Prince Mohammad Bin Fahd University
College of Engineering
Department of Electrical Engineering

Autonomous/Manual Firefighting Robot

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Outline

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- Project Objectives
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- Background
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- Project Management & Teamwork
- Impact of Project
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- Completed & Remaining Work
- Budget Estimate
- References

Project Definition

- To design an autonomous/manual firefighting robotic vehicle capable of detecting and extinguishing fires in indoor and outdoor locations within reasonable responsive time.

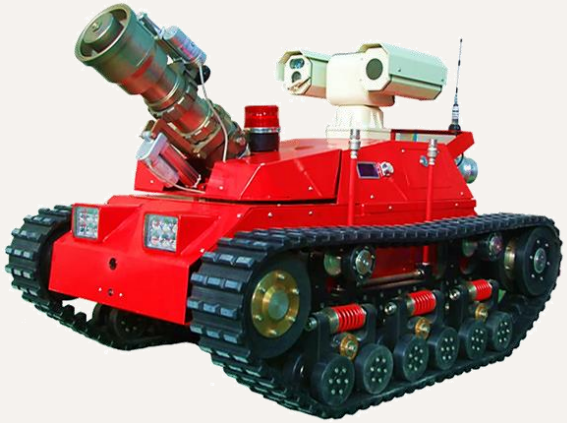


Figure 1: Firefighter Robot Prototype

Project Objectives

i. **Reduce** physical exposure of firefighters.

ii. **Extinguish** fires in obscure areas.

iii. **Rapidly** detects fire to reduce property damage.

iv. **Protect** against injuries via rapid detection & extinguishment.

Figure 2: Firefighter Robot Simulation

Project Specifications

- Assumes Power Supply of **12V DC Output @ 145 RPM**.
- Power Supply for battery charging **220 volts 60 Hz**.
- Operates on **9x 18650 batteries**; **3500MAh** each.
- Requires **3-4 hours** to fully charge.
- Robot lifting capacity up to **12kg**.
- Weight **3.8kg**
- Size is **620* 370 *110mm** (length * width * height).
- Remote Control Frequency is **2.4 GHz – 8 channels, Range up to 1 km**
- Remote Control Max Range (Distance) is **100m**.
- Pump power **2.5 watts**.
- Water tank capacity **2 liters**.

Project Constraints and Standards

Economic

Safety

Culture/Social

Project Architecture

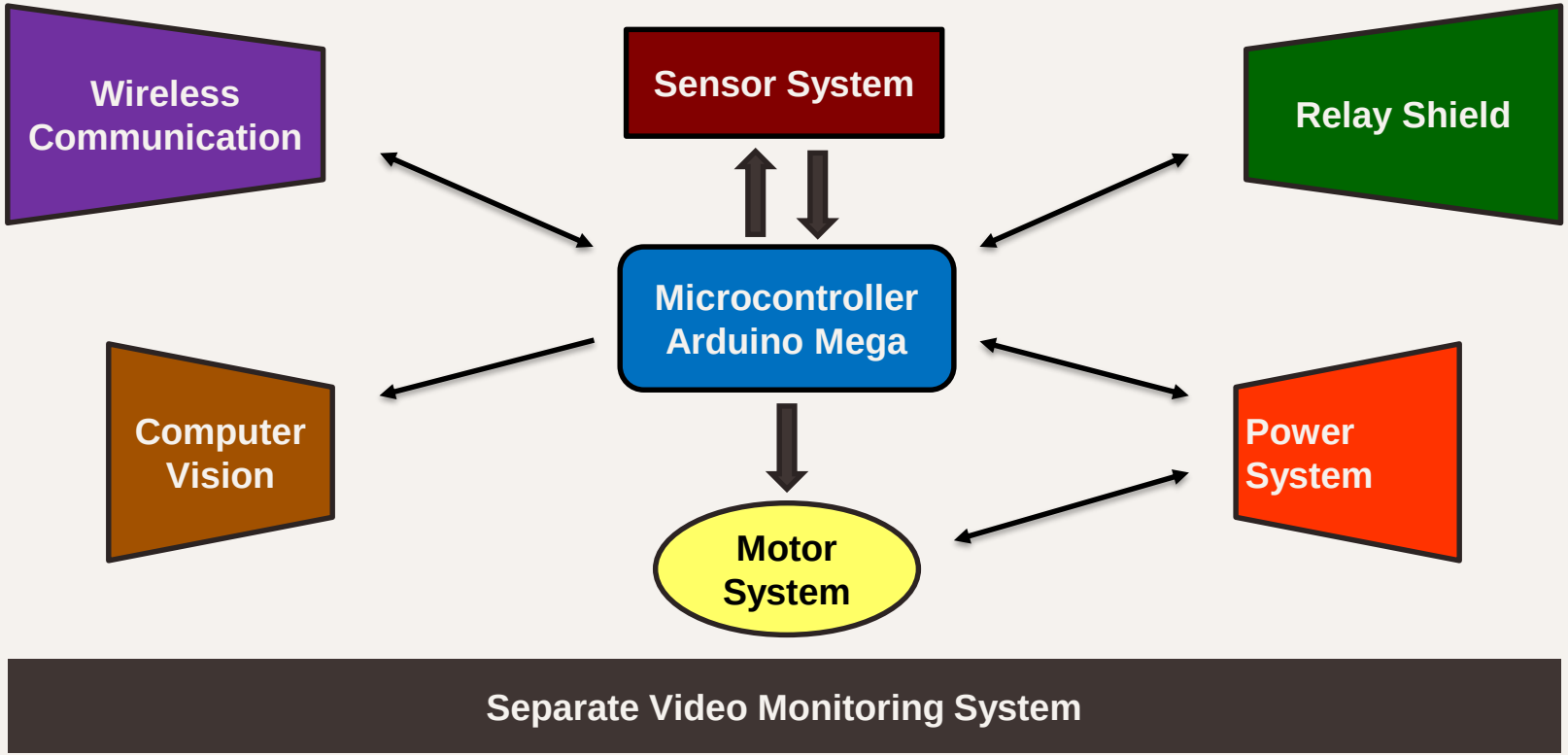


Figure 3: Firefighter Robot Project Architecture

Planning

- The project is feasible.
- The majority of components are not readily available locally.
- PMU Labs can perform some of the required testing.
- COVID-19 situation and the necessary safety precautions.
- 3-D printer requirement to fabricate certain components.

Figure 4: 3D Printing Laboratory

Background: Problem

- Firefighter expose to extreme heat temperatures
- Lack of technological advancement tools
- Fires in difficult-to-reach areas are difficult to extinguish.

Figure 6: Fire in Wilderness

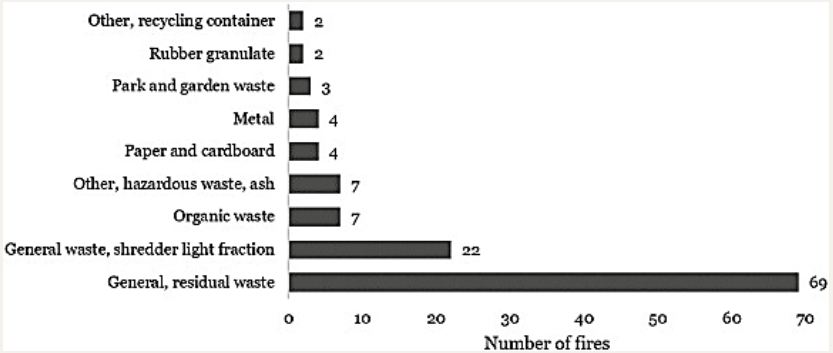


Figure 5: Fires in Waste Facilities (Scandinavia)

Background: Solution

- Technological advancements required in the field of firefighting.
- Reduced requirement for firefighter presence.
- Access to hard-to-reach areas.

