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Prototype of a Compact Assistant Surveillance Robot for Search and Rescue Operations

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ABSTRACT

This paper presents a prototype of a compact, affordable mobile rescue robot that can be used to gather real-time information on difficult to reach locations during rescue operations. The prototype uses Arduino Mega 2560 as the main microcontroller, FPV camera for real-time video streaming mounted on a tilt assembly. Continuous track differential wheels were utilized for all-terrain navigation. The robot can be used in simple rescue operations such as for detecting, locating injured and characterizing obstacles in collapsed structures.

Key words: Rescue operations, continuous track differential wheels, all terrain navigation, obstacle avoidance**.**

1. INTRODUCTION

The Philippines is located on the Pacific Ring of Fire, which is a path that spans along the Pacific Ocean where majority of the Earth's volcanic activity and earthquakes take place. Its location and the tropical climate make it prone to disasters like earthquakes and typhoons. These disasters are hard to predict and could potentially cause destruction and casualties. This makes the Philippines one of the most vulnerable countries in the world.

Poorly built and outdated infrastructures increase the chances of urban catastrophes. Once natural disasters hit, there are numerous disasters that would follow it. A recent example is when a 6.5 magnitude earthquake stuck Davao City, Philippines, last October 2019. The quake resulted to numerous people dead, missing, and injured, on top of that, over 2,000 houses and buildings have been damaged. Aftermaths like these will require Urban Search and Rescue, USAR units to be deployed to look for victims that are possibly trapped under rumbles and ruins of damaged buildings. Search and surveillance is a dangerous operation and greatly involves risk for both the rescuers and victims. The risks that rescuers would go through in such operation can be minimized and could possibly made faster through the use of mobile surveillance robot.

The primary objective of this study is to develop a prototype robot that can be used for surveillance during search and rescue operations. A small scale tank robot chassis with general drive motors was utilized as the base machine for the CASROS robot as shown in Figures 1 and 2. Arduino Mega 2560 was used as the main microcontroller which sends commands to the L298N motor driver through a handheld remote controller. An ultrasonic sensor was installed to provide distance measurement of the obstacles.

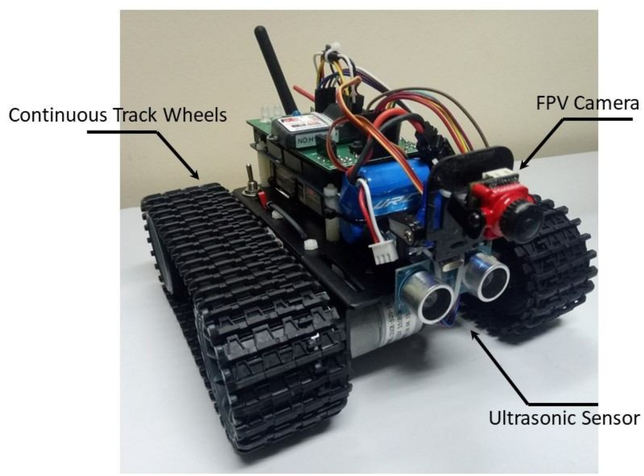

Figure 1: The CARSOS Robot

2. MATERIALS AND METHODS

The CASROS robot was developed based on the existing robot design used for search and rescue operations. The researchers came up with an affordable prototype considering various factors such as field test area, geometric limitations, parts and material availability, and assembly.

2.1 Robot Design Specifications

The field test area and geometric limitations were considered because of different terrains that the robot will encounter. The robot is expected to go through structural collapses such as rubble, sand, and concrete, hence a high torque, geared DC motor was considered.

Tracked wheels were selected because it can offer good traction and maneuverability in various terrain such as in uneven surfaces with rocks and debris. The CASROS robot was designed to be small and compact to allow it to navigate through narrow spaces. A First Person View, FPV camera is the primary component installed in the robot. Its purpose is to stream real-time video recordings of the area. This information serves as a valuable resource to the rescuers. The live updates recorded by the FPV are transmitted to a laptop computer via a receiver. Servo motors were used to vertically tilt the FPV.

