This is a Graduation Project to obtain a Master's Degree in

Electronics of Embedded Systems

Under Ministerial Resolution No.1275 Certificate of
« Start-Up & Patent »

Smart Multi-Tasking Marine System
« SM-TMS »

Project Team

Mr. Raid BENAMOURA

Pr. Abdelkrim BOUKABOU

Promotion 2022-2023

Abstract

The maritime industry relies heavily on humans for decision making, processing and operations. The use of Internet of Things (IoT) and Artificial Intelligence (AI) for marine applications are promising technologies that facilitate and improve productivity.

Our project is a **smart boat prototype** based on IoT and AI with various tasks, including supporting the Coast Guard's work to secure the coasts against illegal immigration attempts, assisting Civil Protection to rescue the drowned, automating fishing practices and other activities related to the sea and water dams.

Outline

Problematics

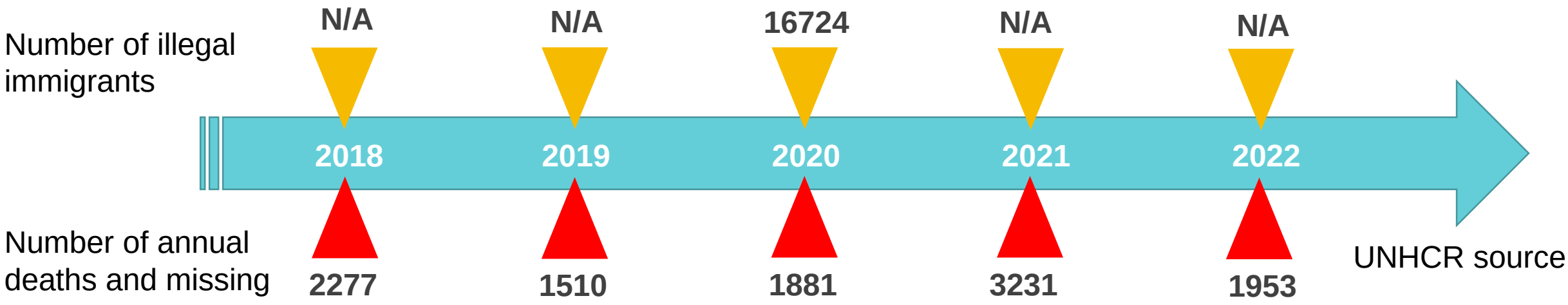
- Coast Guarding
- Fishing Conditions
- Tourism Guidance
- Ecosystem Preserving

PROBLEMATICS

COAST GUARDING

The length of the national coastline of 1,200 km makes daily monitoring inevitable 24h/24h. The Algerian League for the Defense of Human Rights reported that the actual number of illegal immigrants "harraga" is very large, exceeding 17,500.

For its part, the United Nations High Commissioner for Refugees (UNHCR) gives a terrifying figure on the number of annual deaths and missing on the Mediterranean Sea.



PROBLEMATICS

COAST GUARDING

- High prevalence of illegal immigration issues.
- Difficulty for coast guarding in irregular weather and high-risk rate.
- Absence of remote assistance to Civil Protection teams to evacuate drowning people.
- Absence of remote coastal surveillance, port security, and vessel traffic monitoring.

PROBLEMATICS

FISHING CONDITIONS

- Risk of fishing in inclement weather conditions.
- Lack of known fishing maps.
- Lack of real-time study and analysis of territorial fish life cycle.
- Lack of automated fishing practices.
- Lack of monitoring against illegal fishing practices (fishing in closed areas or during closed seasons).

PROBLEMATICS

TOURISM GUIDANCE

- Unavailability of marine self-driving boats for leisure and marine picnics.
- Lack of remote guided tours and immersive experiences for tourists.
- Absence of data for sustainable marine tourism using well-predefined cruise itineraries.

PROBLEMATICS

ECOSYSTEM PRESERVING

- Lack of real-time monitoring against marine pollution, plastic waste, and debris.
- The absence of a field study concerning carbon emissions from boats.

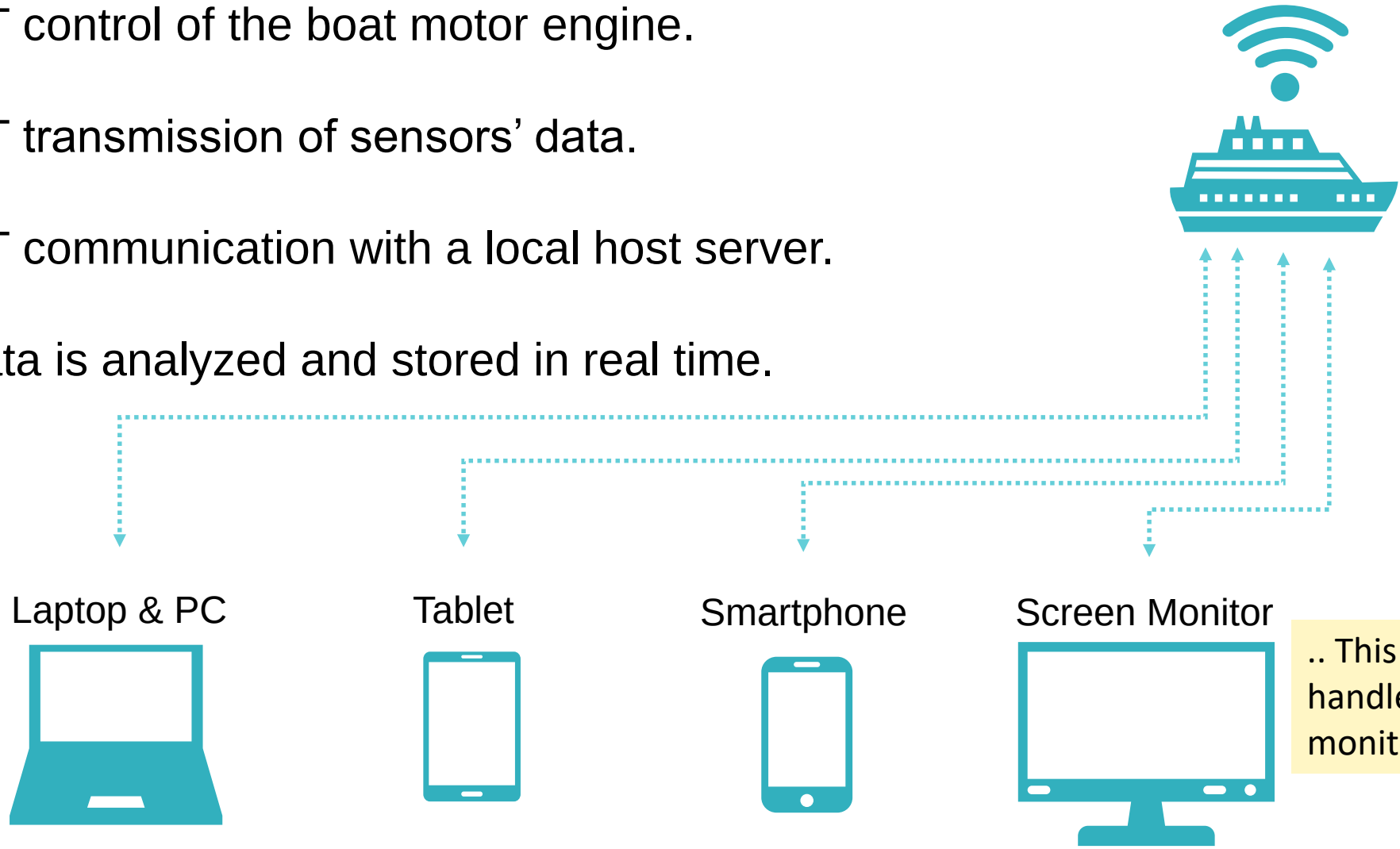
Solutions

- IoT Control & Transmission
- Geopositioning
- Smart Object Recognition
- Night Vision Assistance

SOLUTIONS

IoT Control & Transmission

- IoT control of the boat motor engine.
- IoT transmission of sensors' data.
- IoT communication with a local host server.
- Data is analyzed and stored in real time.



.. This is a better solution to handle all employed monitoring software & apps.

SOLUTIONS

GEOPOSITIONING

- Geolocation using a GPS module.
- Visualize the collected GPS data over a predefined real map.
- Human operator monitors the boat's position and speed using well-predefined cruise itineraries.

SOLUTIONS

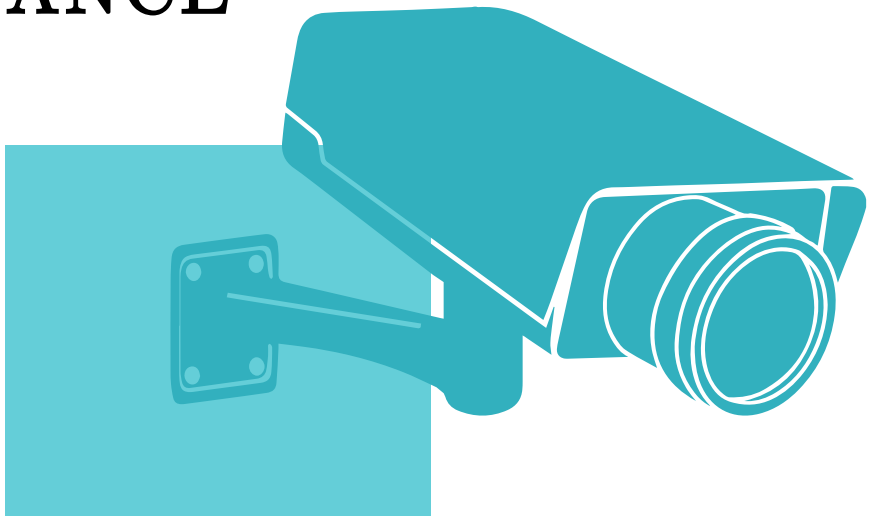
Smart Object Recognition

- Real-time image processing on collected image dataset from an on-board camera.
- Distinguishing unsuspicious boats from suspicious ones using artificial intelligence (AI) with high recognition efficiency.
- Annotate recognized objects with appropriate names (human, boat, plastic, debris, etc.)
- Rapid diagnosis of drowning people.

SOLUTIONS

Night Vision Assistance

- An embedded night vision camera that supports small single-board computers.
- Assistance for rescue missions in pitch darkness and inclement weather.
- A cost-effective solution that eliminates the need for excessive lighting.



Preliminaries

- Reasoning & Problem Solving
- Hardware Devices & Sensors
- Software Programs & Apps.
- SDG

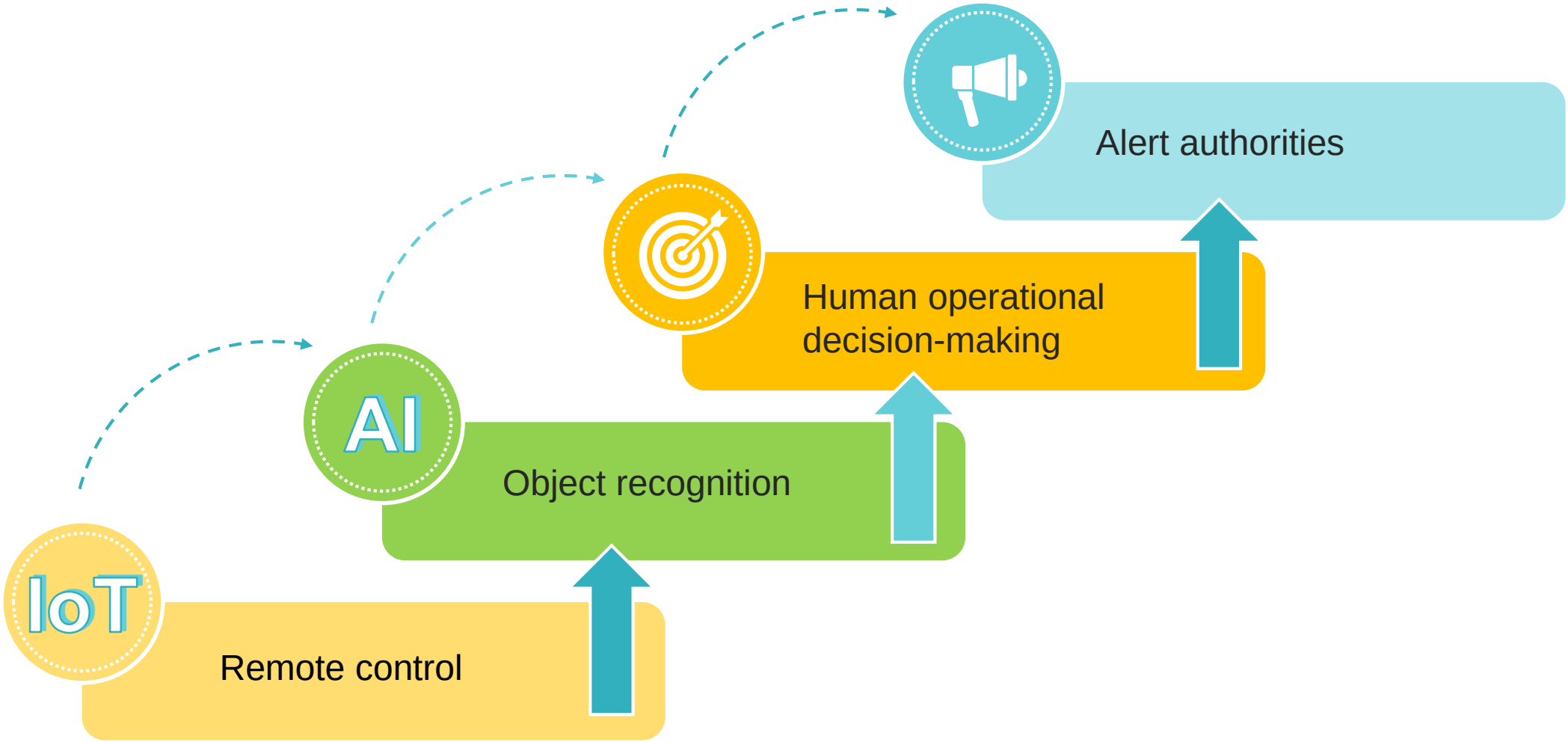
REASONING & PROBLEM SOLVING

Providing tools and resources to be implemented on the smart boat to ensure remote control and object recognition using both IoT and AI.

