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Présenté par :
Boumedien Meriem
Khorsi Sarra Hadile

Thème

Développement et Implémentation d'un robot désinfectant a base des lampes ultraviolets pour diverses applications

Soutenu publiquement, le 04/07/2024, devant le jury composé de :

M. GHOUTI Abdellaoui	MCA	ESSA-Tlemcen	Président
M. BENNEKROUF Mohammed	MCA	ESSA-Tlemcen	Examinateur 1
Mme KHEDIM Amel	MCA	ESM-Tlemcen	Examinateur 2
M. MAGNAFI Hicham	MCA	ESSA-Tlemcen	Encadrant
M. BEMMOUSSAT Chems Eddine	MCB	Univ-Ain Temouchent	Encadrant
Mme GHERBI Sabah	MCA	Univ-Ain Temouchent	Co-encadrant
Mme OUHOUD Amina	MCB	ESSA-Tlemcen	Co-encadrant

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بسم الله الرحمن الرحيم

Summery

To meet the growing demand for disinfection in sensitive environments, we have developed an innovative line-following robot using UV technology to disinfect surfaces and air. This versatile robot follows black lines using infrared sensors and avoids obstacles with a distance sensor. It also includes an MQ135 sensor to monitor air quality. The 3D design ensures the protection and stability of the UV lamps. This innovative solution improves safety and reduces the risk of contamination without using harmful chemicals.

Keyword: Robot , Pathogen ,Disinfection ,UV-C ,Air quality.

Résumé

Pour répondre à la demande croissante de désinfection dans des environnements sensibles, nous avons développé un robot suiveur de ligne innovant utilisant la technologie UV pour désinfecter les surfaces et l'air. Ce robot polyvalent suit les lignes noires grâce à des capteurs infrarouges et évite les obstacles avec un capteur de distance. Il intègre également un capteur MQ135 pour surveiller la qualité de l'air. La conception en 3D assure la protection et la stabilité des lampes UV. Cette solution innovante améliore la sécurité et réduit les risques de contamination sans utiliser de produits chimiques nocifs.

Mots clés :robot, pathogene , disinfection , UV-C, qualité d’air.

ملخص

لتلبية الطلب المتزايد على التطهير في البيئات الحساسة، قمنا بتطوير روبوت مبتكر يتبع الخطوط باستخدام تقنية الأشعة فوق البنفسجية لتطهير الأسطح والهواء. يتبع هذا الروبوت المتعدد الاستخدامات الخطوط السوداء باستخدام مستشعرات الأشعة تحت الحمراء ويتجنب العقبات باستخدام مستشعر المسافة. كما يتضمن مستشعر MQ135 لمراقبة جودة الهواء. يضمن التصميم ثلاثي الأبعاد حماية واستقرار مصابيح الأشعة فوق البنفسجية. تعمل هذه الحلول المبتكرة على تحسين السلامة وتقليل مخاطر التلوث دون استخدام مواد كيميائية ضارة

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Dedication

First and foremost, I thank ***Allah*** *Almighty for His continuous presence in my life. He has been my support, listening to my prayers and granting my supplications. His mercy and blessings have guided and strengthened me throughout this journey.*

I dedicate this work wholeheartedly to ***my beloved father****, my hero, whose love and sacrifices have inspired me to persevere. To* ***my mother****, whose tenderness and encouragement have always comforted me. To my sister* ***Hadjer****, her husband* ***Hamza****, and their children* ***Assil*** *and* ***Iyad****, for their unwavering love and support. To my brother* ***Abdelkader****, his wife* ***Amina****, and their son* ***Tidjani****, who have always believed in me. To my sister* ***Nesrine*** *and my cousin* ***Habiba****, for their warm presence and words of encouragement.*

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With all my gratitude and love, I dedicate this work to you

Meriem

Dedication

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Sarra Hadile

Abstract

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List of abbreviations

UV	Ultraviolet
WHO	World Health Organization
TOC	Total Organic Carbon
DBP	Disinfection By-Products
PM2.5	Particulate Matter 2.5 micrometers
HEPA	High-Efficiency Particulate Air
EPA	Environmental Protection Agency
AM	Arduino Mega
ICSP	In Circuit Serial Programming
UART	Universal Asynchronous Receiver-Transmitter
SRAM	Static Random-Access Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
DC	Direct Current
HC-SR04	High-Conductance ultrasonic sensor
MQ135	senses gases
USB	Universal Serial Bus
CAD	Computer-Aided Design
IDE	Integrated Development Environment
PCB	Printed Circuit Board
VCC	Voltage Power Supply
GND	Ground
OUT	Output
Trig	Trigger pin
IoT	Internet of Things
MQ135	Air Quality Sensor Type
LED	Light Emitting Diode
3D	Three-Dimensional Printing

General introduction

Disinfection is a critical process in preventing the spread of infectious diseases, yet it faces several scientific challenges. Firstly, traditional disinfection methods, such as chemical or heat-based approaches, may prove ineffective against resilient pathogens. Moreover, the excessive use of chemicals can lead to increased microbial resistance and adverse environmental effects. Additionally, some disinfection methods may be limited in their ability to reach difficult-to-access areas or to eradicate microbial biofilms. Furthermore, there are concerns regarding the safety of healthcare workers and the general public, particularly regarding exposure to disinfectants and UV radiation. Confronted with these challenges, it is imperative to develop new disinfection methods that are both effective and environmentally friendly, as well as safe for use in various contexts. This requires a multidisciplinary approach involving researchers in microbiology, engineering, chemistry, and public health to design and implement innovative solutions to address current and future disinfection needs.

In this context, the use of ultraviolet (UV) radiation for disinfection represents a promising approach. UV enables biological disinfection without the addition of potentially harmful chemicals to the environment and human health. This method thus offers an environmentally friendly and sustainable alternative to eliminate pathogens while reducing the risk of resistance and preserving air and water quality. By integrating the benefits of UV into disinfection technologies, it is possible to develop effective and ecological solutions to current health challenges.

In the scope of this thesis project, our ultimate goal is to develop a UV-based line-following robot, intended for environments requiring strict and frequent disinfection. We aim to provide an innovative and efficient solution for autonomous navigation in hospital settings, laboratories, or any space where hygiene is paramount. This robot is designed to follow pre-defined trajectories marked by UV lines, thereby enabling precise automation of movement and disinfection tasks. The objective is to facilitate control and tracking of the robot's trajectory without requiring constant human intervention, while ensuring ease of use and straightforward installation for ordinary users.

The thesis is divided into three chapters, the first chapter examines classical and innovative disinfection methods, highlighting the efficacy of UV radiation in sanitation.

The second chapter delves into the heart of our exciting project: the design and implementation of our UV-based line-following robot. It also presents the equipment used for our project, such as the microcontroller, sensors, lamps, software, etc.

The third chapter offers a comprehensive exploration of our solution, detailing the step-by-step process of its conception and realization. The thesis will be concluded with a general conclusion.

Chapter I: Disinfection.

Introduction

In the realm of public health and hygiene, disinfection stands as a cornerstone for preventing the spread of infectious diseases. It encompasses the vital process of eliminating harmful pathogens from surfaces, objects, and fluids, thereby reducing the risk of transmission and ensuring a safe environment for all.

This chapter delves into the fundamental aspects of disinfection, beginning with its definition and purpose. We will explore classical and innovative methods employed in disinfection, ranging from traditional chemical agents to cutting-edge technologies such as ultraviolet (UV) light. Understanding these methods, their mechanisms and their applications is essential for implementing effective disinfection strategies. Additionally, we will highlight UV radiation's efficacy in sanitation and detail the essential equipment required for our startup project's implementation.

This chapter delves into classical and innovative disinfection methods, highlighting UV radiation's efficacy in sanitation. The subsequent section will detail the essential equipment required for our startup project's implementation.

I.1 Definition

Disinfection, defined as the process of eliminating a significant portion, or even all, of harmful pathogen like bacteria and viruses from inanimate surfaces, plays a vital role in maintaining hygiene and preventing the spread of disease. Disinfection involves eliminating pathogenic microorganisms on objects, essential for preventing the transmission of infections. The effectiveness of disinfection depends on factors like organism qualities and environmental conditions. Despite claims, the WHO advises against spraying individuals with chemicals like alcohol or chlorine due to potential harm. (Patil, 2020)

I.2 Purpose of disinfection

Disinfection serves to achieve a clean state by not only removing visible dirt and debris through cleaning with detergents but also by significantly reducing or eliminating microorganisms that may pose health risks. This process involves three essential steps: cleaning, rinsing, and disinfection itself. Cleaning ensures the macroscopic cleanliness of surfaces or instruments, while disinfection targets the microscopic level, effectively eradicating harmful microorganisms. (Jost, 2024)

I.3 Disinfection Methods

There are different methods of disinfection, including classic and innovative approaches. Here we will explore both classic and innovative methods used for disinfection.

I.3.1 Classic disinfection method

Classic disinfection methods have historically relied on a range of chemical agents to effectively inactivate or eliminate pathogens. Here are some widely used examples.

I.3.1.1 Chemical Disinfectants

Chemical disinfection is the process of eliminating or reducing the number of Pathogen, such as bacteria, viruses, fungi, and protozoa, from surfaces, water, or other substances using chemical agents.

- **Alcohols (ethanol, isopropanol):** They are most effective against lipophilic viruses, less effective against non-lipid viruses, and ineffective against bacterial spores.
- **Chlorine compounds:** Chlorine solutions, while universally disinfectant and potentially sterilizing against bacterial spores, are hindered by rapid inactivation by organic substances and corrosive tendencies, limiting their laboratory use.
- **Formalin**: is a 37% solution of formaldehyde gas in water. Diluted to 5% formaldehyde it is an effective disinfectant; at 0.2% - 0.4% it can inactivate bacteria and viruses.
- **Glutaraldehyde:** Glutaraldehyde are potent against bacteria, fungi, and viruses, including spores, with less irritating vapors than formaldehyde, but require careful use in well-ventilated spaces to minimize exposure.
- **Phenol:** Phenol solutions, long used as disinfectants, pose limitations in laboratories due to sticky residue post-processing, and concentrated phenol's high toxicity and skin absorbency necessitate stringent personal protective equipment use. (Selection and Use of Chemical Disinfectants)

I.3.1.2 Product overview: BioPhen Xtra Phenolic Disinfectant

BioPhen Xtra is a synergistic blend of synthetic phenolics specifically designed to provide flexibility and broad-spectrum activity with efficacy against viruses, bacteria, and fungi in a wide range of temperatures and the presence of organic challenge, as shown in **Figure I.1**. BioPhen Xtra provides a highly convenient multipurpose biosecurity solution for a wide range of disinfectant applications including surfaces, equipment, boot dips, wheel dips.

Price: 5,958.09$

Figure I.1 BioPhen Xtra Phenolic Disinfectant *(Dalton, s.d.)*

I.3.1.3 Thermal Disinfection

Equipment can be disinfected by using moist heat which maintains a specific temperature for a specific amount of time. Steam is produced, and if the correct temperature is maintained for the right amount of time, it will kill any bacteria that may be on the surface. (Dekomed, s.d.)

I.3.1.4 Product overview: Washer disinfector

The Deko D25 is compact yet has a powerful circulation pump that delivers the cleaning performance of larger models as shown in Figure I.2.

Figure I.2 Washer disinfector *(Dekomed, s.d.)*

I.3.1.5 Disinfection by Filtration

Filtration process consists of the passage of a liquid/gas through a screen like material with pores small enough to retain pathogen . It can prevent the passage of both viable and non-viable particles. (Waly)

I.3.1.6 Product overview: Bio Sure Post-Filtration Disinfection System

Bio Sure Post-Filtration Disinfection System uses patented electrolytic ozone to provide instant and residual-free sanitation with simple installation, as shown in Figure I.3.
This easy-to-use system can keep beverage makers, water coolers, or dental unit waterlines clean and safe. (Model: EOS7177-BX)

Figure I.3 Bio Sure Post-Filtration Disinfection System *(Sentai, s.d.)*

I.3.2 Innovative disinfection method

Innovative disinfection methods are crucial for addressing pathogen resistance and ensuring effective sterilization in various industries. Here are some widely used examples.

I.3.2.1 Plasma disinfection

When a solid is heated, it transforms into a liquid and then from a liquid into a gas. If enough energy is applied to gas, it becomes an ionized gas known as plasma. This method covers almost all of the resistance hierarchy of pathogens.
The applicability of plasma technology in disinfection/sterilization is potentially wide-ranging. (Sakudo, 2019)

I.3.2.2 Product overview: The PE-25

The PE-25 is our most affordable, entry-level plasma cleaner. It's a robust machine that is perfect for small production facilities, research labs, universities or any industry needing a small-scale, affordable plasma solution. as shown in Figure I.4.
Price: 5,900$

Figure I.4 Plasma Cleaner *(Plasma Etch, s.d.)*

I.3.2.3 Air Ionization Disinfection

An air ionizer is a device that ionizes air molecules by applying a high voltage to eliminate airborne pollutants. Air ionizers release charged ions into the atmosphere, making contaminants too heavy to float, necessitating manual cleaning of surfaces. While they effectively remove particles from the air, contaminants settle on nearby surfaces, requiring users' proactive cleaning for optimal efficacy. The effectiveness of air ionizers in eliminating airborne contaminants is contingent upon users' cleaning diligence. (Air ionizers case study, 2021)

I.3.2.4 Product overview: Smart Air Purifier

As shown in Figure I.5, the OEM Portable Smart Air Purifier for Office is a compact and versatile solution for purifying indoor air. It features advanced technologies including a True HEPA 13 filter, UVC light sterilization, and an ionic air purification system. This purifier effectively removes PM2.5 particles, allergens, bacteria, and viruses from the air, ensuring a clean and healthy environment in office spaces.
Price: 60.00$

Figure I.5 Smart Air Purifier *(Purifier)*

I.3.2.5 Ozone disinfection

Ozone is produced when oxygen (O2) molecules are dissociated by an energy source into oxygen atoms and subsequently collide with an oxygen molecule to form an unstable gas, ozone (O3),
which is used to disinfect wastewater.
The cost of ozone disinfection systems is dependent on the manufacturer, the site, the capacity of the plant, and the characteristics of the wastewater to be disinfected. Ozonation costs are generally high in comparison with other disinfection techniques. (EPA)

I.3.2.6 Product overview: Water Ozone Generator

As illustrated in Figure I.6, O3 (ozone) stands out as one of the most potent sterilizing agents globally. It surpasses molecular chlorine by five times in its ability to eradicate germs, bacteria, and viruses. Ozone acts as a robust and efficient natural algaecide, bactericide, disinfectant, fungicide, germicide, sanitizer, and anti-viral agent. This device will generate ozone for you in a natural and safe manner, allowing you to sterilize and clean air, water, fruits, and vegetables effectively.

