the 3D model. In this chapter is also shown how the software is communicating with the hardware and also the working principle of the whole platform. The last chapters are reserved for the conclusions taken and also for proposals of future research that can be made, so that this product can be found in the market soon.

2. BUSINESS ANALYSIS

For the presenting project idea is necessary to identify the potential that it can have on the market. As part of the market research is mandatory to identify the main competitors and also to meet the requirements to innovate what already exists.

2.1. Market research

Abhay S. (2020) underlined that the smart parking systems can be classified as following: based on type they can be divided into off-street and on-street; based on end user, the smart parking market is studied across private and public institutions; by region, it is analysed across North America, Europe, Asia-Pacific, Middle East & Africa and Latin America. Regarding key players profiled in the smart parking market, the top of the list is highlighted by Amano McGann, Continental AG, IEM SA, Smart Parking Limited and Urbiotica.

Figure 2.1 shows the global smart parking market share by regions (2021-2027) realized by Abhay S. (2020).

Figure 2.1-Global Smart Parking Share

In the chart above it is clear the increase of investment on smart parking compared with the traditional ones.

From the point of view of market size value, the forecast for 2027 shows 12.7 billion USD compared with the 4.6 billion from 2020, which means an expected increase of approx. 310% for the next 7 years. North America dominated the market for smart parking systems in 2019 and the market is expected to grow even more, thanks to the growing number of vehicles in the region. The regional markets of Asia Pacific and Latin America are also predicted to rise, owing to the increasing number of cities in emerging economies, such as China and India. In Europe, the market for smart parking system is equally expected to present significant growth opportunities for the market players, mainly owing to the favourable government initiatives being sought by the European Union in promoting the deployment of intelligent parking systems as part of the efforts to reduce the pollution and ensure a sustainable environment. Moreover, the growing vehicle production and increasing concerns regarding the growth of car theft in Europe is expected to accelerate market adoption in the region. It is highly important to get in touch with some ideas and projects that are already on the market in order to control these issues.

Table 2.1 shows the main competitive products in the market. The meaning of knowing these competitors is to evaluate their advantages and disadvantages. Some conclusions of each project can be seen on the second column.

Table 2.1-Main competitive products

Online Parking Booking System (Nevon Projects)	Users can get details about parking areas across the map, they will be able to reserve the slot whenever they wish. However, no information was found concerning the way of blocking the place.
Smart Parking	This is a product that is already working with city councils, and it has the capacity of showing real time data about the status of each space, also, allows the user to make the payment through an app, replacing the parking meters. This product does not have the capacity of reserving a place.
ParkMe	ParkMe is an App that finds the cheapest private parking nearby. It is possible to reserve and, in some cases, to have real time data about the private parking. This app has the disadvantage of

	working only with private parking. It contains the reserve options, however, it is just on the private that it is possible to control that free slot.
Fybr	Fybr is a product that, like the others, is offering real time data to the users about the free slots and prices of it. It allows the users to make payment through an app and is capable of alerting through a message on the phone, every time the user exceeds the time. Is also working with city councils but does not allow to book the places.
Urbiotica	Urbiotica is a company that is working alongside with city councils. This company is using sensors to detect the presence of vehicles on public parking slots. Is using dynamic screens across the cities showing how many parking spaces are free and their location. It is not possible to reserve a place.
ParkMobile	This company has a mobile application where the users have access to the prices in the area where they park the car. They can also use the app to select an amount of time and to pay the corresponding parking fee. The users are receiving an alert when the time is exceeding the limit and they can decide to add a bit more time, paying the amount requested. The app does not offer any details about the status of the parking spaces across the city.

2.2. Need analysis

The product will have the drivers as the main client profile, however, people that are not in touch with technologies can be out of the client profile, once a few abilities are required to work with the smartphones and for now, it will only work in contact with the city council.

The smart parking system will not only bring benefits to the customers but also to the city council that will implement it. In terms of controlling the traffic, reducing pollution, as well as fighting against other environmental issues and even to make tourism to grow, the smart parking systems are expected to be part of the solution. It sounds like a useful product, isn't it? In order to picture a better view of the usage of these systems and to define the answers to the basic questions of developing a new product, was made a functional analysis system technique (FAST), Figure 2.2. The FAST presented in this diagram shows all the functions of the presenting project in a logical order. Starting with the main function of this product, booking a parking place, until passing through all the answers for the questions "Why?" and "How?". On the left side of the diagram are the answers to the "Why?", most relevant function. The lower order function is on the other extreme (right side).

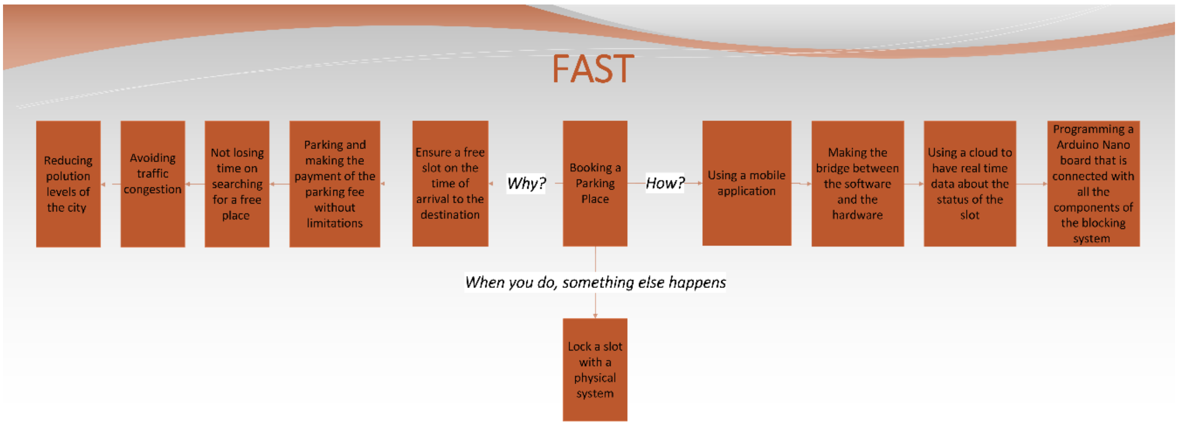


Figure 2.2-Functional Analysis Systems Technique of the smart parking system

As already mentioned, the project research shows that the target customers of the system are divided into commercial and city council. Table 2.2-Needs analysis shows the needs of each target.

Table 2.2-Needs analysis

Council expressed need	The need characterized: Performance
Increasing the profits	Earning money while the place is free. (reservation payment).

Reducing the car traffic	The search around the old town/city center of a free slot will decrease. With the reservation system the roads will be emptier.
Helping the local commerce	The roads will be more organized, and people can now lose more time on the street than on the roads searching for a free parking place.
City center less polluted	Each driver can normally take 10 minutes searching for a free slot. With this app those 10 minutes multiplied for a significant number of drivers will decrease the emissions of carbon monoxide.
Better logistic/can be implemented in all the city	The intention of this app is to spread the cars through the surroundings of the city center. If all the slots are occupied in the city center, the people can occupy other places in the surroundings, which will also increase the profits of the council.
To reach everyone	No one is excluded from this plan. People that don’t use the app can always park in this place without any restrictions. They will keep searching for a free slot hoping to be lucky to find one.
To control the borders of the slot	It is important to avoid one car to occupy two free slots. This will take the opportunity of another driver to use that place.
Customer expressed need	**The need characterized: Performance**
Reserving a parking slot before arriving to the desired place	The driver has the option of reserving a place that’s currently free. He will have different options according to the time that the driver wishes to reserve. Different times, different payments.

Ensure that the place will be free when arriving at the destination slot.	The slot will be integrated with a block/unblock system that will provide a better answer for the need of the driver.
Where is the place?	The app will be organized according to a map. A tool can also be installed later that will notify the driver of the distance to the parking slot.
What places are available?	On the app it will show up in green lights the number of free places, in red lights the occupied places and in orange the reserved places.
The time chosen on the app was not enough for arriving there.	It will be possible to add more time of requisition through the app. This will represent additional costs.
Giving up on the reservation.	Is possible to give up on the reservation. The app will have an option of cancelling and the person will be charged starting with the first reserve until the moment of cancelling. If the person does not cancel the reservation, all the time chosen at the beginning will be charged.

3. SYSTEM STRATEGY

Last chapter provides important details concerning the increase of investment on smart parking systems and also about the different products already implemented in the market. The presenting project is going to be developed considering all the advantages and disadvantages of the main competitors, as well as all the needs expressed by the customers and city councils.

The idea is to develop a system where the drivers can easily reserve a place on the parking spaces that belong to the city council because, as shown before, there are already some solutions for the private parking.

The next step of this project is then, to create a strategy about the working principle of the system. The user flow diagram (Figure 3.1) is the necessary tool to advance with a blocking system concept. This system has to be ready to face all the adversities occurring in the diagram.

3.1. User flow chart

Succeeding, a user flow chart diagram has been developed so the entire process of searching, booking, and parking the car on a public slot can be easy and clear.

On the flow chart presented below, it is possible to define all the options the customer has in order to use the system. During the process, the first need that comes up refers to finding a free slot. Will be up to the customer to install the app and to use it. Once the app is installed the user will have the option of choosing a free place, wherever he desires across the map. After, he can decide which reserving options he wants to select, considering all the modalities available. If the user still wants to go on with the operation, some credits will be discounted from his virtual account previously charged. The user can charge his virtual account every time he wants. After the reservation is confirmed, the blocking system is activated and the platform will block the slot immediately. Directions to the slot will be shown in the app. When the user arrives, the platform will go down by pressing the same button that put it up, and the user can park the car.

The user flow is showing in different moments, that the user can always have the option of cancelling the operation, also, it is evident that sometimes things are not happening as expected and for that reason, the user flow presents solutions for the obstacles that can happen along the process.