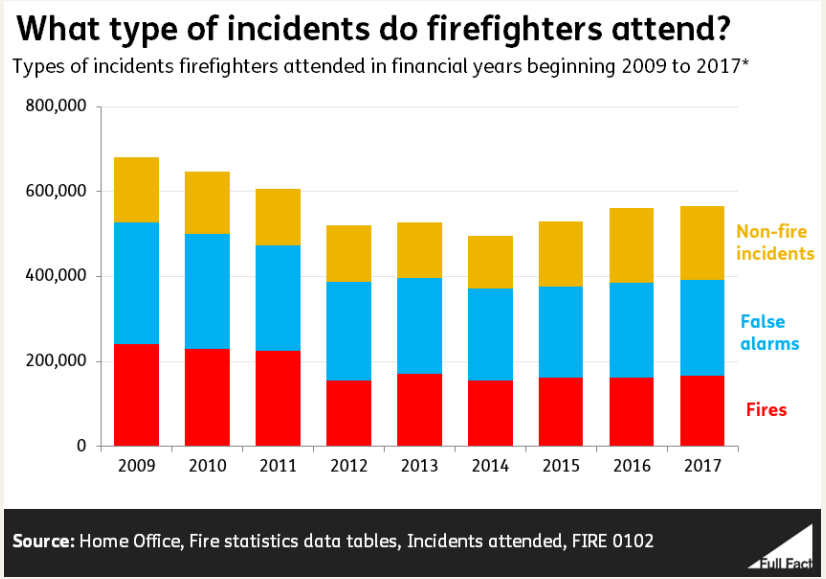


Figure 6: Types of Incidents Firefighters Attend

Background: Advantages of Fire Fighter Robot

Firefighter (Fireman)	Firefighting Robot
Highly physical exposure	Less physical exposure
Some areas	Access to obscure areas
Slower detection	Faster detection
Slower fire-extinguishing time	Faster fire-extinguishing time
Increased reliance on firefighter presence	Reduced reliance on firefighter presence

Background: How does it work?

The system will be composed of subsystems that perform the following functions:

- **Detect** source of fire.
- **Alert** concerned parties.
- **Utilize** subsystems to carry out functions.
- **Drive** towards fire to extinguish it.

Previous Project (1)

Development of Fire Fighting Robot (QRob), Malaysian Institute of Industrial Technology at Universiti Kuala Lumpur, Malaysia, 2019

- QRob relies only on heat sensors to detect fires.
- Relies on super sensors to detect surroundings and avoid obstacles.
- Operates on an Arduino UNO.
- Basic model; designed for small-sized indoor fires.
- Ineffective extinguishing mechanism.
- Lacks autonomy; manually controlled.

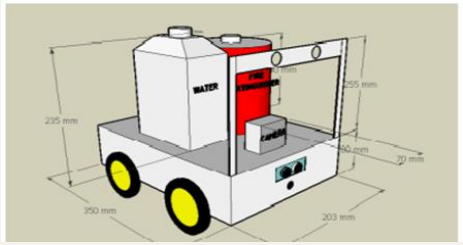


Figure 7: 3D Structure of QRob with Dimensions

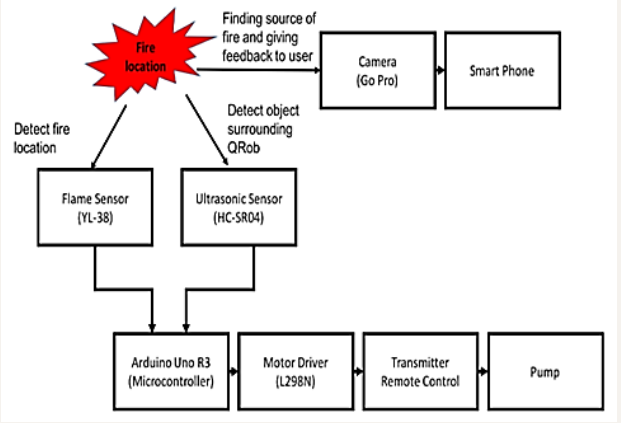


Figure 8: Block Diagram of QRob

Previous Project (2)

Autonomous Fire Fighter Robot Based on Image Processing, Department of Electrical and Electronic Engineering Bangladesh University of Engineering and Technology, Bangladesh, 2019

- A raspberry pi 3 is used for image processing and an Arduino board serves as the controller for all sensors and motors.
- Detects fire using image processing technology only.
- Uses effective spray mechanism to put out medium-sized fires.
- Suitable for indoor/outdoor use; but not on rough terrain.

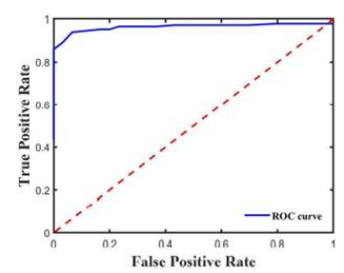


Figure 9: ROC Curve

Figure 10: Fire Extinguisher Robot Model

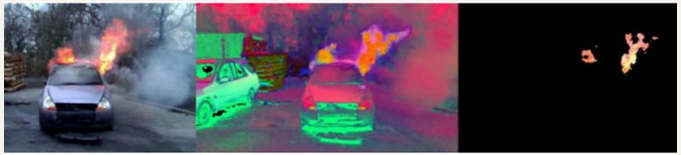


Figure 11: HSV transformed image and fire pixel separated image (image processing)

Previous Project (3)

Fire-fighting robot with vision camera and gas sensors, Department of Computer Science & Engineering, Vels Institute of Science, Technology & Advanced Studies (VISTAS), India, 2018

- Displays video live stream via webcam and WIFI USB adapter.
- Operates on 3 cell lithium polymer battery; 11.1v & 2200mAh.
- Controlled manually using a receiver and a 2.4 GHz remote controller.
- Uses sonar distance sensor, a pyro thermal sensor, and a GSM module to send SMS alerts
- Only suitable for small-size indoor fires.

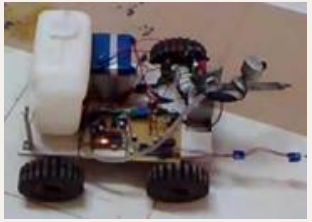


Figure 12: Extinguishing Robot Model

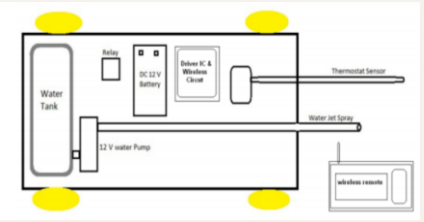


Figure 13: Auto Firefighter Architecture

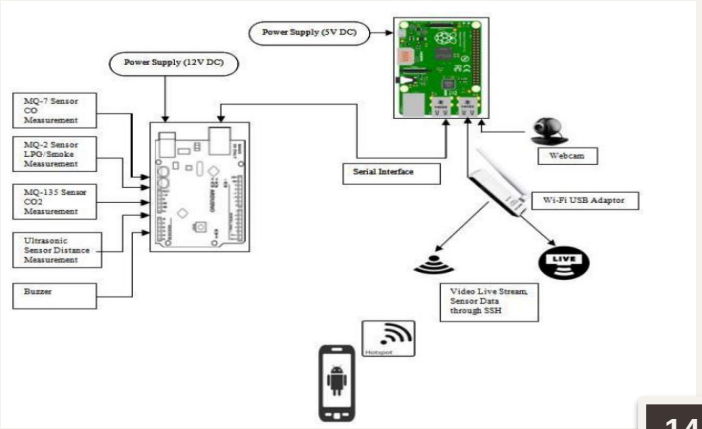


Figure 14: System Overview

Previous Project (4)

Firefighting Remote Exploration Device, Worcester Polytechnic Institute, United States of America, 2019

- The sole function of this robot is to detect and visually record the thermal map of a fireground.
- It utilizes image processing tech with heat, infrared, humidity, gas, and distance sensors to assist firefighters locate fires.
- Powered by Raspberry Pi 3.
- Transmits data to users via Wifi.

