LAST INSTALLMENT - MECHATRONICS DESIGN

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SUMMARY

The following will represent the progress with respect to the line cleaner bot robot project, which will present the different stages that were obtained for this last delivery, making a brief introduction to the previous state of the project, the gradual progress that had the robot with respect to the creation and design, demonstrate the tests assemblies and fabrications made for this project, in addition to evaluating the required and desired performance for the robot, using the analysis of QF and cost of value, where we will see the process from the initial concepts proposed by each of the students, to the population of concepts which is had thanks to the necessary matrices for proper implementation, in addition to analyzing the regulations for the design identifying what is the age we're in the most relevant way with respect to our project, all this from a detailed point of view and making a proposal for redesign that goes in favor with the environment, also present the report of our development and progress of our project to date. We will include extensive discussions on what has been done lately, explain the tools we have used, the difficulties we have encountered, and finally commenting on the experience we have lived as coworkers in the mechatronic design course at the Universidad Autónoma de Occidente.

INTRODUCTION

Over the years robotics has begun to be implemented in various fields due to the efficiency and effectiveness with which they perform the tasks that are imposed on a robot, robotics daily faces new challenges and challenges, where advances of all kinds occur, this time a mobile robot is developed fsinceleaning lines of brick dust tennis courts, snce these courts require specific maintenance and cleaning.

Thanks to the research carried out in the design area, we followed a planning route, which went from the needs of the robot to the functof thety and design for the device to take part ofinhe tasks of the maintenance staff, so the robot will take the work of cleaning the lines, since this task is the most time consuming of all and therefore is the one that is most exposed to the sun and dust, In addition, the surface material may have crystalline silica and inhaling it can generate silicosis which is a lung disease caused by inflammation and scarring of the lung, for example the particles of clay or brick dust can trigger these lung problems, also can also cause diseases such as asbestosis, pneumoconiosis, byssinosis, occupational asthma, among others.

PROBLEM STATEMENT:

In tennis, the different tennis courts such as: grass, cement and brick dust, specifically this third that of brick dust are the most used in this discipline, this court is made up of clay or brick dust and is characterized by a game slow since the ball loses speed when it hits the surface, players tend to prefer this type of court due to the ease of sliding during the game to reach the ball, this type of terrain requires moderate maintenance, since it has to be watered on average four times a day, in addition to cleaning the lines that demarcate the playing area due to the constant skidding of the players, because they fill with brick dust, due to the constant movement of the tennis players on the playing field, making them hardly visible to the players or the game referee, so they must be cleaned at most every 3 games (games) during the tennis match or a recreational game, this affects the experience of user of the players and also increases the workload of the person in charge of maintaining the tennis courts.

Illustration 1: Worker cleaning tennis lines from brick dust

The need to keep tennis court lines clean becomes evident as tennis players need to have a ready and visible playing environment to be able to make the relevant annotations, as well as validate or invalidate a point, which implies that staff of the institutions that own tennis courts carry out a monotonous and respective exercise due to the constant maintenance of cleanliness in the lines that demarcate the playing area, which can have repercussions such as excessive fatigue and respiratory health problems, in addition to consuming a considerable amount of time when it comes to cleaning the lines that delimit the tennis court.

Illustration 2: Comparison of the lines of clay tennis courts (Dirty lines and clean lines

The exponential development of technology has shown us that an autonomous process model can be implemented for any type of repetitive work, increasing its efficiency and effectiveness. In the current context related to field tennis, there are some indirect factors that affect the quality of the game, the well-being of the st,aff of the institutions that own tennis courts ,and the satisfaction of the users, in this case the tennis players, with everything mentioned, it is planned to create a device capable of cleaning the lines of the tennis court, improving in several aspects such as the reduction of personnel cleaning the lines of the tennis courts, cost reduction, greater performance in the cleaning aspect, reduce health risks in the boleros, which are the most appropriate personnel for this type of cleaning, in addition, the use of time is generated so that these people can take care of other tasks in the institutions.

JUSTIFICATION

Unlike other sports, tennis can be played on different types of surfaces such as clay, brick dust, grass and asphalt, the change in surface affects both the speed of movement of the players as the bounce of the ball. Of these terrains, clay or brick dust stands out for being one of the most used for this discipline because it allows the player to make various movemmakeon the court, the ball bounce is slower, and thanks to the type of terrain makes it possible to observe the location of the ball falling on the court, this is feasible due to the correct maintenance of the court.

Currently, for the conservation and preparation of the playing field it is a tedious process due to the movements of the players that remove the clay and cover the white lines that delimit the playing area, before each game the field must be in optimal conditions and ready for the next matchup.

The people in charge of maintaining the brick dust tennis court, better known as "boleros" or "caddies", carry out this action using conventional brooms or cylindrical brushes to remove the dust that is on the lines of the tennis courts being exposed to prolonged daily sun exposure, generating adverse effects due to solar overexposure and ultraviolet radiation, thus resulting in consequences of many alterations like phothetoaging, photocarcinogenesis, pityriasis alba, pityriasis versicolor, acne, benign tumors in skin, skin cancer. According to a survey carried out by the skin care dermatology group in Medellín, a random sample of 164 caddies was taken, where 106 of these are golf and 58 tennis, it is shown that all tennis caddies have suffered some affectation by the high sun exposure during their working day being 35.3% of the sample.

Caddies, in addition to being exposed to the sun, are also exposed to large amounts of dust that can cause respiratory diseases, since the court material is clay or brick dust, which has crystalline silica and can cause lung diseases such as silicosis (chronic, accelerated or acute), fibrosis, COPD, even lung cancer, in addition to the great effort put into cleaning the court, which has dimensions of (23.76m X 10.97m), a tennis assistant usually takes around 10 min and 15 min cleaning the lines of a single tennis court.

Considering

that the main owners of tennis courts are private entities that profit from the rental and use of these courts, achieving time optimization and at the same time protecting their workers from possible health risks is beneficial and timely for institutions. such as universities, colleges, parks, country clubs, private owners among others; For this reason, the need to create a device capable of performing this task arose. One of the members of the project perceived this problem because he works part-time at the CLUB CAMPESTRE DE CALI, which has more than 30 fields that are occupied daily. by the members of the club, who must be in constant maintenance, for this reason the idea of creating a robot that cleans the lines of the tennis court turns out to be novel.

According to our investigations carried out in the current context, there is a lack of devices that perform this specific function of cleaning the lines of tennis courts, there are similar devices that are related to some characteristic of the device proposed in this project, of which is the (NISSAN PITCH R) that paints lines delimiting the playing area in soccer, is characterized by painting a field anywhere, another device is the (Tenni Bot) this uses artificial intelligence to detect tennis balls and pick them up autonomously.

This project seeks to create a device that enters the maintenance ecosystem of brick dust tennis courts, to support the work of bowlers using collaborative engineering integrating human-machine functionality and thus obtaining beneficial results in the health area. , time and discipline on the clay tennis courts.

OBJETIVES

GENERAL OBJETIVE

To develop a prototype mobile robot for cleaning the lines of brick dust tennis courts.

SPECIFICS OBJETIVES

● Identify the variables and field conditions for the design and implementation of the prototype line cleaner robot for brick dust tennis courts.

● Design a mobile robot that cleans the lines of the brick dust tennis courts.

● Build the prototype of the mobile robot designed

● Validate the operation of the prototype built in situ (on site).

In this case, a segmentation of the target market of Cali - Colombia is carried out where the target population is tennis players or people who practice this sport, so this leads us to investigate the different existing tennis clubs in the city of Cali.

Illustration 3: Potential customers

QFD I AND DESCRIPTION OF THE CONCEPT

The QFD I is carried out to know the needs of the client and how they can be satisfied, since the information collected through surveys and field work, data could be taken and analysis of all the aspects expressed by the workers, the entire process of the development of QFD I is attached to this document as Annex 1

REVERSE ENGINEERING AND FUNCTIONAL ANALYSIS

All the different options to improve in the "line cleaner bot" product were considered the process of its functionality regarding cleaning the line, and how it would be marketed, therefore the redesign proposal must be an attractive and that fulfills its main functionality.

With the functional analysis, it was observed which were the procedures carried out at the beginning of the processes, development and completion, and how these had to be fulfilled.

In reverse engineering it was estimated:

- The robot needs to be fast when making its movements, so its size is a problem that must be solved to gain time in those movements.
- The traction on the tires plays a super important role in the robot, because it needs to be a great traction so that the competitors do not sweep the robot.
- The robot must meet a minimum weight, since if it is over 500g it will be disqualified, but if it is much below that, it will be a shaky robot compared to other competitors.
- The robot must be autonomous, so it is expected to make the most accurate movements when competing, all this based on the information received by the sensors.

All this reverse engineering and functional analysis are in their respective annexes.

DESIGN FOR MANUFACTURING AND ASSEMBLY

The assembly time of the robot "line cleaner bot" is approximately four minutes and fifty-seven seconds, so estimating the great production of this is a good time in the execution of actions in its composition. Therefore, the optics and things that should be improved in this assembly process are evident. (See corresponding link of annex)

The aspects that they do well are:

- The assembly is done intuitively starting with the bottom part
- The assembly has a stable base and is easy to manipulate.
- The pieces are designed to be intuitive
- Assembly of a single circuit board with easy electrical installation
- Assembly speed is relatively fast

The aspects that need to be improved are:

- The robot's casing is assembled with the use of glues, becoming annoying or tedious for users
- Multiple screws and nails are used, eliminating or hindering the disarmament process.
- The circuit assembly is mostly on a breadboard.
- Multiple connections that generate your reading difficulty.
- Openings between the circuit and the brush causing it to be damaged by external objects
- The tires do not match the appropriate dimensions of the robot, being easily overcome by external obstacles.

FMEA

FMEA is a risk mitigation tool used to identify, prioritize, and alleviate potential failures of a system, design or process before they reach the consumer.