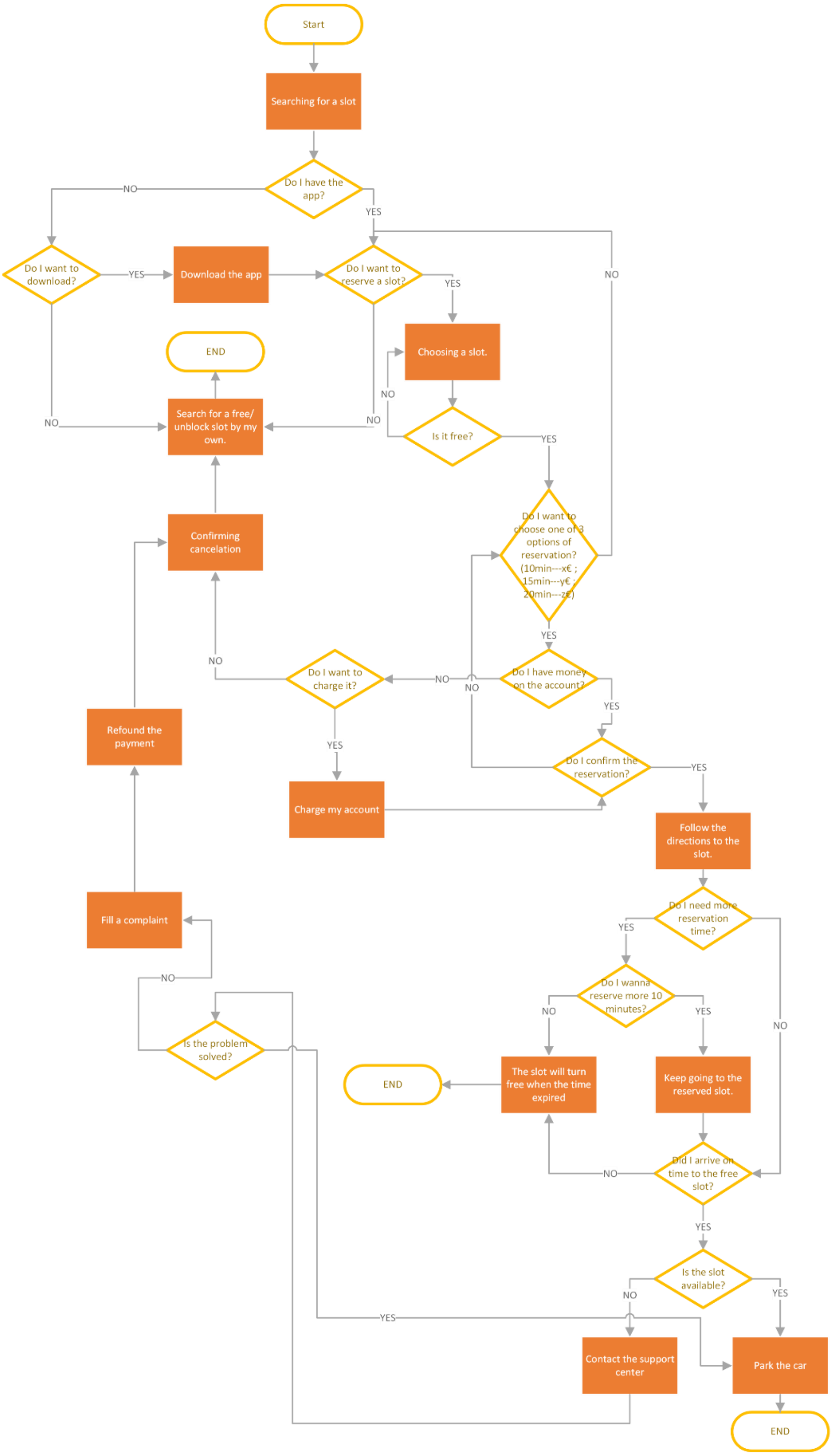


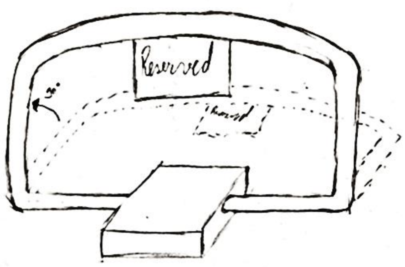
Figure 3.1-User Flow Chart

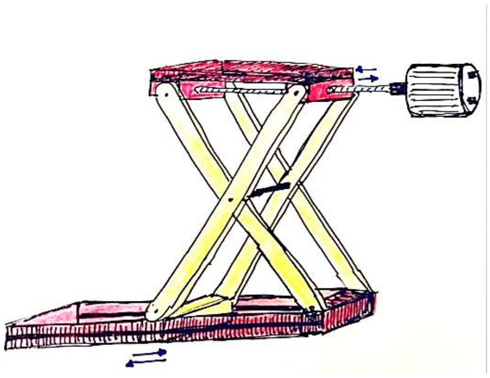
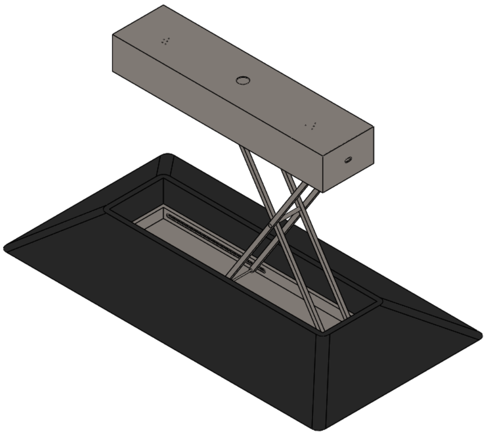
3.2. Generation of concepts

Considering all the research and studies made regarding this topic, the present project intends to create a concept for the blocking system in a parking spot that accomplishes the requirements of the market, feasible from the point of view of costs, segment targets and needs. The innovative possibility of selecting and reserving a slot for a limited period of time, using a blocking system to ensure the availability of the space until parking the car, has to be concretize with a prototype. The system prototype has to integrate a hardware subsystem, composed by an Arduino board and other components, a software subsystem, for programming the hardware, and a mechanical subsystem, generated through the usage of SolidWorks software in order to design and assemble the platform.

Initially it was proposed to generate ideas according to the existential needs of the market. There were three proposed ideas, which have been studied and analysed, in order to accomplish the request, not only of the project, but also of the markets' innovations. During the process it was necessary to think wisely and to come up with solutions that would produce an efficient system. The sketches below show the evolution that the system went through until getting the final shape.

Table 3.1-Concepts of the product

Nr crt.	Photo	Description
1		The first concept idea was to create a blocking system as shown in the sketch, composed by a box and a curved metal bar. Once the slot was reserved, the curved bar would be lifted 90 degrees so that the space would be reserved until the customer's arrival.

2		The second sketch refers to a blocking system that would be composed by 2 individual boxes, one up and one down. These will be joined through 2 movable legs so when the slot is reserved, the upper part will stand up to prevent the space from being occupied until the customer unblocks it through the mobile application. It will be placed at the middle of the parking slot.
3		The third concept is an improvement of the second one, so that the engine moved from the right side of the box to the middle of it; when closed, the upper part will fit perfectly on the downside structure; the system will be designed so that the two boxes' dimensions are equal and a case protection will be developed in order to avoid weather issues. Also, this concept presents ramps of protection for the system.

The first sketch is used nowadays by local residents and ensures that their place (the one that belongs to them) will never be occupied. A quick analysis was carried out, which demonstrates that the efforts needed to stand up the metal bar 90 degrees in that way were much higher than using the system of the lead screw. Also, the resistance of the platform would not be the same. More energy is spent and there is less resistance to eventual drivers that are forcing the barrier.

On the second sketch the idea of using a lead screw to stand up and to bring down the platform was defined, however, a few things needed to be considered. Where is the electric system fitting? Is the motor outside the platform? Is it closing perfectly? The answers for all these questions are found on the third sketch.

It was defined by a matter of volume management and protection, for the possible environmental issues, that the DC motor would fit inside of the top platform and instead of being on the left side, it was placed on the middle of it since the mechanical system would not be affected by this change. From the second to the third sketch, changes were made that allowed the platform to close perfectly.

The three concepts have been analysed to come up with the final model.

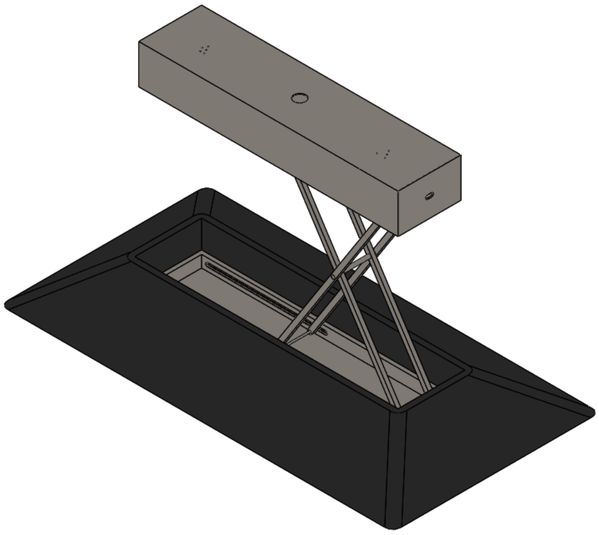


Figure 3.2-Chosen concept of the product

The concept is quite simple to use. The user will be presented with a map of the city illustrating the car places that are available or occupied across the city in real time. Supposing that the user will try to reserve it, starting with the moment the reservation is paid, the platform on the slot will stand up, to avoid other cars to park there. During the process of the project, some risks or critical issues have been discovered, that could affect the idea. The main problem was to control the limits of each parking slot because it is kind of normal to happen, people to park their car outside the ground marks. To avoid this from happening, the solution was to implement two ultrasonic sensors that can read and warn, through a buzzer, the drivers that did not respect the marks on the ground.

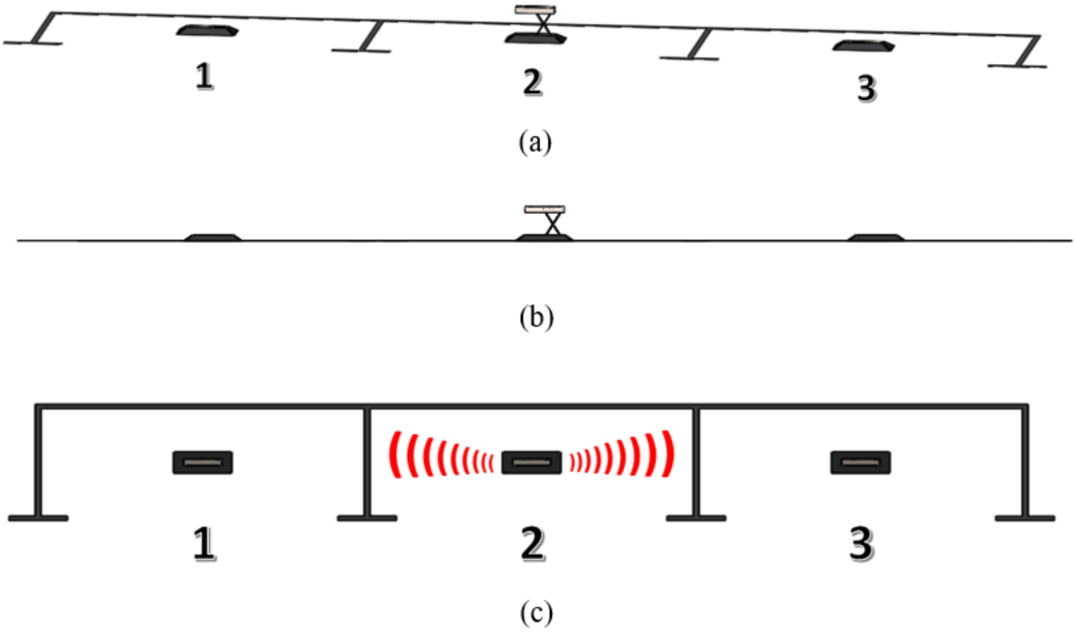


Figure 3.3- (a) Isometric view on 2 different scenarios (slot available /slot reserved);(b) Front view of the system; (c) Top view showing the range of the ultrasonic sensors

The images presented in figure 3.3 are simulating the two possible scenarios that the smart parking system can found: (1) the available one, when the system is closed and the car can be parked there and (2) the scenario where the user is reserving the parking place through the app and so, the system will block the availability of the slot by standing up the platform.

All the slots are sending the information to the app about the status of each of them. Through a magnetometer it is possible to know if there is a car parked above the platform or not, and if so, the information sent to the app is that the slot is unavailable. In case of being free, the magnetometer is giving the information that the slot is empty and available to reserve. Once the user decides to reserve a free slot, the app will send a signal to the platform that will stand up, thanks to the activation of a DC motor. The DC motor will spin the lead screw and the nut will pull the platform up. On the opposite side, when the user arrives at the local, the DC motor is activated and starts to spin in the opposite direction. This time the nut is pushing the platform down. The system will be integrated with two ultrasonic sensors that are giving the information to potential bad behaviours of drivers that are not respecting the limits of the slot.

