NATIONAL UNIVERSITY OF ENGINEERING
COLLEGE OF MECHANICAL ENGINEERING
MECHATRONICS ENGINEERING PROGRAM

SENIOR DESIGN PROJECT REPORT

"Design and Implementation of an Explosive Deactivator Robot Based on the Vanguard MK2 model"

Course: Mechatronic Project (MT818)

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ÍNDICE

I.- PROBLEM SITUATION

Recently, in the last months, threats of explosives have continually been on the news, generating alarms and panic in the population.

This makes you think:

How prepared is our national police to deal with these problems?

The truth is that in all cases in which the deactivation of the alleged explosive was expected, it was a policeman who approached putting at risk his physical integrity and even his life. An unfortunate event occurred on September 7, 2015 in which police Adolfo Leonidas Castellano Carrillo belonging to the Unit for the Deactivation of Explosives (UDEX) died at age 51 due to an explosive which he tried to deactivate. This explosive was left in front of a school in Villa El Salvador.

That is why it is necessary to find a solution to this problem and stop putting the life of anti-explosive agents at risk.

II.- GENERAL PROBLEM

Unsafe method for the manipulation and final disposal of explosives, limited economic resources to be able to work with a robot already implemented and with the necessary functionalities.

III.- ENGINEERING PROBLEM

What engineering considerations have to be taken into account for the mobility, control and transmission of information in order to satisfy the requirements for this type of robot?

IV.- SOLUTION ALTERNATIVES

ROBOT MOBILE

- **With differential wheel**

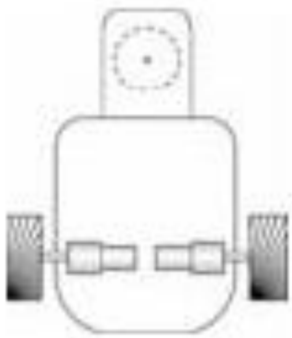


Figure 1. With differential wheel.

This robot requires two identical motors (RPM and torque) to perform the straight movement (front or back) working with the same battery. To perform lateral movements (left and right) it is necessary to modify the relative speed between the motors generally by removing the power from one of them and the rotation is produced by sliding.

The advantages that this robot presents are its simple implementation and design. As a disadvantage it presents the ease with which it can be blocked by some obstacle, when moving on slopes is prone to slip, in the case that the motors are not identical precise control is required for straight trajectories.

- **Ackerman Locomotion**

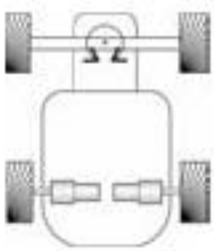


Figure 2. Mobile with Ackerman configuration.

The operation of this robot is similar to the differential wheel with the addition that the steering is controlled with the front wheels by means of 4 bars.

As an advantage, it has the simplicity of its implementation and control. The main disadvantage of this robot as well as the differential wheel is that it can be easily blocked (not all terrain) and that when only wheels are used it is prone to sliding.

- **Omnidirectional (Omniwheels)**

Figure 3. Omnidireccional mobile.

This system allows a greater freedom of movement than previously seen systems, allows complicated movements (lateral) because they reduce kinematic restrictions.

The disadvantages of this system is that straight-line motion is complicated due to mechanical constraints, requires more complicated control.

- **Track type robot**

Figura 4. Track type robot.

The caterpillar type robot is mainly designed to be able to move in any type of terrain and to overcome obstacles, the control of this system is simple and it is possible to work in slopes without any problem since it presents a greater resistance to the slip. The disadvantage of this system is the high power consumption when making turns, but this is reflected in its high capacity to overcome obstacles and difficulty of the terrain where it works.

- **Robot with legs**

Figure 5. Robot with legs.

They can move on any terrain, dodge and overcome obstacles. The main drawback is that by using many degrees of freedom and trying to maintain stability control becomes complex, energy consumption is higher than previously seen systems.

- **Unmanned Aerial Vehicle (UAV)**

Figure 6. Drone.

UAVs have the advantage over terrestrial vehicles of having a more dynamic view of the object to be examined besides that it can identify objects by means of overflight in a simpler and faster way than the mentioned vehicles.

On the other hand, these air vehicles have the limitation of working in open spaces or open areas so that they can operate freely. In addition, in case a remote manipulator is needed, the motion control would be much more complicated if it were attached to an UAV than to a land vehicle.

- **Protective Suit**

Figure 6. Protective suit.

Anti-explosive suits provide explosive detonation technicians with relative protection that can save lives in the event of a detonation. However, it is known that these suits present problems of ventilation, maneuverability, and also that for the manipulation of the explosives it is necessary that the hands are less discovered, reason why an explosion would affect directly those extremities.

If full protection suits were designed, indirect manipulation without the use of hands by the technician would make the deactivation a more complex and probably prolonged process, which creates an additional risk of explosion.

Of the solutions explained above, the caterpillar robot is selected for its simplicity of work and because it is possible to work on slopes and hilly environments without any problem.

COMMUNICATION PROTOCOL

- **Bluetooth**

Figure 7. Bluetooth.