In the design process, FMEA was used to identify potential failures and device fittings by performing the assembly of the device, analyzing the disassembly time of the robot, identifying the construction process and making the assembly tree, in addition to the actual time estimation table. Thanks to all this information to identify the aspects that are done well, as now the failures in the line cleaner bot can be presented at any time, given the concerns that can occur and the consequences of these in the circumstances of exposure that occur both internal and external, an FMEA is developed to know the possible failures that may occur, the tables are in annexes.

DESIGN FOR THE ENVIRONMENT

Through the environmental concerns that can be made in the production of the "line cleaner bot", environmental considerations are implemented where the stages of the life cycle will be considered as resource extraction, product manufacturing, packaging, product use, recycling and disposal where they are related between all in material selection, energy consumption, solid waste, liquid waste and gaseous waste, these parameters are analyzed in such a way that they are quantified in the possible consequences that will cause. The carbon footprint is defined as the amount of greenhouse gases emitted into the atmosphere derived from the activities of production or consumption of goods and services of human beings, varying its scope, from a simplistic view that considers only direct emissions of CO2, to other more complex, associated with the full life cycle of greenhouse gas emissions, including the processing of raw materials and the final destination of the product and its respective packaging. The carbon footprint is intended to reduce all these consequences, which is why it is vitally important to take environmental considerations into account and to improve its design..(look table in annex correspondent)

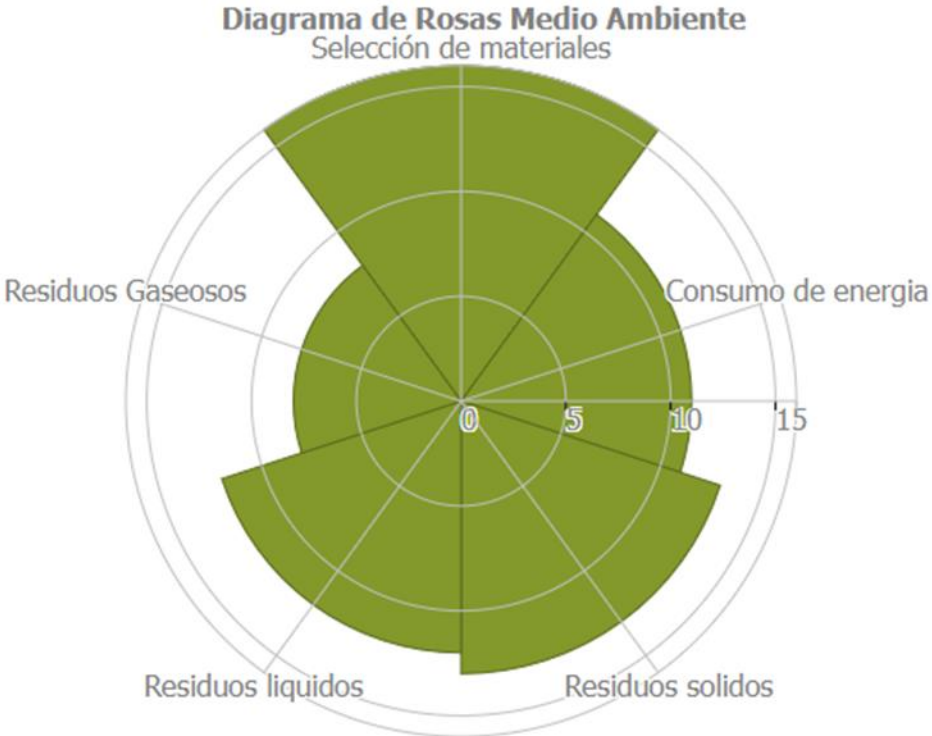

Illustration 4: Rose diagram

QFD 2 AND COST-VALUE ANALYSIS

Thanks to QFD II it was possible to identify the subsystems of the robot and observe how they are related with respect to the metrics, thus reflecting the importance of each subsystem for the robot, being the positioning control with the greatest weight for the line cleaner bot, followed by the brush movement control.

For this case, the positioning control subsystem will be used to perform a more specific study, comparing general metrics of the robot with the subsystem metrics, and thus identify which has greater importance or is more relevant to the operation of the positioning control.

Performing the comparison of the metrics, it was identified that the performance of the CPU (central processing unit) is the most important for the operation of the positioning control subsystem, in addition to the encoder accuracy metric and the effective range metric which is the distance range of the CPU and the robot is not a conflicting factor.
Once the general metrics were analyzed with the subsystem metrics, we proceeded to analyze which components of the positioning control were being affected by the subsystem metrics. This makes sense given that the computer is the central processing unit of the positioning control system. (look table in anexo corresponding)

Illustration 5: QFD COST-WORTH DIAGRAM

The pertinent calculations were made for each of the subsystems in order to perform the cost-value analysis and see the weight of each subsystem with respect to its price, in order to place it in the worth diagram graph, and observe the differences between costs in each of the subsystems, thus analyzing what could unbalance or what changes could be made to improve the cost-value analysis and make everything more balanced, with the purpose of providing a good product to the final customer.

SELECTION OF CONCEPTS

For the selection of concepts, each member of the group proposed to capture the ideas in sketches of how the creation of the line cleaner bot v2 was planned, taking as a reference the prototype of the line cleaner bot v1, the ideas captured by the members of the group are shown below.

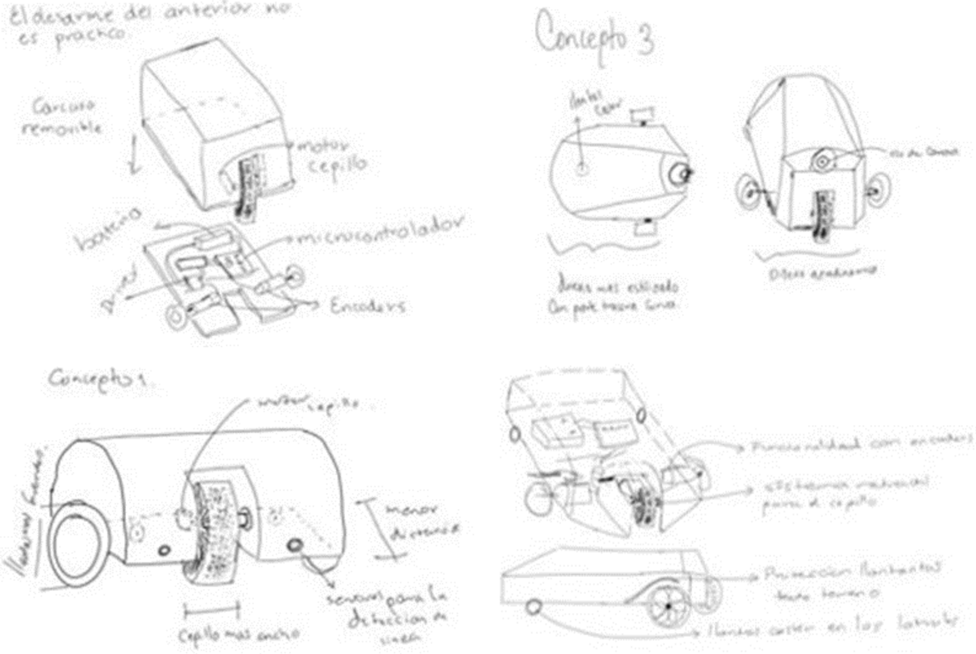

Illustration 6: New concepts

Once the concepts were developed by each of the group members, we proceeded to make a screening matrix, which helped us to know more deeply which concept was going to be the most appropriate to take it as a guide and improve it little by little, in the screening matrix we were able to qualify in a certain way the four concepts generated by the group students, so we can see the table below. (Look table in annex corresponding)

In this table we can see the evaluation of the four concepts with the selection criteria proposed for the desired robot, these concepts were evaluated with a negative, zero or positive, to validate whether they meet the selection criteria with respect to the reference robot which was the line cleaner bot v1.

Once made the screening matrix for the selection of motion and line tracking in addition to identifying which concept will be more convenient if combine them to create a better version of themselves, for the Line Recognition in the group was raised 3 main ideas for implementation in our robot, so another screening matrix was made for the selection of components that emphasize the idea of working on the robot, that is to say with the color sensor component its operation is that when it detects the white color of the line the brush subsystem actions its operation to clean the line, when we refer to the esp32 cam it is about Recognition and segmentation of line for the execution of the brush operation, and for the encoders it is about a system programmed in the robot in which when it passes through the line, it activates the brush system.

Once the 2 screening matrices were done, in the first one where we were able to identify that the concepts could be combined to improve and create a better version of themselves, it was identified that concept one should be combined with concept 2 and concept 3 with concept 4, and thanks to the second screening matrix we were able to identify that the encoder system would not continue and therefore both the color sensor and the camera sensor would be combined with the concepts previously identified in the screening matrix.

Illustration 7: combination of concepts

Here we can see the combination 1 and 2 with the implementation with the sensors that emerged in the screening matrix 2, i.e. combination 1, which is the combination of concept 1 and 2, the color sensor system was incorporated and combination 2, which is the combination of concept 3 and 4, the camera system was incorporated

			Line Cleaner Bot V1					
	Criterios de selección	POND %	Nota	Criterio ponderado	Nota	Criterio ponderado	Nota	Criterio ponderado
1	Facilidad de limpiar lineas	0,15	3	0,45	4	0,6	3	0,45
2	Bajos costos	0,11	3	0,33	3	0,33	4	0,44
3	sistema de deteccion o seguimiento de linea	0,12	3	0,36	4	0,48	3	0,36
4	diseño campacto	0,13	3	0,39	4	0,52	3	0,39
5	evacion de obstaculos	0,09	3	0,27	3	0,27	4	0,36
6	reduccion de tiempo	0,11	3	0,33	4	0,44	3	0,33
7	optimo desplazamiento	0,09	3	0,27	4	0,36	4	0,36
8	Falicilidad de emsable y mantenimiento	0,2	3	0,6	5	1	3	0,6
	Positivos	1		3		4		3,29

Illustration 8: Validation matrix

Once the relevant combinations were made thanks to the results of the screening matrix, we proceeded to create the evaluation of concepts and analyze which concept was the most appropriate, from this table we can see that combination 1 with the color sensor had a higher score than combination 2, i.e., taking as a reference the line cleaner bot v1, combination 1 emerged from the screening matrix was the winner with a score of 4 while combination 2 had a score of 3.29. Thanks to this, it was possible to identify which components and which operation was the most suitable for the creation of our robot, thanks to the identification of the positive and negative points with respect to the selection criteria, we proceeded to continue with the design of the robot.

