Development of Mobile Photovoltaic Robot for Exploring Disaster Area

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Abstract

A mobile robot for exploring disaster area in tropical region has been developed. It has capability to travel over a rough irregular terrain within disaster area and capable of performing a range of functions such as collecting samples and capturing images from the disaster scene. Furthermore, the robot is equipped with solar panel for extending the operation rather than relying on rechargeable battery only. Construction of the robot consists of 2 degrees of freedom (DOF) in robot arm, including gripper, wireless camera, wireless RF controller and electrical controller of photovoltaic system. The robot can be controlled remotely and also has capability to send captured images wirelessly to a designated controller/server. The transmitted live images can also be used to monitor robot movement and allow real time interactions between the operator and the robot.

KEYWORDS: Mobile Robot, Solar Cells, Charging system

1. Introduction

Today natural disasters occurring frequently across the globe cause severe devastation of the existing infrastructure in addition to huge fatalities [1]. When a major disaster occurred and devastating public infrastructure such as buildings, elevated highways and roads, this creates a situation where the rescue teams and other ground-based operations may be prevented from reaching the disaster area that further increase unnecessary fatalities. Rescue operation in many instances are limited to very slow pace or are even halted from progressing due to both the risk of injury/damage to the personnel themselves or further injury to disaster victims.

In order to prevent further injury, information regarding the disaster situation must be collected accurately and rapidly. One approach to overcome this problem is via robots. Robots are very powerful as they are capable of performing many different tasks and operations precisely and do not require common safety and comfort elements that human needs. Robots can access, traverse, maintain, and explore the environments which are hazardous and unreachable by humans also can approach a stricken area very quickly and perform initial information gathering as well as rescue operations.

This research relates to following research fields. In the research field of robot for disaster monitoring and supporting, many of researchers focused on a mechanism to overcome uneven grounds. Hirose et al. proposed snake type's mobile robot[1] and Gunryu (several mobile robots with arm overcome rocks by cooperation among them) [2] for search and rescue tasks. Murphy proposed a parent-and-child robot [3]. The parent mobile robot can navigate on uneven ground, and the child robot (that is getting ready in the parent's inside) can explore so places like cliffs using its rope connecting to the parent robot. Nguyen proposed a robot can discover of the sufferers [4-5]. Where the robot has many sensors, go into a collapsed house and perform searching for victims. However, the reported research above about robot which operated in Japan, USA and European countries. In ASEAN countries, we need to develop similar robot which can operate in the different climate setting and environmental conditions such as typical tropical climate with high humidity and heavy rainfall.

In this paper we report the first stage of developing a mobile robot for disaster monitoring and supporting that has capability to travel over rough irregular terrain within the disaster area and also has capabilities to collect samples and capture real time images. In addition to that the robot is able to operate in longer

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time period because supported by solar panel compared to conventional battery-powered ones.

2. Construction of a Mobile Robot

Robots are very useful as they are capable of performing many different tasks and operations precisely and do not require common safety and comfort elements humans need. Robots can access, traverse, maintain, and explore the environments which are hazardous and unreachable by humans. They have been used commonly in space. This is the same for other ground applications. However, most of these robots are unable to generate energy by themselves. The ability of robot to self-energize is an advantage as it can operate continuously without refueling. Sun is the available source of energy which is free of cost and available almost everywhere and every day. If a photovoltaic cell is mounted to robot, it will flawlessly supply electricity as long as the sun is available [6-7].

Basic block diagram of this mobile robot powered by photovoltaic system is as shown in Fig. 1. The designed mobile robot has 2 degree of freedom (DOF) robot arm including gripper, wireless camera, wireless RF controller and efficient PV electrical control as shown in Fig. 1. The robot is controlled by a person by using radio remote control. The control signal is generated from the PIC on the transmitter module. The transmitter transmits the data into a receiver and the receiver sent the data signal to the output devices.

![Figure 1: The block diagram of the overall system](image)

3. Mechanical Design

Mechanical design of the prototype robot consists of four main parts which are the robot chassis, robot arm, robot wheel set and box. Figure 2 show the photo the prototype robot.

The chassis of the robot as shown in figure 3 is used to mount solar panel, robot arm, camera, wheel set, battery and box. The chassis is made from anodized aluminum alloy, thermoset PV Plastic and Perspex.

![Figure 2: A prototype robot](image)

![Figure 3: Drawing of robot chassis](image)

The entire robot arm is made from Perspex, which have light weight, rigid and strong and heat resistance of up to 200°C. The robot arm has 2 links. The first link rotates with respect to the z axis and with respect to the chassis and second link rotates with respect to y axis and with respect to the first link [8]. Figure 4 shows drawing of robot arm.
Each joint of the robot arm is actuated by servo motor with torque value of 0.29 Nm including the gripper. For joint 2, the torque is increased to 0.619 Nm by using gear set [9]. The robot wheel set is actuated by using modified servo motor which has same torque.

The electrical design is categorized into six main modules which are transmitter module, keypad module, receiver module, DC motor driver module, servo motor module and power distributor module. Figure 6 shows the block diagram of the electrical design.

The microcontroller for the robot is PIC16F876A-20IP [10-11]. By using PIC16F87-20IP the design of the system becomes flexible, compact in size and low power consumption. PIC16F876 operating speed is 20 MHz. There are three PIC's used in this prototype robot, where first is placed at the transmitter module, second is placed at the receiver module and third is placed at the power distributor module [6].

The RF module for the robot is running at 1200bps (baud rate) with 300 to 433MHz band. It use amplitude modulation (AM type) and the range that it can transfer data is maximum 10 meters for very stable transmission and can extent to 50 meters. The RF module is RWS-TWS434.

