Development of Real Time Night Vision Camera Monitoring Robot Integrating DTMF and GPS System

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Abstract. In general, spy robots were employed mostly in military field to patrol over the country border and also can be assigned for a rescue and search mission. Even though this technology has a rapid growth recently, the major problem is what is there in Malaysia security sector, there are many lacks in this technology if compared to other countries. Furthermore, most robots use the RF technology which means the person can only monitor or control the robot within a limited range. Even though the patrol robot can be operated from a long range, there is a circumstance that it can be hard to be located or tracked. Moreover, the ordinary camera can’t deliver a better performance under dark circumstances. In view of confinements that have been featured previously, this project plans to develop a mobile patrol robot with wireless night vision camera that can be controlled by using DTMF and GPS system that can be used in military field. There are several parts to be in implement in this project as following; software simulation & hardware development of robot. As example the DTMF technology, GPS system and wireless night vision camera as well are implemented in this project so the working principle of the robot features needs to be simulated and programmed into the robot using Arduino and Proteus software. Only then if the simulation is succeeded the progress is then proceeded to the hardware development of the robot. Later the successful simulation is integrated into the robot to make the robot can be fully operated. To conclude, this robot is supposed to be able to easily be tracked by GPS system and monitored from long range using DTMF while performing such monitoring or guarding duty at the country border or other public areas.

1. Introduction
It is almost hard to say that human can do a certain task with nonstop condition. Therefore, that is the reason that most robots are implemented nowadays. They are undoubtedly are capable of performing a job continuously. Most of robots are applied in many fields especially in industrial, households, medical services, military and entertainment. In addition, there were increasing demands of security robots in military sectors. Generally, robots in military are usually consists of spy mobile robot that has many purposes as they are capable of working for longer hours than human and can be operated from a long-distance range. These robots basically are equipped with high technology accessories and artificial intelligence such as articulated arm, ultrasonic sensors, and wireless camera for monitoring, GPS (Global Positioning System) for tracking and many others. Besides, these spy robots also are convenient to be employed in surveillance system as they are also highly demanded in many security fields.

However, the robot production in present days employed with RF, Bluetooth, Wi-Fi and other technologies which has a major drawback which is restriction of working operation range. This
proposed project allows a person to operate a robot irrespective of the distance of the person operating it. Instead of using RF technology that is commonly used in robot application, the proposed project uses the DTMF technology that provides a large working range as large as the coverage area of the service provider [1,2]. DTMF is a telecommunication signalling system that enables user to switch the signal by only using button keypad. This proves that the range of the DTMF communication is larger enough to operate the robot. Furthermore, control using DTMF technology can provide more robust and powerful results in case of motion and direction of robot using mobile phone through micro controller. In addition, the daylight camera can’t detect enough light in the dark to produce a better view in taped video [2-4]. Thus, to overcome this problem, night vision camera with IR light can be employed to the robot. This camera is widely used in security cameras could allowing them to capture footage even when it’s in dark circumstances [5].

In fact, this project is proposed to develop a prototype of a mobile robot that has the similar designation and specification as the spy robot in many applications nowadays. This means that this prototype will be equipped with a user-friendly wireless communication which can be controlled by using mobile phone and can be monitored by wireless night vision camera and GPS system. In order to achieve the objective, DTMF (Dual Tone Multi Frequency) technology is employed to this robot. DTMF technology has a larger working operation than any other wireless communication available these days such as RF (Radio Frequency), Bluetooth, InfraRed and Wi-Fi (Wireless Fidelity) technology. Thus, it has advantages for the user to control this robot from far and it also provides better motion and direction of the robot [6,7]. Furthermore, user also can monitor the robot movement and location from far with the help of wireless night vision camera and GPS system.

2. Project Block Diagram

The overall project block diagram is illustrated in Figure 1. The block diagram consists of the components that are utilized in this project. There are two modes available in this project working operation. Firstly, controlling mode will involve two mobile phones utilization. The DTMF decoder will read the signal from receiving mode phone and decode the signal input to the Arduino Mega. While, there are night vision camera and GPS module that will aid the monitoring mode of the working operation. Before that, the devices must be connected to Wi-Fi first so that the data can be transmit to the PC or monitoring unit.