4. DESIGN AND DEVELOPMENT OF THE PROTOTYPE

This chapter will show the development process of the project idea. It will start by showing the way that the platform structure got born, where the parts were designed individually and, in the end, assembled to each other. The structure requires the usage of some components that, before being applied, must be sized. This part of the prototype was named as “mechanical subsystem”. Throughout this chapter is included the electric circuit that is integrated on the top part of the platform. In order to simulate what is supposed to happen inside the platform, a hardware subsystem was created, that will show a perspective about the working principle of the platform. For monitoring and controlling the hardware, it is necessary to create an application where all the data is going to be collected and subsequently controlled by this software subsystem. These three subsystems will be communicating permanently, and the last subsection will present the operational method of the whole system.

4.1. Computer-aided design of the platform

After achieving the final sketch concept of the idea, it was necessary to design a 3D model. The CAD modeling software used to generate the concept of the structure was Solidworks, an impressive software that permitted to design all the parts of the structure and to assemble all of them in one complex model.

After all the necessary components have been developed, the assembly of the system was made giving a clear perspective of its final design. In order to realize the task mentioned, was used Solidworks Software, the same for the part’s development, and in the following Figure 4.1, Figure 4.2 and Figure 4.3, the 3D sketches of the assembly in different perspective are presented:

Figure 4.1-"Closed" Position

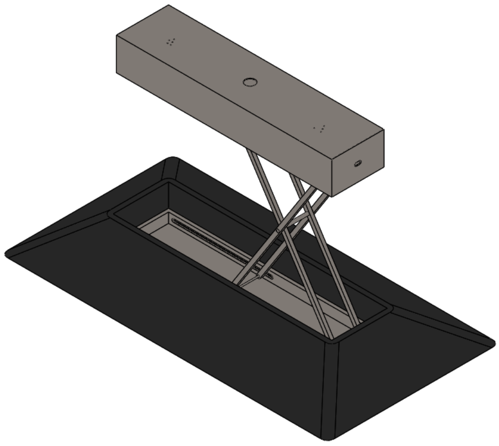


Figure 4.2-"Open" Position

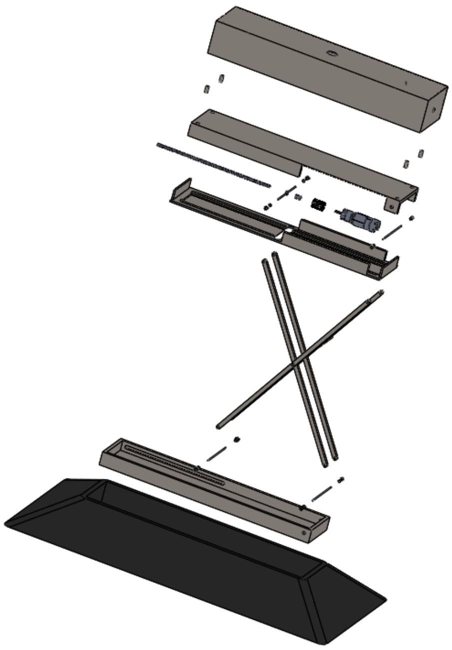


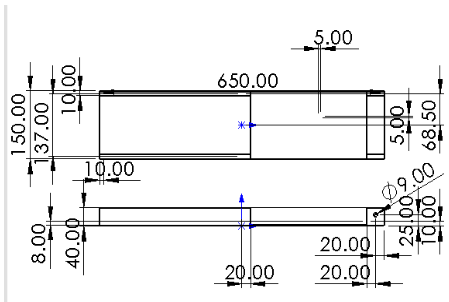
Figure 4.3-Exploded View

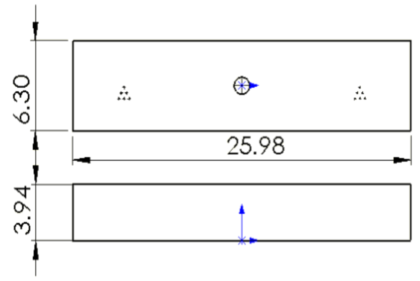
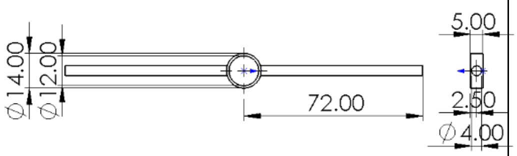
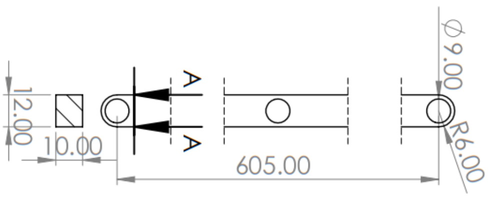
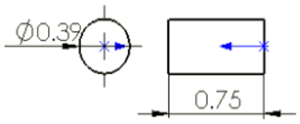
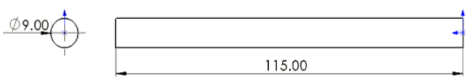
The first image shows the system in open position, which means that the platform is up. The second one represents the system closed and the third perspective is the exploded view of the system, where all the components can be seen, including the ones that will be sized on the next subchapters.

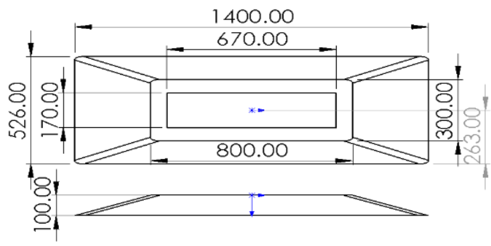
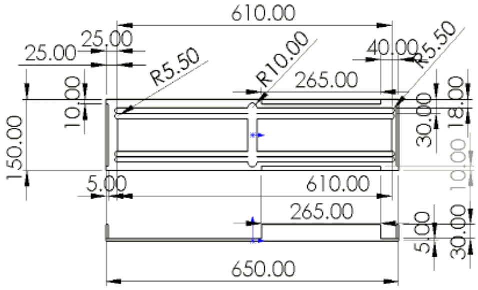
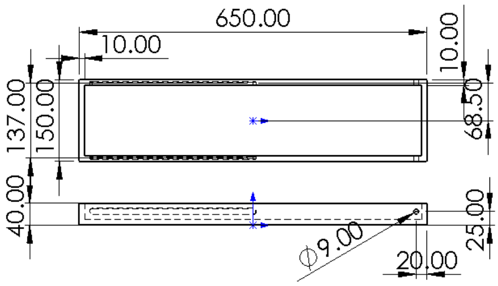
Table 4.1 shows all the main views, dimensions and essential characteristics of each part built. As this is only a project idea, the parts were not designed yet to be manufactured, however, as future research, the chapter 7 is describing what can and should be improved on this 3D model and so, to be possible to produce the components of the structure. Despite of not being ready to be manufactured, the structure will always be like the one built in Solidworks, only with some changes on the dimensions, so it will be easier and cheaper to produce it.

For the platform built, the material chosen for most of the components was stainless steel. Once the platform is fully exposed to the environment, it is necessary to take into consideration all the weather conditions. According to the studies made by Sandmeyer Steel Company (Catalogue) one choice can be the stainless steel 316L. For the ramps, natural rubber was used, the same used for the speed bumps once the main goal of this part is to protect the platform from the car's weight.

Table 4.1-Parts Description

Name	Photo (dimensions)	Properties			
		Mass(kg)	**Density (kg/m^3)**	**Material**	**Qty**
Top		11.186	8027	AISI Type 316L stainless steel	1

Case Structure		4.486	8027	AISI Type 316L stainless steel	1
Connection Nut-Lead Screw		0.015	8027	AISI Type 316L stainless steel	1
Leg		0.579	8027	AISI Type 316L stainless steel	4
Pin for the Structure Case		0.012	8027	AISI Type 316L stainless steel	4
Pin for the legs		0.059	8027	AISI Type 316L stainless steel	4

Ramp		33.719	1020	Natural Rubber	1
Top Case		3.053	8027	AISI Type 316L stainless steel	1
Base		6.718	8027	AISI Type 316L stainless steel	1

4.2. Components Sizing

For fitting the mechanical components on the platform built before, it was necessary to size all of them. The number one and the first to be sized corresponds to the dc motor. Number 2, 3, 4, 5, and 6 are the fasteners named as ball bearing for support, ball bearing for wheels, coupler, jack screw and nut respectively.

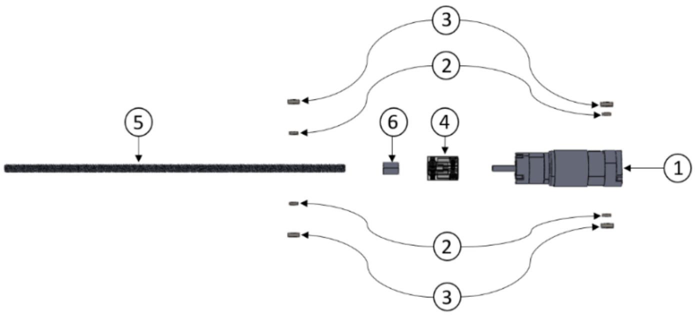


Figure 4.4-Exploded View of fasteners and DC motor

4.2.1. DC Motor

To have a clear view about how the main forces are applied on the structure, the following pictures show the behavior of the legs on the maximum and minimum height. All the measures are presented in millimeters and degrees.

- Platform down (system closed)

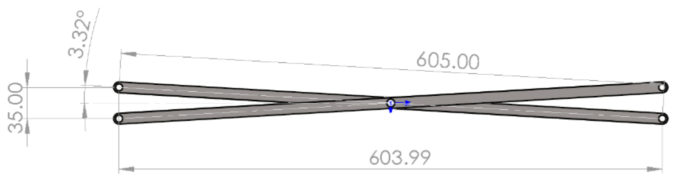


Figure 4.5-Data measures on "closed" Position

- Platform up (system open)

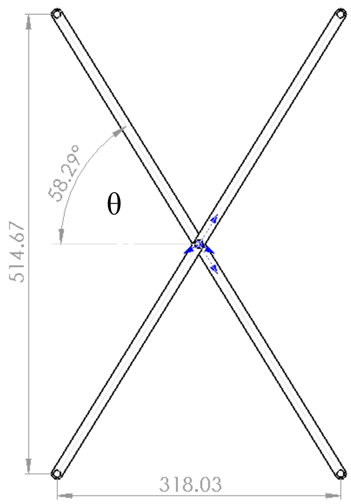


Figure 4.6-Data measures on "open" Position

- Diagram of forces

The study realized demonstrates, through the energies balance (4.1), the necessary forces needed to stand up the platform. The effort required from the DC motor when the platform is in position zero (system closed) will be higher, and later on this chapter, the graph (Figure 4.8) will prove it. The sketch below helps to understand how the study was carried out.