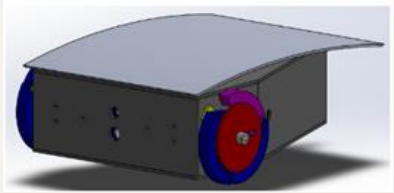


Figure 15: Final Chassis Design

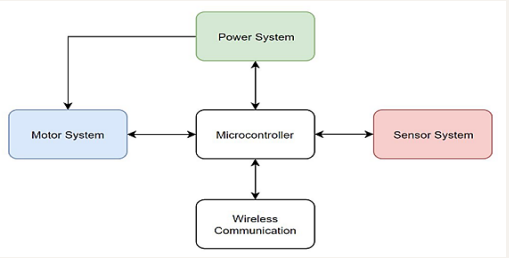


Figure 16: High Level Block Diagram

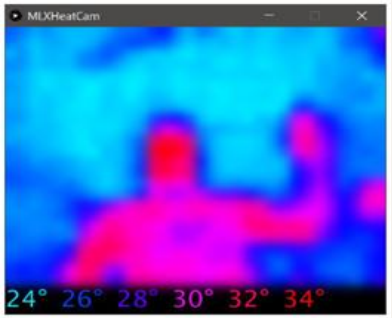


Figure 17: Infrared Array Sensors Readings in Celsius

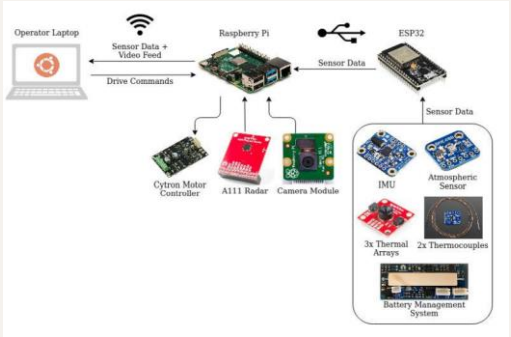


Figure 18: System Communication

Previous Projects Summary

	PROJECT 1	PROJECT 2	PROJECT 3	PROJECT 4	OUR PROJECT
MOTOR	DC Motor	DC Motor	DC Motor	DC Motor	DC Motor
CHASSIS TYPE	Plastic	Plastic	Plastic	Metal	Metal
CONTROL MECHANISM	Autonomous	Autonomous	Manual	Manual	Autonomous/Manual
GSM MODULE	No	No	Yes	No	Yes
IMAGE PROCESSING	No	Yes	No	Yes	Yes
SENSORS	Flame & Ultrasonic	None	Thermal & Distance	Multi	Multi
CAMERA	No	Yes	Yes	Yes	Yes
MICROCONTROLLER	Yes	Yes	Yes	Yes	Yes
MICROPROCESSOR	No	Yes	No	Yes	Yes
SETTING	Indoor Only	Indoor & Outdoor	Indoor	Indoor & outdoor	Indoor & Outdoor