Figure 1. Project block diagram.
2.1. Controlling Unit

Generally, this project is proposed to implement the DTMF technology as a communication medium between the mobile robot and the controlling mode. As stated in the previous section, the DTMF mobile robot is a machine that is supervised by a mobile phone. This project main objective is to build a robot system that is controlled by a mobile phone (controlling mode). This is possible by establishing a communication between controlling and the mobile phone attached to the robot (receiving mode).

At the same time, if any button on the controlling mode screen is pressed, a tone corresponding to the button pressed is heard at the other end of the call. DTMF technology use the dual tone with multi frequency to recognize the input received from the controlling mode. In this case, the DTMF decoder (MT8870) is required to decode the frequency received and send the decoded input in form of binary digit to the Arduino Mega. The received tone is processed by the microcontroller with the help of DTMF decoder.

Later on, the microcontroller is pre- programmed to execute the process for any given input and output the direction to motor drivers in order to drive the motors for forward or backward motion or a turn. The flowchart of the controlling mode process is shown in Figure 2.

![Figure 2. Controlling unit flowchart.](image-url)
2.2. Monitoring Unit

Meanwhile, wireless night vision camera using Wi-Fi and GPS system is employed monitoring unit of the robot. The camera is capable to connect to Wi-Fi connection available in order to communicate and send the live footage video to the monitoring unit (PC or any computer). Suppose that the robot can be controlled beyond line of sight, so the camera has to be able to send the live video to the monitoring unit through Wi-Fi. The camera wireless connection setting has to be configured before the robot start-up. Once the connection is set up to endure, the video that is recorded is expected to able to be viewed from the monitoring unit.

There are many possibilities can happen as the robot can be controlled far from the administrator, it may be stuck in the rough terrain or lost the connection to the controlling unit. Thus, it may cause some trouble to track the robot location. To overcome that possibilities, the robot is equipped with the GPS system that help the administrator to easily track the location of the robot with the help of GPS module that is linked with the microcontroller. All of these process flows are simplified in a form of flowchart in Figure 3.

![Monitoring unit flowchart](image)

**Figure 3.** Monitoring unit flowchart.
3. Hardware Development

3.1. Electrical Circuit Construction

The hardware selection is vital in this project hardware development process. Every hardware components are necessary to be considered first before selected to be utilized in the project. The components selection is according to the advantages and characteristic of the component to fulfills the functionality of every part used. This project uses Arduino Mega, DTMF decoder, Neo-6m GPS module, S10 pinhole night vision camera, L293D Motor Driver, L298N Motor Driver, MG995 servo motor and DC Geared Motor SPG30-20K. The electronic circuit of has been modified and separated in order to replace with a new circuit. A simulated DTMF circuit using Proteus will be constructed and tested first. This circuit will be tested to interface with Arduino Mega that will then drive the motor according to the coding. The circuit also included the GPS module and the battery for the night vision camera. The circuit working diagram can be refer in Figure 1. Figure 4 shows the overall electrical circuit for the robot.

![Figure 4. Electric circuit for the robot.](image)

3.2. Robot Part Assembly

To ensure that the robot can be employed in military field or rescuing and search missions, the robot’s top design will allow the robot to rotate the camera around by using a robot arm. A DC motor powered gripper is also attached to the robot’s arm. Thus, the robot is capable of doing an action such as to grab or pick up something according to the operator’s commands. The robot design is built by using PVC foam board as shown in Figure 5.

![Figure 5. Each part of robot’s top body before assembly.](image)
Then each part or robot arm is assembled together as shown in Figure 6. Then, it is attached to the top body of the robot.

![Overall construction of the robot’s top body.](image)

**Figure 6.** Overall construction of the robot’s top body.

Figure 7 shows the overall assembled robot body. Consequently, this new design will provide a few advantages for the robotic control system. Additionally, this design is suited with the robot so that it can benefit and also can be used in military field with the features in the robot design. It is also can add some new features to the robot such as gripper and night vision camera attached to the robot arm.