It is a communication protocol mainly applied in low consumption devices. Communication is wireless (radio frequency) so the devices do not need to be connected to each other, the range of distance they operate depends on their transmission power, which classifies them into 3 classes:

Class	Maximum allowable power (mW)	Maximum allowable power (dBm)	Range (Approximate)
Class 1	100 mW	20 dBm	100 me
Class 2	2.5 mW	4 dBm	5 – 10 m
Class 3	1 mW	0 dBm	1 m

- **Zigbee**

It is a radiofrequency wireless communication protocol based on the IEEE 802.15.4 standard. Its application is mainly for secure communications with low sending rate and low consumption. It is easy to integrate (creation of nodes) to perform network topology in mesh.

There are modules that allow the conversion of the communication protocol from the communication to serial, one of them is the module Xbee.

Figure 8. Xbee.

The Xbee module allows the conversion of the signal by radio frequency to serial and vice versa, being able to work as slave and master.

The working distance is from 1km to 24km depending on the series, the antenna and the working frequency. But when it is integrated into a Mesh network the distance increases considerably, making it one of the communication protocols with greater reach.

V.- GENERAL OBJECTIVE

Design and implement a robot that supports the national police as an intermediary for the final disposal of explosives.

VI.- ENGINEERING STANDARDS IN THE DESIGN PROCESS

The continuous improvement methodology was used using the Deming PHVA wheel.

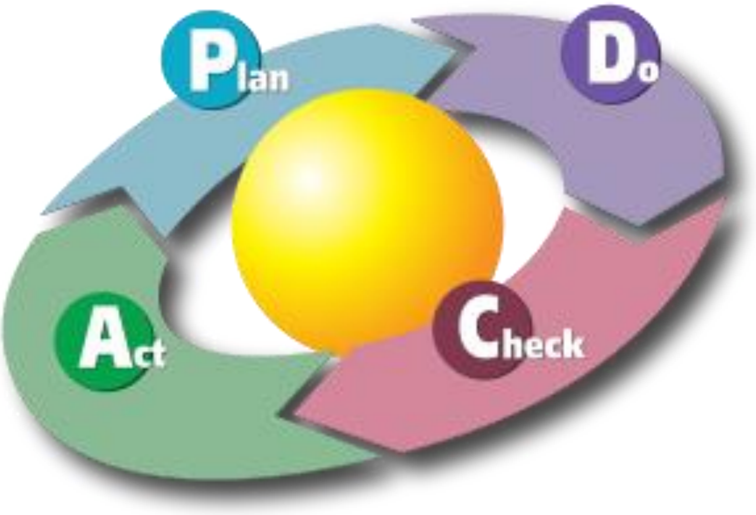


Figure 9. Continuous improvement.

The Deming or PHVA wheel is generally used in industry for the production of a product or service, but its principles were used for the development of the project.

TO PLAN

The need or problem to be solved was defined.

The search for solution alternatives (state of the art) was carried out and it was decided to carry out the project based on an existing one, adding improvements and innovating.

The algorithms, calculations necessary for engine selection and mechanical design for supports and couplings were elaborated. Once the desired efforts, powers and characteristics were calculated, manuals and catalogs of parts and motors were used to select those that complied with the requirement.

TO DO

Execution and implementation of what is planned. We made the connection of the electronics and the placement of the motors in the structure, we added the camera for the vision. The design of the electronic card was made using the CAD-CAE-CAT-CAM process.

TO VERIFY

It was verified the good functioning of the mobility of the robot according to what was requested through the joystick (communication using the ZigBee communication protocol), besides verifying the visibility of the camera and that the electronics do not present any problem of disconnection, overvoltage or false contact.

TO TAKE ACTION

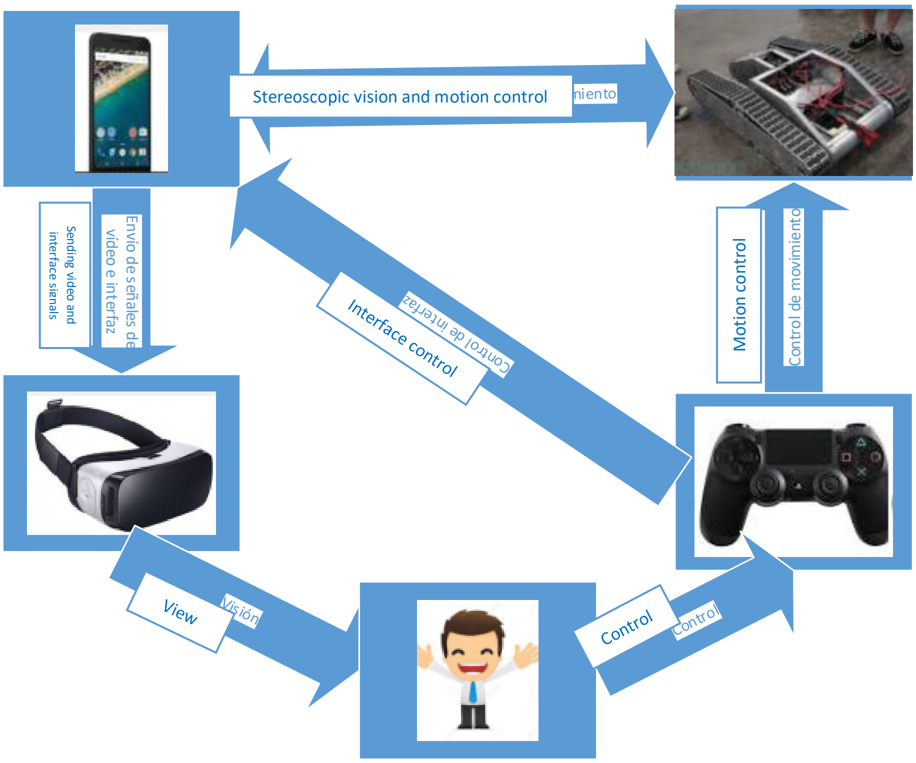
There were problems with the support of the electronic components so it proceeded to secure more firmly.