Design subsystem 1: Body/Frame & Hardware Components

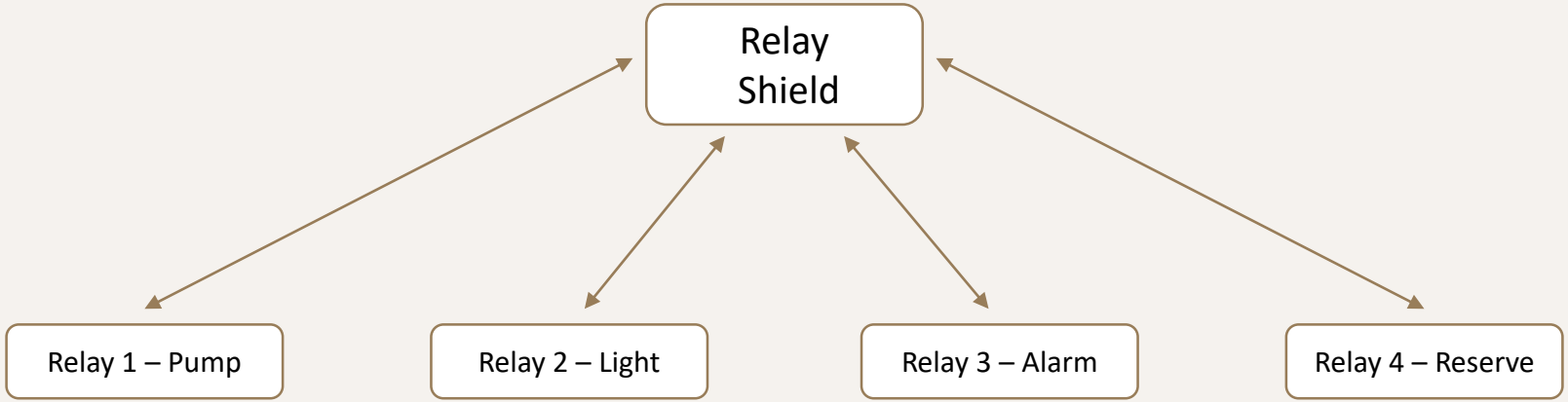


Figure 19: (1.1) Relay Shield

Design subsystem 1: Body/Frame & Hardware Components

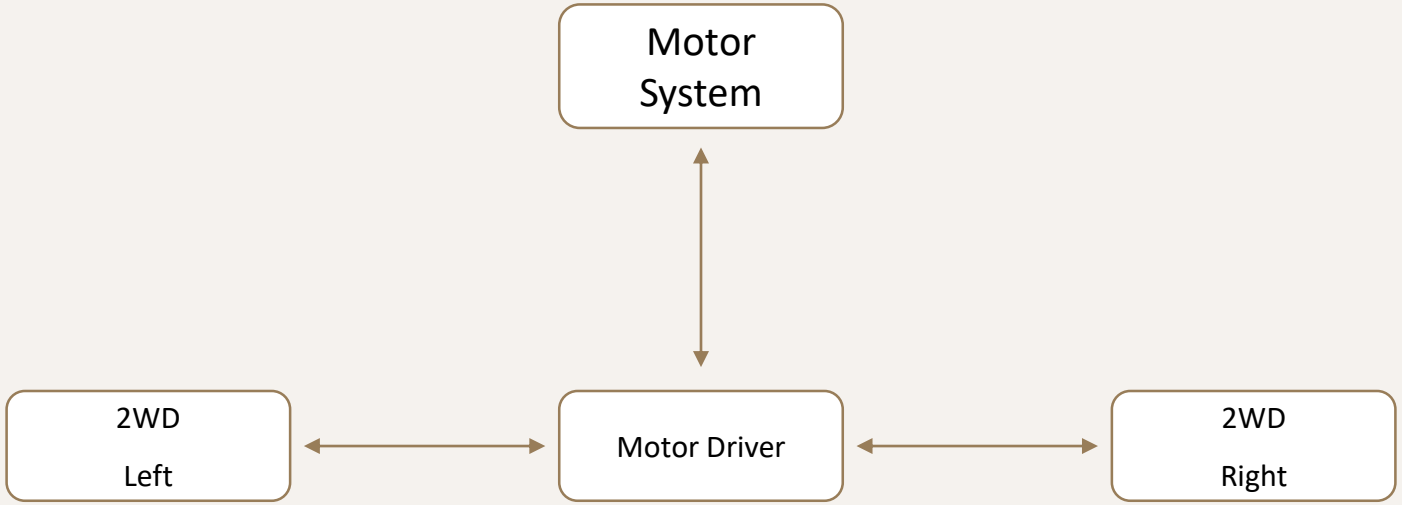


Figure 20: (1.2) Motor System

Design subsystem 2: Electronics and Software

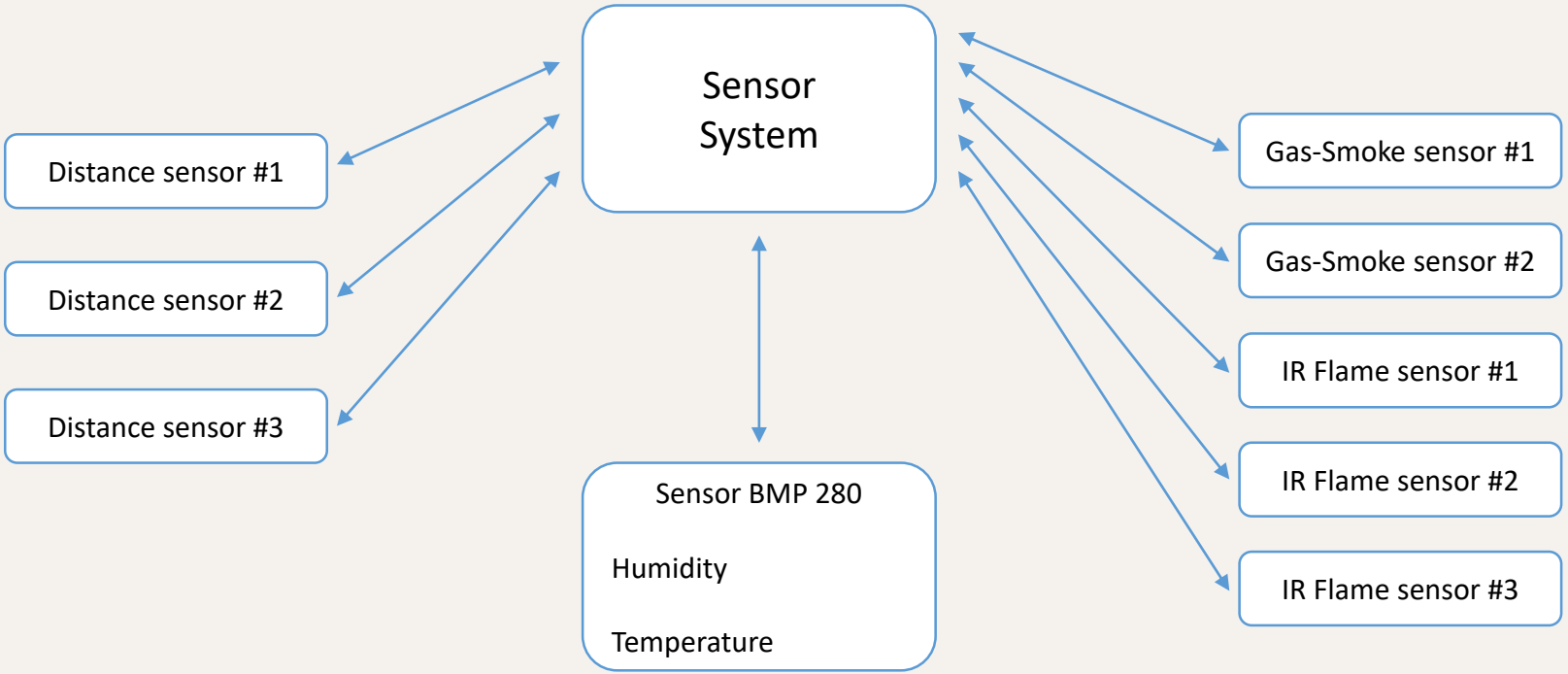


Figure 21: (2.1) Sensor System

Design subsystem 2: Electronics and Software

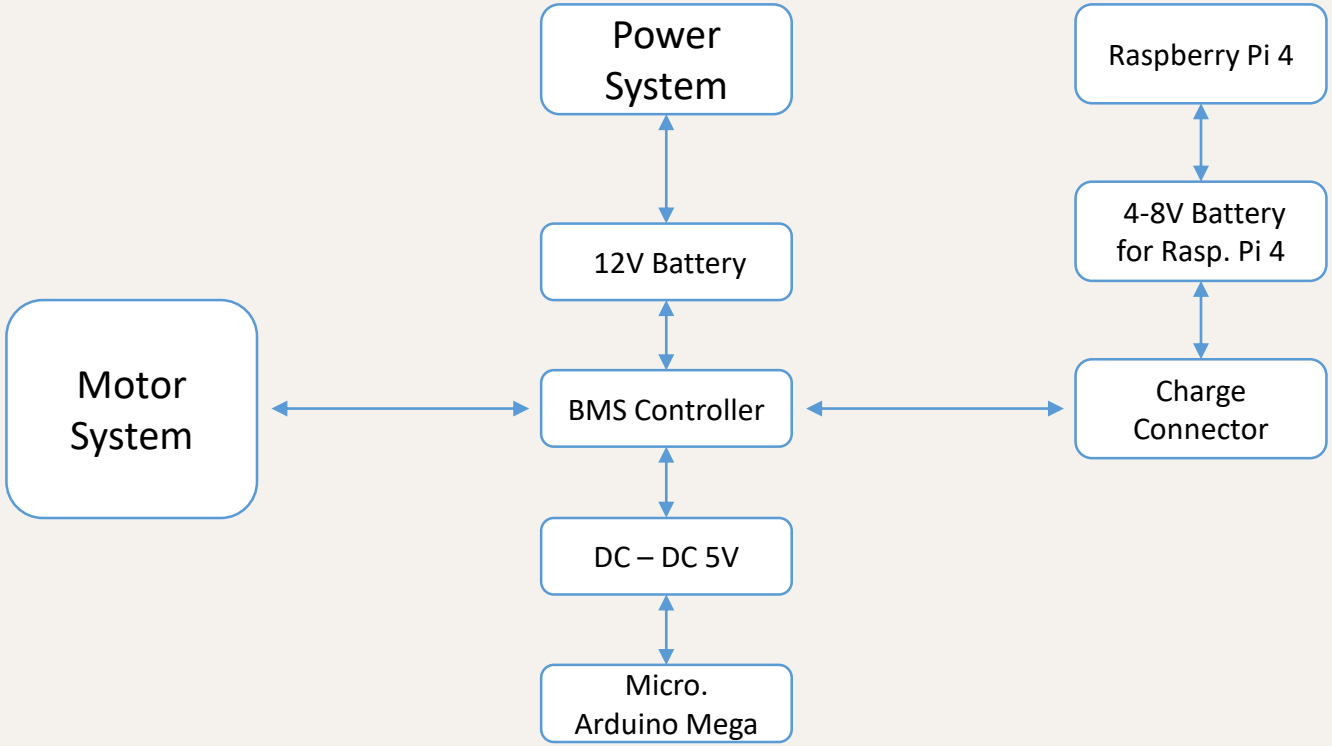


Figure 22: (2.2) Power System

Design subsystem 3: Remote-Control System and Receiver

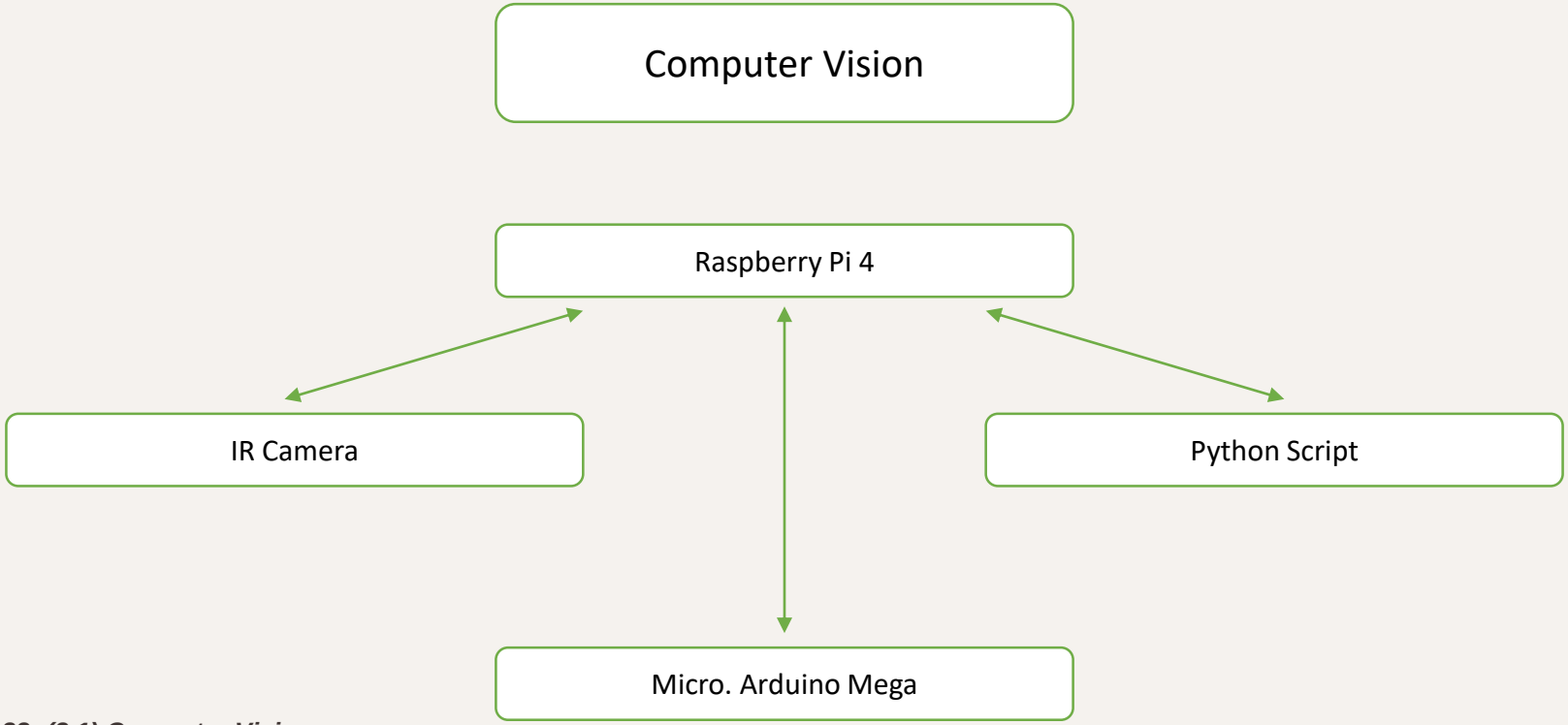


Figure 23: (3.1) Computer Vision

Design subsystem 3: Remote-Control System and Receiver

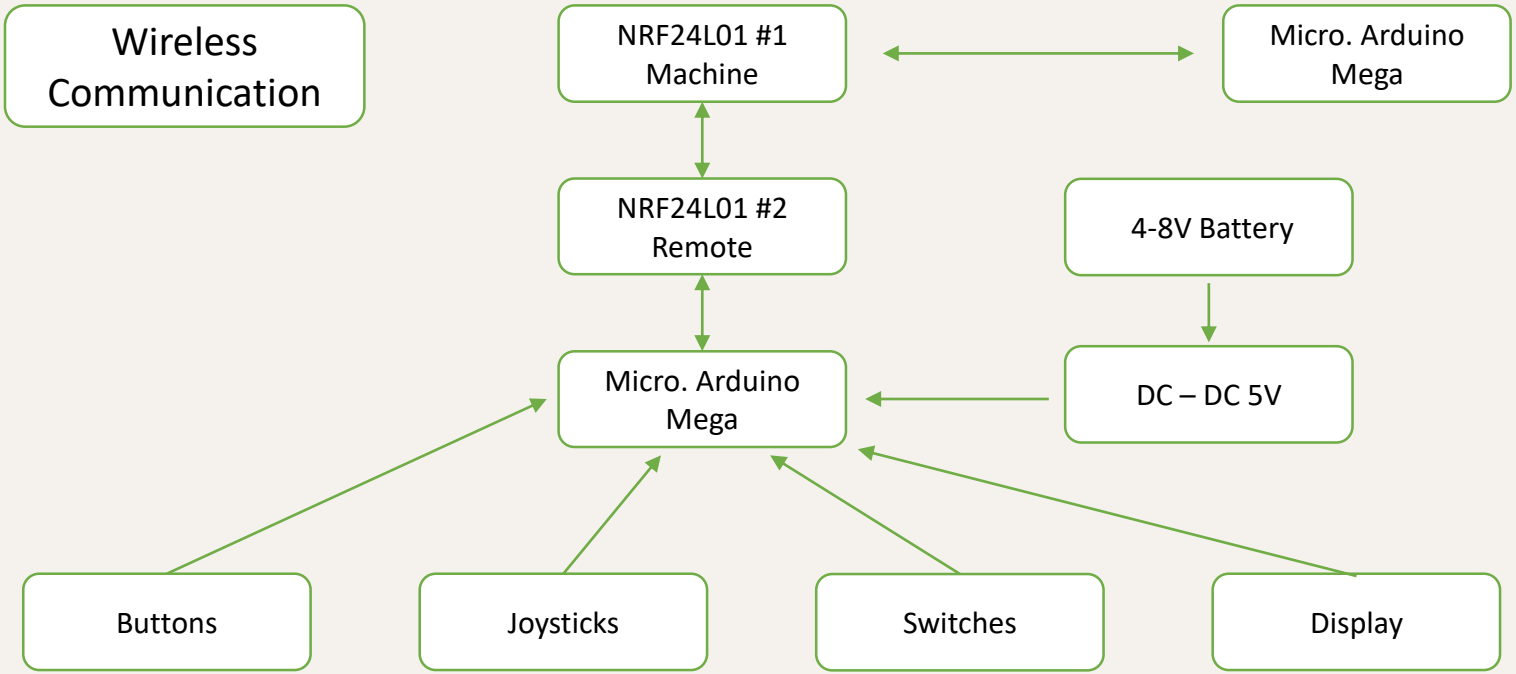


Figure 24: (3.2) Wireless Control

Design subsystem 3: Remote-Control System and Receiver

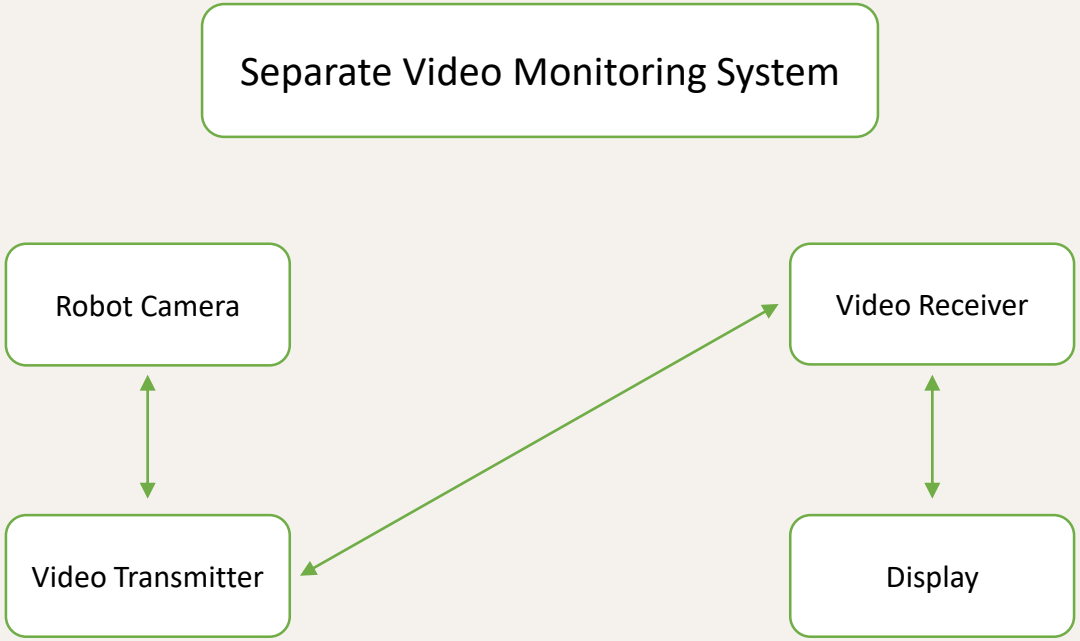


Figure 25: (3.3) Separate Video Monitoring System

Design: Hardware (Chassis Options)

Figure 26: Plastic Chassis Kit

- Small base
- All plastic
- Low voltage
- Flimsy material

Dimensions	Weight	Price
256*150*2mm	28.35g	$27