Figure I.6 Water Ozone Generator *(Amazon, s.d.)*

I.4 The Ultraviolet Disinfection

In this title, we will talk about UV technology

I.4.1 Definition

UV light disinfection disrupts organisms' genetic material, preventing reproduction by penetrating cell walls. Generated by a special lamp through an electric arc in low-pressure mercury vapor, it emits radiation peaks at 253.7 nm and 184.9 nm, optimal for bacteria destruction within the range of 250-270 nm, while shorter wavelengths produce ozone and free radicals to combat bacteria. (Tech Brief)

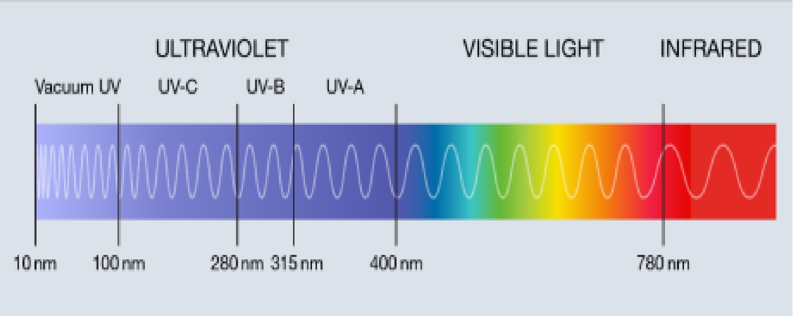


Figure I.7 Ultraviolet Radiation *(Disinfection 101, 2023)*

I.4.2 Ultraviolet types

As shown in **Table I.1,** here is an explanation of each type of ultraviolet in detail.

- **Ultraviolet A (UVA)**
  Ultraviolet A (UVA) radiation spans 320-400 nm, penetrating human tissue and causing DNA damage. Predominantly sourced from sunlight, UVA exposure leads to premature aging, photo immunosuppression, and increased skin cancer risk. Despite its damaging effects, UVA does not stimulate vitamin D production as it lacks efficacy beyond wavelengths of 330 nm. (Parisi, 2021)
- **Ultraviolet B (UVB):**
  UV-B radiation is that portion of the electromagnetic spectrum from 290320 nanometers, it refers to a specific portion of the sun’s energy reaching the earth’s surface. (Gao)
- **Ultraviolet C (UVC):**
  As shown in Figure I.8, the potential for ultraviolet radiation to inactivate viruses or kill bacteria is critically dependent on the wavelength emitted by the source7. UV-C is considered the most effective for disinfection.
  Low pressure mercury lamps, primarily emitting at 254 (253.65) nm in the UV-C region, have been used for many decades and the effectiveness at this wavelength is often used as the metric against which emission from other sources is assessed. Theoretically, the peak effectiveness is at about 260-270 nm, the peak wavelength for RNA/DNA absorption, longer wavelengths have a reduced capability to inactivate viruses and kill bacteria. There is evidence that SARS-CoV-2 may be inactivated using UV-C, but the exact quantity of UV-C to achieve a given level of viral inactivation is still subject to

investigation8. However, comparison with the effectiveness on similar coronaviruses suggests that a radiant exposure of about 7 J m-2 at 254 nm would be expected to inactivate 90% of SARS-CoV-2.9 It is estimated that about 28 J m-2 at the same wavelength is needed to inactivate 99% of this virus and that 99% inactivation will require 280 J m-2 at 295 nm; 2,800 J m-2 at 305 nm; 28,000 J m-2 at 309 nm; and 280,000 J m-2 at 320 nm. (Office for Product Safety & Standards)

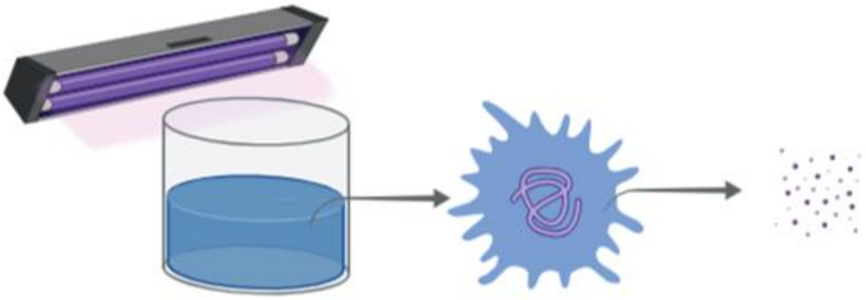


Figure I.8 Scheme of damage caused to bacterial DNA by UV Radiation *(Office for Product Safety & Standards)*

Table I.1 Ultraviolet types *(Abd Rahman Tamuri)*

Name	**Abbreviation**	**Wavelength, nm**	**Energy per photon,eV**
Ultraviolet A	UVA	400 - 315	3.10 – 3.94
Ultraviolet B	UVB	315 – 280	3.94 – 4.43
Ultraviolet C	UVC	280 – 100	4.43 – 12.4

I.4.3 Product Description: UV Disinfection Robot SEIT-UV

As shown in **Figure I.9** SEIT-UV has been specifically developed to prevent and reduce the spread of infectious diseases, viruses, and germs. This cutting-edge technology has been clinically tested and verified by accredited universities, research laboratories, and hospitals. It kills 99.99% of germs. (expo, Robot de désinfection à UV SEIT-UV)

Figure I.9 UV Disinfection Robot SEIT-UV *(expo, Robot de désinfection à UV SEIT-UV)*

I.4.3 Advantages and Disadvantages of UV

There are many advantages and disadvantages for UV disinfection, as described in the following section.

I.4.3.1 Advantages

- It is a very effective disinfection technology for Cryptosporidium and Giardia.
- It does not significantly alter the water quality; that is, no change in total organic carbon (TOC), pH, corrosively, DBP formation potential, or turbidity.
- The technology is relatively inexpensive with low capital and operating costs, compared to other disinfection options for protozoa.
- It is relatively easy to operate (i.e., turn up or turn down) the UV equipment based on changes in water flow, water quality, etc.
- The UV equipment has a relatively small footprint and is usually amenable to retrofit into existing water treatment plants.
- No chemicals are needed for UV disinfection.
- Disinfection is very fast. Contact times are in the range of a few seconds.

I.4.3.2 Disadvantages

- There is no residual disinfection capacity. Therefore, some level of chlorine or chloramines is usually added to maintain a disinfection residual in the distribution system.
- At present, it is not possible to continuously monitor the UV dose, so operators have to rely on secondary measurements (sensor readings, UV transmittance, water flow rates, etc.).
- Most UV reactors contain mercury lamps, so breakage of UV lamps represents a possible mercury hazard. However, calculations (USEPA 2006b) appear to show that even if the mercury in a lamp where to enter the water completely, the mercury level in the distributed water would still be well below maximum contaminant levels. More research is required to address this issue.
- The electric power supply to the utility could be subject to interruptions, which could cause UV lamps to extinguish for time periods of 1–5 min. This could result in some water not being treated unless the water is diverted to waste.

- There are times when water could be under disinfected because of power interruptions or lamp warm-up. These situations are considered by the USEPA as off specification events because the UV system would be operating outside of the verified limits of performance.

I.5 Conclusion

This chapter examined classical and innovative disinfection methods, emphasizing the effectiveness of UV radiation in sanitation. The next chapter will detail the essential equipment needed to implement our startup project. It will cover the necessary hardware, including UV lamps and sensors, as well as the software and programming tools required.

Chapter II: Equipment used for our project.

Introduction

In this chapter, we delve deep into the heart of our exciting project: the design and implementation of our UV-based line-following robot. This promising technological advancement has been garnering increasing interest in the field of robotics, offering innovative opportunities to address various challenges across industries, logistics, and even education. Our exploration of this captivating theme unfolds in two distinct dimensions: the hardware aspect, where we intricately craft the physical components of the robot with technical precision and ingenuity, and the software facet, where we develop algorithms and programs that enable our robot to autonomously and efficiently navigate the designated lines. By melding technical expertise with creativity, our aim is to present a robust and pioneering solution that opens up new vistas in the realm of applied robotics.

II.1 Hardware

Exploring Hardware: An Overview of Key Components Used in the Design Process

II.1.1 Arduino Board

Arduino Mega: is an exemplary development board dedicated for building extensive applications as compared to other maker boards by Arduino. The board accommodates the ATmega2560 microcontroller, which operates at a frequency of 16 MHz. The board contains 54 digital input/output pins, 16 analog inputs, 4 UARTs (hardware serial ports), a USB connection, a power jack, an ICSP header, and a reset button as shown in **Figure II.1** and **Table II.1.** (Arduino MEGA 2560 Rev3, 2024) (Hicham, 2024)

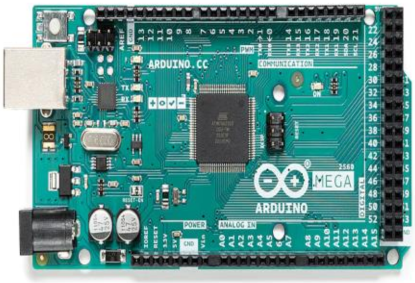


Figure II.1 Arduino Mega Image *(Arduino MEGA 2560 Rev3, 2024)*

Table II.1 Arduino MEGA Module Characteristics *(Arduino MEGA 2560 Rev3, 2024)*

Features	Values
Microcontroller	ATmega328P
Operating Voltage	5V
Recommended Input Voltage	7-12V
Number of Digital I/O Pins	14 (including 6 providing PWM output)
Number of Analog Input Pins	6
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Frequency	16 MHz
Interfaces	UART, SPI, I2C
Dimensions	68.6 x 53.4 mm

II.1.2 Comparison Table of Arduino Boards: Nano, Uno, and Mega

We find in the market three types of the most commonly used Arduino boards, which are: Arduino Uno, Arduino Mega, and Arduino Nano. In **Table II.2** and **Table II.3** , we summarize the different characteristics of these Arduino boards:

Table II.2 Comparison of Arduino Module Advantages

Feature	Arduino Nano	Arduino Uno	Arduino Mega
Size and weight	compact and lightweight	relatively large	relatively large
number of I/O pins	14(including 8 analog)	20(including 6 analog)	54(including 16 analog)
memory	32 KB(flash)/2 KB(SRAM)	32 KB(flash)/2 KB(SRAM)	256 KB(flash)/8 KB(SRAM)
Price	affordable	affordable	higher
Ease of use	easy to program	easy to program	more complex
Shield compatibility	compatible with most shields	high with most shields	compatible with most shields
Support community	large support community	large support community	large support community

II.1.3 Limitations

Summarizing the limitations of the three types of Arduino boards as shown in **Table II.3**.

Table II.3 Comparison of Arduino Module Characteristics

Feature	**Arduino Nano**	**Arduino Uno**	**Arduino Mega**
Number of I/O Pins	Limited for complex projects	Limited for projects requiring many connections	-
Memory	Limited for large programs and data	Limited for large programs and data	-
Size and Weight	-	-	Size and weight can be a disadvantage for compact or portable projects
Price	-	-	Higher than other models

II.1.4 Justification for Choosing the Arduino Mega for Our Project

The choice of the Arduino Mega for our project is justified by its ability to provide a high number of I/O pins, which simplifies the task of connecting and interfacing with the components needed to build our line-following robot.

II.2 Sensors

We will now discuss the sensors used in this section.

II.2.1 Infrared Sensor

The Infrared Sensor is a digital sensor that detects movement within its field of vision based on infrared radiation as shown in **Figure II.2** and **Table II.4** . (Scribd)

.

Figure II.2 Infrared Sensor Image *(kniss)*

Table II.4 Infrared Sensor Characteristics *(kniss)*

Feature	Values
Power Supply	DC 3-5V
Detection Distance	2 ~ 30cm
Standby Consumption	35°
Dimensions	3.1 x 1.5 cm

However, it is important to note that there are other types of sensors also used in similar applications as shown in **Figure II.3.** (imotion.fr) (what did you add this sensor)

Figure II.3 Infrared Sensor Image *(imotion.fr)*

II.2.2 Ultrasonic Sensor HC-SR04

The HC-SR04 sensor utilizes ultrasound to determine the distance to an object as shown in **Figure II.4** and **Table II.5**. It offers an excellent non-contact detection range with high precision and stable measurements. (baruck)

Figure II.4 Ultrasonic Sensor HC-SR04 Image *(baruck)*

Table II.5 Ultrasonic Sensor HC-SR04 Characteristics *(baruck)*

Feature	Values
Power Supply	5V
Detection Range	2cm to 4cm
Detection Angle	15°
Consumption	15mA
Pulse Width on Input	10 µs
Dimensions	45 x 20 x 15 mm

II.2.3 The MQ135 sensor

The module using the MQ2 gas sensor is designed to detect multiple types of gases, such as LPG, isobutane, propane, methane, alcohol, hydrogen, and smoke. It is characterized by high sensitivity and fast response time. Additionally, its sensitivity can be adjusted using a potentiometer, providing flexibility to adapt to specific needs. This functionality is illustrated in **Figure II.4** and **Table II.6**. (Binarytech, n.d.)