Problems arose with the mobility of the robot, blocked in a single movement (not stopped) and corrected by reviewing the programming used and modifying some values.

It was detected that the time in the video frame had a lot of delay so we proceeded to correct the times in the programming.

VII.- DESCRIPTION OF THE PROPOSED SOLUTION

Pictorial Block Diagram:



Functioning:

The robotic system that is proposed has the following characteristics:

- It will consist of a mobile platform which will contain the electronic and communication system and allow the movement of the system in the vicinity of the explosive. It will have an articulated robot that will serve for the monitoring to short distances of the possible explosive. In addition, it will be able to deactivate explosives that do not need the intervention of a human technician, depending on the type of explosive that is.
- It will have an "all terrain" movement system so that caterpillar type wheels will be used to access any environment or terrain.
- The articular arm will have a camera for the monitoring and identification of the explosive in addition to the supervision of the tasks of the robot. In addition, it will have a disruptor gun with which the bomb can be detonated remotely after making a perimeter of security.

Limitations of the solution:

The robot to be developed will serve as an intermediary between the explosive and the person, being controlled remotely by the person, not becoming purely autonomous.

Expected results:

The robot is expected to comply with basic features such as maneuverability in any type of terrain and stereoscopic vision suitable for depth perception.

Design Methodology and Implementation

Stage 1: Design of control and communication algorithms.

Identify the movements that you want the robot to perform and design a movement algorithm through indicators or signals, which will be defined later.

Make the selection of the appropriate sensors to obtain the signals required for the motion algorithm.

Develop a radiofrequency communication system for the robot to work remotely from a computer.

Stage 2: Design of the electrical and electronic subsystem.

Make the proper selection of the motors making previous calculations to determine the necessary torque with which they must work.

Determine the electronic components to use for signal conditioning.

Develop an interface in the computer, for the sending and acquisition of signals and images remotely.

Perform imaging tests for stereoscopic vision.

Stage 3: Design of the mechanical subsystem.

Perform the calculation of the necessary machine elements according to the weight and mobility of the robot.

Develop a virtual design of the robot, having the dimensions and elements of machines previously calculated, to have an estimate of the real development of the robot and to check according to efforts the behavior of the developed mechanical structure.

Perform the implementation of the robot taking as a reference the virtually developed design. Realizar la implementación del robot tomando como referencia el diseño desarrollado virtualmente.

Step 4: Commissioning and testing

Check the mobility of the robot, the reception of the images of the camera and the correct operation of the interface develops for its control.

Verify that the mechanical structure implemented does not present faults, that the selected motors are suitable, and that the communication is well established and there are no interferences.

VIII.- TECHNICAL STANDARDS USED IN THE PROJECT

AGMA NORMALIZATION [6]

<u>DESIGN - ENDLESS GEARS</u>

- **ANSI/AGMA 6022** Design manual for helical gears.

<u>FAILURE MODES</u>

- **ANSI/AGMA 1010**, Appearance of gear teeth - Terminology of wear and failure.

<u>INSPECTION AND TOLERANCES</u>

- **AGMA 915-3** Inspection Practices - Spacing, wheelbase and parallelism.
- **ANSI/AGMA 2111** Cylindrical Tolerance of Screw Gear and Inspection Methods (Metric).

<u>PROPORTIONS</u>

- **ANSI/AGMA 1103** Tooth proportions for straight and helical gears of fine pitch (metric edition).

<u>ENDLESS GEARS</u>

- **ANSI/AGMA 6034** Practical for speed reducers of closed cylindrical gears and geared motors.

ASME NORMALIZATION [7]

- **ASME B1.1:** Unified inch screw threads (UN and UNR thread form).
- **ASME B107.28:** Electronic instruments of par.
- **ASME B107.55:** Axes: Safety requirements.
- **ASME B18.2.3.1M:** Metric hex head screws.
- **ASME B18.22M:** Flat washers metric.
- **ASME B4.2:** Preferred metric limits and settings.
- **ASME B4.3:** General tolerances for dimensioned metric products.
- **ASME Y14.5M:** Dimensioning and Tolerance.

ASTM STANDARDIZATION [8]

- **ASTM F467:** Non-ferrous nuts for general use (metric).
- **ASTM F468:** Non-ferrous bolts, hexagonal head bolts and general purpose asparagus (metric).

