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Master's thesis

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Design, implementation and control of an Intelligent Surveillance Robot Monitoring Outdoor Security

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Abreviation list

Chapter 1: general-robotics-final

ARM	Adjustable-Rate Mortgage
AUVs	Autonomous underwater vehicle
BCR	Bell Communications Research
CCD	Charge-Coupled Device
CMOS	Complementary Metal Oxide Silicon
CPU	Central Processing Unit
CNN	Convolutional Neural Network
DSR	Dynamic Spatial Reconstructor
EERPROM	Electrically Erasable Programmable Read-Only Memory
EO	Ex Officio
GPS	Global Positioning System
ILS	Instrument Landing System
IR	Infrared Radiation
L/D	Lift-to-Drag
MTCNN	Multi-task convolutional neural network
MR	Magnetic resonance imaging
NASA	National Aeronautics and Space Administration
NMR	Nuclear magnetic resonance
OTPROM	One-time programmable read-only memory.
RAM	Random access memory
RHIB	rigid-hulled inflatable boat
RISC	Reduced instruction set computer
ROM	Read Only Memory
PTZ	with pan , tilt and controllable zoom functions
SAR	Special Administrative Region
UAVs	unmanned aerial vehicle
UGVs	unmanned Ground Vehicles
UUVs	unmanned undersea vehicles
UVPROM	Ultra Violet Programmable Read Only Memory
WIFI	wireless networking technology that allows communication

Chapter 2: Intelligent Surveillance Robots - State of Art

ART	Assisted Reproductive Technology
BLOS	Boss Looking Over Shoulder
CEO	Chief Executive Officer
CORBA	Common Object Request Broker Architecture
DFRS	Defence Fire and Rescue Service
EAFB	
GHOC	Global Hawk Operations Center
ISR	Intelligence, Surveillance, and Reconnaissance
LBP	
LOS	Law Of the Sea
PC	Personal Computer
RSTA	Rockford Science and Technology Academy
UAV	Unmanned Aerial Vehicle

Abreviation list

Chapter 3: Theoretical study and Inception

CERIST	Centre de Recherche sur l'Information Scientifique et Technique
MP	Megapixel
PID	Proportional Integral Derivative
PIR	Passive Infrared
PWM	Pulse Width Modulation
SDK	Sotfware Development Kit
RPI	Raspberry Pi

Chapter 4: conception and simulation

ANT	Actor-Network Theory
AVR	Automatic Voltage Regulator
CDC	Communications Device Class
CPU	Central Processins Unit
DC	direct current
DK	Development Kit
DFU	device firmware update
DSR	Dynamic Source Routing
GPIO	General Purpose Input/Output
IC	integrated circuit
IDE	integrated development environment
LE	low energy
LED	light emitting diode
MCU	microcontroller
NFC	Near Field Communication
NRF	
OB	on-board
RAM	Random Access Memory
ROM	Read Only Memory
SES	Segger Embedded Studio
SIG	
SoC	
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter
UK	United Kingdom
USB	Universal Serial Bus

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General introduction

In recent years, the community is increasingly interested in robotics, the development of autonomous and remote operated intelligent systems within mobile robotics such an interest can be seen as a logical consequence of the emergence of potential applications of intelligent machines (industrial, services, handling or even mobility assistance for the elderly or disabled, etc.). The objective is to put the robots on various tasks such as interventions on accident sites, handling of sensitive or nuclear sites, as well as for the exploration of maritime and planetary sites… etc.

The increasing need for automated surveillance of indoor environments, such as airports, warehouses, production plants, etc. has stimulated the development of intelligent systems based on mobile sensors. Differently from traditional non-mobile surveillance devices, those based on mobile robots are still in their initial stage of development, and many issues are currently open for investigation.

The main challenge of current mobile robotics is to develop systems for intelligent navigation, where autonomous navigation is a research axis that aims to give a machine the ability to move in an environment without assistance or human intervention to accomplish a desired goal. The navigation task is to give the robot the possibility of obtain the information it needs to reason and endow it with the ability of locomotion adapted to its environment. However, this involves complex systems in the realization, where their control faces important difficulties not only technological but also scientifically.

Consider a mobile robot or an autonomous vehicle that must move in an environment outdoors, either on the road or in a natural open environment; it must follow a path defined by a curve on the ground, or by an instruction defined in the sensory data. This robot must embed capacities functional and decisional allowing it to control the execution of all his movements, to estimate the movements actually carried out, in order to stay on the planned trajectory, and to detect in real time that this trajectory is free of obstacles.

General introduction

The context in which our work takes place is to design and produce a remotely controlled system of a mobile surveillance robot with a night vision camera taking into account obstacle avoidance.

We have decomposed this report into five parts, which describe the logical sequence we have adopted to bring this project to fruition. In the first part we will discuss generalities on robots and surveillance robots then we will discuss the state of the art on the technologies used for and discuss the study we have made of the field of robotics as well as the specification of the robot of the project which was deduced from it. In the three other parts we will approach the theoretical design, the simulation and the realization of the two modules which make up our Robot.

Chapter 1: General robotics

1.1 Introduction

Robotics is a field that is growing in importance with each passing year, and which is considered to be one of the most strategic fields of science and industry in the world. Several hundred companies and multinationals specialize in the research and manufacture of robotics equipment. In addition, robotics finds applies in a wide variety of research fields such as medicine, astrophysics, telecommunications, transport and the production of high-tech materials and equipment.

Robotics encompasses a very wide field of human engineering activities. More than 700,000 robots are at work in global industry today, and thousands more are used in the sciences of ethology, medicine and space research. Barely fifty years old, is robotics taking advantage of the rapid progress of micro technologies and nanotechnologies to evolve into a form of artificial intelligence that is beyond the imagination of the most prolific science fiction authors. Yet science fiction author Isaac Asimov (1926-1996) is responsible for the term robotics and the three laws that must govern the manufacture of robots:

1. First law: A robot cannot harm a human being or, remaining passive, leave this human being exposed to danger.
2. Second law: A robot must obey orders given by human beings, unless such orders contradict the first law.
3. Third Law: A robot must protect its existence as long as this protection does not contradict the First and Second Laws. Thus, robotics is defined as having to serve and protect human beings.

We could also add: and be inspired by it because, by comparing human functions with those of existing robotic systems, we discover that researchers and inventors have always drawn inspiration from human physiology, whether it is to create simple machines, industrial robots or androids.

Robotics was born, a long time ago, from the desire of humans to surpass themselves. After inventing machines to use and protect themselves, humans wanted to go further even in space.

1.2 Definition (1)

1.2.1 Etymology of the word ‘Robot’

The term "robot" derives from Slavic languages (Czech and Polish) and literally means "Slave" or else (Robota) which means forced labor. The precise definition of a robot, and in counterpoint to robotics, is complex. Complex assembly of mechanical parts and electronic parts, all driven by artificial intelligence.

A robot is a device controlled by an automatic control system based microprocessors and which has been designed to perform a specific task in the field industrial, scientific or even domestic.

In addition, robotics calls for several fields, mainly:

- Mechanics: design, production, modeling of robots.
- Electronics: installation of components for robots to control from distance using telecommunication concepts.
- IT: creation of programs for managing the transfer of information between the different components of the robot.
- Automatic: control, calibration of sensors, effectors, identification of settings.
- Signal processing: analyzing information systems recorded by the robot's sensors.
- Mathematics: mathematical models for decision making and / or learning, calculation of trajectories, location, planning.
- Cognitive sciences: human-machine, machine-machine interactions, decision-making

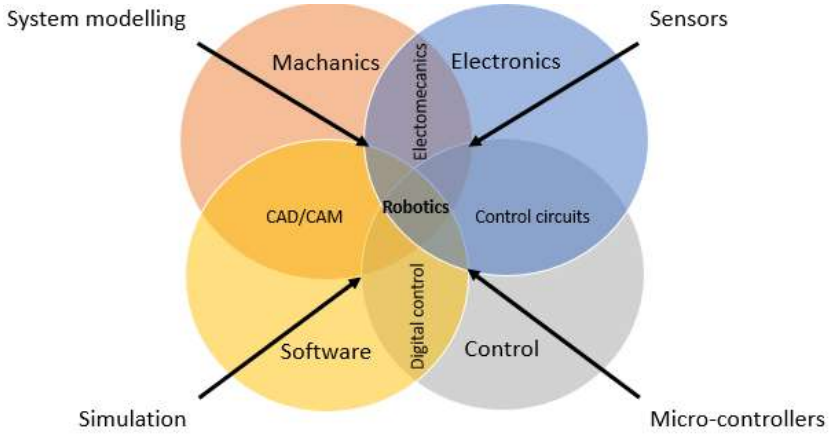


Figure 1-1 different robotic fields

1.2.2 Definition of Robotics

Robotics is the intersection of science, engineering and technology that produces machines, called robots, that substitute for (or replicate) human actions. [2]

1.3 Evolution [3]

1.3.1 History timeline

320 BCE: Aristotle's the first recorded musings on automation come from Greek philosopher Aristotle:

> *"If every tool, when ordered, or even of its own accord, could do the work that befits it… then there would be no need either of apprentices for the master workers or of slaves for the lords."*

1495: Leonardo Da Vinci's Mechanical Knight we would have to wait almost 2,000 years to take our next steps towards robotic automation. Leonardo Da Vinci's years of anatomical research allowed him to develop plans for a humanoid automaton resembling a medieval knight. With an anatomically correct jaw, and working movements ranging from standing, sitting, and moving its arms independently, the plans have since been developed into a working robot. [4]

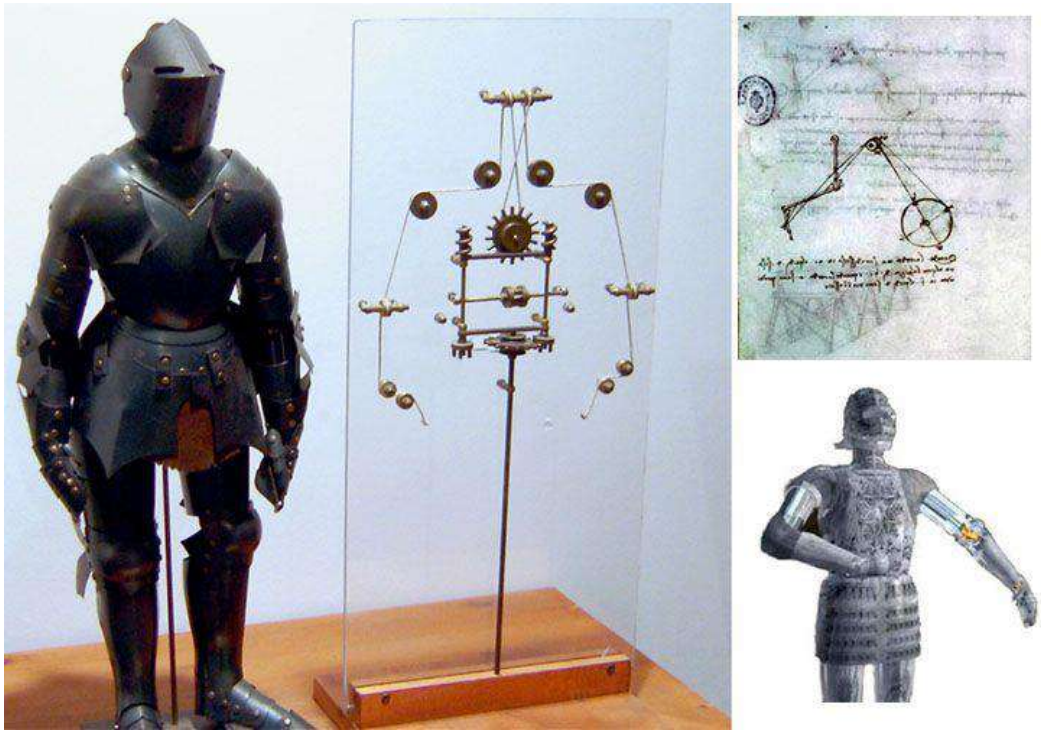


Figure 1- 2 Da Vinci's Mechanical Knight

1947: first remote operated electric manipulator.

1954: first programmable robot.

1961: appearance of a robot on a General Motors assembly line, which made the first robot with effort control.

1.4 Types of robots [5]

Today, robots are classified in order to give an idea of the current presence of robotics and the extent of this field in the years to come

The most common categories of robots:

1.4.1 Industrial robots (manipulators)

The majority of these robots have fixed base. When the base is not fixed, it is usually mounted on a rail. In this category, we find man ipulation robots, "Pick And Place" type, welding robots or painting robots. This represents the majority of robots currently in service.

1.4.2 Surgical robots

They are actually another branch of industrial robots. They work either by mechanical arms connected to a computer, or by articulated arms directed by the surgeon and whose movements are reproduced at the same time.

1.4.3 Domestic robots

They can multitask or just entertain us. Several companies have created an automatic lawn mower which, on a given perimeter, can avoid obstacles while cutting the grass. To entertain us, a well-known brand has designed a robot dog named Aïbo. The most recent version has very advanced features such as camera, voice recognition, etc.

1.4.4 Robot Surveillance and Security

Security robots automatically move along the patrol route, detect strangers, and transmit messages to the guard. The operator behind the monitor screen is already in the past, the robots themselves detect the intrusion. A security guard will only be required to physically counteract a potential intruder. [6]

1.4.5 Military robots

They are mainly used for surveillance in the air and in the sea. There is an American unmanned aircraft that watches, recognizes, identifies or even destroys enemy targets. There is also a submarine which has the same properties.

1.4.6 Mobile robots (explorers)

Alternatively, UGV (Unmanned Ground Vehicles), this category encompasses the sub-category of mobile robots with wheels, the other robots generally called by their category name corresponding to their functionality. This category includes robots with a base actuated by wheels or by caterpillars. They are generally exploited for exploration; this is the reason for which they are called rovers (vagabonds). The best-known are: The Curiosity, which was sent to Mars by NASA to explore and identify Martian terrain.

The fields of application of mobile robots are very varied: the transport of mail and goods, exploration in hostile environments as example, nuclear, space and underwater environments; construction sites: demining, both in the civilian sector such as airports and in the military, fight against the fire, help for disabled or sick people.

1.4.7 Special case of the automobile

The automobile is today a particularly active development area for robotic technologies. It is not generally considered a sector of robotic because of its traditionally very "mechanical" character. However, it is undeniable that it is undoubtedly the first mass market for robotics of personal service. The automobile is also the basis of much research in the field. Driving assistance and automatic driving, both techniques than on operational safety, reliability, environmental development complex, interaction with the driver or external systems ... etc.

On all navigation, mapping, target tracking (perception) systems, of decision support ... etc., the automobile constitutes a field of experimentation scale and an important market for robotics techno providers (software, sensors, mechatronics ... etc.)

1.5 Robot architecture [7]

1.5.1 Robots main component

A robot is a complex machine, because it can "learn" to do repetitive, dangerous jobs or go to places that are inaccessible (very small) or hostile (such as in space or under the sea). The robot is therefore a machine or device, which operates automatically or in response to a remote control. An automatic toaster or microwave oven are robots just like the manipulator robot on the International Space Station. Robots can do almost anything: breathe in perfumes, detect faulty products in an assembly line, "see" like a human eye, and assemble complicated parts with meticulousness and perfection. There are also so-called "intelligent" robots capable of learning, working and making decisions. Robotics is the study and technology of robots. It allows the development of automated mechanisms capable of replacing humans in certain functions. The systems that make up robots could be classified into six large families, which are similar to the functions of the human body:

Human system	Robotic system	Functions
The brain	Embedded processors	They have operations management functions. Example: Industrial microcontrollers
Skin, nose, ears, taste buds	Sensors	They make it possible to capture tactile, light or sound information.
The eyes	Vision systems	They work with optical signals, able to "see". Example: a webcam.

Arms, hands	Effectors	They perform all functions of handling or supporting tools: pliers, drills, poles, hammers, brooms, etc.
The feet	Transport systems	They use mechanisms related to movement: wheels, feet, wings, propellers, rockets, etc.
Scientifically unidentified in humans!	Telecommunications systems	They are used to communicate or act at a distance. Example: telephone, Internet, fax machine.

Table 1-1 robots main component

1.5.2 Embedded processors

The processor is the robot's equivalent of the brain. It controls, decides, directs and interprets programs and commands actions. Computers, chips with memory, computer systems are processors. When these devices are tiny, they are called by microprocessors [8]

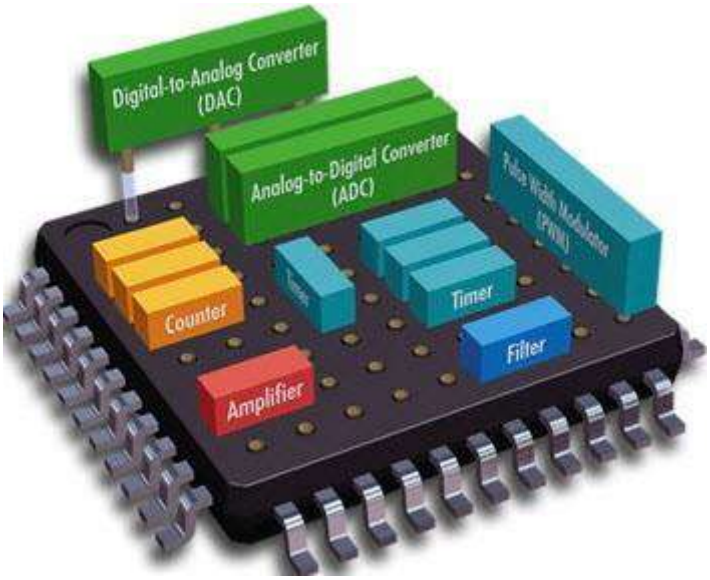


Figure 1- 3 embedded processors

The human brain must demonstrate wonders of creativity and logic in order to construct a space home such as the space station. Today, though, he is no longer

alone. Supercomputers perform the most difficult computations and run high-speed algorithms that drive a variety of robotic devices. The latest robotic devices are so little that they are almost undetectable! These Nano machines will soon enable the construction of microscopic factories and robots that can swim through arteries and repair them! As a result, the size and weight of computer interfaces are shrinking, resulting in significant space savings. These processors' architectural styles differ based on the function and application field. These processors' architectural styles differ based on the robot's purpose and field of use. We offer a list of the most widely utilized processors:

1.5.2.1 DSP processors

Mainly used in digital signal processing. DSPs are used in most real-time digital signal processing applications. Example: Robot controlled remotely via a WIFI connection.

1.5.2.2 ARM processors

These are processors with RISC architecture. ARM processors are among the dominant processors in the embedded computing market, particularly in the mobile phone and tablet sector.

1.5.2.3 Microcontrollers

A microcontroller is in the form of an integrated circuit bringing together all the elements of a microprocessor-based structure. This is generally, what is inside such a component:

- A microprocessor (C.P.U)
- Data memory (RAM and EEPROM)
- Program memory (ROM, OTPROM, UVPROM or EEPROM)
- Parallel interfaces for the connection of inputs / outputs
- Serial interfaces (synchronous or asynchronous) for dialogue with other units
- Timers to generate or measure signals with high temporal precision

Among the printed circuits in which one can find microcontrollers, and which are widely used in robotics, one can quote the Arduino modules.

1.5.2.4 Programmable Logic Circuit (FPGA)

This type of product can combine multiple user programmable logic functions into a single circuit. It is very easy to operate using a programmer, microcomputer and appropriate software

1.5.3 The sensors

Sensors are systems that allow the robot to collect information about the environment around it. There are tactile (touch), sound, light and thermal (heat) sensors. The machine vision system is a separate version of this type of system. Sensors are very similar to our senses. In fact, our hands, which can touch and feel heat, our ears, which can hear, our eyes, which can see, and even our nose, which can smell, are excellent examples of sensors. Our senses pick up sensations and transmit them to our brain, our "processor". You can see that the humans really designed the robot to look like them… sort of! Here is an overview of the types of sensors that can be found in the robotics industry:

	the most used sensors
Inductive	Produce a magnetic field oscillating in the axis of the sensor. This field is generated by a system consisting of a salt and a capacitor connected in parallel. When a metallic object enters this field, there is disturbance of this field, attenuation of the oscillating field.
Capacitive	Proximity sensors that detect metallic or insulating objects. When an object enters the detection field of the sensitive electrodes of the sensor, the frequency of the oscillations changes along with the coupling capacity of the capacitor.
Photoelectric or optical sensor	Consists of a light emitter associated with a receiver. The detection of an object is done by cutting the light beam
Position sensor.	These are contact sensors. They can be equipped with a roller, a flexible rod, a ball. The information given by this type of sensor is of the all or nothing type and can be electric or pneumatic.

ILS Sensor (Soft Blade Switch)	An ILS sensor is a proximity sensor made up of a flexible blade sensitive to the presence of a moving magnetic field. When the field is under the blade, it closes the circuit contact causing the sensor to switch. This sensor is putted directly on a jack, which make it possible to detect other positions than extreme positions. To use this type of sensor, it is necessary to use a cylinder comprising a magnet on the piston.
Liquid leakage sensors	Leak sensors are contact sensors. Contact with the object to be detected can be made either by a flexible rod or by a ball. To be able to function correctly, these sensors must be coupled with a relay for leakage sensor. The sensor is supplied with pressure by the relay. The air can then escape from this sensor through an orifice provided for this purpose. When the ball or the flexible blade moves in its housing, it closes the air evacuation orifice and the relay for leakage sensor has been triggered and emits a signal at industrial pressure.
Temperature sensor	pyrometer, thermometer, PT100 probe, thermocouple, thermistor ...
Pressure sensor	Bourdon tube, aneroid capsule, piezoelectric, vibrating wire, barometer, hypsometer ...
Light sensor	photodiode or phototransistor, photographic sensor, photoelectric cell ...
Flow sensor	Turbine flowmeter, oval impellers, orifice plate, Pitot tube, vortex flowmeter, flowmeter, electromagnetic, Venturi flowmeter, ultrasonic flowmeter, ion flowmeter, mass flowmeter ...
Current sensor	Hall effect current sensor, Shunt ...
Sound sensor	microphone, hydrophone ...

Table 1- 2 most used sensors

1.5.4 Different Types of Sensors (9)

1.5.4.1 Vision systems

Machine vision systems, like the human eye, collect optical signals. They can "see" other parts of the electromagnetic spectrum, such as microwave and infrared, unlike our eyes.

For example, the Canadian Space Vision System, on board shuttles and the International Space Station, provides real-time data on the orientation, location and position in space of an object. Its precision is such that it can tell if the object is moving forward, backward or turning, using synthetic visual cues, since in an environment like space, there are no natural cues to identify where the object is up and down.

Among the related disciplines that allow us to extract information or from a series of images we have:

1.5.4.1.1 Pattern recognition

The problem that pattern recognition seeks to solve is to associate a label with data that can be in the form of an image or a signal. Data may be given the same tag; this data is the achievements or copies of the class identified by the tag. For example, the sound / a / uttered by different speakers leads to different signals but these differences are not significant from the point of view of sound identification, these signals are realizations of the class / a /. Likewise, the handwriting of the character A varies from one writer to another, but the reader will identify the character A for each of these implementations.

General methods have been developed in pattern recognition to automatically extract information from sensitive data in order to characterize pattern classes (learning) and automatically assign data to these classes (recognition). The implementation of these general methods for particular problems leads to the introduction of the notion of recognition process, which raises the question of the integration of the methods of pattern recognition in a system, which aims to recognize patterns.

Along with work on recognition methods, image processing, computer vision, and speech processing were developed. These fields have focused the problem of recognition on specific data, but on the other hand, they have made

it possible to situate recognition in a larger process of image interpretation or speech understanding involving specific levels of perception and knowledge to the field.

1.5.4.1.2 Industrial vision

Industrial vision can have used at the level of production chains in order to control the production rate or even manage the flow of objects at the level of these chains. Furthermore, machine vision can be used in non-deterministic robotics where the machine must make a decision according to the events with which it is confronted.

Among the applications of computer vision in the field of robotics, we can mention:

- obstacle avoidance
- 3D reconstruction
- unstructured / hostile environment
- real-time control

The vision system depends on the field of application, the physical environment and the functions of the robot.