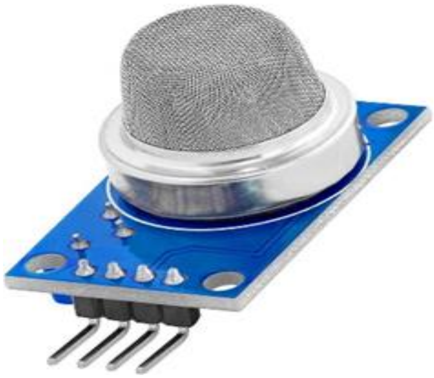


Figure II.5 The MQ135 Image *(Binarytech, n.d.)*

Table II.6 The MQ135 Characteristics *(Binarytech, n.d.)*

Feature	**Values**
Power Supply	5 Vcc
Measurement Range	10 to 10000 ppm
Sensitivity	2 to 20 K ohms
Operating Temperature	-20 to 50 °C
Compatibility	Arduino and Raspberry Pi
Dimensions	30 x 20 x 22 mm

II.3 L293D Motor Driver Shield

This motor driver shield is based on the L293D motor driver chip which is designed to provide bidirectional drive currents of up to 1.2 A each bridge with thermal shutdown protection at voltages from 4.5 V to 36V. (impulse, n.d.) (MEGNAFI H. A., 2019)

Figure II.6 L293D Motor Driver Shield Image *(impulse, n.d.)*

Table II.7 L293D Motor Driver Shield Characteristics *(impulse, n.d.)*

Characteristic	**Value**
Motor Driver Chip	L293D
Number of Motors	2
Maximum Current Per Motor	600mA (1.2A peak)
Voltage Range	4.5V to 25V
Compatible with Arduino?	Yes
Dimensions	Varies depending on model

II.4 DC motor

A direct current (DC) motor as shown in **Figure II.7** is a type of electric motor that converts electrical energy into linear or rotational mechanical motion A normal DC motor would have only two terminals. Since these terminals are connected only through a coil they have no polarity. Revering the connection will only reverse the direction of the motor. (MEGNAFI H. , 2024)
(university, 2023)

Table II.8 DC motor Characteristics (university, 2023)

Feature	**Values**
Operating Voltage	4.5V to 9V
Recommended/Rated Voltage	6V
Current at No load	70mA (max)
No-load Speed	9000 rpm
Loaded Current	250mA (approx)
Rated Load	10g*cm
Motor Size	27.5mm x 20mm x 15mm
Weight	17 grams

Figure II.7 DC motor Image *(university, 2023)*

II.5 4-Wheel Chassis Kit

A 4-wheel chassis kit as shown in **Figure II.8** is a set of components designed to construct a mobile platform with four wheels. This kit typically includes materials such as chassis plates, motors, wheels, and mounting hardware. It provides a foundation for building various robotic or vehicular projects, offering versatility and stability in movement. (A2itronic, n.d.)

Table II.9 4-Wheel Chassis Kit Characteristics Image *(A2itronic, n.d.)*

Feature	Values
Type	4WD Arduino mobile robot development platform
Motors	4 high-quality micro-speed motors
Plate Material	Imported acrylic with mounting holes
Sensors	Various sensors can be added
Size	295mm x 150mm
Torque Force	0.8 kg to 1 kg
Voltage	3V to 6V

Figure II.8 4-Wheel Chassis Kit Characteristics Image *(A2itronic, n.d.)*

II.6 Energy (Rechargeable Lithium Batteries)

Rechargeable lithium batteries are batteries utilizing lithium-ion or lithium-polymer technology that can be recharged multiple times. They typically offer higher energy density, better lifespan, and greater capacity than other types of rechargeable batteries as shown in **Figure II.9.** (CO) (Chellal, 2021)

Figure II.9 Rechargeable Lithium Batteries Image *(CO)*

Table II.10 Lithium Batteries Characteristics *(CO)*

Characteristic	Value
Type	Rechargeable Lithium Batteries
Capacity	6800mAh
Voltage	4.2V
Rechargeable	Yes
Dimensions	Varies depending on model
Weight	Varies depending on model
Chemistry	Lithium-ion
Cycle Life	Varies depending on model
Charging Time	Varies depending on charger and model

However, it is important to note that there are other types of power sources used in addition to infrared sensors, such as 9V batteries, solar panels, and power banks.

II.7 Lamp Ultraviolet (UV)

An ultraviolet (UV) lamp is a light source that emits ultraviolet radiation, situated between visible light and X-rays on the electromagnetic spectrum. UV lamps are designed to primarily produce UV-A (315 to 400 nm), UV-B (280 to 315 nm), or UV-C (100 to 280 nm) radiation. These lamps are utilized in various fields such as disinfection, counterfeit detection, photography, sterilization, and chemical analysis, as illustrated in **Figure II.10**. (Meriem)

Figure II.10 (UV) lamp Image *(getty)*

II.8 Male-to-female jumper cables

Male-to-female jumper cables are temporary connectors used between electronic components, offering versatility in connecting development boards like Arduino and modules such as sensors.as shown in **Figure II.11 .**

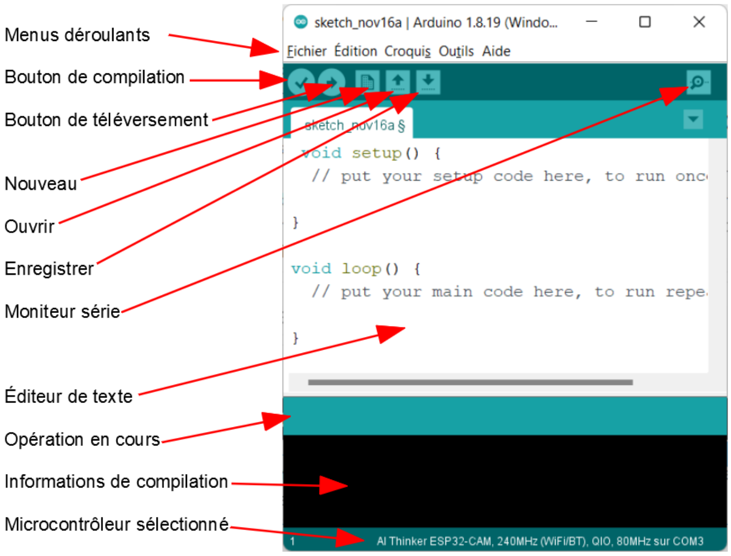
Figure II.11 Male-to-female jumper cables Image *(robotcraze, n.d.)*

II.2 Software

In this section, we will discuss the software and programs that we have used.

II.2.1 Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.



```
void setup() {
  // put your setup code here, to run onc

}

void loop() {
  // put your main code here, to run repe

}
```

Figure II.12 Main interface of the Arduino IDE (Arduino Integrated Development Environment (IDE) v1, s.d.)

II.2.2 Fritzing

Fritzing is an open-source hardware initiative that makes electronics accessible as a creative material for anyone. We offer a software tool, a community website and services in the spirit of Processing and Arduino, fostering a creative ecosystem that allows users to document their prototypes, share them with others, teach electronics in a classroom, and layout and manufacture professional PCBs.

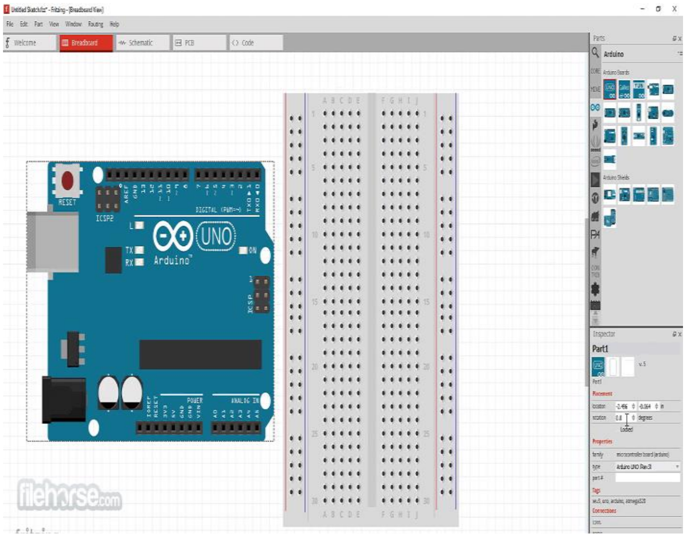


Figure II.13 Interface of Fritzing *(Fritzing, s.d.)*

In our approach, we will leverage Fritzing not for simulation purposes but specifically to visually demonstrate the connections between components using professional-grade images and to enhance the clarity and comprehensibility of component interconnections through high-quality visual representations.

II.2.3 SolidWorks

SolidWorks is a powerful computer-aided design (CAD) software used primarily for creating 3D models, simulations, and technical drawings in various industries such as engineering, architecture, and product design.

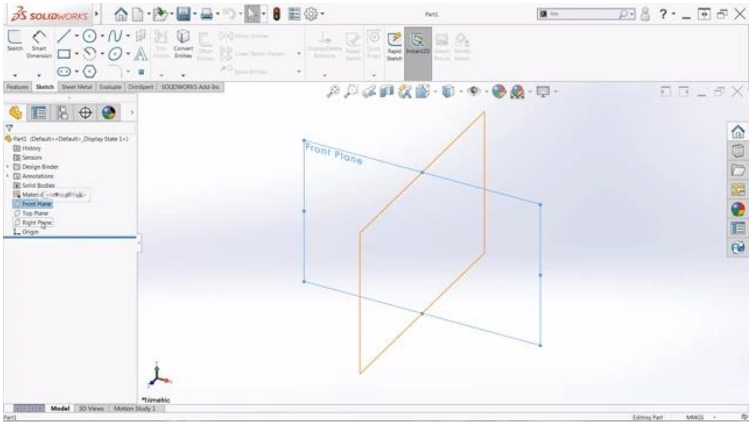


Figure II.14 Interface of SolidWorks *(SolidWorks, s.d.)*

We will employ SolidWorks not for simulation but specifically to generate professional-quality images showcasing the structural components of our robot. we aim to produce accurate and visually appealing renderings that highlight the intricacies and functionality of our robot's structure, aiding in both design development and communication of our project's vision. This approach ensures that our robot's design is effectively showcased with precision and clarity.

II.3 Conclusion

This chapter has meticulously detailed the hardware and software components essential for our UV-based line-following robot project. By selecting the Arduino Mega board for its extensive I/O capabilities and integrating sensors like infrared, ultrasonic, and gas detectors, we aim to create a versatile and autonomous robotic system. The inclusion of vital components such as motor drivers, DC motors, chassis kits, and rechargeable lithium batteries underscores our commitment to robust design and functionality. Additionally, leveraging software tools like Arduino IDE, Fritzing, and SolidWorks will enable us to program, visualize, and refine our robot's operation and physical structure with precision and clarity. This comprehensive integration of hardware and software forms the foundation for our innovative robotics solution. The next chapter will be dedicated to the practical implementation of our project.

Chapter III: Conception and Realization of a UV-Based Line-Following Robot.

Introduction

Welcome to the third chapter of our journey, where we delve into the intricate details of the conception and realization of our UV-based line-following robot. This chapter serves as a comprehensive exploration of our solution, detailing the step-by-step process of its design and development. From the initial conceptualization to the rigorous testing phases, we provide an in-depth analysis of the challenges faced and the innovative solutions implemented along the way. Join us as we navigate through the creative journey of bringing our robot to life, showcasing the dedication, ingenuity, and relentless pursuit of excellence that characterized our development process. Through this chapter, we aim to offer valuable insights into the complexities of robotics engineering while highlighting the practical application of theoretical concepts in a real-world setting.

III.1.1 Our Solution

Our project is an automatic and autonomous robot equipped with advanced UV technology for comprehensive disinfection of large spaces as shown in **Figure III.1** . We chose UV technology due to its proven effectiveness in eliminating up to 99.99% of viruses, bacteria, and other pathogens, making it a powerful tool to improve public health and safety. UV technology has emerged as an effective, safe, and environmentally friendly disinfection solution, offering a valuable alternative to traditional chemical disinfection methods. Its increasing adoption across various sectors attests to its importance in preserving public health and product safety while maintaining their integrity and natural appearance. However, it is essential to recognize that UV technology also has disadvantages, including its harmfulness to human health and the risk of eye damage. Therefore, it is imperative to avoid direct contact with UV rays and take necessary precautions during their use.

By choosing a line follower for our robot, we took into account the harmfulness of UV rays, which guided our decision towards an automated solution. Thus, the robot is programmed to follow a predefined route, allowing it to optimize its trajectory and effectively cover targeted areas autonomously. This approach has the advantage of minimizing the time required to disinfect a given area while ensuring comprehensive and systematic coverage. Moreover, by avoiding any human interaction with the robot, we eliminate potential risks to both equipment and human health. Automation thus offers a safe and effective solution for disinfection while preserving the security and integrity of treated environments.