NORMALIZACION ISO [16]

- **ISO 31.020** Electronic components in general. Magnetic components, see 29.100.10
- **ISO 31.190** Electronic components. Includes preassembled modules.
- **ISO 31.200** Integrated circuits. Microelectronics. It includes electronic chips, logical and analog microstructures.
- **PERUVIAN LEGAL STANDARDS OF BROADCASTING [11]**
- Supreme Decree No. 006-2013-MTC.

IX.- WEEKLY SCHEDULE OF PROJECT DEVELOPMENT

Week	Date range	Activity
Week 1	09/17/16 - 09/23/16	Choice of project to be developed.
Week 2	09/17/16 - 09/30/16	
Week 3	08/31/16 - 09/06/16	Delimitation of the progress of the project to be developed during the cycle.
Week 4	09/07/16 - 09/13/16	- Review of previous theoretical aspects about deactivation of bombs and robots of caterpillar type. - Search for solutions (state of the art). - Structure or schedule to be developed throughout the project.
Week 5	09/14/16 - 09/20/16	- Design of the control subsystem of the robotic system, part 1.
Week 6	09/14/16 - 09/27/16	Presentation Development N ° 1
Week 7	09/14/16 - 10/04/16	- Design of the control subsystem of the robotic system, part 2.
Week 8	10/95/16 - 10/11/16	
Week 9	10/12/16 – 10/18/16	- Design of the sub-system of sensors and actuators of the robotic system
Week 10	10/19/16 - 10/25/16	
Week 11	10/26/16 - 11/01/16	- Design of the mechanical subsystem of the robotic system

Week	Date range	Activity
Week 12	11/02//16 - 11/08/21	Presentation Development N ° 2
Week 13	11/09/16 - 11/15/22	- Implementation of the model.
Week 14	11/16/16 - 11/22/23	
Week 15	11/23/16 - 12/29/24	- Implementación del modelo.
Week 16	11/30/16 - 12/05/16	Development of the final presentation

Leyenda:

	Preview completed
	Exam date

X.- PROJECT PROGRESS

- **Advance: Motion control interface and communication protocol.**

a. Purpose of the progress

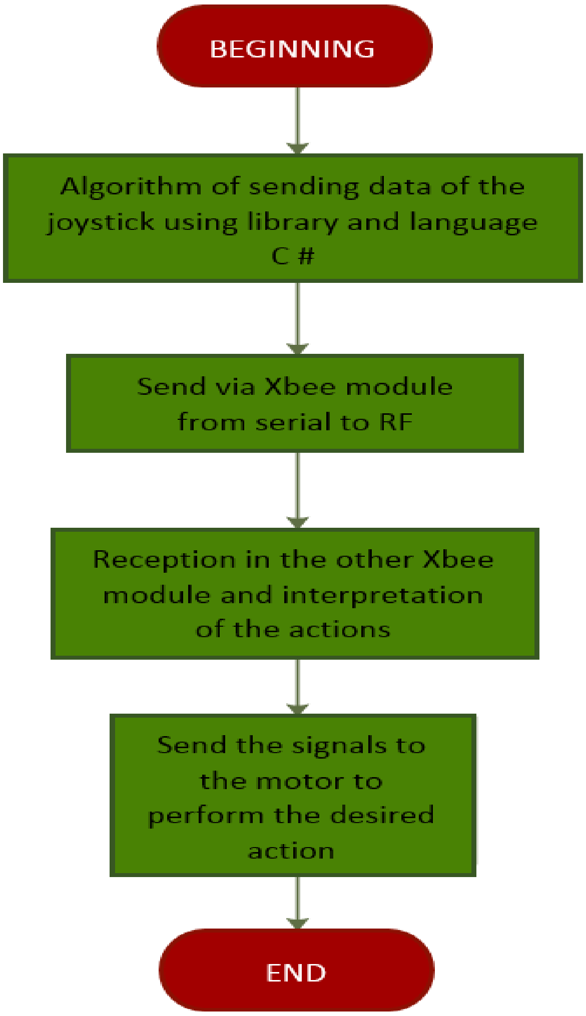
To make an interface in the computer that allows to select the movements that are wanted to realize by means of serial communication and radiofrequency so that it is of remote form, in addition a joystick control like alternative of control will be added.

b. Theoretical support:

The programming of the interface is done in the development environment of Visual Studio using C # language in which the actions to be sent are designated (the library that allows manipulation of the joystick is used) via serial communication towards an Xbee module that converts communication Serial to radiofrequency in order to control the robot remotely.

In the robot uses the arduino development module and its respective Xbee that converts the radio frequency to serial communication and receives the bits sent by the joystick and translates them to signals that are reflected in the actions performed by the engines (forward, backward, right and left).

c. Analysis of progress:



d. Results, Measurements and Validation:

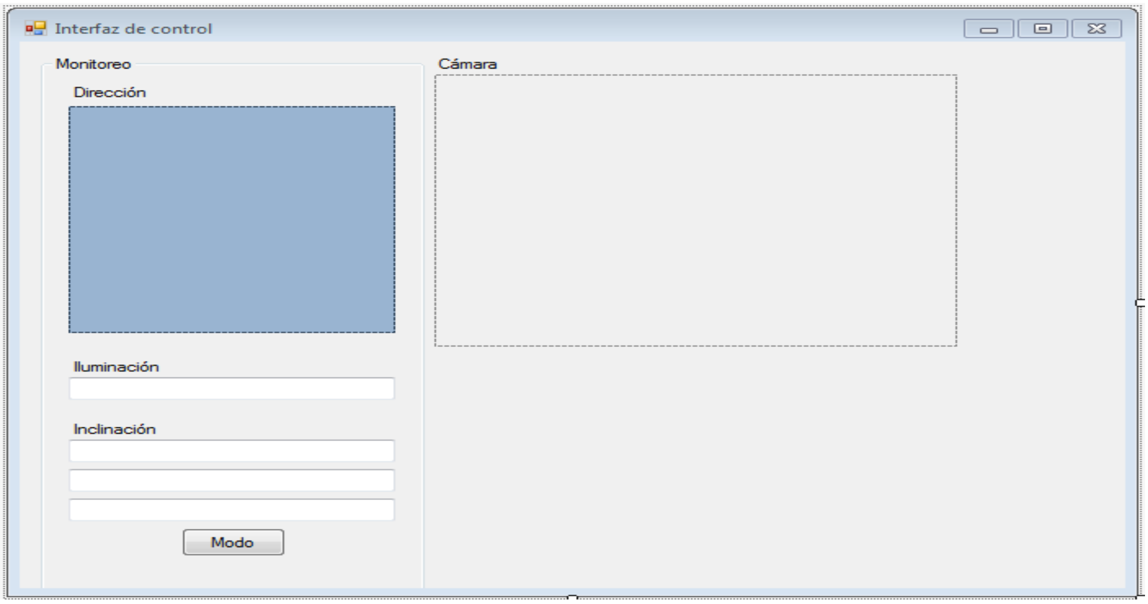


Figure 10. Developed interface.

e. Problems faced

An additional library was required for the configuration and data acquisition of the joystick.

Additional hardware was required for the simple programming of the XBee modules, since they had a Firmware that was not compatible for the communication between them.

A period of time was needed in which the status of the joystick and the commands to be sent would be updated, but in some cases the sent commands would be executed (locked), so the appropriate execution timer has to be designated to avoid this Problem, with multiple tests was chosen a time of 500ms since it will be transmitted a video that will be added later.

f. Comments and conclusions

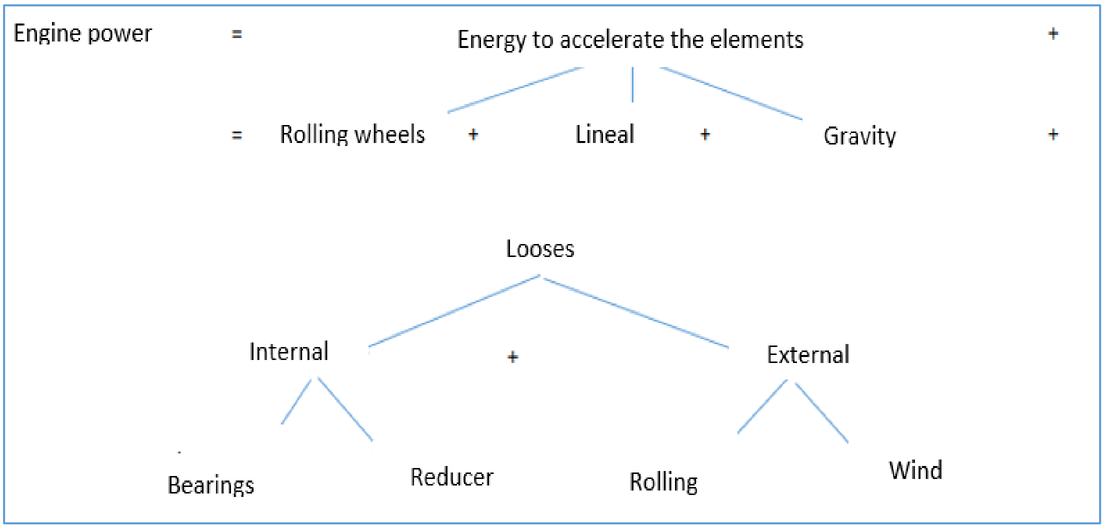
It is possible to perform a remote transmission using radiofrequency, and an Xbee module that transforms the radiofrequency to serial and vice versa, which is a communication protocol with which it has already been worked and is easier to handle with the various embedded systems used

- ## Progress: Calculation of engines to use.

a. Purpose of the progress

The purpose of calculating the motors is to select those that allow the mobility of the robot without any inconvenience referring to the required power.

b. Theoretical support:



CALCULATION OF PARAMETERS	
Lineal speed	
w. out	= Lineal speed / (d.out*2)
Force of gravity	= ((m.chassis +m.arm+m.rest) * (accel.grav. + Lineal speed/accel. Time)) * sin(alpha)
Resulting bearing force	= ((m.chassis +m.arm+m.rest) * accel.grav.) * cos(alpha) * brearing coeff.
Resulting air force	= ½ * (air density) * (lineal speed)^2 * (width * high) * (drag coeff.)
Bearing frictional force	= Brearing friction coeff. * (m.chassis+m.arm) * grav. accel.