DESIGN GUIDELINES

The identification of the regulations that the line cleaner bot should have were analyzed in their respective function in which is the protection against dust and against splashing water considered for the development of new design concepts.

The first digit will be in protection against dust where it will be persuaded in the level of 5, where dust will be prevented from outside the device, but this should not enter in an amount that interferes with the operation of the device called line cleaner bot.

Primer dígito (IP [X] [ ])

Nivel	Tamaño del objeto entrante	Efectivo contra
0	—	Sin protección
1	<50 mm	El elemento que debe utilizarse para la prueba (esfera de 50 mm de diámetro) no debe llegar a entrar por completo.
2	<12.5 mm	El elemento que debe utilizarse para la prueba (esfera de 12,5 mm de diámetro) no debe llegar a entrar por completo.
3	<2.5 mm	El elemento que debe utilizarse para la prueba (esfera de 2,5 mm de diámetro) no debe entrar en lo más mínimo.
4	<1 mm	El elemento que debe utilizarse para la prueba (esfera de 1 mm de diámetro) no debe entrar en lo más mínimo.
5	Protección contra polvo	La entrada de polvo no puede evitarse, pero el mismo no debe entrar en una cantidad tal que interfiera con el correcto funcionamiento del equipamiento.
6	Protección completa contra polvo	El polvo no entra bajo ninguna circunstancia.

The second digit will be against dripping water where it will be persuaded in the level of 2, where it is protection against dripping water avoiding it from outside the device, but this should not enter in an amount that interferes in the operation of the device called line cleaner bot and other regulations given in the information of results in the following illustration.

Segundo dígito (IP [ ] [x])

Nivel	Protección frente a	Método de prueba	Resultados
0	Sin protección.	Ninguno	El agua entrará en el equipamiento en poco tiempo.
1	Goteo de agua	Se coloca el equipamiento en su lugar de trabajo habitual.	No debe entrar el agua cuando se la deja caer, desde 200 mm de altura respecto del equipo, durante 10 minutos (a razón de 3-5 mm³ por minuto)
2	Goteo de agua	Se coloca el equipamiento en su lugar de trabajo habitual.	No debe entrar el agua cuando se la deja caer, durante 10 minutos (a razón de 3-5 mm³ por minuto). Dicha prueba se realizará cuatro veces a razón de una por cada giro de 15° tanto en sentido vertical como horizontal, partiendo cada vez de la posición normal de trabajo.
3	Agua nebulizada. (spray)	Se coloca el equipamiento en su lugar de trabajo habitual.	No debe entrar el agua nebulizada en un ángulo de hasta 60° a derecha e izquierda de la vertical a un promedio de 11 litros por minuto y a una presión de 80-100 kN/m² durante un tiempo que no sea menor a 5 minutos.
4	Chorros de agua	Se coloca el equipamiento en su lugar de trabajo habitual.	No debe entrar el agua arrojada desde cualquier ángulo a un promedio de 10 litros por minuto y a una presión de 80-100 kN/m² durante un tiempo que no sea menor a 5 minutos.
5	Chorros de agua.	Se coloca el equipamiento en su lugar de trabajo habitual.	No debe entrar el agua arrojada a chorro (desde cualquier ángulo) por medio de una boquilla de 6,3 mm de diámetro, a un promedio de 12,5 litros por minuto y a una presión de 30 kN/m² durante un tiempo que no sea menor a 3 minutos y a una distancia no menor de 3 metros.

Therefore, the standards to be met are IP [5][2] stipulated against dust and dripping.

In order to have a standard against impacts it is decided to raise it with the following standards of the standard

TABLA DE DIMENSIONES DE ELEMENTOS DE IMPACTO EN 60068-2-75

CÓDIGO IK	IK00	IK01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	IK10	IK10+
Energía de impacto (julios)	*	0.14	0.20	0.35	0.50	0.70	1.00	2.00	5.00	10.00	20.00	50.00
Alturas de caída (mm)	*	56	80	140	200	280	400	400	300	200	400	500
Masa (kg)	*	0.25	0.25	0.25	0.25	0.25	0.25	0.50	1.70	5.00	5.00	10.00
Material	*	P[1]	P[1]	P[1]	P[1]	P[1]	P[1]	S[2]	S[2]	S[2]	S[2]	S[2]
R (mm)	*	10	10	10	10	10	10	25	25	50	50	50
D (mm)	*	18.5	18.5	18.5	18.5	18.5	18.5	35	60	80	100	125
f (mm)	*	6.2	6.2	6.2	6.2	6.2	6.2	7	10	20	20	25
r (mm)	*	-	-	-	-	-	-	-	6	-	10	17
l (mm)	*	Debe adaptarse a la masa correspondiente										
Martillo de péndulo	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Martillo de resorte	*	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Martillo de caída libre	*	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Especificaciones de la norma EN 60068-2-75
* no protegido por la norma
1.Poliamida 85 ≤ HRR ≤100 dureza Rockwell según ISO 2039/2
2.Acero Fe 490-2 según ISO 1052, dureza Rockwell HRE 80...85 según ISO 6508

Interelectronix e.K. UNE EN IEC 62262 IK Grado de protección al impacto. Retrieved October 13, 2020, from Interelectronix.com website: https://www.interelectronix.com/es/en-62262-ik-grado-de-proteccion-al-impacto.html

Illustration 9: Impact elements

It is proposed to have an IK05 standard that helps to protect the entire structure of the robot's operation, such as the circuits and communication systems.

SELECTION OF ACTUATORS AND INSTRUMENTATION

In the selection of the actuators, a selection was made for the wheels of the motor that had encoders as sensors because the path of the robot will be carried out depending on the data of the encoders analyzed to give its execution.

Illustration 10: Actuator selection (Motor)

In the part of the brush, a motor that had a gearbox was selected because it would generate more torque so that the state of dust removal was efficient.

Illustration 11: Actuator selection (brush motor)

Finally, a rgb color sensor would be chosen because it stays on the line and cleans what is properly the line to be cleaned and does not clean another non-profiled area.

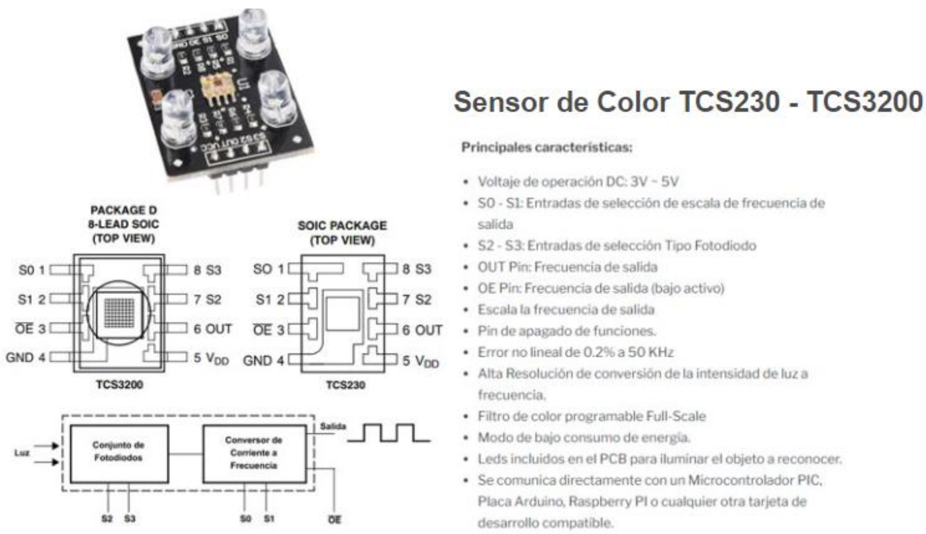

Illustration 12: Actuator selection (color sensor)

This is because the following requirements were met:

- High precision and easy handling
- Low battery consumption

And your due choices:

- The inputs can be controlled from an Arduino digital output or other control board.
- Converts the measured light intensity into frequency.
- The frequency can be interpreted either through current or from the same frequency for the average evaluation of the colors, generating a simple conversion and reading function.
- The module accepts a 3-to-5-volt supply.

SYSTEMS INTEGRATION

For the operation of the line cleaner bot is seen first activate the switch of the device so that the Arduino one begins to perform the processes of communication with the computer, Since the computer is the central control unit and sends the parameters of the tracking of roads, Since the operation of the robot is thanks to the 5 days in quadrature that allows to know the angular positioning of the motor and the tire which allows us to know the total positioning of the device in the area of the game. Next, we can see the schematic for the system integration.