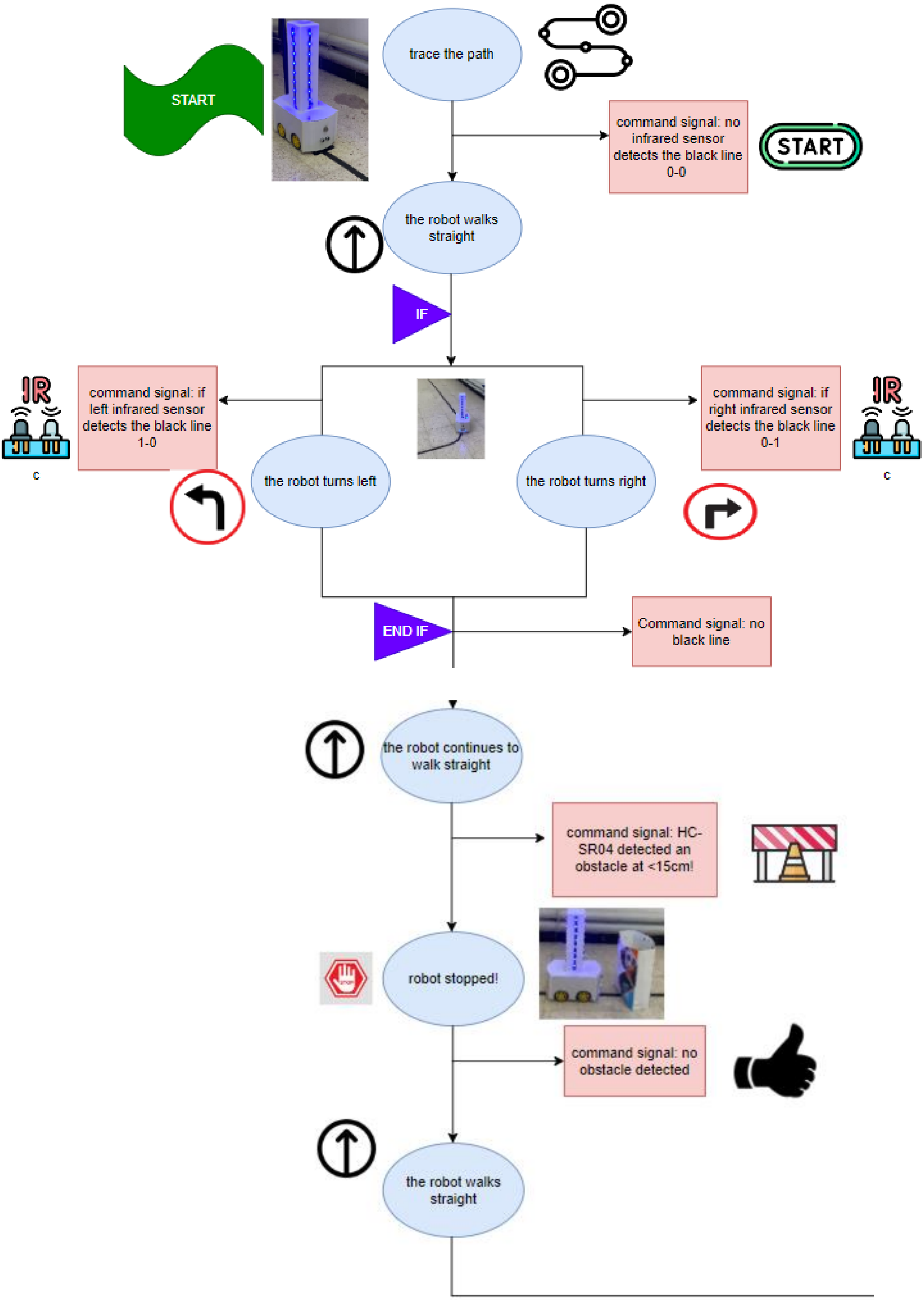
The line path is determined by us before the robot starts moving. We establish the desired trajectory by placing a black line on the floor to guide the robot in its disinfection process. The end of the path is marked by a perpendicular black line to the main route. When the robot's infrared sensors detect this perpendicular black line, it indicates that the disinfection of the target area is complete. At that point, the embedded program in the robot is designed to interpret this signal as a stop indication.

The specific choice of these sensors is motivated by several factors. Firstly, infrared sensors are essential for guiding the robot in line following, ensuring precise and systematic navigation. As for the HC-SR04 sensor, it plays a crucial role in protecting the surrounding equipment. By detecting nearby obstacles, this sensor allows the robot to avoid collisions and potential damage to surrounding objects. However, the most important element among all is the MQ135 sensor. Its ability to measure air quality is essential for our disinfection objective. By detecting levels of dust, microbes, and other contaminants in the air, this sensor allows us to identify the most critical areas requiring intensive disinfection. With these choices and this approach, our robot is capable of thoroughly disinfecting critical environments, thereby contributing to public health protection and the creation of safer and healthier environments.

Figure III.1 Our Prototype

III.1.2 Understanding Robot Operation through Sequential Diagram

To understand the functioning of our robot, we have developed the diagram illustrated in the figure. This diagram serves as a visual aid, describing the sequential steps and decision-making processes involved in the robot's operations. By referring to this diagram, readers can understand how the robot navigates its environment, responds to various stimuli, and performs tasks autonomously. It provides a clear framework for understanding the complex interaction between sensors, commands, and actions that determine the robot's behavior as explained in **Figure III.2**


START
trace the path
command signal: no infrared sensor detects the black line 0-0
START
the robot walks straight
IF
IR
command signal: if left infrared sensor detects the black line 1-0
c
the robot turns left
the robot turns right
command signal: if right infrared sensor detects the black line 0-1
IR
c
END IF
Command signal: no black line
the robot continues to walk straight
command signal: HC-SR04 detected an obstacle at <15cm!
STOP
robot stopped!
command signal: no obstacle detected
the robot walks straight

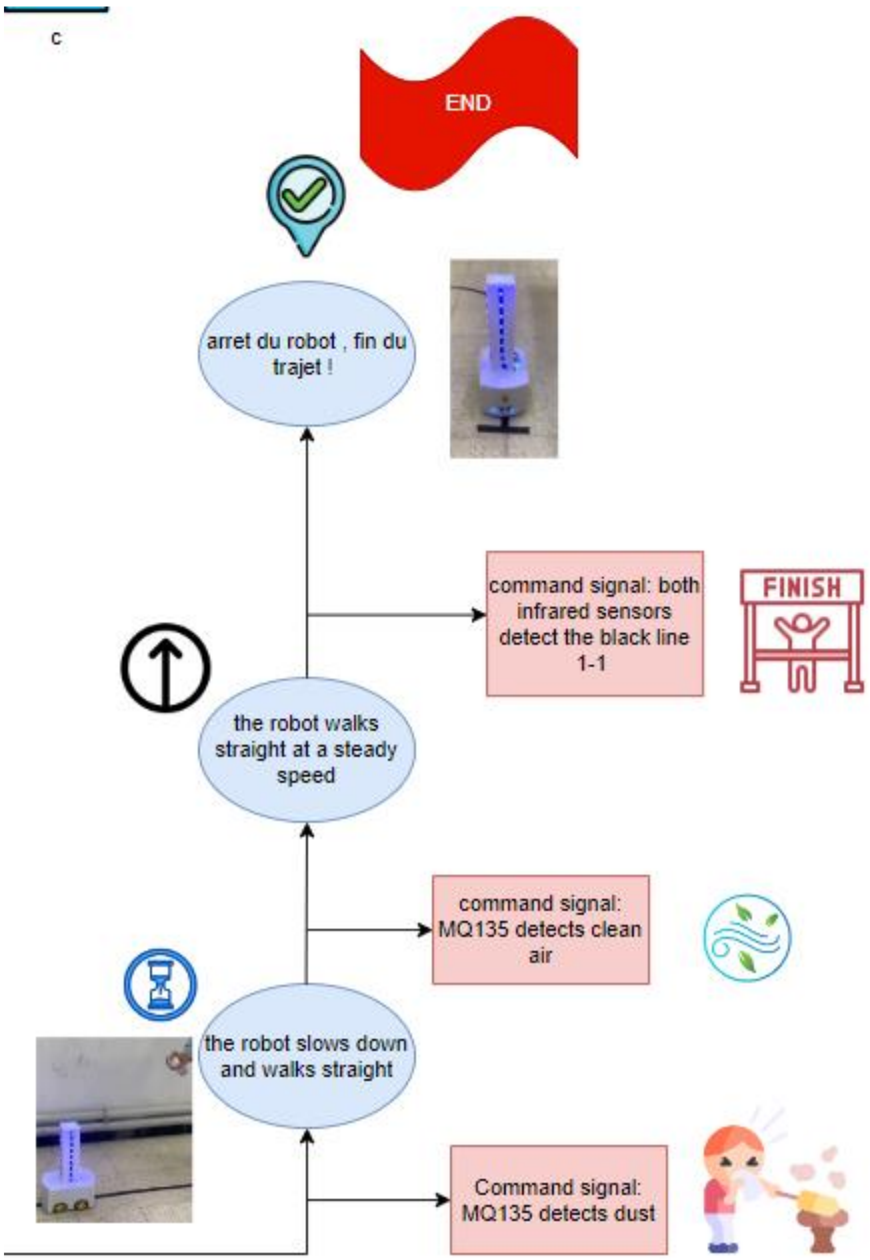


Figure III.2 Sequential Decision Diagram for Robot Operation *(Operation)*

III.2 Design Steps of Our Robot

1. Assembly and Construction of the Robot Chassis.

2. Programming and Development of Control Algorithms.

3. Fabrication of the Robot Support and Frame.

4. Power Supply and Assembly of Electronic Components.

5. Program Upload and Installation of UV Lamps.

6. Testing and Verification.

7. Deployment and Establishment of a Post-Sales Service Network to Ensure Technical Support and Maintenance of Sold Robots.

In this chapter, we will discuss each of these steps in detail, beginning with the initial tests conducted before assembling the robot and connecting its components.

In Figure III.3, we focus on the overall circuit of our project, created by using the FRITZING software.

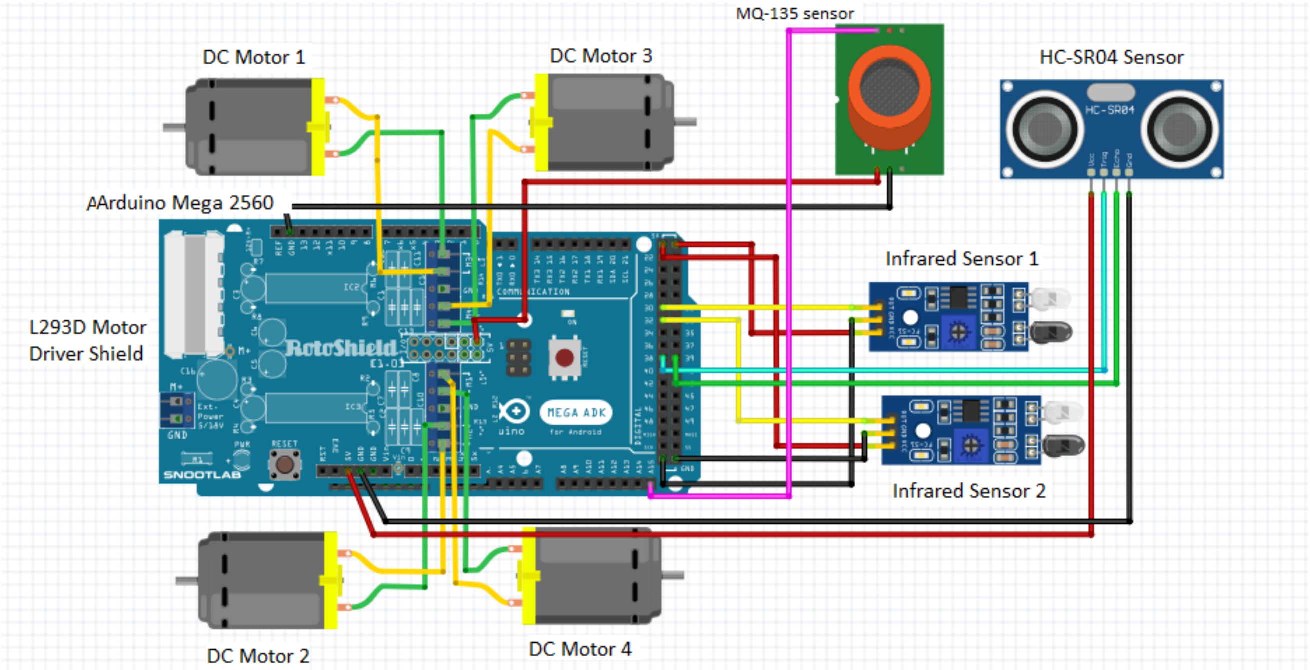


Figure III.3 General wiring of our circuit.

III.3 Connection

Mapping the Connection of Sensors Pins with Arduino in the Following **Table III.1**

Table III.1 The general wiring of our circuit

Components	Pins	Arduino
Infrared Sensor 1	VCC	5v
	GND	GND
	OUT	30
	VCC	5v

Infrared Sensor 2	GND	GND
	OUT	32
Ultrasonic Sensor HC-SR04	VCC	5v
	Trig	38
	Echo	39
	GND	GND
MQ135 sensor	VCC	5v
	GND	GND
	OUT	A15

III.4 Component Testing

In the following section, we will discuss the testing of the components and the results obtained.

III.4.1 Verification of Chassis Hardware and Testing of Wheel Functionality

The initial step in our design process involved verifying the chassis hardware. This included inspecting both levels of the chassis, ensuring the wheels were securely attached, and confirming the presence of all necessary screws and fasteners. Additionally, we soldered red and black cables for both ground (GND) and voltage supply (VCC) for the four motors. Subsequently, we conducted a thorough test to ensure the motors functioned correctly using a 9V battery. This verification process was crucial to ensure the structural integrity and functionality of the chassis before proceeding with further assembly and integration of components.