![Overall construction of the robot’s top body.](image)

**Figure 7.** Overall construction of the robot’s top body.

### 4. Software Development

Generally, most of project involves various type of software to be utilized in order to simulate and analyse the hardware configuration. This process can at least help the project member to troubleshoot and analyse the project configuration and result. Therefore, in this project few types of software will be used in order to develop the project. Arduino IDE, HD Mini Cam app and Proteus were used in this project.
4.1. Circuit Simulation

First of all, the circuit of Arduino interfacing with DTMF decoder is designed using Fritzing software. This basic circuit is designed first to study the wiring connection between Arduino and the DTMF decoder. Then, the design the wiring connection between the L293D motor driver and DC motor interfacing with Arduino microcontroller.

![Figure 8. Circuit design using Fritzing.](image)

Based on previous research, the motor driver can be connected to PWM output pins on the microcontroller. DTMF and motor driver circuit is combined. Later on, the schematic wiring connection is reconstructed in Proteus. Thus, this wiring connection can be used to be tested in Proteus simulation software to simulate the circuit functionality.

![Figure 9. Circuit connections in Proteus software.](image)

The components used in this simulation are keypad that represents as mobile phone on-screen keypad due to unavailability of DTMF decoder in the software libraries. L293D motor driver IC also is used to control the motor rotation when receives signal from microcontroller.

Next, after the robot movement simulation is done, then proceed to simulation for robot’s arm which involving the circuit that consists of servo motors and L298 motor shield that is used to drive the direction of gripper motor rotation. There are 3 servo motor used in this circuit that corresponds to
the number of joint for the robot’s arm. These servo motors have 3 pin connection each which are voltage supply (Vin), ground (g) and signal pin. Each signal pin of servo motors is connected to PWM pin of Arduino Mega.

Apart from that, robot’s arm gripper also included in this circuit because the gripper is actuated by using mechanical actuators (a single DC motor). As mentioned before, motor shield (L298) is used to drive only the direction of a motor rotation which means the speed of rotation is excluded. This is because the motor is only required to change the direction of rotation in order to enable the gripper whether to open or close.

Hence, ENA and ENB pins on L298 motor shield is neglected. Only pin IN1 & IN2 is necessary to ensure the working operation of the motor is as described. This is because when IN1 is set high, and IN2 is set off, the motor will rotate counter-clockwise (CCW). Meanwhile, when IN1 is set low, and IN2 is set high, the motor will rotate vice versa. Figure 9 shows the overall electrical circuit connection for the robot.

5. Hardware Results and Testing
5.1. DTMF Network Signal & Range Analysis
Since this robot uses DTMF technology, which means the robot can be controlled from long distances. Thus, the operator or personnel can control the robot from far during military operations, rescuing or searching mission. Therefore, it is essential to record and analyse the GPRS signal strength at a various points or places. In this experiment, the signal strength is recorded and collected from different locations around Perlis including in the woods, downtown, opened area and also in a building (refer Figure 10).

![Figure 10. Signal reading from receiving mode (robot).](image)

The signal strength is read by measuring Reference Signals Received Power (RSRP) in dBm unit using a cell phone. The power ranges between 0 dBm to -140 dBm. The closer the readings to 0 dBm, it means that signal is very good or in other words, the signal is close to the base station. Meanwhile, if the reading is close to -140 dBm, the communication with the robot may be intermittent or may disconnected from controlling mode. In case if the communication may disconnect, still the operator can reconnect to the robot if he made a call back to the receiving mode (phone attached to robot). These signal readings can be referred to observe on how fast the signal can be processed by the robot (receiving unit). The signal readings are collected and recorded in Table 1. From the results shown in Table 1, the signal is weaker while in the woods when the signal is measured at the Wang Kelian View Point. However, the signal is stronger when the signal is measured while in downtown. Based on this experiment, there should be no problem if the robot is sent through the woods but the signal received by the robot may be a bit delay.
| Location                        | Signal readings (dBm) | Distance from control mode, UNICITI Alam, (km) |
|--------------------------------|-----------------------|-----------------------------------------------|
| Wang Kelian View Point         | -80 to -85           | 9.7                                           |
| FELDA Chuping                  | -95 to -105          | 27.7                                          |
| Kampus UniMAP Pauh Putra      | -75 to -79           | 34.4                                          |
| Kangar                         | -41 to -46           | 26.1                                          |
| Kolej Kediaman UNICITI Alam    | -53 to -61           | 0                                             |