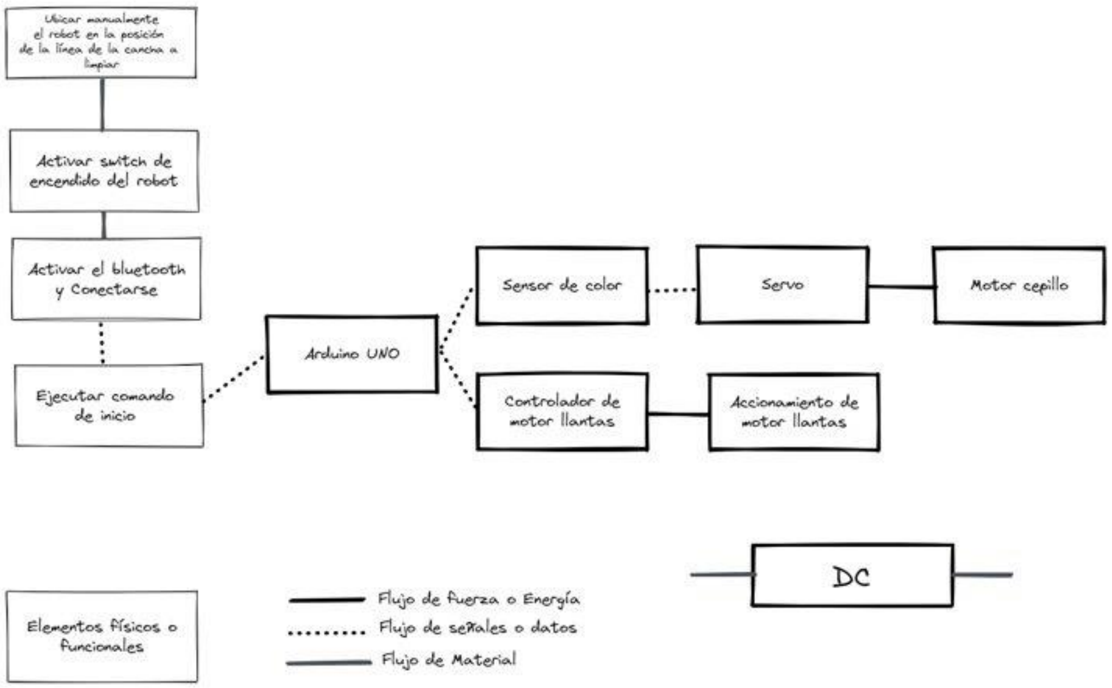

Illustration 13: Operating diagram

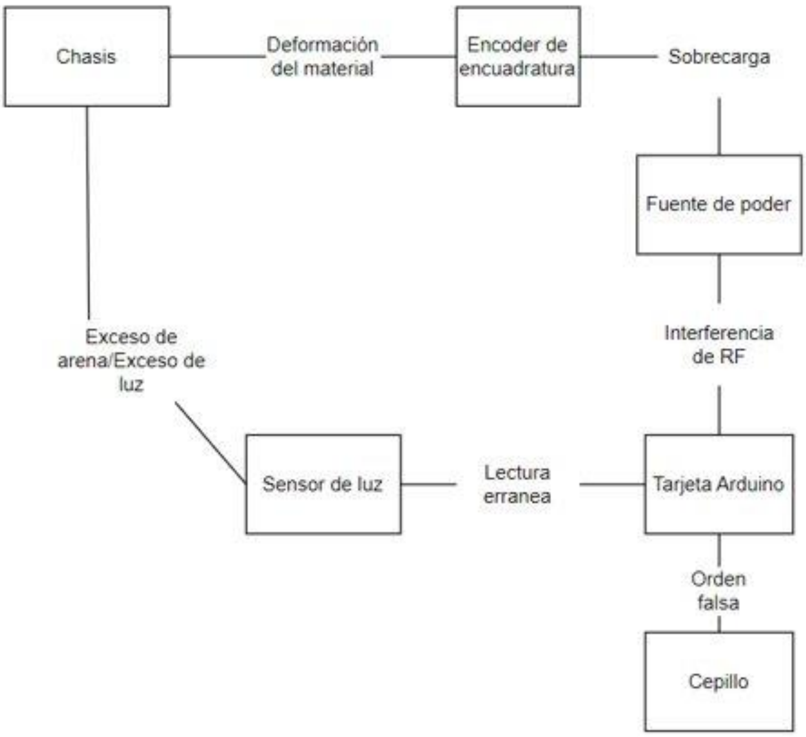

Illustration 14: Operating diagram

WIRING DIAGRAM

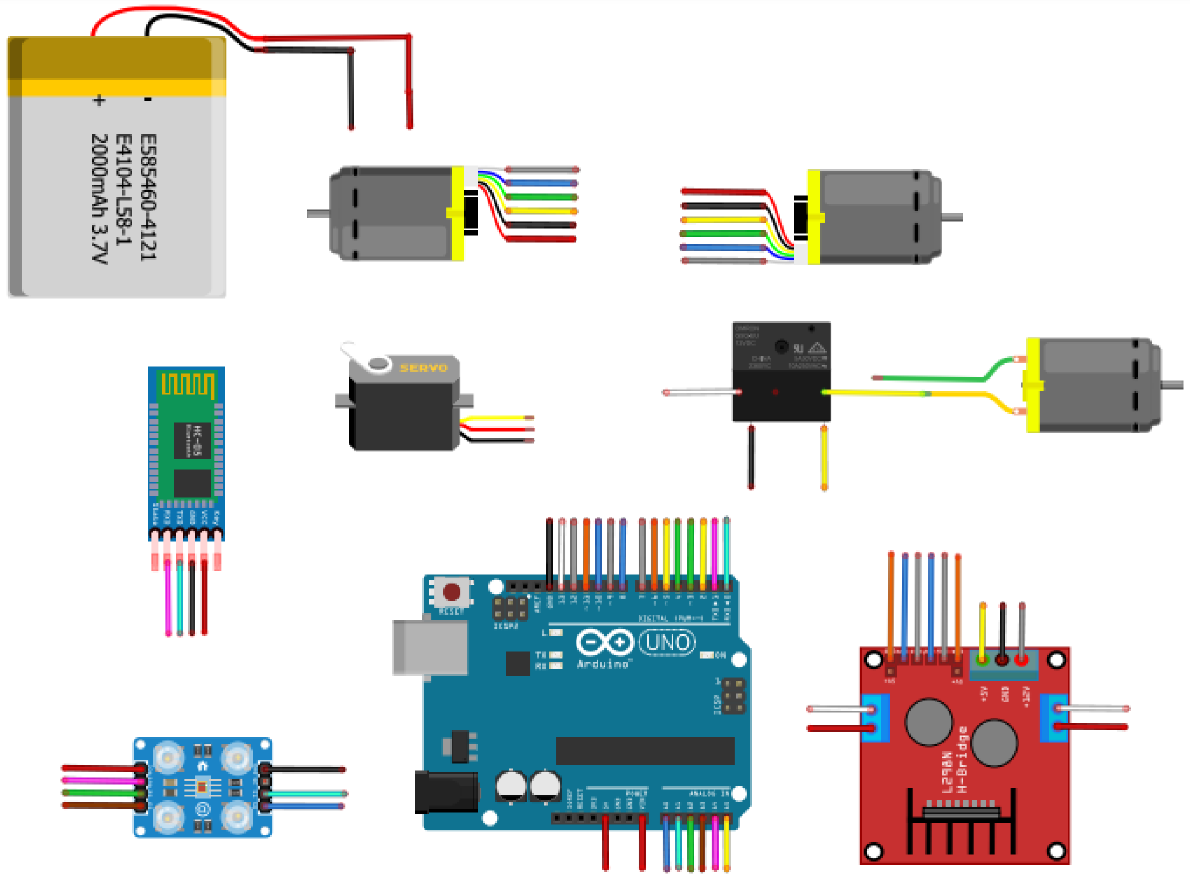

Illustration 15: Wiring diagram

VALIDATION PLAN

At the time of designing the device, some parameters were proposed to be followed, which included the weight or battery, the dimensions of the device, the autonomy, the distance, the strength and the dust removal area. To ensure that we comply with the necessary parameters, we carried out a validation plan in which we measured these characteristics and thus verified that we were complying with the initial purpose, observing the functionality in the work area.

Peso maximo [Kg]		Cumple	
Actual	Esperado	Si	No
2,16	<3	x	
Bateria [minutos]		**Cumple**	
Actual	Esperado	Si	No
<= 60	120		x

Autonomia [minuto]		Cumple	
Actual	Esperado	Si	No
>2	>1	x	
Distancia con seguimiento de computador [m]		**Cumple**	
Actual	Esperado	Si	No
>9,4 m	>8	x	
Distancia sin seguimiento de computador [m]		**Cumple**	
Actual	Esperado	Si	No
>=4,1	>5		x

Ancho [cm]		Cumple	
Actual	Esperado	Si	No
25	25	x	
Largo [cm]		**Cumple**	
Actual	Esperado	Si	No
37,5	37,5	x	
Ancho cepillo [cm]		**Cumple**	
Actual	Esperado	Si	No
6,8	6,8	x	

Fuerza [kg]		Cumple	
Actual	Esperado	Si	No
1,4	4,2		x

Area de remoción de polvo [gramos]		Cumple	
Actual	Esperado	Si	No
<=44 gramos	<20		x

Illustration 16: **Validations**

In the process of validation of the device we were able to identify certain parameters that did not meet the initial metrics, such as the battery which was expected to last 120 minutes, in the tests conducted showed that the robot lasts 60 minutes non-stop operation, also the operation of a device is thanks to the connection between it and a central control unit, which is the one that performs the processing of the tracking of the path and we had defined as an initial parameter for this distance of 5 m, however they surrounded a lower instance of this to function properly, and the other parameter in which it did not meet was the dust removal area here the metric of measurement was the amount of dust removed, and it was identified that it did not see the sufficient amount, although it performed the task correctly and the line is identified in the best way.

In the other expected parameters, it was achieved with the expected, guaranteeing adequate dimensions, autonomy, following distance from the computer, strength, and weight of the robot.

SOCIAL IMPACT

Line cleaner bot will have a good social impact because it will generate many jobs, since inductions will be given in the production, development and maintenance of the same, giving job opportunities to several people; In addition to this, as an innovative product in the area, its application in the economy will be taken as a sample, so it is an economically viable solution and time reduction.

Contributing to the tennis community since the most common factors the forced labor to clean the courts are related to the discomfort in the extremities by having to sweep repeatedly and quickly that the number of courts that are in the sector are greater in such a way the forced labor is still manual. The main occupational health risks related to the forced cleaning work would be:

Repetitive movements.
● Fast sweeping
● High force demands
● Form of awkward postures.
● Number of courts in the sector
● Tedious muscles such as in the arm and leg.

greatly influencing the playing experience as court users do not have to wait for the court fitter to be available but can make immediate use of a "Line cleaner bot" robot.

DEVELOPMENT PROCESS

For the development process of the line cleaner bot began thanks to see the need for the “boleros” in the tennis court making a first prototype based on the principles of design for engineering, which managed to create a device that performs the task of cleaning the lines of brick dust tennis courts by remote control, with respect to the design of the device was something rudimentary and very square with almost no aesthetics, and were key points to create a new redesign in functionality and statics.