After placing the motors and wheels, we proceeded to connect the ground (GND) and voltage supply (VCC) wires of each motor to the L293D shield, which was positioned atop the Arduino Mega. Subsequently, we conducted comprehensive testing to ensure the functionality of both the motors and the shield. This meticulous testing process involved verifying proper motor operation, including direction control and speed regulation, to ensure seamless integration with the overall system. The successful outcome of these tests confirmed the effectiveness of our motor and shield configuration, laying a solid foundation for the subsequent stages of our robot's development as shown in **Figure III.4.**

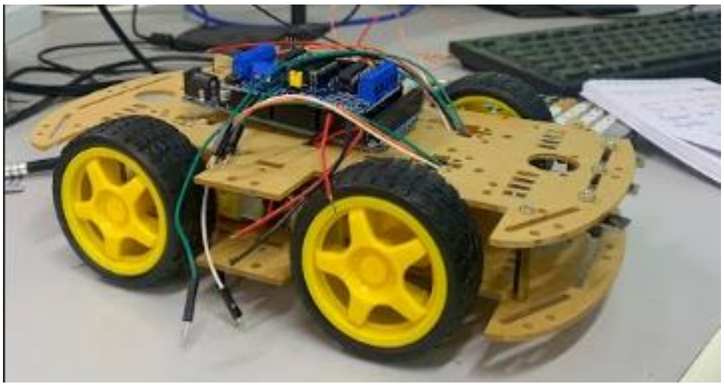


Figure III.4 Image of the assembled chassis

We will demonstrate the setup of a DC motor with Arduino Mega via a shield in **Figure III.5.**

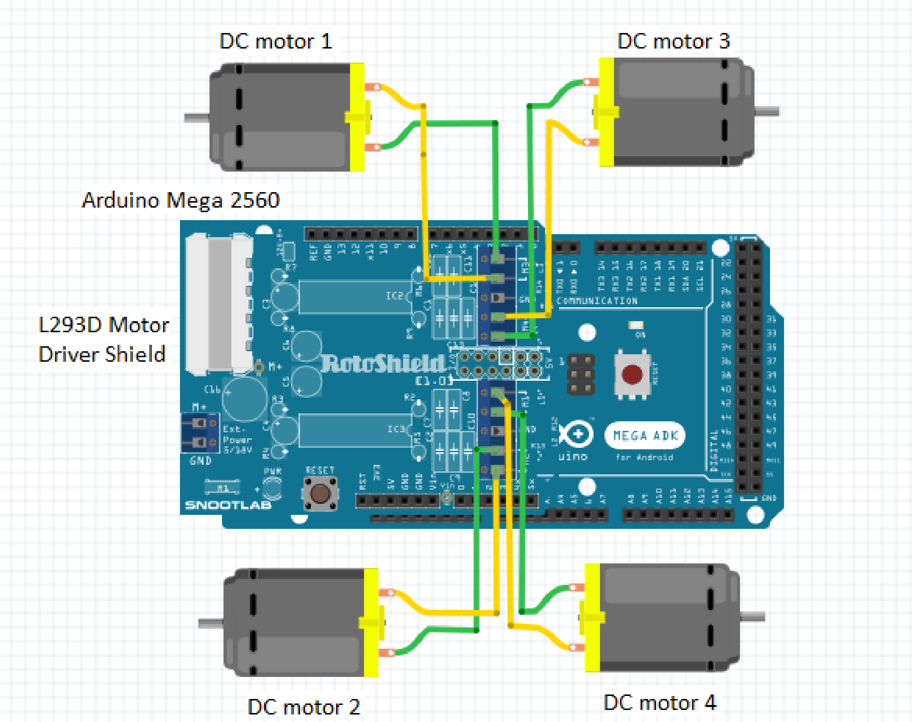


Figure III.5 Mounting the DC motor with Arduino Mega via a shield

III.4.2 Testing of Infrared Sensors and Line Following Algorithm Development

In this section, we will discuss the tests conducted on the infrared sensors as well as the development of the line-following program for our robot. The main objective of this section is to evaluate the functionality of the sensors and to effectively integrate them into our control system.

III.4.2.1 Sensor Testing

We initially tested five infrared sensors of type hw511 tc50001 to assess their functionality. However, we encountered several difficulties in handling these sensors, resulting in unsatisfactory outcomes. Consequently, we decided to switch to a new type of sensor. The new sensors underwent thorough testing, and their operation proved to be much more reliable. As shown in **Figure III.6 and Figure III.7**

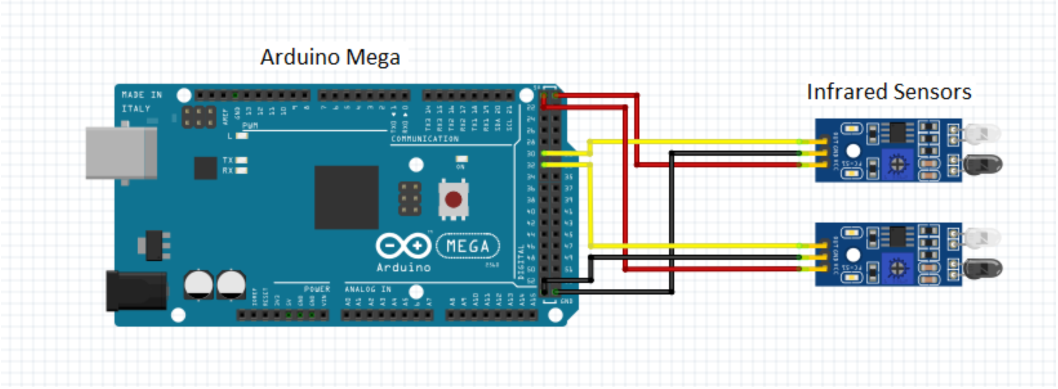


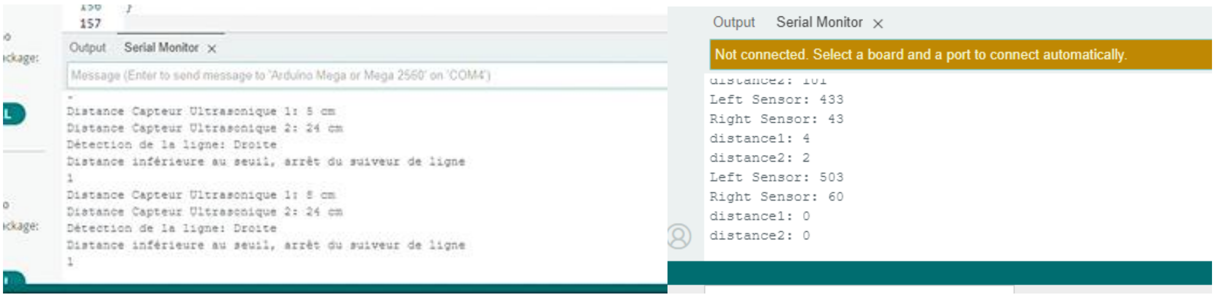
Figure III.6 Mounting the Infrared Sensors with Arduino Mega

III.4.2.2 Connection

Mapping the Connection of Sensors Pins with Arduino in the Following **Table III.2**

Table III.2 Infrared Sensors connection with Arduino

Components	**Pins**	**Arduino**
Infrared Sensor 1	VCC	5v
	GND	GND
	OUT	30
Infrared Sensor 2	VCC	5v
	GND	GND
	OUT	32



```
Distance Capteur Ultrasonique 1: 5 cm
Distance Capteur Ultrasonique 2: 24 cm
Détection de la ligne: Droite
Distance inférieure au seuil, arrêt du suiveur de ligne
1
Distance Capteur Ultrasonique 1: 5 cm
Distance Capteur Ultrasonique 2: 24 cm
Détection de la ligne: Droite
Distance inférieure au seuil, arrêt du suiveur de ligne
1
```

Not connected. Select a board and a port to connect automatically.

```
distance2: 101
Left Sensor: 433
Right Sensor: 43
distance1: 4
distance2: 2
Left Sensor: 503
Right Sensor: 60
distance1: 0
distance2: 0
```

Figure III.7 Images of the tests of the two infrared sensors

III.4.2.3 Role of the Two infrared Sensors for Line Following

We positioned two infrared sensors at the front of the chassis to detect the black line. These sensors play a crucial role in the robot's line-following behavior. We developed an Arduino program to control the motors based on the signals from the sensors. If neither sensor detects the black line, the wheels move straight ahead. If the left sensor detects the line, the motors on the left side reverse while those on the right side move forward at a higher speed, and vice versa. The motors stop when both sensors detect the black line, indicating the end of the path.

Figure III.8 Image of the actual test of the robot's turning maneuver

III.4.3 Testing and Integration of HC-SR04 Ultrasonic Sensors

The objective of this phase is to test the HC-SR04 ultrasonic sensors and integrate them effectively into the robot's line-following system. We embarked on this endeavor to enable the robot to detect obstacles and adjust its behavior accordingly.

III.4.3.1 Testing of the Two Ultrasonic Sensors

After several attempts, we found that the results were unsatisfactory with the two HC-SR04 sensors as shown in **Figure III.9 and Figure III.10** . Despite our repeated efforts, the sensors failed to accurately detect obstacles due to reflections from surrounding objects. Specifically, the sensors often provided erroneous distance readings, displaying a value of 0 in the serial monitor even when objects were present at a certain distance. We identified that reflections from nearby objects disrupted the sensors' operation, leading to detection errors.

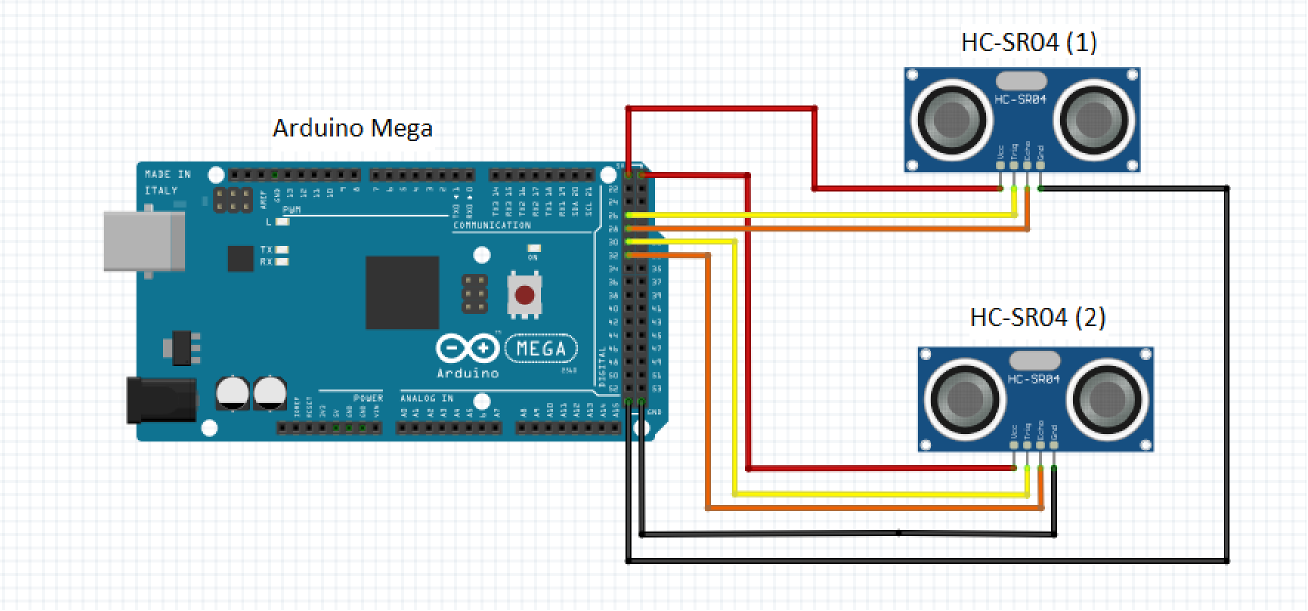


Figure III.9 Mounting the two Ultrasonic Sensor HC-SR04 with Arduino Mega

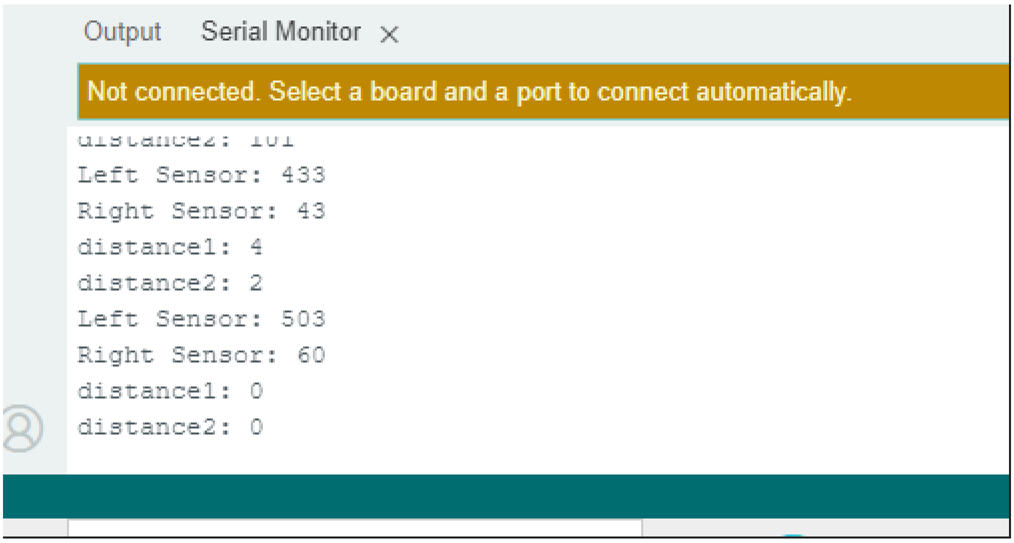
III.4.3.2 Connection

Mapping the Connection of Sensors Pins with Arduino in the Following **Table III.3**

Table III.3 Ultrasonic Sensors connection with Arduino

Components	**Pins**	**Arduino**
Ultrasonic Sensor HC-SR04 (1)	VCC	5v
	Trig1	26
	Echo	28
	GND	GND
	VCC	5v