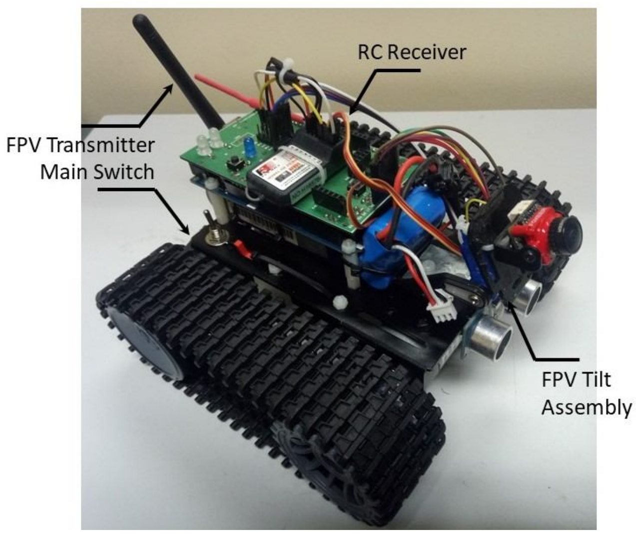

Figure 2: Microcontroller Board and Sensors

The overall construction of the CASROS robot was designed to be economical, considering that during search and surveillance operations the chances of damaging the components or even losing the whole robot from accidental collapse of the structure would likely to occur. These factors were also considered without sacrificing the basic functions of the robot. Table 1 shows the overall design specifications of the CASROS robot.

2.2 System Architecture

The entire robot system was powered by a 9V supplied by a LiPo battery pack. Two channels from the transmitter send signals that navigate the robot in different directions and the additional two channels were allotted for the pan and tilt view for the FPV Camera. The pan and tilt platform was mounted in the chassis and has a range of 90 degrees in the horizontal and vertical axis. The overall system architecture of the CASROS robot is shown in Figure 3.

Table 1: OVERALL ROBOT KEY SPECIFICATIONS

Overall Weight	0.80 kgs
Length – Width – Height, mm	193-163-100
Operating Voltage	9-12V
Max. Speed	0.5-0.7 m/s
Turning Radius	9.6 mm
Max. Load Carrying Capacity	3 kgs
Battery Life (Continuous Operation)	1.5 hrs
Max. Incline (no load)	45 deg
Max. Video Transmission Distance (Outdoor)	200-500m
Max. Radio Transmission Distance (Outdoor)	1.6km

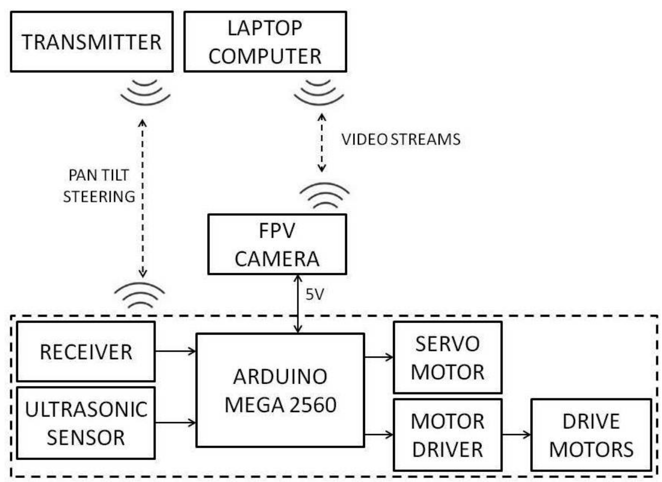

Figure 3: System Architecture

The HC-SR04 ultrasonic sensor provides distance measurement to the robot and was used for obstacle avoidance behavior. An ultrasonic sensor works by bouncing a sound wave at high-frequency to an object and measures the amount of time it takes for the sound to return to the sensor.
The L298N Motor Controller was used to drive DC motors through its H-bridge configuration. "H-bridge" is similar to letter H and simply changes the direction of rotation of the motor by shifting its polarity. The L298N Motor Controller has two H-bridge channels that can be used to control two DC motors. Table 2 shows the lists of sensors and actuators interface used for the CASROS robot.