For the line cleaner bot version we rethought some engineering design concepts such as QFD, transparent boxes, we were able to identify the specific needs that the device should cover, we performed analysis to version one of our device to identify what kind of improvements we should make, improvements of which are those of manufacturing and assembly, environmental analysis, identification of relevant protections for the design regulations, Selection of actuators all this was taken into account for the redesign creating and taking concept and integrating them to create a better version of the line cleaner bot that served us for the development process of the device, visualizing the main needs of the user and the parameters that met the previous version, analyzing where we should improve, from the operation of the design and the specific needs of the user, performing all these tasks accurately to ensure a good end result.

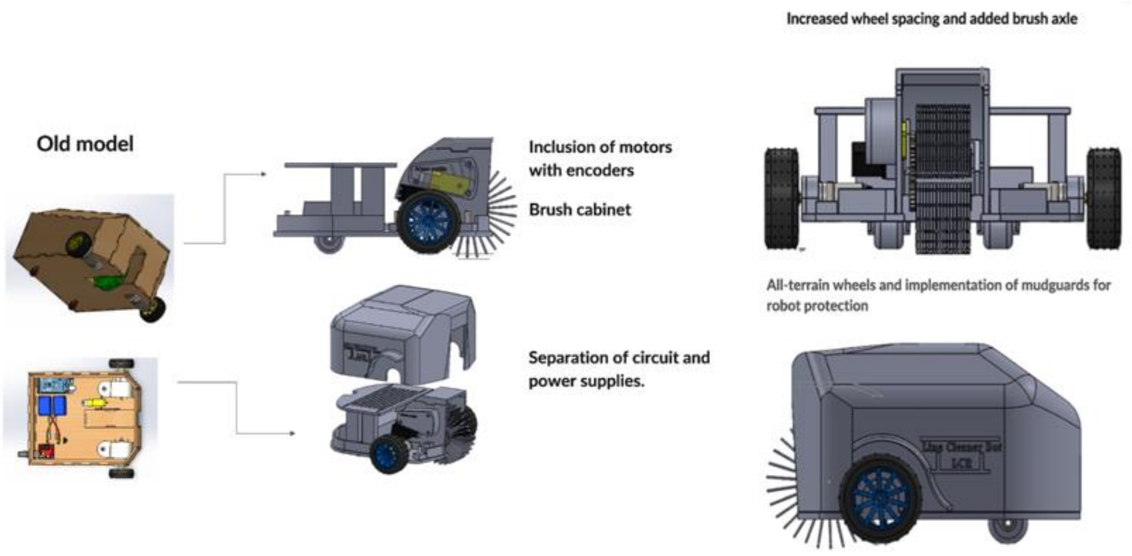

Illustration 17: **Development process**

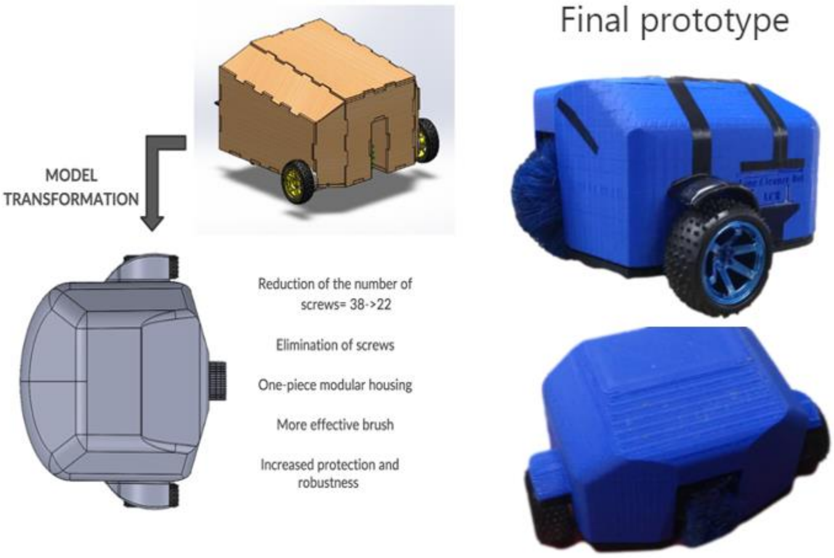

Illustration 18: **Development process**

CONCLUTIONS

- In the screening matrices we were able to identify which components and which functionalities the concept and the final robot should have.

- Thanks to the researched regulations we were able to identify which legal contributions our robot should have now of going to market or working in its area.

- Initially we had version one of the line cleaner bot, which had a remote-control operation via Bluetooth signal, now in the design advances functionality of the robot can implement a viable solution for ro perform tasks in an automated manner without the need for a staff controlling the robot directly in real time.

- With respect to the QFD provided us with information relevant to the metrics and functions of the subsystems of the robot and thus manage to identify the importance of each one managing to weight the operation in the robot and provide a symmetrical work between all its functions so that the robot is as balanced as possible not only in quality but also in their respective prices.

- With the studies carried out, it was possible to identify the environmental impacts in its elaboration and assembly for the creation of the prototype of the robot and thus to know the consequences that it could generate to the environment.

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Annexs

Annex 1 QFD I

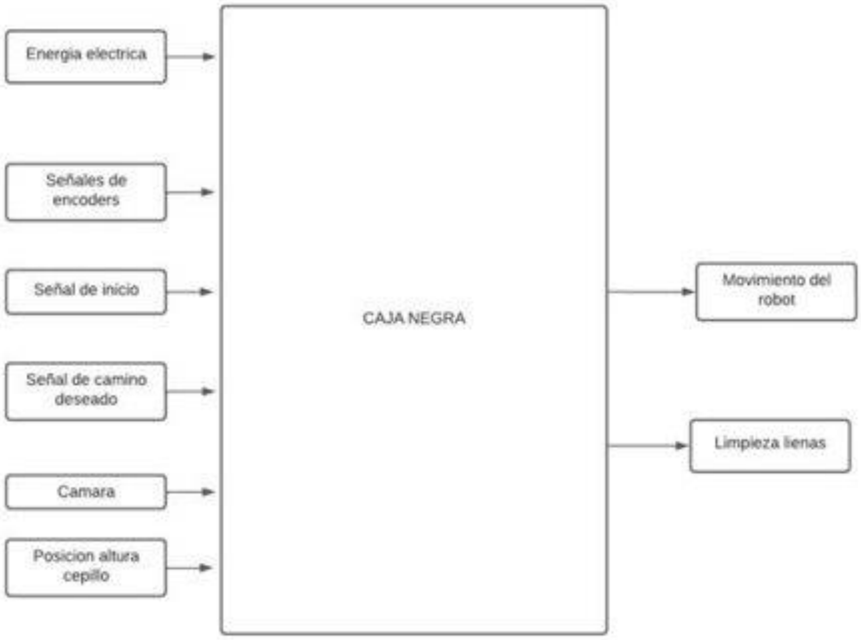
Velocidad dispositivo												
Área de remoción de polvo												
Dimensiones	+	-										
Peso (dispositivo)	+											
Velocidad de remoción de polvo		-		+			***NO INPUT IN THIS AREA***					
Resistencia (polvo y agua)												
Batería	+		-	-								
Tiempo (autonomía)			-	-	+		-					
Costos	-			+	-	+	--	-				
Ruido					-				-			
Distancia (autonomía robot)	+			+			+	+	-			
Capacidad de procesamiento							+		-			
Preferred	1	0	-1	-1	1	0	1	1	-1	-1	1	0

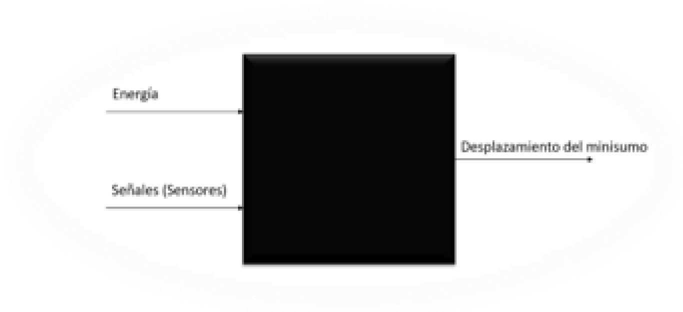
Correlation Codes	
+ +	Very Positive
+	Positive
-	Negative
- -	Very Negative

