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DUAL MODE MOBILE SURVEILLANCE ROBOT

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ABSTRACT

The dependability of mobile robot towards the accomplishment of insistent tasks such as surveillance, continue to promote it real-world application. Propulsion of mobile robot can be legged or wheeled. However, the wheeled propelled mobile robot has been said to be the most applied category of mobile robots with mono-mode mobility control in literature. Therefore, the present work describes the methodology for the development of a dual mode mobility control for mobile robot. The research object is a differential drive wheeled mobile robot with night vision camera for remote surveillance. To validate the feasibility of the proposed mode of mobility experiment was conducted with comparison to mono-mode mobility control. Experimental result shows that the drawback with mono-mode platforms such as Wi-Fi, Internet, Bluetooth, Voice recognition and ZigBee as presented in literature is eliminated. In future, the incorporation of path planning competence will be given consideration for robot performance and application improvement.

Keywords: mobile robot, surveillance, RF 434 MHz, PIR sensor, dual mode

INTRODUCTION

The dependability of mobile robot towards the accomplishment of insistent tasks such as surveillance, continue to promote it real-world application (Ulrich, 2001; Nguyen and Xuan, 2016). A mobile robot can traverse end-to-end within it workspace environment either by legged or wheeled propulsion (Siegwart and Nourbakhsh, 2004). However, the wheeled propelled mobile robot has been said to be the most applied category of mobile robots (Nikranjbar et al., 2018). Nevertheless, the mode of achieving mobility control in the workspace environment differ in literature. Hence, it is imperative to establish the effect of these modes on the mobile robot application and present alternative.

Surveillance is a premeditated activity which entails the interest to observe and obtain real-time update information about the desired area of concern chiefly to supervise or secure such area (Onwuka and Onwubiko, 2015; Udupa, et al., 2017). This act of surveillance can be achieved either by insistent patrol of the area by human as practiced in border patrol (Sakali & Nagendra, 2017) or with the use of electronic devices such as cameras and mobile surveillance robots (Saad, et al., 2018) or both. The cradle of electronic surveillance is the fitting of surveillance cameras in the area of interest either public or private places and in some home appliance for example refrigerator (Saad, et al., 2018). This approach as achieved significant results as regards prevention and spotting of illegality (Kobayashi, et al., 2014). Notwithstanding, it still experiences a major setback of limited coverage area due to it fix location with real-time variation impracticable (Nagaraju and Nagendra, 2017; Saad, et al., 2018). This fact has lead to research relating to design and application of mobile robot for surveillance (Grocholsky et al., 2006; Waslander, 2013). In addition, mobile surveillance robot can be deployed to some human restricted areas such as lethal areas with possible casualty when conducting surveillance (Singh and Nandgaonkar, 2019).

The achievement of this surveillance task by the mobile robot requires it interaction with the real-world in terms of movement within the area of interest. This movement can be achieved by human control through Wireless Frequnecy (Wi-Fi), Radio Frequency (RF), Internet of Things (IoT) among other paltforms (Singh, et al., 2017) or autonomously which requires path planning competence on the part of the mobile robot (Nguyen and Xuan, 2016; Mandai et al., 2013).

However, path planning competence incorporation in mobile robot requires advance technology and high level of intellegence development in the mobile robot. The computational expense with such robutness makes battery capacity a challenge. Research are ongoing in the development of low power processor such as the ultra-low-power Artificial Intelligence Processor by (Kim, et al., 2017), thus, path planning is not considered in this work. The present work however, emphasize on the design and fabrication of a prototype dual mode mobility control mobile surveillance robot with obstacle avoidance. This dual mode avert the stalling of the robot operation in the event of inadequate coverage of it mono mode mobility control counterpart.

