



Design of Landmine Robot with Battery Swapping and Solar Charging Using MPPT Technique

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Abstract: This paper presents a battery swapping and solar charging robot system. A camera mounted on the robot provides visual information to help the user control the robot remotely through any user terminals with Internet connections. The robot sends visual information to a server through a Wi-Fi network. The server transmits visual information to the user through the Internet. RF transmitter and RF receiver also used here to transmit and receive the command and data. Proximity sensor is used to detect the landmines. A six degree-of-freedom manipulator mounted on a four-wheeled robot base is used to remove the landmines. The battery gets electricity from atmospheric temperature using solar panel with MPPT. Robot can swap the dead battery with charged one by using manipulator. By using MPPT technique battery can get maximum electricity power from atmospheric temperature.

Keywords: Landmine robot, Battery swapping, solar charging, Human assistance

I. INTRODUCTION

Robot systems have been widely used in military automation applications to provide safe working environments. Some researchers have developed surveillance robot systems for military security. A patrol robot system for military security is proposed to gather environment information and detect abnormal events. The authors present an intelligent landmine robot focusing on safety and security. There are also many robots developed for military service applications such as spy robot, soldier robot. The robot can provide visual information and dangerous situation detecting. The research work on a military assistant robot is introduced. The robot improves the ease and productivity of soldier's activities. In order to realize reliable and flexible decision making, an inference mechanism is used by the robot to decompose higher level task specifications into primitive tasks. RF transmitter and RF receiver also used here to transmit and receive the command and data. In order to realize various functions such as locomotion, positioning, manipulation, and sensing, a great many motors and sensors are used in robot systems. The battery gets electricity from atmospheric temperature using solar panel with MPPT. Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce. The fill factor, abbreviated FF, is a parameter which characterizes the non-linear electrical behavior of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar cell to the product of Open Circuit Voltage

V_{oc} and Short-Circuit Current I_{sc} . A load with resistance $R=V/I$ equal to the reciprocal of this value draws the maximum power from the device. This is sometimes called the characteristic resistance of the cell. This is a dynamic quantity which changes depending on the level of illumination, as well as other factors such as temperature and the age of the cell. If the resistance is lower or higher than this value, the power drawn will be less than the maximum available, and thus the cell will not be used as efficiently as it could be. Maximum power point trackers utilize different types of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell.

In this paper, the design and implementation of a battery swapping and solar charging robot system are presented for military automation applications. A six degree-of-freedom manipulator is mounted on a four-wheeled robot base. The manipulator can remove the landmines. The robot sends visual information from a camera mounted on it to the server through the local Wi-Fi network. The server transmits the visual information to the operator. The operator can control the robot to move to the position where they want to detect. The rest of this paper is organized as follows. Section II introduces the overall architecture of the robot system. The system design is presented in Section III. The experimental results of the proposed robot system are given in Section IV. Concluding remarks and future work are given in Section V.

II. SYSTEM OVERVIEW

The system is composed of a four-wheeled base with a six degree-of-freedom manipulator, a camp unit, a server, and remote control devices such as PCs, PDAs, and smart phones with Internet connections. The robot can be controlled to patrol around the home environment. A camera is mounted on the four-wheeled base. The visual information from the camera can be sent to the camp server through the local Wi-Fi network. Users can use smart phones or computers in remote places to see the visual information of the place and control the robot to exchange the dead battery with a charged one. The block diagram of robot system and camp unit is shown fig.3 and fig.4.

III. SYSTEM DESIGN

A. Four-Wheeled Base and Manipulator

The 3D model of the robot is shown in Fig. 2. The robot is composed of a four-wheeled base, a six degree-of-freedom (DOF) manipulator, 12 V, 1.3 Ah Li-ion battery backup, a camera, and a control unit. The four wheels are driven by four DC gear motors. The front wheels are synchronized with their wheels respectively in the left and right sides. The kinematic model of the planar locomotion of the robot is a differential model as shown in Fig.1 The centre of mass (COM) of the robotics in its geometric centre. Assuming that the original point of the robot coordinates is in the position of the COM. The x axis x_R and they axis y_R of the robot coordinates are shown in Fig.2

