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Mini-Bot: a Patrol Robot with Multi Mechanical Joint and Swap Algorithm

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Abstract- The main contribution of this paper is an improved method for charging the patrol robot, without human machine interaction. The robot retains their charging position as per the commands stored in the memory. The other feature in this patrol robot is design of a track wheel, which helps to move in the rough terrain surface with high precision. A single folded mechanical joint is set up with the base for the site surveillance and which is rotated 360 degree. For the real time visuals a camera is mounted on the top of the mechanical joint. All the control commands are exchanged between the base station and robot through zig bee module. A battery monitoring mechanism is also attached with the system. As the battery charge reaches the threshold level, drive the robot to the charging panel with the proper command which is stored in the memory of the microcontroller.

Index Terms- robotics, locomotion, arm, charging

I. Introduction

Robot is a machine to execute different task repeatedly with high precision. Thereby many functions like collecting information and studies about the hazardous sites which is too risky to send human inside. Robots are used to reduce the human interference nearly 50 percent. Robots are mainly in different types like fire fighting robot, metal detecting robot, rescue robots, patrol robots other humanoid robots etc. Mostly used in industrial purpose, military, defense, research and development etc. The focus for the patrol robot applications are on difficult surfaces and simple smooth platforms. Some patrol robots use their small size model, for the easy site assessment. However the small size robots will have a problem while climbing over the steps higher than their height and want to move fast. There are some jumping patrol robots which try to move over the high obstacles by using a pneumatic cylinder, which also having the problem of gravity and stability. For the better surveillance of the vital environment visual sensor must be placed at certain height. Hence a camera is fixed on the tip of the joint. such as the mini bot will equipped with the track wheeled method along with the charging option to overcome this problem.

This paper focuses on the systems of hardware and software which control robot locomotion and mechanical arm movement. It gives the details to the hardware and battery monitoring system as well. Section two and three gives literature survey and limitations and idea of new methodology. In section four, the robot mechanical design and hardware parts are explained. Section five gives the methodological design. And section six gives basic software aspects. Section seven shows the result and discussion last section gives the conclusion and the future work of the robot.

II. Hardware Concept

The main design concept is using the simple method but highly effective and reliable. The block diagram of the patrol robot system is shown in fig 1and fig 1.1. All of controlling commands are sent from the base station computer to robot via zig bee. The controlling commands compose of the locomotion control, robot's navigation path and multi-joint mechanical arm control. In order to monitor video in real time, a wireless surveillance camera is mounted on the mechanical joint. The controlling commands are generated from the base station. The codes are transmitted with the help of terminal window. On the receiver side zig bee is configured as receiving purpose. A separate power station is setup for the independent power delivery to the motors and to the on board. A secondary back up power source is also arranged. All the control commands are received and compared with the help of predetermined program which is loaded in the microcontroller. A battery monitoring mechanism is setup along with the board for the awareness of the current charge level. Whenever the voltage level reaches the threshold value, the driving motors will get the power to drive the robot to the charging station. The movement of the robot is based on the commands stored in the memory during the real time. Commands are executed in last in first out, will be executed by swap algorithm.

A stepper motor is fixed at the base of the mechanical joint. This will help to rotate the arm up to 360 degree. This takes 8 steps to complete one rotation. Thus the surveillance became easier. DC gear motors are also attached to other mechanical joints for several purposes like stretching the arm, tilting the camera and one at the charging terminal for rotating the flap to make the contact with the charging station

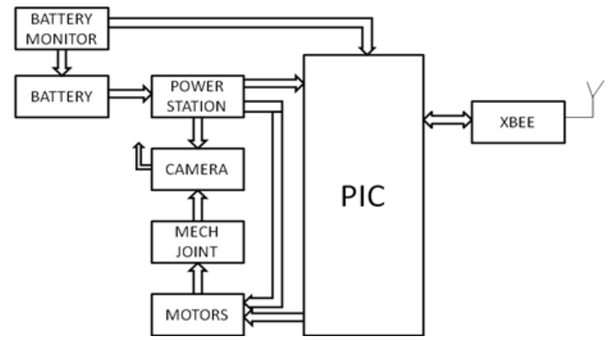

Fig.1 Receiver side

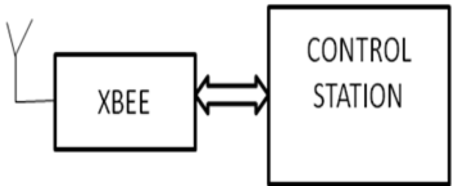

Fig. 1.1 Base station

III. LITERATURE REVIEW AND LIMITATION

The major criteria for the patrol robots are the navigation path. Several methods are implemented for the path following purposes like developing a sensor packages and algorithms [14]. Such a robots designed on these aspects should lack on the simplicity of the hardware. This will also increment the software complexity. Other approaches like stereo vision based obstacle avoidance and visual servings, both follows algorithms and image recognition methods [15]. Hence high end processors and modules are needed to compute the path. In order to overcome this difficulty some map creation as well as artificial route mapping approaches are used [18][20][21][23]. But the mathematical computation becomes much more complex. Especially by locating the position of the robot using the markov localization method, bayes approach. This will take large amount of time to fix the position of the robot and also the next goal positions. All of these executions will drain too much power and it will affect the system performance.