Figure 27: 4-Part Tank Chassis

- Small base
- Plastic tracks
- Durable material
- Suitable for outdoors/indoors

Dimensions	Weight	Price
393*206*84mm	600g	$141.64

Figure 28: 4-Part Tank Chassis

- Large base
- Plastic tracks
- Suitable size
- Suitable for outdoors/indoors

Dimensions	Weight	Price
720*350*125mm	2000g	$141.64

Figure 29: Full Metal Tank Chassis

- Large base
- Metal tracks & chassis
- Durable material
- Non-flammable
- Suitable for outdoors/indoors

Dimensions	Weight	Price
620* 370 *110mm	2000g	$300

Design: Components (Microcontroller Options)

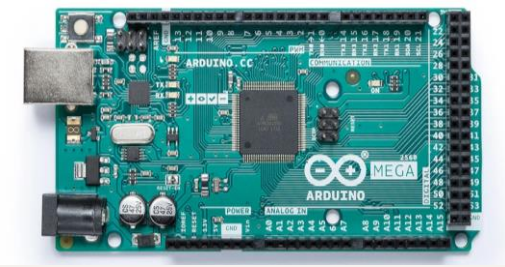


Figure 30: Arduino Mega 2560

- Flash memory is 256kb
- SRAM Space is 8kb
- 16 Analog Pins
- 5V

Figure 31: Arduino Mega UNO

- Flash memory is 32kb
- SRAM is 2kb
- 6 Analog pins
- 5V

Design: Components (Microprocessor Options)

Figure 32: Raspberry Pi 4

- 4GB RAM
- 5V via USB type-C up to 3A
- Native Gigabit Ethernet
- Bluetooth 5.0
- 1.5GHz

Figure 33: Raspberry Pi 3

- 1GB RAM
- 5V via micro USB up to2.5A
- 300 Mbps Giga Ethernet
- Bluetooth 4.2
- 1.4GHz

Design: Components (Camera Options)