Physical phenomenon	Measured quantity	Sensor
Emission and reflection of visible light	Reflectance, luminance...	CCD, CMOS.
Infrared radiation	IR luminance (heat), ...	Bolometers, ...
Ultrasonic-echo	Distance, tissue density...	Ultrasound, sonar,
Magnetic resonance	Presence of a chemical element ...	MRI, NMR
Electromagnetic echo	Distance, surface secularity	Radar, SAR

X-ray absorption	Tissue density	X-ray, tomography, ...

Table 1- 3 Physical phenomena, image and sensors

1.5.4.2 Effectors

In the human body, effectors are the messengers who react when one of the senses (sensors), asks for an action. In robotics, effectors "perform" the "manual" tasks requested by the user using their tool-endings. Example: Manipulator arm.

1.5.4.3 Locomotion systems

To move from room to room in the house, you have the choice of walking, crawling, jumping, or a multitude of other ways. When building a robot, it is important to determine how it will move. Some robots have wheels, like tractors. The rest are part of an assembly line, which means they stay in one place while the objects that are made, or repaired, move on a conveyor belt.

1.6 Applications domain

The applications of robotics can be classified into three broad categories namely: intervention, professional service and personal robotics. (10)

1.6.1 Intervention robotics

Remotely operated robots (operated remotely) generally characterize intervention robotics through direct controls (joysticks, master arm and other organs physical or virtual orders), or orders by high-level orders for carry out and chain tasks ("go to such and such a position", "take this designated part on a screen" …). The operator is therefore systematically in the robot's control loop in order to interact and help him achieve his mission according to changes in the environment material and human. Intervention robotics are generally used to perform tasks in environments that are difficult to access or dangerous for humans (nuclear industries and military, inspection and maintenance, interventions in natural disasters, marine exploration, space exploration (mission on Mars), etc.) or when the absence of humans makes exploitation easier or more effective.

1.6.2 Professional service robotics

Its functions are mainly to relieve professionals of repetitive tasks or dangerous (in a perspective close to industrial robotics), or to assist them in interventions that

require a level of precision or qualities inaccessible to the human operator (agriculture, cleaning, construction and demolition, automatic transport of people and goods, public relations, medicine, gestural assistance, security and surveillance…).

1.6.3 Personnel robotics

Personal robotics is a field potentially as abundant as service robotics professional. Uses are possible to meet a large number of needs and expectations (carrying out domestic tasks for the maintenance of daily life, helping to people with loss of autonomy, education, games, domestic surveillance, etc.)

1.6.2 Surveillance and Security robots (11)

Overview

Surveillance and security robots have similar tactical designs, but their precise missions are vastly different. The surveillance robot's payload is used to map or search an area, whereas the security robot's payload is used to defend and safeguard an asset, such as an airport perimeter. When comparing the actions of these two types of robots, it is like comparing surveillance to a global problem to security to a local problem. The surveillance robot captures data with its electronic payload during operation.

1.6.2.1 Aerial Domain

Fixed-wing vehicles flying at a given height and monitoring broad surface regions are used in the bulk of long-distance aerial applications. As explained in Chap. 50, aerial vehicles range in size from full-scale platforms the size of passenger jetliners to small quad-rotors, vertical take-off and landing vehicles, and micro flapping wing aircraft. Sensors that capture surveillance data include electro-optical (EO), infrared (IR), and synthetic aperture radar (SAR). Although a fixed-wing aircraft can be utilized for security, rotorcraft platforms (particularly quad-rotors) are the mobility of choice due to their hovering capability. Weight restrictions, such as sensor payload weight and vehicle flight time, are a shortcoming of rotorcraft platforms. Reynolds number, wing lift-to-drag (L/D) ratio, Breguet range analysis, vehicle endurance, and vehicle aspect-ratios are all important factors to consider while designing an aerial vehicle. When using satellites or other UAVs as a communication repeater, communications between

the aircraft and the ground control station are direct line-of-sight or over-the-horizon.

1.6.2.2 Ground Domain

Ground vehicles are either custom-built or modified commercial or military vehicles. They come in a variety of sizes, from car-size to desk-size to shoebox-size, like the Dragon Runner mentioned in Chap. 48 and maybe walking as stated in Chap. 65. Surveillance data is collected with the help of an EO, IR, or rangefinder. Vehicle steering modes, propulsion system (wheeled, track, legged, or hybrid), range, suspension, and draw-bar pull performance are all important ground design restrictions. Because the bandwidth of the common packet-radio used for communications is restricted, ground robots would benefit from an autonomous RSTA capability (RSTA: reconnaissance, surveillance, and target acquisition).

1.6.2.3 Surface Water domain

Surface vehicles are either custom-built or retrofitted from an existing boat, such as a rigid-hull inflatable boat (RHIB). They come in a variety of sizes, ranging from a little jet ski to an 11-meter RHIB. Surveillance and security robots on the surface of the water are still in their infancy. A radar could be used for surveillance, data collection, and robot security, with a mix of radar and EO sensors. Vehicle speed, range, and draft and beam diameters for flotation are all important surface water design restrictions. When optical approaches fail and water features are indistinguishable, surface navigation requires GPS for localization.

1.6.2.4 Underwater domain

Unmanned underwater vehicles (UUVs) range in size from small, man-portable platforms to vehicles with a diameter of over 10 meters. In terms of endurance and sensor payload weight capacity, the larger vehicles have the upper hand. Sonar (side scan or other) is the payload sensor that collects surveillance and navigation data. Although tethered UUVs account for the bulk of operating UUVs, untethered vehicles are more common in research (better known as autonomous underwater vehicles or AUVs). The Reynolds number is one of the most important underwater design limitations. Number, buoyancy,

endurance, pressure, and whether or not they are attached are all factors to consider. Connecting undersea is a challenge.

1.6.2.5 Space domain

By definition, spacecraft are robotic. During crucial occurrences, there is a mix of onboard automation and controlling from the ground. Surveillance spacecraft range in size from microsatellites (50-100 kg) to standard surveillance-scale spacecraft (about 15 000 kg), with high-definition cameras and SAR as common payload sensors. Security satellites defend assets on the ground, and the capacity to identify and track objects from orbit is critical for averting attacks, whether real or imagined. Weight, power consumption, thermal cycling, surviving launch stresses, and working at cryogenic temperatures are all important design restrictions.

1.7 Challenges (12)

Autonomous cars, delivery drones and surgical operations: robots will soon be part of our daily lives. All sectors are preparing for this new revolution, including private security. A number of companies have already bet on the robot market to carry out rounds and doubts.

1.7.1 Missions for robots in surveillance and security

Modern robots are mobile devices with a battery life of several hours and operational in all weathers. What sets them apart from other robots, such as mine clearance machines, is that they do not need a pilot.

Without any human intervention, they know how to avoid static obstacles (post, barrier, etc.) but also dynamic obstacles, such as cars or pedestrians. With these qualities, the robots can fulfill missions of rounds and raising of doubts on site. Capable of driving on almost any terrain, including sloping or muddy, they carry PTZ type cameras (with pan, tilt and controllable zoom functions), and possibly remote calling means, such as loudspeakers.

1.7.2 Strengthening robots for site security

For example, the robot performs its fence verification circuit and, if an alert is triggered, it automatically moves to the physical doubt spot. He arrives on the scene quickly and intervenes.

As a result, the site is always "squared," as the robots may work 24 hours a day, seven days a week.

In fixed camera systems, a small fleet of robots makes monitoring more dynamic and less frozen. The robots can be re-programmed at any moment to adapt to a circumstance, such as labor, a special event, a reorganization, a video escort, and so on [13]

1.7.3 The collaboration between the security guard and the plane

At this point, robots are unable to "interpret" the images captured by their cameras. They can't tell whether removing doubt is a good thing or a bad thing, let alone decide whether or not to intervene.

The video stream delivered by the robot clears the doubt for the remote monitoring operator or the security guard stationed at the local security post. He is the one who implements the instructions' measures, such as strobes, audio messages, synthetic DNA projection, and other remote interpellation techniques on board the robot.

The robots provide the images, but it is the humans who analyze them and make the decisions. This relationship between humans and machines has a name: collaborative robotics, also called cobotics. In addition, that is the current trend for bots entering the private security industry.

Chapter 2:

Intelligent Surveillance Robots - State of Art

2.1 Introduction

We recognize that the state of the art component is critical in any research topic, as a result, it plays a critical role in deepening and solidifying our investigation so that the outcomes are based on a variety of works and credible sources.

The stability of cameras in autonomous mobile surveillance robots, as well as the quality of captures taken at the time of detection, is a key issue that is now a hot topic in the field of mobile surveillance robots. As a result, we ran across problems while investigating current projects because robotics is evolving at a rapid pace, therefore, we ran into difficulty while looking for current work because there are not many studies that address these issues.

In this chapter, we will first talk about the surveillance domain going through technical issues. In the second part of this chapter, we will share the literature reviews as well as the different approaches and solutions proposed. At the end, we will discuss the different results obtained in the old works in order to conclude that will help us to implement and complete the following chapters.

2.2 Systems service

In the previous few decades, technology has become increasingly important in our lives, the evolution of the role of service robots is also noteworthy. In general, the term service robot refers to robots that provide useful services to humans and equipment, excluding manufacturing operations [14]. Service robots are now commonly found in many environments.

Surveillance robots have gained in popularity in recent years, primarily in public settings to help with property and people safety and protection. In the field of surveillance and security robotics, the technology integrated in recent robots allows for remote observation, detection, recognition, monitoring, and analysis of behavior, thereby saving the security agent unnecessary trips.

2.2.1 Medical services

Industrial robotics mainly dedicated to manufacturing processes has recently used the technology of its robot arms for applications outside the factory. Since robots in surgery industry are based on surveillance in many variant tasks, This “service robotics”, and more particularly its advanced component, medical robotics (Dario et al.,

1996) has greatly modified the issue of the security of robotic systems [15]. While the safety problems of industrial robots essentially stemmed from failures of protection systems (barriers, fences, etc.), and the human operator only entered the workspace for maintenance or programming operations, the service robotics requires taking into account the physical proximity and close collaboration between humans and robots.

As the functions and autonomy of service robots develop, the urgent need to improve surveillance and security systems becomes even more pressing. Thus, Robodoc, a medical robot designed to replace the head of the femur at the level of the hip (Pransky, 1997; Cain et al., 1993) [16], performs the cutting and preparation of the femoral cavity in total autonomy after the operation is planned. Furthermore, telemedicine (remote medical) systems are now being developed, allowing the robot to be controlled remotely by professionals who are positioned far away from the patient.

Several research efforts based on arthroscopy are attempting to minimize surgical operations by miniaturizing instruments and utilizing endoscope guidance. Miniature robots (or micro-robots) could meet this demand, allowing hitherto impossible operations, such as sophisticated heart or brain operations, to be performed.

Despite the fact that these principles have been investigated for some years in major industries such as aeronautics and nuclear power, the uniqueness of medical robotics necessitates a re-examination of these ideas, In order to analyze and accord the concept of anatomy and safety inherent in robots, it seemed fundamental to us to go back to basics, and to understand the mechanism of occurrence of an issue in any type of surveillance robotic system.

An autonomous surveillance robot such as a medical systems, it is important to take into account the state the system is in and the environmental conditions when defining a hazard. These considerations come close to the definition given for computer systems by Leveson (1995), where the hazard is defined by "a state or a set of conditions of a system (or of an object), which, coupled with other conditions of the system (or object) environment will inevitably lead to an accident”.

2.2.2 Home services

The future of smart homes points clearly towards the ambient intelligence paradigm [4]. We expect to build an intelligent environment that discovers and adapts itself automatically to the user's needs. In this environment, service robots are completely integrated in the home and it is easy to imagine scenarios in which robots and smart home systems cooperate. For example, an autonomous mower would only perform its daily tasks if it is not raining. Another example could be to use surveillance robots to complement the information from the intrusion sensors. Unfortunately, the road toward ambient intelligence is full of obstacles, one of the most important ones being the lack of interoperability. Nowadays, multiple heterogeneous electronic devices coexist in homes but most of them are independent and difficult to integrate with other devices.

The requirement for middleware to connect disparate devices in a network is not new. Several attempts have been made to standardize how disparate systems can be integrate [17]. The Common Object Request Broker Architecture (CORBA), which dates back to the early 1990s, was the first significant attempt to handle this problem in a systematic fashion. CORBA is a networked architecture for integrating objects regardless of their hardware, operating system, or programming language [18]. Many different solutions have been presented since the first definition of CORBA.

2.3 Technologies enablers

Sensing, data collecting, mobility (optional), navigation, communication, control, computer vision, and a preplanned response as a security action are all required for robot surveillance and security. Acceptable reactions range from alerting a human guard to immobilizing the threat to even using a weapon to eliminate the threat. This application necessitates a plethora of essential technology. We will talk about mobile navigation in the next chapter, payload sensors, relevant algorithms, and the human–robot interface at the operator control console in this part.

2.3.1 Algorithms for Detection and Tracking

Reconnaissance, surveillance, and target acquisition are all significant aspects of surveillance technology (RSTA). This subject is also linked to intelligence, surveillance, and reconnaissance (ISR) as well as automatic target recognition (ATR) (ATR). ATR, RSTA, and ISR are classic challenges in the military for identifying and

classifying environmental activities of relevance [19]. During surveillance, the user has the option of acquiring a target at a specific location, searching an area or sector for stationary or moving targets, performing a panoramic reconnaissance of an area or sector, initiating fire control, or manually controlling its sensors by a human operator to acquire surveillance imagery as depicted, If the sensor and the target are both stationary, for example, a maximum average-correlation-height technique, in which a bank of linear correlation filters is adjusted to respond to the presence of a given target object by producing a peak at its corresponding location, can be quite effective. When performing a stationary target search, the platform is told to look for targets in a certain area using stationary target detection and recognition algorithms.

These algorithms can recognize both stationary and moving targets, although moving target detection does not take into account the robot's velocity. The majority of visual surveillance applications that use EO/IR sensors are interested in moving things in the scene. When events of interest occur in the scene, the behaviors of moving objects must be watched, and appropriate flags must be raised. To assist with the surveillance work, the mobile platform must be regulated. As a result, the surveillance task's objectives and the associated real-time computing limitations provide tough hurdles in developing highly reliable yet computationally efficient surveillance systems.

As a result, the surveillance task's objectives and the related real-time computation limitations provide tough hurdles in developing highly reliable yet computationally cheap detection, classification, and correlation algorithms.

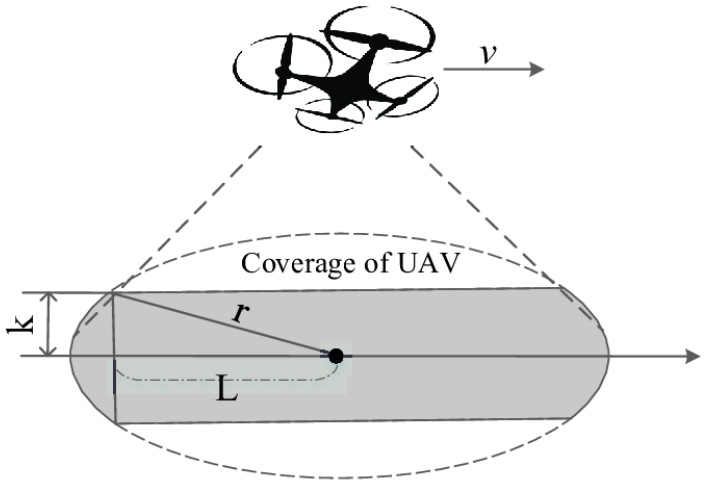


Figure 2- 1 Coverage analysis of UAV-based aerial base station

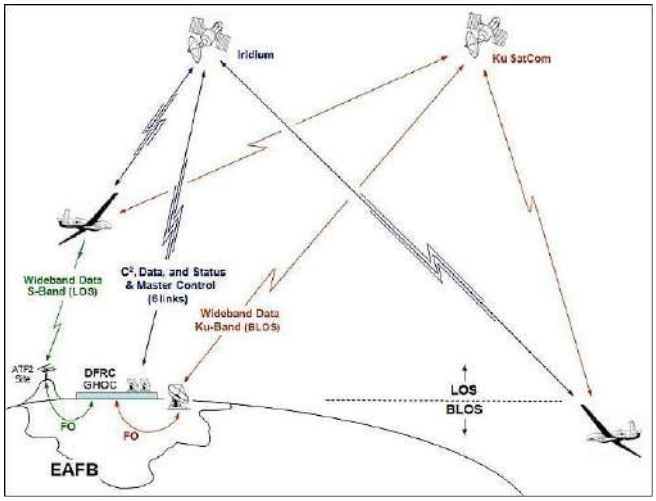


Figure 2- 2 overview of the global Hawk communications architecture

2.4 Investigative Study

There are several active areas of robot research, such as being able to provide high-quality imagery from a mobile platform, that pose a number of obstacles in addition to enabling robotic surveillance and security systems. Poor environmental conditions, data link degradations, Automatic target recognition, and bandwidth limits can all degrade the quality of video images. Poor lighting at dawn, dusk, or night, the existence of shadows, target occlusion, and inclement weather are all examples of atmospheric variables.



Figure 2- 3 automatic target recognition

2.4.1 Resolving the Data Processing Issue

With all of the useful information provided by UAVs comes the challenge of sorting through it all and finding actionable data. The military is dealing with a Big Data issue. One manual solution to the problem of data explosion is to tag the data, store it, and retrieve it when needed. Sadly, this information would be out of date. Data fusion is the use of techniques and software to combine data from multiple sources and analyze the data in order to make it useful to the end user.

Wide area surveillance is a future technology that is based on a new sensor system called Gorgon Stare, which is a video capture technology that uses a spherical array of nine to twelve cameras attached to an unmanned aerial vehicle (UAV). Gorgon Stare requires a system of tagging and incorporating metadata to be fully effective with so many sensors. According to early reports on Gorgon Stare's development, it has deficiencies in its IR performance, numerous interoperability issues, a lack of sensor stability, and reliability issues. As the program matures, these issues will be resolved. Unfortunately, the new sensor system is still limited by the human inability to process the information gathered from multiple cameras or rely on advanced automatic processing techniques to fuse the information into a coherent picture.

2.4.2 Human activity detection in Surveillance

The problem of tracking and understanding human behavior using computer vision is a critical tool for surveillance and security operations. This problem, at its most advanced level, attempts to recognize human behavior and understand intent and motive from visual observations [21] even for humans, this is a difficult task, and misunderstandings are common. Human motion recognition, surveillance, tracking, and activity detection are all subdomains of the problem.

The majority of these human activity applications necessitate the automatic recognition of high-level activities, which are made up of several simple (or atomic) acts performed by individuals, as seen in fig4. The purpose of human activity recognition is to use a succession of image frames to automatically interpret ongoing activities from EO/IR sensors.

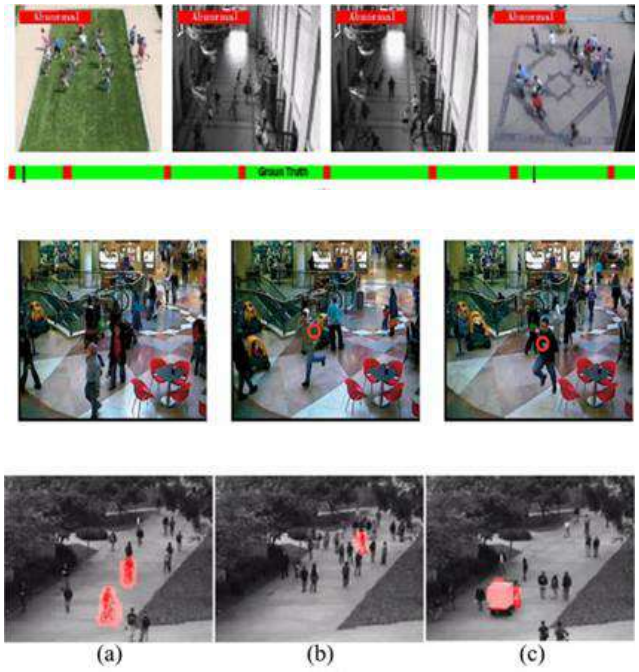


Figure2- 4 Monitoring individual and group human activities

2.4.3 Security Identification Using Facial Recognition

In order to carry out a successful security robot assignment, it will occasionally come across people who must be classified as either friends or foes. Face recognition is essential for making such a conclusion [22]. The majority of today's face recognition algorithms fall into one of two categories: image template-based or geometric feature-based. The template-based approaches compute the correlation between a face and one or more model templates to estimate the face's identity. The geometry feature-based methods, on the other hand, examine explicit local facial characteristics and their geometric correlations. Face recognition is a two-step process that involves first identifying a face and then recognizing it. The most important procedure involved, according to top researchers, is the accurate identification of human faces in arbitrary settings, followed by face recognition. When a person's face can be precisely located in any scenario, the recognition stage determines whether the individual is a friend or an adversary. Algorithms are utilized to figure out how to tell a simple face apart from the rest of the surroundings.

Facial recognition has a number of distinguishable markers when it comes to recognizing faces, with different peaks and troughs forming facial features (Fig5). These characteristics are measured by a variety of methods:

- Distance between the eyes

- Width of the nose
- Depth of the eye sockets
- The shape of the cheekbones
- The length of the jaw line.

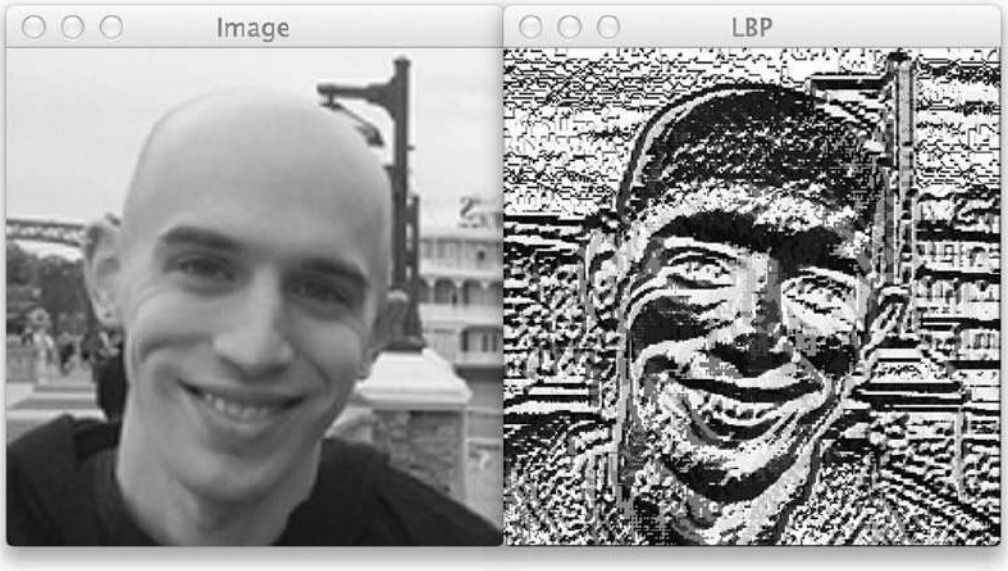


Figure 2- 5 Local binary patterns with python & OpenCV

2.4.4 Images analyzed in real time to "remove doubts

Image analysis aids, alert software on smartphone or tablet, decision support platform ... so many tools that allow companies to improve the efficiency of their agents' rounds and to men to secure their trades. The Ile-de-France Company Trackforce, which manufactures web and mobile solutions for private security professionals, has designed a smartphone allowing the agent to have access to the instructions of the site to be monitored, to schedules, to key management, to rounds, to make its reports. It has a GPS and a sensor that detects abnormal signs. Among the tools in full explosion: thermal cameras, able to detect the slightest anomaly over a hundred meters, even during the night, and generate an alert. “They cost 5,000 euros four years ago, the price has been halved,” says Servan Lépine, CEO of Excelium, specializing in digital solutions [24]

All the equipment is connected to an interface, which alerts the agent on his smartphone or on his security PC. At the heart of the chain, more and more powerful algorithms which analyze the images, and allow the "removal of doubts". “The algorithms will be capable of finer and finer analyzes: for the moment, only 5% of the

risk information given by customers is processed", describes Servan Lépine. Foxstream publishes software specialized in video analysis. "The precision of our tool lies in its ability to detect as many dangers as possible while avoiding false alarms", explains its director Jean-Baptiste Ducatez. A detail that matters

Video surveillance systems are increasingly used in different fields, from the domestic to the commercial environment. Current systems are being improved and complemented with new elements and functionalities. This paper proposes the design of a video surveillance robot based on Raspberry Pi with the abilities to perform tasks of motion detection, send video on real time, fire detection and also, the possibility of control it remotely from the Internet. In order to check the information received from the robot, as well as the video sent, a client application has been developed to any device with an Internet connection. In addition to this, in order to protect the information obtained by the robot, a secure system is proposed, which uses different security mechanisms to achieve this goal. [25]

2.5 Popular surveillance robots

They patrol establishments and warehouses, are silent, autonomous and work 24 hours a day, even at night. Equipped with sensors, infrared cameras, capable of detecting the slightest intrusion, detecting smoke, and recording data in real time, surveillance robots have soared for two years. But they are still at the experimental stage. The e-vigilant patroller of the company Eos Innovation, despite a promising start - Parrot has invested a million euros in it - has struggled to break through. The company was put into compulsory liquidation in March 2017. It has since resumed service under the banner of U-become (ex-Econobots), the robotic entity of the Econocom group, which had already launched in 2016 a surveillance robot in the data centers called "Captain DC". The promising security sector is pushing robotics players. The American Knightscope, after the setbacks of its K5 robot which left to throw itself into a fountain, released a new K7 model last year. The patrolling robot transmits all the information collected to a center analyzing and sorting this data. Gamma 2 Robotics launched Ramsee in partnership with a large safety company, Hexagon Safety & Infrastructure. And the Chinese AnBot can even, on a signal, release a security device in case of trouble [23].