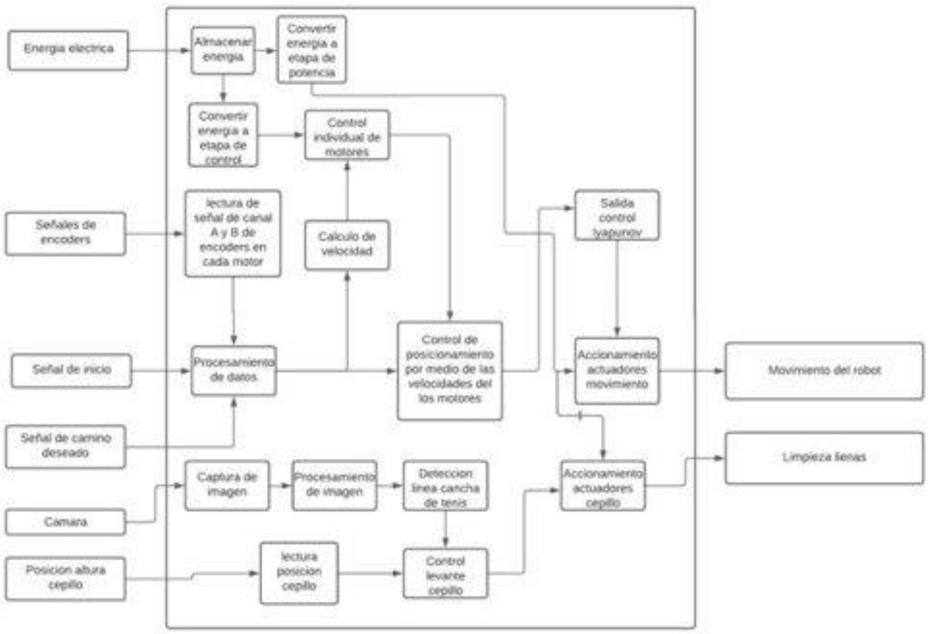
Customer Requirements	Customer Weights	Velocidad dispositivo	Área de remoción de polvo	Dimensiones	Peso (dispositivo)	Velocidad de remoción de polvo	Resistencia (polvo y agua)	Batería	Tiempo (autonomía)	Costos	Ruido	Distancia (autonomía robot)	Capacidad de procesamiento	1 Worse	2	3	4	5 Better
		Engineering Metrics												Customer Perception				
Ser autónomo en la limpieza de lineas	9	3			3	3		9	3			9	9	AD	BC			
Reducir tiempo de limpiado de las canchas	9	3	9			3			9			1		AD	C	B		
Limpiar completamente las lineas de las canchas	9		9					3	3	1				AD				BC
Generar limpieza de Múltiples canchas casi al mismo tiempo	3	9		1	3		3		3	9		1		BC	A	D		
Facilidad de uso	3			1	1							3	1			B	AC	D
Dimensiones compactas para el transporte del producto	1			9	3					3					A	C	B	D
Tener capacidad de trabajar una jornada razonable	3	3				3	3	9				1			CB			AD
El producto debe de ser compacto para el área de trabajo	3			3						1		3			A	C	B	D
Tener una vida útil prolongada	3							1	9	3						A	D	BC
Ubicación espacial al finalizar tarea	9				1					1			9	CB			A	D
Tiene que convivir con la infraestructura y trabajadores	9	1		9		1							3		D	A		BC
Movilizarse a ritmo constante	3	3							3			3					CB	AD
Los costes de inversión y mantenimiento deben ser razonables	3			3						9			3			BA	D	C
No ser muy ruidoso	1										9		1		B	A	DC	
Units		m/s	cm²	cm	Kg	cm²/s	ug/m³	mAh	s	$cop	dB	m	hz					
	Raw score	108	162	114	51	72	18	138	180	87	9	123	202					
	Relative Weight	9%	13%	9%	4%	6%	1%	11%	14%	7%	1%	10%	16%					

	Customer Requirements	Customer Weights	Velocidad dispositivo	Área de remoción de polvo	Dimensiones	Peso (dispositivo)	Velocidad de remoción de polvo	1 Worse	2	3	4	5 Better
			Engineering Metrics					Customer Perception				
1	Ser autónomo en la limpieza de lin	9	3			3	3	AD	BC			
2	Reducir tiempo de limpiado de las	9	3	9			3	AD	C	B		
3	Limpiar completamente las lineas	9		9				AD				BC
4	Generar limpieza de Múltiples canc	3	9		1	3		BC	A	D		
5	Facilidad de uso	3			1	1				B	AC	D
6	Dimensiones compactas para el tr	1			9	3			A	C	B	D
7	Tener capacidad de trabajar una jo	3	3				3		CB			AD
8	El producto debe de ser compacto	3			3				A	C	B	D
9	Tener una vida útil prolongada	3								A	D	BC
10	Ubicación espacial al finalizar tarea	9				1		CB			A	D
11	Tiene que convivir con la infraestru	9	1		9		1		D	A		BC
12	Movilizarse a ritmo constante	3	3								CB	AD
13	Los costes de inversión y mante	3			3					BA	D	C
14	No ser muy ruidoso	1							B	A	DC	
	Units		m/s	cm²	cm	Kg	cm²/s					
	Technical Targets		>=0,3	<25	< 40	< 5	>=15					
	Technical Benchmarking	Our Previous Product	1	20	28	3	10	A: Tenibot				
		Competitor A	0.626	0	65	6	0	b: rodillo manual				
		Competitor B	0,3	35	15	1	15	c: escoba				
		Competitor C	0,3	250	50	0,8	42	d: roomba				
		Competitor D	0,15	16	40	2	18					
		Raw score	108	162	114	51	72					
		Relative Weight	9%	13%	9%	4%	6%					

Annex 2 Functional analysis







Anexo 3 Ingenieria Inversa

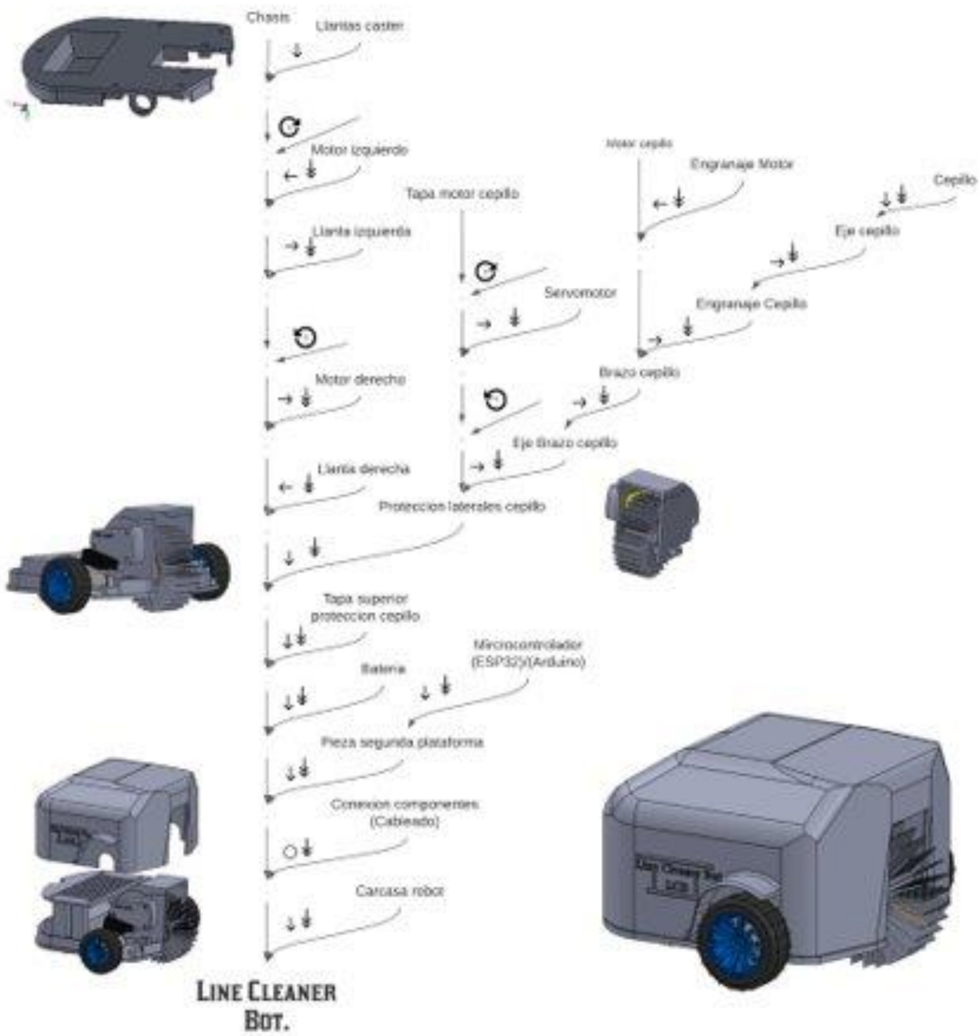
	Ensamble Principal	Sub ensamble de 2do orden	Sub ensamble de 3er orden	Numero de parte / Identificador	Nombre descriptivo	Cantidad	Costo Unitario	Costo total	Función	Dimensiones máximas (L x A x A)	Peso Gramos	Proceso de Manufactura	Acabado / Condición especial
1	Chasis	Transmisión	Rodamiento	1	Rueda	3	12000	36000	Genera el desplazamiento del robot	6,6cm x 6,6cm x 2,6cm	24	impresión 3D, fundición, etc	Totalmente circular
2	Chasis	Estructura	Transmisión	2	Motor	2	20000	40000	Trasmite el torque a la llanta	2,2cm x 1,22cm x 2,85cm	27	Nd	Giro de 360°
3	Carrosería	Cuerpo	Sitema de control	3	Arduino	1	45000	45000	Recibe info y envía ordenes al robot	6,5cm x 0,8cm x 6,8cm	25		
4	Chasis	Sistema eléctrico	Alimentación	4	Batería	1	15000	15000	Energizar al robot	4,85cm, x 2,65cm x 1,75cm	45,6		Voltaje entre 7-9V
5	Chasis	Sistema eléctrico	Cableado	5	Placa de prototipado	1	70000	70000	Conectar todos los componentes del robot				
6	Chasis	Sistema eléctrico	Encendido	6	Botón de incio	1	5000	5000	Controla el paso de la corriente al robot	0,5cm x 0,5cm x 0,5cm	1		
7	Carrosería	Cuerpo	Sistema Electrónico	7	Sensor infrarrojo CNY70	4	17500	70000	Detectar bortes u obstaculos en el suelo	0,7cm x 0,7cm x 0,6cm	5		
8	Carrosería	Cuerpo	Sistema Electrónico	8	Sensor infrarrojo sharp gp2	5	29000	145000	Detectar obstaculos en frente del robot	2,95cm x 1,3cm x 1,35cm	40		
9	Carrosería	Cuerpo	Parachoques frotal	9	Rampa	1	22000	22000	Hacer contacto con el robot oponente	15cm x 11cm x 0,3cm	60	Mecanizado	Resistente y liviano
10	Carrosería	Cuerpo	Base	10	Chapa (aluminio)	2	22000	44000	Sostener los componentes del robot	25cm x 25cm x 0,3cm	140	Mecanizado	Resistente y liviano
11	Carrosería	Sistema electrónico	interfaz	11	Pantalla LCD	1	18000	18000	Comunicar al Usuario información del robot	8,2cm x 3,5cm x 1,8cm	30		
12	Carrosería	Cuerpo	Sujeción	12	Tornillos	1	20000	20000	Fijar los componente al chasis y carrosería		15		