In literature, significant number of works on mobile surveillance robot and obstacle avoidance has been accomplished. However, the mode of achieving control communication with the mobile robot and their merits results in a considerable characteristic factor. Singh and Nandgaonkar (2019) describe the development of an IOT-Based local Wi-Fi sever by an harmonious web page control mobile surveillance robot. It has the capacity to live stream a unicolor video, image capture and storage and audio transfer to the remote monitor and eludes obstacles in the process. This design adopts dual Android phones for video streaming and audio transfer discretely. Wireless interconnectivity was achieved through NodeMCU ESP8266 Wi-Fi Module. The Android phone is used to give motion and direction command to the mobile robot and receive the video using the install IPCAM application on the Android phone. This communication is achieved through developed robot control web page on the phone or computer through internet. The shortcoming of this design is it dependence on the internet as its insufficiency will stall it operation. Saad et al (2018) develop a line follower mobile surveillance robot with infrared light set transceivers (four pairs) to substantiate the line position and to resolve the wheel turning through binary control system. Arduino Uno as main controller was used for the development of the line following robot while the surveillance system is develop using LabVIEW. Both platforms are incoorporated into a line following surveillance system. Wireless connection was done by NI MyRIO device to the PC using Wi-Fi with monitoring through LabView. The webcam is link to the NI MyRIO device USB port for surveillance. Their result show that the line follower mobile robot performs satisfactorily on straight path and poorly on the curved path as it veers off-track due to the dissonance between the Arduino process speed and infrared sensor resolution. In addition, mobility is restricted within the line loop area and it cannot be varied effortlessly. Sakali and Nagendra (2017) develop a prototype mobile robot for border surveillance. The mobile robot is control through the Internet with PI camera for surveillance and PIR sensor for unauthorized human intrusion sensing. These informations are transmitted to the webpage for user attention. The horizontal camera movement around it horizontal axis for wider coverage of it environment is done through the user interface webpage. Visual processing and transmission of same to user PC is done by the Raspberry Pi 3 through the internet and it also interface the Motors and PIR sensor. ARM-based processors are used due to real-time visual processing speed required. Although the control range is boundless due to the use of internet, nevertheless, the drawback is the same as observed in Singh and Nandgaonkar (2019). Singh et al., (2017) explain the design of a mobile surveillance robot control via a Raspberry Pi computer. Motion and direction control are achieved by the combination of Raspbian android operating system wirelessly through Wi-Fi 802.11. Raspbian camera is used for real-time visual streaming over a particular IP (Internet Protocol) address. The innovation of their design is with the quartet direction of the transmitted footage due to the pan tilt module. However, Wi-Fi finite coverage becomes a challenge in long range deployment. Nyi and Kyaw (2016) use Bluetooth and Android phone, interfaced with a self-developed graphical user interface (GUI) with an Arduino Uno to control their propose daytime snoop robot. Motion and direction control are done through the Android phone while the robot receives command from the Android phone via a Bluetooth module link to the Arduino. Though the design is cost effective, the Bluetooth minimal effective area hamper it deployment in long range applications. Vivek et al (2015) develop a military snoop mobile robot control via Zigbee technology with ATmega 16 as microcontroller. It is equip with gas sensor, colour sensor, metal detector and wireless night vision camera. The design is for military reconnaissance with the ZigBee extend range to 1.6 km, thus, resulting in the same demerit with the Bluetooth technology. Kumar et al (2015) design a voice recognition control mobile robot using ARM7 board controller. The voice recognition circuit (VRC) HM2007 functions for motion and camera control. Voice data from the microphone is transmitted to the ARM through RF transmitter. The VRC switch the voice command into code recognize by the transmitter. However, individual speech variation becomes a challenge for the develop system to execute voice command from diverse individuals. Vansh (2015) describ a remote control mobile robot through RF transmitter and receiver module at 434 MHz. The mobile robot has a smoke sensor and fire extinguishing capability. The design is for deployment at oilfields or combustible areas for fire extinguishing mission. The mobile robot control is achieved when it is within the RF range. Dhayagonde and Shantanu (2014) propose a web control mobile surveillance robot with human detection competence through the PIR sensor. Webcam is interfaced with Raspberry Pi and visual is wirelessly transmitted from the robot to the User's web browser. Raspberry pi is connected with the Wi-Fi module which enables Raspberry pi to transmit over the web network. The system uses PIC16F877 microcontroller and motion control is achieved through the web. The Raspberry gives indefinite range so long internet is accessible. Dhiray et al (2013) developed a control for mobile snoop robot through Dual Tone Multi Frequency (DTMF). A mobile phone is attached to the robot and another mobile phone is used to connect a call to the former through mobile network. While the call last, the matching tone of any key pressed on the latter is received by the former hence the DTMF achieved. The robot receives these tones through the former on the robot. The received tones are process through 8051 micro-controller with the help of DTMF decoder IC CM8870. This IC sends a signal to the motor driver IC L293D to execute the matching motion. This process is effective provided mobile communication network is accessible. Evidently, mono-mobility control mode for mobile robot motion control will hamper the operation of the robot in the event of the inadequacy of such platform. Thus, this paper presents a dual mode mobile surveillance robot.