5.2. Electrical Circuit Testing

By referring to the circuit drawing in software simulation (Fritzing software), the prototype circuit for the project is reconstructed and remodelled. Based on Figure 11, the working between controlling unit and receiving unit works well according to the working principle of the DTMF system. When the call is received and picked up, the communication between controlling and receiving unit is established. Then, when any button is pressed on controlling unit, the signal is received by the mobile phone that is attached to the DTMF decoder. The DTMF decoder is then sends the binary decoded signal to the microcontroller to process the signal in order to give direction to the motor via L293D motor driver.

![Figure 11. DTMF circuit construction.](image)

Later, the circuit simulation is reconstructed by dismantle the motor wiring connection and replacing with the LEDs. The mobile phone on the left is used as receiving unit while the mobile phone on the right is used as controlling unit which sends DTMF signal to receiving unit. The particular LED will light up when any key (2, 4, 6 and 8) is pressed. Otherwise, the whole LEDs will be turned off when key 5 is pressed which means the robot will stop. Based on ideally result of the simulation, the practical results of the circuit operation are concluded in Table 2.
Table 2. DTMF controlled LED testing results.

| Key pressed | LED output | Direction of robot represented |
|-------------|------------|-------------------------------|
| 2           | Blue       | Forward                       |
| 4           | Red        | Turn left                     |
| 6           | Green      | Turn right                    |
| 8           | Yellow     | Reverse                       |
| 5           | Null       | Stop                          |

5.3. Robot Part Application
As mentioned before, this robot is designed applicable in military or rescue missions. Thus, by referring to Figure 12, the robot arm is built with 3 degree of freedom which enable the robot arm to make a waist rotation, shoulder rotation and elbow rotation. Therefore, a servo motor with 180 degrees rotation is attached to each joint of the arm robot. In this case, it would make the robot arm can be move faster than a stepper motor with high torque. It also can make the robot arm move to a desired coordinate with high precision by controlling the servo motor angle of rotation.

Figure 12. Overall robot assembly.

In other hands, the gripper uses the DC motor activation. This means that the motion of DC motor is converted into linear motion by using a bolt and nut as shown in Figure 13. There is limitation for the gripper to lift up a load because the force isn’t sufficient enough to lift a heavier load because the design is only for prototype.
In addition, the night vision camera is located at the robot arm’s shoulder as shown in Figure 14. By this way, the camera can move freely about the waist and shoulder rotation of the robot arm. Furthermore, monitoring the live video would be easier without turning the mobile robot to left or right. It also gives the operator the view of in front of the gripper whereas also make it easier for the operator to command the robot gripper to pick up or holding something while observing the gripper position.

6. Hardware Results and Testing
6.1. GPS Coordinate Analysis
This robot will be equipped with a GPS module that will help the robot operator to track the location of the robot during it is assigned on a mission in military application. The robot tracking concept is when the robot moves to anywhere it being con-trolled by the user, the data from GPS is sent to the monitoring unit for every 1 minute to see the location of the robot. The data receives are in form of longitude and latitude of the current position of the robot. Figure 15 shows how the data is received from the GPS by using IDE serial monitor.
However, when the robot is in operation, user can’t monitor the robot location by using IDE serial monitor because the controller must be connected directly to the monitoring device such as PC. In order to upgrade the system, the GPS coordinate data must be sent through IoT platform which make it more convenient to be applied in military field. By using IoT, wherever the robot is located, the operator still can track the location of the robot as long the Wi-Fi shield plugged into the robot is connected to the assigned Wi-Fi network. Thus, in this case a mobile app called Blynk as shown in Figure 16 is used to interface with the GPS coordinate location.