SM-TMS

- Practical
- Available
- High-Tech
- Easy to use

REASONING & PROBLEM SOLVING



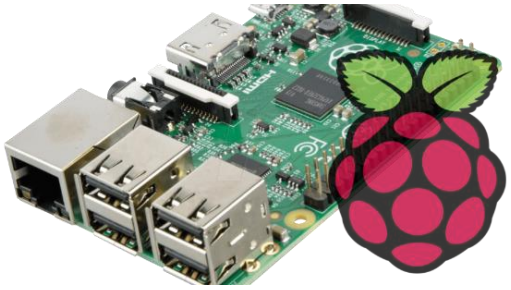
HARDWARE DEVICES & SENSORS

- Single-board computers
- A Temperature/Humidity sensor
- A GPS module
- Motor engines
- A high-resolution camera
- A night vision camera
- A clean-energy power source

SOFTWARE PROGRAMS & APPS.

- IoT remote control & transmission
- Single-board computers' OS
- Real-time tracking of GPS data
- Generating predefined maps
- Synchronization with localhost servers
- AI smart object recognition

Proteus Design Suite

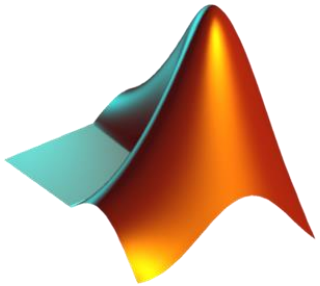


Raspberry Pi OS

SAS Planet

WinSCP

Python



MATLAB

SDG

Our project satisfies the following Sustainable Development Goals (SDG):

"United Nations https://sdgs.un.org/"

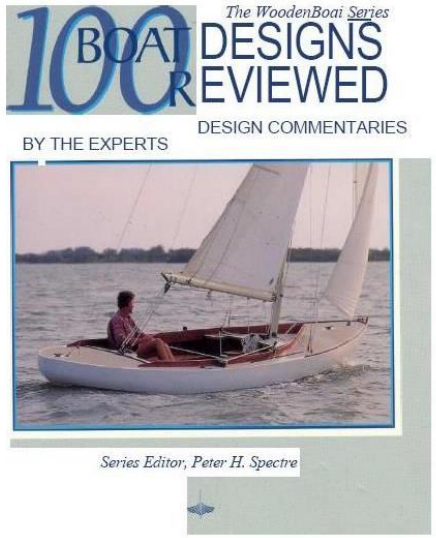
Our Project

Boat Shape

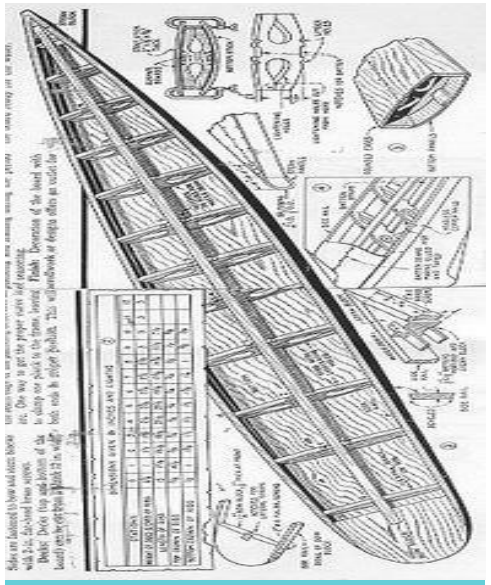
Electronic Board

IoT and AI Multi-tasking

Part I. Boat Shape



A. Specifications



B. Design

I.A. Specifications

I.A.1. Choice of the boat shape

The key to choosing the best boat shape is to be able to provide sufficient stability and perform the assigned tasks/missions while safely maintaining the electronic components carried on the boat deck.

Quality	Specification
Dimensions (Lenght x Width x Beam)	2335 x 800 x 110 [mm]
Weight	15Kg

References for the design purpose:

[1]. Peter H. Spectre, “100 Boat Designs Reviewed: Design Commentaries by the Experts” Woodenboat Series, 1997

[2]. Gavin Atkin, “Ultrasimple Boat Building: 17 Plywood Boats Anyone Can Build” International Marine Ragged Mountain Press, 2007

[3]. Ted Salois, “How To Build The World's Most Incredible Wooden Surfboard” Elbow Key Media, 2014

[4]. Ken Hankinson, “How To Fiberglass Boats” Glen-L Marine Designs, 1986

I.A. Specifications

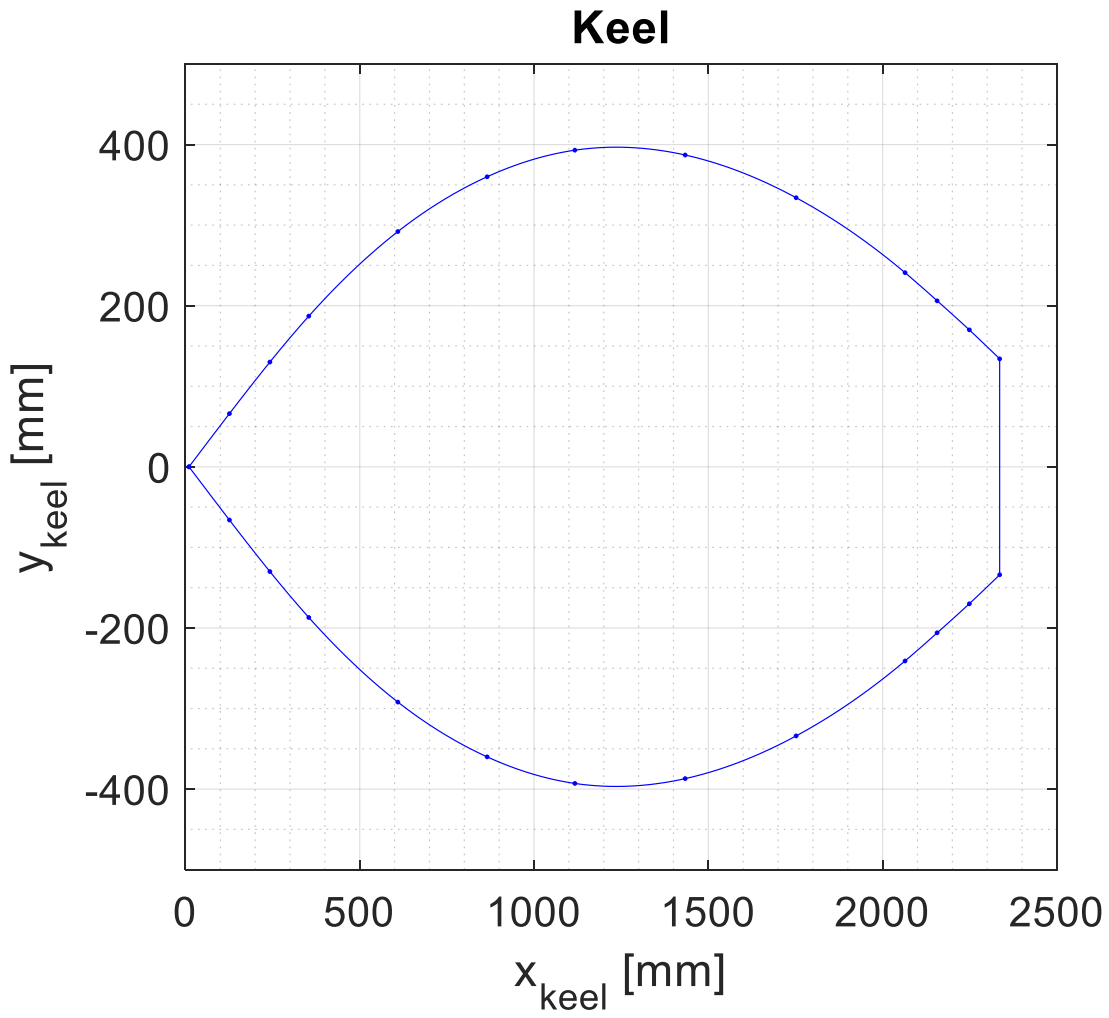
I.A.2. Needed products & accessories

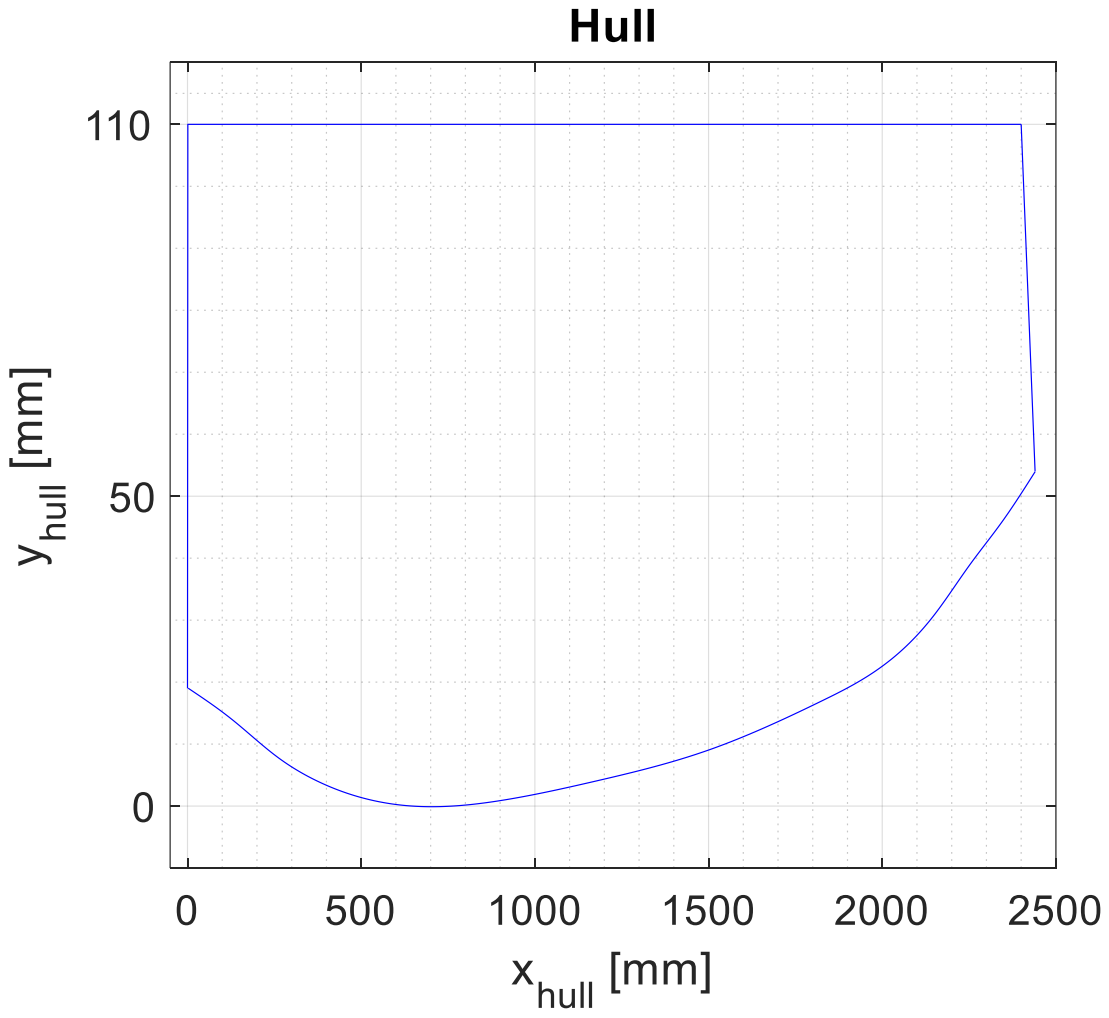
Quality	quantity
3mm plywood 1220 x 2440 [mm]	3 Sheets
Plank wood 360 [mm]	12 Meters
Surfset Epoxy	8 Liters
30x12 Meranti	12 Meters
Fibreglass (400) 1.27m	12 Meters
Leather Roll	5 cm x 6m
Antislip carpet	0.80 x 1m
Propeller 180 [mm]	1
Ppr tube + PVC tube + accessories	2 Meters
Ball bearing 8x16x5 [mm] & 20x47x14 [mm]	2 + 2
Additional accessories	

I.B. Design

I.B.1. Conception

The keel and hull parts have been designed using the curve fitting function.