Ultrasonic Sensor HC-SR04 (2)	Trig1	30
	Echo	32
	GND	GND



Not connected. Select a board and a port to connect automatically.

```
distance2: 101
Left Sensor: 433
Right Sensor: 43
distance1: 4
distance2: 2
Left Sensor: 503
Right Sensor: 60
distance1: 0
distance2: 0
```

Figure III.10 Images of the tests of the two Ultrasonic sensors

III.4.3.3 Modification of Sensor Configuration

We opted to retain only one sensor at the front of the chassis. This decision was made to streamline the system and minimize interference caused by object reflections.as shown in **Figure III.11, Figure III.12 and Figure III.13 .**

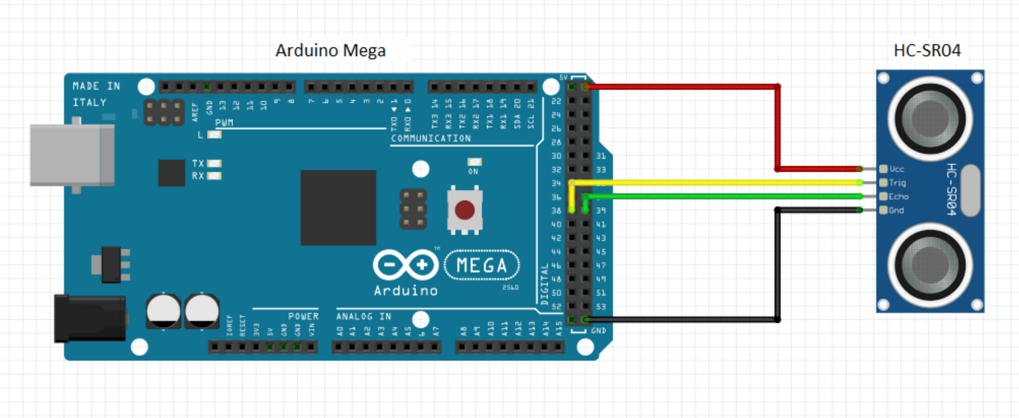


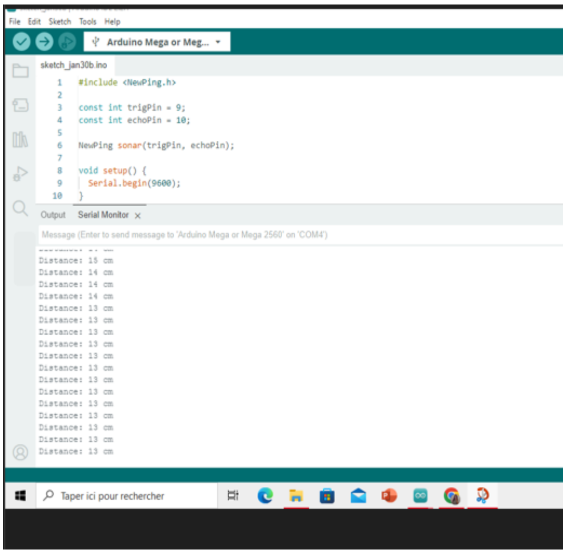
Figure III.11 Mounting the Ultrasonic Sensor HC-SR04 with Arduino Mega

III.4.3.4 Connection

Mapping the Connection of Sensor Pins with Arduino in the Following **Table III.4**

Table III.4 Ultrasonic Sensor connection with Arduino

Components	**Pins**	**Arduino**
Ultrasonic Sensor HC-SR04	VCC	5v
	Trig	38
	Echo	39
	GND	GND



```
#include <NewPing.h>

const int trigPin = 9;
const int echoPin = 10;

NewPing sonar(trigPin, echoPin);

void setup() {
  Serial.begin(9600);
}
```

```
Distance: 15 cm
Distance: 14 cm
Distance: 14 cm
Distance: 14 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
Distance: 13 cm
```

Figure III.12 Images of the tests of one Ultrasonic sensor

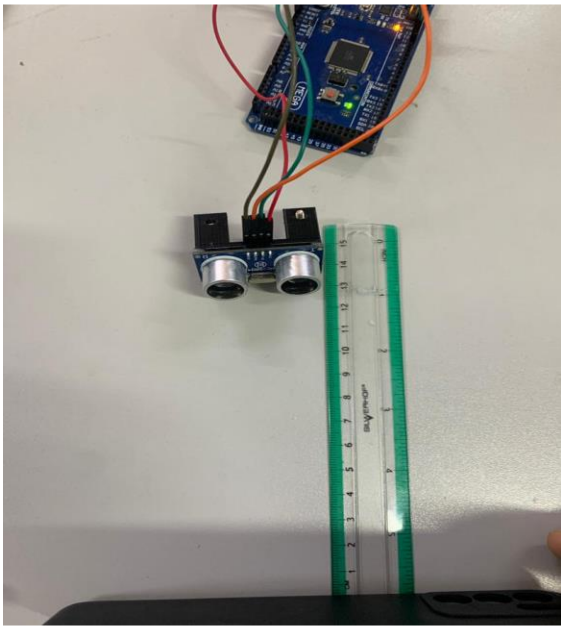


Figure III.13 Images of the tests of one Ultrasonic sensor with obstacles

III.4.3.5 Sensor Programming

Next, we programmed the Arduino for the remaining HC-SR04 sensor. We set a threshold distance, typically around 15 cm, beyond which the robot considers there is no obstacle. When the sensor detects an object within this threshold distance, the robot automatically stops to avoid a collision as shown in **Figure III.14** . This safety feature ensures the protection of surrounding objects and prevents potential damage to the robot itself.

By adopting this approach, we successfully integrated the HC-SR04 sensor into our line-following system, enhancing our robot's obstacle avoidance capabilities.

Figure III.14 Images of the tests of one Ultrasonic sensor with obstacles

III.4.4 Testing and Integration of MQ135 Air Quality Sensor

The MQ135 sensor plays a crucial role in our project as a key component for monitoring air quality. Our goal is to integrate it into the disinfection system to detect atmospheric contaminants such as dust and microbes. By monitoring air quality in real time, this sensor will allow us to identify areas with a high risk of contamination and focus our disinfection efforts where they are most needed. Furthermore, as part of our IoT project, this sensor is of particular importance as it will provide valuable data for intelligent environmental management. Through several tests with perfume odors, we have confirmed that the MQ135 sensor is reliable and provides satisfactory results. Thus, this sensor represents an essential element of our system, making a significant contribution to our overall goal of effective and targeted disinfection.

III.4.4.1 MQ135 Sensor Testing

We conducted multiple tests with the MQ135 sensor alone, exposing it to the scent of deodorant. The results of these tests were satisfactory, demonstrating the sensor's ability to detect air quality variations.as shown in **Figure III.15 and Figure III.16.**

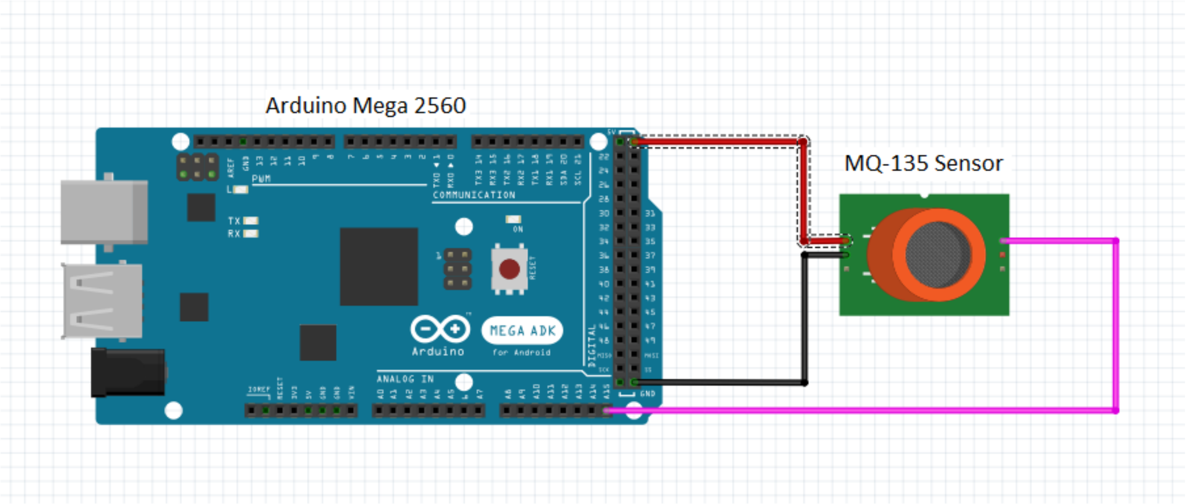


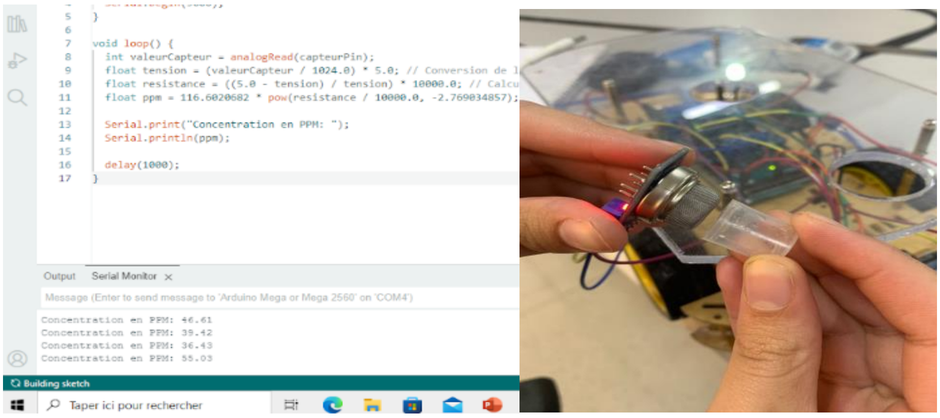
Figure III.15 Mounting the MQ-135 sensor with Arduino Mega

III.4.4.2 Connection

Mapping the Connection of Sensor Pins with Arduino in the Following **Table III.5**

Table III.5 MQ135 Sensor connection with Arduino

Components	Pins	Arduino
MQ-135 sensor	VCC	5v
	GND	GND
	OUT	A15



```
}

void loop() {
  int valeurCapteur = analogRead(capteurPin);
  float tension = (valeurCapteur / 1024.0) * 5.0; // Conversion de l
  float resistance = ((5.0 - tension) / tension) * 10000.0; // Calcu
  float ppm = 116.6020682 * pow(resistance / 10000.0, -2.769034857);

  Serial.print("Concentration en PPM: ");
  Serial.println(ppm);

  delay(1000);
}
```

Message (Enter to send message to 'Arduino Mega or Mega 2560' on 'COM4')

```
Concentration en PPM: 46.61
Concentration en PPM: 39.42
Concentration en PPM: 36.43
Concentration en PPM: 55.03
```

Figure III.16 Images of the tests of the MQ135 sensor

III.4.4.3 Sensor Programming

Subsequently, we programmed the Arduino for the MQ135 sensor by setting an air quality threshold. When the sensor detects a decrease in air quality below this threshold, the robot slows down in that area as shown in **Figure III.17**. This functionality is particularly useful in our project, where the primary source of odor is dust and microbes. By slowing down in these areas, the robot can better disinfect them, thereby contributing to maintaining a cleaner and healthier environment.

Figure III.17 Images of the final tests of the MQ135 sensor with deodorant

III.4.5 Power Management

Power management has been a crucial and demanding step in our project, requiring meticulous and thorough exploration of various approaches. We have devoted considerable time to experimenting with different methods and addressing challenges encountered throughout the process.

III.4.5.1 Test

Initially, we attempted to power our robot with 9V batteries, but quickly encountered difficulties due to insufficient power to effectively operate the motors and other components. This initial attempt prompted us to explore other options, such as using a power bank as shown in **Figure III.18**, but we found that it was not sufficient to power all the robot's components without encountering performance issues. Our efforts to bolster the power supply with an additional 9V battery were unsuccessful, leaving us in search of a more reliable solution.