MATERIALS AND METHODS

The mobile robot chassis and circuit protective cover are fabricated from a 1-millimeter thickness commercially available acrylic plastic. This plastic possesses favorable properties such as machinability, durability and impact resistance (IPS, 2019). The Fig. 1 and 2 presents the dimension of the chassis and circuit protective cover respectively.

Fig. 1: Robot Chassis (dimensions in mm)

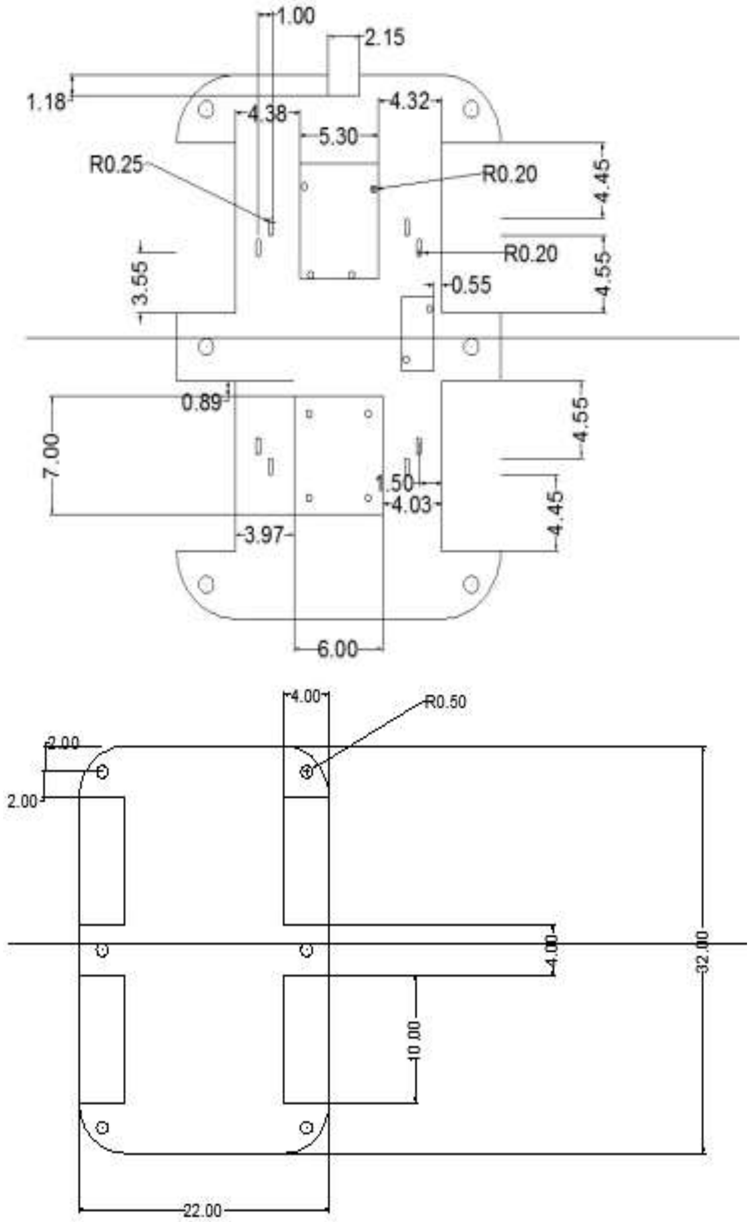

Fig. 2: Robot protective cover (dimensions in mm)

The hardware overview is presented in Table 1 and Fig. 3, 4 and 5 presents the block diagram of the surveillance mobile robot, circuit diagrams and the prototype surveillance mobile robot.

Table 1: Hardware overview

S/N	Hardware	Qty	Model/ Version	Description	Justification
1	DC motors and non-deformable traction wheels	4	TT motors	The DC motors drive the non-deformable traction wheels	Robot locomotion
2	Arduino board	2	UNO R3	ATmega328 microcontroller.	Automation of attached motor shield, servo motors, sensors and RF module
3	Ultrasonic Sensor	1	HC-SR04		Mobile robot obstacle avoidance competence
4	Pyroelectric Infrared (PIR) Sensor	3	HC-SR501		Human detection within range in the survey area
5	Servo Motors (plastic and metal gear)	2	SG90 and MG90S		The ultrasonic sensor and camera orientation control.
6	Motor bracket T-head set	4	TT geared	Machined acrylic plastic for attachment	Attachment of DC motors to robot base.
7	Wireless CCTV camera set	1		Handy hexad infrared LED camera for night illumination with 1/3-inch CMOS imaging sensor	Wireless visual and audio transfer within the range of 100 meters.
8	Adafruit Motor shield	1	Adafruit		DC and servo motor driver.
9	Push buttons	6		Quartet pin push button	Mobile robot remote-control buttons
10	RF 434 MHz transmitter and receiver	1	434 MHz	It's a 434 MHz RF module with a maximum range of 200 meters	Mobile robot remote control.
11	TV TUNER	1	USB 2.0 video capture card AVG rabber		Real-time visual reception through USB on computer or phones
12	Battery	2	2020 mAh (output 5 V, 1 A) and 9V	Rechargeable battery	The 5 V battery power's the motor shield and the 9 V power's the wireless camera.