2.6 Discussion

After mentioned the most common technologies used in robotic surveillance, we have been know now what we need to integrate to build what we call **Intelligent Surveillance Robot,** the following table presents a summary of some works cited above that represent a similar representation to what we are building , they are organized according to their respective time series, All the approaches and their experimental results are listed in a concise manner, without forgetting to mention that e during our review of In the literature we have noticed that the subject itself is recent and there is not much work on the precision of camera captures, which made our investigation more difficult.

2.7 Conclusion

In this chapter we started by introducing surveillance robots, passing through their use in the robotic world, we ended up citing some recent approaches in this field with a comparison between them. In the next chapter we will see our proposed solution for this problem as well as the design and the different systems used in our work.

Chapter 3: Theoretical study and Inception

3.1 Introduction

Starting from a high level of abstraction, in this chapter we will see the stages through which we have taken to arrive at a well-defined idea, which is that of the computer-controlled (raspberry and NRF52 in our case) surveillance robot. Furthermore, since a robot can be considered a "complex system", this study phase allowed us to break down our system into a set of subsystems whose interaction would lead to the expected result. Thanks to the different mathematical models that we used, we were able to choose the main components of the robot, in this case those of the electronic and mechanical systems. The IT part when it allows us to control the robot while providing it with a certain form of intelligence, the functional analysis and the design of the computer modules of which the computer system is composed will be detailed.

3.2 Background

Our approach to the design and production of a computer-controlled surveillance robot is a personal process through which we wanted to apply a large part of the knowledge that we had been able to acquire at CERIST while exploring other scientific fields such as electronics or mechanics and much more of mechatronics.

3.2.1 Principle and functionalities

3.2.1.1 Principle

SAWS is a robot equipped with a camera a PIR sensor and can be consulted remotely via a mobile application thanks to the NRF52 module which has Bluetooth service by default, as well as the auto-balance system at the level of the camera arm which allows to keep the camera image stable through its original axes, in a fast, precise way using PID.

3.2.1.2 Functionalities

SAWS can be controlled by the user remotely in a given environment without the user being present in the same place as the robot. Indeed, thanks to the on-board camera of the robot, it can be controlled thanks to the images transmitted in real time

to the control station, so the user can make the necessary decisions based on the images received. Taking advantage of this on-board camera and wanting to open up to the field of image processing, we have included a motion detection function allowing the user to be alerted to a suspicious movement produced when the robot is stationary and when the user was not in front of his control center. We also worked in an autonomous mode. This mode gives the robot an intelligence that allows it to detect an obstacle and avoid it. Here is a summary of all the functions of the SAWS:

- Remote consultation via a mobile application
- Remote monitoring
- Motion detection and intrusion alert
- Autonomous mode thanks to an obstacle detection function and another based on a prerecorded circuit.

Figure 3.1 shows the block diagram of the whole system. The heart of the system is a single board credit card size computer known as Raspberry Pi (RPI). It is the central platform for image processing and signal alerting. An ordinary webcam with its IR filter removed captures the scene to be processed by the RPI. A Night vision camera MP illuminator circuit during night time to enhance night vision mode. The system has the capability of detecting motion of an object by the background subtraction algorithm using PIR sensor. When the moving object is detected, the system can classify it as human or smoke. If there is detection, the system sends out alerting signal in the form of sound and email to indicate fire or unauthorized invasion.

3.2.2 Explanatory diagram of the project

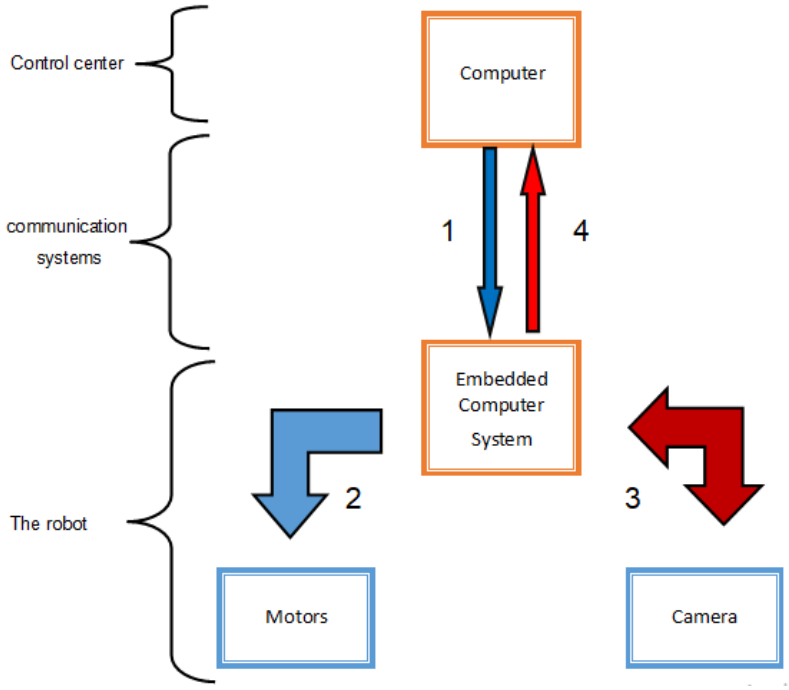


Figure 3- 1 explanatory diagram of the flow of information

Messages N ° 1: These messages are sent from the command center to the robot. They break down into two categories:

- ✓ Camera's arm control (move with certain angle θ to the left, move with certain angle θ to the left, move with certain angle θ to the right, keep the angle θ as a target angle).
- ✓ Camera control messages (Open, stream, compare to data base, capture, close...).

Messages N ° 2: These messages are the direct orders sent to the engines after processing of messages N °1 at the level of the on-board processing unit.

Messages N ° 3: These messages can be broken down into two categories:

- ✓ Orders to the camera.
- ✓ Images transmitted from the camera to the on-board processing unit.

Messages N ° 4: These messages represent the images transmitted in real time to the control center.

3.3 Detailed study of the on-board computer system

In order to be able to process requests sent from the control station, the robot must be equipped with a communication receiver allowing it to extract information from an analog signal. Then to be able to transform this information into an effective order, the robot needs a microprocessor, which, after processing the information, will transmit the order directly to the target through a specific output. Having opted for direct current motors and stepper motors, and in order to be able to control their speed, it was necessary to have an on-board system equipped with outputs allowing this kind of maneuver.

Likewise, in order to be able to process the images and send them to the control station, the robot needs a powerful microprocessor, the modulation speed of which allows high-speed transfer to have a reasonable images / second ratio.

Since our system verifies the concept of autonomy, the communication, which concerns the processing of information to obtain the order of command, will be operational, therefore the communication between the robot and the responsible agent will be by Wi-Fi and the communication between on-board microprocessors will be via Bluetooth in case of using the android application.

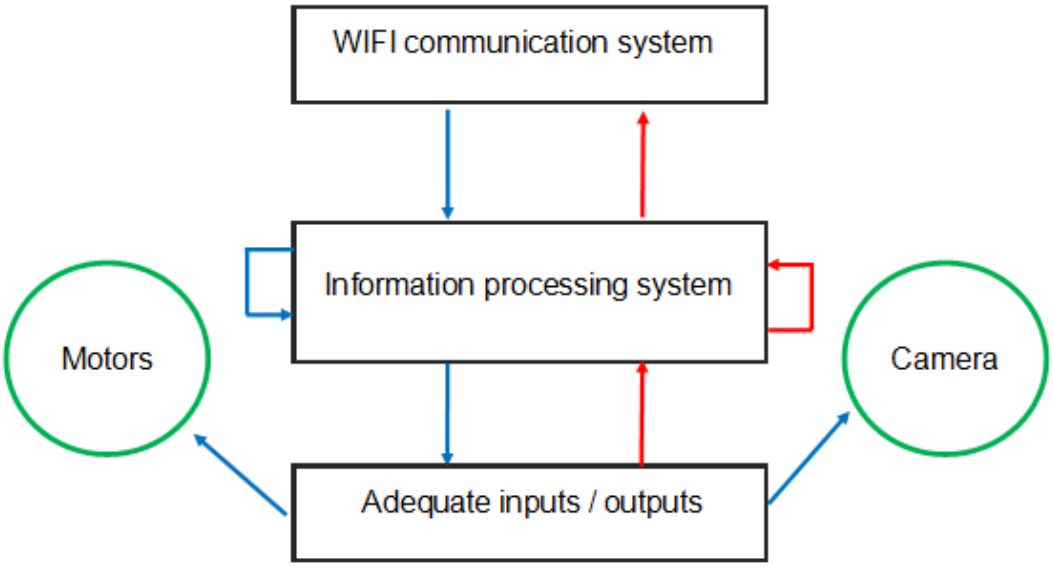


Figure 3- 2 Abstract architecture of embedded computer system

3.3.1 Autonomy of a mobile robot

The mobile robot is a physical agent performing tasks in its environment, endowed with the capacities of perception, decision and action. The goal is to allow the robot to rationally interact with its environment automatically (without human intervention). This new machine is characterized by its ability to be programmed to perform a wide variety of tasks. Implementing in particular a set of sensors and a set of actuators. Its skills in handling objects have enabled it to be integrated into industrial production lines, where it replaces humans in difficult, repetitive or risky tasks for humans**.**

The figure shows the interaction of the robot with its environment. The way the mobile robot manages these different elements is defined by its control architecture, which can possibly call upon an internal model of the environment or an intelligent strategy to enable it to plan its actions in the long term. We consider a system to be autonomous if:

- ✓ It is able to accomplish without human intervention the objectives for which it was designed,
- ✓ He is able to choose his actions in order to accomplish his missions.
- ✓ The activity of such a robot boils down to the following tasks as shown in the figure...

Perception: the robot must acquire information about the environment in which it operates through its sensors. This information makes it possible to update an environment model (hierarchical or deliberative architectures) or can be directly used as low-level behavior inputs (purely reactive architecture);

Decision: the robot must define sequences of actions resulting from reasoning applied to a model of the environment or responding reflexively to stimuli closely linked to the sensors;

Action: it must execute the sequences of actions developed by sending instructions to the actuators via the control loops.

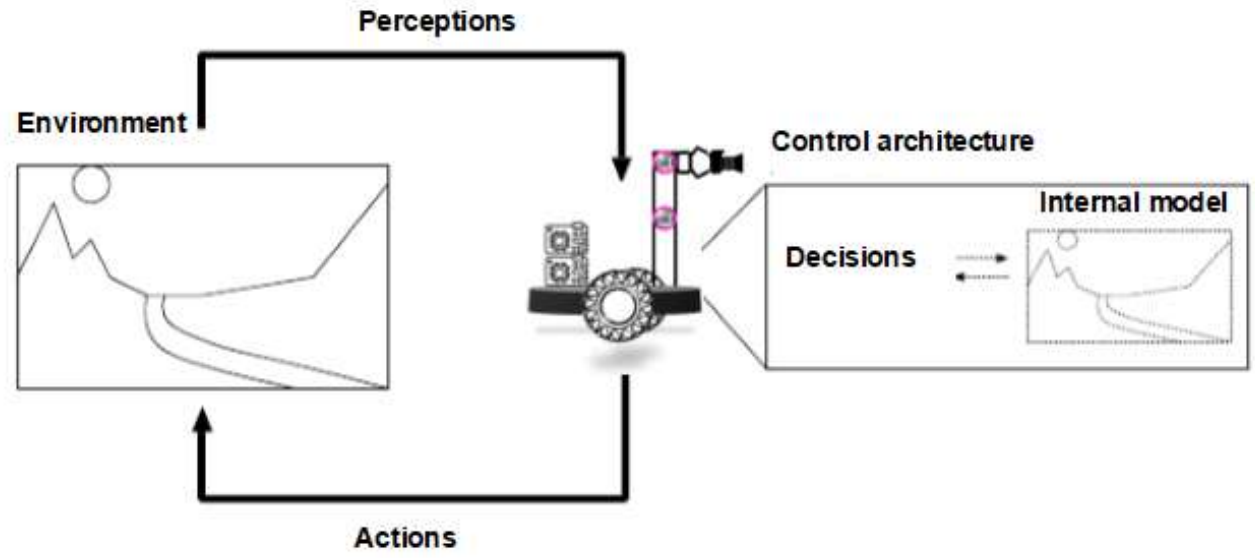


Figure 3-3 Interaction between the robot and the environment

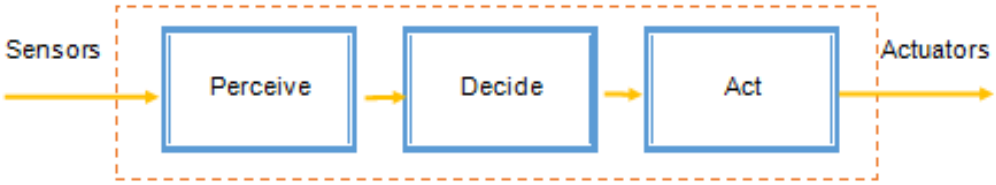


Figure 3- 4 Automatic processing steps

3.3.2 Constitution of an autonomous mobile robot

An autonomous mobile robot is broken down into three subsystems as shown in the figure 3.5:

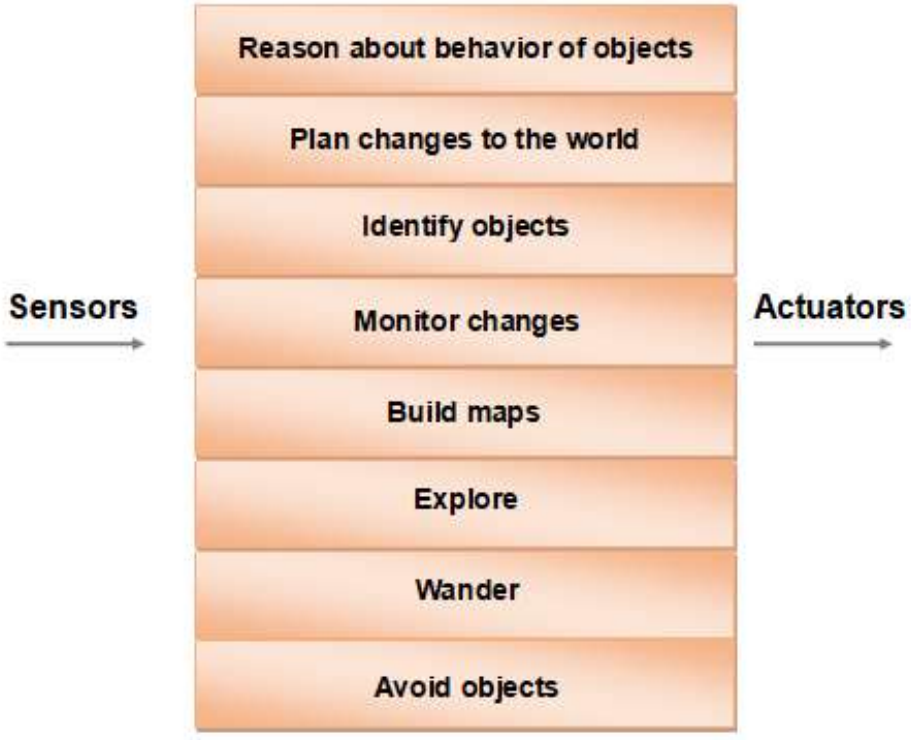


Figure 3- 5 Decomposition of an autonomous mobile robot

3.3.2.1 Mechanical structure

It brings together the mechanical and electrical elements to ensure the mobility function. The movement is achieved by combining propulsion and down force on the middle. Propulsion, closely linked to the application of the robot, is provided by various techniques (electric, thermal, pneumatic or hydraulic) depending on its size, mass and location. The environment in which the mobile operates generally determines the mode of support. There are two main types of natural media: the solid medium and the fluid medium. The majority of applications of autonomous mobile robots fall under the first case. The second, more restricted, concerns underwater robots or flying robots. We are rather interested in the first type which opens up more avenues of application. Three locomotion mechanisms are used on solid ground:

- Wheeled mobiles
- Tracked mobiles
- Mobiles with legs

3.3.2.2 Payload

The payload is the load that the robot can carry; it is significantly less than the maximum load that the robot can carry, which is directly dependent on the actuators. The mobility of the autonomous robot is not an end in itself. The movement is dictated by an action to be carried out on the environment. The payload directly relates to the robot application. This generally involves carrying either a tool (e.g. brush for the cleaning robot), or a measuring instrument (e.g. a camera for the inspection robot) or any object (e.g.: container for the cleaning robot, transport).

3.3.2.3 Command structure

The control structure is based on three modules that work independently from each other. These are the modules:

- ✓ Perception of the environment;
- ✓ Human-machine communication;
- ✓ Control.

3.3.2.4 Perception of the environment

The autonomy of a mobile robot is linked to its ability to perceive and interpret its environment. The variations of random states of evolutionary space require the robot to constantly adapt and react different from those expected when planning the movement. The perception module is broken down into several elements: the transducer, the modeling, the determination of the type of event and the decision making. The acquisition of a state of the environment is carried out either by measuring clean energy from the space of evolution, or by the reflection of energy emitted by an artificial source. The data to be processed is contained in the energy characteristics thoughtful.

3.3.2.5 Human-machine communication

The control structure integrates the aspects of communication between the robot and the task scheduler. Communication is carried out using multiple media: written, visual, sound. In fact, this communication module seems to be gaining more

and more importance today. This seems paradoxical with the principle of autonomy of our robot. In fact, the idea of the fully autonomous mobile robot seems to be losing ground. The majority of current developments, industrial or in laboratories are oriented towards autonomous functions of robots to facilitate the task of an operator. For this reason, communication with humans is an essential link. More and more user-friendly interfaces are being developed.

3.3.2.6 Command

The planning of actions and the control of movements fall into three different frames of reference. From the most abstract to the most concrete, we have spotted them: ideal world, perceived world and real world. This breakdown is classic for automatic control systems. The new element, with regard to mobile robots, is that the ideal world has a very wide field, because it may refer, possibly, not only to representations of the integrodifferential type, but also to representations and classifications of the semantic type. For example notions of corridor, rooms, etc. Thus, the ideal world in which the robot operates will be the object of at least three models, corresponding to different levels of planning. These are semantic modeling, topological modeling and geometric modeling.

3.3.3 Autonomous navigation of mobile robots

Navigating a mobile robot is a task that generally consists of finding free movement in the configuration space (working environment) without colliding with obstacles close to the robot. The configuration space is the set of parameters characterizing the position of the robot in its environment (position and orientation). This movement brings the robot from an initial configuration $q_0 = q(t_0) = (x_0, y_0, q_0)$ to another desired final $q_f = q(t_f) = (x_f, y_f, q_f)$.

Figure 3.6 presents a description of the navigation task of a mobile robot. As shown, the robot starts from an initial situation s, it must perform the movement actions, which are usually the speed and the steering angle $(v(t)$ and $a(t))$ allowing it to move towards a new situation $s(t+1)$. Navigation is achieved through an iterative process as follows:

1. At each instant t, with $t = 0,1,\ldots,k,\ldots$, the robot must measure the distances to the obstacles of the environment di and the positions: current and final: $(x_r(t), y_r(t), q_r(t))^T$, $P_g(x_g, y_g)$
2. The control system determines the appropriate control variables v_r
1. $(t + 1)$ and $a\ (t + 1)$,
2. The robot executes its actions by moving to the new coordinates,
3. Repeat the same process (steps: 1, 2 and 3) of detecting the situation and generating the actions until the final destination called goal.

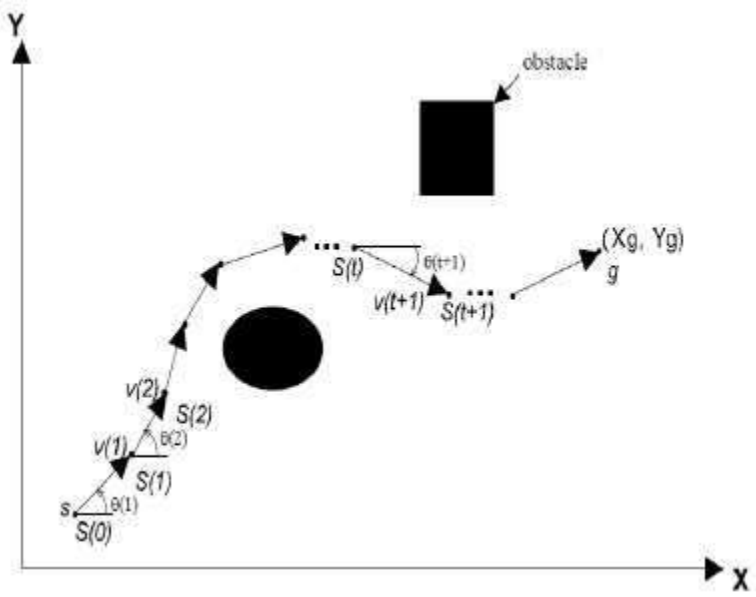


Figure 3- 6 Autonomous navigation process

To perform an autonomous navigation task, a mobile robot must implement a number of features, which we detail here:

3.3.3.1 Location

In order to perform the planned movement, the robot must locate itself in the environment. Location is the estimate of the robot's position relative to a fixed benchmark in the environment. This position estimation can be done either by measuring the movements of the robot or by measuring its absolute position in the environment.

Due to the uncertainties on the measurements useful for localization, the problem of localization is generally modeled in a probabilistic framework.

3.3.3.2 Trajectory tracking

The trajectory following consists in calculating the commands of the actuators of the system making it possible to carry out the planned movement. Since a robot is considered to be a dynamic system, state feedback control methods are used to control the system on a reference path.

3.3.3.3 Reactive obstacle avoidance

Following the planned path does not guarantee the absence of collision with existing static or dynamic objects. Obstacle avoidance is a basic behavior present in almost all movements of mobile robots.

Indeed, collisions can occur during the execution of the trajectory, due to:

- Imperfect localization,
- Imprecise plan, obstacles that were not in the environmental model used for path planning. All these elements mean that the initially planned movement which must be adapted during its execution, and those reactive obstacle avoidance strategies must be implemented. Different strategies will be adopted depending on the type of system, its speed, and the field of application.

3.3.3.4 Parking

Parking is the final phase of autonomous navigation. It occupies a special place for two reasons:

- The parking maneuver is generally a highly constrained movement which requires great precision
- The objective of a navigation mission is often to reach a specified final configuration. The success of this mission depends on the achievement of this goal.

3.3.3.5 Movement planning

Motion planning in its classical formulation is the problem of calculating a collision-free path for a mechanical system, between a given start configuration and a

given end configuration, in a geometric model of the environment. The effective motion planning methods are based on probabilistic algorithms that randomly explore the configuration space in order to characterize their connectivity.

3.3.4 Wi-Fi communication system

In order to be able to communicate remotely with our robot, it must be equipped with a communication system allowing it to send and receive data. Since we have integrated a video streaming function into our project, this communication system must offer a fairly high transmission rate. This is how we decided to use the WIFI communication protocol.