POWER REQUIRED	
Power to accelerate the elements	= Force of gravity * Lineal speed
Bearing loss power	= Bearing frictional force * (w.out * d.out / 2)
Power of rolling losses	= Resulting bearing force * Lineal speed
Loss power by wind resistance	= Resulting air forcé * Lineal speed
Output power	

ENGINE POWER	
Engine power	Output power / n. reducer

c. Analysis of progress:

The parameters are defined as follows:

DATA	
Max. Speed	0.2 m/s
Accel. time	1s
alpha	40°
m.chassis	15 kg
m.arm	10 kg
m.rest	2.5 kg
d.out	75 mm
Grav. Acce.	9.81 m/s^2
Bearing coeff.	0.3
Air density	1.205 kg/m^3
Drag coeff.	2
Bearing friction coeff.	0.01
width	444 mm
high	371 mm
n. reducer	80%

The calculations are as follows:

Calculation of parameters:

Lineal speed	=	0.2
w. out	=	5.33333333
Force of gravity	=	250.25
Resulting bearing force	=	56.3617199
Resulting air force	=	0.0070397
Bearing frictional force	=	2.4525

POWER REQUIRED:

Power to accelerate the elements	=	50.05
Bearing loss power	=	0.4905
Power of rolling losses	=	11.272344
Loss power by wind resistance	=	0.00158794
Output power	=	61.8144319

The motor power must be:

Engine power	
Engine power	77.2680399 W

d. Results, Measurements and Validation:

After the calculation of the engines, they were acquired.

Figure 11. Reducer motor purchased.

Measurements of current consumption at full load were made for proper selection of the drivers to be used. The current consumption at full load was approximately 4 amps, so a 24 V H-bridge (voltage with which it is intended to work) was chosen and with a working current greater than 4 A.

e. Problems faced

In the market there were no engines with the required power, which meant that motors of values close to the necessary ones were acquired. The torque obtained from the reducer is greater than is needed, but this in turn produces a decrease in the angular speed of the motor and therefore the speed of the robot.

It was necessary to design supports for the assembly of the motors and to attach to the axis of the transmission pinion (fixed) of the same ones

f. Comments and conclusions

In spite of having a decrease of the speed of the motor this still allows to make the necessary movements and does not present any dysfunctionality.

- ## Progress: Video transmission.

a. Purpose of the progress

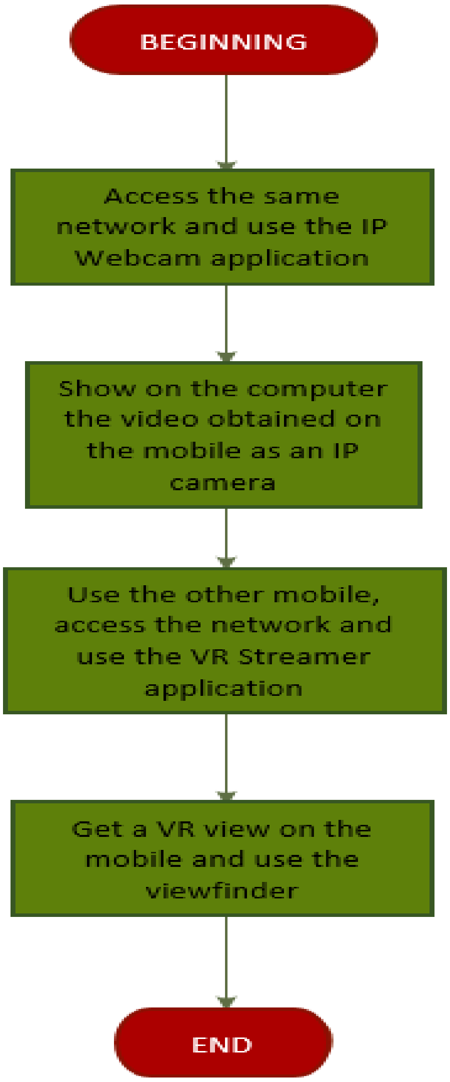
Obtain a video frame that allows to have a visualization around the robot in a computer and that in turn is transferred to an Android mobile that allows to realize the stereoscopic vision.

b. Theoretical support:

To obtain video remotely an application is used that allows to obtain in the computer what is seen through a camera connected to the same network (similar to a streaming), the application to use is called IP Webcam which converts the camera Of an Android mobile in an IP camera that when being connected to the same network of the computer allows the visualization, to make that the mobile and the computer belong to the same network is used an access point or anchorage by the mobile and through Wifi Both access the same network.