I.B. Design

I.B.2. Data

The corresponding data of the Keel and Hull parts are given in the following tables:

Data of the Keel [mm]			
(50,23)	(650,305)	(1250,397)	(1850,309)
(100,51)	(700,320)	(1300,396)	(1900,295)
(150,79)	(750,334)	(1350,393)	(1950,280)
(200,107)	(800,346)	(1400,390)	(2000,263)
(250,134)	(850,357)	(1450,385)	(2050,246)
(300,160)	(900,367)	(1500,380)	(2100,228)
(350,185)	(950,375)	(1550,373)	(2150,209)
(400,209)	(1000,382)	(1600,365)	(2200,189)
(450,231)	(1050,388)	(1650,356)	(2250,169)
(500,252)	(1100,392)	(1700,346)	(2300,149)
(550,271)	(1150,395)	(1750,334)	(2335,134)
(600,289)	(1200,396)	(1800,322)	

Data of the hull [mm]			
(50,110)	(650,127)	(1250,122)	(1850,109)
(100,112)	(700,127)	(1300,121)	(1900,108)
(150,114)	(750,127)	(1350,121)	(1950,106)
(200,116)	(800,127)	(1400,120)	(2000,104)
(250,119)	(850,127)	(1450,119)	(2050,102)
(300,121)	(900,126)	(1500,118)	(2100,99)
(350,122)	(950,126)	(1550,117)	(2150,96)
(400,124)	(1000,125)	(1600,116)	(2200,92)
(450,125)	(1050,125)	(1650,115)	(2250,88)
(500,126)	(1100,124)	(1700,113)	(2300,84)
(550,126)	(1150,123)	(1750,112)	(2350,81)
(600,127)	(1200,123)	(1800,111)	(2400,77)
			(2440,73)

I.B. Design

I.B.3. Realization of the boat shape

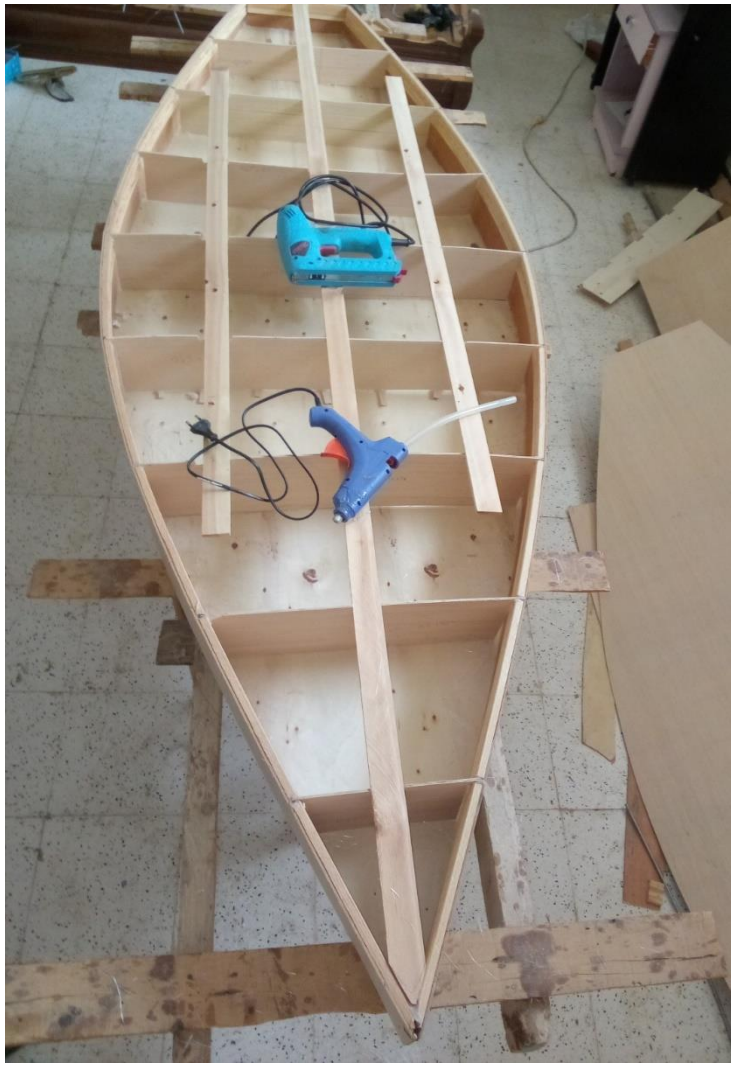
Principal steps for the design of the boat shape:

- Use 3 sheets of 3mm plywood 1220 x 2440 [mm].
- Mark plywood sheets according to the obtained keel and hull data.
- Drill hole every 200mm for stitches.
- Joining the two hull sides using planks of the corresponding length.
- Support the keel base using wood chips.
- Ensure the board is level with the bench.
- Cover the whole constructed boat using fiberglass.
- Apply epoxy to the frame/deck joint.

Photos of the boat shape

Step 1

Step 2



Step 3

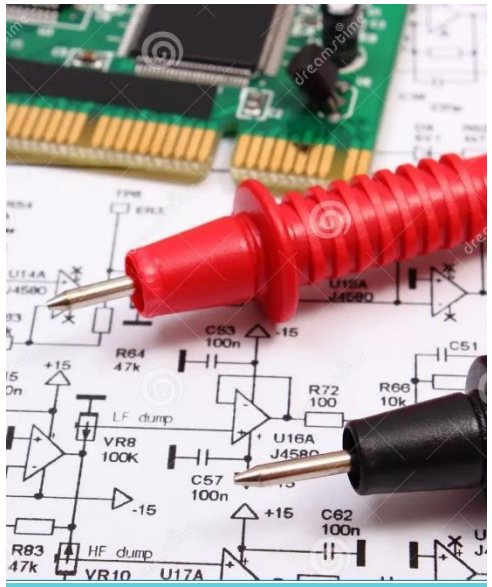
Photos of the boat shape

Step 4

Step 5

Step 6

Part II. Electronic Board



A. Specifications

B. Configuration

II.A. Specifications

II.A.1. Components

Quality	Specification
Resistances	470 (2), 1.5k (2), 4k (2), 10k (2)
LED 5mm	Green (1); Blue (1); Red (1), White (2)
Diode	1N4007 (2)
Transistor	1N2222 (2)
Mosfet	IRF830 (1)
Integrated circuits	ULN2003A (1), L298N (1)
Relay	12V (2)
Jumper wires	20 cm (20)
Breadboard	Small type (1)

II.A. Specifications

II.A.2. Devices

Quality	Specification
Master	Raspberry pi 4 model b 2gb
Slave	Arduino Mega 2560
GPS module	NEO-M8N
Temperature/Humidity sensor	DHT11
DC motor	775 High Power DC Motor, DC 12V-24V, 12000 rpm
Stepper motor	NEMA-17 Size - 200 Steps/rev, 12V 350mA
Servo motor	SG90 Maximum angle: 120° Voltage: 4.8V - 6.0V
Camera Infrared Night Vision Light	OV5647 5 mp, 160° Raspberry Pie Camera
Smartphone	Wifi & integrated Camera
Storage device	SD card 32 gb memory card

II.A. Specifications

II.A.3. Power

Quality	Specification
Voltage	5V and 12V DC
Battery for cars	12V/60A
Regulated Power Supply Module	Input: 8V-35V Output: 5V
Charger port	Yes