Figure 34: Raspberry Pi Camera v2

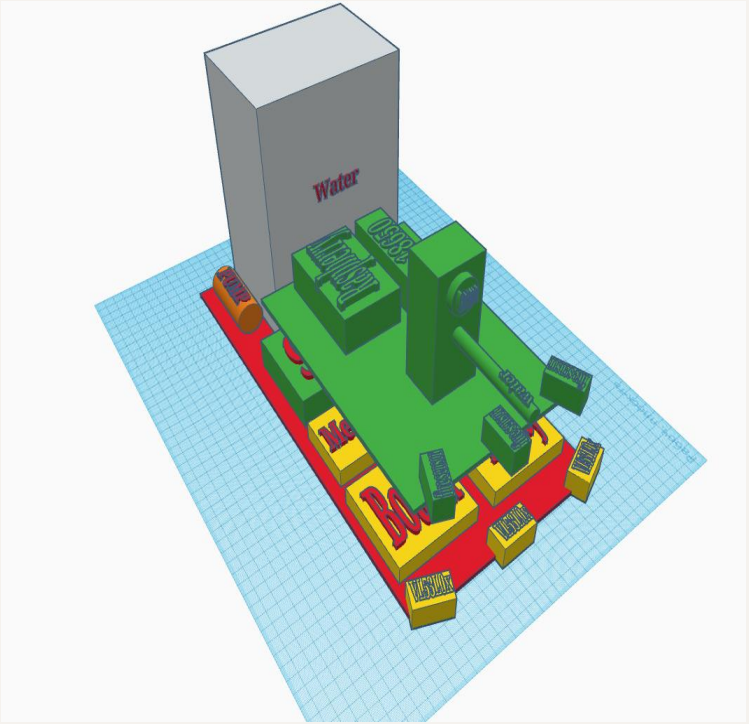
- High frame rate
- High compatibility with microprocessor
- Attaches directly to GPU
- Minimal impact on CPU
- 8 megapixels
- Capable of 1080p30

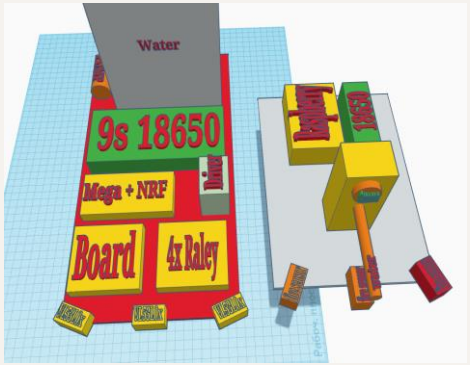
Figure 35: Mini PC Webcam

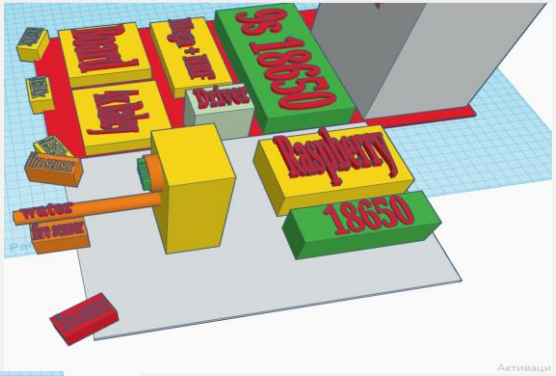
- Low frame rate
- Low compatibility with microprocessor
- Indirect attachment to GPU
- High impact on CPU
- 5 megapixels

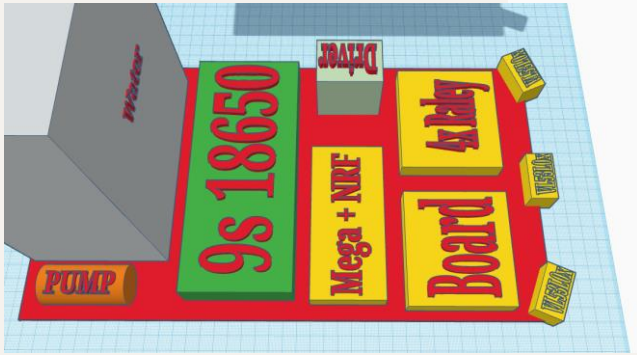
Design progress: Subsystem 1 (Body/Frame & Hardware Components)

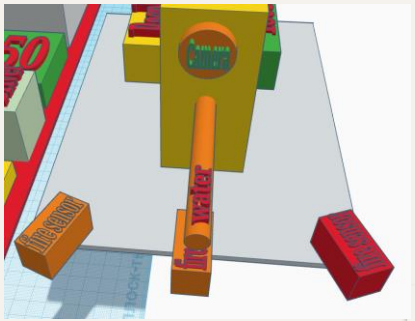
- Components of subsystems will be placed on the chassis in the following manner shown below in the 3-D models.



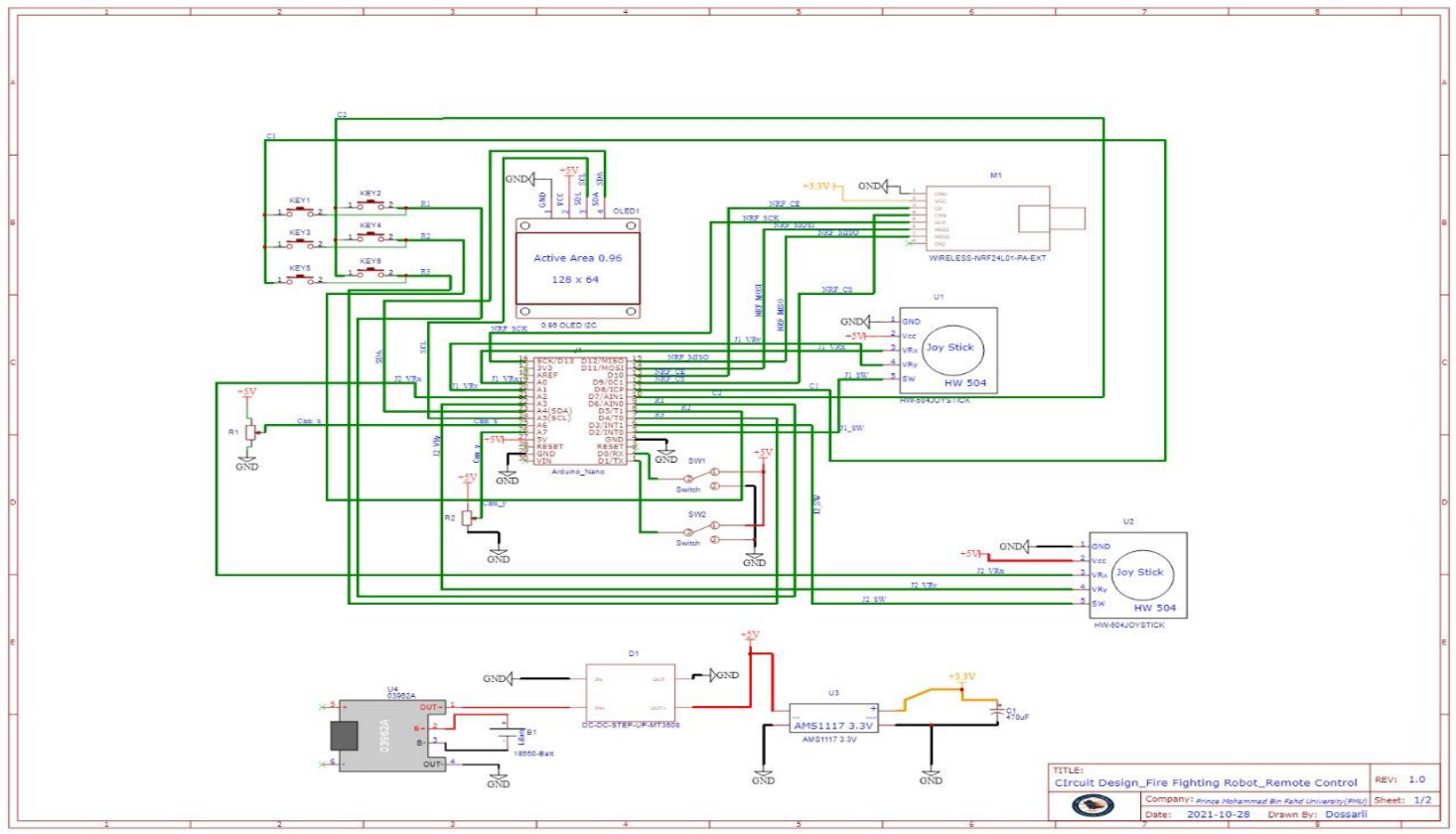






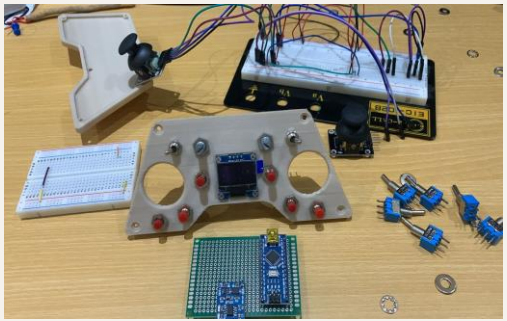


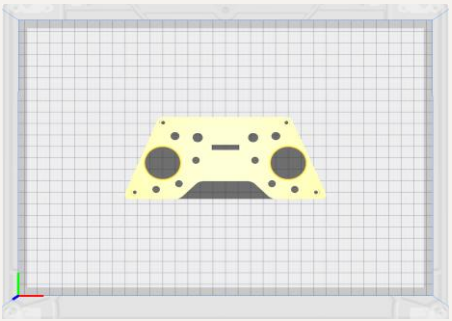
Design progress: Subsystem 3 (Circuit diagram of the remote Cont.)