3.3.5 Processing system

To have a great computing power two possibilities were offered to us:

3.3.5.1 Embedded development kits

These are embedded solutions, generally equipped with an embedded operating system such as "Linux Debian" or "Windows". These kits make it possible to develop various applications in fields such as robotics, home automation or transport. we found a development kit equipped with an SDK processor and a WIFI transmission system, a default input to connect to a camera as well as several PWM outputs very useful to operate the motors (we will explain their principles below). It is on this solution that we focused our attention since the processor offered the necessary power to develop our various modules, especially that of motion detection. Only acquiring this kind of card requires importing it from abroad, which prompted us to look for another solution.

3.3.5.2 Laptop (preferably lightweight)

A laptop has several advantages. The first is that it offers very satisfactory computing power; it can be equipped with an integrated camera and WIFI. On the other hand, the computer does not offer the outputs to control the motors or to retrieve information already processed by another microprocessor. Choosing this option forced us to look for a system that acts as an interface between the effectors (Motor) and the processing unit (Computer). Thus a card which, with two PWM outputs and eight digital

outputs, allowed us to interface between the computer and the motors. We will study the PWM signal and see its usefulness later.

All of this guides us to suggest using a raspberry pi as a computer and Nordic NRF Bluetooth module in order to smoothly achieve the goals and proposed solutions that we have mentioned above.

3.3.6 The inputs / outputs

The flow of information through our system assumes the existence of inputs and outputs. The inputs and outputs we need are as follows:

- Analogue PWM outputs: to vary the speed of the motors
- Digital outputs: to operate the motors in all or nothing mode.

3.4 Study of robot kinematics

3.4.1 The platform

To be able to choose the engines, the on-board computer system and the necessary platform, a fundamental study using a few mathematical models was necessary. Indeed, it was not necessary to be with a card not allowing to control the motors with a variable speed, or the motors not being able to support the weight of the robot.

3.4.1.1 Motor control by PWM

It is very often necessary to vary the power transmitted to a load. For example, the intensity of a lamp must vary or the speed of a motor must be adjusted. The first idea that comes to mind is to vary the voltage or current in the load. But this requires complex electronic circuits. It is generally much easier to alternate the times when maximum power is transmitted to the load with the times when no power is transmitted.

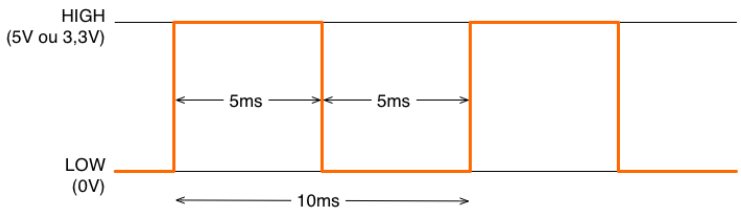


Figure 3- 7 PWM working principal

As shown in the figure, the signal is of constant period, but the duration of the active part of the signal varies. In the first part, 25% of the maximum power is sent to the load, since the signal is at "1" for 25% of the time, while it is at "0" the rest of the time. Likewise, the power goes to 50% in the middle of the path and to 75% on the last part.

The frequency of the signal will depend on the application. To control a light diode, the frequency must be greater than 100Hz, so that the human eye does not see the blinking. In this case, it is indeed the eye, which integrates the signal in order to perceive an average value. For a direct current motor, it is both the inductance of its electrical circuit and its inertia, which participate in this integration. The frequencies of the PWM signals can commonly go up to hundreds of khz. However, the higher the frequency, the greater the electrical losses at the instant of switching, and can dissipate energy in the switching elements.

3.4.2 The kinematics system

The choice of the motor that best meets our needs and that makes the robot move depends on the calculation of the necessary power that it must have.

To calculate the engine power, the kinetic energy theorem was used. This theorem translates the variation of the kinetic energy between time 0 and time t is equal to the sum of the work of the external forces. The work of a force is equal to the multiplication of the force vector by the displacement vector ...)

$$\Delta E_T = \sum_{Fexteriors}^{W} \quad (1)$$

With:

$$E_T(t) = \frac{1}{2}.\, m.\, v.\, (t)^2 \ (2)$$

In addition:

$$\sum_{Fexteriors}^{W} = \sum_{i=0}^{N} F_i . d_i W_{Fexteriors} = \sum_{i=0}^{N} F_i . d_i \quad (3)$$

Here is a simple diagram to visualize the problem:

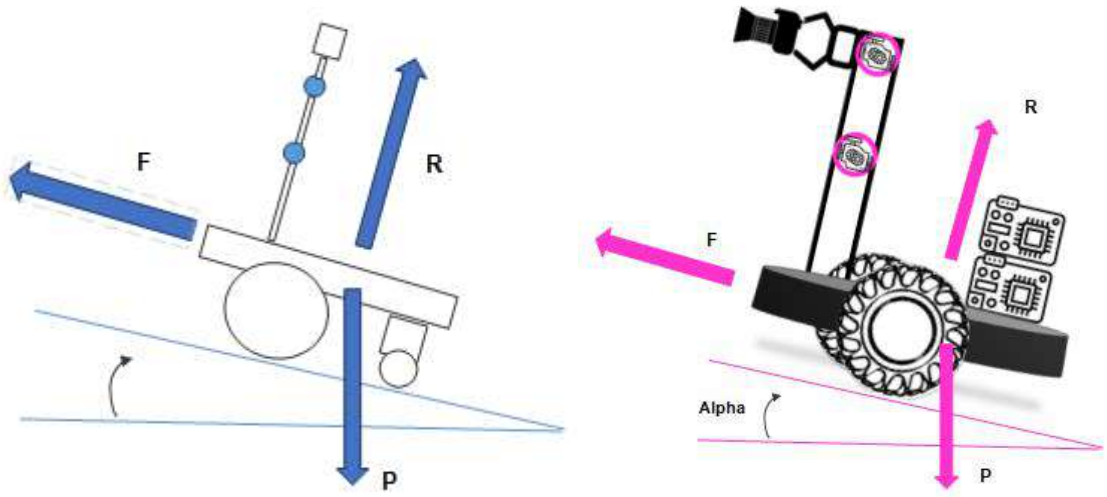


Figure 3- 8 diagram to visualize the problem

Therefore:

- The motor force which makes the robot move forward (force forwards and parallel to the ground: the robot climbs the slope). The work is positive because the force is in the same direction as the movement of the robot:

$$W = F . d \ (4)$$

The weight of the robot which tends to make it go down the slope. The angle between the vertical and the force is equal to the angle of the slope the work is negative because the movement is in the opposite direction of the force:

$$W = -m . g . \sin(\alpha) . d \ (5)$$

According to the formula, if there is no slope then there is no work on the part of this force. Conversely, the larger the angle, the more work is done, so it will take more work from the motor to move the robot forward.

Where:

$$\sum_{Fexteriors}^{W} = F.d - m\,.g\,.\sin(\alpha)\,.d\; + 0$$

In result:

$$\Delta E_T = \sum_{Fexteriors}^{W}$$

$$\frac{1}{2}.m.[v(t)^2 - v(0)^2] = F.D - m.g.\sin(\alpha)\,.d$$

$$F = m.g.\sin(\alpha) + \frac{m}{2}d.[v(t)^2 - v(0)^2]$$

Therefore, we know the force F that must be supplied by the motor through the wheels for a speed v. However, a motor provides a torque:

$$T_m = F.r$$

We can therefore calculate the power required for the motor:

$$P_{motor} = T_m \times (-)(t) = r.m.g.\sin(\alpha) + \frac{m}{2}d\,[v(t)^2 - v(0)^2]\; \times \frac{v(t)}{r}$$

$$P_{motor} = \left[m.g.\sin(\alpha) + \frac{m}{2}d[v(t)^2 - v(0)^2]\right] \times \frac{v(t)}{r}$$

The application of the numerical values according to the data corresponding to our case allows us to determine the necessary power, which our engine needs.

3.4.3 Study the dynamics of the camera's arm

Manipulators arm have variant degree of freedom robots. They are useful because they function like human arms. We can begin to understand the complex movement of human arms after defining the movement of any link manipulator. The total potential and kinetic energies of a single link system are defined and used to form the Lagrangian. The Euler-Lagrangian equation was used to define the torques applied to each link. To solve for the angle of the link relative to the positive x-axis we use PID control.

PID control is developed and considered to show how you can force the system to specific angles. We also show graphical results of the system after the PID control is applied. The purpose of this research was to allow us to gain experience with the mathematics applied to the design and analysis any multiple links on top of a moving object, we used a variety of resources including a Mathematical Introduction to Robotic Manipulation to show a visual representation of the problem and the solution, some texts on how to numerically solve non-linear equations.

3.4.3.1 Motor control by PID control

To control a robot, a drone or more generally an actuator correctly, it is often necessary to go through a servo and regulation step. PID (Proportional Integral Derivative) regulation is an effective method for your robot or drone to obey you at your fingertips!

PID control can, for example, allow any robot to roll straight or else a drone to remain stable despite external conditions.

The role of a PID correction algorithm is to improve 3 main characteristics of a system: speed, precision and stability.

For an engine for example, these elements result in a rapid increase in speed, a real speed very close to that requested and operation at the set point speed without oscillations (acceleration, deceleration, etc.).

In short, the PID is used to reduce the difference between a set point and the measured value. In our example: the error between the actual speed of a motor and the set point given to it.

To operate the PID therefore needs several things: an actuator to be controlled, a sensor to measure the desired quantity and a control organ (microcontroller for example) capable of making the calculations and interpreting the set point and sensor information.

The regulation also needs 3 parameters which are coefficients to be entered by the user. A parameter for proportional (K_p), integral (K_i), derivative (K_d) regulation.

These coefficients will have an influence on the behavior of the system: it can be fast, slow, stable, oscillating, precise...

These coefficients are to be changed according to each application which will not have the same needs but also according to each actuator which will not have the same way of behaving for the same triplet of parameters, The easiest way do we get K_p, K_i, K_d is to do it manually (by trial and error) by changing one parameter at a time!

K_p will have an influence on the speed of a motor to reach its set speed, K_i will reduce the static error (error between the requested speed and the measured speed) and $K_d$will reduce the oscillations generated.

We consider this figure 3.8 as a simple example of robotic arm with a single inverted pendulum, which explain the physical-mathematical system we created:

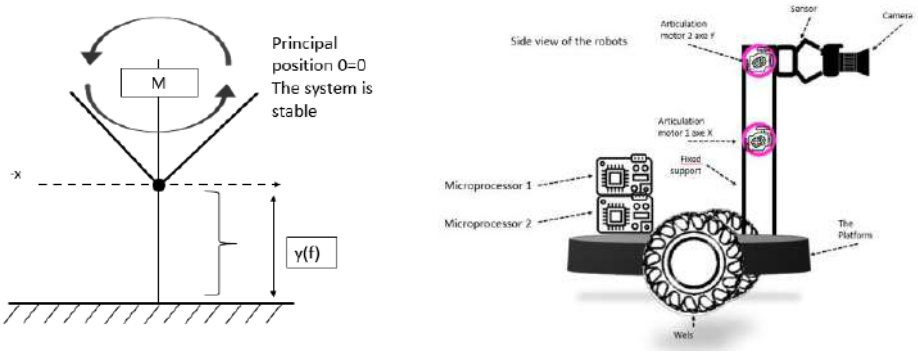


Figure 3- 9 the robot in the initial state

We consider figure 3.10 as a simple representation of the physical-mathematical study, and the figure 3.11 as the virtual study of the real robot in the two opposite cases:

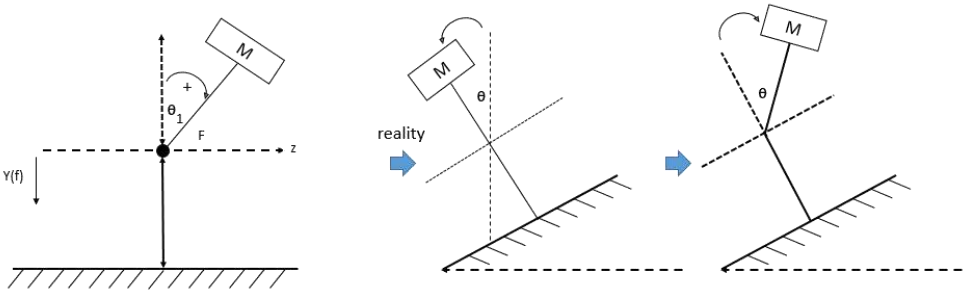


Figure 3- 10 a simple representation of the physical-mathematical study

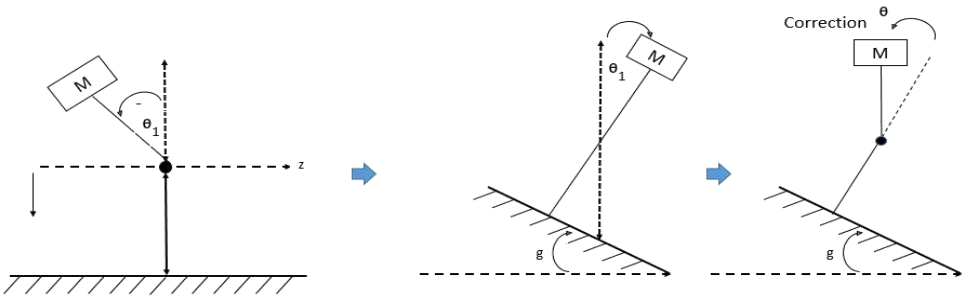


Figure 3- 11 the virtual study of the real robot in the two opposite

The system consists of 1 mass connected by weightless bars k the bars has length L. The mass is denoted by M .Let θ denote the angle in which the bars rotates about the original.

The equations for the x-position and the y-position of M is given by:

$$x = L\cos\theta \qquad \text{and} \qquad y = L\sin\theta$$

Next, we define the velocity of M as:

$$v = \sqrt{\dot{x}^2 + \dot{y}^2}$$

Where

$$\dot{x} = -L\dot{\theta}\sin\theta \qquad \text{and} \qquad \dot{y} = L\dot{\theta}\cos\theta$$

And the "*dot*" is a derivative with respect to t, i.e., $\dot{\theta} = \frac{d\dot{\theta}}{dt}$, $\dot{x} = \frac{d\dot{x}}{dt}$, and so on.

Further **Kinetic Energy** at the very basics is defined

$$KE = \frac{1}{2} M\, v^2$$

Once again this kinetic energy is based on the $x - y$ axis labeled on the first link of figure 1. The velocities are only going to occur in the $x - y$ plane. The velocity $v_i,\ i = 1,2$ is the magnitude of the xy velocity of the center of mass of the link. We have no velocities in the Z-axis because this problem had the joints fixed in a barring that only moves in the $x - y$ plane.

The equation for the kinetic energy can be written as:

$$KE = \frac{1}{2} M(\ \dot{x}^2 + \dot{y}^2\ )$$

Plugging in the velocities, we get:

$$\text{KE} = \frac{1}{2}\,\text{M}\,[(\dot{x} = -L\dot{\theta}\,\sin\theta)^2 + (L\dot{\theta}\,\cos\theta)^2] \quad = \frac{1}{2}\,\text{M}\,\text{L}^2\,\dot{\theta}^2$$

Now that we have defined the kinetic energy, we need to define the **potential energy**, PE. Further, we have to understand that this is the potential energy due to gravity of each pendulum. The potential energy of the i^{th} pendulum is: $PE_i\ \theta = M_i g h_i(\theta)$

Where h_i is the height of the center of mass of the i^{th} pendulum, g is the acceleration due to gravity constant, and M_i is the mass of the i^{th} pendulum. Therefore, the total potential energy for both pendulums can be given by:

$$PE = PE(\theta) = \sum_{i=1}^{2} PE_i\,(\theta) = \sum_{i=1}^{2} M_i \text{g} h_i(\theta)$$

And **Potential Energy,** written out, is:

$$PE = \text{M}gL\sin\theta$$

The definitions for kinetic energy and potential energy can be found in many physics texts books, these are much considered common knowledge.

Next, by Lagrange Dynamics, we form the **Lagrangian, which** is defined as

$$\mathcal{L} = KE - PE$$

From the previous contribution we got:

$$KE = \frac{1}{2} \text{M L}^2 \dot{\theta}^2$$

$$PE = \text{M}gL \sin \theta$$

Substituting the values for the kinetic and potential energies in for KE and we get:

$$\mathcal{L} = \frac{1}{2} \text{M L}^2 \dot{\theta}^2 - \text{M}gL \sin \theta$$

The **Euler-Lagrange Equation** is given by the equation:

$$\frac{d}{dx}\left[\frac{\partial \mathcal{L}}{\partial \dot{\theta}_i}\right] - \frac{\partial \mathcal{L}}{\partial \theta_i} = f_{\theta_i}, i = 1,2,$$

Where f_{θ_i} is the torque applied to the i^{th} link?

The derivations for the Lagrangian Equation and Euler-Lagrange Equation can be found in [2]. We were more concerned with using the formulas in this problem rather than going into too much in detail for these derivations.

We have:

$$\frac{\partial \mathcal{L}}{\partial \dot{\theta}} = \text{M L}^2 \dot{\theta}^2$$

$$\frac{d}{dx}\left[\frac{\partial \mathcal{L}}{\partial \dot{\theta}_i}\right] = \text{ML}^2\ddot{\theta}$$

$$\frac{\partial \mathcal{L}}{\partial \theta} = - \text{M}gL \cos \theta$$

Therefore, forθ we get:

$$ML^2\,\ddot{\theta} - (-MgL\,cos\theta) = f_\theta$$

Finally, we obtain the dynamics equations

$$ML^2\,\ddot{\theta} + MgL\,cos\theta = f_\theta$$

Solving the linear system for $\ddot{\theta}$ we get:

$$\ddot{\theta} = -\frac{MgL\cos\theta + f_\theta}{ML^2}$$

In order to solveθ, we need to solve the above second-order system of differential equations. To do this, we will reduce the system into an equivalent system of first-order differential equations.

Let us introduce new variables:

$$z_1 = \theta \qquad\qquad z_2 = \dot{\theta}$$

After differentiating:

$$\dot{z}_1 = z_2 \qquad\qquad \dot{z}_2 = \ddot{\theta}$$

Plugging in the equation for $\ddot{\theta}$ we obtain

$$\dot{z}_2 = -\frac{MgL\,\cos z_1 + f_\theta}{ML^2}$$

Thus, we obtain a system of first-order nonlinear differential equations of the form

$$\frac{d\boldsymbol{Z}}{dt} = \boldsymbol{G}(t, \boldsymbol{Z})$$

Subject to $\boldsymbol{Z}(0) = \boldsymbol{Z}_0$

Where $Z = [z_1, z_2]^t$ and $G = [g_1, g_2]^t$

$$g_1 = z_2$$

$$g_2 = -\frac{MgL\ \cos z_1 + f_\theta}{ML^2}$$

The initial conditions are given by $\boldsymbol{Z}_0 = [z_1(0), z_2(0)]^t$, where

$$z_1\ (0) = \theta(0)$$

$$z_2\ (0) = \dot{\theta}(0)$$

The above system subject to the initial condition can be solved for the unknown vector $\boldsymbol{Z}$, using, for example, the **ode45** command defined in Matlab to solve the system of differential equations numerically. This command is based on the fourth-order Runge-Kutta method.

3.4.3.2 Control design

We define control (like we mentioned above) as the ability to hold the system of two links in a particular position on a xy-plane. Having control gives us the ability to hold each link at a particular angle with respect to the positive x-axis. PID is a common control algorithm. The ***P*** in ***PID*** stands for ***Proportional control***, the ***I*** stands for ***Integral control***, and the ***D*** stands for ***Derivative control***. This algorithm works by defining an error variable that takes the position you want minus the position you are at. You get the proportional part of the ***PID*** control by taking a constant defined as ***KP*** and multiplying it by the error. The ***I*** comes from taking a constant ***KI*** and multiplying it by the integral of the error with respect to time. Derivative control is defined as a constant ***KD*** multiplied by the derivative of the error with respect to time. Below is a table describing PID control.

Below is a table describing PID control formula:

$$u(t) = k_p e(t) + k_i \int e(t)dt + k_p \frac{de}{dt}$$

- $u(t)$ = PID control variable
- k_p = proportional gain
- $e(t)$ = error value
- k_i = integral gain

- de = change in error value
- dt = change in time

Term	Math Function	Effect on Control System
P Proportional	$K_p \times Verror$	Typically the main drive in a control loop, K_p reduces a large part of the overall error.
I Integral	$K_I \times \int Verror\ dt$	Reduces the final error in a system, summing even a small error over time produces a drive signal large enough to move the system toward a smaller error.
D Derivative	$K_D \times d\ Verror\ /\ dt$	Counteracts the K_p and K_I terms when the output changes quickly, this helps reduce overshoot and ringing. it has no effect on final error.

Table 3- 1 description PID control formula

The equations of motion can be written as

$$B(q)\ddot{q} + C(\dot{q}, q) + g(q) = F$$

Where

- $q = \theta$
- $B(\boldsymbol{q}) = M\ L^2$
- $C(\dot{q}, q) = 0$
- $g\ (q) = MgL\cos\theta$
- $F = f_\theta$

We can solve for some theoretical values of forces given certain initial inputs:

Solving for $\ddot{\boldsymbol{q}}$, we get

$$\ddot{\boldsymbol{q}} = B(\boldsymbol{q})^{-1}[-\boldsymbol{C}(\dot{\boldsymbol{q}}, \boldsymbol{q}) - \boldsymbol{g}(\boldsymbol{q})] + \hat{\boldsymbol{F}}$$

Where

$$\hat{F} = B\ (q)^{-1}\boldsymbol{F}$$

Thus, we decoupled the system to have the new input: $F = f$ However, the physical torque inputs to the system are:

$$f_\theta = B\,(q) f$$

Let us denote the error signals by $e\,(\theta) = \theta_f - \theta$

Where the target positions are given by: θ_f

We assume that the system has initial positions: $\theta_0 = \theta(0)$

General structure of PID controller for any input would be

$$f = K_P e + K_D \dot{e} + K_I \int e\, dt$$

In our case:

$$f = K_P\big(\theta_f - \theta\big) - K_D \dot{\theta} + K_I \int e(\theta)\, dt$$

Where θ_f is given constant

The complete system equations with control would be

$$\ddot{q} = B\,(q)^{-1} - \boldsymbol{C}(\boldsymbol{q}, \boldsymbol{q}) - g\,(\boldsymbol{q})] + \hat{F}$$

$$\dot{f} = -K_P \dot{\theta} - K_D \ddot{\theta} + K_I\big(\theta_f - \theta\big)$$

Where

$$\hat{F} = f = K_P\big(\theta_f - \theta\big) - K_D \dot{\theta} + K_I \int e(\theta)\, dt$$

Note that the actual physical torques

$$f_\theta = B(q)\, f$$

In order to apply all controls of Proportional-Derivative-Integral actions, we add a dummy state is added for each angle to resemble the integration inside the computer.

$$x = \int e\,(\theta)dt \;\; \Longrightarrow \dot{\mathrm{x}} = \; \theta_f - \; \theta$$

The complet equations are :

$$\left\{\begin{array}{c} \dot{\mathrm{x}} = \; \theta_f - \; \theta \\ \ddot{\theta} = B\,(q)^{-1}\,[-C(\dot{q}\,,q) - g(q)] + \left[K_P\left(\theta_f - \theta\right) - K_D\dot{\theta} + \; K_I x\right] \\ f_\theta = B(q)\left[K_P\left(\theta_f - \theta\right) - K_D\dot{\theta} + \; K_I x\right] \end{array}\right\}$$

To discretize the above differential equations in time, we transform them into a system of first-order ordinary differential equations. To do this, we define new variables as follows

$$z_1 = x \qquad z_2 = \; \theta \qquad z_3 = \; \dot{\theta}$$

After differentiating, we get

$$\dot{z}_1 = \dot{x} \qquad \dot{z}_2 = \; z_3 \qquad \dot{z}_3 = \; \ddot{\theta}$$

Where $\dot{z}_2$

$$\ddot{\theta} = B\,(q)^{-1}\,[-C(\dot{q}\,,q) - g(q)] + \left[K_P\left(\theta_f - \theta\right) - K_D\dot{\theta} + \; K_I x\right]$$

The new system of differential equation is

$$\dot{z}_1 = \; \theta_f - \; z_2$$

$$\dot{z}_2 = z_3$$

$$\dot{z}_3 = \; -\frac{MgL\cos z_2 + f_{z_2}}{ML^2} + K_P\left(\theta_f - \; z_2\right) - \; K_D z_3 + K_I\, z_1$$

The initial conditions are given by $\boldsymbol{Z}_0$ = [$z_1(0)$, $z_2(0)$, $z_3(0)$] ^{t}, where

$$z_1(0) = x(0)$$

$$z_2(0) = \theta\,(0)$$

$$z_3(0) = \dot{\theta}\,(0)$$

The above system subject to the initial condition can be solved for the unknown vector $\boldsymbol{Z}$, using, for example, the **ode45** command defined in Matlab to solve the system of differential equations numerically. This command is based on the fourth-order Runge-Kutta method.