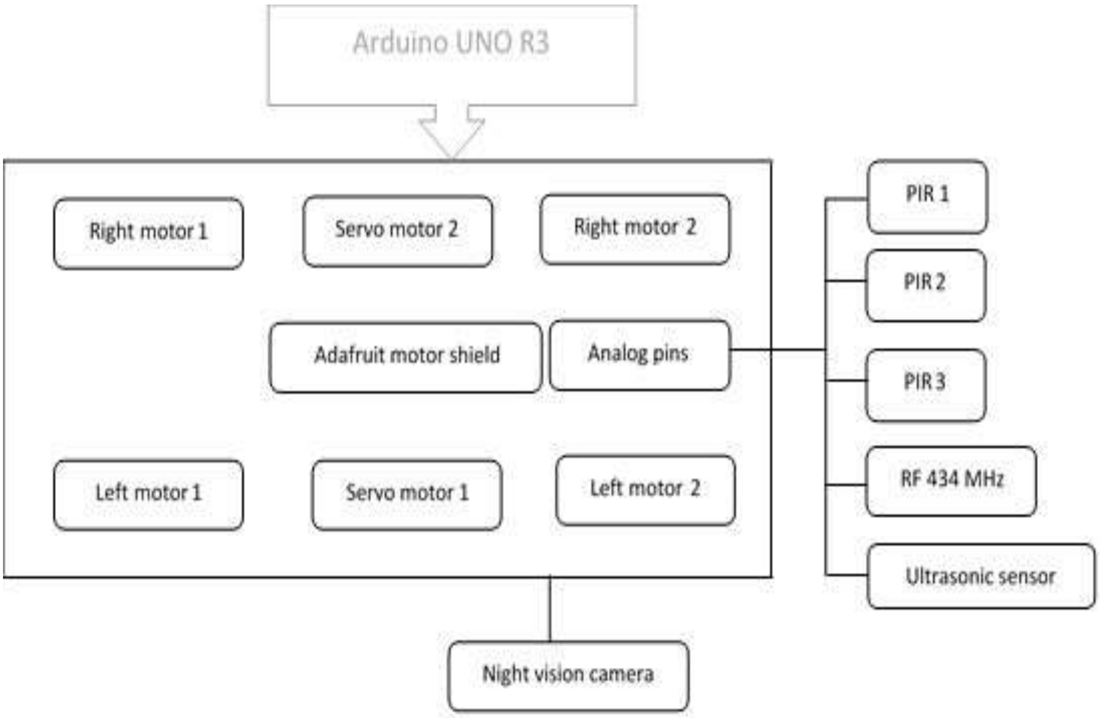

Fig. 3: Surveillance Robot Block Diagram

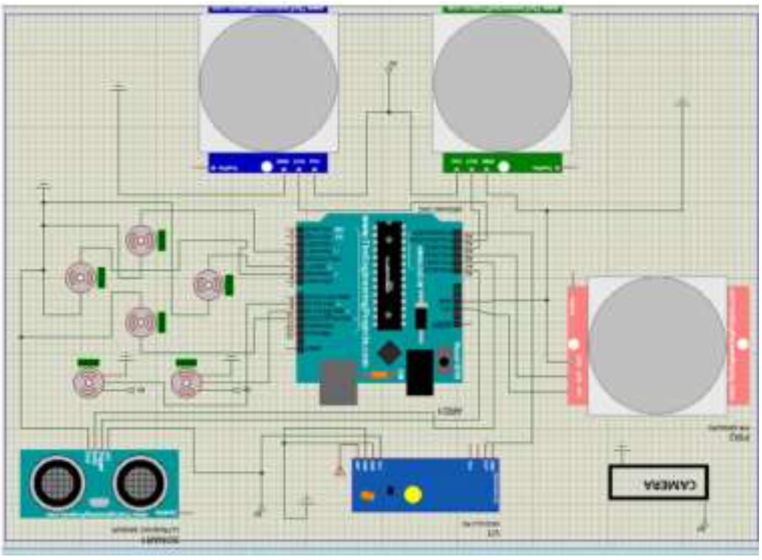

Fig. 4: Surveillance Robot Circuit Diagram

Circuit component selection analysis

Ultrasonic sensor

Ultrasonic sensor oscillator frequency is 20 MHz

$$Cycle = \frac{Period}{Oscillator\ frequency}$$

Period for transmitter and receiver for the ultrasonic sensor is 4. Thus,

$$Cycle = \frac{4}{20} = 0.2\mu S$$

Equivalent timer count = $cycle\ x\ prescaler$

Equivalent timer count = $0.2\ x\ 8 = 1.6\ \mu S$ (prescaler = 8)

Distance per count of the equivalent timer count =

$$Equivalent\ timer\ count\ x\ speed\ of\ souund\ in\ the\ medium$$

Sound speed in air at $21^{o}C$ is 33100 cm/s (NASA, 2010)

Hence, Distance per count of the equivalent timer count =

$1.6\ x\ 0.000001\ x\ 33100 = 0.0523$ cm / count

The sensor transmitter transmits the pulse and the reflected pulse by an obstacle is received by its receiver.

Hence, $\frac{0.0523}{2}$ = 0.0262 cm / count

Obstacle distance measurement is initiated by a pulse of 10 μS sent to the trigger input and then transmits 8 periods of ultrasound pulse of about 40 KHz (within 200 μS). The transmitted echo signal is assigned logic level **1** and received echo signal is assigned logic level **0**. To prevent inputs into form the receiver when the emitter sends the 40 KHz pulse Timer 1 is used to measure the duration. Timer 1 count again when its 210 µS. Hence, minimum obstacle distance (theoretically) is

$D_{min} = 210 \times 0.0262 = 5.502\ cm$

Therefore, the ultrasonic sensor limit for this work is set at 5.502 cm.

LED resistor

Table 2 LED design parameter

	Component	
Property	**Red LED**	**Green LED**
Current	15 mA	25 mA
Voltage (V_{LED})	2 v	2.1 v

Resistor value for the LEDs $R = \frac{V_{source} - V_{LED}}{I_{LED}}$ (LED, 2019)

V_{source} and V_{LED} is the source voltage and LED voltage respectively. I_{LED} is the LED current in Ampere