Table 2: SENSORS AND ACTUATOR INTERFACE

Sensors and Actuators	Details	Connection
FPV Camera	5.8G 40CH Mini First-Person View Camera (FPV), 5V and 250mA with a 600 TVL resolution.	Independent
FPV Reciever	5.8G, 150 CH FPV receiver connected to Open Broadcaster Software to stream real time video footages	Independent
UltraSonic Sensor	Range 1-180cm, outputs a pulse proportional to distance	Pulse Width
Transmitter	2.4GHz, 6CH Mode 2	Remote Controller
Receiver	2.4GHz, R6-B	Digital PWM
Tilt Servo motors	Controls FPV Camera view angle	Digital PWM
Motor Driver	L298, 6-12V with 2A operating current	Digital PWM
Drive motor	3-7 voltage, general geared motors 130	Digital PWM

2.3 Differential Steering System

The CASROS robot employs a differential steering system that has two independent DC motors that also serve as the power drive as illustrated in Figure 4. Steering left is achieved by simply stopping the rotation of the left motor and letting the right motor rotate continuously. This is also the same for the right steering. This can be mathematically illustrated by the following:

$$V_R = \omega\left(R + \frac{1}{2}L\right) \quad (1)$$

$$V_L = \omega\left(R - \frac{1}{2}L\right) \quad (2)$$

At any instance, we can determine ω and R:

$$\omega = \frac{V_R - V_L}{L} \quad (3)$$

$$R = \frac{1}{2}\left(\frac{V_L - V_R}{V_R - V_L}\right) \quad (4)$$

Where:

V_R and V_L = right and left wheel linear velocities, in cm/s

Linear velocities of the wheels can be calculated from:

$$V = \omega r \quad (5)$$

Where:

r = is the wheel radius.

ω = angular or rotational speed of the wheels, rad/s

L = distance between the centers of the two wheels, in cm

R = radius of the steering circle or turning radius, in cm

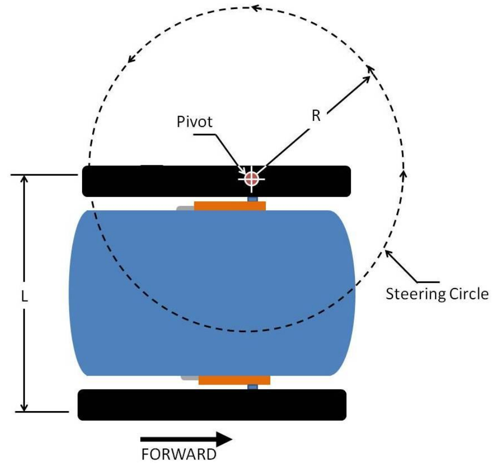

Figure 4: Differential Steering System

The following observations can be made from the equations illustrated above:

- If $V_L = V_R$, then forward motion in a straight line is achieved.
- If $V_L = - V_R$, then R = 0, then the rotation of the robot will just rotate in its place.
- If $V_L = 0$, then the center of rotation is in the left wheel and the robot will steer in left direction. Same is true during $V_R = 0$.

3. RESULTS AND DISCUSSION

The CASROS robot navigation capabilities were also tested in different conditions. It was observed that the robot was able to maintain its overall stability while continuously streaming real-time video updates to a laptop computer. Uultrasonic sensor sends signal to stop the robot when an obstacle is detected 20 centimeters away. This allows the operator to look for other paths to navigate.

An imaginary search and rescue operation map was used to test the performance of the CASROS robot. An operator was asked to operate the robot by driving it from behind and following the robot from the initial position going to the goal position using a Remote Controller. The map of the imaginary scenario is shown in Figure 6 and the distance between points is shown in Table 3.