Once we solve for $\boldsymbol{Z} = [z_1, z_2, z_3]^t$, we obtain to torques using

$$f_\theta = B(q)\left[K_P(\theta_f - z_2) - K_D z_3 + K_I z_1\right]$$

Or equivalently:

$$f_\theta = ML^2\left(K_P(\theta_f - z_2) - K_D z_3 + K_I z_1\right)$$

The PID controller helps get the outputs, which are the final positions of M determined by the angles θ where we want it, in a short time, with minimal overshoot, and with little error.

3.5 Conclusion

This demonstration detailed the forming of dynamics equations and Lagrangian equations in order to solve for the angle of a single link manipulator. We also described how a PID controller could be used to keep the links in set positions. The solutions we came up with in this demonstration can be used to design and code control algorithms for a mobile robot with multiple number of links. These algorithms can allow you to balance upside down pendulums on a mobile robot. There could be many solutions for coding this PID control depending on what sensors are used to find the angles of the links.

Chapter 4: conception and simulation

4.1 Introduction

Given the complexity of the project and the interaction between its different components, we had to find a solution allowing us to work in parallel on the different sub-systems of the robot. This allows the project to be divided into several parts that are not closely related, or independent of each other. This modularity has saved us a lot of time and effort.

The control part consists of building a smart mobile surveillance robot, avoiding human intervention as much as possible, and retrieving the saved data remotely; thus, the control is dependent on the user/server architecture, specifically the application used on the control computer or phone, which is connected to the robot server to retrieve the data.

For three months, we thought about the functionalities to be implemented, taking into account the length of time available, we finally decided to retain the functionalities considered feasible.

Initially, our goal was limited to remote control of robot movements to validate the concept of autonomy more and more. However, there was talk of expanding the possibilities of control. We then decided not to be sufficient for our initial objective, but to add other control modes or possibilities, namely movement in autonomous mode, in a pre-recorded circuit, or by detecting and avoiding obstacles. In the latter case, the robot is moved independently of the intervention of the user.

In this chapter we will do the design starting with the presentation of components, hardware and software, the most common in mobile robotics. Subsequently, we will choose the final components that we must use to make our robot depending on the availability of means and the task to be performed. We will then explain all our development choices as well as the progress of the project. In particular, we will discuss the problems that we have encountered and the solutions that we have tried to provide in order to achieve a finished and functional prototype...

We have decomposed our project into several relatively independent modules in order to parallelize our work and thus save time and effort. Our project being to develop a computer-assisted remote monitoring robot, we decided to divide the work into three main systems (almost independent). The first concerns the robot's platform control, the second part was that of the camera arm control. Finally, the third part concerns the camera's remote monitoring and vision system, on which the other parts were going to be integrated.

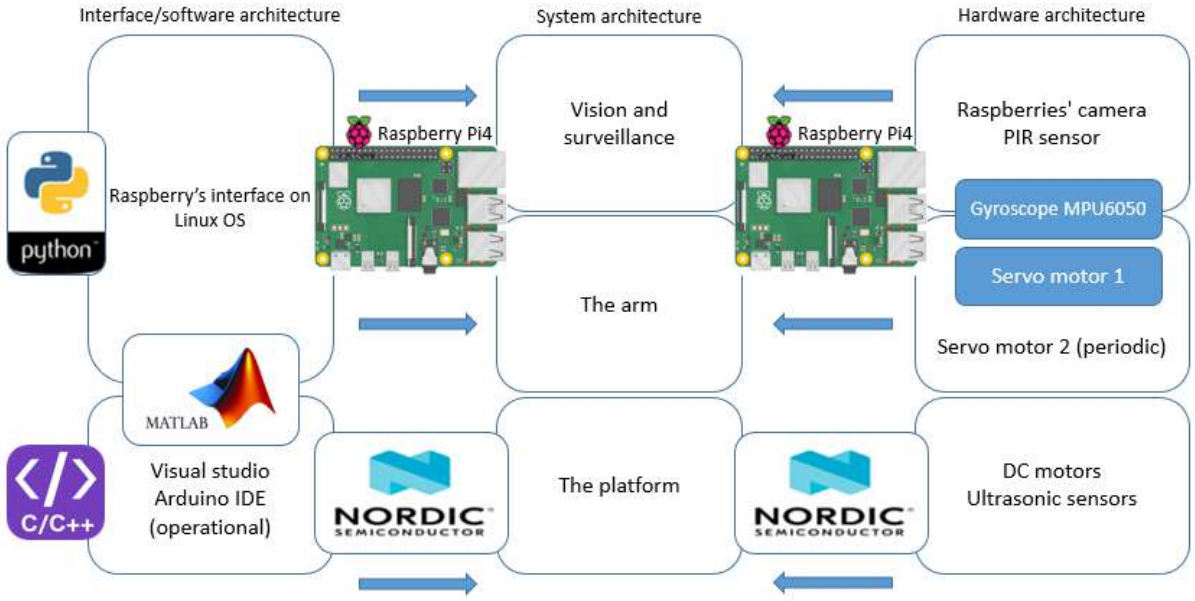


Figure 4. 1 The general structure of the robot.

4.2 Conception

4.2.1 Mobile robot components

We can distinguish the different functional parts of the robot:

- Mechanical;
- Electronics;
- IT.

4.2.2 Mechanical part

4.2.2.1 Robot chassis

A robot chassis is a plate that holds all of the robot's components and allows it to stay balanced. Aluminum is the most common material used to construct a robot's

chassis. This material has numerous advantages; it is available in plate, tube, square, round, and other shapes. Aluminum is lightweight, easy to work with, cut, and drill. Furthermore, it allows for the construction of a very strong chassis; for these reasons, we will use it to construct the chassis of our robot.

4.2.2.2 Modes of locomotion

For a mobile base, locomotion is very important, as part of its stability. The constructive principles for moving a mobile robot are many and varied. We can distinguish as major categories wheels and tracks.

4.2.2.2.1 Caterpillars

Robots with caterpillars are convenient for many functions. Indeed, caterpillars offer robots the ability to move in environments with all kinds of obstacles, such as rocks, ditches. Considering the material of the tracks, traction is excellent, even on slippery surfaces. The use of caterpillars has the advantage of good grip on the ground and the ability to overcome obstacles. The use is geared towards use on uneven or poor quality ground. The basic design of driven robots is simple: two tracks, one on each side of the robot, act like giant wheels.

4.2.2.2.2 Wheels

Mobility by wheels is the most widely used mechanical structure. This type of robot provides movement with rapid acceleration and speed but requires relatively flat ground. There are mainly three types of wheels:

- Fixed wheels whose axis of rotation passes through the center of the wheel;
- The oriental centered wheels, the orientation axis is perpendicular to the ground, it passes through the center of the wheel.
- Off-center steerable wheels, often called idle wheels, where the slewing axis is perpendicular to the ground, it does not pass through the center of the wheel.

We opted for fixed wheels; the main reasons for this technological choice are as follows: the wheels are easier to control, they dissipate less energy and they allow the vehicle to move faster.

To put the wheels in motion we need a rotation system, which is the motor. A motor will drive each wheel.

4.2.2.3 Motors

They are components for converting electrical energy into mechanical energy. These motors tend to be controlled by the control part in interaction with the information transmitted by the sensors. The motors encountered in the field of robotics are essentially of three types:

4.2.2.3.1 Servomoteurs

Un servomoteur est un type de moteur électrique capable d'atteindre des positions prédéterminées, puis de les maintenir ou à l'inverse de tourner de façon continue dans un sens donné à une vitesse comprise entre 60 et 120 TPM (tours par minute).

The actuators are controlled by a PWM signal. They have a connection made up of 3 cables:

- Red: + 5V.
- Black: Ground.
- Orange or Yellow: PWM signal

In the field of robotics, the purpose of the servomotor is to allow the rotation of the sensors and to know their angles of rotation.

4.2.2.3.2 Stepper motors

These motors work on a different principle: here you can make the motor move forward a certain number of "steps". Basically there are a predefined number of possible positions, and the motor will go from position to position. They therefore allow more precise positioning, but require a control card, and they are much more complex to use. Each motor step corresponds to an angle of rotation (eg 1.8 ° for 200 step motors). It will therefore be possible to precisely control the speed of rotation and therefore the movement of the rotor. The stepper motor transforms an electrical impulse into an angular movement.

There are three types of stepper motors:

- The variable reluctance motor.

- The permanent magnet motor.
- The hybrid engine, which is a combination of the two previous technologies.

4.2.2.3.3 Direct current motors (DC)

The DC motor is made up of two major components: the rotor (the rotating part) and the stator (the stationary part) (fixed part). In electrical engineering, the stator is also known as an inductor, and the rotor is known as an armature. In the image below, we can see the rotor, which is made of copper wires wound on a support that is mounted on an axis, in the center, surrounded by the blue and red magnets that make up the stator. This axis is the motor's output shaft. He is responsible for transmitting the movement to the mechanical assembly (pinions, chain, actuator, etc.).

In the case of a robot on wheels, for example, we will put the wheel on this axis, often through a reduction gear that decreases the speed of rotation while increasing the torque. The coupling, motor and reducer, gives a fourth type of motor, which is called Geared Motor.

4.2.2.3.4 Gear motor

The geared motor is a set made up of a gearbox already fitted with an electric motor and ready to be mounted on the installations. Depending on the need, there are several types of geared motors, either with an offset motor axis, or with an axis perpendicular to the output axis (male output or female output), the latter can be single axis or double axis.

4.2.2.3.5 Using the gear motor

A reducer is a set made up of gears, which makes it possible to reduce the speed of rotation of the motor axis which is generally 1,500 rpm (for an excitation frequency of 50 Hz) while increasing the torque by exit. These motors can be direct current for micro reducers or alternating current for large industrial geared motors.

Our choice is a geared motor for platform: this choice was made by elimination. we have eliminated the stepper motors because they are too complex to use. More difficult to operate than a DC motor, relatively low speed and torque, Torque decreasing rapidly as speed increases, and the servomotors

for the camera's arm because they have an angular system at a constant invariable speed.

Finally, there are three types of motors: direct current motors, servomotors and geared motors. First we considered the use of direct current motors. But the later have the disadvantage of having unusable characteristics: their speed is very high, which means the robot would move too quickly. Then, to vary the speed of the motor, it is necessary to vary the voltage that feeds it. For that, it would be necessary to supply a very weak current, which is difficult to accomplish because there is loss of electric current. So we chose the only solution we had left and also the most advantageous; Geared motors are direct current motors but coupled with a reduction gear. This will reduce the rotational speed of the engine thanks to a system of gears. Thus we can control the speed of the robot to be able to optimize its capacities. We therefore no longer need to vary the voltage, which further simplifies the robot for the same capacities.

4.2.3 Electronics part

We have motors, wheels, now we have to control all that, we need a circuit capable of turning the motors in one direction or the other in order to give mobility to the robot. The NRF52 SDK card is more suitable for this purpose.

The platform's control concerns setting up a system to control the robot's movements remotely. Indeed, after the theoretical study phase we had decided to communicate with our robot using the electronic card "NRF52" it was necessary to develop an Android application to validate the final step of the surveillance, which consists of recovering the images captured by the camera under form in order to register them in the database. The robot is capable of controlling and manipulating its outputs in response to messages received from the control center.

4.2.3.1 NRF52 SDK

4.2.3.1.1 Description of NRF52 SDK

The nRF52 DK is a single-board development kit (DK) for Bluetooth Low Energy, Bluetooth mesh, ANT and 2.4 GHz proprietary applications using the nRF52810 and nRF52832 SoCs.

It facilitates development exploiting all features of the nRF52810 and the nRF52832 SoCs. It includes an NFC antenna that quickly enables utilization of the NFC-A tag peripheral on the nRF52832. The kit gives access to all I/Os and interfaces via edge connectors and has 4 LEDs and 4 buttons which are user programmable.

The kit is compatible with the Arduino Uno Revision 3 standard, making it possible to use 3rd-party shields that are compatible to this standard. It comes with an on-board SEGGER J-Link debugger allowing programming and debugging both the on-board SoC and external SoCs through the debug out header. It can be powered by USB or by an external source, but also includes a CR2032 battery holder, enabling in-field testing of prototypes. (1)

Simply, the Nordic Semiconductor nRF52840 module is a USB experiment board providing controlled I / O from a computer connected to a PC. Indeed, thanks to this card, it is possible to connect the motors. (1)

4.2.3.1.2 Key features

- Affordable, rapid prototyping and development solution for the nRF52810 and nRF52832 SoCs
- Supports Bluetooth LE, Bluetooth mesh, ANT and 2.4 GHz proprietary development
- Bluetooth 5 feature support: 2 Mbps, Advertising Extensions and Channel Selection Algorithm #2 (CSA #2)
- Arm® Cortex™ M4 with floating point support DSP instruction set
- Arduino Uno Rev. 3 compatible for use with 3rd party shields
- All I/Os and interfaces are available via connectors
- Segger J-Link OB programming/debugging supported
- Support for programming/debugging of external boards
- Pins for power consumption measurements
- Coin-cell battery holder
- 1.7-3.6 V supplied from battery, USB or external

4.2.3.1.3 Applications

- Internet of Things (IoT)
- Wearables
- Appcessories

- Desktop peripherals
- Remote controls
- Sports & medical
- Smart watch
- Smart home sensors
- Lighting
- Toys
- Industrial

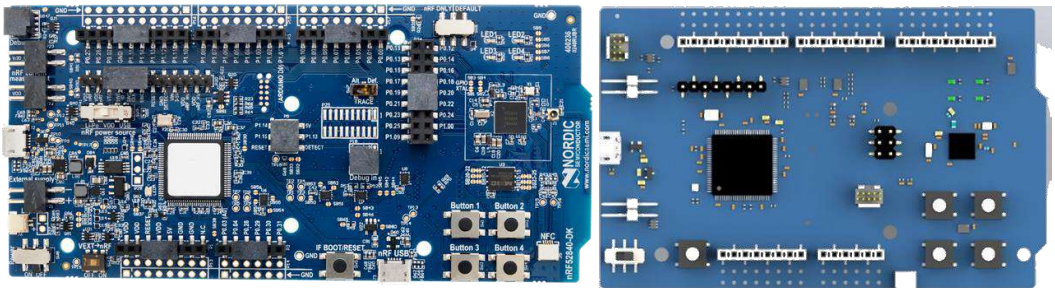


Figure 4-2 NRF52 SDK

4.2.3.1.4 The good reasons to choose NRF52 SDK

However, there are multitudes of platforms in commerce that allow you to do the same thing. In particular “PIC” microcontrollers from the manufacturer Microchip.

NRF52 SDK constitutes two things:

- The software
- The hardware

The software, like the card, is compatible under the most common platforms (Windows, Linux and Mac), unlike other commercial programming tools which are, in general, only compatible with Windows, also because it contains a default Bluetooth module as well as the information processing speed. Finally, we opted for this card in relation to all its qualities.

The NRF52 SDK card drives the motors via a specially designed power circuit, because the current that is demanded by the motors is far too large compared to what a digital output of any control card delivers. In addition, DC motors are real sources of interference that could damage the board, when they run, generate very large surges compared to their supply voltage. These are two good reasons not to connect the

motors directly to the board. So, we need a power interface that runs the motors at the right speed and in both directions (clockwise and counterclockwise) without damaging the board. For this there is a very common component in the world of robotics, it is the **H Bridge.**

4.2.3.2 MOtor driver (H-bridge)

4.2.3.2.1 Principle of the H-bridge

An H-bridge is a power circuit for controlling the direction of rotation of a motor, which uses four transistors mounted in such a way that current can flow in either one direction or the other. By reversing the direction of the current in the motor, the latter will change the direction of rotation. It has two main roles:

- To supply the current necessary for the operation of the motor.
- Make it possible to reverse the direction of the current (therefore the direction of rotation of the motor). You can even control the speed of the motor (this is called PWM modulation).

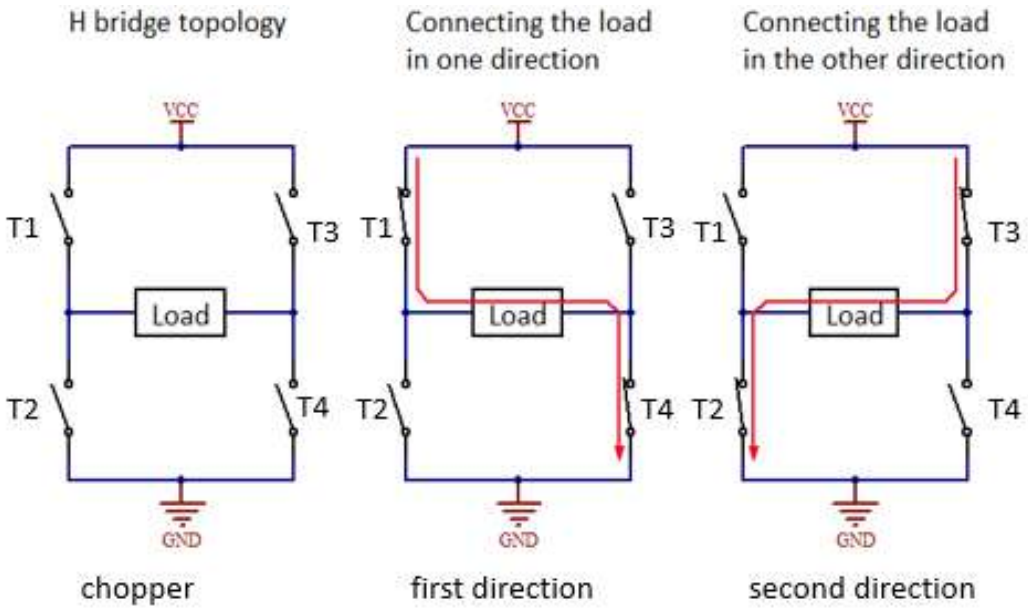


Figure 4- 3 H-bridge

There are four transistors, symbolized in figure above, by switches T1, T2, T3 and T4, are connected in bridge and make it possible to control the direction of rotation of the motor: When T1 and T4 are closed (saturated), the motor turns in one direction (direction 1). When T2 and T3 are closed, the motor will rotate in the other direction (direction 2). To avoid the connections of transistors and their control logic,

components have been developed and produced based on the H-Bridge. We will now see two of them: The L293 (D) and the L298.

4.2.3.2.2 L293 (D)

The L293 is a power bridge composed of several transistors, it is a double H-bridge, which means that it is possible to use it to control 4 separate motors thanks to its 4 channels.

It is also possible to form two H-bridges to drive two separate motors, in both directions and independently of each other. This component is made to work with transistors from 4.5V to 36V and it is capable of delivering 600mA per channel (which makes 1.2A per motor)

Finally, this component exists in two versions, the L293 and the L293D. The only difference between the two is that the L293D already integrates the diodes in parallel with the transistors to protect the latter. This therefore implies concessions on the characteristics, the maximum current goes to 1A per channel for L293D and 2A for the version without the diodes. This component has 16 pins and operates on a simple symmetry system.

4.2.3.2.3 L298

This is because its operation is very similar to that of the L293, but it is capable of delivering currents up to 2A nominal per bridge and up to 3A for a short time. It also offers a function, which may be of interest, which is the measurement of the current passing through the bridge. There are two power pins, one for logic and the other for power. That for logic can go from 4.5 to 7V (there we can use that of the NRF). The power input, on the other hand, admits a voltage between 5 and 46V.

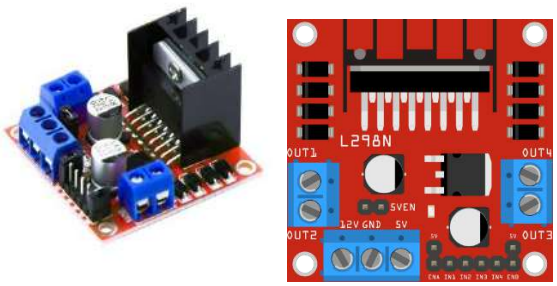


Figure 4- 4 L298n H-Bridge

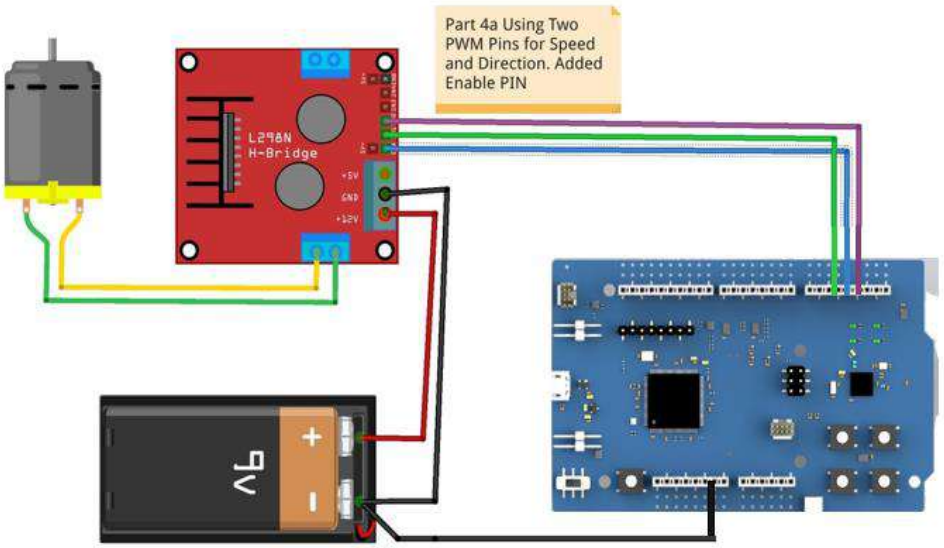


Figure 4- 5 L298 connected to two motors with SDK

4.2.3.3 Sensors

Sensors have a predominant place in the processing system of a robot. They can both inform the robot about the external environment and inform it about its own actions by checking the state of its actuators [31]. They are therefore essential elements for an autonomous robot to know what it is doing, what is happening and to make the right decisions accordingly. All robots must be equipped with sensors allowing the robot to be located and obstacles to be detected. There are two types of sensors:

- External sensors (exteroceptive) which provide certain knowledge of the environment (robot-environment distances, temperature, contact, etc.).
- Internal sensors (proprioceptive) which provide information on the state of the robot, elementary information on kinematic parameters (position or speed of the wheels, battery charge, etc.) [31]. and which make it possible to know the trajectory followed by the robot [32].

In a mobile robot, sensors are used to avoid obstacles and to take on the intended task. The sensors used in our systems are:

4.2.3.3.1 Ultrasonic rangefinders

Ultrasonic rangefinders are historically the first to be used. They use the measurement of the return time of a sound wave reflected from obstacles to estimate the distance [36].

The distance sensor from an obstacle consists of an ultrasonic transmitter and receiver [36]. The transmitter sends out an ultrasonic wave, which is reflected back by an obstacle encountered in its path. The ultrasonic receiver will receive this wave. The pilot module manages the ultrasonic module's transmitter and receiver by sending a command to transmit an ultrasonic wave train and checks whether the receiver receives its echo. It calculates the time it takes for the echo to return and thus determines the distance from an obstacle located within the range of action of the ultrasound module.