V_{source} is 5 Volts from Table 1, Thus, R = 0.116 KΩ and 0.2 KΩ for green and red LED respectively. These resistor values will keep the LED at maximum illumination. Hence, to reduce the illumination a 1 KΩ resistor is used.

Servo motor torque required to rotate the fixed camera

$$T = F \cdot r$$

$$T = (m \cdot g \cdot c \cdot f)r$$

T is torque, m is load (camera) mass, g is acceleration due to gravity, r is working gear. $c = 0.78$ is coefficient of friction (steel to steel) and f = 0.35 is Coefficient of friction between meshing gears (steel to polypropylene) (Handbook, 2019).

Servo motor design parameter

Working gear = 2 kg/cm = 0.02 kg/m

Reaction speed = 0.11 seconds / 60 degrees

Rotation angle = 180 degrees

Operating voltage = 4.8 V

The camera to be rotated weighs 0.19 kg

Hence, $Torque = 0.0102\ kg/m$

Circuit implementation

The mobile robot is design to detect presence of humans within it range in the surveil area therefore, the PIR sensor operation is significant. Fig. 3 and 4 shows the PIR sensor connected to the analog pins of the Arduino. This interfaces the ATmega328 microcontroller on the Arduino with the output signal form each PIR sensor. The three (3) PIR sensors are located at the rear, right and left side of the robot and senses humans in these directions. The orientation control ultrasonic sensor is located at the front and the orientation control camera is located on the robot (Fig. 5). The PIR terminals are connected as follows: VCC to a 5 V supply from the motor shield, ground to the ground terminal of the motor shield. The ultrasonic sensor terminals are connected as follows: trigger is connected to analog pin A0, echo to analog pin A1, VCC and ground to a 5 V supply and ground terminal on the motor shield respectively. The Ultrasonic sensor range is set to 300 cm. The remote-control transmitter is connected to pin 13 on the remote panel Arduino (Fig. 6) and the receiver is connected to analog pin 5 (Fig. 4).