II.A. Specifications

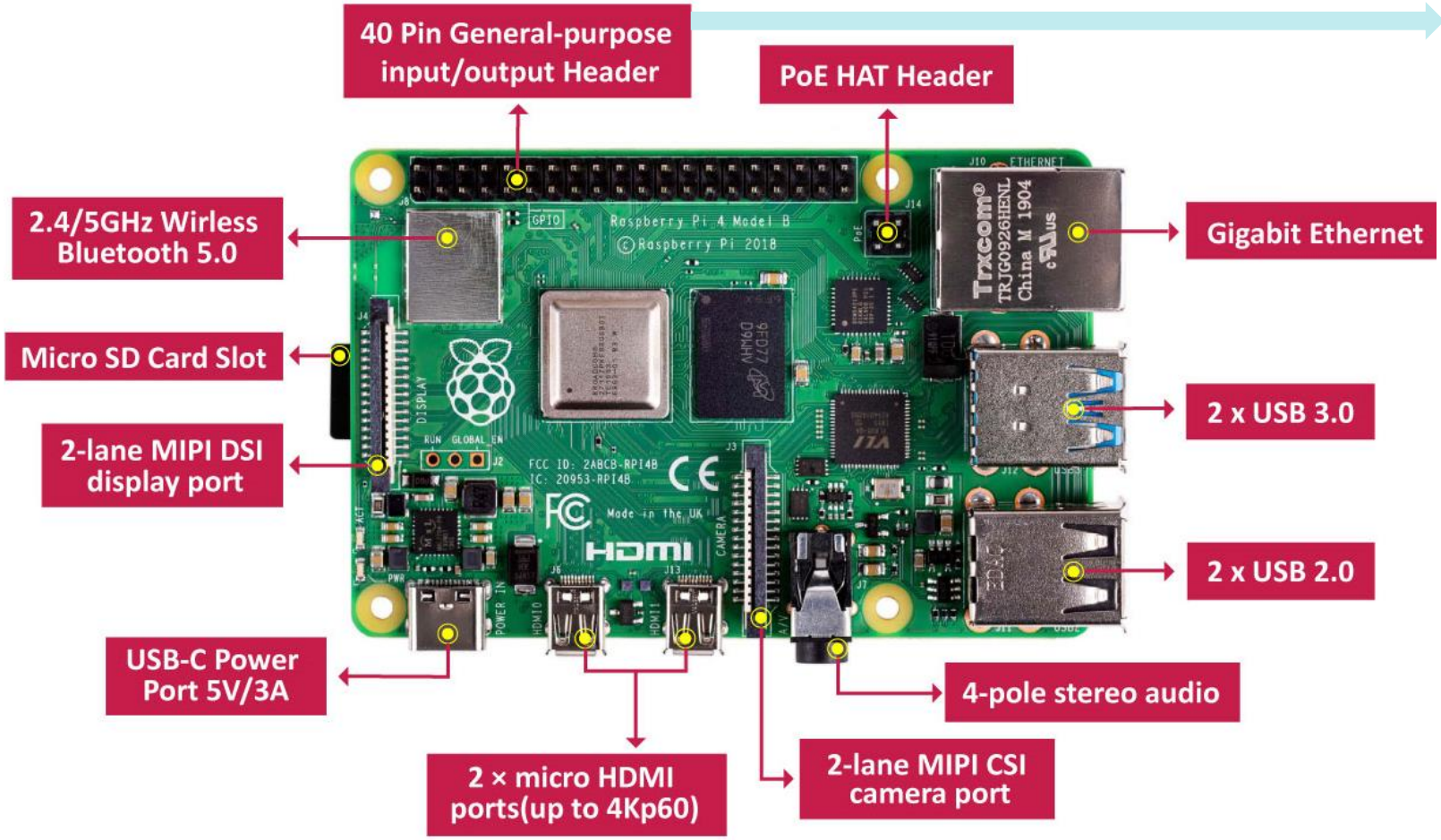
II.A.4. Software

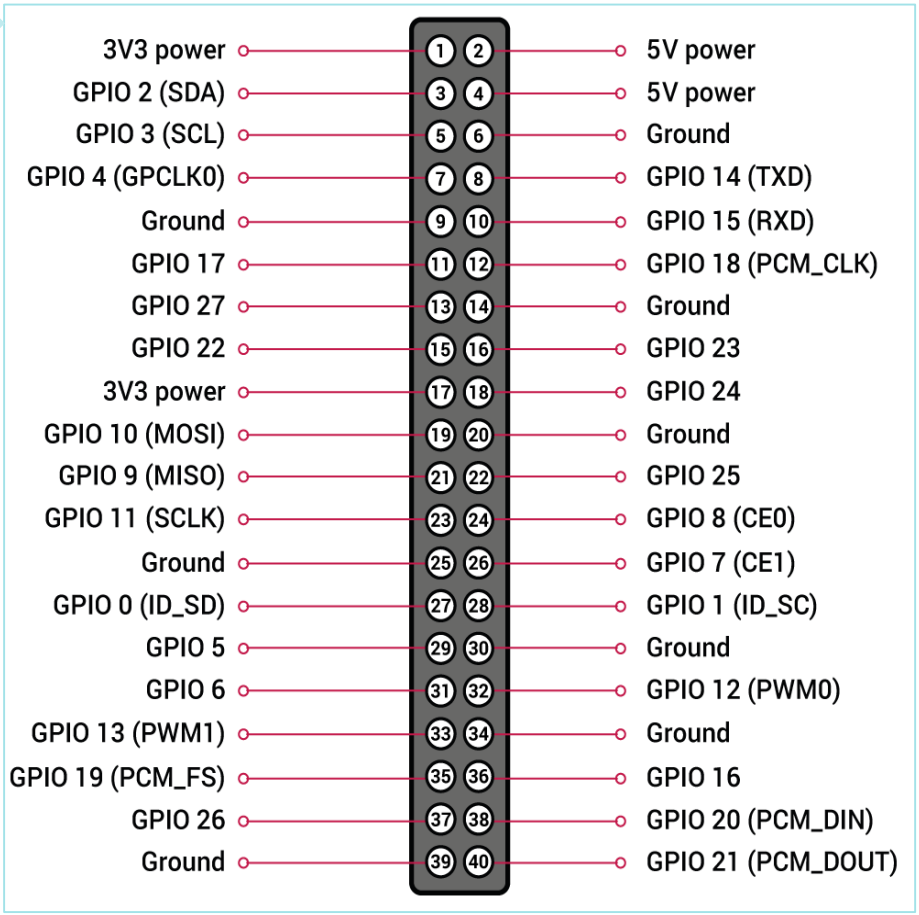
Quality	Software
IoT System Managing	Proteus IOT Builder
Temperature/Humidity	Python – DHT Library
GPS Tracking	Python – GPSD Library + WinSCP + MATLAB 2018a
Motors Control	UART Master-Slave Communication Protocol
Camera Infrared Night Vision Light	Raspberry Real VNC Viewer
Smart Object Detection	Python – Artificial Intelligence Library (OpenCV)

II.B. Configuration

II.B.1. Configuration of the Raspberry Pi 4

Hardware





II.B. Configuration

II.B.1. Configuration of the Raspberry Pi 4

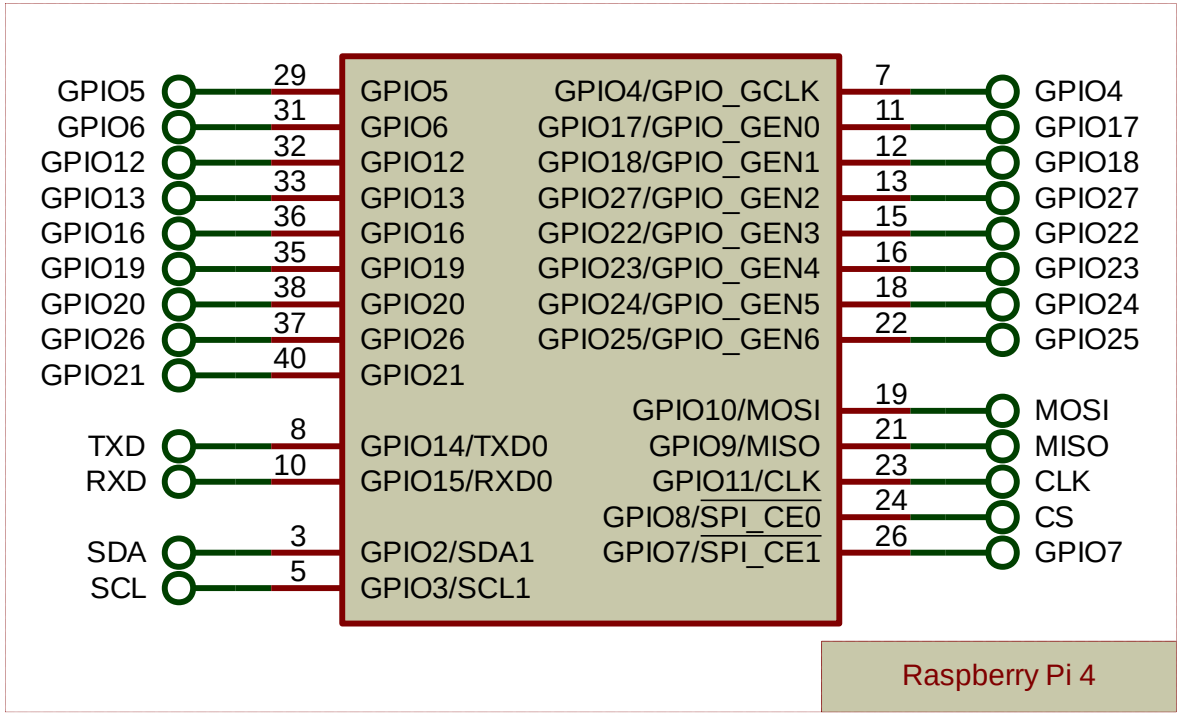
Software The main steps for the software configuration of the Raspberry Pi 4 are :

- Run Raspberry Pi Imager software to install the Operating System (OS) onto the micro SD card. Note that the standard OS 32-BIT has been installed.
- Upload useful files (configuration, ssh , iotbuiled) on the sd card storage.
- Make some preliminary adjustments, upgrades, and updates using the Raspberry terminal.
- Install the Python IDLE software.
- Install the DHT library to read temperature and humidity from the DHT sensor.
- Install the GPSD library to decode GPS data from the NEO-M8N GPS module.
- Install the Picamera2 library to run the Camera Infrared Night Vision Light.

II.B. Configuration

II.B.1. Configuration of the Raspberry Pi 4

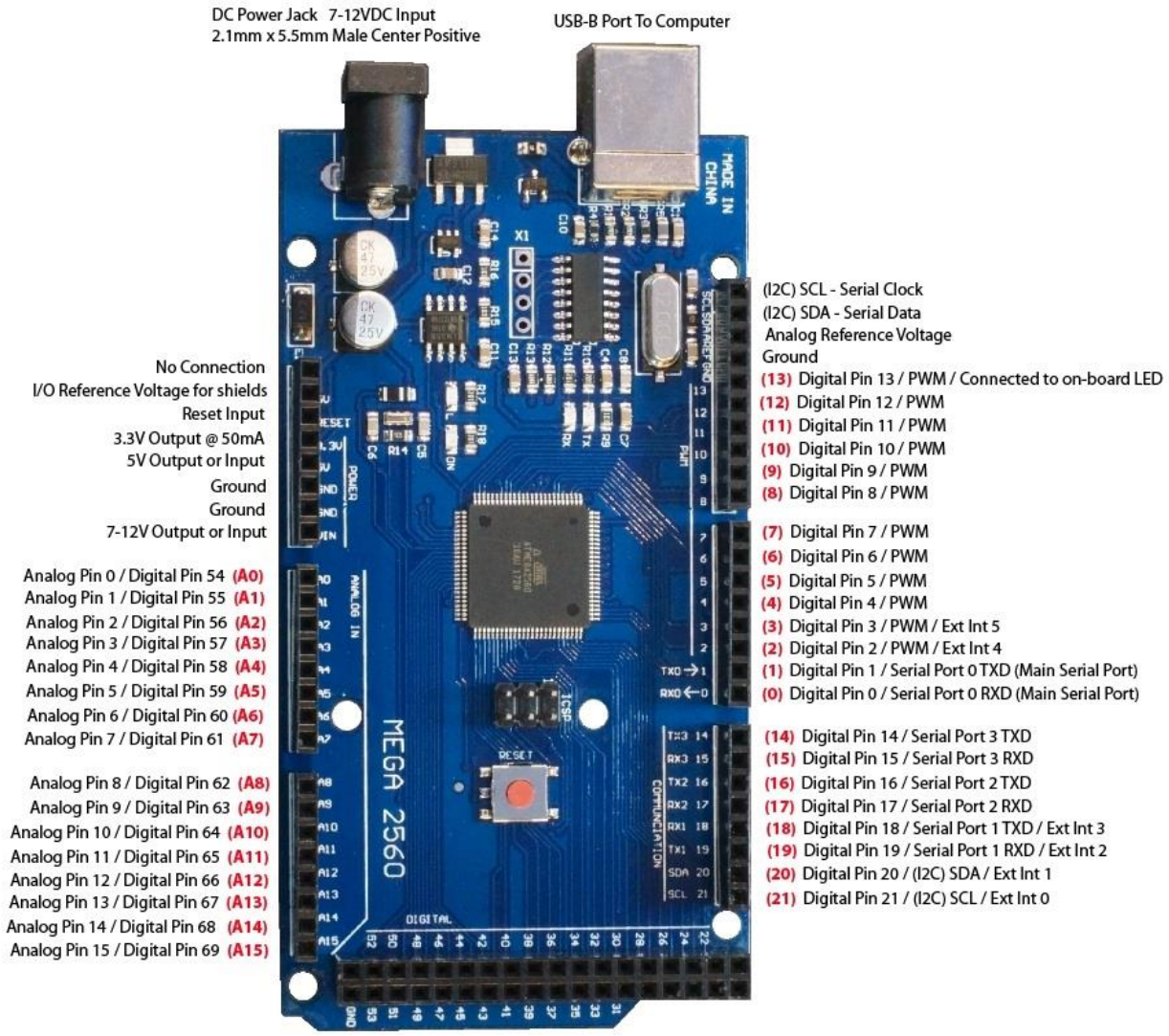
Software Simulated Raspberry Pi 4 using Proteus.



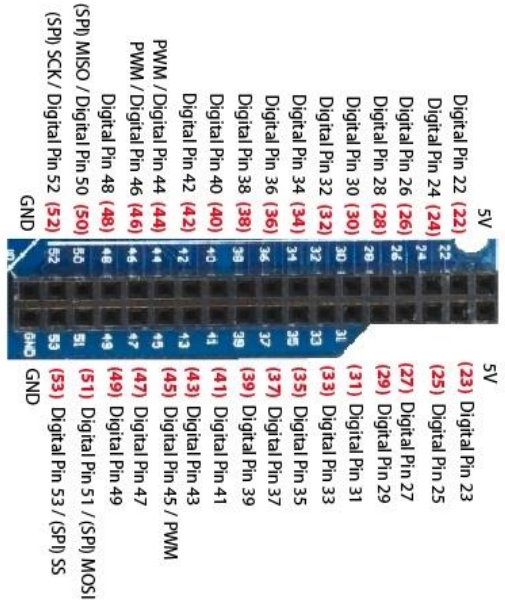
II.B. Configuration

II.B.2. Configuration of the Arduino Mega 2560

Hardware



Arduino Mega 2560 is selected since our project requires many I/O lines. Proteus is used as the programming software.