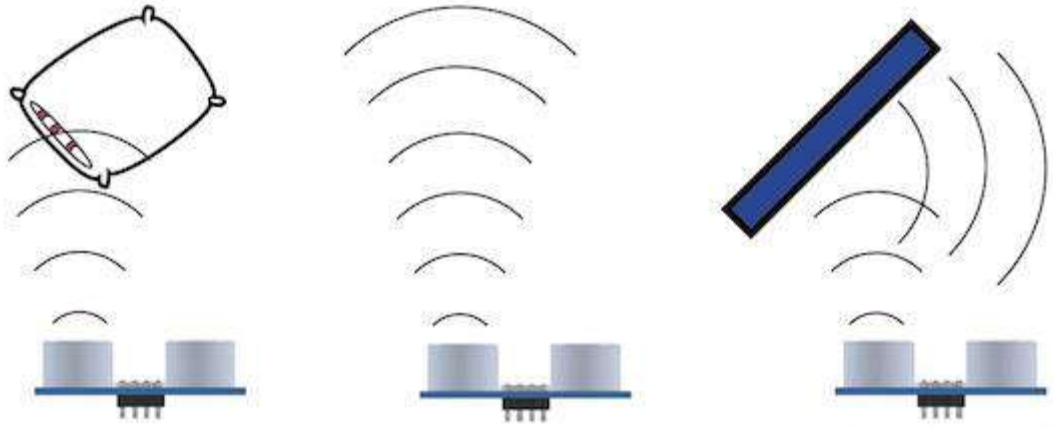


Figure 4- 6 Principle of the ultrasonic range finder.

The ultrasonic range finger might fail trying to detect:

- Soft objects that absorb sound
- Objects too far
- Objects bouncing the sound away from it

There are several types of ultrasonic range finders, among them we have the HC-SR04 sensor.

4.2.3.3.2 Operation of the HC-SR04 module

A high level pulse (at + 5v) must be sent for at least 10 µs on the “Trig Input” pin; this triggers the measurement. In return, the "Output" or "Echo" output will provide a + 5v pulse whose duration is proportional to the distance if the module detects an object. The signal received by the receiver is the echo of the transmitted signal. The measured flight time is that of the round trip of the wave train.

Knowing the speed (s≈ 340m / s) of this signal in the air, (it takes 29.4 microseconds to travel 1 cm). In 1 ms, the ultrasonic wave travels 340 mm = 34cm.

We can then calculate the distance traveled by this signal and therefore the distance D to the obstacle by the relation:

$$v = 340\ m/s$$

$$v = 0{,}034\ cm\ /\mu s$$

Time =distance/speed:

$$t = \frac{s}{v} = \frac{10}{0{,}034} = 294\ \mu s$$

Distance in cm:

$$s = t.0{,}034/2$$

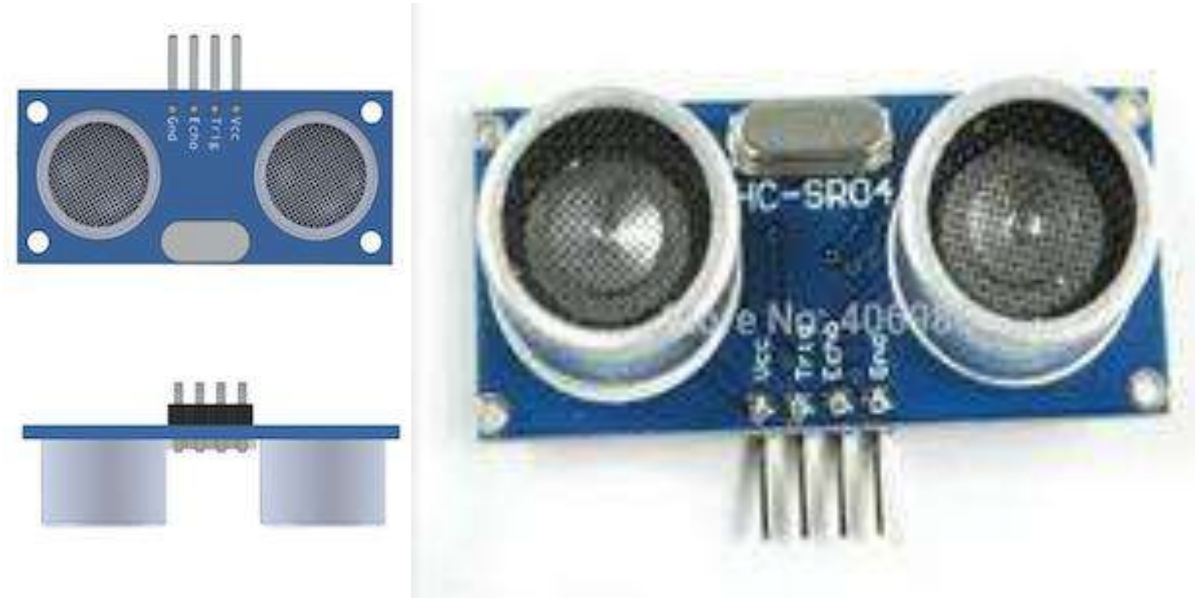


Figure 4- 7 HC-SR04 sensor

We have chosen to use the HC-SR04 type ultrasonic sensor, because it is very easy to interface with a microcontroller, it provides very useful information on the presence of obstacles for the robot in its environment, it simply processes data and for its cost that is affordable. Our robot will have one or more such sensors.

4.2.3.3.3 Gyrometer / Accelerometer / Gyroscope

Le gyromètre est un capteur de mouvement. Il fournit une information de vitesse angulaire. Il est utilisé principalement dans les avions, les bateaux, les sous-marins pour déterminer leurs vitesses et leurs positions et dans les applications de robotique mobile

An accelerometer is a sensor that attaches to a mobile or any other object makes it possible to measure the linear acceleration of the latter. One still speaks of accelerometer even if it is in fact three accelerometers, which calculate the three linear accelerations according to three orthogonal axes [35].

A gyroscope is a device for measuring the absolute rotation of its housing. The physical phenomena used to make these sensors are essentially: the inertial properties of matter for mechanical gyroscopes and the properties of coherent light for laser gyroscopes.

Note: the same device can operate as a gyroscope or gyrometer.

4.2.3.3.3 MPU6050 (Accelerometer+Gyroscope)

- MPU6050 sensor module is an integrated 6-axis Motion tracking device.
- It has a 3-axis Gyroscope, 3-axis Accelerometer, Digital Motion Processor and a Temperature sensor, all in a single IC.
- It can accept inputs from other sensors like 3-axis magnetometer or pressure sensor using its Auxiliary I2C bus.
- If external 3-axis magnetometer is connected, it can provide complete 9-axis Motion Fusion output.
- A microcontroller can communicate with this module using I2C communication protocol. Various parameters can be found by reading values from addresses of certain registers using I2C communication.
- Gyroscope and accelerometer reading along X, Y and Z axes are available in 2’s complement form.

Gyroscope readings are in degrees per second (dps) unit; Accelerometer readings are in g unit**.**

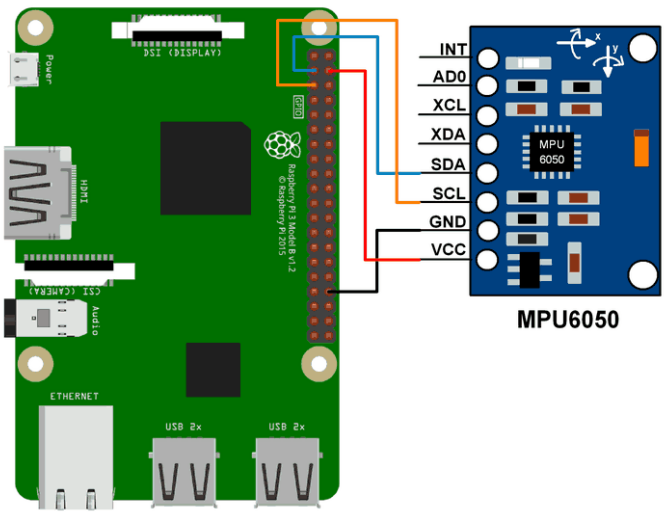


Figure 4- 8 MPU6050 Interfacing with Raspberry Pi

4.2.3.4 Raspberry Pi 4

Raspberry Pi is the name of a series of single-board computers made by the Raspberry Pi Foundation, a UK charity that aims to educate people in computing and create easier access to computing education.

The Raspberry Pi launched in 2012, and there have been several iterations and variations released since then. The original Pi had a single-core 700MHz CPU and just 256MB RAM, and the latest model has a quad-core CPU clocking in at over 1.5GHz, and 4GB RAM.

The Raspberry Pi is a very cheap computer that runs Linux, but it also provides a set of GPIO (general-purpose input/output) pins, allowing you to control electronic components for physical computing and explore the Internet of Things (IoT).

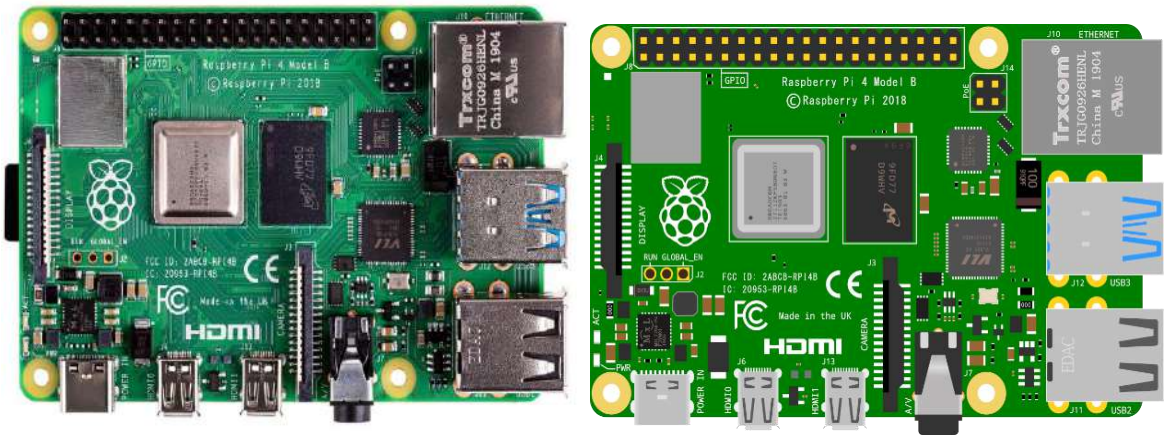


Figure 4- 9 Raspberry Pi 4model B

4.2.3.5 Power supply

The different circuits and actuators require different voltages and currents, for this we have chosen to take a 12V battery with a resistor and a potentiometer to power the different parts of the robot.

4.2.4 Computer part

It is this part, which will allow the robot to analyze the data coming from the sensors and to send the orders relating to the motors. The microcontroller physically materializes the control part. To manage all of the control circuits, we are going to need to use a powerful processing unit, a microcontroller, which is programmed to achieve the goal of the achievement and that's why we used the Raspberry Pi and the NRF52 SDK.

4.2.4.1 Microcontrollers in robotics

The microcontroller is the brain of the robot. It is he who will process the information coming from the sensors and who will give the desired response to the motors in order to give the robot autonomy. Microcontrollers are frequently used in on-board systems, such as automotive engine controllers, remote controls, home appliances, toys, mobile phones, etc. It is made up of:

- ROM memory, which contains the program.
- RAM memories which contain temporary data used by the program,
- A microprocessor, which will take charge of the information processing part and send orders. It is therefore he who will execute the program embedded in the microcontroller.
- inputs to connect sensors (micro switches, phototransistors,),
- outputs to connect effectors in general through appropriate interfaces (motors, ultrasonic transmitter...). Compared to electronic systems based on microprocessors and other separate components, it is preferred to use the microcontroller because it reduces the size, power consumption and cost of the products.

Compared to electronic systems based on microprocessors and other separate components, it is preferred to use the microcontroller because it reduces the size, power consumption and cost of the products.

4.2.4.2 Common microcontrollers in robotics

- Atmel AVR microcontrollers (ATmega, ATtiny, etc.)
- PIC microcontrollers using microchip technology (PIC16, PIC24, etc.)
- Microcontrollers based on ARM technology.

Our choice fell on the ARM microcontroller. Because the Raspberry and SDK boards are a prototyping platforms based on an ARM microcontroller equipped with various elements that facilitate its implementation.

4.2.4.3 Background & Software interface

4.2.4.3.1 NRF52 SDK interface

A. MCU Interface

The DK's interface MCU runs either SEGGER J-Link OB or mbed OB interface firmware, which is used to program and debug the nRF52832 IC's firmware.

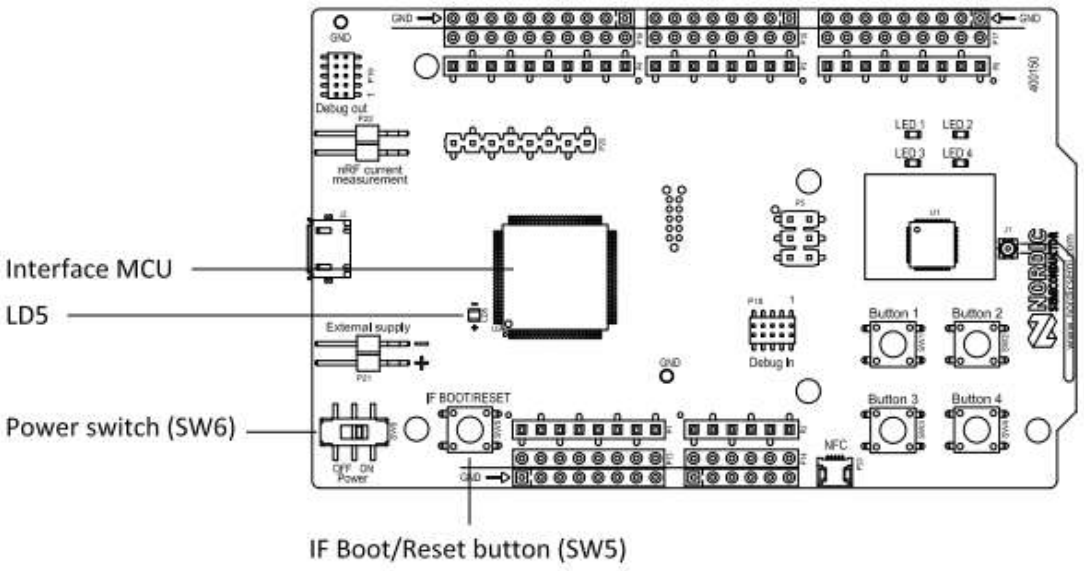


Figure 4- 10 Interface MCU

B. Software tools

The extensive range of supporting software tools that help with testing and programming on the chip.

C. NRF5 SDK

The nRF5 Software Development Kit (SDK) provides source code of examples and libraries forming the base of the application development.

D. **NRF Command Line Tools**

J-Link ARM, J-Link CDC, NRFjprog, and mergehex are all included in the NRF command Line Tools package. The NRFjprog command line utility is used to program nRF5 chips. Also, It could be used in a production environment.

E. NRF Connect for Desktop

NRF Connect is a desktop application that allows to program Nordic devices. It consists of a basic delivery system into which apps may be connected to provide other features. All apps can be downloaded through NRF Connect for Desktop, and new apps would be available as soon as they are released. Bluetooth Low Energy, Programmer, and Power Profiler are the three main apps that support the nRF52 DK.

F. NRF Connect for Mobile

NRF Connect for mobile is a sophisticated generic tool for scanning and exploring Bluetooth Low Energy devices and communicating with them via a smartphone. Together with the Device Firmware Update (DFU) profile from Nordic Semiconductor, NRF Connect for mobile supports a number of Bluetooth SIG accepted profiles.

We also might use third party software tools that are useful when developing with any products:

G. Keil MDK-ARM Development Kit

The Keil MDK-ARM Programming Kit provides a development environment for microcontroller applications that allows us to use the nRF5 SDK application and sample files to get started.

H. SEGGER J-Link Software

The J-Link software is required to debug using the J-Link hardware that is packaged with our development kits.

I. SEGGER Embedded Studio (SES)

SES is a fully cross-platform Integrated Development Environment (IDE) that may be used on a variety of operating systems.

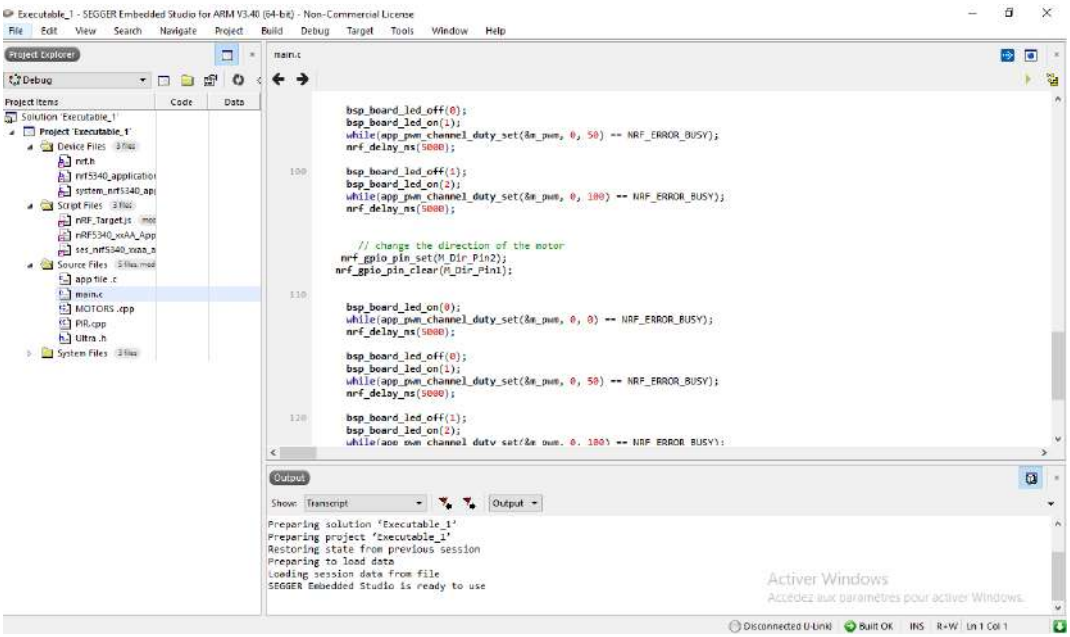


Figure 4- 11 SEGGER Embedded interface

4.2.4.3.2 Raspberry Pi interface

On the GPIO header of the Raspberry Pi, there are three types of serial interfaces. The UART serial port enables the use of a serial terminal application, such as PuTTY, to launch a login session. The Serial Peripheral Interface (SPI) and the Inter-Integrated-Circuit bus are the other two serial interfaces (I2C). SPI on the Pi supports up to two attached devices, whereas I2C can support many devices as long as their addresses do not conflict.

- **Software Details**

Since the Pi's launch, the software landscape has changed dramatically. Many different operating systems have been ported to the Raspberry Pi, and the device driver infrastructure has evolved significantly.

We used the wiring Pi I/O library for C/C++ (or spidev/smbus for Python) and a recent version of Raspbian.

Some of the exact interface enablement details have changed since the implementation of device tree overlays in Raspbian.

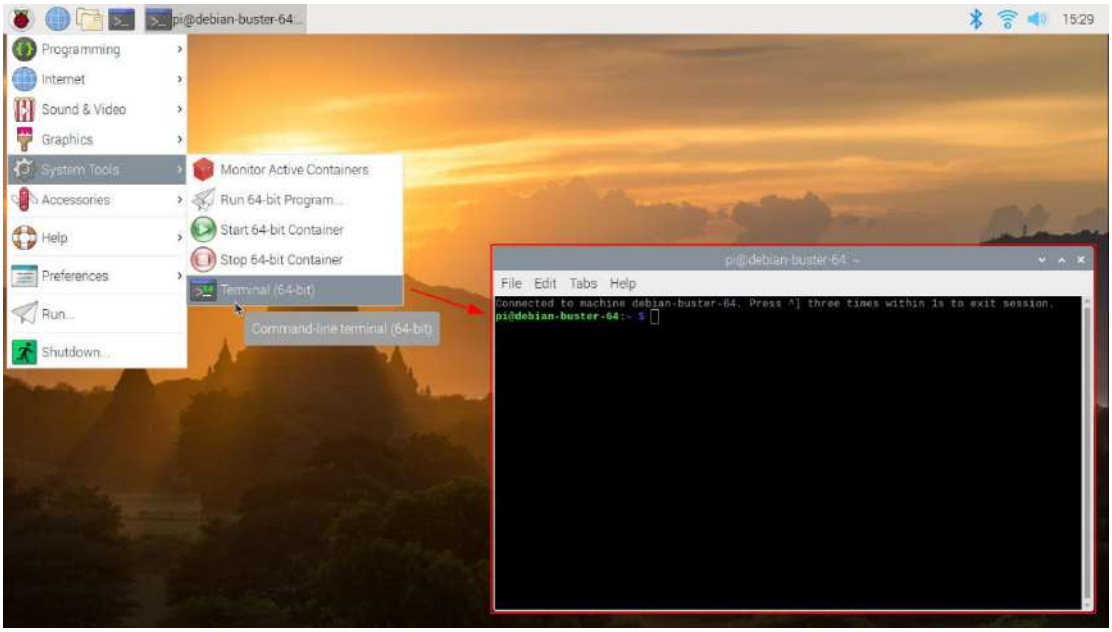


Figure 4- 12 Raspberry desktop

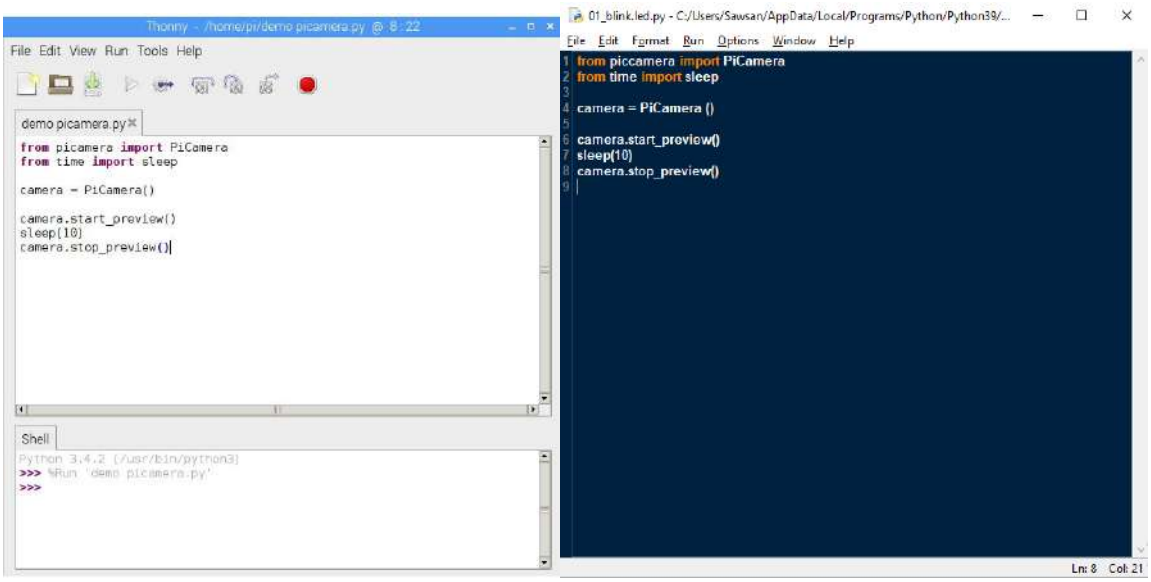


Figure 4- 13 Python screen on Raspberry Vs on windows

4.3 Matlab Simulation

The previous chapter system contains the theoretical part which consist to prove the positive use of PID through the stability of the camera the system that we have been created subject to the initial condition can be solved for the unknown vector $\boldsymbol{Z}$, using, for example, the ode45 command defined in Matlab to solve the system The above system subject to the initial condition can be solved for the unknown vector $\boldsymbol{Z}$, using, for example, the ode45 command defined in Matlab to solve the system of differential equations of differential equations like we mentioned before.

Numerically. this command is based on the fourth-order Runge-Kutta method. For more details, consult.