Sistema / Producto:	Robot
Número total de partes en el sistema	23
Número total de partes únicas en el sistema	7
Peso total	412,6
Costo total	530000

Annex 4 Design for manufacture and assembly

		Time Factors (seconds)														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
No.	Part Operation Description	End-to-End Orientation	Rotational Alignment	Part Size	Part Thickness	Insertion Clearance	Insertion Direction	Insertion Conditions	Fastening	Fastening Process	Handling Conditions	Time Each Operation (Top)	Number of Repetitions (Nrep)	Repetition Time (K*L) (Trep)	Insert Part (1 = Yes; 0 = No)	Eliminate Part (1=yes; 0 = No)
1	Chasis	0,8	1,0	0,1	0,2	1,6	0,6			4,0	-	8,3	1,0	8,3	1,0	-
2	Llantas caster	0,8	0,5	0,1	0,1		1,4			1,0	-	3,9	2,0	7,8	1,0	-
3	Tornillo						2,0	1,6			-	3,6	8,0	28,8	0,0	-
4	flip Over							2,3			-	2,3	1,0	2,3	0,0	-
5	Motor izquierdo	0,8	1,0	0,1			0,6		4,0	4,0	-	10,5	1,0	10,5	1,0	-
6	Llanta izquierda	1,8	0,5			1,6			4,0	4,0	-	11,9	1,0	11,9	1,0	-
7	Abrazadera metalica	0,8				1,6				1,0	-	3,4	1,0	3,4	1,0	-
8	Tornillo						2,0	1,6			-	3,6	8,0	28,8	0,0	-
9	Motor derecho	0,8	1,0	0,1		1,6	0,6		4,0	4,0	-	12,1	1,0	12,1	1,0	-
10	Llanta derecha	1,8							4,0	4,0	-	9,8	1,0	9,8	1,0	-
11	Abrazadera metalica		1,5			0,9				1,0	-	3,4	1,0	3,4	1,0	-
12	Tornillo						2,0	1,6			-	3,6	8,0	28,8	0,0	-
13	Pegamento laterales, proteccion cepillo y tapa tracera									11,0	-	11,0	1,0	11,0	0,0	-
14	Tapa lateral derecha	0,8	1,5				1,4			1,0	-	4,7	1,0	4,7	1,0	-
15	Tapa lateral izquierda	0,8	1,5				1,4			1,0	-	4,7	1,0	4,7	1,0	-
16	Tapa tracera	0,8	1,5							11,0	-	13,3	1,0	13,3	1,0	-
17	Tapa proteccion tracera cepillo	0,8	1,5				1,4	2,3	4,0	1,0		11,0	1,0	11,0	1,0	-
18	Pegamento para union de tapas									11,0	-	11,0	1,0	11,0	0,0	-
19	Tapa proteccion izquierda cepillo	0,8	1,5				1,4	2,3	4,0	1,0	-	11,0	1,0	11,0	1,0	-
20	Tapa proteccion derecha cepillo	0,8	1,5	0,4			1,4	2,3		1,0	-	7,4	1,0	7,4	1,0	-
21	Pegamento para tapa frontal, delantera, derecha e izquierda									11,0	-	11,0	1,0	11,0	0,0	-
22	Tapa frontal delantera	0,8	1,0	0,4				2,3	4,0	4,0	-	12,5	1,0	12,5	1,0	-
23	Tapa frontal derecha	0,8	1,0	0,1		1,6	2,6		9,0	4,0	-	19,1	1,0	19,1	1,0	-
24	Tapa frontal izquierda	0,8	1,0				0,6			4,0	-	6,4	1,0	6,4	1,0	-
25	Cepillo	0,8	0,5	0,1			1,4		4,0	1,0	-	7,8	1,0	7,8	1,0	-
26	Eje cepillo	0,8						2,3	4,0	1,0	-	8,1	1,0	8,1	1,0	-
27	Motor Cepillo	0,8	0,5		0,2		1,4		4,0	4,0	-	10,9	1,0	10,9	1,0	-
28	Tornillo						2,0	1,6			-	3,6	8,0	28,8	0,0	-
29	Protoboard	1,3	0,5							1,0	-	2,8	1,0	2,8	1,0	-
30	Arduino	0,8	0,5	0,4			1,4			7,0	-	10,1	1,0	10,1	1,0	-
31	Conexiones	0,8	1,5							7,0	-	9,3	1,0	9,3	1,0	-
32	Tapa superior	1,3	1,0	0,4	0,2		0,6			1,0	-	4,5	1,0	4,5	1,0	-
33	Pegamento en tapa superior lateral tracera, derecha e izquierda									11,0	-	11,0	1,0	11,0	0,0	-
34	Tapa tracera superior	0,8	1,0				1,4			1,0	-	4,2	1,0	4,2	1,0	-
35	Tapa lateral derecha superior	1,3	1,5				0,6			1,0	-	4,4	1,0	4,4	1,0	-
36	Tapa lateral izquierda superior	0,8	1,5				0,6			4,0	-	6,9	1,0	6,9	1,0	-
													65,0	387,8	27	
													TOP	TAT	NUP	

Resumen estadistico		
NUP	27	= numero de partes unicas (suma de la columna N)
TOP	65,0	= numero total de operaciones (Suma de la Columna L)
TAT	387,8	= tiempo total de montaje (6,45 minutos)
NP	28	= numero de partes = sumproduct(L,N)
Tavg	6,0	= tiempo promedio/operación = TAT/TOP
Pmin	28,0	= min # parts = NP - sumproduct(L,N,O)
AR	0,17	= Clasificación de montaje = 2.35 * NP /TAT
PE	1,00	= Eficiencia parcial = Pmin/NP
C	231,80	= Complejidad de ensamble= TAT - (2.4*TOP)
OR	2,49	= Indice de dificultad de operación = TAT/(2.4*TOP)



Annex 5 Design For The Environment

Etapa del ciclo de vida	Consideraciones Ambientales					
	Selección de materiales	Consumo de Energia	Residuos Solidos	Residuos liquidos	Residuos Gaseosos	total
Estraccion de recursos	4	1	2	0	1	8
Manufactura de producto	3	4	2	3	0	12
Empaque y transporte	3	3	4	4	3	17
Uso del producto	2	2	3	4	4	15
Reciclaje y desecho	4	1	2	1	0	8
Total	16	11	13	12	8	60

Annex 6 QFD II

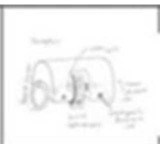
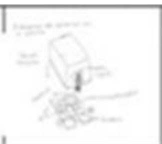
		Partes Caracteristicas				
Engineering Metrics	**Phase I Relative Weights**	Control de movimiento del cepillo	Control de posicionamiento	Accionamiento del movimiento	Control del funcionamiento	Carcaza
Velocidad dispositivo	9%		3	9	9	
Área de remoción de polvo	13%	9			1	
Dimensiones	9%	3	9		9	9
Peso (dispositivo)	4%	3		9		9
Velocidad de remoción de polvo	6%	9			9	
Resistencia (polvo y agua)	1%			1	9	9
Bateria	11%		3	9		
Tiempo (autonomia)	14%	9	9	1		
Costos	7%		1	1		9
Ruido	1%			1		
Distancia (autonomia robot)	10%		9	9	9	
Almacenamiento del Hardware (Gb)	16%	9	9			
	Raw score	4,8	5,1	3,2	3,2	1,9
	Relative Weight	26%	28%	18%	18%	11%

Subsystem Name:		CONTROL DE POSICIONAMIENTO							
		Subsystem Engineering Metrics							
System Engineering Metrics	Weights	Velocidad (RPM)	Precision encoders (resolucion)	Potencia (W)	Dimensiones (cm)	Bateria (mAh)	Torque (Nm)	Rango de efectivo (m)	Rendimiento UCP (Hz)
Velocidad dispositivo	9%	9		3					
Área de remoción de polvo	13%				1				
Dimensiones	9%		1		9				
Peso (dispositivo)	4%			1			3		
Velocidad de remoción de polvo	6%	3			1				
Resistencia (polvo y agua)	1%				1				
Batería	11%	3		1		9	1		3
Tiempo (autonomia)	14%			1		3			9
Costos	7%	9			3		9		
Ruido	1%		3						
Distancia (autonomia robot)	10%					9		1	
Almacenamiento del Hardware (Gb)	16%							3	9
Raw Score		1,89	0,112	0,548	1,2176	2,29	0,85	0,58	3,05
Normalized Score		18%	1%	5%	12%	22%	8%	5%	29%

Subsystem Name:	*CONTROL DE POSICIONAMIENTO*							
		Part Characteristics						
Subsystem Engineering Metrics	**Phase 1 Relative Weights**	Arduino Uno	Modulo Bluetooth	Encoders del motor	Motor	PC (unidad central de procesamiento	Puente H	Bateria
Velocidad (RPM)	18%			3	9			1
Precision encoders (resolucion)	1%	3		9	3	3		
Potencia (W)	5%				9		9	3
Dimensiones (cm)	12%		1				3	
Bateria (mAh)	22%	3				3		9
Torque (Nm)	8%				3			
Rango de efectivo (m)	5%	3	9			3		1
Rendimiento UCP (Hz)	29%			3		9		
#N/D	0%							
	Raw score	0,8	0,6	1,5	2,4	3,5	0,8	2,3
	Relative Weight	7%	5%	13%	20%	29%	7%	20%

Part #	Partes	Costo Partes	Relative Worth *	Part Relative Cost	Cost / Worth
			QFD FASE II		
1	*Control de movimiento del cepillo*	*$35.500,00*	*26%*	9%	0,35
2	*Control de posicionamiento*	*$140.000,00*	*28%*	36%	1,31
3	*Accionamiento del movimiento*	*$54.800,00*	*18%*	14%	0,81
4	*Control del funcionamiento*	*$74.000,00*	*18%*	19%	1,09
5	*Carcaza*	*$80.000,00*	*11%*	21%	1,97
	Total Part Cost	$384.300,00	100%	100%	