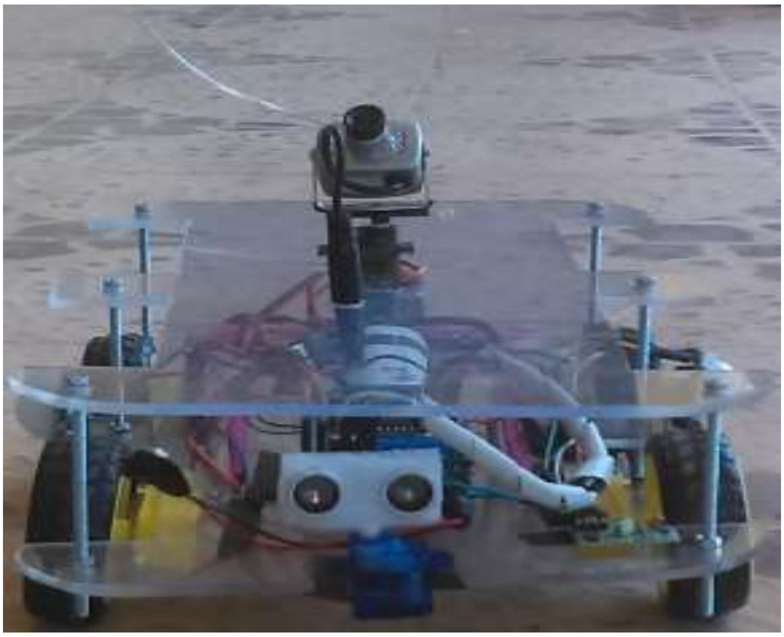

Fig. 5: Prototype Surveillance Robot

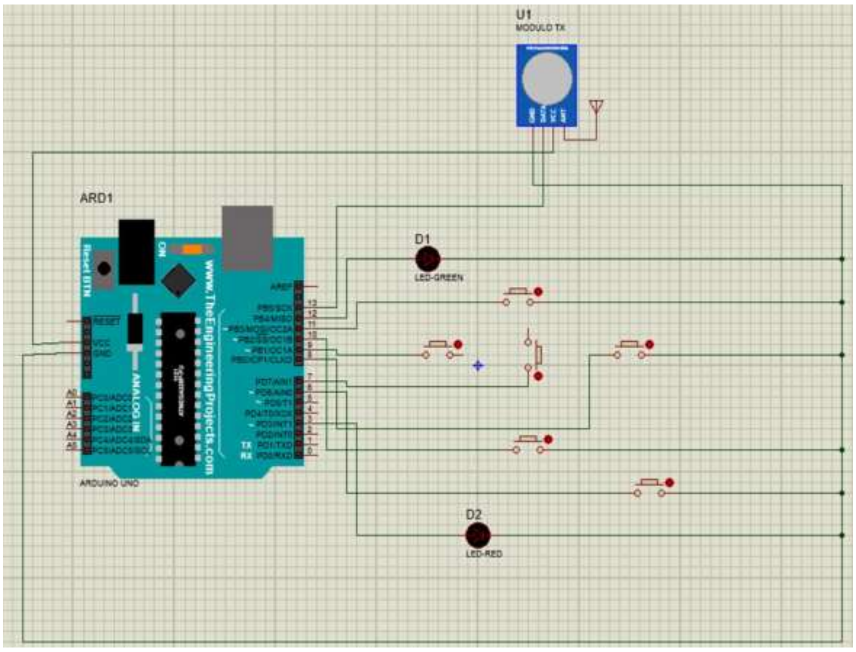

Fig. 6: Remote-control Circuit Diagram

RESULTS AND DISCUSSION

Autonomous mode

The PIR sensor operation controls the movement of the mobile robot in this mode. This sensor has a sensitivity range of 5 meters and triggers off frequently at a time delay of 3 seconds. The binary output (HIGH or LOW) of the PIR sensor is processed by the ATmega328. A HIGH logic level for instance from the right PIR sensor indicates human inbound on the right of the robot. Hence, the microcontroller commands the motor driver and metal gear servo to rotate the robot and camera to the right. The camera then captures the human sensed in that direction. Ditto for other directions of the PIR sensors. The ultrasonic sensor direction is oriented by the plastic gear servo motor. This sensor transmits ultrasonic signals in these directions to sense possible collision with obstacles. HIGH logic level output from this sensor when processed by ATmega328 will control the robot to reverse and maintain it minimum obstacle avoidance range of 30 cm. LOW logic level output from the 3 PIR sensors will course the mobile robot to move within the environment using the ultrasonic sensor to detect and elude obstacles. Also, visual and audio of the environment will be transmitted to the remote monitor pending a HIGH logic level output from any PIR sensor.