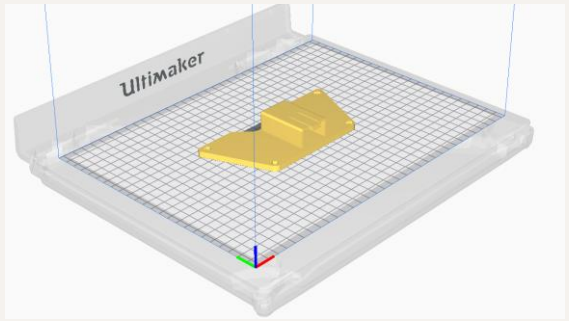


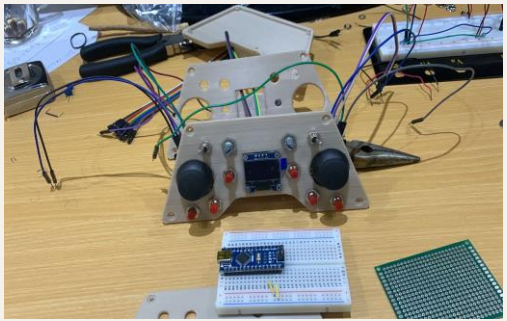
Design progress: Subsystem 3 (Design of 3D printing case)

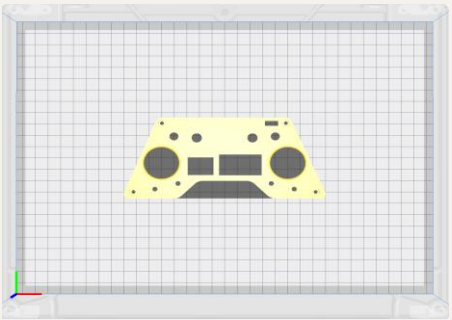
- We took the idea from this website https://howtomechatronics.com/projects/diy-arduino-rc-transmitter/ .
- The design of 3-D models was done using Ultimaker Cura app.





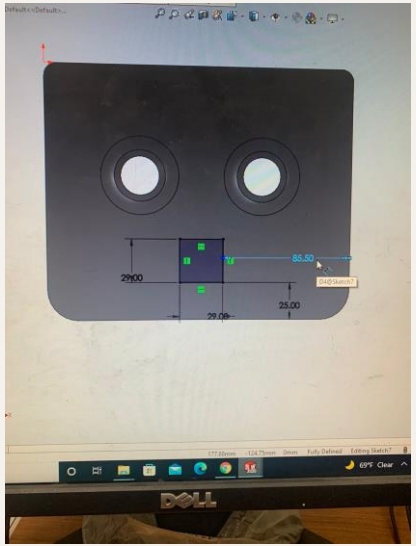


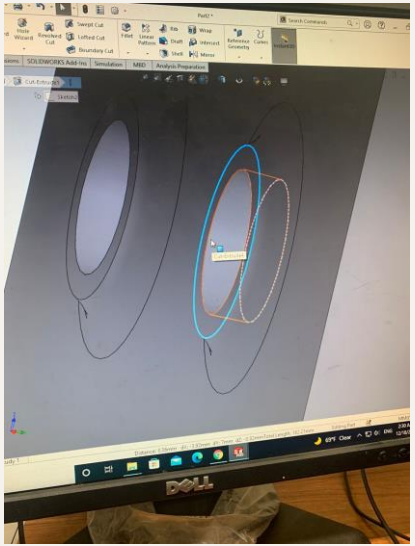


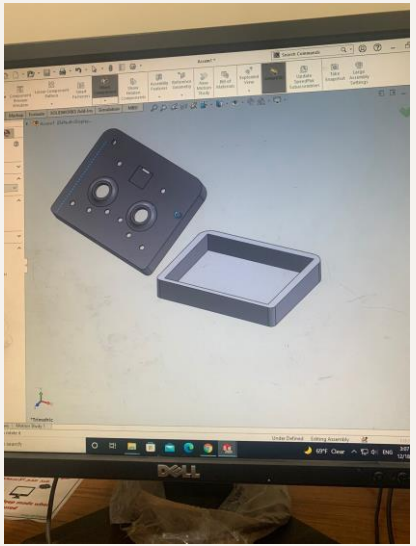


Design progress: Subsystem 3 (Design of 3D printing case)

- We are working on version 2 of the remote case as shown below.







Testing

- Testing will be conducted once component assembly and programming begins.....

Completed & Remaining Work

Subsystem 1

#	Task	(%)
1	Planning & Calculations	100
2	Circuit Design	75
3	Assembly of Body/Frame	0
4	Power Supply System	0
5	Motor System	0
6	Wireless Control System	0
7	Testing Motor & Wireless Control System	0
8	Fire Detection System	0

Subsystem 2

#	Task	(%)
9	Motion Control System	0
10	Testing Fire Detection & Motion Control System	0
11	Alert system & GSM Module	0
12	Assembly of Fire Extinguishing Mechanism	0
13	Testing Alert System, GSM Module, & Extinguishing Mechanism	0

Subsystem 3

#	Task	(%)
14	Microprocessor Programming	0
15	Fire Detection Programming	0
16	PTZ Camera Configuration	0
17	Remote-Control System	100
18	Testing of Programming & RC System	0
19	3-D Printed Case	100
20	Final Test	0

Project Management & Teamwork

Title: Autonomous/Manual Firefighting Robot	Advisor: Dr.Samir El-Nakla & Dr.Sadiq Alhuwaidi	Design II (ASSE III)	Fall 2021
Khalid Al-Bishi (K) 201401705		Project PLAN & Progress	
Saud Al Dossari (S) 201600827		ProgRpt No. 8	
Mohammed Aldayhani (M) 201800363		Plan updated (Date): December 21 2021	
		Instructor: Dr.Sadiq Alhuwaidi	

ACTIVITY	PLAN START	PLAN DURATION	Assigned To	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Write a plan	1	1	ALL	2	2	100%
Literature research	2	2	ALL	3	3	100%
Ordering components	3	2	S	4	7	100%
Literature review	5	2	M	3	4	100%
Design robot architecture	5	2	K	3	7	100%
Design Subsystem 1: Body/Frame & Hardware Components	7	4	K,S			0%
Circuit design of the car	7	3	ALL	8	11	100%
Test Subsystem 1	7	2	M			0%
Prepare midterm presentation and video	7	2	M,K	6	9	80%
Write progress report	8	2	M,S	7	7	100%
Design Subsystem 2: Electronics and Software	9	4	K,S			0%
Test and simulation for Raspberry Pi coding (image processing)	10	3	M			0%
Test and simulation for Arduino coding	10	3	K,S			0%
Calibrate and integrate all sensors to the system	11	2	M,K			0%
Test Subsystem 2	11	2	M,S			0%
Design Subsystem 3: Remote-Control System and Receiver	12	4	M			0%
Circuit design of the remote controller	12	2	K,S	12	14	100%
Test and simulation for Arduino coding (display screen)	12	3	S,M			0%
Test Subsystem 3	12	2	K	14	15	25%
Correct/modify design and errors in system	13	3	M,K			0%
Implement Industrial Design	13	2	ALL			0%
Display data to end-user (live video feed)	14	1	S			0%
Prepare Final Report	14	3	ALL			0%
Prepare Final Presentation	15	2	K,S	15	15	80%
Prepare Project Demo	15	3	ALL			0%
Submit Rpt/PPT/Brochure/Video...etc.	15	2	ALL			0%