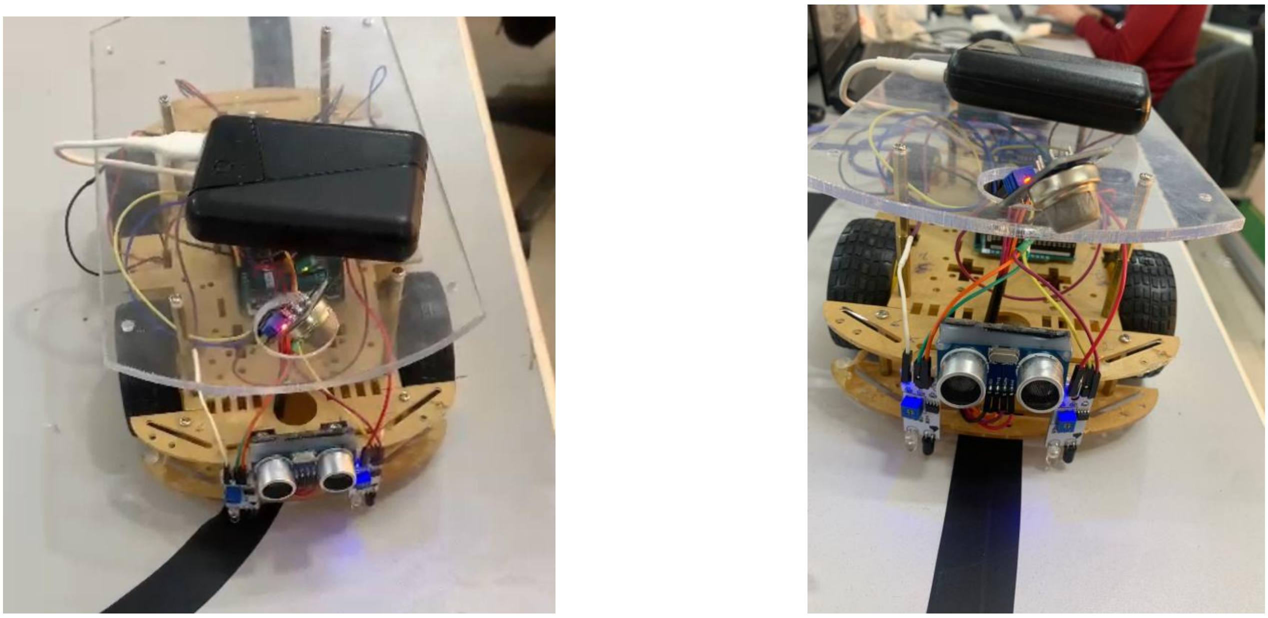


Figure III.18 An image of a test with a power bank power supply

III.4.5.2 Final result

Eventually, after many hours of research and testing, we discovered that lithium-ion batteries ere the ideal solution to meet our power needs as shown in **Figure III.19 and Figure III.20**. By connecting them to a dedicated holder and integrating them into our system, we observed a significant improvement in the overall performance of the robot. However, even with this solution in place, we faced new challenges, such as managing the limited lifespan of the batteries and investing in a dedicated charger to echarge them efficiently. Despite the numerous obstacles encountered throughout this process, our perseverance and determination ultimately paid off, with the identification of a reliable and effective power supply solution for our robot. This arduous journey has reinforced our understanding of the critical importance of power management and the need to consider all details to ensure the successful operation of our project.

Figure III.19 An image of lithium batteries being charged

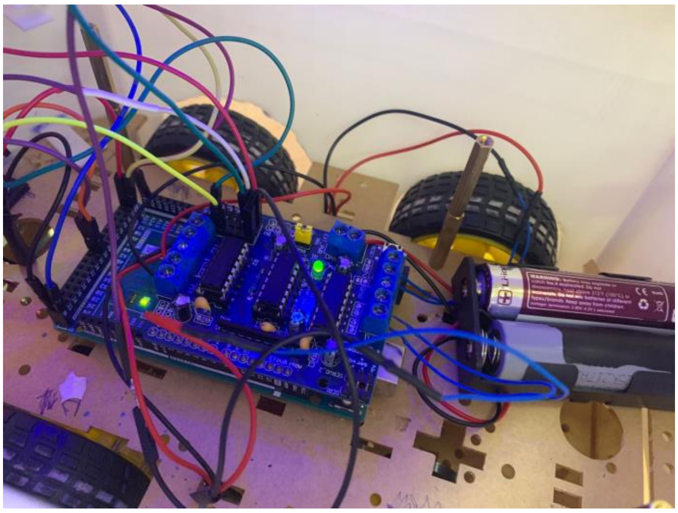


Figure III.20 An image of power supply with two lithium batteries

III.4.6 UV Lamps

In the following section, we will discuss the lamps, the tests conducted, and the results obtained.

III.4.6.1 Test

In our testing process, we initially examined traditional UV lamps available on the market. However, we encountered several major challenges. Firstly, these lamps were extremely expensive, making it difficult to integrate them into our project with a limited budget. Additionally, they required a 220V power supply, which was incompatible with our available resources and posed safety risks. Furthermore, their direct exposure posed health hazards to users. These obstacles prompted us to seek a more convenient and affordable alternative for our disinfection project.

III.4.6.2 Results

Faced with these challenges, we opted for UV LED strip lamps as shown in **Figure III.21 and Figure III.22**. These lamps, powered by a 5V source, were more affordable, safer, and easier to use. We mounted these lamps on a 30cm 3D structure and connected them to the shield, achieving positive results during operational tests.

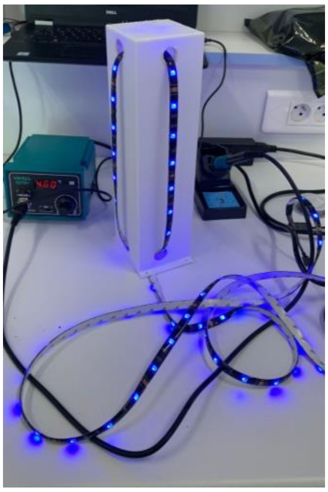


Figure III.21 Image of UV LED strip lamps

Figure III.22 Image of UV lamps installed in the prototype

III.5 Carcass structure

The carcass structure of our robot, fabricated using 3D printing via SolidWorks 2020, consists of various components such as the rear, front, sides, top, and UV lamp holder. Each piece was meticulously designed and printed to ensure structural integrity and functionality. The material used is white in color, and the entire carcass weighs 600g, optimized to match the weight capacity of the line follower robot. The fabrication of these components required a total of 50 hours of printing time, completing the operation in 3 days. Detailed measurements and visual representations of these components are illustrated in the accompanying figures.

III.5.1 Front and rear part

The front and rear sections were constructed with identical dimensions, each featuring a slight incline of 24°. Notably, the front facade includes three strategically placed openings: one for the MQ135 sensor and two beneath for the HC-SR04 sensors. These parts required 6 hours of printing time. As shown in **Figure III.23, Figure III.24** and **Figure III.25.**

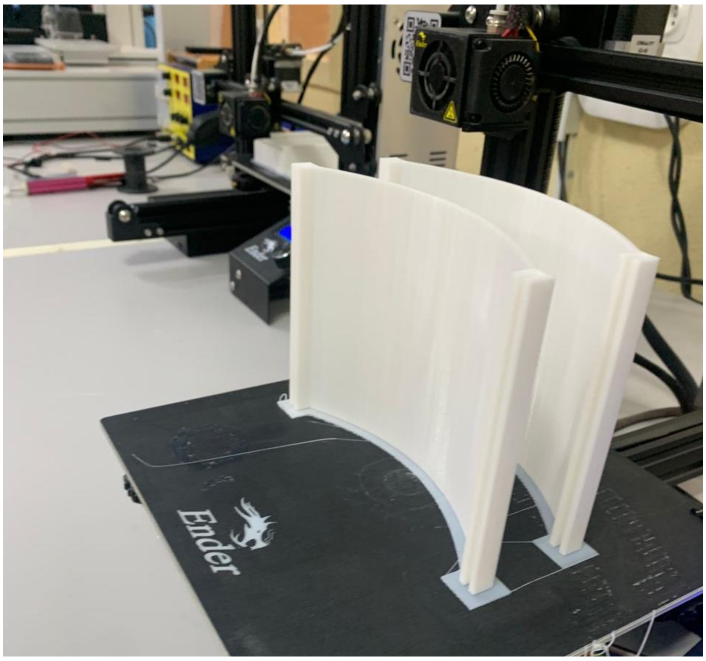


Figure III.23 Image of the print of front and rear parts

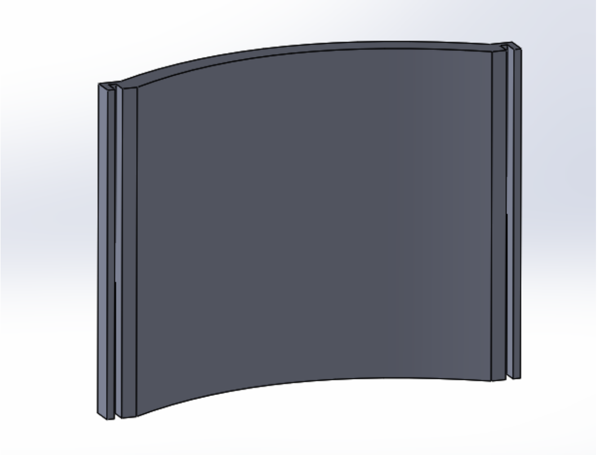


Figure III.24 Image of the print of front and rear parts on SolidWork

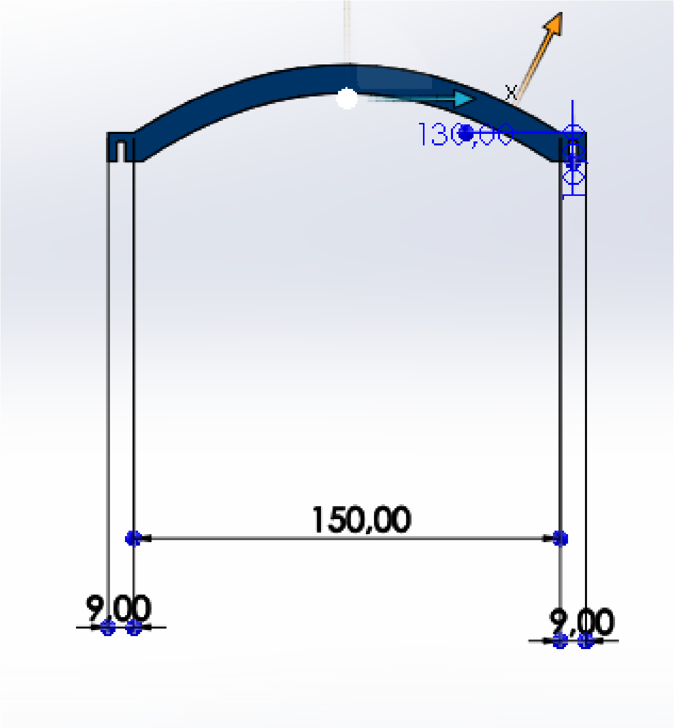


Figure III.25 Dimensional Measurements of Front and Rear Parts in SolidWorks

III.5.2 Sides and top part

For the sides and top, we fabricated rectangular pieces with semicircular cutouts to accommodate the wheels. These four sections (front, rear, and two sides) were securely affixed using super glue, ensuring a cohesive assembly. The printing process for the sides and top parts took a total of 23 hours. The UV lamp holder required 21 hours of printing time as shown in **Figure III.26 and Figure III.27.**

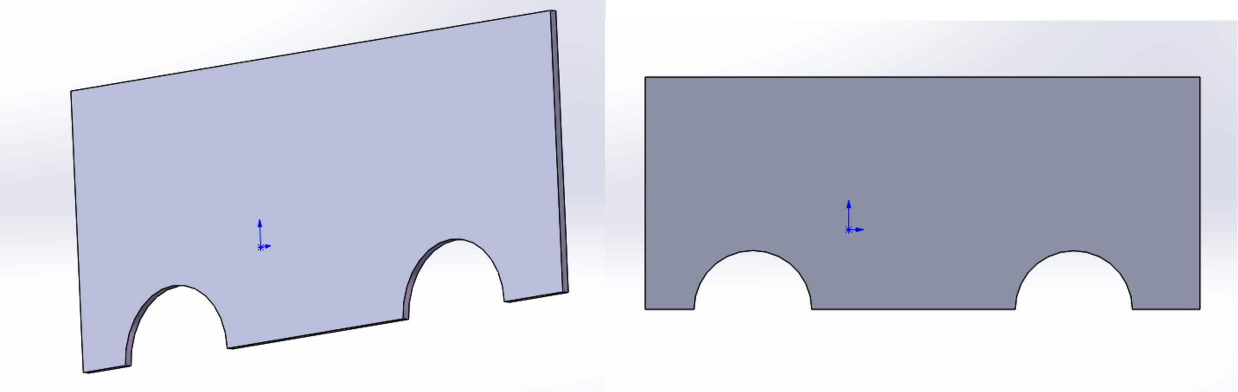


Figure III.26 image of the left and right sides of the structure based on SolidWorks

