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Remote surveillance of enclosed and open architectures using unmanned vehicle with advanced security

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ABSTRACT

Monitoring behavior, numerous actions, or any such information is considered as surveillance and is done for information gathering, influencing, managing, or directing purposes. Citizens employ surveillance to safeguard their communities. Governments do this for the purposes of intelligence collection, including espionage, crime prevention, the defense of a method, a person, a group, or an item; or the investigation of criminal activity. Using an internet of things (IoT) rover, the area will be secured with better secrecy and efficiency instead of humans, will provide an additional safety step. In this paper, there is a discussion about an IoT rover for remote surveillance based around a Raspberry Pi microprocessor which will be able to monitor a closed/open space. This rover will allow safer survey operations and would help to reduce the risks involved with it.

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1. INTRODUCTION

A rover is a movable vehicle having 4 or more wheels and can be used for many operations and this project is an radio controlled (RC) rover that is based upon robotics and automation and has many sensors that are used to sense various parameters such as temperature, and atmospheric pressure. The said rover will consist of various sensors such as humidity and temperature, light, distance, and visual sensors such as camera. These will help in identifying the potential threats in the area that is being surveyed, will provide more security and help in having a more secure environment. The rover can be used for both indoor and outdoor applications. On comparison with the existing work studied, some of the systems didn't have remote monitoring [1], some didn't use rocker bogie mechanism [2], and some had noisy data from sensors making them less efficient [3]. This rover stands unique in such terms and uses a NGRok server [4] to remote access the Raspberry Pi.

An important development in the development of global systems is the appearance of security robots. Large institutions' security coverage can be significantly enhanced by autonomous mobile robots created for outdoor use. Rovers can patrol a facility's grounds continuously. Rovers do not get tired or need to take breaks like people do. They are not bothered by the sweltering sun or the freezing nights [5]. The highest level of security can be provided by security robots for a reasonable price that is often significantly less than the salaries of hired employees.

Also, homeowners can use their robot's skills to check out regions of questionable behaviour while inside their homes or remotely from security stations using broadband internet networks. Homeowners may observe what is happening without facing the risk of bumping into any intruders, which provides an added safety bonus [6]. The use of outdoor security sensors may be challenged by potential false alarms brought on by fallen branches, wild animal movements, and changes in weather. Due to frequent false alarms from an outdoor security system, using them at locations where there are no security officers nearby frequently necessitates regular security patrols [7]. The amount of false alarms that security patrols examine can be considerably decreased using a rover.

2. RESEARCH METHOD

For ease of understanding, this section has been divided into a number of sections. The parts include the building blocks for the model, its block diagram, the ability to enable internet of things (IoT) for the rover, and its engine design. Both the hardware and the software components will be mentioned in the section on the components used.

2.1. Mechanical parts

2.1.1. Motor and motor controller

Six motors total three on each side make up the rover. A 2,000 W DC pulse-width modulation (PWM) motor controller is used to regulate each motor. Raspberry Pi provides direct input to the motor controller [8]. The motor controller is in charge of managing the speed and direction of the motors. By turning off the motors on one side of the rover, the direction of the rover may be changed.

2.1.2. Chassis

The rover's chassis is built of waterproof acrylic material [9], allowing it to move over wet and rainy terrain. The chassis was first developed via computer aided design (CAD) and then parts were 3D printed. Measurements were made accurately to ensure proper symmetry. To make room for the rocker bogie mechanism, the rover's legs were cut in half. Screws have been used to connect various components.

2.1.3. Raspberry Pi

The Raspberry Pi is responsible for controlling our motors via the motor controller by allowing the user to give inputs on where to steer the motor. The Raspberry Pi is also in charge of allowing IoT servers [10] since it employs NGrok, an open-source programme that establishes a sort of tunnel between the Raspberry Pi and the user's device, enabling users to control and programme the Pi from various locations over a WiFi network. The Raspberry Pi is also used for data extraction and logging. The framework of the rover is illustrated in Figure 1.

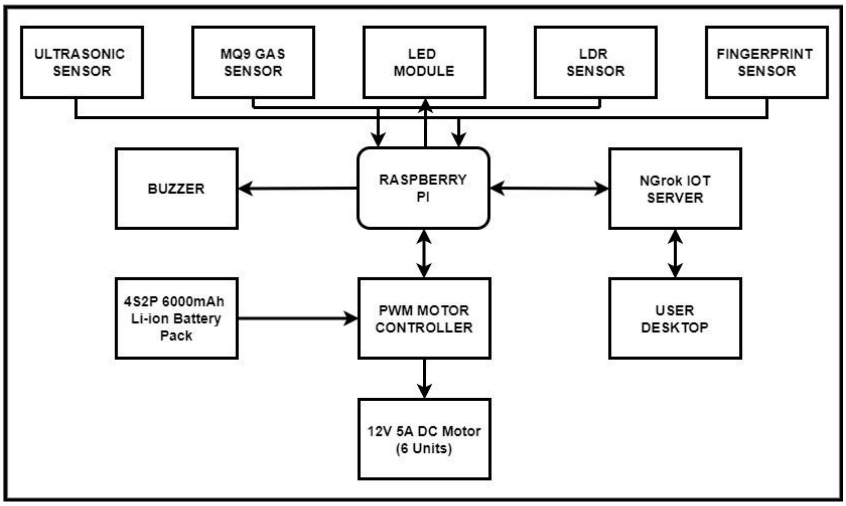

Figure 1. Framework of rover

2.1.4. Camera

A 1/3″ CMOS 1500TVL Tiny FPV camera 2.1 mm Lens PAL/NTSC with OSD has been used to give the user visual input [11]. This can be seen on a phone or laptop and operates via an antenna [12]. The maximum tested range for the current antenna varies between 1-2 km, its range can be further increased by using a higher range antenna.