5. Testing and Analysis

The robot performance is analyzed through several testing and experiment which is divided to three parts which are mechanical part, electrical part and video part. The nominal speed of the robot is 1.59cm/s and the maximum radius of turning is 81.3cm. The maximum inclined surface that the robot can climb is 30 degrees. The robot arm performance is analyzed due to the error analysis which shows the accuracy of the robot. To test the robot arm performance, the robot arm is instructed to make some movements and the error between position desired and the result of position made by the robot is calculated. The error is 14.97%. The gripper is also tested to see its performance to lift up object. The gripper can pick up maximum 248 grams of load. Figure 7 shows the robot gripper.

The measured distance of a good transmission for wireless robot microcontroller is 10m and acceptable distance is around 10m to 20m. Meanwhile for wireless camera transmission in a range of 50m to 100m without any obstacle between them.

The wireless camera is attached below the front chassis between the robot arm and the box. The viewpoint of the camera is set to see the image of the gripper. Thus, the video frame is limited to see the image around the gripper. In the other word, the camera can’t capture video for far distance. The dimension of camera frame is 180mm x 180mm. However, the operation of the gripper...
can’t be captured by the camera. To solve this problem one more camera should be installed on the gripper. Figure 8 show the dimension of the camera frame.

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Figure 8: The dimension of the camera frame

To test the robot arm performance, the robot arm is instructed to make some movements and the error between position desired and the result of position made by the robot is calculated. The gripper is also tested to see its performance to lift up object. Table 1 shows the arm reaching error analysis of the robot arm.

Table 1 Error analysis of robot arm performance

<table>
<thead>
<tr>
<th></th>
<th>1st Test</th>
<th>2nd Test</th>
<th>3rd Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm 1 error</td>
<td>7.3%</td>
<td>1.1%</td>
<td>4.4%</td>
</tr>
<tr>
<td>Arm 2 error</td>
<td>16.6%</td>
<td>4.4%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Total Error</td>
<td>23.9%</td>
<td>5.5%</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

The average error of the robot arm is \((23.9+5.5+15.5) / 3 = 14.97\%\). This error analysis and performance test is made by using manual measurement (using rulers and protractors). The precision of error calculated is low. The performance of first arm is the best. This is due to the first arm doesn’t affected by gravitational force. It rotates with respect to z-axis. The error of the second arm is greatest because it must support a magnified force at the end-effectors. The gripper can pick up 248 grams of load. Figure 9 show the procedure to pick up object by robot arm and figure 10 show the experiment of pick up behavior.

Figure 9: Procedure to pick up object by robot arm

Table 2 Final Specifications of the Prototype Robot

Table 2 shows the final specification of this prototype mobile robot. This specification based on measured the dimensional of robot and testing results.

6. Final Specifications of the Prototype Robot

Table 2: Final Specifications of the Prototype Robot
Robot Dimensions

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Net Weight</th>
<th>Chassis dimension</th>
<th>Wheel diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.32 kg</td>
<td>63cm x 27.3cm x 14.3cm</td>
<td>60cm</td>
</tr>
</tbody>
</table>

Material Used

<table>
<thead>
<tr>
<th>Used</th>
<th>Solar Panel</th>
<th>Chassis</th>
<th>Front Panel</th>
<th>Bottom Chassis</th>
<th>Robot Arm</th>
<th>Tire</th>
<th>Rim</th>
<th>Box</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used</td>
<td>Anodized Al. Alloy</td>
<td>Perspex</td>
<td>Thermoset PV Plastic</td>
<td>Perspex</td>
<td>Plastic Rubber</td>
<td>Thermoset PV Plastic</td>
<td>Perspex</td>
<td></td>
</tr>
</tbody>
</table>

Robot Arm Performance

<table>
<thead>
<tr>
<th>Performance</th>
<th>Gripper Maximum load</th>
<th>Accuracy of end effector</th>
<th>First arm Torque</th>
<th>Second arm Torque</th>
<th>Gripper torque</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>248 grams</td>
<td>85%</td>
<td>0.29 Nm</td>
<td>0.619 Nm</td>
<td>0.29 Nm</td>
</tr>
</tbody>
</table>

Wheel Set Performance

<table>
<thead>
<tr>
<th>Performance</th>
<th>Gear train ratio</th>
<th>Nominal speed</th>
<th>Wheel Torque</th>
<th>Max. turning angle</th>
<th>Radius of maximum turning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.5 : 1</td>
<td>1.59 cm/s</td>
<td>3.05 Nm</td>
<td>28 degrees</td>
<td>81.3 cm</td>
</tr>
</tbody>
</table>

Electronic Performance

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-m (Stable) 20-m (Acceptable)</td>
<td>7 W</td>
<td>13 V</td>
<td>0.51 A</td>
</tr>
</tbody>
</table>

7. Conclusions

A prototype photovoltaic robot has been successfully designed and implemented. The three main mechanical parts of the robot are the robot arm, robot chassis and the robot wheel set. The robot arm has accuracy of 85%. The end effectors can lift object of up to 248 grams. The robot can move forward with the torque of 3.05 Nm. The wireless camera allowed the interaction between the user and the robot's environment. This photovoltaic robot is capable to be operated in a rough irregular terrain, where it is equipped with rugged pump tires, a very high torque cruising DC motor, a quite tough chassis and robot arm. The transmitter and receiver can be upgraded by using high performance UHF digital transmitter and receiver with bit rate of 20kbps and above. The servo unit can be upgraded by using more powerful torque servo but with slow speed to ensure that the power needed by the servo is low.

References