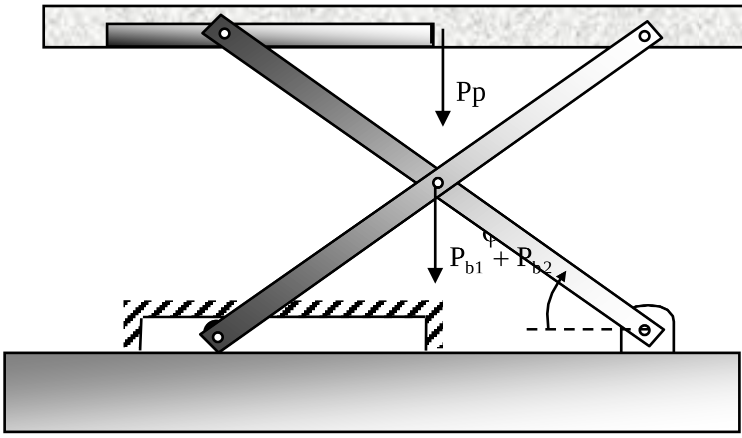


Figure 4.7-Forces' Diagram

$$\frac{dE_c}{dt} = \frac{dW^{ext}}{dt} + \frac{dW^{int}}{dt} \quad (4.1)$$

The first consideration to be made is the load speed equal to 0.

$$\frac{dE_c}{dt} = 0$$

$$\frac{dW^{ext}}{dt} = M_m\omega_m - (P_{b1} + P_{b2})\frac{v_y}{2} - P_p \times v_y$$

As a second consideration, the energy dissipation will be equal to fifty percent, which is a reasonable value, taking into consideration some situations that can happen during the lift of the platform.

$$\frac{dW^{int}}{dt} = -0.5 \times M_m\omega_m$$

Replacing the considerations made, on the equation (4.1):

$$\frac{dE_c}{dt} = \frac{dW^{ext}}{dt} + \frac{dW^{int}}{dt}$$

$$\Rightarrow 0 = M_m\omega_m - (P_{b1} + P_{b2})\frac{v_y}{2} - P_p \times v_y - 0.5 \times M_m\omega_m$$
$$\Leftrightarrow 0.5 \times M_m\omega_m = (\frac{P_{b1} + P_{b2}}{2} + P_p) \times v_y$$

In order to determine v_y, it is necessary to make a cinematic analysis, where the equation (4.2) shows:

$$v_y = \frac{dy}{dt} \quad \textbf{(4.2)}$$

$$\Leftrightarrow v_y = \frac{dy}{dx}\frac{dx}{dt}$$

The next step is to find out both terms of the equation, $\frac{dx}{dt}$ and $\frac{dy}{dx}$:

$$\frac{dx}{dt} = v_x = \frac{n_m}{60} \times p$$

To find out $\frac{dy}{dx}$, first it must be put y in order to x:

$$x^2 + (y)^2 = L^2$$

$$\Leftrightarrow y = \sqrt{L^2 - x^2} = (L^2 - x^2)^{0,5}$$

Now, it is possible to define the derivative of y in order to x:

$$\frac{dy}{dx} = 0,5 \times (-2x)(L^2 - x^2)^{-0,5}$$

$$\Leftrightarrow \frac{dy}{dx} = \frac{-x}{\sqrt{L^2 - x^2}} = -\frac{x}{y}$$

$$\Leftrightarrow \frac{dy}{dx} = -cot\,g\,(\theta)$$

Replacing the derivatives found on the equation (4.2):

$$\Rightarrow v_y = -cot\,g\,(\theta) \times v_x = -cot\,g\,(\theta) \times \frac{n_m}{60} \times p$$

The power required for lifting the platform is calculated through the equation (4.3):

$$M_m\omega_m = 2 \times (\frac{P_{b1}+P_{b2}}{2} + P_p) \times \cot g(\theta) \times \frac{n_m}{60} \times p \quad \textbf{(4.3)}$$

For keep going with this analysis it is a must to have access to some relevant data that can be seen below:

1. P_b=P_{b1}= P_{b2}=0.579×9.81=5.7 N
2. P_p=22×9.81=216 N
3. p=4×2=8 mm=0.008 m
4. $\theta_{min} = 3.32°$
5. $\theta_{max} = 57.81°$
6. $x_1 = 604\ mm$
7. $x_2 = 318\ mm$
8. $y_1 = 35.00\ mm$
9. $y_2 = 514.67\ mm$
10. The distance travelled by the nut on the lead screw:

$$(d_n) = x_1 - x_2 = 604 - 318 = 286\ mm$$

11. Lead of the screw $(l) = p = 4 \times 2 = 8\ mm$
12. Screw diameter $(d) = 8\ mm$
13. Small diameter$(d_s) = d - \frac{p\times2}{4} = 7\ mm$
14. Number of rotations required on the nut, for the system to stand up completely:

$$N = \frac{d_n}{l} = \frac{286mm}{8mm} = 35.75\ rot$$

As a first approach, has been estimated a value for the DC motor load speed of:

$n_m = 30\ rpm$ (Rotation per minute)

Thanks to all the data available and to the equation (4.3), it is now possible to define the minimum power that must be applied on the platform using the angle "θ", as a variable, once this value is between 3.32°and 57.81°:

$$M_m\omega_m = 2 \times (5.7 + 216) \times \cot(\theta) \times \frac{30}{60} \times 0.008 = 1.7736 \times \cot\theta$$

According to the graphic of Figure 4.8, for a start angle equal to 3.32°, corresponding to the minimum angle that the platform can get, on the closed position, the necessary power to lift the platform is equal to 30.57 W.

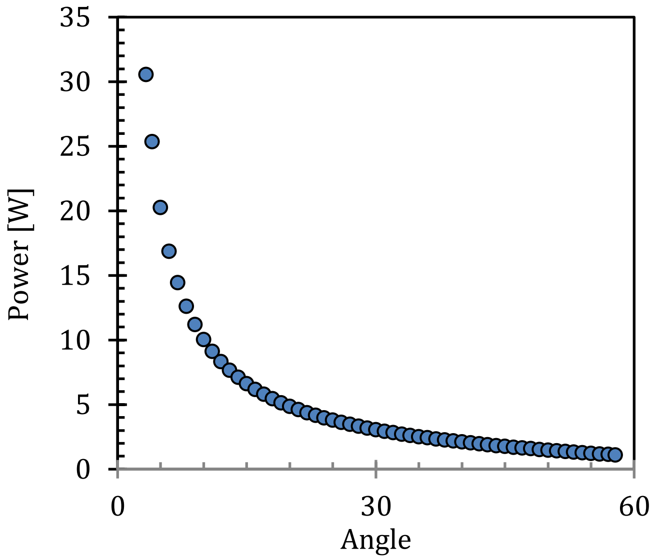


Figure 4.8-Necessary power to lift the platform with angle variation between [3.32;57.81]

The next step is to find out a DC motor with enough strength to transmit the necessary power to the shaft. By definition the output power of a DC motor is equal to:

$$P_{out} = M_m \times \omega_m \textbf{ (4.4)}$$

Where,

- $\omega_m = (n_m \times \frac{2\pi}{60})$ - Angular Velocity $[rad/s]$
- P_{out}- Output power (power that the shaft is transmitting to the coupler)
- M_m- Torque in N.m
- n_m-Load speed of the DC motor $[rpm]$.

In order to calculate this power, first, it is necessary to select a DC motor. From the catalogue of (GoBilda) the one selected has the following characteristics:

Table 4.2-DC Motor Parameters

Motor Size	RS-555
Motor Type	Brushed DC
Nominal Voltage	12VDC
Output Shaft	8mm REX, 24mm Length
Gearbox Style	Planetary
Gear Ratio	99.5:1
Gear Material	Steel
No-Load Speed @ 12VDC	60 RPM
No-Load Current @12VDC	0.25A
Stall Current @12VDC	9.2A
Stall Torque @12VDC	133.2 kg.cm (13.06N.m)
Wire Length	470mm (including connectors)
Encoder Voltage Range	3.3 - 5VDC
Weight	486g

The supplier of this DC motor is not offering data concerning the nominal usage of the DC motor. However, as the DC motor selected is a low voltage one, it is possible to analyse the characteristic curves of current, speed, torque and power. The diagram of the Figure 4.9 is standard and can be used for the majority of DC motors.

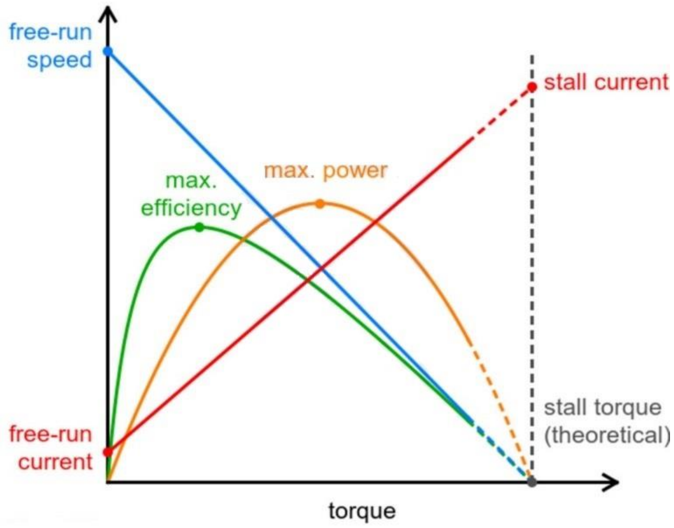


Figure 4.9- Curves diagram of low voltage DC Motor

To understand if the DC motor selected, has enough power to lift the platform, the value corresponding to the maximum power on the graphic above has to be taken.

In these conditions and through the analysis of Figure 4.9, it can be assumed that the maximum power is achieved when the torque is half of the stall torque and half of the maximum speed. This means that, for the maximum output power of the DC motor (the power on the shaft), is corresponding a speed of $n_m = \frac{60}{2} = 30\, rpm$ and a $T = \frac{13.06}{2} = 6.53\, N.m$. Applying these values in equation (4.4):

$$P_{out} = 6.53\ \times \left(\frac{60}{2} \times \frac{2\pi}{60}\right) = 20{,}51\, W$$

This value is under the required value of 30.57 W. At this point, the easiest solution would be to select another DC motor, however, it is also possible to improve the power of this DC motor. The DC motor can be supplied from -50% to +100% of the nominal voltage, as mentioned on the catalogue of Crouzet Mechatronic Components (Crouzet)

Applying these concepts and using a battery of 18 V (+50% of the nominal voltage), almost all the curve values of the Figure 4.9 will increase.

Hence the torque will increase with the same ratio of the voltage (1.5), therefore, $T = 1{,}5\ \times 13.06 = 19{,}59\ N.m$. The same relation is used to take the value of no-load speed, so, $\mathrm{n}_m = 60\ \times 1{,}5 = 90\ rpm$.

The current will have the same values because it is not possible to increase the stall current. That value is the maximum the wires can drive.

The current corresponding to the maximum output power can be taken by linear regression using the values given by the suppliers as shown in table 4.3:

Table 4.3-Linear regression to find "x"

Current I [A]	**Torque T [N.m]**
0.25	0
X = 4.725	9.795
9.2	19.59

Combining the Ohm's law ($V = RI$) with the input power, equal to $P_{in} = R \times I^2$, the equation for the input power is equal to:

$$\mathrm{P_{in}} = \mathrm{V} \times \mathrm{I} \quad \textbf{(4.5)}$$

Replacing the values of voltage and current, the input power on the motor is:

$$P_{in} = 18\ \times 4.725 = 85{,}05\ W$$

Using again equation (4.4), the output power of the DC motor is equal to:

$$P_{out} = \frac{1{,}5 \times 13{,}06}{2} \times \left(\frac{1{,}5\ \times 60}{2} \times \frac{2\pi}{60}\right) = 46.16\ W$$

For the required power to lift the system, the equation (4.3) used before will get a change in the speed. The speed will be half of the no-load speed with the change of voltage, which means that $n_m = \frac{90}{2} = 45\ rpm$ So,

$$P_{required} = M_m \omega_m = 2 \times (5.7 + 216) \times \cot(\theta) \times \frac{45}{60} \times 0.008 = 2.660 \times \cot\theta$$

Using, $\theta = 3.32°$

$$P_{required} = 45{,}85W$$

Table 4.4-Power results express the results of the DC motor sizing:

Table 4.4-Power results

$P_{input}[W]$	85.05
$P_{output}[W]$	46.16
$P_{required}[W]$	45.85

Using the selected DC motor, with a battery of 18V, the platform will work perfectly, because, even if the output power is very close to the required one, at the beginning of the sizing, the energy dissipation was assumed to have a conservative value (50%).