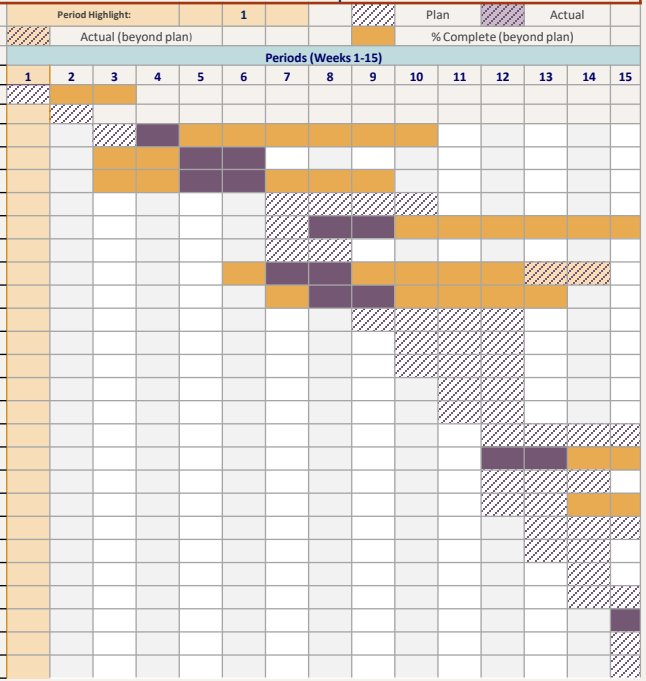


Figure 36: Progress Report

Project Management & Teamwork

➢ Team work task division

#	Task	Mohammed	Khalid	Saud
1	Planning & Calculations	34%	33%	33%
2	Circuit Design			
3	Assembly of Body/Frame	30%	30%	40%
4	Power Supply System	25%	50%	25%
5	Motor System	33%	34%	33%
6	Wireless Control System	40%	30%	30%
7	Testing Motor & Wireless Control System	33%	33%	34%
8	Fire Detection System	33%	33%	34%
9	Motion Control System	35%	35%	30%
10	Testing Fire Detection & Motion Control System	30%	40%	30%
11	Alert system & GSM Module	40%	30%	30%

#	Task	Mohammed	Khalid	Saud
12	Assembly of Fire Extinguishing Mechanism	30%	40%	30%
13	Testing Alert System, GSM Module, & Extinguishing Mechanism	33%	33%	34%
14	Microprocessor Programming	34%	33%	33%
15	Fire Detection Programming	30%	40%	30%
16	PTZ Camera Configuration	25%	25%	50%
17	Remote-Control System	40%	30%	30%
18	Testing of Programming & RC System	30%	40%	30%
19	3-D Printed Case	25%	30%	45%
20	Final Test	33%	34%	33%

Project Management & Teamwork

#	Risk Description	Risk Management	Impact
1	**Shipping Delay**	Chose premium shipping *ONLY* for select items	Quick but pricey delivery for essential parts
2	**Programming with Python**	Thorough research	All team are learning

Covid-19 Situation

- Shipments delay
- Customs issues
- Higher cost of shipping

Impact of Project

- Reduced the number of fire-related deaths
- Limiting firefighters' exposure to fires.
- Save more lives.
- Reduce the cost of fire-related damage.
- Reduce time required for extinguishment.

Figure 37: Firefighter utilizing firefighter robot

New Skills Acquired & Applied

- Literature research
- Brainstorming
- Problem-solving
- AutoCAD Design
- Time management
- 3D Printing
- Programming in Python
- Utilizing OpenCV

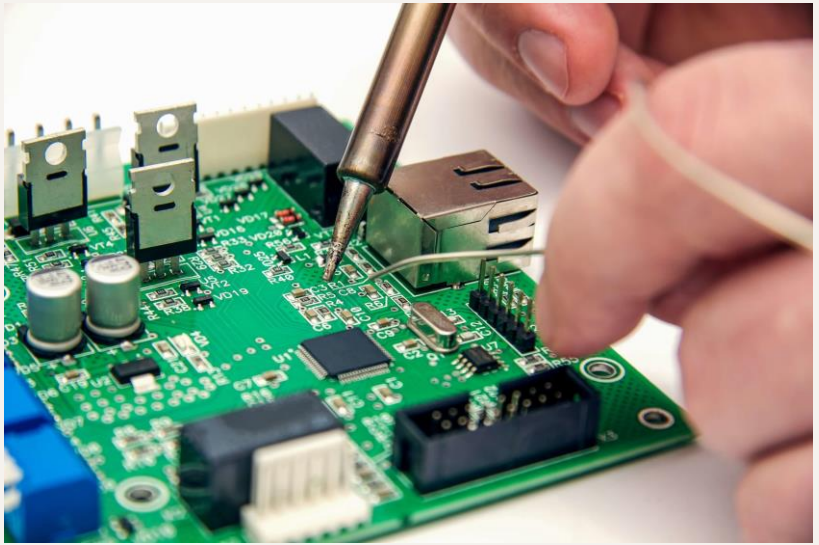


Figure 38: Circuit Board Design

Budget Estimate w/ Shipping (a)

Item	#	Cost ($)	Subtotal ($)	Est. Arrival
Distance sensor VL53L0X	4 pcs	1.6	6.4	3-4 weeks
BMS controller 12v	1 pcs	0.83	0.83	3-4 weeks
Water windshield spray	1 pcs	2.23	2.23	3-4 weeks
PTZ camera Attachment	1 pcs	13.01	13.01	3-4 weeks
Tracked chassis	1 pcs	299.00	299.00	2-3 weeks
Water tank	1 pcs	12.03	12.03	3-4 weeks
Water hose	1 pcs	15.73	15.73	3-4 weeks
Arduino mega 2560	1 pcs	15.80	15.80	1-2 weeks
Driver for 2 dc motors	2 pcs	7.8	15.59	1-2 weeks
Nrf24l01	1 pcs	4.35	4.35	1-2 weeks

Item	#	Cost ($)	Subtotal ($)	Est. Arrival
Dc-Dc for nrf24l01	2 pcs	1.17	2.34	1-2 weeks
Servo motors	3 pcs	4.82	14.46	2-3 weeks
GSM module sim800	1 pcs	2.45	2.45	3-4 weeks
BMP280 module	1 pcs	4.05	4.05	3-4 weeks
Relay shield 4 channel	1 pcs	2.15	2.15	3-4 weeks
Fire sensor	3 pcs		4.80	3-4 weeks
Smoke sensor	1 pcs	0.85	0.85	3-4 weeks
GAS sensor	1 pcs	1.54	1.54	3-4 weeks
joystik (RC)	2 pcs	0.47	0.94	3-4 weeks
Sound buzzer	2 pcs	0.54	1.08	3-4 weeks

Budget Estimate w/ Shipping (b)

Item	#	Cost ($)	Subtotal ($)	Est. Arrival
Potentiometer 10 k	2 pcs	1.37	2.74	2-3 weeks
Buttons (RC)	10 pcs	0.08	0.82	2-3 weeks
Switch for (RC)	2 pcs	2.18	4.36	2-3 weeks
Dc-Dc for arduino	1 pcs	8.39	8.39	2-3 weeks
battery 18650	9 pcs	3.42	30.79	2-3 weeks
18650 x3 Battery Holder	3 pcs	1.02	3.06	2-3 weeks
Raspberry pi 4	1 pcs	125.6	125.60	1-2 weeks
Raspberry pi 4 IR CAM	1 pcs	13.97	13.97	2-3 weeks
LEDS	1 pcs	0.55	0.55	2-3 weeks
PUMP	1 pcs	2.80	2.80	2-3 weeks

Overall Cost Estimates

Factor	Cost (SR)	Cost ($)
Items Subtotal	$740.96	2,778.60SR
Shipping Fees	$797.50	2,990.63SR
TOTAL	$1538.46	5769.23SR

References

- https://ieeexplore.ieee.org/document/8971157
- https://www.researchgate.net/publication/325117402_Fire_fighting_robot_with_vision_camera_and_gas_sensors
- https://web.wpi.edu/Pubs/E-project/Available/E-project-042419-233823/unrestricted/Firefighting_Remote_Exploration_Device_.pdf
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Thank you for listening