4.3.1 Numerical application

The PID controller helps get the outputs, which are the final positions of M Determined by the angles $\theta_f \ and \ \theta$, where we want it, in a short time, with minimal overshoot, and with little error. This will be demonstrated using the real dimensions of the robot:

We consider the simplified model of a pendum or the single link of the manipulator arm shown in **Fig3.1**, We take the following parameters after measuring: M= 75g, L= 5 cm

The target positions (final positions) are:

$$\theta_f = \frac{\pi}{2}$$

The initial positions, initial angle velocities, and initial states are, respectively, taken as:

$$\theta\,(0) = \frac{\pi}{2}, \qquad \dot{\theta}\,(0) = 0, \qquad x\,(0) = 0$$

The PID parameters for θ is taken as:

$$k_P = 50, \quad k_D = 20, \quad k_I = 30$$

The following figure show the initial and target positions of the camera ‘arm:

The camera arm

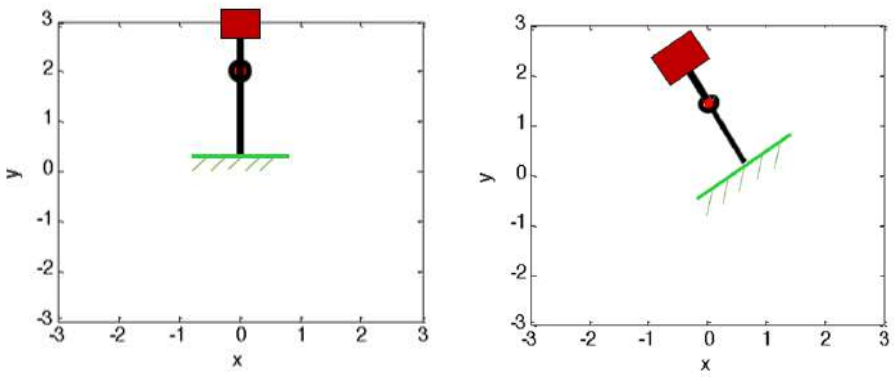
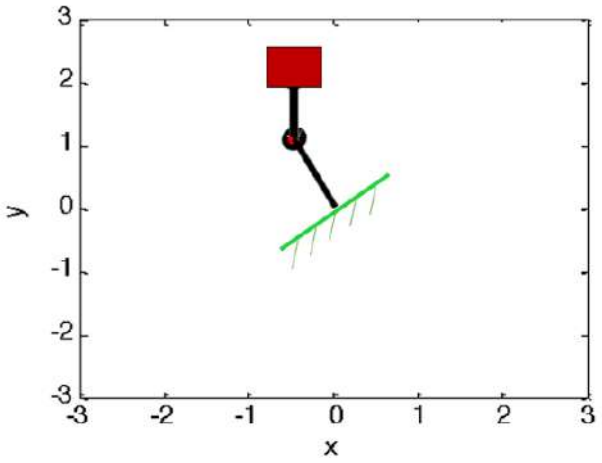
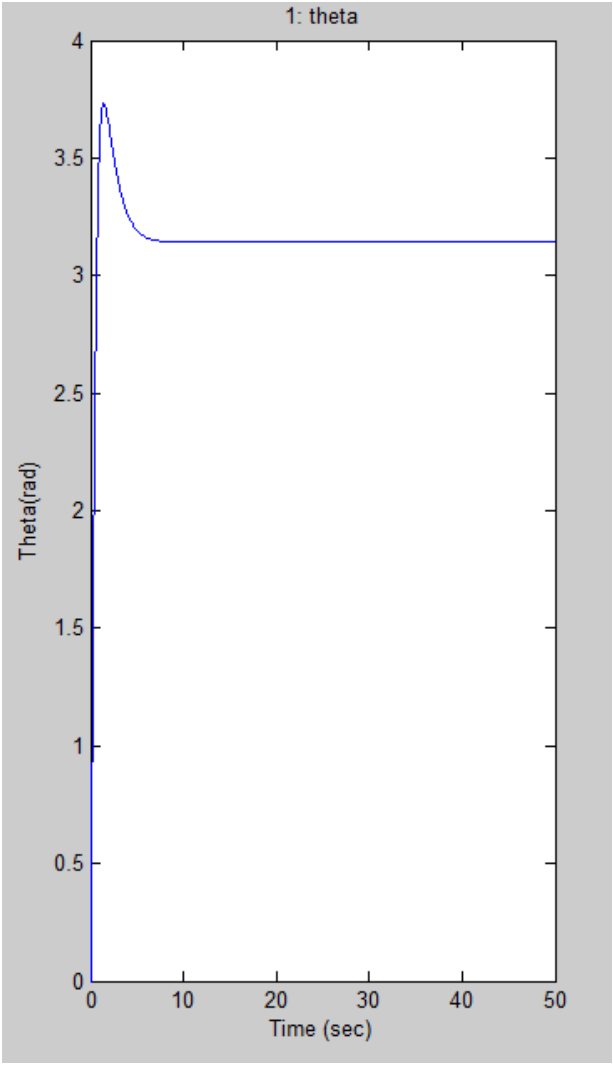


Figure 4- 14 Initial position (left) and middle position (right)



Figur 4- 15 Final position

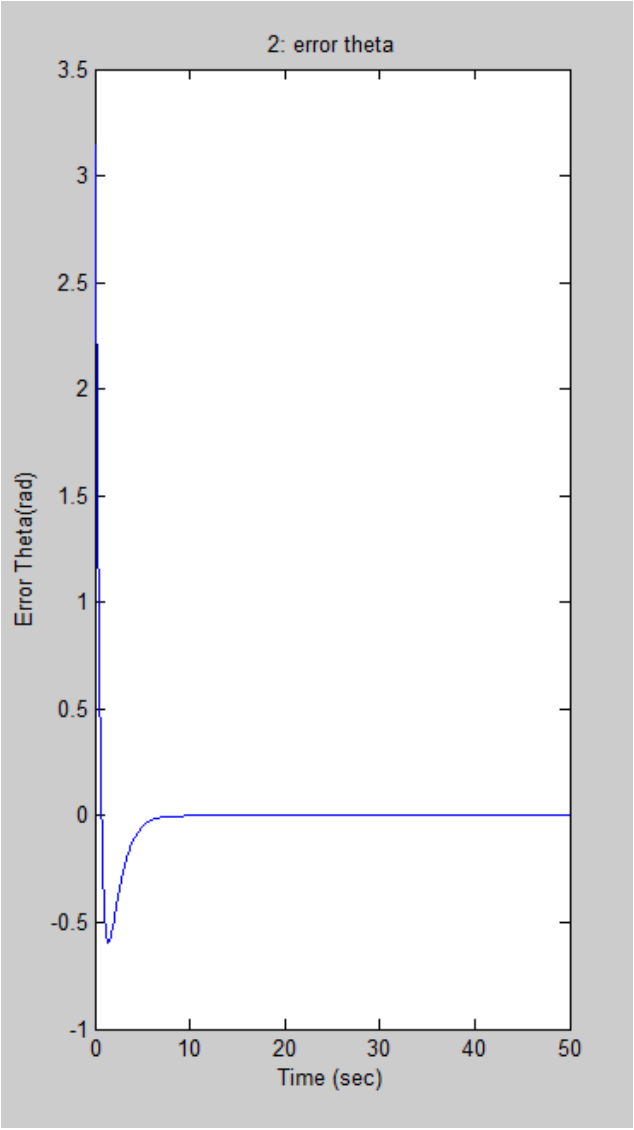
We first plot the positions θ of M versus time



Next, we plot the difference between where we want to go and where we are actually at i.e:

$$\theta(t) - \theta_f$$

Where θ_f the target positions and $\theta(t)$ is the numerical solutions obtained by solving the system of ODEs



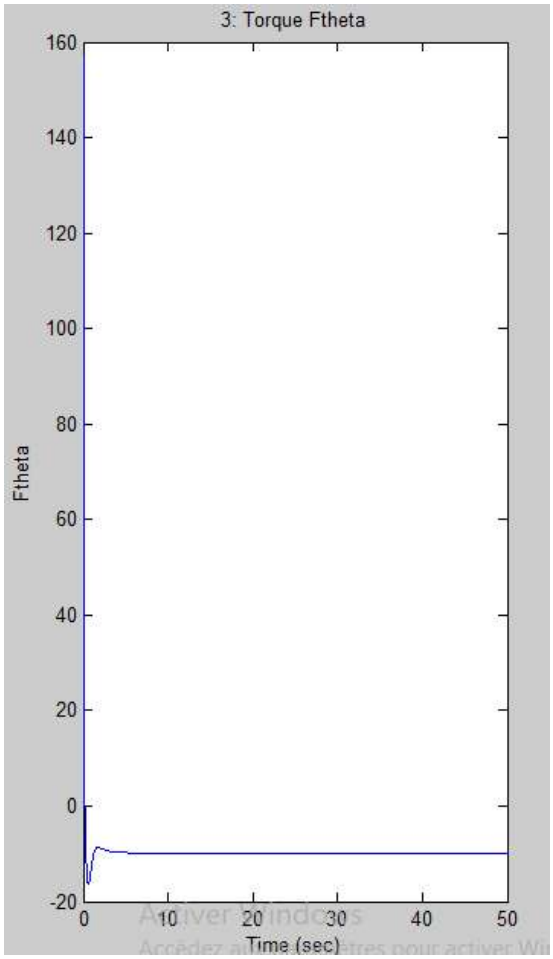
Comment: As shown in the above figures, The PID controller gets the final positions of M determined by the angles θ, in a short time (almost 7 seconds) with little error.

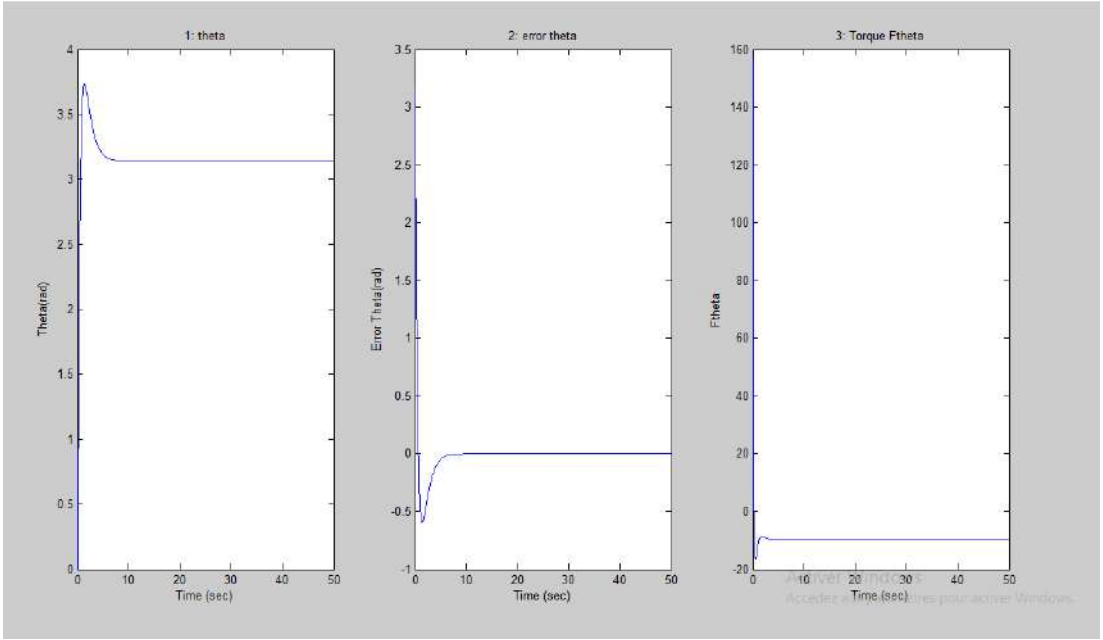
Finally, we plot the torques versus time

$$\hat{F} = f$$

Note that the actual joints torques is:

$$f_\theta = B(q)\, f$$





All the Matlab simulation for Theta, Error and Theta

4.4 Conclusion

We studied the most well-known and widely used components in mobile robotics in this chapter, which enabled us to select everything we needed to build our mobile robot, which is made up of three parts: mechanical, electronic, and computer.

We will integrate these components in a reasonable manner to construct a robot that operates according to our demands after we have compiled a list of hardware and software that we will need for the project and understand how they work.

In the following chapter, we will get further information. Design is an important part of completing a project and ensuring that it runs well.

Chapter 5: integration

5.1 Introduction

In the previous chapter, we made the conception and the simulation where we chose all the hardware and software components and we validated our hypothesis using Matlab simulation, this overview will allow us to make our mobile robot and its remote control for communication and data transmission. In this chapter, we will see the stages of the realization

All the tasks to carry out our robot in the form of this diagram:

Validation	**Task name**	**duration**
Validated	theoretical study	40 days
Validated	conception of the remote monitoring part	14 days
Validated	realization of the remote monitoring part	9 days
Validated	conception of the control part	20 days
Validated	Construction of the platform	5 days
Validated	Construction of the arm	16 days
Validated	Matlab simulation	20 days
No valid	Integration	until now

Table 5- 1 out of the robots

5.2 The platform

5.2.1 The platform 's operating algorithm

The figure 5.1 below shows the flow chart of the platform

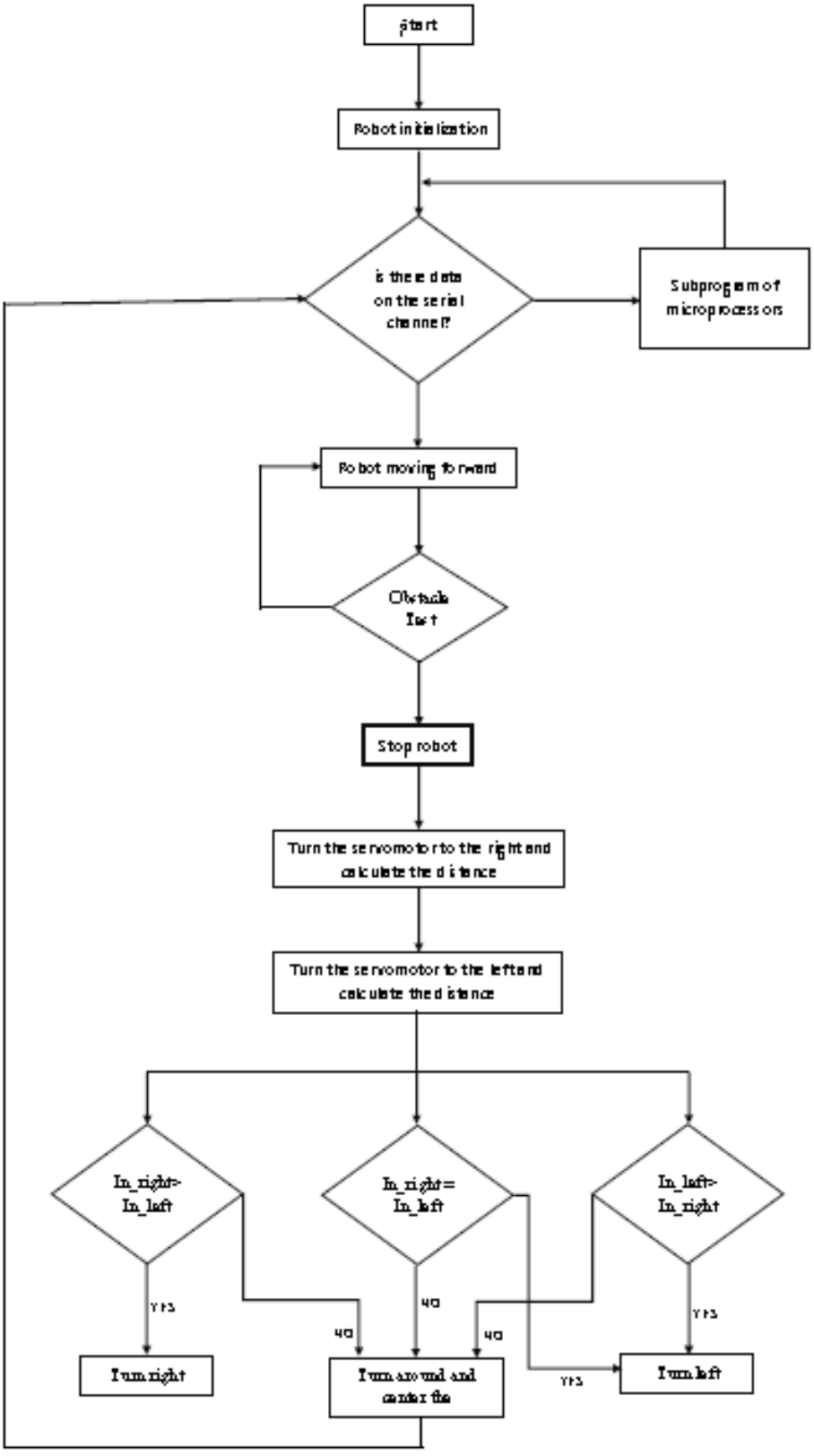


Figure 5- 1 flow chart of the platform



Figure 5- 2 used material

The plan of the robot is provided, but its construction has been subject to many adjustments, due to its compactness. However, from the photos provided, it is certainly possible to make a robot with the same architecture.



Figure 5- 3 Platform's parts

- The mechanical part (aluminum angle, screws, washers, threaded rod, etc.) without going into more details
- The electronic part mainly, with a little mechanics
- The required material is broken down into two parts.

Step 1: Mechanical part 1: the chassis

To begin with, we will need to build the chassis, which supports the DC motors, The NRF52 board and the raspberry pi, the motor control shield, the battery...etc.

Step 2: Mechanical part 2: assembly of wheels and motors

The main mechanical parts used are illustrated in the additional photos. after You must first set up the drive axis



Figure 5- 4 assembled wheels and motors

Step 3: Mechanical part 3: last steps

- The hardest part being done, it remains to assemble the 2 servomotors,
- The wheels are in place (first you have to fix the adapter hubs - see additional photos)
- The NRF52 with the motor control shield is attached to an Altuglass plate which will then be attached to the top of the robot.
- The motor control shield is clipped onto the NRF52 board and the RPI
- Finally, we position the battery which will be fixed using Velcro.
- All that remains is to connect the various elements On the shield and NRF
- Finally, raspberry camera and the Gyroscope

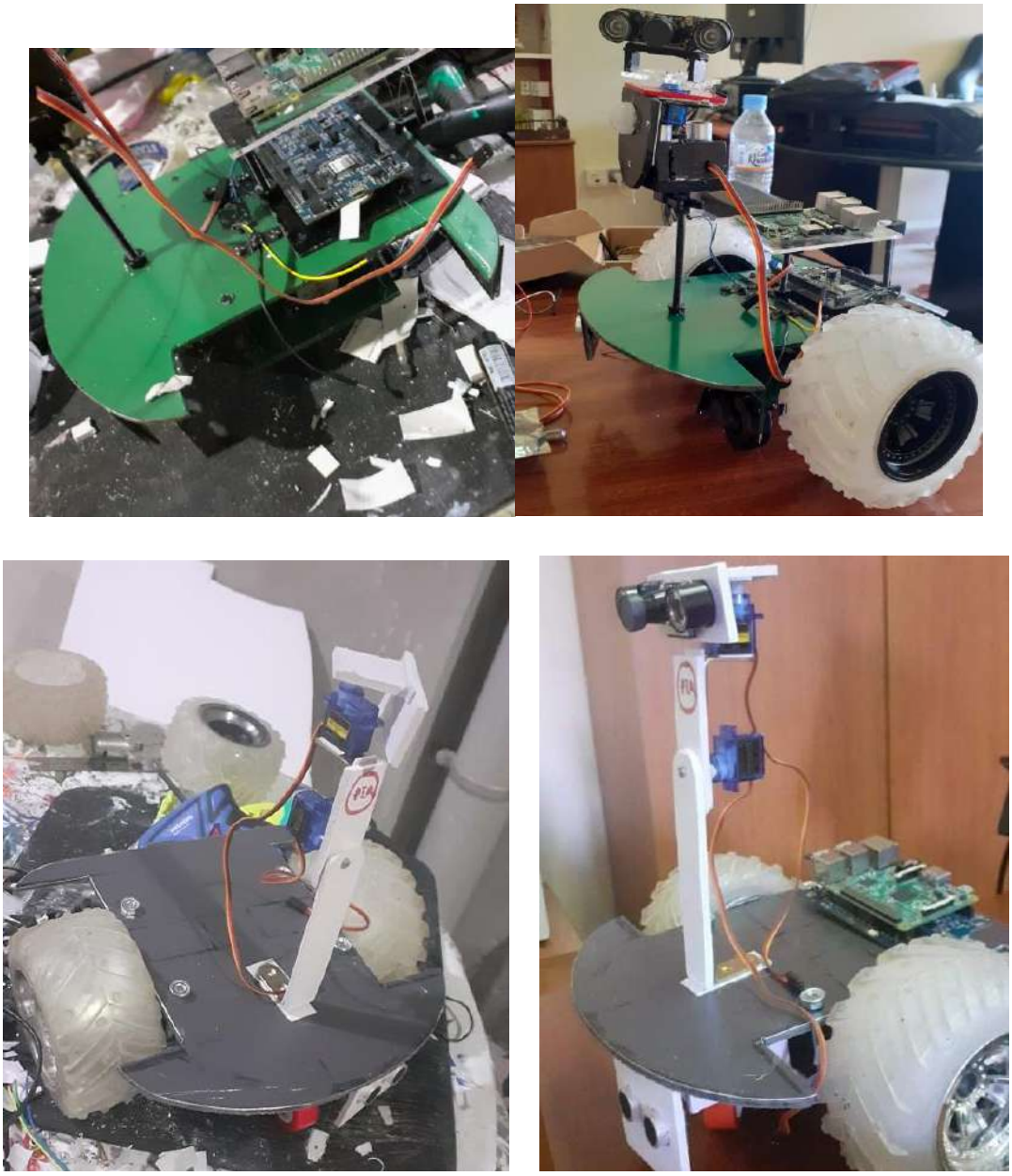


Figure 5- 5 assembled the rest of the elements

5.3 The camera and its arm

5.3.1 The arm's operating algorithm

At this point, we have reached the most important part of the project that we want to validate through visual experience, the system is to keep the camera image clear and stable in case of small obstacle, in order to get the solutions perfect for better monitoring conditions. To be more obvious, we can summarize it using this flowchart based on figure 5.1:

- Case 1: If there is an obstacle that the robot could not pass on:

The robot will use the previous algorithm figure 5.1

- Case 2 : if there is an obstacle that the robot can pass on it:

A small obstacle most like a rock, to avoid time and energy loss, we program the robot to pass on it, knowing that we are using big wheel on rough terrain, when the robot passes over this obstacle, we will have an image distortion if the sensor detected a parasite, and the camera was analyzing, which will lengthen the image processing time in or maybe let the parasite swipe out.

To validate the notion of information processing precision and speed, as well as the movement of the Servo motors utilizing the PID in the joint movement responsible for the camera's stability. Mathematically implying that the angle must stay $sin\frac{\pi}{2}$. Physically implying that the overall mass M (camera + servo motor + PIR) must remain vertical on the same axes as in the initial state, as stated in the chairman chapter.

5.3.2 Control unit

For calculate the unknown angle we use gyroscope MPU-6050, which includes a 3-axis gyroscope and a 3-axis accelerometer, as well as a digital motion processor (DMP) on the same chipset. The MEMS motion tracking system includes a programmable gyroscope and accelerometer, designed for precise tracking of fast and slow motion. The MPU-6050 motion-processing unit integrates Motion Fusion algorithms to also access external sensors and magnetometers via the I2C master auxiliary bus. Applications of the MPU-6050 include sensors, tablets and smartphones. The Intenseness MotionAppsTM platform extracts associated motions and offloads sensor management from the operating system to provide an application-programming interface (API).