4.2.2. Fasteners

Several components must be selected from standard catalogues to finalize the assembly of the system and in the following tables the properties of each of them. Parts like the lead screw, coupler and nut, were important to define considering what already exist in the market. As it was necessary to calculate various forces for defining the proper dimensions and parameters of the DC motor, the next chapter shows the way of selecting it and why.

Table 4.5-Standard Components Selection

<table>
<tr><th rowspan="2">Ball Bearing</th><th colspan="7">Properties</th></tr>
<tr><th>D (mm)</th><th>d(mm)</th><th>B(mm)</th><th>Mass (g)</th><th>KN</th><th>Rpm</th><th>Quantities</th></tr>
<tr><td>618/4</td><td>9</td><td>4</td><td>2.5</td><td>7</td><td>0.005</td><td>140000</td><td>12</td></tr>
<tr><td>604</td><td>12</td><td>4</td><td>4</td><td>21</td><td>0.012</td><td>120000</td><td>4</td></tr>
<tr><th rowspan="2">Coupler</th><th colspan="7">Properties</th></tr>
<tr><th colspan="3">In</th><th colspan="2">Out</th><th colspan="2">Mass</th></tr>
<tr><td>SUK: 4006-0008-1006</td><td colspan="3">6 mm D-Bore</td><td colspan="2">8 mm Round Bore</td><td colspan="2">36</td></tr>
<tr><th rowspan="2">Lead Screw - Trapezoidal</th><th colspan="7">Properties</th></tr>
<tr><th>Pitch</th><th>Lead</th><th>Starts</th><th>Mass</th><th>Material</th><th colspan="2">Length</th></tr>
</table>

SUK: 3501-0804-0350	2	8	4	106	Stainless Steel	350
Nut	**Properties**					
	Pitch	**Lead**	**Starts**	**Mass**	**Material**	**External Diameter**
SUK: 3500-0804-1216	2	8	4	10	Bronze	12

5. MONITORING AND CONTROL

In the previous chapter it was developed the mechanical structure that will block the parking space when activated. This chapter will complete the platform created. A place was reserved in the mechanical platform for all the hardware components. After being inserted on the platform all the electronic components, as shown on the bottom of Figure 5.1, the structure will communicate via Wi-Fi with the application. A cloud will be used as a broker between the dashboard of the application and the platform. Figure 5.1 is a diagram that shows how the monitoring and control of the system is made. The dashboard is shown on the top and the cloud in the middle of the diagram. On the green arrows it is described all the exchanges data occurring between each subsystem.

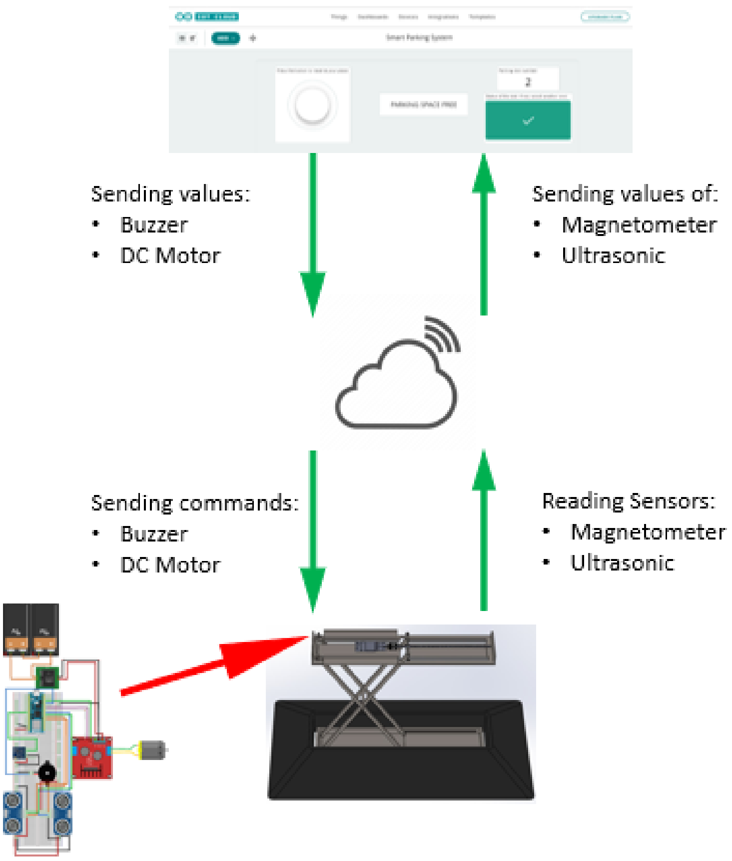


Figure 5.1- IoT project diagram

5.1. Hardware

5.1.1. Components

The hardware of this project is making the bridge between the software and the mechanical system. Previously a suitable DC motor for the platform was selected. Alongside the hardware topic, it is described all the components used, as well as theirs function on the platform. All the components can be found in Table 5.1.

Table 5.1-Hardware Components

Hardware	
Actuator	12V DC motor
PLC	Nano RP 2040 connect
Magnetic field sensor	HMC 5883l
Ultrasonic Sensor	Hc-sr04
Piezo	Buzzer
Motor Driver	L298N
Power Source	18V battery

For a wider image and a better understanding of the prototype circuit, on the following a few words describing each of the hardware components:

- Actuator- 12V DC motor

The brushed dc motor is composed by two main parts, the stator and the rotor, that will transform electric energy into mechanical energy. All this process will be made through multiple reactions of attraction and repulsion between the stator and the rotor. The commutation of the current is made with the help of brushes. This DC motor has a gearbox incorporated, with the goal of increasing the torque. Figure 5.2 shows the one selected.

Figure 5.2-5202 Series DC Motor [GoBIlda]

- PLC- Nano RP 2040 connect

The Arduino boards are an excellent tool for executing prototypes and are used nowadays in multiple applications in order to build electronic projects. All the boards have in common a microcontroller that, in other words, is a very small computer. This microcontroller will process all the inputs, such as sensors and outputs, like DC motors or led lights. There are various boards and the selection was made taking into account two considerations. First and most important, the board must have a Wi-Fi module that can be configured on the Arduino IoT cloud software, so it can be possible to create IoT (Internet of Things) projects, like the smart parking system. The price had also an important role because from all the boards suitable for this project, the one chosen was the cheapest. The main characteristics of this board can be found on the Table 5.2, given by the manufacturers.

Table 5.2- Arduino RP2040 Parameters

BOARD	Nano RP2040 Connect with Headers	
	SKU: ABX00053	
MICROCONTROLLER	Raspberry Pi RP2040	
USB CONNECTOR	Micro USB	
PINS	Built-in LED pin	13
	DIGITAL I/O PINS	20
	ANALOG INPUT PINS	8

	PWM PINS	20 (Except A6, A7)
	EXTERNAL INTERRUPTS	20 (Except A6, A7)
CONNECTIVITY	Wi-Fi	Nina W102 uBlox module
	BLUETOOTH	Nina W102 uBlox module
	SECURE ELEMENT	ATECC608A-MAHDA-T Crypto IC
SENSORS	IMU	LSM6DSOXTR (6-axis)
	MICROPHONE	MP34DT05
COMMUNICATION	UART	Yes
	I2C	Yes
	SPI	Yes
POWER	Circuit operating voltage	3.3V
	INPUT VOLTAGE (VIN)	5-21V
	DC CURRENT PER I/O PIN	4 mA
CLOCK SPEED	Processor	133 MHz
MEMORY	AT25SF128A-MHB-T	16MB Flash IC
	NINA W102 UBLOX MODULE	448 KB ROM, 520KB SRAM, 16MB Flash
DIMENSIONS	Weight	6 g
	WIDTH	18 mm
	LENGTH	45 mm

Figure 5.3 describes all the pins and functions of the Arduino board selected.

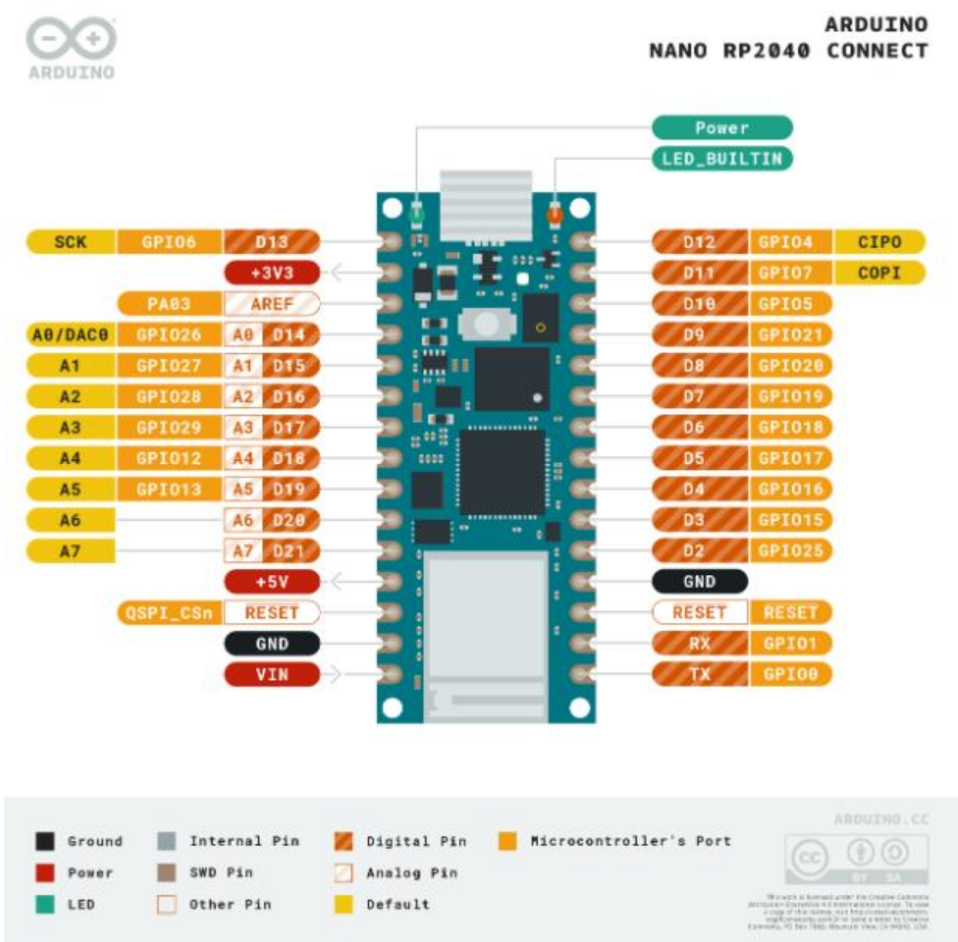


Figure 5.3-Pinout description of nano RP2040 Connect

More detailed information regarding this board can be found on the product reference manual (Arduino.cc).