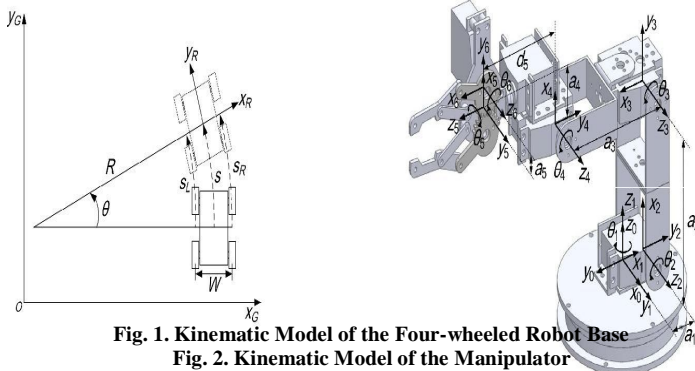


Fig. 1. Kinematic Model of the Four-wheeled Robot Base

Fig. 2. Kinematic Model of the Manipulator

$$\Delta s_L = \Delta \theta (R - W/2) = v_L \Delta t$$

$$\Delta s_R = \Delta \theta (R + W/2) = v_R \Delta t$$

$$\Delta s = (\Delta s_L + \Delta s_R) / 2 = v \Delta t$$

where s_L , s_R , and s are moving distances of the left wheel,

the right wheel, and the COM of the robot respectively, θ is the change of the azimuth angle of the robot, R is the radius of curvature, W is the width of the robot, v_L , v_R , and v are the velocities of the left wheel, the right wheel, and the COM of the robot respectively.

The wheel base of the robot has five locomotion behaviors: go forward, go backward, turn left, turn right, and stop. The moving direction of the robot is decided by the velocities of the left and right wheels. The rotation velocity of the DC gear motors can be controlled by using the PWM (pulse width modulation) technology.

The kinematic model of the manipulator is shown in Fig.2 The parameters of the links and joints of the manipulator are shown in Table I. a_{i-1} is the length of link $i-1$. α_{i-1} is the rotation angle of link $i-1$. d_i is the distance between link $i-1$. and link i . θ_i is the angle between link $i-1$ and link i . θ_i is the joint variable. i is from 1 to 6. The default values of θ_i are -90° , -120° , -90° , 210° , 90° , and 90° respectively. The ranges of the joint variables and the parameters of the links are shown in Table I. The six rotation joints are driven by six DC gear motors.

TABLE I

The Parameters of the Links and Joints of the Manipulator

| | a_{i-1} | α_{i-1} | d_i | θ_i | Range of joints variable/ $^\circ$ | Parameter of links of links /mm |
|---|-----------|----------------|-------|-----------------|------------------------------------|---------------------------------|
| I | /mm | / $^\circ$ | /mm | / $^\circ$ | | |
| 1 | 0 | 0 | 0 | $\theta_1(-90)$ | $[-190, 10]$ | $a_1=21$ |
| 2 | a_1 | -90 | 0 | $\theta_2(-90)$ | $[-180, 0]$ | $a_2=105$ |
| 3 | a_2 | 0 | 0 | $\theta_3(-90)$ | $[-190, -10]$ | $a_3=95$ |
| 4 | a_3 | 0 | 0 | $\theta_4(90)$ | $[70, 270]$ | $a_4=30$ |
| 5 | a_4 | 90 | d_5 | $\theta_5(90)$ | $[80, 280]$ | $a_5=14$ |
| 6 | a_5 | 90 | 0 | $\theta_6(90)$ | $[20, 110]$ | $d_5=76$ |