Stereoscopic vision is also required so the VR Streamer application will be used in another mobile device, which converts the application that is active in the monitor into a VR image that when using a viewer gives the perception of stereoscopy, for the application to work Properly it is necessary that it is connected to the same network so the network previously created using the Wi-Fi connection will be used.

c. Analysis of the progress:



d. Results, Measurements and Validation:

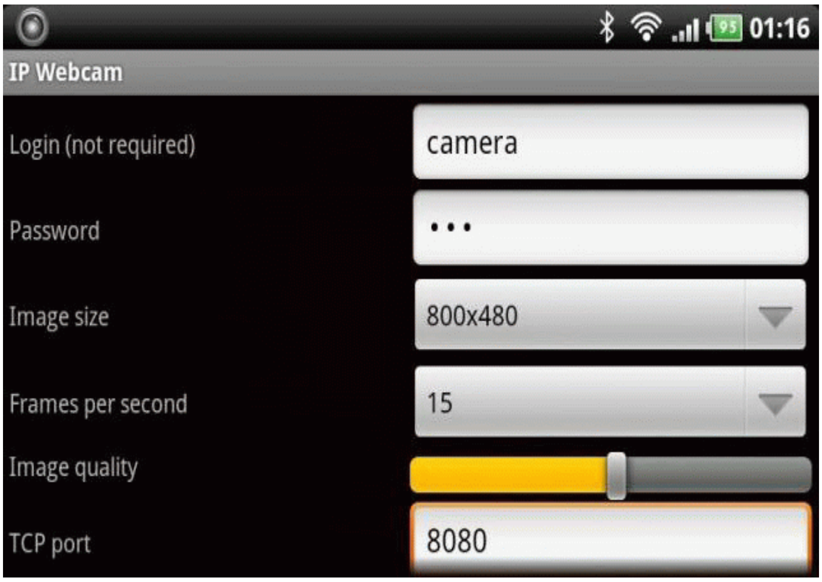


Figure 12. IP Mobile Application Webcam.

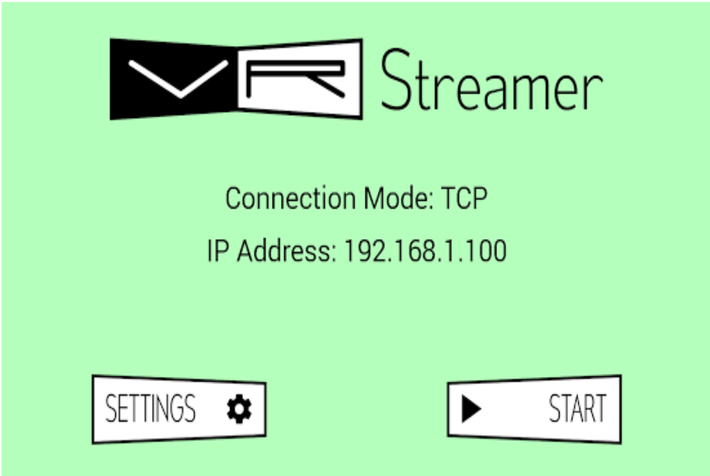


Figure 13. VR Streamer mobile application.

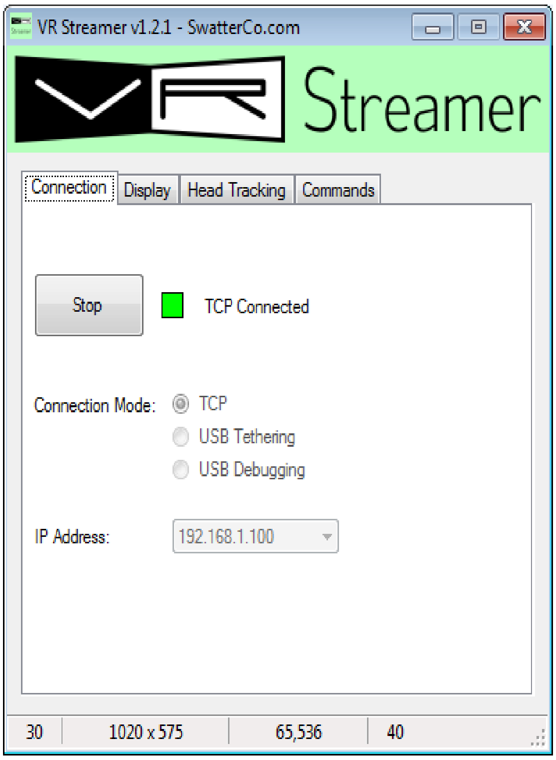


Figure 14. Connecting the VR Streamer.

e. Problems faced

The main problem facing network video transmission is the limited distance to which it works, since a wireless connection between all the components can not be separated by a considerable distance (no more than 10 meters).

f. Comments and conclusions

It is possible to improve the video transmission using another protocol, such as radiofrequency, which allows video transmission at a greater distance and return to the robot remotely, the transmission of radiofrequency video is similar to those used by analogue signal stations.

XI.- FINANCIAL AND ECONOMIC REPORT

Name	Quantity	Unit cost	Total cost	Comment
Mechanical structure	1	s/. 0.00	s/. 0.00	Provided by Eng. Oliden
Xbee 1Mw Trace Antenna – Series 1 (802.15.4)	2	s/. 0.00	s/. 0.00	Provided by Eng. Oliden
Gamepad (Joystick)	1	s/. 25.00	s/. 25.00	Bought at Jr. Paruro
Power Driver for Engines	1	s/. 77.00	s/. 77.00	Bought at Jr. Paruro
12V lead-acid batteries	2	s/. 25.00	s/. 50.00	Bought at Jr. Paruro
Battery charger 12V	1	s/. 20.00	s/. 20.00	Bought at Jr. Paruro
24VDC reduction motor	2	s/. 50.00	s/. 100.00	Bought at Jr. Leticia
3D mobile viewer up to 6"	1	s/. 35.00	s/. 35.00	Bought at Jr. Paruro
Smartphone	2	s/. 0.00	s/. 0.00	Provided by group members
Computer (Laptop)	1	s/. 0.00	s/. 0.00	Provided by Marco Rodríguez
Arduino UNO	1	s/. 0.00	s/. 0.00	Provided by David Fernández
Mechanical - structural system	1	s/. 0.00	s/. 0.00	Provided by Eng. Oliden
Miscellaneous components (protoboard, cables, resistors, etc.)	1	s/. 50.00	s/. 50.00	Bought at Jr. Paruro
		Total	s/. 357.00	

XII.- CONCLUSIONS AND FINAL COMMENTS

The robot remote control was achieved with the proposed system.