![Figure 15. Coordinate from GPS in serial monitor.](image)

6.2. GPS Accuracy
Apart from that, it is also important to analyse the coordinate data accuracy from the GPS module. It is because autonomous and self-navigating robots use GPS sensors to calculate longitude, latitude, speed, time and heading. The robots get these data from the GPS and then decode and analyse them to output easy movements. Furthermore, requirement of GPS accuracy in this project is important to track the definite position of the robot when the robot is employed in searching and rescue mission.

In this experiment, the GPS data is collected from 10 different location around Uniciti Alam campus. This experiment needs two GPS devices which is from Blynk interface and from a cell phone to compare the coordinate data between both of them. Firstly, both devices are placed on a certain...
location around the campus. Then, the data from both devices is obtained and recorded. The data location on the map from Blynk interface and the cell phone is then monitored. The procedure is repeated for the other 9 different locations.

Based on Figure 17, the data from both devices is then compared using Google Maps coordinate that is obtained during experiment in order to analyse the difference in distance.

![Figure 17. Compared data location on Google Maps.](image)

The distance difference between the coordinates obtained is recorded as in Table 3. Based on the table, the average error of the distances for the 10 different location is 13.8 metre which make it less accurate and precise in coordinate computing because the latest technology of GPS sensor has only 4 cm accuracy. This is because the GPS module that is utilized to the robot has a lower specification for its sensor. As a result, the GPS employed in this project cannot calculate the precise coordinate as required.

| Location number | Distance difference, d (m) |
|-----------------|--------------------------|
| 1               | 10                       |
| 2               | 21                       |
| 3               | 0                        |
| 4               | 20                       |
| 5               | 26                       |
| 6               | 3                        |
| 7               | 0                        |
| 8               | 32                       |
| 9               | 23                       |
| 10              | 3                        |
| Average         | 13.8                     |
However, the accuracy for this GPS module is still acceptable to be employed in this robot as long as the robot stay in a certain location for a minute. While the GPS sensor is computing the exact location, the coordinate displayed varies over time. This is because the GPS sensor needs for about a minute to detect the exact coordinate of the robot. As outlined in table above, there are no errors in distance detected for location 3 and 7.

6.3. Night Vision Camera Configuration
The camera specification and operation must be studied first to make sure it is safe and fulfil all the requirements needed before being applied to this robot. The camera specification that is outlined in Table 4 is enough to prove that it can be applied to this robot application.

This robot is employed with a small size night vision camera for monitoring system during light-visible time especially in night time and a smaller amount intensity of light. The employment of this night vision camera is well-situated for the military applications. Usually military use this robot to search and rescue type operations. Night vision goggles or camera are capable to help militant operate their vehicles or robots harmlessly during night and in shrink-visibility conditions. Therefore, the use of night vision camera placed on this robot is necessary. The night vision camera view is shown in Figure 18.

Since the camera is using wi-fi connection, a pocket wi-fi is required to attach along with provide the wi-fi connection to the camera. Thus, this enables the robot to achieve the main objective for the robot application which able to operate the robot from long range.

Table 4. Night vision camera specification.

| Specification            | Details                      |
|-------------------------|------------------------------|
| Battery capacity        | 2200mah Li-ion               |
| Operating period        | 3-4 Hours                    |
| Video quality           | 1280 x 1080p                 |
| View angle              | 140°                         |
| Charge Voltage          | DC 5v                        |
| Sensor                  | InfraRed Night Vision        |

Figure 18. Night vision view from camera.
As mentioned before, a night vision camera is attached to the robot arm to make it easier for user to monitor or move the camera to a desired angle without turning the mobile robot. The camera is tested and well operated and monitored by using cell phone. The video also can be view via laptop or PC with using a wi-fi connection. The camera has 2 mode of connections which is Access Point (AP) and Peer-to-peer (P2P).