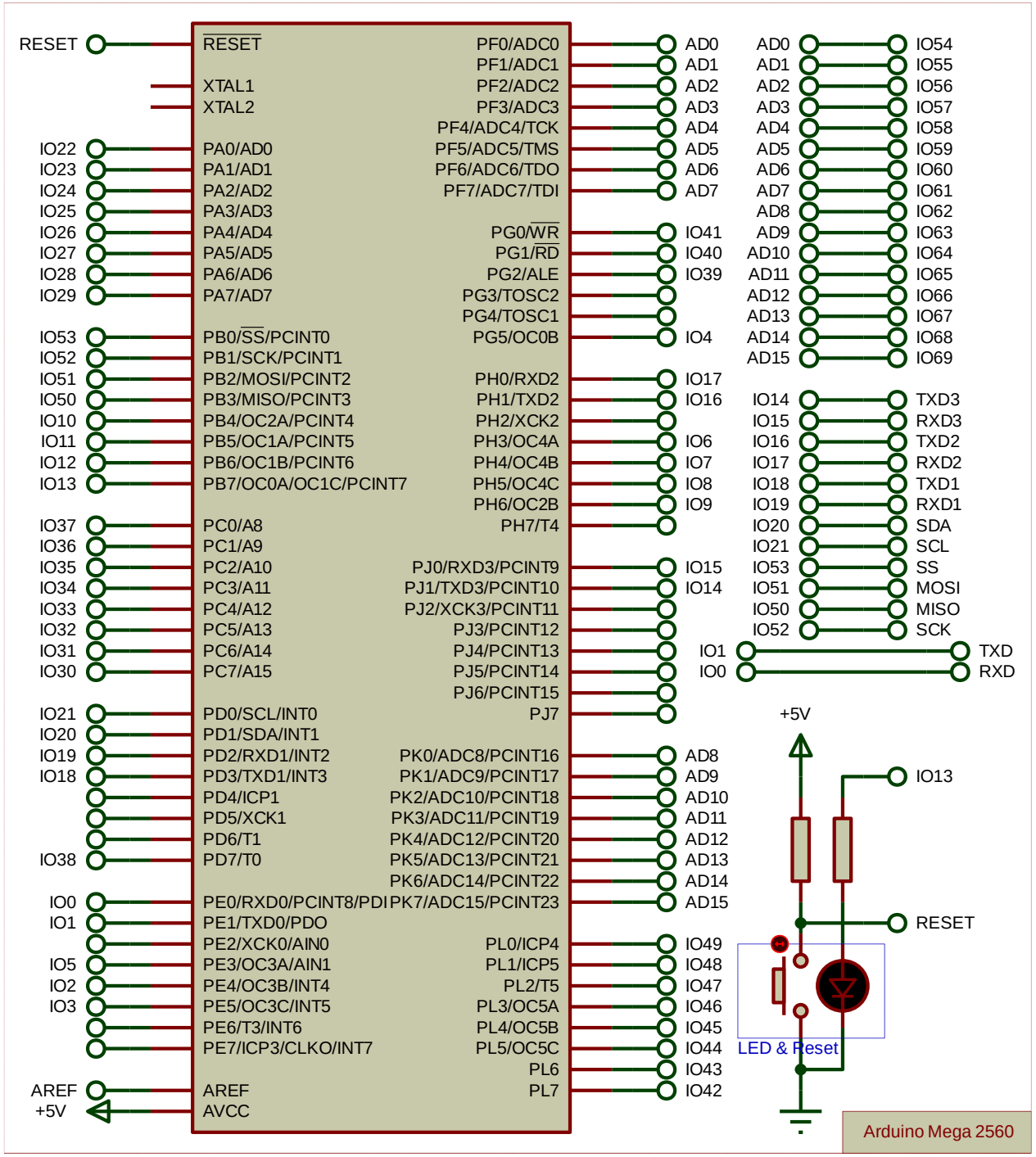


II.B. Configuration

II.B.2. Configuration of the Arduino Mega 2560

Software Simulated Arduino Mega 2560 using Proteus.

… in the next page


RESET
XTAL1
XTAL2
IO22
IO23
IO24
IO25
IO26
IO27
IO28
IO29
IO53
IO52
IO51
IO50
IO10
IO11
IO12
IO13
IO37
IO36
IO35
IO34
IO33
IO32
IO31
IO30
IO21
IO20
IO19
IO18
IO38
IO0
IO1
IO5
IO2
IO3
AREF
+5V
RESET
PA0/AD0
PA1/AD1
PA2/AD2
PA3/AD3
PA4/AD4
PA5/AD5
PA6/AD6
PA7/AD7
PB0/SS/PCINT0
PB1/SCK/PCINT1
PB2/MOSI/PCINT2
PB3/MISO/PCINT3
PB4/OC2A/PCINT4
PB5/OC1A/PCINT5
PB6/OC1B/PCINT6
PB7/OC0A/OC1C/PCINT7
PC0/A8
PC1/A9
PC2/A10
PC3/A11
PC4/A12
PC5/A13
PC6/A14
PC7/A15
PD0/SCL/INT0
PD1/SDA/INT1
PD2/RXD1/INT2
PD3/TXD1/INT3
PD4/ICP1
PD5/XCK1
PD6/T1
PD7/T0
PE0/RXD0/PCINT8/PDI
PE1/TXD0/PDO
PE2/XCK0/AIN0
PE3/OC3A/AIN1
PE4/OC3B/INT4
PE5/OC3C/INT5
PE6/T3/INT6
PE7/ICP3/CLKO/INT7
AREF
AVCC
PF0/ADC0
PF1/ADC1
PF2/ADC2
PF3/ADC3
PF4/ADC4/TCK
PF5/ADC5/TMS
PF6/ADC6/TDO
PF7/ADC7/TDI
PG0/WR
PG1/RD
PG2/ALE
PG3/TOSC2
PG4/TOSC1
PG5/OC0B
PH0/RXD2
PH1/TXD2
PH2/XCK2
PH3/OC4A
PH4/OC4B
PH5/OC4C
PH6/OC2B
PH7/T4
PJ0/RXD3/PCINT9
PJ1/TXD3/PCINT10
PJ2/XCK3/PCINT11
PJ3/PCINT12
PJ4/PCINT13
PJ5/PCINT14
PJ6/PCINT15
PJ7
PK0/ADC8/PCINT16
PK1/ADC9/PCINT17
PK2/ADC10/PCINT18
PK3/ADC11/PCINT19
PK4/ADC12/PCINT20
PK5/ADC13/PCINT21
PK6/ADC14/PCINT22
PK7/ADC15/PCINT23
PL0/ICP4
PL1/ICP5
PL2/T5
PL3/OC5A
PL4/OC5B
PL5/OC5C
PL6
PL7
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
IO41
IO40
IO39
IO4
IO17
IO16
IO6
IO7
IO8
IO9
IO15
IO14
AD8
AD9
AD10
AD11
AD12
AD13
AD14
AD15
IO49
IO48
IO47
IO46
IO45
IO44
IO43
IO42
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
AD8
AD9
AD10
AD11
AD12
AD13
AD14
AD15
IO54
IO55
IO56
IO57
IO58
IO59
IO60
IO61
IO62
IO63
IO64
IO65
IO66
IO67
IO68
IO69
IO14
IO15
IO16
IO17
IO18
IO19
IO20
IO21
IO53
IO51
IO50
IO52
TXD3
RXD3
TXD2
RXD2
TXD1
RXD1
SDA
SCL
SS
MOSI
MISO
SCK
IO1
IO0
TXD
RXD
+5V
IO13
RESET
LED & Reset
Arduino Mega 2560

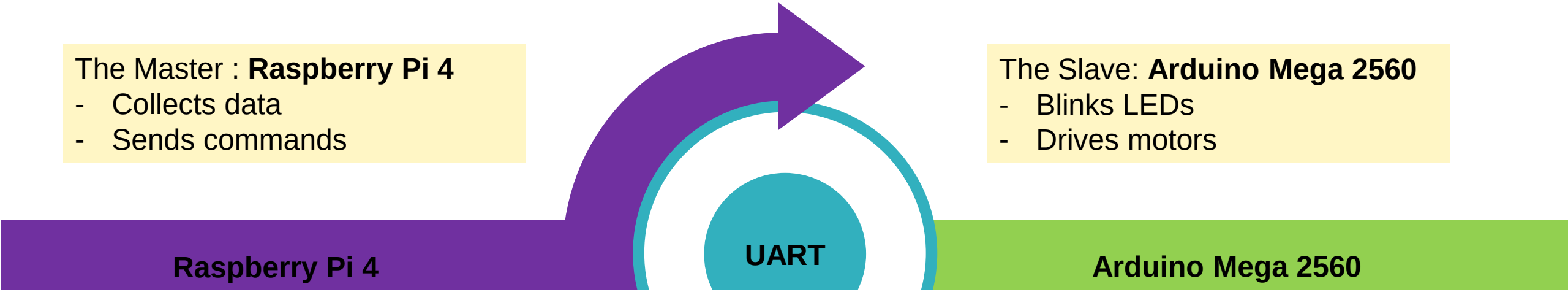
II.B. Configuration

II.B.3. Configuration of UART Communication

UART (Universal Asynchronous Receiver-Transmitter) is one of the most widely used device-to-device communication protocols. In our project, Raspberry Pi 4 is considered as the Master and Arduino Mega 2560 as the Slave.

The Master : **Raspberry Pi 4**
- Collects data
- Sends commands

The Slave: **Arduino Mega 2560**
- Blinks LEDs
- Drives motors



The Raspberry pi is connected to the Arduino Mega 2560 via UART as follows:

Raspberry Pi GND	→	Arduino Mega 2560 GND
Raspberry Pi TX (GPIO 14)	→	Arduino Mega 2560 RX (IO 0)

II.B. Configuration

II.B.4. Configuration of LEDs and sensors

Three LEDs are activated by the Raspberry Pi through the UART communication to the Arduino Mega.

LED green	→	Arduino Mega IO 13 // to check the system start
LED blue	→	Arduino Mega IO 12 // to activate alarm
LED red	→	Arduino Mega IO 11 // to activate alarm

For their part, the DHT sensor, the NEO-M8N GPS module, and the water sensor are directly connected to the Raspberry Pi as follows:

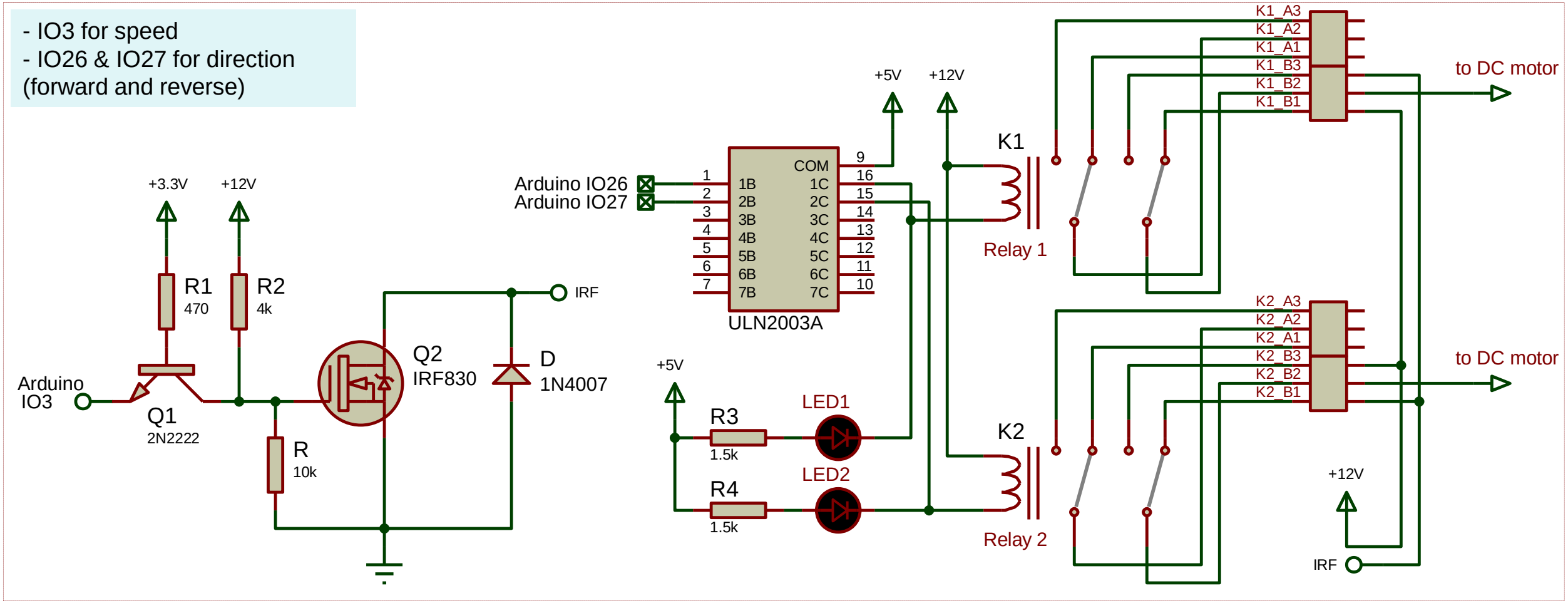
DHT 11 OUT	→	Raspberry Pi GPIO14
NEO-M8N RX	→	Raspberry Pi TX (GPIO 14) //Not required in our case
NEO-M8N TX	→	Raspberry Pi RX (GPIO 15)
Water S OUT	→	Raspberry Pi GPIO14

II.B. Configuration

II.B.5. Configuration of the DC motor driver

The DC motor is derived using Mosfet IRF830, ULN2003A, and two 12V Relays.