2.1.5. Sensors

Processing data is necessary for any archaeological survey since it helps determine the age of the structures, the flora and fauna there, and whether or not the area is packed with gases that could be dangerous to the people conducting the survey. As a result, important atmospheric factors like temperature, humidity, gases, light, and distance [13] have been taken into account. The rover includes a variety of sensors, including MQ9 gas sensor, ultrasonic sensor, ambient light sensor, fingerprint sensor, LED module and buzzer.

2.1.6. MQ9 gas sensor

Investigating gases in the environment will be an important factor. The MQ9 gas sensor used can detect various gases such as carbon monoxide gas (CO), liquefied petroleum gas (LPG), and methane [14], [15]. This sensor will detect all the gases, as they can be risky in a closed environment and can possess a threat to life.

2.1.7. Ultrasonic sensor

This sensor is used to detect the distance of rover from the object placed in front of it. A continuous stream of distance data shall be sent from the rover to the user. Thus, the user can navigate the rover safely without causing it any harm.

2.1.8. Ambient light sensor

As the name suggests, the ambient light sensor will help in detecting the amount light present in surroundings. This will thus help in judgement of whether the place is dimly lit or brightly lit in case of indoor conditions [16], [17]. In case of lowly lit surroundings, an light-emitting diode (LED) module shall be switched on to provide visibility for the rover to move.

2.1.9. Fingerprint sensor

This component has been used to provide an additional layer of security to access the rover [18]–[20]. If the user fails to overcome this stage, then he/she has to wait for 30 mins before trying again. After 3 failed attempts, an alert is sent to the owner via email/message.

2.1.10. LED module and buzzer

In the event of theft, these elements have been employed to notify the owner and nearby neighbors. The user can use the computer to trigger the buzzer and alert the neighbors to potential intruders, adding an extra layer of security. A flashing LED module will help to detect the rover in a low-lit environment and can also provide a steady light for the user to see in dark areas via the rover.

2.2. Algorithm

The project's code is entirely written in Python. To access and use the Raspberry Pi's GPIO pins, libraries like RPi.GPIO have been used. With sensors like the DHT11 and MQ9 gas sensor, specific sensor-based libraries have been used. GPIO pins have been utilised to send signals high or low to the motor controllers in order to drive the motors. As the method for sensors and motors has comparable characteristics, they are depicted in a single flowchart in Figure 2.

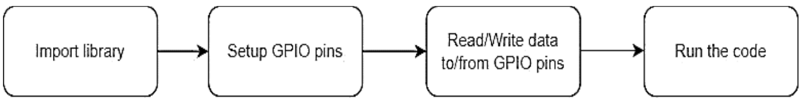

Figure 2. Logic flowchart

2.3. Powertrain design

The motor and battery pack calculations that follow will attempt to support the battery pack configuration [21] based on the motor power requirements. Factors mentioned will help us understand the power requirement. The values from the motor's datasheet are shown in Table 1. The datasheet above indicates clearly that the motor requires at least 11.4 V and 0.4 A to function. To attain high torque and the motor's maximum output power, a current requirement of 4 A is required. Six motors will be used in tandem by the rover, requiring a total of 24 A and 12 V. To be able to meet the current and voltage needs, eight 3.7 V 6,000 mAh Li-ion batteries would be used in total. 8 cells must be arranged in a 4 s2p configuration, or 4 in series and 2 in parallel.

Given that each cell has a 3.7 V output and a 6,000 mAh capacity, this combination was chosen because, when four of those cells are linked in series, it can provide 14.8 V and 6 A of current for an hour. When two stacks of 4 cells are connected in parallel, the result is 14.8 V and 12 A overall. If the cells are discharged at a rate of 2C, there would be a current supply of 24 A, which would be enough to run the motor.

A few scenarios have been considered, such as motor stop-start situations, the sudden requirement for high torque and current to climb a bump, and a 90% battery pack efficiency. The rover's typical operating time, taking all of these factors into account, is 45 minutes. If the motors are driven at their maximum torque, the runtime is shortened to 20 to 25 minutes. The normal rover speed would be 10 to 15 metres per second.