B. Stability Analysis

The proposed military robot can patrol around the outside environment and grasp objects. The COM of the robot is high because of the heavy manipulator on the robot base. The stability of the robot is a crucial problem that needs to be considered carefully. The static stability and dynamic stability will be analyzed next. The static stability is the situation when the robot is in the static state. The dynamic stability is that the robot should be stable when it is moving or the manipulator is working. The extreme postures of the manipulator, the maximum speeds of the DC gear motors should be analyzed. When the robot is in the static condition, the projection of the COM of the robot on the ground coincides with the zero-moment point (ZMP). The ZMP must be in the support polygon of the robot. The

support polygon is the rectangle ABCD with the size of 160 mm × 130 mm which is the contacting rectangle of the four wheels on the ground. The robot goes into three extreme conditions when the manipulator stretches out and points to the forward, left, and right directions of the robot. The left and right directions are symmetrical. The conditions when the manipulator points to the forward and left directions are analyzed. In these conditions, the ZMP is near the borderline of the support polygon. The ZMP is within the support rectangle. The robot is stable in the two extreme conditions. In the practical condition, the manipulator is not in the extreme conditions. The ZMP is close to the geometrical centre of the support rectangle and the robot is statically stable in this condition.

The moving and turning speeds of the robot must be analyzed to obtain the maximum permitted values. The robot moves forward in a velocity of v_0 . The robot inclines forward because of its kinetic energy when the four wheels stop rotating immediately. It is assumed that there is no slippage between the wheels and the ground. The translational kinetic energy of the robot will convert into the rotational kinetic energy and the gravitational potential energy. The robot will rotate around point P. There is an extreme value of the initial kinetic energy under which the robot will rotate to the condition that line CP is perpendicular to the horizontal plane and the rotational kinetic energy of the robot is zero. The relationship between the initial kinetic energy and the gravitational potential energy is

$$mv_0^2 / 2 = mgh$$

where m is the mass of the robot, v_0 is the initial velocity of the robot, h is the height changes of the COM of the robot.

$$ha_0^2 = \sqrt{h_0^2 - h_0}$$

where a_0 is the initial distance between the projection point of the COM and the front side of the support rectangle, h_0 is the initial height of the COM of the robot. v_0 can be calculated,

$$v_0 = \sqrt{2g(\sqrt{h_0^2 - h_0})}$$

C. Solar charging and Remote Control

The gets electricity from atmospheric temperature using solar panel with MPPT battery. By using MPPT technique battery can get maximum electricity power from atmospheric temperature. Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce. The fill factor, abbreviated FF, is a parameter which characterizes the non-linear electrical behavior of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar

cell to the product of Open Circuit Voltage V_{oc} and Short-Circuit Current I_{sc} .

In tabulated data it is often used to estimate the maximum power that a cell can provide with an optimal load under given conditions, $P = FF * V_{oc} * I_{sc}$. For most purposes, FF, V_{oc} , and I_{sc} are enough information to give a useful approximate model of the electrical behavior of a photovoltaic cell under typical conditions. For any given set of operational conditions, cells have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to V / I as specified by Ohm's Law. The power P is given by $P = V * I$. A photovoltaic cell, for the majority of its useful curve, acts as a constant current source. However, at a photovoltaic cell's MPP region, its curve has an approximately inverse exponential relationship between current and voltage. From basic circuit theory, the power delivered from or to a device is optimized where the derivative (graphically, the slope) dI/dV of the I-V curve is equal and opposite the I/V ratio (where $dP/dV = 0$).^[4] This is known as the maximum power point (MPP) and corresponds to the "knee" of the curve.

A USB camera is used to provide video information for the robot. The visual feedback information can help the user to observe the military environment, the position of the robot, and the posture of the manipulator. Users can control the robot to swap batteries between the robot and the charging station. The remote control terminals such as PC and PDA connect with the home server through the Internet. The robot connects with the home server through the Wi-Fi network. When the voltage of the Li-ion battery is lower than a preset threshold, the robot will send an alarm message to the user. The user can send moving commands to the robot to swap batteries.