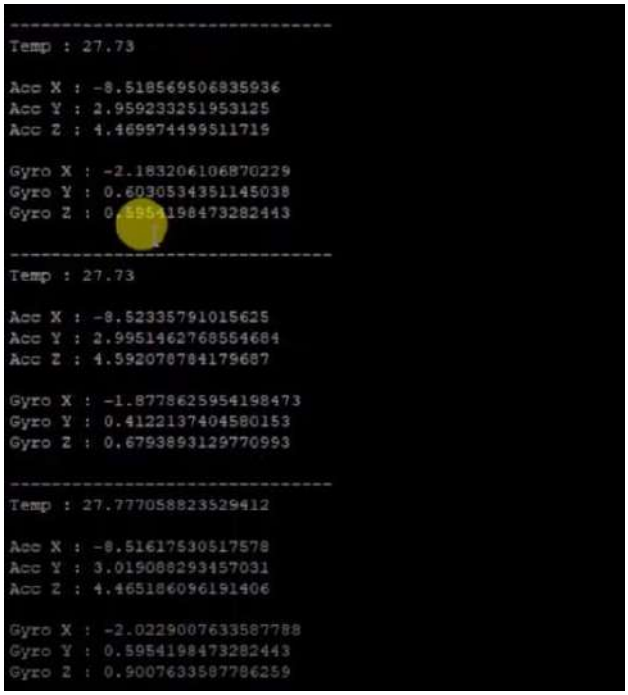


Figure 5- 6 Data recovery through the interface

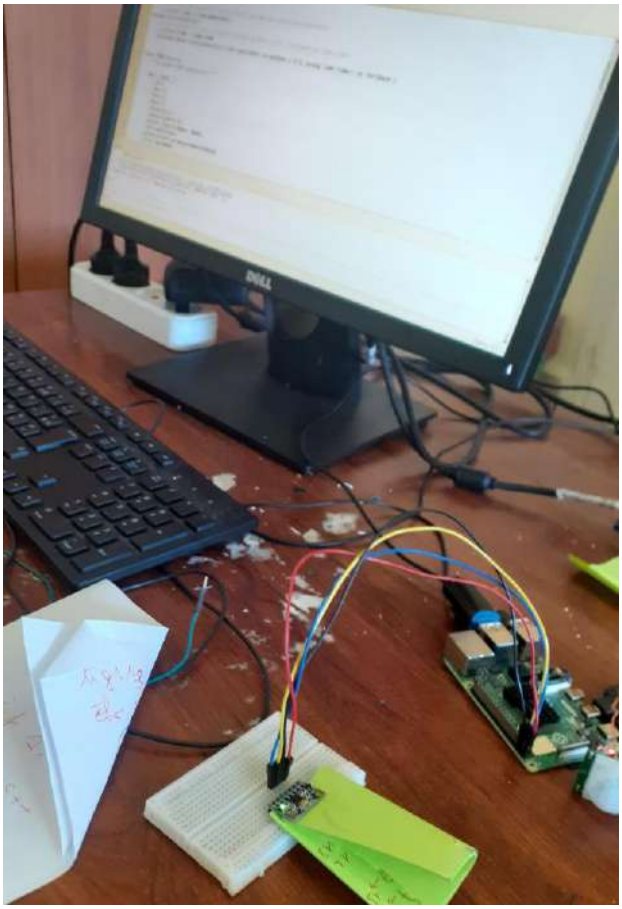


Figure 5- 7 The gyroscope installation

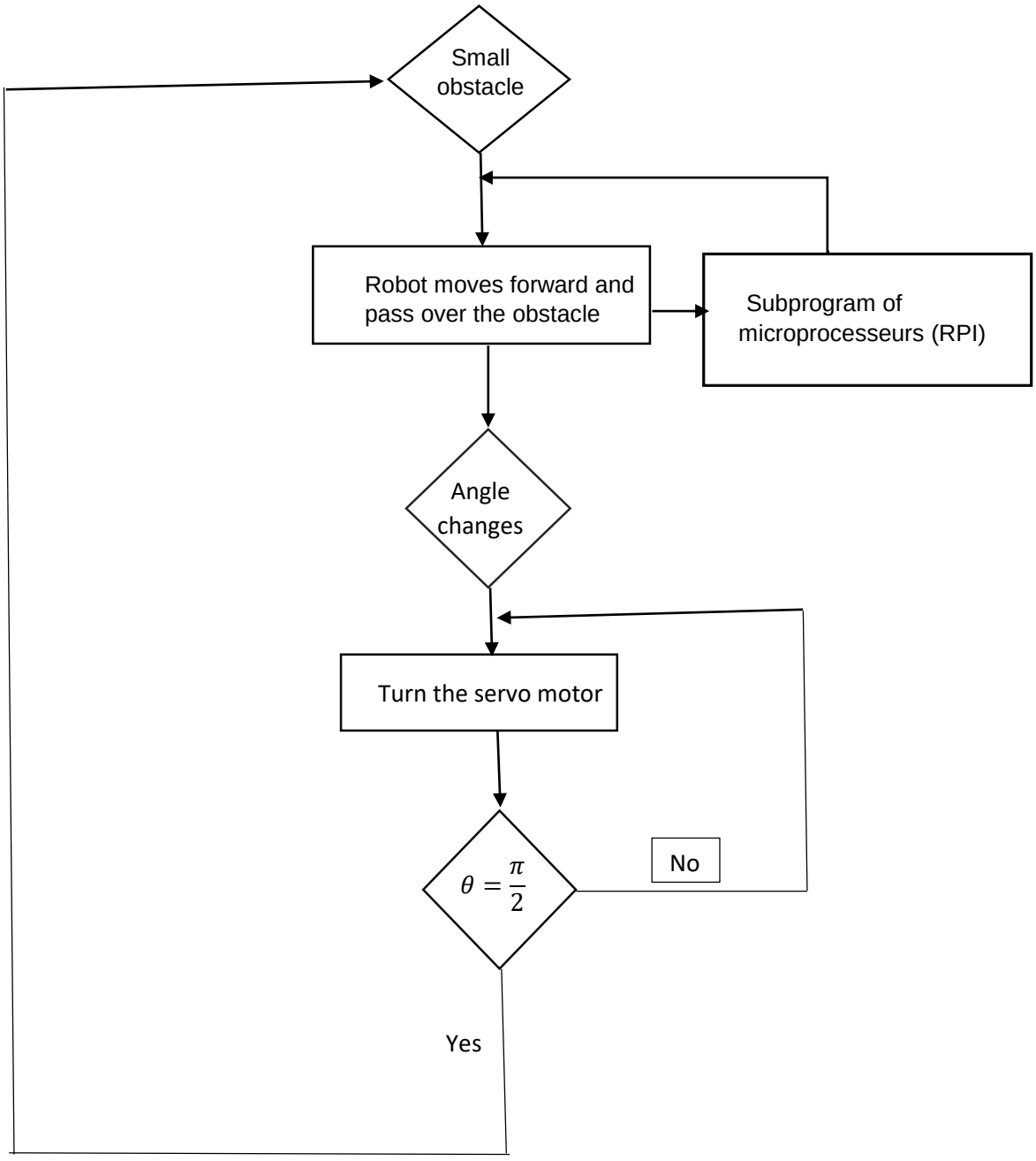


Figure 5- 8 Flowchart of the camera's arm

To resume to process we resume:

- The gyroscope would detect the variation of between the target angle and the current angle.
- The gyroscope send the information to the raspberry as vector.
- The raspberry receves the information and send it to servo motor as an action.
- The servo turns in order to adjust the camera's arm position.

5.3.4 The camera is operating algorithm

As we know, the main role of the camera in our project not just surveillance but the face **using Face Recognition**, Figure 5-1 depicts the flow structure of the activity cycle. Each of the robot's observation cycles is separated into two states:

Idle and active. The robot remains stationary on the floor within the office during the day and around the office compound at night when in the idle condition. Meanwhile, the PIR sensor is constantly scanning the area for any object movement. Because the sun emits a large amount of infrared radiation, the PIR sensor will provide a false warning throughout the day, and this is why we are using a night vision camera.

The robot enters the active state when it detects IR radiation from a specific direction. The robot's power consumption is minimal in this condition because it is stationary. In a region where the physical specifications of the site are unknown, it is preferable to deploy a static robot rather than an autonomous continuously moving robot.

The Camera module is initiated in the active state by I2C communication between the NRF52 and the Raspberry Pi. It captures an image of the item and begins the face detection process. When the robot detects a human face, the facial recognition program kicks in. If there is a match with the dataset, the robot sends the user an SMS with the name of the person who was recognized.

If the identified face is that of an intruder, an alarm SMS is sent to the user via the NRF right away. If no human face is seen, the robot returns to its idle state and searches for infrared radiations again.

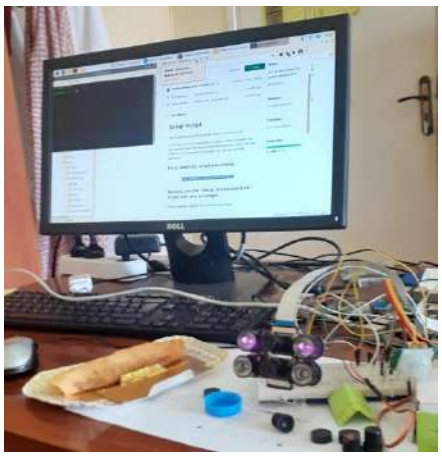


Figure 5- 9 The PIR installation

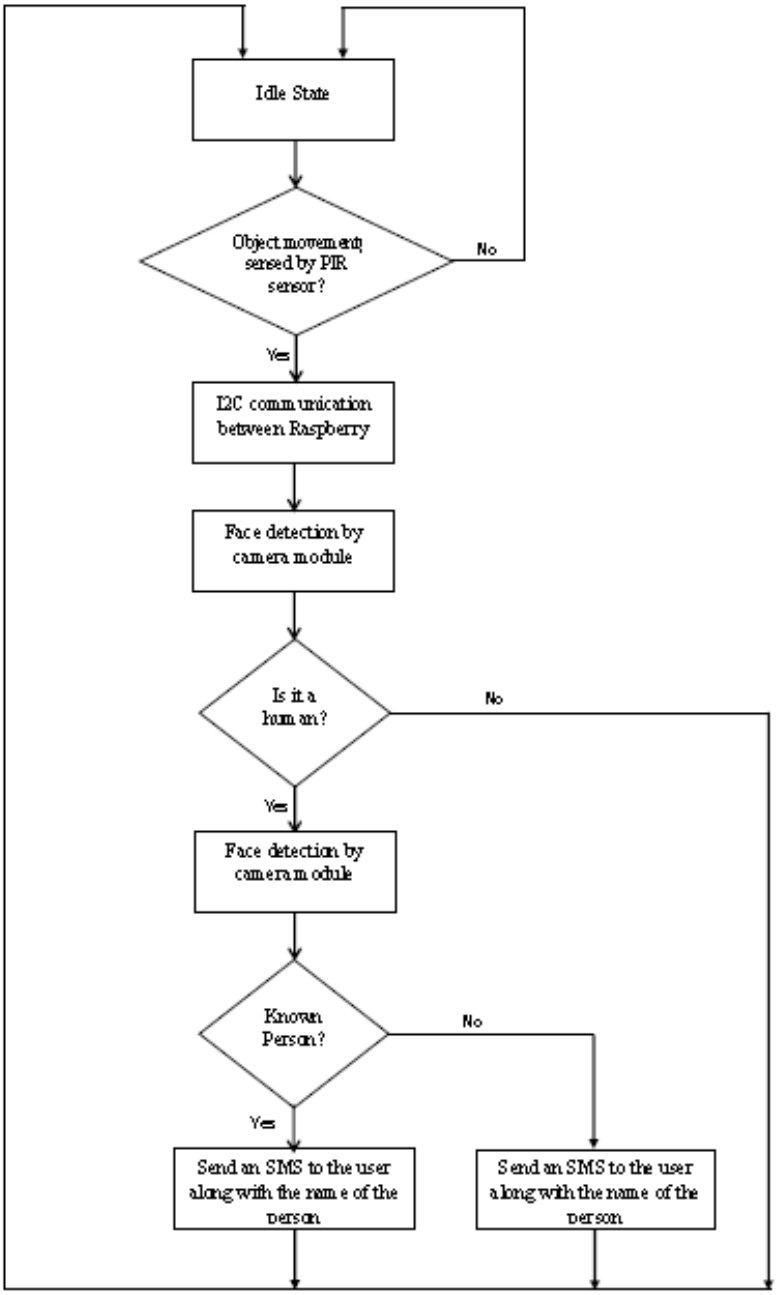


Figure 5- 10 Flowchart of the camera

5.3.5 Control unities

The Surveillance Robot's control unit is built around a Raspberry Pi 3 (Model B) and an NRF52. The Raspberry Pi has an advantage over other microcontrollers in that it is a full-featured credit card-sized computer with a 900 MHz microprocessor.

For interacting with various peripherals, the Raspberry Pi has Camera Interface and General-Purpose Input and Output (GPIO) pins. The GSM Module is connected via the Universal Asynchronous Receiver Transmitter (UART) pins. The motor control

cannot be done with this controller since the Raspbian Operating System installed on the Raspberry Pi is not a Real Time Operating System (RTOS). As a result, the Arduino Uno is used to fulfill the task. The I2C protocol is used to connect the Uno to the Raspberry Pi. The PIR sensors are connected to an Arduino Uno for easy human detection.

5.3.5.1 Face Detection

The face recognition module is divided into two phases: detecting the face in the image and identifying the face by comparing it to a database.

5.3.5.2 Detection phase

The first phase of the MTCNN algorithm contains three phases that detect the bounding boxes of faces in an image as well as their five face landmarks (two eyes, two ends of the mouth and the nose). Each step improves detection results by sending its data through a CNN, which produces candidate bounding boxes and scores. Face / non-face categorization (face / non-facial), bounding box regression, and face landmarks localization are the three fundamental tasks performed by CNN networks.

The input image is scaled numerous times to produce an image pyramid in step 1, and each scaled version is delivered via CNN.

We extract sub-pieces of pictures for each bounding box, resize them, and transport them via the associated CNN in stages 2 and 3.

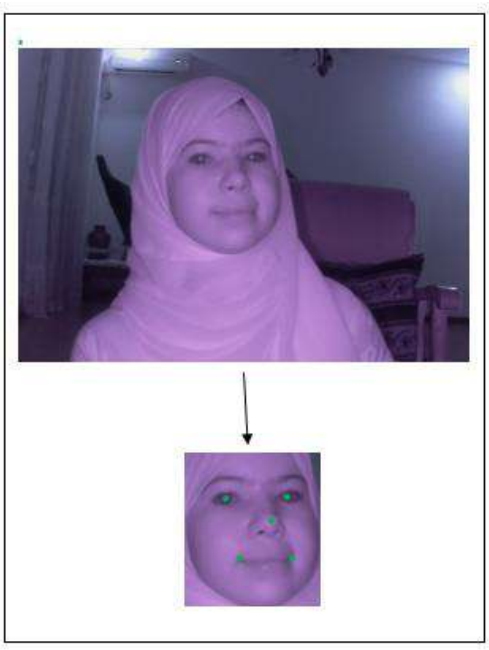


Figure 5- 11 Fixed a face rotating with detected landmarks

Face recognition is more favorable than fingerprint or iris-based approaches because it is a non-contact process]. The image-capturing technology does not interfere with the person's activities and takes pictures from a safe distance. Furthermore, the identification procedure is self-contained and does not interrupt the individual. Facial recognition technology can also reduce crime rates because the acquired face photographs can be stored in a database and retrieved to identify risks. Face recognition is more favorable than fingerprint or iris-based approaches because it is a non-contact process [ ].

Face recognition is performed in real time on the detected faces. A video frame is used to identify the person. To recognize a face in a frame, the frame must first detect a face. A region of interest (ROI) is marked if it exists. Facial recognition is performed on the ROI. Face recognition is broken into two stages: Creating a database

Result:

Its following figure depicts our system's overall execution architecture for facial and:

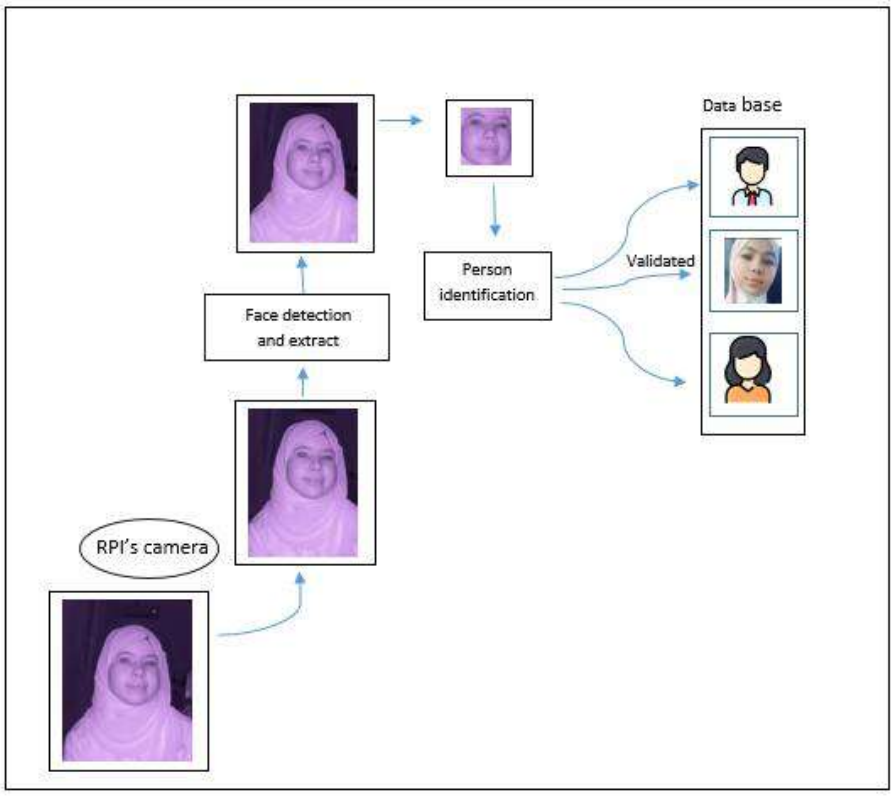


Figure 5- 12 Path to full execution of the facial recognition module

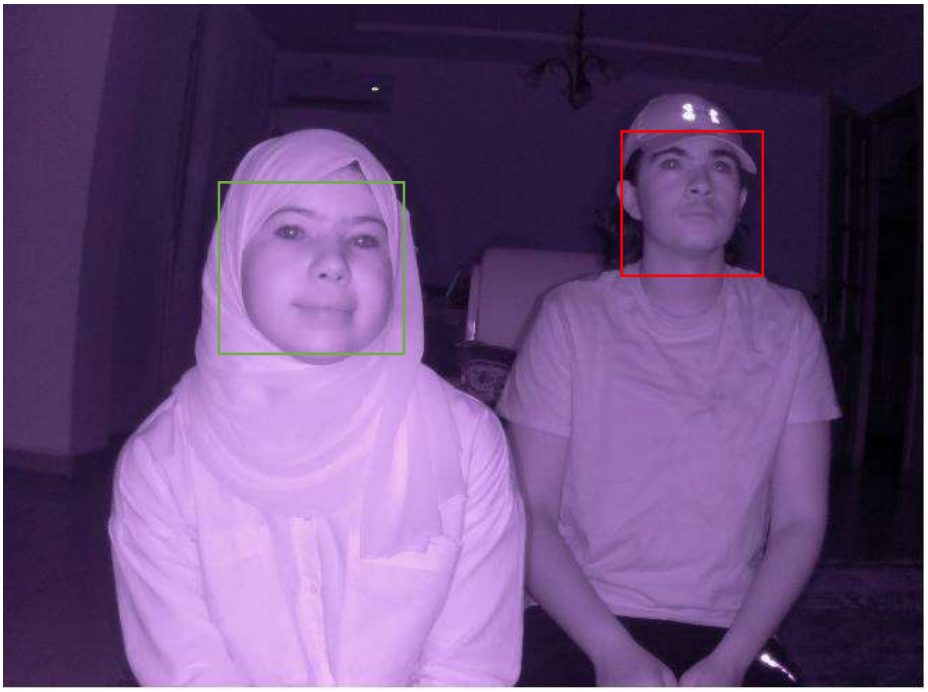


Figure 5- 13 Face Recognition as Known and unknown person

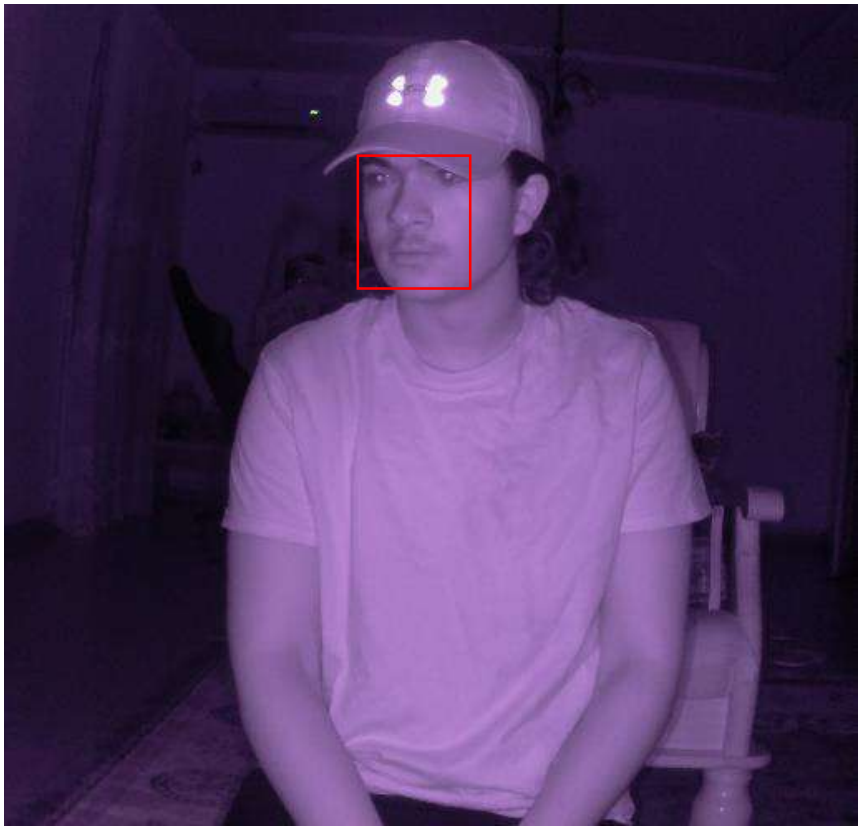


Figure 5- 14 Face Recognition as unknown person

5.6 Conclusion

In this chapter, we have illustrated the steps followed during the realization of our mobile prototype with figures and electronic wiring diagrams. We also made the recognition algorithm to detects human presence in its vicinity

By employing the camera module and PIR sensors. The PIR sensors aid in sensing the motion of IR radiating objects. The human face is detected using camera module.

Abstract:

This project is about a surveillance robot equipped with a camera a PIR sensor and can be consulted remotely via a mobile application thanks to the NRF52 module which has Bluetooth service by default, as well as the auto-balance system at the level of the camera arm which allows to keep the camera image stable through its original axes, in a fast, precise way using PID.

Résumé :

Ce projet concernes de robot de surveillance équipé d'une caméra et d'un capteur PIR et consultable à distance via une application mobile grâce au module NRF52 qui dispose du service Bluetooth par défaut, ainsi que le système d'auto-balance au niveau du bras de la caméra ce qui permet de maintenir l'image de la caméra stable sur ses axes d'origine, de manière rapide et précise en utilisant PID.

ملخص

هذا المشروع عبارة عن روبوت مراقبة مزود بكاميرا ومستشعر PIDبالإضافة إلى نظام التوازن التلقائي على مستوى ذراع الكاميرا مما يسمح بالحفاظ، على ثبات صورة الكاميرا أثناء معالجة الصور، بطريقة سريعة ودقيقة باستخدام Bluetooth التي تحتوي على خدمة NRF52

General conclusion

A surveillance robot is a machine that needs specialists in many fields including mechanics, automation, electronics and IT to operate.

This project was both very interesting and very educational. We were able to design and develop a surveillance robot, applying our knowledge acquired during our studies throughout our training. Thus, it allowed us to improve our knowledge in robotics and to master new technology such as facial recognition

On the other hand, the use of the Raspberry and NRF52 card in C language and in python which allowed us to save time and simplify the program

We chose our hardware according to our needs and then tried different solutions to achieve the desired functionality. The realization of this robot also gave us the opportunity to work on several areas at the same time, in particular programming and electronics. So in the end we were able to do real system design work, which is most like engineering work. In general, this project made us discover the world of surveillance robots and all its professional perspectives.

This thesis allowed us to acquire theoretical and practical knowledge during our research and training, in particular to achieve our objective which is to achieve a surveillance robot at zero, despite all the technical problems that we face but there is always a prototype that can obviously be improved by diversifying its tasks by including new components in order to increase its performance.

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IoT Controlled Mobile Robot for Home Security and Surveillance P. S. N. Suryavamsi1 and A. Arockia Selvakumar2. 2020

M. BENCHORA Mohamed Amine- M. MAHMOUDI Sid AliMise en oeuvre d'un système de contrôle d'accès pour les bâtiments intelligents basé sur la reconnaissance conjointe faciale et vocale.

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Abd raouf TOUATI Mémoire_PFE_Master_Mécatronique_Djeddou_Touati_2019