Table 1. Motor datasheet values

Specifications	Voltage (V)	Current (A)	Input power (W)	Torque (mN.m)	Speed (rpm)	Output power	Efficiency (%)
No load	11.8	0.438	5.745	0.024	93.7	0.235	4.5
Max efficiency point	11.51	2.734	31.48	1.736	79.2	14.4	45.7
Max output power point	11.4	4.134	47.32	2.767	71	20.56	43.6
Max torque point	11.4	4.134	47.32	2.767	71	20.56	43.6
End point	11.4	4.134	47.32	2.767	71	20.56	43.6

2.4. Internet of things enabling

As was previously discussed, this project uses an IoT server to allow the control of the rover from anywhere in the world. The platform called Ngrok is used to accomplish this. With Ngrok, a secure tunnel secure shell (SSH) tunnel [22] between the Raspberry Pi and a laptop or computer can be established. Through Ngrok, an IP address is created. The VNC viewer loads the desktop of the Raspberry Pi when this IP address is supplied. As a result, the Raspberry Pi can be controlled via the internet without an HDMI cable, monitor, or keyboard (headless setup). Figure 3 displays the Pi OS running through VNC on a Windows desktop.

Figure 3. Pi desktop on VNC

2.5. Prototype

Proteus software was used to test the prototype. The rover's design included mounting the abovementioned sensors in various places. In order to give the Raspberry Pi a constant internet connection, a mobile hotspot in the form of data card was installed. The rover's body was built of acrylic because it was a test model. The rover can move continuously on many types of floors thanks to the rocker bogie mechanism [23], [24]. The rover prototype is shown in Figures 4 and 5. The final design of the rover has been a slight modification of an already existing design [25].

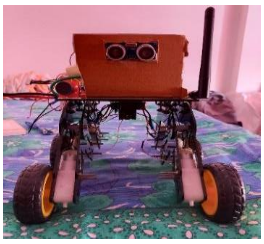

Figure 4. Front view of rover

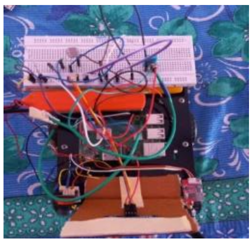

Figure 5. Top view of rover

3. RESULTS AND DISCUSSION

The project's results and outcomes will be shown in the next part in the form of images and output values. To begin with, the motors of the rover was being successfully controlled using the Raspberry Pi. The direction of the rover was being controlled by turning one side of the motors on while leaving the other one off. The CMOS camera's output provided good enough images so the user could get a sense of the location. The rover can only move along the ground; it cannot fly. A CMOS camera snapshot is seen in Figure 6. About the sensor section, DHT11, LDR, ultrasonic, and gas sensors demonstrated successful results. Yet, there were a few value peaks during transmission. In the following Figures 7 and 8, the sensor output values are displayed.

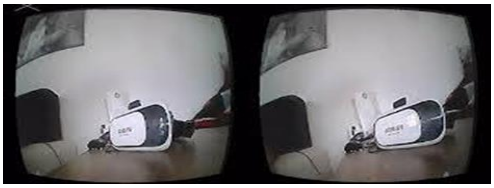

Figure 6. CMOS camera output

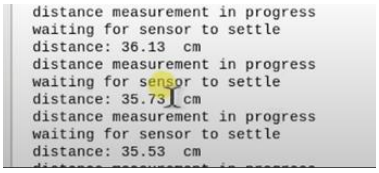

Figure 7. Ultrasonic sensor output

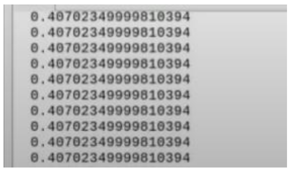

Figure 8. LDR sensor output

The threshold values for each sensor that have been set are mentioned below. These values serve as a range for the user operating the rover. Providing such ranges helps the user understand the environment around the rover. Parameters are as: i) ultrasonic sensor: if distance is between 0-10 cm, then object is too close. If distance is above 10 cm, safe and drivable range, ii) LDR sensor: if output value is between 0 to 2, then area is dimly lit, if value is between 3-6 then area is moderately lit and if value greater than 7 then area is brightly lit. (values are on a scale of 0 to 10), and iii) MQ9 gas sensor: if value is between 0-20 then area has clear air, low smoke, if value is between 20-60, then area is moderately smoky, if value is between 70-80 then area is highly smoky and any value above this means area is harmful for humans (values are on a scale of 0 to 100).

4. CONCLUSION

An IoT rover for remote surveillance based around a Raspberry Pi microprocessor which will be able to monitor a closed/open space has been implemented. This rover will allow safer survey operations and would help to reduce the risks involved with it. An efficient connection was established with the rover via the Raspberry Pi using an IoT server which can be accessed through our phones and laptops. This concept of controlling rover with the Ngrok server is unique as compared to other works done on similar areas as well as this method of controlling rover provides extremely reliable and secure connection. This rover also had a security feature in the form of fingerprint system unlocking which was itself unique as well as gives the full control to the owner to unlock the system and operate it. This feature also helps saving it from getting misused. Thus, a successful rover was developed that would provide a sense of security for users in both indoor and outdoor environments. An effort can be made to ensure that the sensor data received will be reliable. An user interface (UI) can also be developed to provide a dashboard display to the user so that he/she can monitor all the sensor values in a clean and effective manner.

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