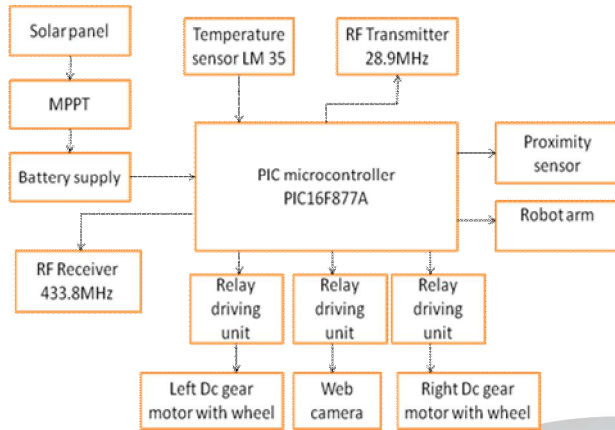


Fig.3. Block Diagram of Robot system

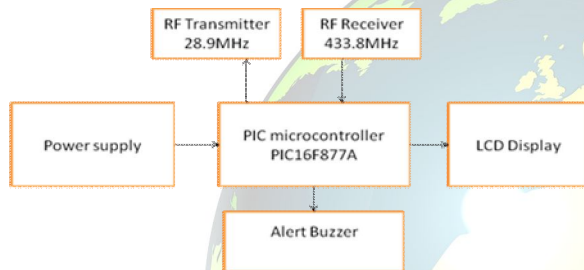


Fig.4. Block Diagram of Camp Unit

IV. RESULTS AND DISCUSSION

A. Remotely Controlled Battery Swapping and solar charging

The robot is controlled remotely by the user using a PC to swap its battery. The visual information from the camera on the robot is transmitted to the PC and shown on the human-computer interface. The below fig.5 shows the human computer interface on the remote control PC. The robot spends 62 s on swapping the battery. The swapping time can be decreased when the user operates the manipulator proficiently after practicing several times. Solar charging provides maximum power from atmospheric temperature by using MPPT technique.

Fig.5. The Human Computer Interface on the Remote Control PC.

B. Locomotion Velocity

The locomotion of the robot can be controlled by the user through the human computer interface. The maximum velocities of going forward, going backward, turning left, and turning right of the robot are tested ten times respectively. The average velocities of forward and backward going are 0.35 m/s and 0.33 m/s respectively when the ZMP of the robot is close to the geometrical center of the support rectangle. The robot is stable when it goes forward and backward. The average velocities of left and right turning are about 3.4 °/s and 4.2 °/s respectively. The turning radii are about 90 cm.

C. Video Data Transmitting

The real-time visual feedback can help the user to control the robot remotely. The video data transmitting speed will affect the real-time control of the system. The video data transmitting speed through Wi-Fi is about 14 frames per second which can meet the real-time control requirement. The fig shows the simulation of this project.

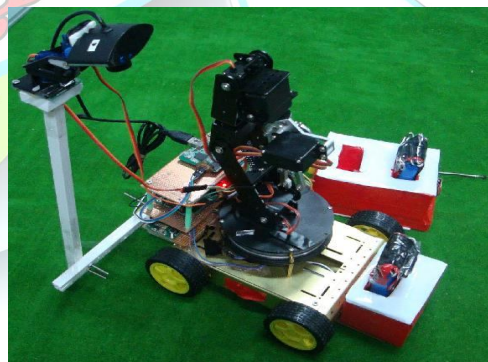
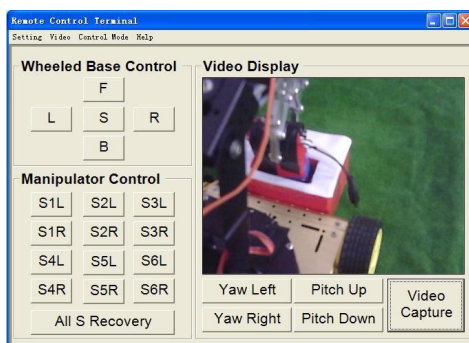


Fig. 5. Prototypes of the Proposed landmine Robot.



V. CONCLUSION

The design and implementation of a battery swapping and solar charging robot system have been presented for military automation applications. Solar



charging provides maximum power from atmospheric temperature. A four-wheeled base is used to provide mobile capability for the robot. A six degree-of-freedom manipulator is adopted to grasp the dead battery and swap it with a charged one. A remote control system with visual feedback is used to help the user control the robot remotely. The experimental results show that the peak charging current is about 2.4A. The robot can swap its battery in about 62 s with the assistance of a remote operator. The robot system can be used in outdoor environments for military automation. It is used as a spy robot to avoid human loss and Army vehicles and machines loss.

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