IV. NEW METHODOLOGY

In order to reduce the complexity in both the hardware and software, we are introducing a robot with a swap algorithm along with track wheel. By this we can reduce the power consumption and it will lead to minimize the software as well as hardware complexity. Thereby the cost of the robot should be an economical one. With the usage of swap algorithm the robot can easily driven to the charging panel without any other human machine interactions. Mostly we can reduce the computational time.

V. MECHANICAL DESIGN

Robots are several types wheeled, tracked, and legged, multi robots, vibration types. The simplest are wheeled robots, while tracked wheels are used because of their ability to move in rough terrain surface and their greater stability. The mini bot is tracked wheel vehicle. They are relatively lightweight about 10 kg. They are quite active and fast in unstructured environments and they also perform well on uneven terrain. The whole robot structure is constructed in mild steel and the mechanical joints are effectively works with gears.

A. Body and Driving System

Thick aluminum sheet is folded to be the base frame. The locomotion driving system, all motors and mechanical joint sets and the batteries are placed in this frame in order to have the low level centre of gravity. Two 12V DC motors are used for driving base wheels separately. Both are controlled bi-directionally. Mechanical joint is fitted at the centre of the robot. With suitable commands from the operator the joint moves.

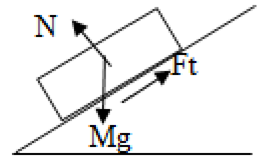

Fig. 2 Free body diagram

When a solid body slides over a rough or smooth stationary surface, a force is exerted at the surface of contact by the moving body. This force is frictional force and is always acting in the opposite direction [25]. Consider a simplified model of the system as shown in Fig. 3. The minimum torque required for climbing a surface with slope of 20° is calculated by second law of Newton. The mini bot can be covers the steps up to 20°, because the height of the wheel is 8cm.

$$F=Ma$$

Assume the linear acceleration and thus the rotational acceleration of the wheels to be zero.

$$a=0$$

$$Ft-mg \sin\theta$$

$$Ft= mg \sin\theta; \quad \text{let } m=10kg$$

$$Ft=33.5N$$

The torque becomes,

$$T=Ft*r\approx 10Nm$$

The locomotion system consists of two separate sides connected to the main body while a motor independently drives the track at each side. So the desired torque is obtained by dividing the T/2 [3].

$$T=5Nm$$

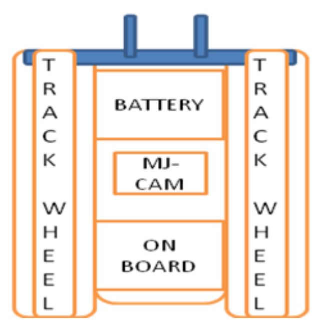

Fig. 3 Hardware model

B. Flipper and Driving System

The flippers (dark color flap) are created in order to raise the charging terminal up for better connectivity, which is shown in the fig 3. Another 12V DC motors and transmission chains are required for flipper driving. Separate commands are generated for this action.

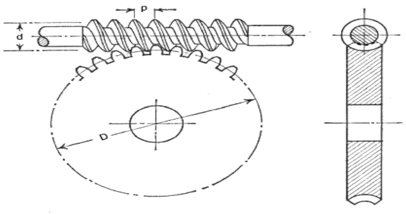

Fig. 4 worm gear

For a large speed reduction worm gear is used as shown in fig.4. It consists of a large diameter worm wheel with a worm screw meshing with teeth on the periphery of the worm wheel. The worm is similar to a screw and worm wheel is similar to a screw and worm wheel is similar to a section of a nut. As the screw wheel rotates leads to rotate the wheel also.

C. Mechanical joint

The mechanical arm does credit to the mini –bot. This enables the robot to expand its tracks whenever it needs to close vision on the obstacles. It helps the robot to explore in many ways such as, from high level and able to get vital signs of victims [12][15][4][17][16]. In Fig. 5 shows the drawing of mechanical arm. Because the pay load at the tip of arm is small and the arm structure weight is not much, DC motor with gear set still can regulate the joint angle quite well. Arm motor is coupled to the planetary gear set with 20:1 worm gear set, which results a maximum speed of 4rpm. Let 'h' be the height from base to the joint. The angle of rotation is determined by $\theta 1$ and $\theta 2$. If two rotational angles could change between 0and 360 degrees, the work-space should be between a spherical surface and a cylinder. Therefore, the work-space is between a semi-spherical surface and a cylinder. A stepper motor is fixed at the bottom of the mechanical joint for the full surveillance. It takes 8 steps instead of 4 to complete one complete rotation.