Annex 7 Selection Of Concepts

	Criterios de selección				
1	Facilidad de limpiar lineas	+	0	0	+
2	Bajos costos	+	-	0	-
3	sistema de deteccion o seguimiento de linea	-	+	-	+
4	diseño campacto	0	+	+	-
5	evacion de obstaculos	-	+	0	+
6	reduccion de tiempo	-	+	0	0
7	optimo desplazamiento	+	+	0	+
8	Falicilidad de emsable y mantenimiento	-	+	+	0
	Positivos	3	6	2	4
	iguales	1	1	5	2
	negativos	4	1	1	2
	Total	-1	5	1	2
	Orden	4	1	3	2
	Continuar?	COMBINAR		COMBINAR	

Criterios de selección					
1	Bajo costo	0	0	+	
2	baja complejidad de programacion	+	0	-	
3	facilidad de implementacion	+	+	0	
4	efectividad	0	+	0	
5	Dimensiones	0	+	+	
6	facil ubicación en el chasis	+	-	0	
	Positivos	3	3	2	
	Iguales	3	2	3	
	Negativos	0	1	1	
	Total	3	2	1	
	Orden	1	2	3	
	Continuar	si	si	no	

			Line Cleaner Bot V1					
Criterios de selección		POND %	Nota	Criterio ponderado	Nota	Criterio ponderado	Nota	Criterio ponderado
1	Facilidad de limpiar lineas	0,15	3	0,45	4	0,6	3	0,45
2	Bajos costos	0,11	3	0,33	3	0,33	4	0,44
3	sistema de deteccion o seguimiento de linea	0,12	3	0,36	4	0,48	3	0,36
4	diseño campacto	0,13	3	0,39	4	0,52	3	0,39
5	evacion de obstaculos	0,09	3	0,27	3	0,27	4	0,36
6	reduccion de tiempo	0,11	3	0,33	4	0,44	3	0,33
7	optimo desplazamiento	0,09	3	0,27	4	0,36	4	0,36
8	Falicilidad de emsable y mantenimiento	0,2	3	0,6	5	1	3	0,6
	Positivos	1		3		4		3,29

Annex 8, FMEA

Item, Function or Requirement	Potential Failure Modes	Potential Causes of Failure	Occurrence	Local Effects	End Effects on Product, User, Other Systems	Severity	Detection	RPN
Falla en el cepillo	Falla del motor del cepillo	Desgaste de los engranajes de movimiento del cepillo	1		No limpieza de línea	6	1	6
	Falla del motor del cepillo	Deformación de las cerdas del cepillo	2		No limpieza de línea	5	2	20

	Falla del motor del cepillo	Separación de los engranajes de movimiento del cepillo	1		No limpieza de línea	8	8	64
	Falla del motor del cepillo	Desajuste de piezas por vibración generada por el cepillo	2		No limpieza de línea	5	3	30
	Falla del motor del cepillo	Falta de lubricación de los engranajes del cepillo	1		No limpieza de línea	4	2	8
	Falla del motor del cepillo	Fatiga de soportes del cepillo	1		No limpieza de línea	1	1	1
	Falla del motor del cepillo	Deflexión del eje del cepillo	1		No limpieza de línea	8	4	32
	Falla del motor del cepillo	Fragilidad de los engranajes de movimiento del cepillo	1		No limpieza de línea	9	5	45
	Falla del motor del cepillo	Atascamiento de los piñones del cepillo	2		No limpieza de línea	5	2	20

Daño de Batería	**Falla Batería**	**Falla por sobrecalentamiento de las baterías**	**1**	**No funcionamiento del robot**	**6**	**1**	**6**
Daño de circuitos integrados	Falla Circuito	Desajuste de circuitos eléctricos por vibraciones	2	No funcionamiento del robot	5	2	20
	Falla Circuito	Cable de alimentación desconectado	1	No funcionamiento del robot	9	5	45
	Falla Circuito	Falla de interruptor de encendido	1	Funcionamiento inestable	5	1	5
	Falla Circuito	Falla en conexión inalámbrica Robot - Computadora	1	No funcionamiento del robot	4	1	4
	Falla Circuito	Sobre impulso de entrada de corriente en la etapa de carga	1	Posible quema de circuitos	9	4	36
	Falla Circuito	Fugas eléctricas	1	Posible quema de circuitos	8	3	24

	Falla Circuito	Operación intermitente del robot	1		Posible quema de circuitos	7	2	14
	Falla Circuito	Operación Nula del Robot	1		No funcionamiento del robot	9	4	36
	Falla Circuito	Fallo en las conexiones lógicas del microcontrolador	1		Posible quema de circuitos	8	3	24

Daño de Batería	**Falla Batería**	**Falla por sobrecalentamiento de las baterías**	**1**		**No funcionamiento del robot**	**6**	**1**	**6**
Daño de circuitos integrados	Falla Circuito	Desajuste de circuitos eléctricos por vibraciones	2		No funcionamiento del robot	5	2	20
	Falla Circuito	Cable de alimentación desconectado	1		No funcionamiento del robot	9	5	45
	Falla Circuito	Falla de interruptor de encendido	1		Funcionamiento inestable	5	1	5
	Falla Circuito	Falla en conexión inalámbrica Robot - Computadora	1		No funcionamiento del robot	4	1	4
	Falla Circuito	Sobre impulso de entrada de corriente en la etapa de carga	1		Posible quema de circuitos	9	4	36
	Falla Circuito	Fugas eléctricas	1		Posible quema de circuitos	8	3	24
	Falla Circuito	Operación intermitente del robot	1		Posible quema de circuitos	7	2	14
	Falla Circuito	Operación Nula del Robot	1		No funcionamiento del robot	9	4	36
	Falla Circuito	Fallo en las conexiones lógicas del microcontrolador	1		Posible quema de circuitos	8	3	24

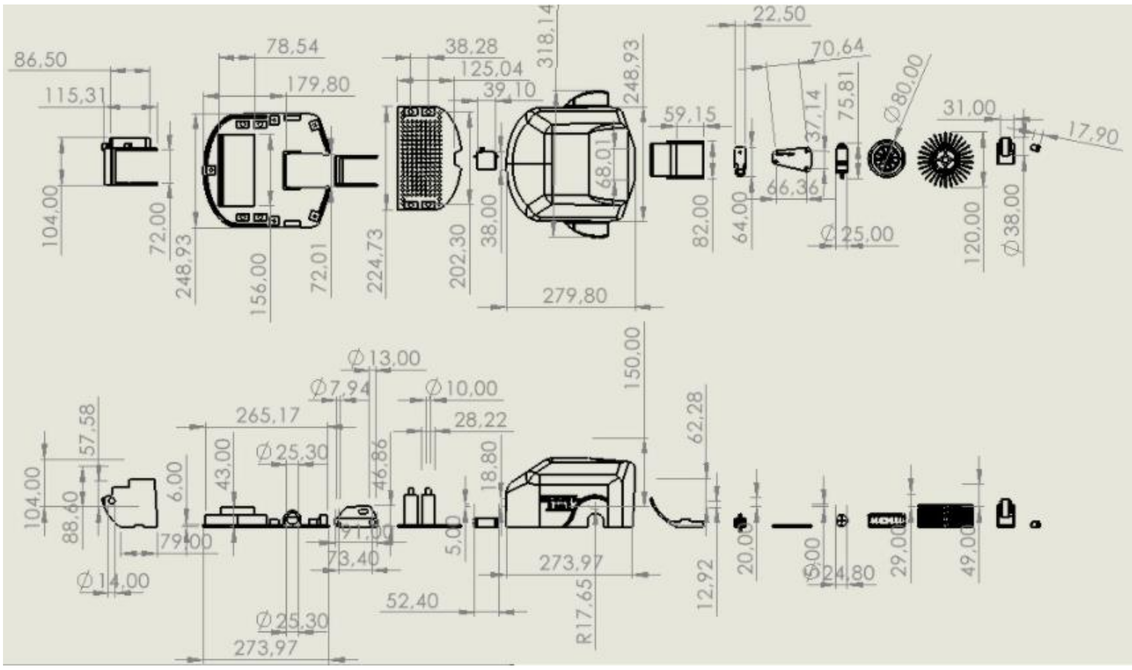
Fallo de carcasa	**Fallo de carcasa**	**Expansión térmica de la carcasa del robot**	**1**		**Posible Ruptura del material**	**2**		**4**	**8**
Deterioro por UV	Fallo por UV	Expansión térmica de partes de ensamblaje por altas jornadas de operación bajo al sol	1		Posible Ruptura del material	2		3	6
Falla chasis	Falla chasis	Fatiga del chasis del robot	1		Posible Ruptura del material	3		1	3

	Falla chasis	Deflexión del chasis	1		Posible Ruptura del material	4		2	8
	Falla chasis	Cedencia del material de construcción	1		Posible Ruptura del material	3		1	3
Falla motores	Falla motores	Falla de los enconder de los dos motores de tracción diferencial	1		Inmovilidad del robot	7		4	28
	Falla motores	Endurecimiento de las escobillas de los motores	1		Inmovilidad del robot	6		4	24
	Falla motores	Oxidación interna de los motores	1		Inmovilidad del robot	7		5	35
	Falla motores	Desalineación de motores de tracción diferencial	1		Inmovilidad del robot	8		4	32
	Falla motores	Doblamiento de los ejes de los motores	1		Inmovilidad del robot	8		4	32

Falla externa	**Falla externa**	**Ingreso de agua al interior del robot**	**1**		**Degradación de materiales de construcción**	**3**		**1**	**3**
	Falla externa	Corrosión de componentes electrónicos	1		Degradación de materiales de construcción	2		2	4
	Falla externa	Fallo bajo altas temperaturas de operación	1		Degradación de materiales de construcción	4		1	4
	Falla externa	Falla por humedad relativa	1		Degradación de materiales de construcción	2		2	4

	Falla externa	Ingreso de polvo al interior del robot	1		Degradación de materiales de construcción	2		1	2

Annex 9, Development Process



Codigos line cleaner bot
https://drive.google.com/drive/folders/1tcJzMKBGkGFdorA6QdmbU8O2f5lZyVnw?usp=sharing