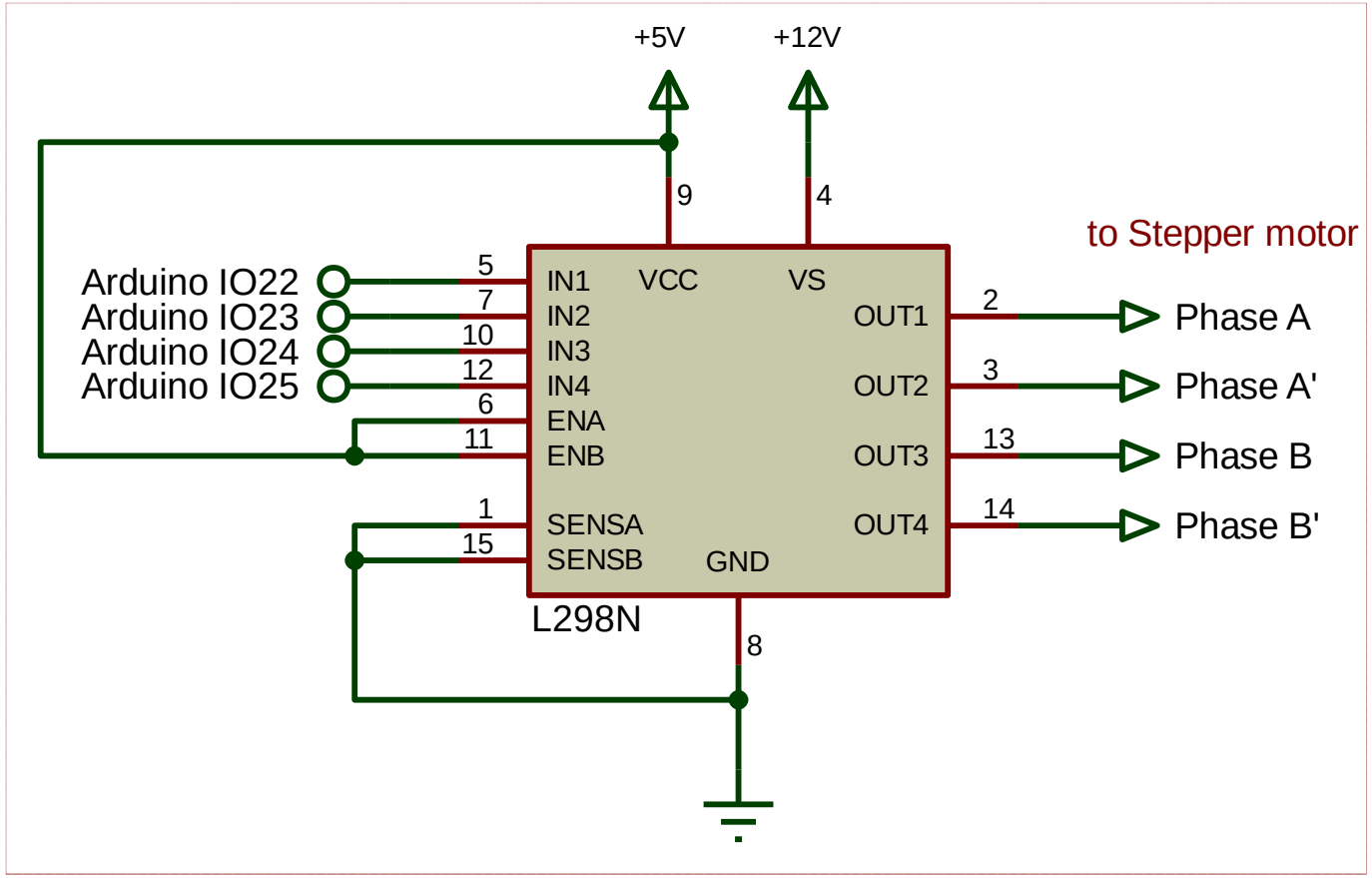
- IO3 for speed
- IO26 & IO27 for direction (forward and reverse)



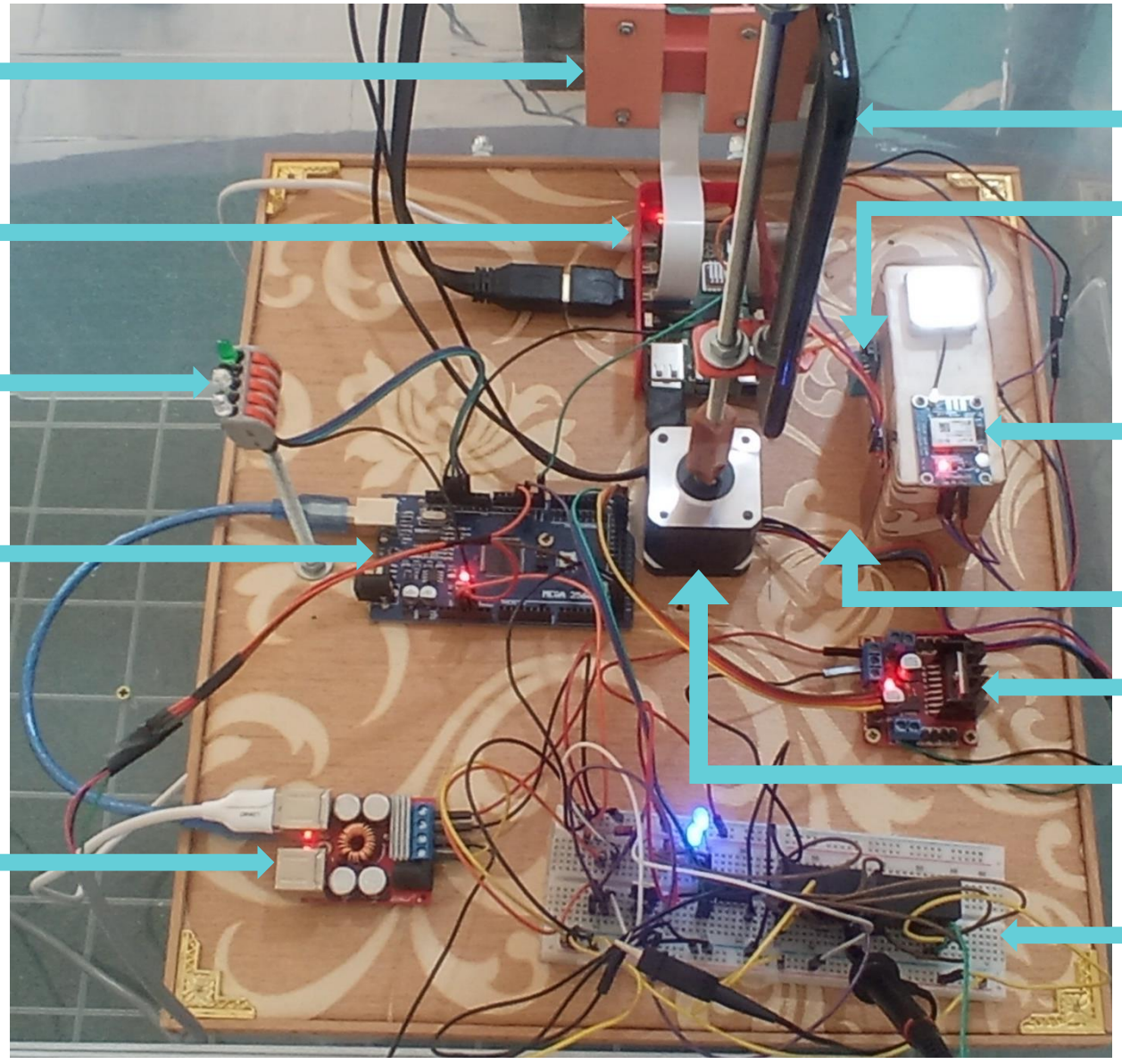
II.B. Configuration

II.B.6. Configuration of the stepper motor driver

The stepper motor is derived using the L298N driver.



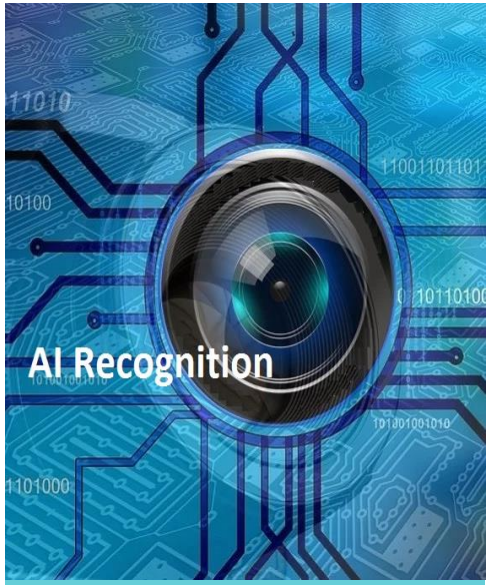
Photos of the electronic board



Part III. IoT and AI Multi-Tasking

A.

IoT managing platform

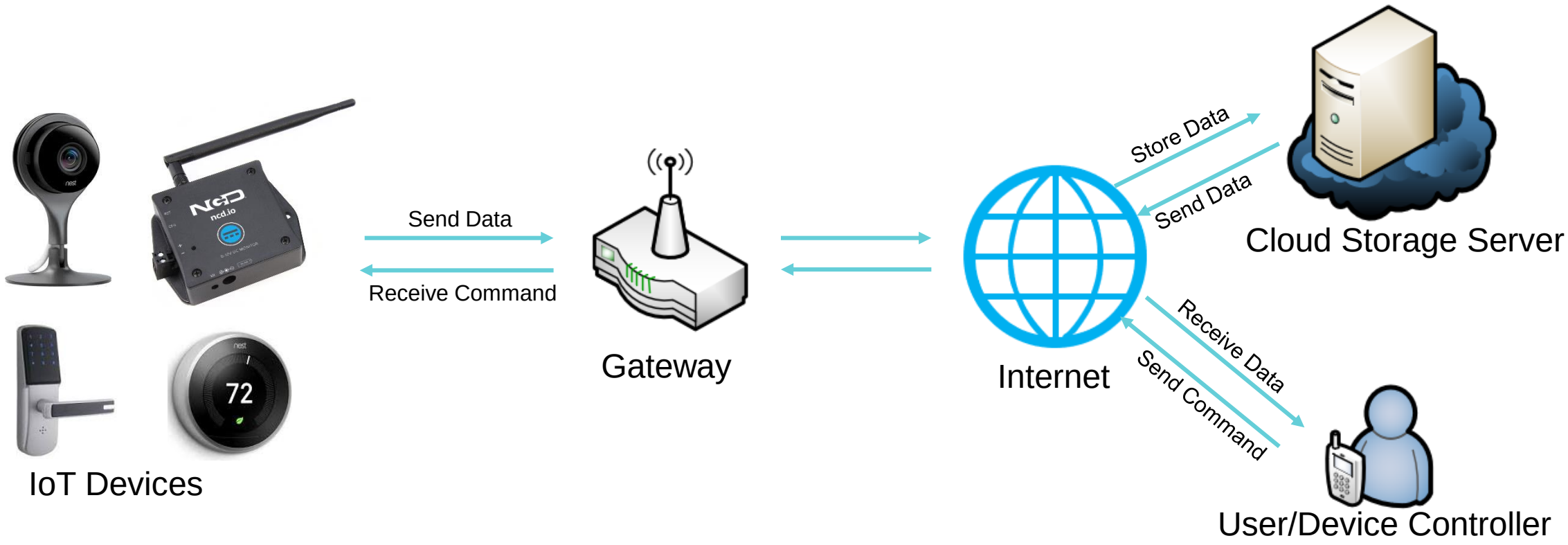


B.