Figure 5: Actual Test Run

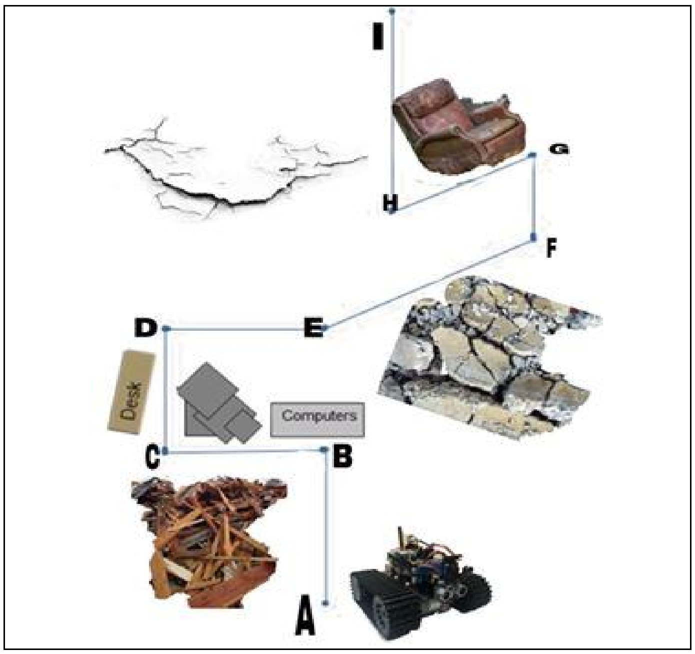

Figure 6: Imaginary Map of Search and Rescue Operation

After reaching the goal, the operator was asked to stay in the initial position and once again to drive the robot, but using the FPV camera as a tool for navigation. The real-time video recordings streaming from the laptop computer was used to monitor the track. The time difference between manual RC navigation and FPV guided navigation is illustrated in a graphical form in Figure 7.

The graph compares the time difference between Manual RC operated navigation and FPV camera guided navigation. It can be observed that operating the robot using Manual RC provides a faster completion of the map, this is due to a better visibility of the operator with respect to the track. On the other hand, FPV guided method limits the view of the operator. A robot should be familiar with a given map to navigate effectively.

Table 3: IMAGINARY MAP DISTANCES BETWEEN POINTS

Point	Distance (m)	Average Time (sec) Manual RC	Average Time (sec) FPV Guided
A-B	3.5	6.2	6.7
B-C	2.0	6.5	5.8
C-D	2.0	6.8	8.3
D-E	2.0	6.7	11.2
E-F	3.0	6.3	7.2
F-G	2.5	7.8	8.3
G-H	2.6	6.5	7.5
H-I	5.5	10.5	14.3
Total	**19.6 m**	**57.3 sec**	**69.3 sec**

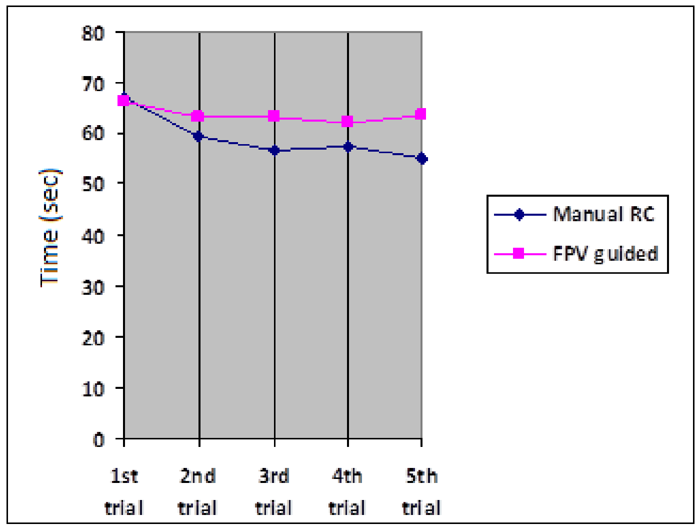

Figure 7: Imaginary Map of Search and Rescue Operation

3.1 Project Consultation with Rescue Volunteers

The second phase of the study involves presenting the CASROS robot for consultation to different agencies involved in risk reduction management. RAHA Volunteers Fire Department, Sampaloc, Manila was selected as primary respondent. Some comments were focused on the FPV Camera as a valuable component of the CASROS robot. It was also pointed out that with its compact design, it would be capable to enter difficult to reach areas during operations.

Figure 8: CASROS project presentation and consultation with RAHA Volunteers Fire Department, Sampaloc Manila, Philippines

4. CONCLUSION

The authors were successful in developing a prototype of a compact and affordable surveillance robot for search and rescue operations. The current functions of the robot include remote control navigation and real-time video streaming were acceptable for basic search and rescue operations. Future works will involve the use of long range transmitter and receiver of frequency of 10MHz – 15 GHz for the camera and remote control system to reach a longer range. Larger traction wheels will also be considered to allow the robot to overcome random obstacles during navigation. Lastly, incorporating water and fire resistant enclosure will make the robot more adaptable in different conditions.

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