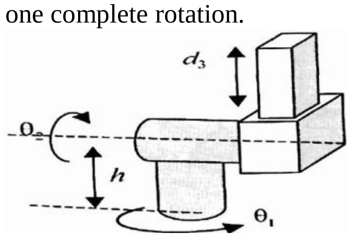

Fig. 5 Mechanical joint

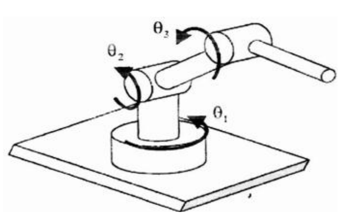

Fig. 6 Mechanical arm

D. Visual sensor

This part is the place to install sensors which are used for searching vital sign of the victims like camera [23]. The second and the third rotary joints cannot freely rotate between 0 and 360 degree in practice. Therefore, the work-space cannot be a complete spherical volume, as shown in Fig.6. A camera is mounted in the top of the mechanical joint, which is used for getting the real time visuals, to have the site study. The data collected by the camera is transmitted to the receiver which is attached to the PC and the data is displayed on the suitable window.

VI. METHODOLOGICAL DESIGN

Here we are implementing the mini bot with two new methodologies like battery monitoring system and is followed by a swap algorithm. Charging the battery is a challenging task in robotics [5]. Robots like automatic charging, solar charging robots having some complexity in the coding. But automatic charging robots will move to the area where the electric field is present. For this high end processors are used. A monolithic integrated circuit LM3914 is used to monitor the battery charge level. This senses the voltage levels of the battery and drives the 10 light emitting diodes based on the voltage level. This IC works in two modes DOT/BAR mode. In BAR mode the current consumption is much more. In order to avoid this we are using the DOT mode, which blinks only the respective LED. When the battery charge reaches the threshold level, this will interrupt the microcontroller. There by the driving wheels get the power and remaining motors are disabled. The movement of the robot depends up on the commands stored on the memory during the running process. These commands are then executed by a swap algorithm. The robot is then driven to the charging panel. This will executed in last in first out manner. The charging of the robot can be held at the charging panel.

For the patrol robot navigation several methods are used like sensing the paths, graphical user interface, map following algorithms and compass, other Kalman filtering methods[1][2][3][14][20]. All these approaches are somehow complex. This can be overcome by using the EEPROM of the microcontroller. PIC16F877A has 256 bytes of EEPROM inside it. So memory can use it to store data that need on a permanent basis and we can read it back from it. There are two functions to accomplish the task. Eeprom_Read and Eeprom_Write. Eeprom_Read function returns an integer and takes a parameter of the address from which the data has to be fetched. Eeprom_Write takes two parameters the first one is the address and the second one is the data.

unsigned short Eeprom_Read(**unsigned int** address);

void Eeprom_Write(**unsigned int** address, **unsigned short** data);

Most of the robot will navigate with different algorithm.[22][24][18][19]. The robot will navigate with respect to the commands from the user. All the running commands are stored in the memory and also a timer is set to determine how long the commands are executed. Now the current position of the robot is at B after starting from A. Whenever it needs to return, the last stored command will execute first (LIFO). If the last executed command is forward, that swaps it into backward command at the same time the timer starts decrements the value. If the path having the deviation as shown in fig.7, halts and proceeds to the left and move forward. At the time of returning, initially the command is fetched and checked which command is executed lastly. Let the last executed command is forward. Then it swaps it in to backward command by calling the forward function in the program. Similarly,

Backward ≈ Forward
Left ≈ Left
Right ≈ Right

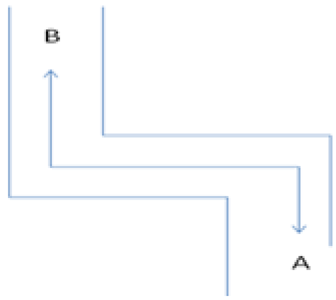

Fig. 7 Navigation path

VII. SOFTWARE ASPECT

Onboard software is mainly developed with micro C. This software interfaces between the operator station software and the robot by receiving operator's command to control all robot functions. Simulations have been executed both in Mat lab and PIC simulator. In Mat lab the approaches were implemented under ideal hypothesis, more realistic settings. The commands are sends through serial communication with the help of terminal window to zig bee module. Zig bee module is configured as a transparent mode for the normal transmission. On recharging and navigation of the robot swap algorithm is executed. Real time visuals can be captured and displayed on the window with the help of surveillance camera. A tunable receiver is connected to the base station for proper reception.

VIII. RESULT AND DISCUSSION

The proposed robot was successfully designed and implemented. With the help of swap algorithm the navigation operation was also effective. Thereby the power consumption is reduced. Battery monitoring system is also worked well. The limitation of this robot is obstacle detection, far objects cannot be detected. Instead of IR we can use ultrasonic sensors.

IX. CONCLUSION AND FUTURE WORK

The mini bot robot was designed and implemented. The patrol robotic system with track wheel type and gearing, driving method has been briefly described. Its performances were observed to be excellent in unstructured environments. The development of this mini-bot robot can be adapted to fit many other applications easily by changing the top part of the robot. Single stretched mechanical arm is designed and implemented. It cannot stretch not much longer. This can solve with the design and implementation of robot with more degree of freedoms mechanical arm which can stretch to 150 cm or more. For better the access of the robot instead of zig bee we can choose WIFI/internet. Instead of using the internal memory, SD card can be implemented. Hence large amount of information can be stored.

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