AI recognition platform

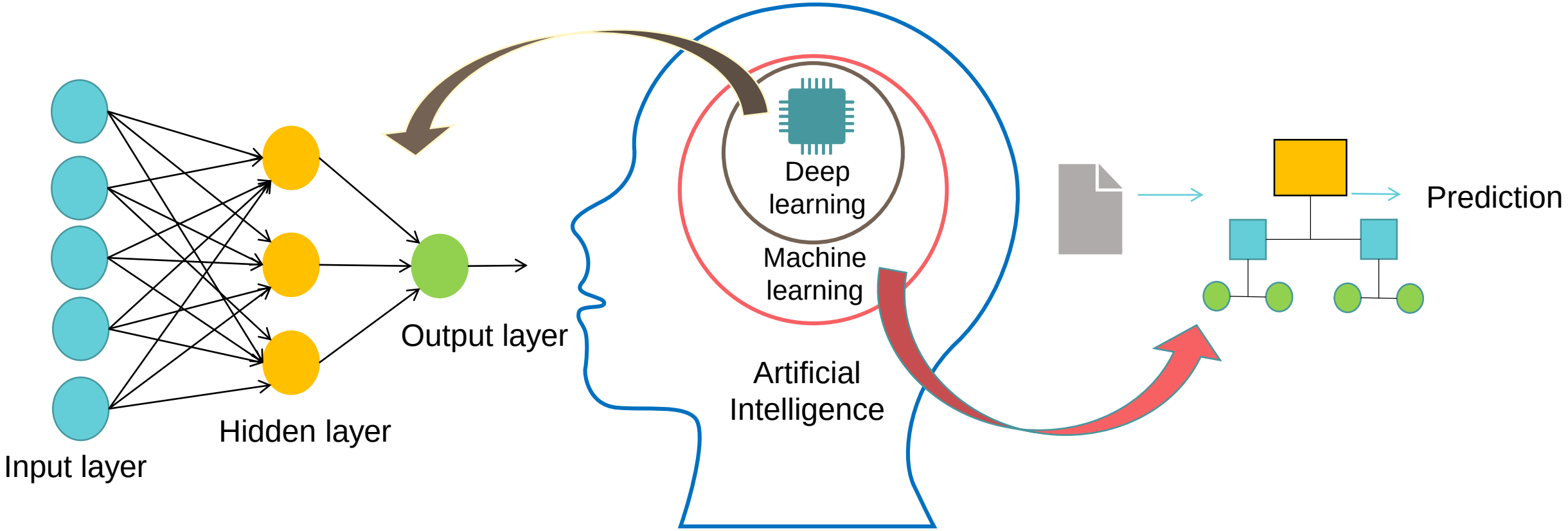
Brief overview of IoT

Internet of Things (IoT) is a network of devices that are integrated with sensors and have the ability to exchange data over the Internet or other communication networks.



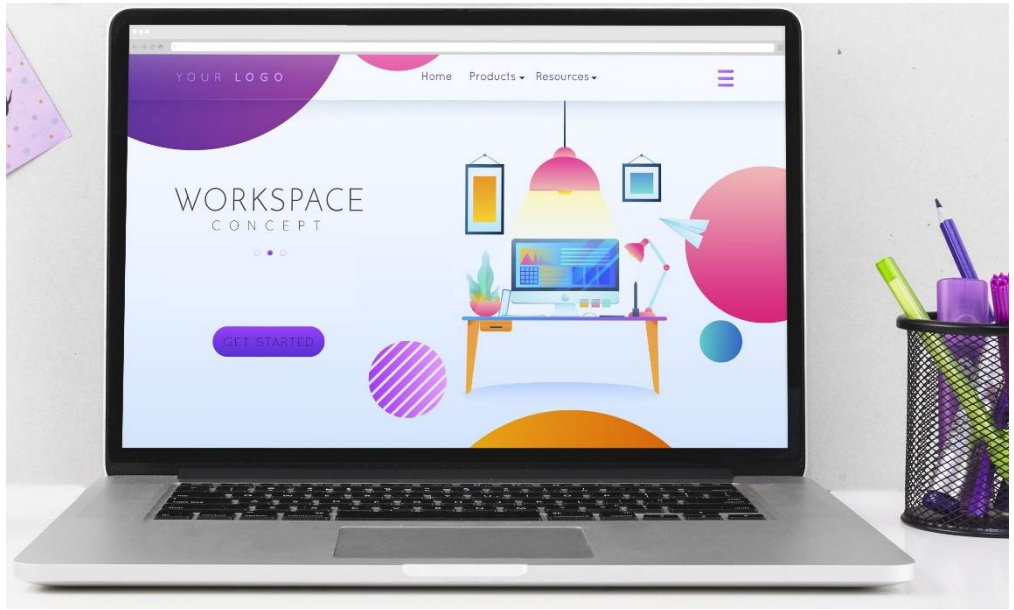
Brief overview of AI

Artificial Intelligence (AI) is a field of research that allows a machine to perform tasks related to human intelligence.



Multi-Tasking principle

Human - Operator

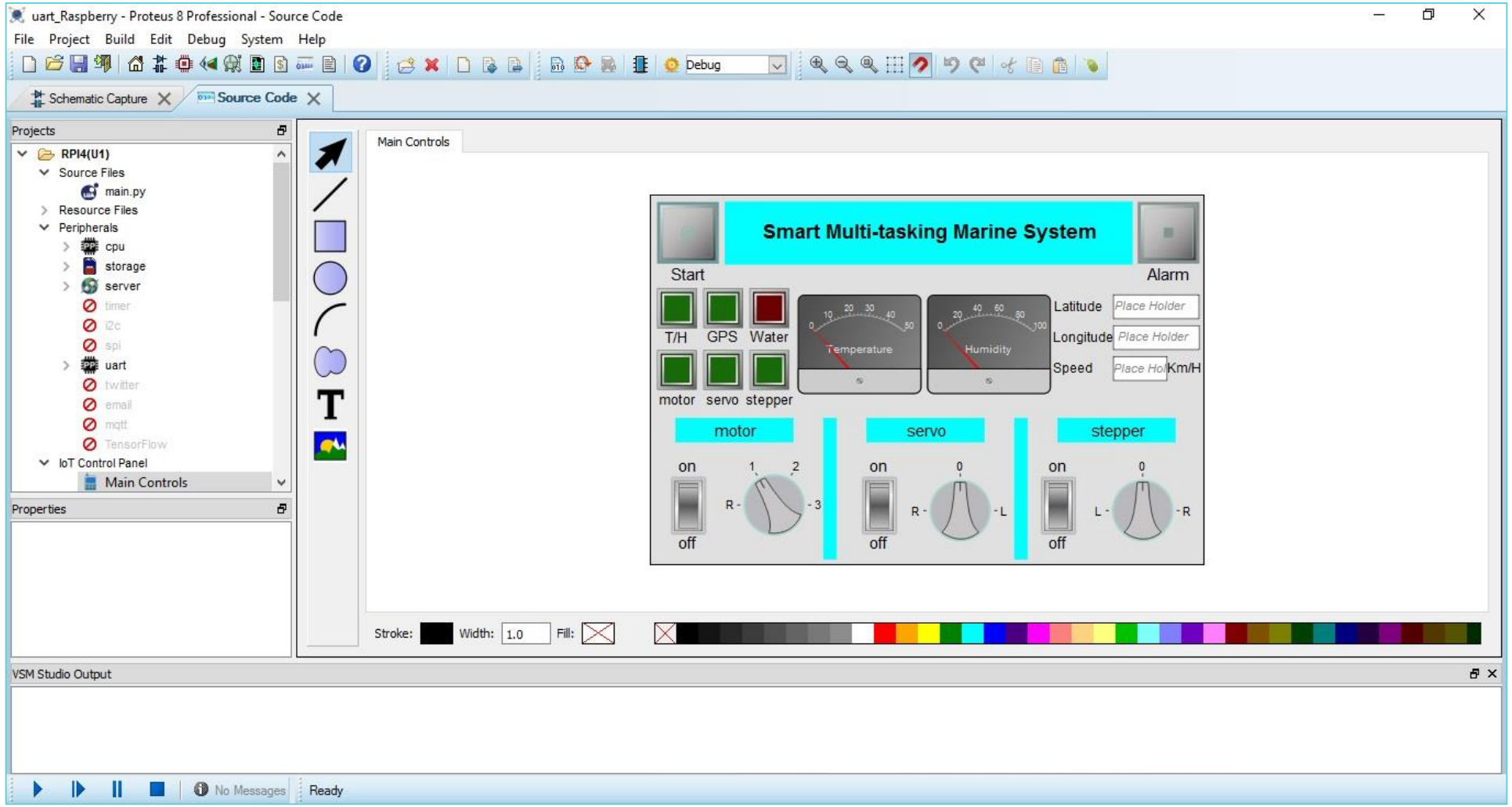


- IoT managing platform
- AI recognition platform

III.A. IoT managing platform

III.A.1. Design of the IoT managing platform

The main IoT platform is designed using Proteus IOT Builder as follows:



III.A. IoT managing platform

III.A.2. Tasks related to the IoT managing platform

The main IoT platform contains:

- One IoT button for the system startup
- One IoT button for the alarm warning
- Two IoT panels to display Temperature and Humidity values
- Three IoT text boxes to show the GPS values (Latitude, Longitude, Speed)
- Two IoT switches to command the DC motor speed
- Two IoT switches to command the stepper motor angle
- Two IoT switches to command the servo motor angle
- A panel of six IoT LEDs in which five green IoT LEDs light up when the sensors and/or motors are operating, and one red IoT LED lights up if the water sensor detects the presence of water in the electronic board box.

III.B. AI recognition platform

III.B.1. Configuration of the AI recognition platform

Some preliminary manipulations must be performed as follows:

- Install the OpenCV (Open-source Computer Vision) package for Python on the remote controller unit.
- A smartphone is embarked on the boat to detect surrounding objects.
- Activate the IP transfer protocol to communicate the captured video frames to the remote controller unit.
- Activate the VNC software installed on Raspberry Pi 4 to get access to the Night Vision Camera from the remote controller unit.
- Enable the live streaming remotely to start the camera from the Raspberry terminal :

```
libcamera-hello -t 0
```

III.B. AI recognition platform

III.B.2. Tasks related to the recognition AI platform

The main tasks of the developed smart object recognition code to prevent against illegal immigration are:

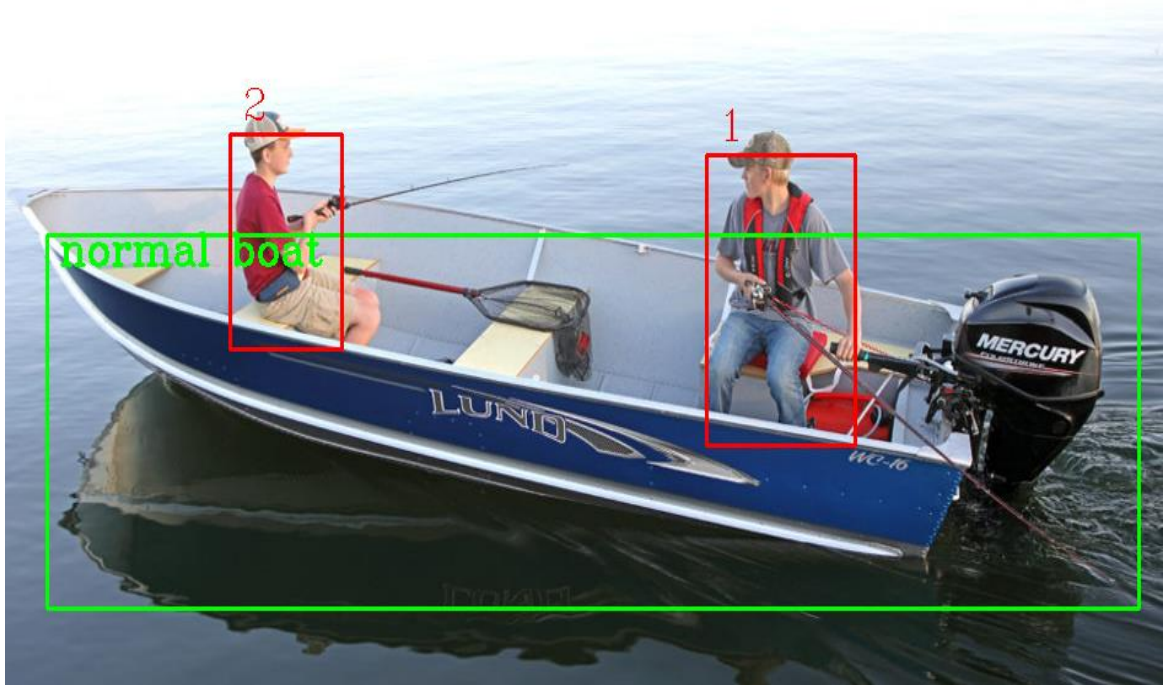
- Initialize the video capture process and generate the corresponding image frames.
- Classify the obtained frame into two different categories by distinguishing between commercial vessels and fishing boats on the one hand, and potentially suspicious boats involved in illegal immigration on the other.
- Train the developed AI code to identify human subjects in frames to ensure rapid detection of suspicious individuals on the boat.
- All captured frames and relevant data are stored securely for future analysis and evidence preservation purposes.