- Magnetic field sensor- HMC 5883

This is probably the main key of this project. This sensor consists of a 3-Axis digital compass capable of measuring the magnetic field in space. The earth's magnetic field allows this magnetometer to feel all the changes that are made to the surroundings. So, every time a magnet is getting close to the sensor, the magnetic field of it will directly affect the magnetic field that the sensor was measuring before. It is possible to determine from where all those changes are coming, watching in detail which and how much the different axis are affected.

The following image (Figure 5.4) explains briefly, how the changes of the magnetic field are felt. In the image it is possible to see how it is being measured the magnetic field by the sensor without the presence of a magnet (ferrous object), where the range of the sensor is not capable yet to detect the ferrous object and when it is getting closer. There, the changes of the magnetic field are felt because the range of the sensor can catch the magnetic field of that object.

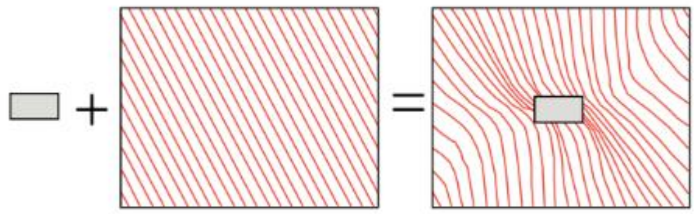


Figure 5.4-Magnetic field with and without disturbance (Michael, 1999)

For this project, at this point, it was not important to know exactly from where all the changes came from. It is important only to detect a big amount of changes on the magnetic field. Usually, all the cars are provided with a magnetic field big enough to cause impact on the measures of the sensor. As it is a big ferrous object, the changes on the sensor will be very significant.

The method used in order to detect a car was based on creating a variable called magnitude, where, all the changes in the 3 different axis (x,y,z) were taken into account. So, $magnitude = \sqrt{x^2 + y^2 + z^2}$. This formula makes possible the study of the magnitude of the change and to understand if the slot is being occupied or not by a car.

Before using the magnetometer, it is recommended to calibrate it, so the values given can be trustful. There are multiple ways of calibrating it. The presenting project used a library from the Arduino IDE software, to make the corrections of the sensor.

The sensor is looking like shown on Figure 5.5.

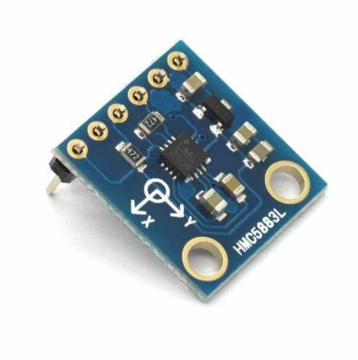


Figure 5.5-HMC5883L Magnetometer (Casa da Robotica)

- Ultrasonic sensor- Hc-sr04

Two ultrasonic sensors were implemented, exactly to check the obstacles that the platform has in front and behind. The sensor has incorporated the echo and the trig pins. The trig pin will emit a sound wave. The wave will be reflected once it finds an obstacle. After that, the wave reflected will be received by the echo pin. This is a very fast process that can happen in a few milliseconds, but through the speed of the sound, it is possible to generate an equation, so the distance from the sensor to the obstacle can be found. It is directly connected with the buzzer and every time it measures an obstacle, it activates the buzzer. The following image (Figure 5.6) shows the shape of this sensor.

Figure 5.6-HC-SR04 Ultrasonic Sensor (Elcrow)

- Piezo- Buzzer

In a simple description, a buzzer piezo is an electronic product that is used to generate a sound as an alarm or a simple tone/beep. It works by using a crystal made by a special material that changes shape when voltage is applied to it. If the crystal is pushed against a diaphragm, it will generate a wave of pressure which the human ear recognizes as sound. The main function of the buzzer inside the project, is to alert the drivers that are not parking the car according to the limits. The one used is shown in Figure 5.7.

Figure 5.7-Buzzer (Arduino.CC)

- Motor Driver- L298N

The L298N is a motor driver capable of controlling the speed and direction of the DC motor. For the presenting project the capacities of this module were used for supplying the DC motor with higher voltage than 5V and also for changing the direction of the motor. The pinout connection of this driver can be seen in figure 5.8(Botnroll).

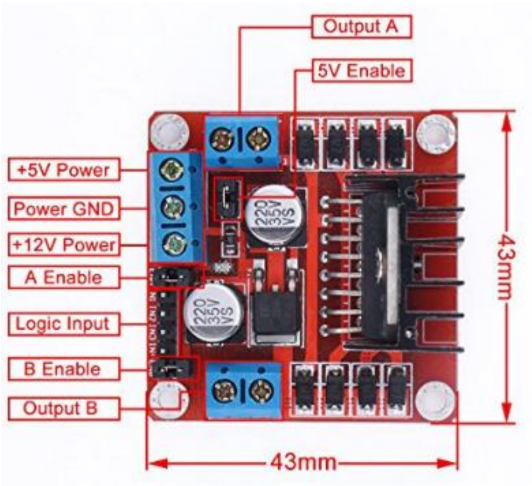


Figure 5.8-Pinout motor driver

- 18V battery

The power source of the circuit is a battery of 18V, as sized before. It will be enough to feed all the components, including the DC motor, that requires a big amount of energy. For getting a battery of 18V, on this project were joined two batteries of 9V each as shown below (Figure 5.9).

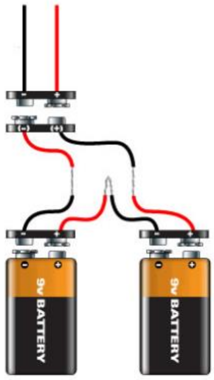


Figure 5.9- 18V Power Source (two batteries of 9V each)

5.1.2. Pinout Connection

For the presentation of the hardware prototype, a normal breadboard was used, so the connections can be easily changed. For a definitive construction, the connecting wires will be welded to the nano board.

Table 5.3 shows all the components connections to the digital and analog pins of the Nano RP2040 connect board, as well as, to the motor driver.

Table 5.3-Pinout Connection

A4	SDA
A5	SCL
D2	Trig Pin1
D3	Trig Pin2
D4	Echo Pin1
D5	Echo Pin2
D6	IN2
D7	IN1
D9	Piezo
D10	ENA
Vin	5V motor driver
GND	GND motor driver

As the driver has a 5V output, the Arduino board is going to be supplied by the same battery that is powering the DC motor. On the system, in order to save battery and also to shut down on any occasion the circuit, was also integrated a toggle switch, as shown on the Figure 5.10.

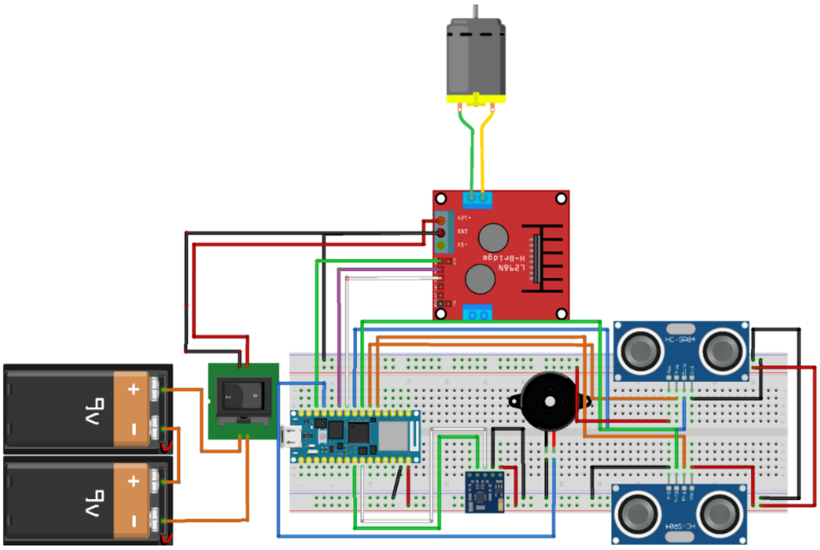


Figure 5.10-Virtual Circuit

After the development of the virtual circuit and defining all the necessary components and pin connections, the project could proceed to the assembly of the real prototype. Figure 5.11 shows the initial version of the hardware system.

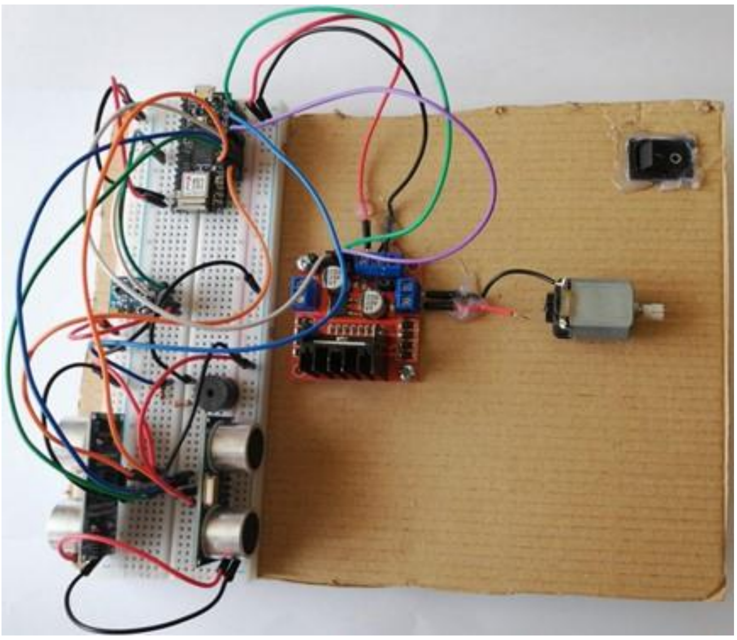


Figure 5.11- Hardware System

5.2. Software

5.2.1. Arduino IoT Cloud

This software allows the users to control the Arduino board through Wi-Fi communication. The only requirement is a cloud compatible board. For the presenting project, the one chosen was the nano RP 2040 Connect with a Wi-Fi module integrated.

To use the software, first, it is necessary to create an account and to register to the Arduino community. Immediately after this step, it is going to be asked to choose a cloud plan. The cloud plan chosen was the free plan. Despite of being the most basic one and with less capacities, this plan is enough to run all this project.

To start the project using this software, after registration, it is mandatory to create a “Thing”, the basis of all Arduino IoT cloud projects . Inside the “Thing”, all the necessary details will be known. First, the Wi-Fi credentials have to be inserted followed by configuring a device and adding also all the variables needed for the project. When trying to configure a device, the Arduino IoT Cloud requires the computer to have the Arduino Agent installed. Basically, the agent is the bridge between the USB port and the Arduino IoT cloud. As most of the web browsers have a security system that does not allow the websites to connect directly to the computer’s resources, this agent is “breaking” that system, allowing the website to connect directly with the USB port of the laptop. Like this, the nano board can get directly in contact with the web editor of the Arduino IoT cloud.

In Figure 5.12, it is possible to see the three steps that must be added to the “Thing”. The name of the “Thing” created is “Smart Parking System Prototype”. As a safety measure, the network data, as well as the device id, have been erased from the image.