While the camera is set on AP connection mode, the range of connection becomes shorter. This is because the camera module act as host to the PC or other monitoring mode. If the robot moves far from the controlling mode, the connection between monitoring mode and the camera may lost.

Meanwhile, P2P connection mode has a higher connection range than AP mode does. The camera must be connected to the wi-fi if it is set to P2P mode. Then, the user also must connect to a wi-fi connection to view the video. Thus, enable the user to monitor the video from anywhere as long as both device (monitoring & streaming) are connected to the Wi-Fi.

Hence, these type of communications of the camera were studied and analyse to ensure whether it is convenient to be applied to this robot. The experiment is conducted in an open area to avoid signal interruption during experiment is conducted. The overall result is outlined and simplified in graph in Figure 19.

![Figure 19: AP Wi-Fi connection signal behaviour corresponding to distance from camera.](image1)

In addition to this, the viewing angle (refer Figure 20) for this camera is wide enough to give the operator wide field of view (FOV), also capable of providing high-definition video to support driving a military vehicle or robot. IR sensors applied to the camera enable war fighters to continue their mission, with minimized loss of efficiency during day and at night. These sensors must be able to enable the operator, to visualize their immediate surroundings while stationary and on the move, day and night.

![Figure 20: Normal mode view from camera.](image2)
The visual distance of the camera during both day and night also plays an important role in providing a great quality in video monitoring for the robot. This aspect is vital to analyse in order to support the smoothness during monitoring the video while the robot is in operation. An experiment is conducted to measure the quality of the camera visual by placing a particular item in front of camera with different distances. The visual distance of the camera during normal mode and night mode is analysed and concluded in Table 5.

| Distance (m) | Visual quality (Normal mode) | Visual quality (Night mode) |
|-------------|------------------------------|----------------------------|
| 1           | Perfectly clear              | Perfectly clear             |
| 3           | Perfectly clear              | Perfectly clear             |
| 5           | Perfectly clear              | Clear                      |
| 7           | Perfectly clear              | Clear                      |
| 10          | Clear                        | Clear                      |
| 12          | Clear                        | Ambiguous                  |
| 15          | Clear                        | Completely blur            |

Based on the results obtained, clearly the visual distance while normal mode is better than night mode. However, technically the ideal visual distance range for the night mode is suitable and acceptable to be implemented. By referring to Equation 1, the velocity of the robot while moving forward is 5 m/s. Therefore, by using two-second rule for the robot safe distance, the clear vision of the camera 10 m ahead of the robot can be regarded as the optimal range to be utilize.

\[
\text{Velocity, } v = \frac{\text{distance travelled, } m}{\text{travel time, } s} \tag{1}
\]

7. Conclusion
To summarize, the development of real time night vision camera monitoring robot integrating DTMF and GPS system can be utilized in many fields such as military, surveying, as well as security fields. Basically, in Malaysia there are a lot of human security guards are hired to patrol around the assigned area. Therefore, this mobile robot can be assigned to patrol around the surveillance area and can reduce the cost to hire the security guard to do the job. In addition, human can’t perform the task continuously as they will get tired over a long period of performing the task. Malaysia also behind other countries in employing robotic force in military field. Thus, the application of this robot will provide few advantages in this field. Lastly, this project has strong potential not just in the military fields, these robots also capable to be employed to play important role in rescuing and search missions, from patrol to dealing with potential explosives.

In addition, this mobile robot is focused on building a mission robot that user can send the robot on a mission to a risky place such as disaster or high radiation place. Thus, the robot is installed with a night vision camera mounted on the robot arm and GPS system that can help the operator to track the location of the robot. On top of that, this robot is equipped with a 3 joints of robot arm with a gripper so that the robot can do some good stuffs that need on spot action. However, in this project, the gripper is design as a prototype only that may have some limitation in lifting a load or things. Some features also can be added to the robot such as equip it with a metal detector so that the robot can be used to detect a bomb or landmines.
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