Remote-control mode

The mobile surveillance robot ultrasonic sensor and camera servo motors are deactivated to ensure the ultrasonic sensor and camera are restricted to the forward direction in this mode. In addition, the PIR sensors are inactivated in this mode as the robot depends exclusively on the control received from the user. The remote panel as shown in Fig. 4 has six push buttons for forward, backward, left, right, stop and U-turn. These buttons are coded to send distinctive data through the remote-control Arduino transmitter. If a button is pressed the data is transmitted to the receiver on the mobile robot. The Arduino decode the data and control the motor diver to output the desired direction. This mode is appropriate for reconnaissance operation. The table below presents how this direction control is achieved by the DC motors.

Table 3: Motor operation in remote-control mode

Operation	Forward	Backward	Left	Right	U-turn
Left motor 1	forward	backward	backward at high speed	forward	forward with timer
Left motor 2	forward	backward	backward at high speed	forward	forward with timer
Right motor 1	forward	backward	forward	backward at high speed	backward at high speed with timer
Right motor 2	forward	backward	forward	backward at high speed	backward at high speed with timer

The developed mobile surveillance robot prototype default mode is the autonomous mode. The real-time visual and audio transmission is achieved with the wireless camera, receiver and TV tuner card. Night surveillance is also achievable since the camera used has hexad infrared LED for illumination. This mode ensures the robot operation will not be stalled in the surveil area due to inadequacy of Wi-Fi, internet or telecommunication network as presented in literature. The alternative mode presented in this paper for this robot is the remote-control mode through the RF 434 MHz remote-control panel. This mode is developed for reconnaissance operation. In this mode the user sends the relevant commands, i.e., forward, backward, left, right, stop and U-turn through the remote-control panel. The dual mode design prevents the use of mono-analog pin control board such as NodeMCU but an Arduino is appropriate.

CONCLUSION

In this work attempt has been made to present a different method of developing a mobile surveillance robot. The robot is developed with the autonomous and remote-control mode for its operation. The default mode is the autonomous mode while the remote-control mode is developed for reconnaissance operation. The drawback with mono-mode platforms such as Wi-Fi, Internet, Bluetooth, Voice recognition and ZigBee as presented in literature is insignificant with the present system. Although night vision camera and PIR sensors has been employed for image capture at night and human detection respectively. It is evident in literature that the camera view and PIR sensor output are not associated. Therefore, in this work the PIR sensor output controls the operation of the camera in capturing the human sensed by the PIR sensor. To view the transmitted visuals on the PC, Horestech TVR 2.5 application software is install on the PC. Audacity computer application is use for noise cancelling from the transmitted audio signal for clarity. In the future, the modification on this work will incorporate path planning, competence, Global Position System with Compass module for the robot self-localization. This will facilitate its deployment for surveillance within two specified point such as hallway in hotels and length of crude oil pipeline to prevent illegality.

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REFERENCES

Abdullah, R. H. (2015). Design and Implementation of Ultrasonic Based Distance Measurement Embedded System with Temperature Compensation. *International Journal of Emerging Science and Engineering (IJESE)*, 31.

Dhayagonde, S. B., and Shantanu, k. D. (2014). Web Based Survillance and Human Detector Robot Using PIR Sensor. *International Journal For Science Research and Development (IJSRD), 2*(6), 169-171.

Dhiray, S. P., Dheeraj, M., Devendra, P., Ankit, S., and Ishwar, R. (2013). Mobile Operated Spy Robot. *International Journal of Engineering Technology and Advanced Engineerng (IJETAE)*, 23-26.

Grocholsky, B., Keller, J., Kumar, R. V., and Pappas, G. J. (2006). Cooperative Air and Ground Surveillance. *IEEE Robotics and Automation Magazine* (pp. 16-17). IEEE.

Handbook, E. (2019, January 13). *EngineersHandbook.com.* Retrieved from Reference Tables -- Coefficient of Friction: http://www.engineershandbook.com/Tables/frictioncoefficients.htm

IPS. (2019, January 13). *ACRYLIC.* Retrieved from International Polymer Solutions Inc: https://www.ipolymer.com/pdf/Acrylic.pdf

Kim, Y., Shin, D., Lee, J., Lee, O., and Jun Yoo, H. (2017). A 0.55 V 1.1 mW Artificial Intelligence Processor With On-Chip PVT Compensation for Autonomous Mobile Robots. *IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS–I: REGULAR PAPERS* , 1.