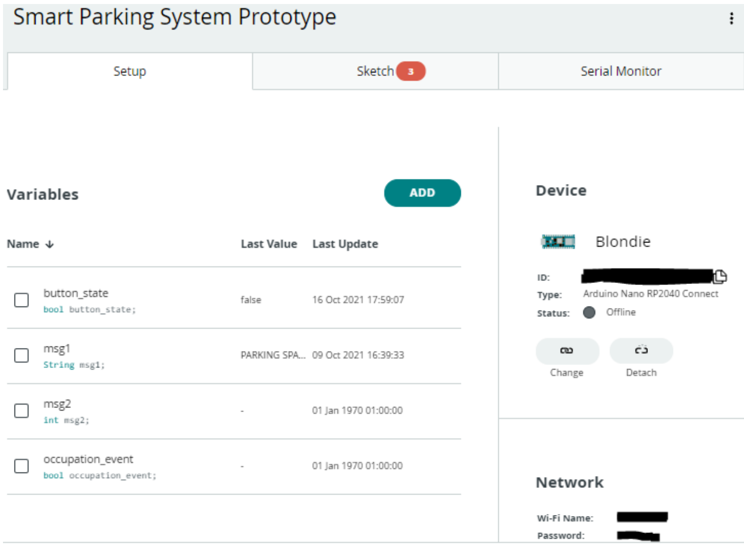


Figure 5.12-"Thing" of Arduino IoT Cloud

For the project, four variables were created: two Boolean variables, named as, “button_state” and “occupation_event”, one string variable, called “msg1” and one integer variable with the name “msg2”. The variables can assume one of the two options, only reading or reading and writing.

Once the variables are created, they will show up immediately on the sketch tab. The code is generated inside the sketch menu. Arduino code is written in C++ language with some additional methods and functions. When a variable assumes the option of reading and writing, is generated on the sketch a function, where, each time the variable is triggered from the cloud, it will execute the code within this function.

When the code is done, it is important to verify and upload it on the board. Subsequent to the upload, the board will be controlled through the Arduino dashboard. The next topic will relate, how the dashboard and its functions can be created.

5.2.2. Dashboard

A dashboard is a visual display that, depending on its function, can be accessible by a web browser by the users. Thanks to it, real time data can be easily accessed, coming from the cloud. It is also working as an issuer, which means that commands can be sent to the hardware, in this case. All this process is using a publish/subscribe pattern over the cloud.

The dashboard is built by dragging widgets into a working surface. Each widget is linked to a variable cloud, the ones created on the "Thing editor", imageFigure 5.12. The Table 5.4 is linking all the variables to its widget, four variables to four widgets.

Table 5.4-Connection between widgets and variables

Widget	Variable Name
Push Button	button_state (bool)
Value	msg1 (string)
Value	msg2 (int)
Status	occupation_event (bool)

As a result, the dashboard appearance will look exactly like the image below.

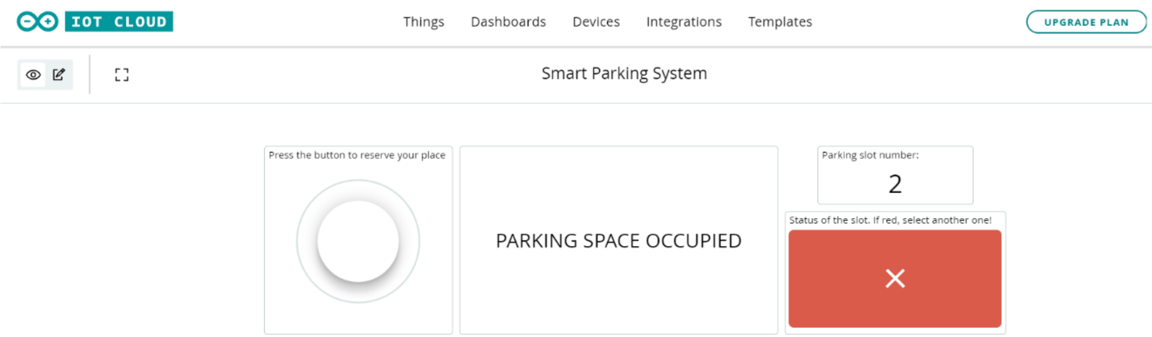


Figure 5.13-Dashboard Interface

On the left-hand side of Figure 5.13, the push button is a widget that, when pressed, will change the value of the variable "button_state" to high. It is through this button that the users will try to reserve their place. The status window, on the bottom right-hand side, is letting the users know if the parking slot is available to reserve or not. This variable is directly connected to the "magnitude" variable created on the code. The "magnitude" reads the values of the magnetic field from the magnetometer. If the slot is available, it means that there was not a change in the values of magnitude and like this, the status of the "occupation event" is green, otherwise, it will show up in red. The widget from the right top corner is showing the number of the place that has been selected. The last widget corresponds to the middle one, the big window. That is a window that is passing different messages along the process of reserving a place. A string variable was inserted on the code, and it is changing its value depending on the part of the code that is running at the moment.

Subchapter 5.3 will explain the working principle of all the subsystems.

5.3. Working Principle

During the previous chapters, it has been analyzed all the subsystems of the project. Now, it is time to understand the interaction between the three of them. Despite of not having a physical 3D model, the explanation of how it will work the whole platform can be made, using the platform created on Solidworks.

First of all, it is important to know some aspects of the code. The base of all this smart parking system is on the magnetometer. This sensor is the key for the presenting project, once it will be the one relating the status of the parking slot, if it is occupied or free to reserve. Another important aspect of the project is the push button. The push button is giving the commands to activate the DC motor. The ultrasonic sensors will just be working when the platform is high and can have different functions, depending on which period of reservation is working the code. The ultrasonic sensors were the solution found to control the marks on the ground, if they are being respected by the other drivers. It is a sensor that can detect the distance from the car in front or behind. When the limits are respected the user that reserved a place, knows that he has enough space to park the car. Otherwise, reserving the place without being sure that all the place is free and the user has enough space to park the car, would bring many problems to this project.

Having these notes clear, the explanation of the working principle will be separated in three different scenarios.

- 1st scenario

The first case is based on perfect conditions, where the reservation is taking place properly. In this scenario and as an example the goal is to reserve the place number two. For this, the values of the magnetometer must be inside the range previously defined in the code, which means, the parking slot is free, and the place can be reserved.
The first step is then, to check if the slot is available or not. That information is provided through the green light and the middle window presented on the dashboard as seen in Figure 5.14.

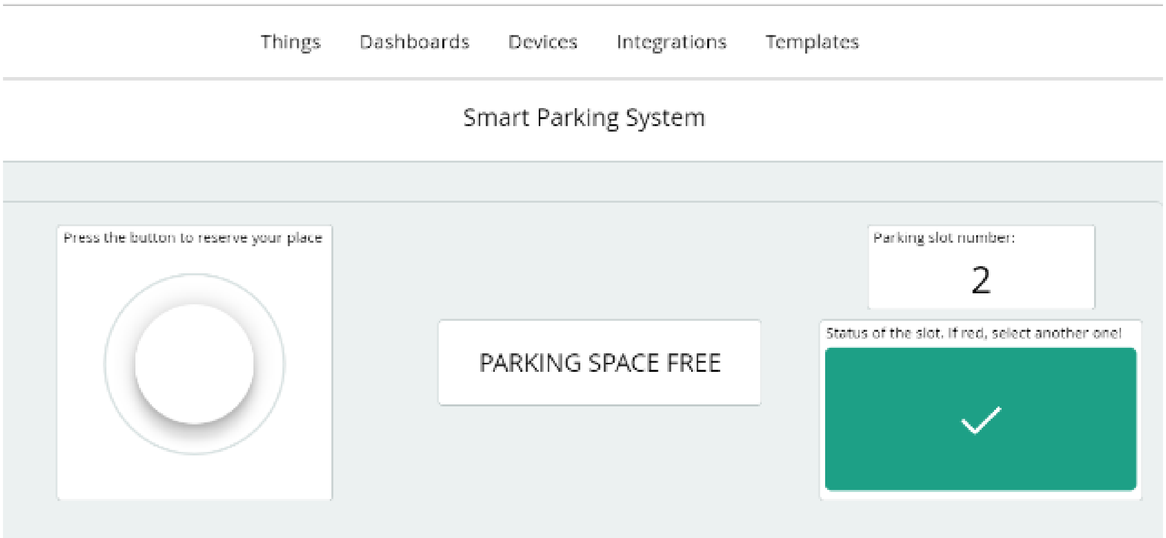


Figure 5.14- Initial Dashboard (Scenario 1)

When the first step is verified and the push button is pressed, the DC motor is starting to work, and the platform is lifting. When the platform is lifted, the ultrasonics will start their function. While it is lifting, the ultrasonic sensors will get enough data to know if the cars are crossing the limits marked on the ground. From Figure 5.15 is possible to confirm that the car parked on the place number three is respecting the limits. The place number one the place is free and obviously, there is nothing crossing the limits.

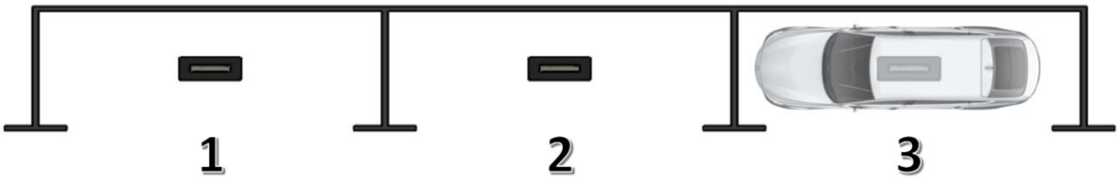


Figure 5.15- Parking Slot (Scenario 1)

In this case, the place number two will be successfully reserved and the dashboard will look as shown on the following image (Figure 5.16).

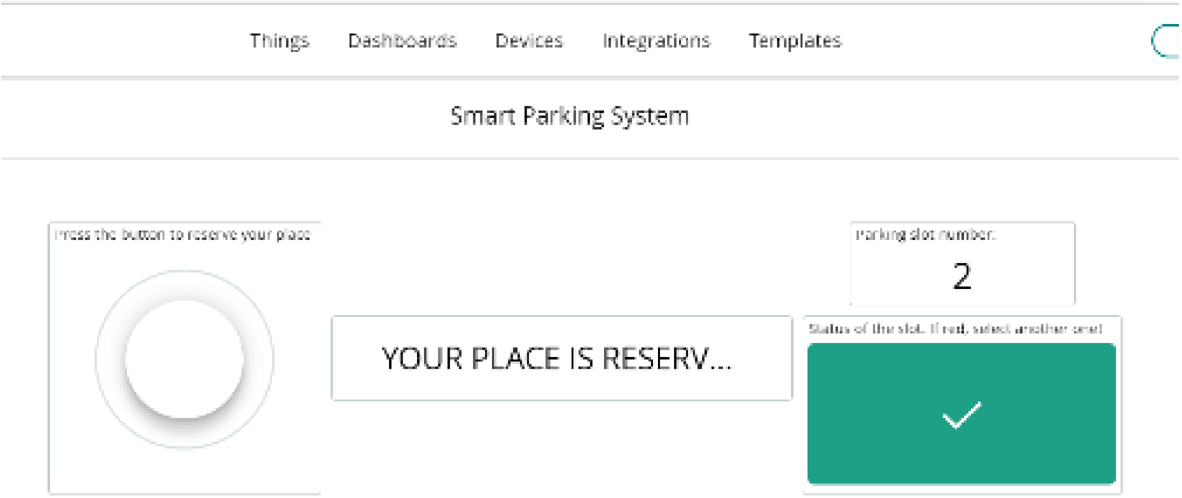


Figure 5.16- Dashboard post reservation (Scenario 1)

While the platform is up, the ultrasonic sensor is again requested to work. During the reservation process the slots around the parking space reserved, can get free or occupied and once again, it is important to verify that the marks on the ground are being respected. As an example, if a driver is parking his car in front or behind the place reserved and that car is crossing the limits on the ground, the ultrasonics will detect that even and a buzzer will give a permanent alert. The alert is received by the driver that parked it wrong and like this, he can go to repark the car correctly this time. The buzzer alert will stop when marks are being respected. Figure 5.17 illustrates the situation of reserving, when the platform number two is up and where the red waves are indicating that the ultrasonic sensors are working all the time, until the user arrive to the slot.