An advance or improvement in the RF communication mechanism can be achieved in comparison to the Vanguard MKII, as there are currently low-power and easy-to-use communication modules (~ 100m) such as the XBee which allow transmission From control signals of the control to the robot and signals of sensation of the robot to the interface.

Xbee modules have limited bandwidth, have been designed for single-data sending and not audio or video.

There is a limitation of the working distance of the robot because for the video transmission it is necessary to work in the same network, which greatly limits the operating distance.

It is possible to improve the transmission of video using the radiofrequency, so that it can be worked at a greater distance.

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APPENDIX A

Engineering Standards Applied in the Project

For developing and completing the project, besides the mechanical engineering standards presented in page 13, the following wireless communication and robotic systems standards and protocols have been used.

Communication Protocols and Standards

- **IEEE 802.15.4 - Zigbee**
  Zigbee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection. Hence, Zigbee is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network. Zigbee operates in the industrial, scientific and medical (ISM) radio bands: 2.4 GHz in most jurisdictions worldwide

- **Bluetooth**
  Bluetooth is a short-range wireless technology standard used for exchanging data between fixed and mobile devices over short distances using UHF radio waves in the ISM bands, from 2.402 GHz to 2.480 GHz, and building personal area networks (PANs).
  The last version is Bluetooth 5.2 – Core Specification Version with new features for audio, power control, isochronous channels.

Real Time Standards

- **IEEE 1003.1b-1993**
  IEEE Standard for Informaytion Technology – Portable Operating System Interfaces (POSIX(TN)). Party 1: System Application Program Interface (API). It defines the applications interface to basic open system services for input/output, file system access, and process management. It also defines a format for data interchange. When options specified in the Realtime Extension are included, the standard also defines interfaces appropriate for realtime applications.

Standards for Mobile Robots

- **ISO 18646-1:2016**

Robotics — Performance criteria and related test methods for service robots — Part 1: Locomotion for wheeled robots
The standard describes methods for specifying and evaluating the locomotion performance of wheeled robots in indoor environments.

- **ISO 18646-2:2019**
  Robotics — Performance criteria and related test methods for service robots — Part 2: Navigation
  The standard describes methods of specifying and evaluating the navigation performance of mobile service robots, measured by pose accuracy and repeatability, as well as the ability to detect and avoid obstacles.

APPENDIX B

Realistic Multiple Constraints Considered in the Project

For the development of the project, the following constraints and restrictions were considered:

Mechanical Constraints

- Lift capacity (arm extended): 8.0 Kg
- Lift capacity (arm retracted): 18.0 Kg
- Vertical reach: 132 cm
- Horizontal reach: 96 cm
- Ground clearance: 5.5 cm
- Overall length: 90.0 cm
- Overall width: 44.0 cm
- Stowed height: 42.0 cm
- Overall weight: 48.0 Kg
- Mission duration: 2.5 hours with quick change battery pack

Power
Not all the electrical and electronic components have the same voltage input requirements and therefore it is required the use of power amplifiers and driver circuits have to be designed to provide the electrical power with the required voltage, current and frequency characteristics.

Maintainability
Easy disassembly and reassembly of the robot. The layout of electrical and electronic boards (component and devices) has been determined for allowing a sequential, ordered and straightforward disassembly and reassembly of the robot. The mechanical components have also been designed and integrated for and easy and intuitive disassembly and reassembly. This allows the easy replacement of parts and components. It is specially required for main and auxiliary batteries, fuses, switches, tires and connectors.

Components Availability
When designing and selecting the mechanical, electrical and electronic components, many of them are too expensive or they are not easily available in market. It is required to look for equivalent components that have to be adapted or modified to be used in the project. Also, some recycled components may be used in case there is not other option.

Budget

For developing the senior design project, students get small funding from the College which covers no more than 20% of the total costs. The most of the budget is covered by the same students. Although the College provides the laboratory space, equipment and machines to be used by students, most of mechanical, electrical and electronic components are covered by students themselves. On average, the total budget covered by students, on average, is between US$ 800 and US$ 1,200.

Schedule

The project must be completed in one academic semester. It is estimated the project requires an average of 150 hours of teamwork with 4-5 students per team. Considering that, besides the senior design project course, students are enrolled in 3-4 additional courses in the academic semester, students have to plan ahead in order for identify all required activities, distribute the tasks among all team members and, finally, integrate all partial tasks to configure the final robot for testing in real working conditions.

Environment and Safety

Selection of mechanical and electronic components, as well as electronic board construction are carried out using environment-friendly materials and processes.