Kobayashi, K., Iwamura, K., Kaneda, K., and Echizen, I. (2014). Surveillance Camera System to Achieve Privacy Protection and Crime Prevention . *2014 Tenth International Conference on Intelligent Information Hiding and Multimedia Signal Processing* (pp. 463-464). IEEE.

Kumar, B. B., Karthik, R., Nischitha, N., Ramesh, L., and Sandhya, M. S. (2015). Multi-task Surveillance Robot Using ARM Controller. *International Journal of Advance Research and Innovative Ideas in Education (IJARIIE)* , 41-48.

LED, R. C. (2019, January 13). *Ohms Law Caculator*. Retrieved from LED Resistor Calculator: http://www.ohmslawcalculator.com/led-resistor-calculator

Mandai, P., Barai, R. K., Maitra, M., and Roy, S. (2013). Path Planning of Autonomous Mobile Robot: A New Approach. *Proceedings of 7th International Conference on Intelligent Systems and Control* (pp. 238-239). ISCO 2013.

NASA. (2010). *Speed of Sound.* National Aeronautics and Space Administration.

Nguyen, H. T., and Xuan, H. L. (2016). Path planning and Obstacle avoidance approaches for Mobile robot. *International Journal of Computer Science Issues*, 3-4.

Nikranjbar, A., Haidari, M., and Atai, A. A. (2018). Adaptive Sliding Mode Tracking Control of Mobile Robot in Dynamic Environment Using Artificial Potential Fields. *Journal of Computer and Robotics*, 1-2.

Nyi, T. T., and Kyaw, T. (2016). Design and Implementation of Wireless Based Android Controlled Spy Robot. *Journal of Electrical and Electronics Engineering (IOSR-JEE), 11*(5), 178-186.

Onwuka, E., and Onwubiko, N. D. (2015). Effects of Surveillance on Oil Pipeline Vandalism in The Downstream Sector, Nigeria. *European Journal of Business and Social Sciences, IV*(3), 127-129.

Saad, W. H., Karim, S. A., Azhar, N. B., Manap, Z., Y. Y., and Ibrahim, M. M. (2018). Line Follower Mobile Robot for Surveillance Camera Monitoring System. *Journal of Telecommunication, Electronic and Computer Engineering*, 2-5.

Sakali, N., and Nagendra, G. (2017). Design and Implementation of Web Surveillance Robot for Video Monitoring and Motion Detection. *International Journal of Engineering Science and Computing*, 4298 - 4301.

Siegwart, R., and Nourbakhsh, I. R. (2004). *Introduction to Autonomous Mobile Robots.* Cambridge, Massachusetts London, England: A Bradford Book The MIT Press.

Singh, D., and Nandgaonkar, A. (2019). IOT-Based Wi-Fi Surveillance Robot with Real-Time Audio and Video. In C. C. B. Iyer et al. (eds.), *Advances in Intelligent Systems and Computing* (pp. 639-641). Springer Nature Singapore Pte Ltd. 2019. doi:https://doi.org/10.1007/978-981-13-1513-8_65

Singh, P., Nigam, P., Dewan, P., and Singh, A. (2017). Design and Implementation of a Raspberry PI Surveillance Robot with Pan Tilt Raspbian Camera. *International Journal of Nanotechnology and Applications*, 69-71.

Udupa, S., Joshi, N., and Raman, S. (2017). Design, Analysis and Control of an Autonomous Underwater Surveillance Robot. *2017 IEEE International Conference on Consumer Electronics-Asia (ICCE-Asia)* (p. 121). Asia: IEEE.

Ulrich, N. (2001). Mobile Robotics: Research, Applications and Challenges. *"Future Trends in Robotics", Institution of Mechanical Engineers,*, (pp. 1-2). London 2.7.2001.

Vansh, R. (2015). War Field Spying Robot With Fire Figthing Circuit: A Model. *International Conference on Engineering Trends in Technology, Science and Upcoming Research in Computer Science* (pp. 78-85). Faridabad: DAVIM.

Vivek, K., Ravindra, J., Aashay, C., and Sanket, D. (2015). Camouflaged Colour Changing Robot For Military Purpose. *International Journal of Advanced Research in Computer Science and Software Engineering, 5*(3), 265-267.

Waslander, S. L. (2013). Unmanned Aerial and Ground Vehicle Teams: Recent Work and Open Problems. In A. C. K. Nonami et al. (eds.), *Intelligent Systems, Control and Automation: Science and Engineering 65* (pp. 21-22). Springer.