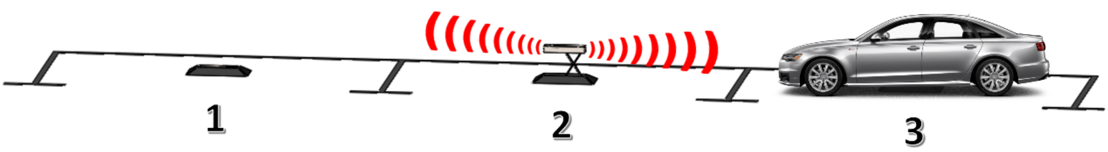


Figure 5.17- Parking Slot post reservation (Scenario 1)

To conclude the reservation, once the driver arrives at the place, he has to press the button again, so the platform can go down and he can park the car.

- 2nd scenario

The second scenario is happening when the parking place is also free. The dashboard is demonstrating exactly the same as the scenario one, Figure 5.14. As the place looks available, the user can try to reserve the place. When the user presses the button, the platform is lifting. However, after a few seconds the platform is going back to the down position. This is happening because on the field, the scenario is like the one represented on the image below (Figure 5.18).

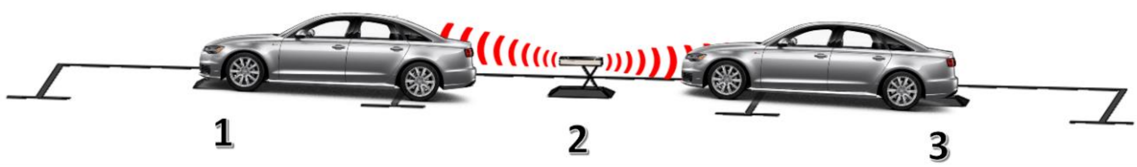


Figure 5.18- Parking Slot (Scenario 2)

Checking the image above, it is clear that the user trying to reserve the place number two, will not have enough space to park his car. Even if the magnetometer read the values well and apparently the place was free, the ultrasonic sensors found out that the cars in front and back were not respecting the limits of their place. The dashboard is going to show this place as unavailable (check Figure 5.19).

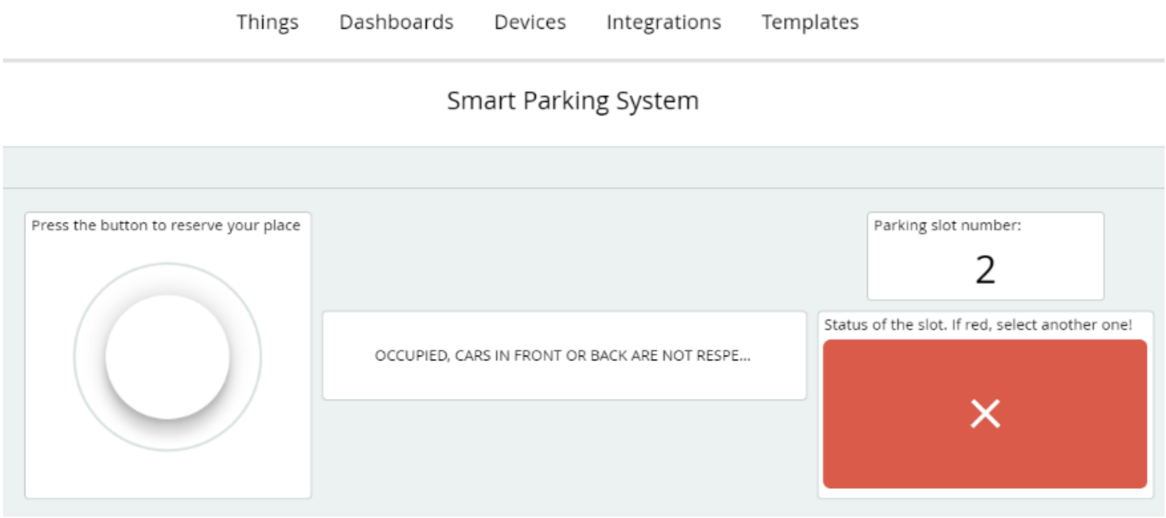


Figure 5.19- Dashboard post reservation (Scenario 2)

- 3rd scenario

On the field is happening what the Figure 5.20 is showing.

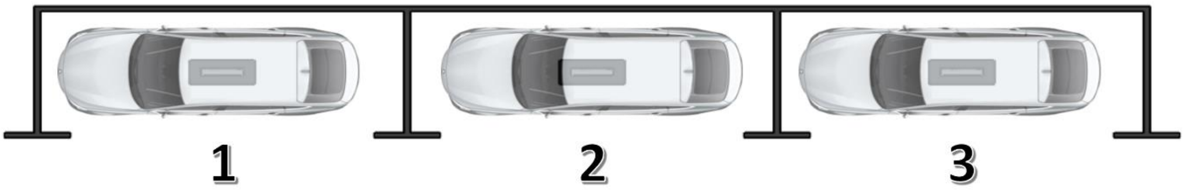


Figure 5.20- Parking Slot (Scenario 3)

The dashboard is indicating that the wanted place is occupied, as shown on Figure 5.21.

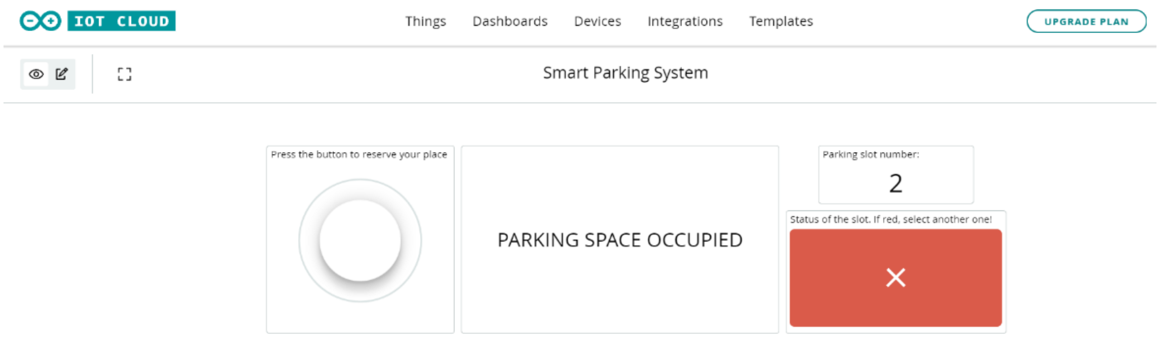


Figure 5.21- Dashboard post reservation (Scenario 3)

In this scenario, the only option left is to select another place, one that is free to reserve.

6. DISCUSSION

During the project idea presented, different choices were made that could result in some disagreement. Some topics that are still open to discussion are given below.

The way of supplying the prototype studied was made through a battery of 18V. Is this the best way of supplying various platforms on the same street? If so, the batteries have to be changed periodically. It is not easier to use transformers of 18V and to supply them with the national power grid?

One of the points that can be added to discussion is the way of connecting the nano boards to the internet. Which Wi-Fi network is responsible for providing the signal to the nano boards? Is it public? Which kind of routers should be used for the signal to get in the boards with enough power to work perfectly, without delays?

In relation to what is happening with the platform and with some built-in components, there are two topics still open.

First, the prototype generated uses a buzzer to give sound alerts to some potential constraints that can happen during the process of reserving a parking space. Is not better to use a speaker that could explain to the drivers what are they doing wrong?

Second, still within the platform components, the magnetometer used is a basic one. There are multiple sensors that can assume the functions of the one used. Which one is the best for the project? Which one is offering the best accuracy?

7. CONCLUSION

7.1. Accomplishments

The strategy of developing this research was to separate the project in three main systems. One raw shape of each subsystem was successfully achieved. The mechanical system, created using Solidworks Software, was meant to correspond to all the requirements expressed alongside the project. In the platform generated are found all the chosen hardware components. Last but not least, the software system, where the users are able to control the platform via WI-FI. All the mentioned steps were successfully achieved and constitute the initial stage of a system that is meant to facilitate the process of finding an available parking slot within a limited period of time.

The project led to a parking system prototype, where all the objectives have been accomplished. The research shows the potential that a product like this has if implemented in the market, with opening to a wide range of places all around the crowded cities. The target market, mainly focused on the city councils, is the key for a better management and logistics of the parking places.

The studies on this product may be continued in terms of costs and production process and so developing the complete methodology of creating it.

7.2. Future work

The project is still an idea and so, there are many parts to be improved so that this project can be implemented in the market.

The first improvement to be made is on the mechanical system. It is crucial to create parts that can be manufactured easily and affordably. Solidworks is presenting us various tools, where, from a sheet metal it is possible to generate some of the complex parts that have been designed.

The most challenging part to accomplish will be the creation of a mobile application with an amplitude big enough to make the bridge between software, hardware and all the customers. Each user will have an account in the future where they will be able to fund it. Different options of reservations will be added on the app, so the users can choose the most suitable for them. Another important tool of this mobile application is to provide directions to the destination (slot reserved) using the API of google maps. Without forgetting that this project must help not only the drivers, but also the city councils, concerning issues of parking slots logistics, the app will have to provide data regarding the occupancy of the slots around the city, during different moments of the day.

Last but not least, the product has to go under a deep business analysis where it must be estimated the price of the whole product and also a forecast of the sales volume to verify if it can be a profitable product or not.

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I) MECHANICAL PROPERTIES OF ALLOY 316L

Mechanical Properties

At Room Temperature

	Typical*	ASTM	
		Type 316	Type 316L
0.2% Offset Yield Strength, ksi	44	30 min.	25 min.
Ultimate Tensile Strength, ksi	85	75 min.	70 min.
Elongation in 2 inches, %	56	40 min.	40 min.
Reduction in Area, %	69	—	—
Hardness, Rockwell B	81	95 max.	95 max.

**0.375 inch plate*

Corrosion Resistance

ALLOY	Composition (Weight Percent) Cr	Mo	N	PRE_N[1]	CCT[2] °F (°C)	CPT[3] °F (°C)
Type 304	18.0	—	0.06	19.0	<27.5 (<-2.5)	— —
Type 316	16.5	2.1	0.05	24.2	27.5 (-2.5)	59 (15.0)
Type 317	18.5	3.1	0.06	29.7	35.0 (1.7)	66 (18.9)
SSC-6MO	20.5	6.2	0.22	44.5	110 (43.0)	149 (65)

[1] *Pitting Resistance Equivalent, including Nitrogen, PREN = Cr + 3.3Mo + 16N*
[2] *Critical Crevice Corrosion Temperature, CCCT, based on ASTM G-48B (6% $FeCl_3$ for 72 hr, with crevices*
[3] *Critical Pitting Temperature, CPT, based on ASTM G-48A (6% $FeCl_3$ for 72 hr)*