III.B. AI recognition platform

III.B.3. Simultaion results of the recognition AI platform

Simulation results of the AI object recognition platform on two tested unsuspicious boats images:

Unsuspicious boats are surrounded with green frames.

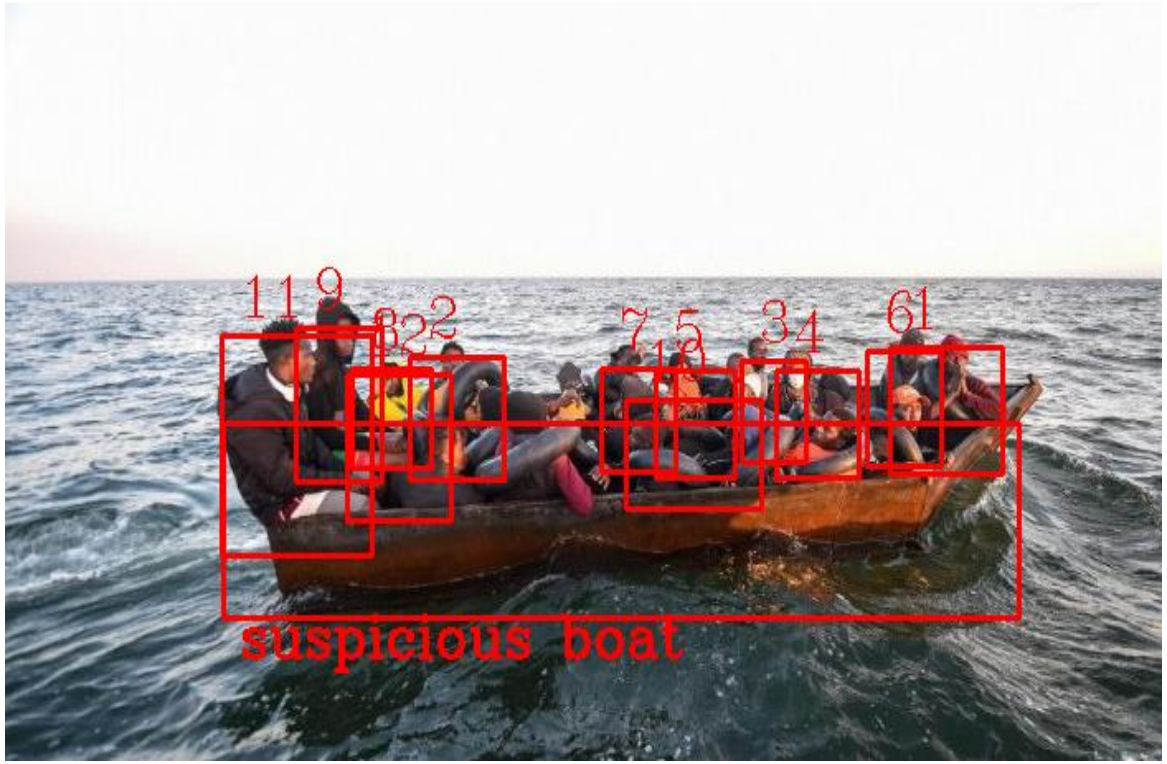


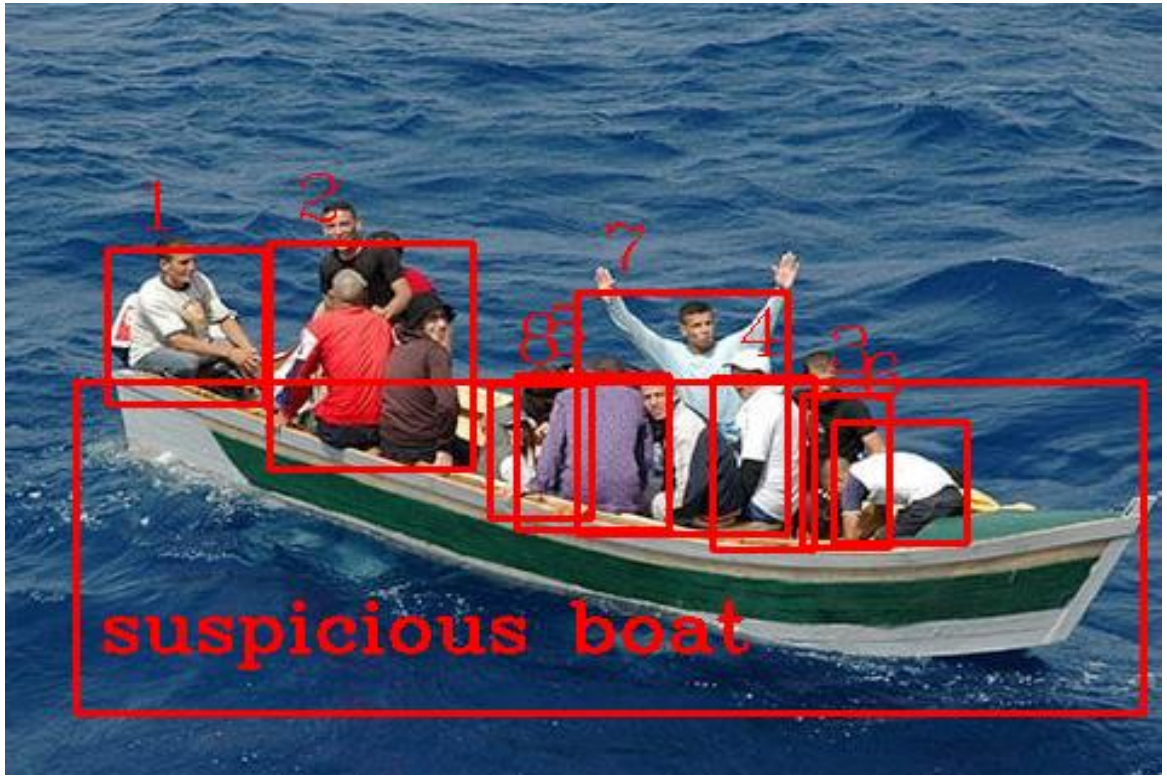
III.B. AI recognition platform

III.B.3. Simultaion results of the recognition AI platform

Simulation results of the AI object recognition platform on two tested suspicious boats images:

Suspicious boats are surrounded with red frames.

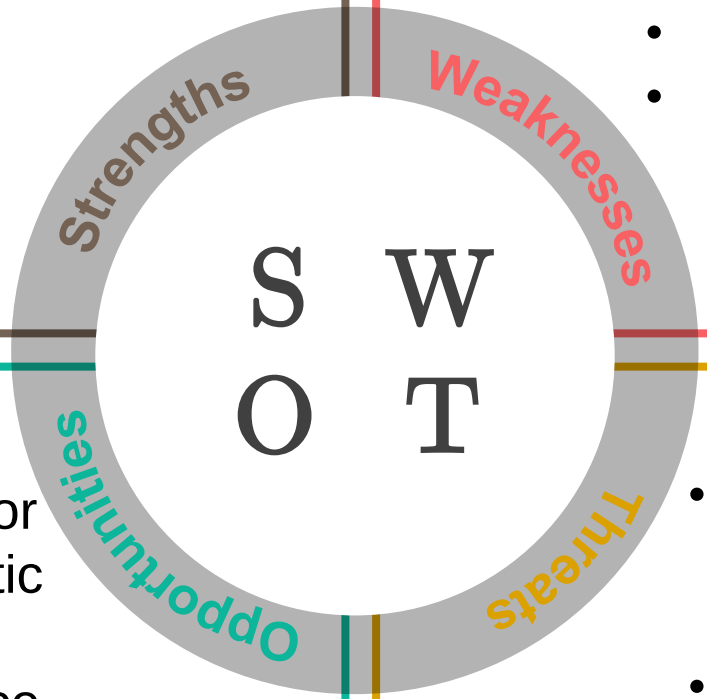




Managing

- SWOT Analysis
- Clients
- Relationships
- Partnerships

SWOT Analysis



- Offering Coast Guards a new patrolling option that has higher efficiency
- Assisting in rescue operations
- Lower maintenance cost
- Not many competitors
- A unique technology

- A potential limitation in immediate expansion opportunities
- Investment cost
- Dependability on weather

- Solve problems related to the maritime socio-economic sector
- Development of the « Automatic cruise itineraries » segment
- Elevates the service experience through automation
- A lot of potential target clients

- Security issues in terms of
  - Boat control failure
  - Physical device
- Legal restrictions: cruise zones

Clients

Government Agencies and Port Authorities
- Assisting in coastal guarding, patrolling and detecting suspicious activities.
- Providing port security, and monitoring vessel traffic.

Fishing Companies and Free Fishermen
- Providing real-time data on fish populations and fishing hotspots.
- Automated fishing practices.

Civil Protection and Rescue Operations
- Assisting in rescue operations and maritime safety.
- Guarantee surveillance outside the working hours and on dangerous beaches.

Tourist Operators and Cruise Companies
Providing interactive guided tours and immersive experiences for tourists.

Water Sports and Recreation Businesses
Providing support for supervision, safety, and guidance for participants.

Research Institutions and Environmental Agencies
Marine research, data collection, and monitoring of marine ecosystems.

Relationships

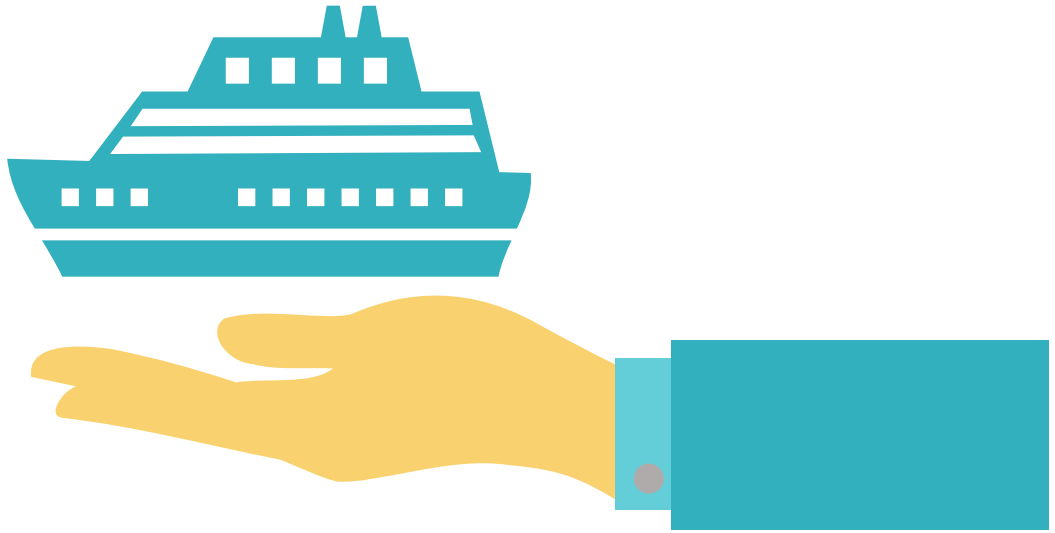
Project Task list

Project	✓	Task Description
	☐	
	☐	
	☐	
	☐	
	☐	

+

Funding

=



PARTNERSHIPS

… and others

Photos of the Prototype

Photos of the Prototype

تم بحمد الله تعالى تجربة النموذج بنجاح في 26 أوت 2023 –
9 صفر 1445 على مستوى شاطئ بوسعدون جيجل

Watch the Project Demo Video on:

https://drive.google.com/file/d/1d4gdrZsIrsoumuRYEGcT-umsGRuTt1DI/view?usp=sharing

SM-TMS presentation.mp4