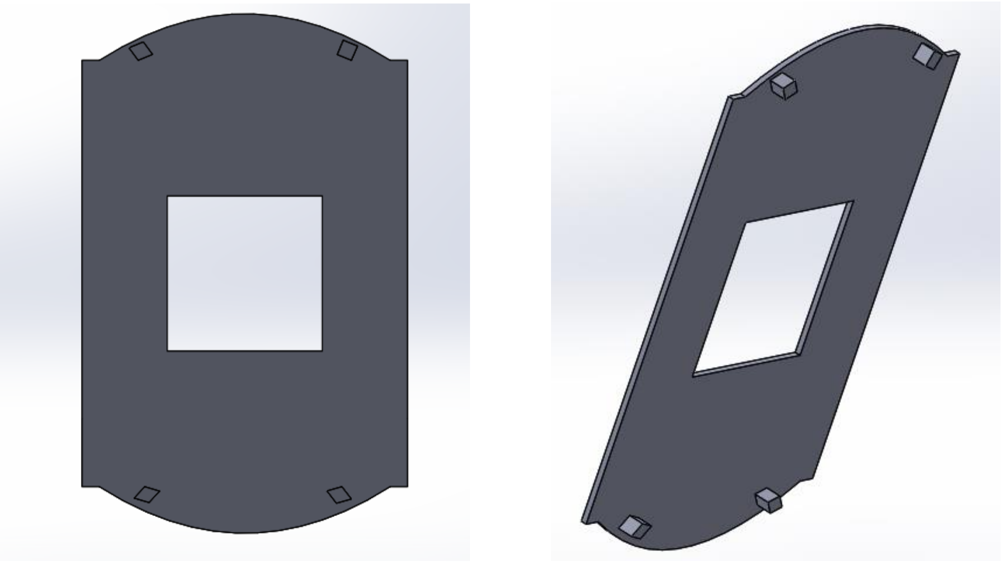


Figure III.27 Image on SolidWorks of the top side of the structure

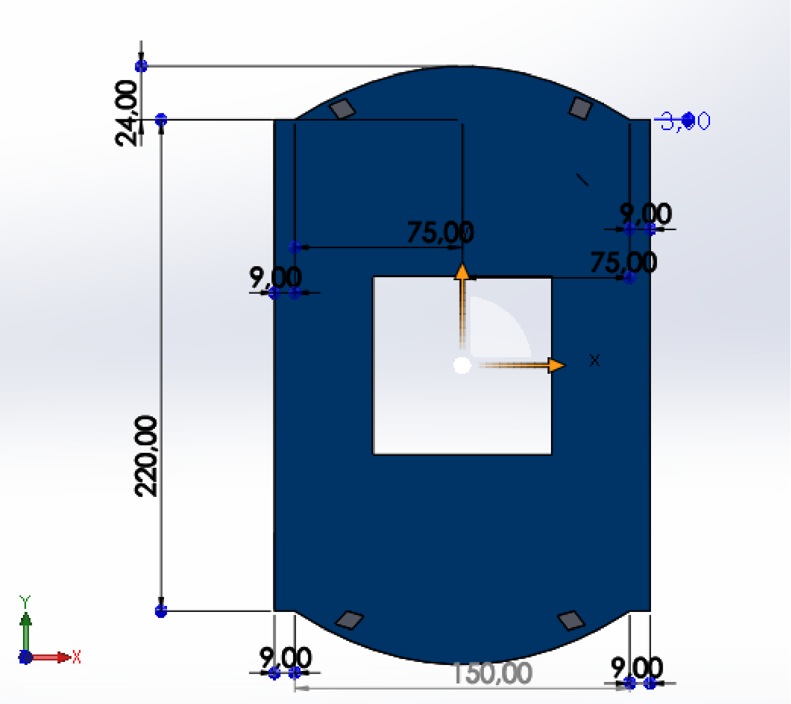


Figure III.28 Dimensional Measurements of top part in SolidWorks

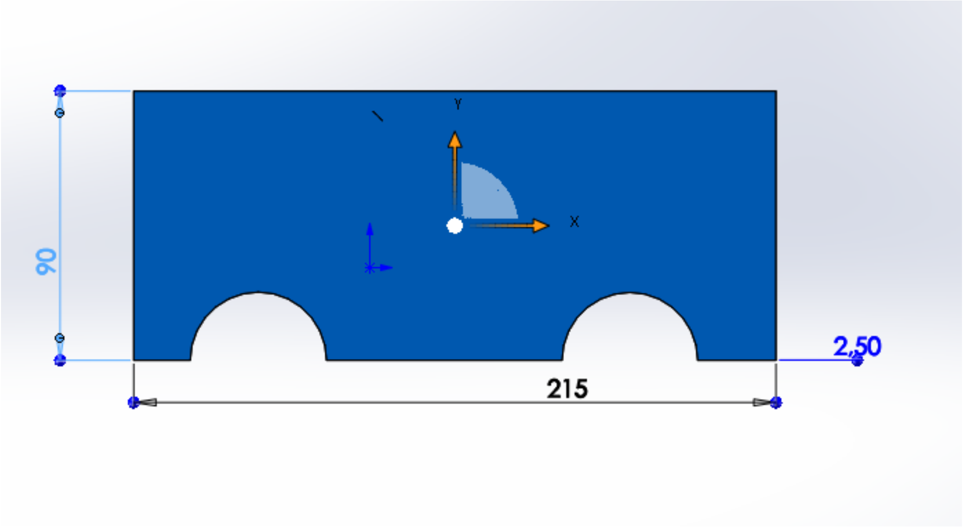


Figure III.29 Dimensional Measurements of Side part in SolidWorks

III.5.3 UV lamp holder

The UV lamp holder measures 30 cm in height with an 8x8 cm square base, featuring four small holes at the bottom for UV lamp wiring. Assembly involved attaching the upper and lower parts with small screws, and the UV lamps were strategically affixed to uniformly cover all sides. The holder required 21 hours of printing time as shown in **Figure III.27 and Figure III.28 .**

Figure III.30 Image of the print of UV lamp holder

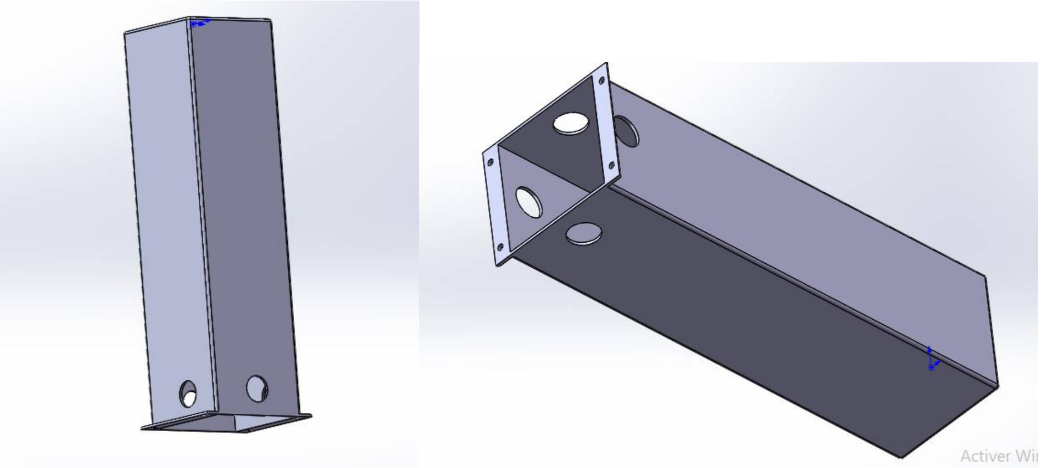


Figure III.31 Image of the print of UV lamp holder on SolidWorks

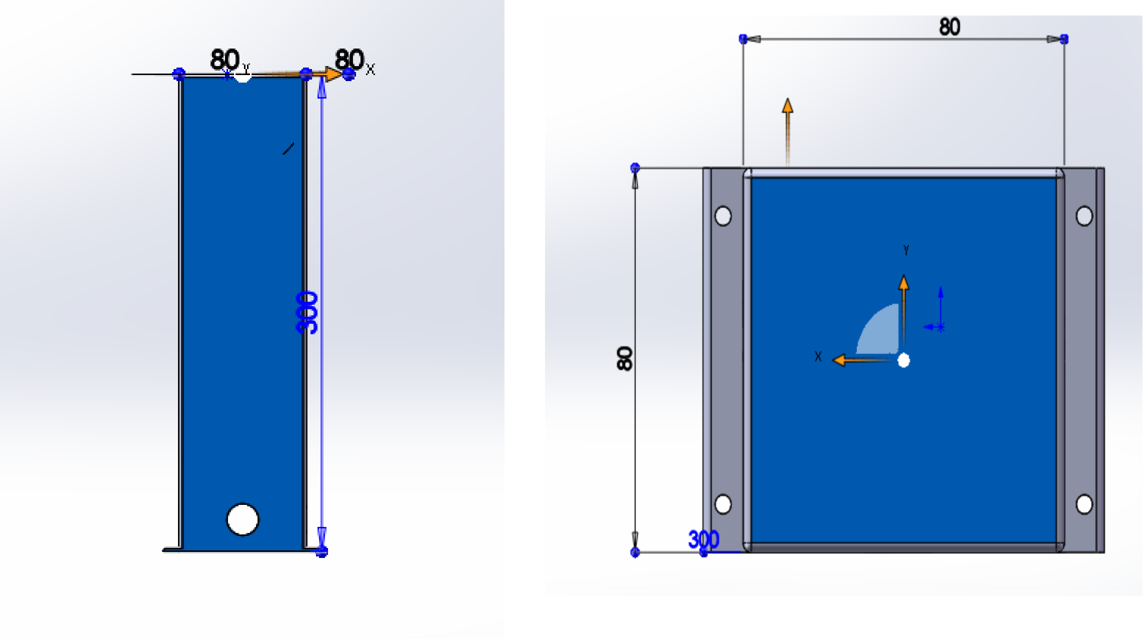


Figure III.32 Dimensional Measurements of UV lamp holder on SolidWorks

Nb:

All figures and photographs in this chapter that are not otherwise referenced were produced by our team.

III.6 Conclusion

In this chapter, we summarized the practical work conducted throughout our project, starting with the general operation of our prototype. We then detailed each component, electronic setups, and the results achieved. Through meticulous design steps and rigorous component testing, we have developed a sophisticated solution capable of autonomously disinfecting targeted environments. Our robot integrates UV-C lamps, infrared sensors, ultrasonic obstacle detection, and air quality monitoring to ensure comprehensive and effective disinfection while prioritizing safety and efficiency. The development journey highlighted the importance of iterative testing, innovative problem-solving, and interdisciplinary collaboration. Moving forward, our UV-based robot holds promise for addressing public health challenges by offering a scalable, automated disinfection solution for diverse settings.

General conclusion

The project titled "A UV-Based Line-Following Robot" represents an innovative approach to addressing contemporary disinfection challenges, crucial for preventing the spread of infectious diseases. This project aimed to develop an effective, ecological, and autonomous disinfection solution using UV radiation, overcoming the limitations of traditional methods. The primary objective was to design a robot capable of autonomously navigating by following marked black paths, intended for environments requiring rigorous and frequent disinfection, such as hospitals and laboratories.

The issues addressed included ensuring precise navigation, reducing human intervention, and guaranteeing ease of use. The project led to the creation of a functional robot, equipped with essential sensors and components, successfully tested for its disinfection and autonomous navigation capabilities. The long-term vision is to refine and commercialize this robot for large-scale use, with planned improvements in sensors, battery life, and detection technologies.

In conclusion, this project has demonstrated the feasibility and effectiveness of integrating UV technology into robotic disinfection solutions, paving the way for safer, more efficient, and environmentally friendly methods. This achievement has deepened our theoretical knowledge and provided valuable practical experience by studying and utilizing various hardware and software, representing a significant step towards intelligent and sustainable disinfection solutions. The project is open to technical improvements, which opens up several perspectives for the future.

The successful development of the UV-based line-following robot represents a notable advancement in the field of automated disinfection. Throughout the project, we tackled several key challenges: ensuring the robot could follow marked paths accurately was critical. The use of advanced sensors and algorithms allowed the robot to maintain its course without human intervention. By automating the disinfection process, we aimed to reduce the risk to human operators, particularly in high-risk environments like hospitals. This automation ensures consistent disinfection without fatigue-related errors. Designing a user-friendly interface and operational protocol was essential to ensure that the robot could be deployed and maintained with minimal training, making it accessible to a wide range of users.

The project's success in these areas underscores the potential for further innovations. Future improvements could include upgrading sensors to improve the robot's ability to navigate complex environments and detect obstacles more effectively. Extending the operational time of the robot to cover larger areas without the need for frequent recharging, and incorporating more sophisticated detection mechanisms to enhance the robot's ability to identify and disinfect surfaces more thoroughly.

Additionally, the open nature of the project invites collaboration and further development. Researchers and developers can build on this foundation, introducing new features and capabilities that could make the robot even more versatile and effective. In addition to the improvements already envisaged, integrating Internet of Things (IoT) and Artificial Intelligence (AI) technologies could revolutionize the capabilities of the UV-based line-following robot. Connecting the robot to an IoT network would enable real-time monitoring and control. This could include remote software updates, optimized resource management, and precise data collection on performance and maintenance needs. Using AI could enhance the robot's autonomous decision-making, allowing for more adaptive navigation and more effective disinfection strategies. AI could also enable the robot to learn and adapt to new environments and obstacles, increasing its versatility and efficiency.

The UV-based line-following robot not only addresses immediate disinfection needs but also sets the stage for future advancements in autonomous disinfection technology. This project exemplifies the integration of innovative technology with practical applications, leading to solutions that are both impactful and sustainable. Through continued development and innovation, this robot has the potential to become a cornerstone in modern disinfection practices, making environments safer and cleaner for everyone.

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Summary

To meet the growing demand for disinfection in sensitive environments, we have developed an innovative line-following robot using UV technology to disinfect surfaces and air. This versatile robot follows black lines using infrared sensors and avoids obstacles with a distance sensor. It also includes an MQ135 sensor to monitor air quality. The 3D design ensures the protection and stability of the UV lamps. This innovative solution improves safety and reduces the risk of contamination without using harmful chemicals.

Keyword: Robot , Pathogen ,Disinfection ,UV-C ,Air quality.

Résumé

Pour répondre à la demande croissante de désinfection dans des environnements sensibles, nous avons développé un robot suiveur de ligne innovant utilisant la technologie UV pour désinfecter les surfaces et l'air. Ce robot polyvalent suit les lignes noires grâce à des capteurs infrarouges et évite les obstacles avec un capteur de distance. Il intègre également un capteur MQ135 pour surveiller la qualité de l'air. La conception en 3D assure la protection et la stabilité des lampes UV. Cette solution innovante améliore la sécurité et réduit les risques de contamination sans utiliser de produits chimiques nocifs.

Mots clés :robot, pathogene , disinfection , UV-C, qualité d’air.

ملخص

لتلبية الطلب المتزايد على التطهير في البيئات الحساسة، قمنا بتطوير روبوت مبتكر يتبع الخطوط باستخدام تقنية الأشعة فوق البنفسجية لتطهير الأسطح والهواء. يتبع هذا الروبوت المتعدد الاستخدامات الخطوط السوداء باستخدام مستشعرات الأشعة تحت الحمراء ويتجنب العقبات باستخدام مستشعر المسافة. كما يتضمن مستشعر MQ135 لمراقبة جودة الهواء. يضمن التصميم ثلاثي الأبعاد حماية واستقرار مصابيح الأشعة فوق البنفسجية. تعمل هذه الحلول المبتكرة على تحسين السلامة وتقليل مخاطر التلوث دون استخدام مواد كيميائية ضارة

الكلمات المفتاحية : روبوت, مُمْرِض ,تَطْهِير ,الأشعة فوق البنفسجية – ج ,جَوْدَة الهَوَاء .