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Design and Construction of a Tree Climbing Robot

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ABSTRACT: With advancement of technology things are becoming simpler and easier for us. Automation plays an increasingly important role in the world economy and in daily experience. Last few decades has witnessed a rapid development in robotic technology. Different types of intelligent machines which facilitate various tasks in industry environment are becoming popular. The project presented here, focuses on designing a tree climbing robot. Our prime consideration in designing tree climbing robot is of the motion planning and method of gripping. With arms involving four legs and sharp end as feet. The mechanical structure is designed to move the structure upwards against the gravitational forces in successive upper body and lower body movements similar to a tree climber. The gripping is designed in a way to dig the upper or lower part of the structure in to the tree facilitating the upward movement. The results shows that the it can successfully climb the trees. Tree climbing robot has the potential to be applied to various pursuits, such as harvesting, tree maintenance, and observation of tree dwelling animals.

KEYWORDS: DC Motor, Current Sensor, RF Module, Threaded rod & Spikes.

I.INTRODUCTION

Climbing robots have many applications and their capabilities of the robot differ according to the mechanical design. Climbing robots should be capable of dealing with different surfaces and adapt with a variety of cross-sections. The most critical challenge here is to move one part of the structure with respect to the other part against gravitational force.The scope of this project is limited to climb coconut trees having diameters between 10 and 20 cm. Therefore, maintaining sufficient friction force capable of handling the self-weight, maintaining the stability of the structure while in motion, reducing the total weight, and achieving the precise gripping are the important parameters that have to be considered. The climbing mechanism used in this paper is inspired from the technique used by inchworm. Inchworm design is one system of legs that all move relative to each other in a gait [1]. The simplest form of this includes two gripping points at each end of the robot along the climbing axis with an actuated, bendable set of connections between the grip points that allow the grippers to move relative to each other. With this designs gait, one gripper releases to move to a new position and re-grip while the other gripper remains attached to the climbing surface to support the robot. The main advantage of the inchworm design is that it is a simpler mechanism than the system described in the literature [5]. This greatly simplifies the mechanical dynamics and their design along with the corresponding overall cost, actuator programming, and weight.

Climbing robots constitute a challenging research topic that has gained much attention from researchers. Most of the climbing robots that are reported in the literature are designed to work on man-made structures, such as vertical walls and glass windows [1]. Few climbing robots have been designed to work on natural structures, such as trees. WOODY [4] is one of the climbing robots that are designed to replace human workers in the removal of branches from trees. The robot fastens onto a tree by encircling an entire tree trunk and climbs up by extending and contracting its body. Kawasaki [8] developed a climbing robot for tree pruning. It uses a gripping mechanism that was inspired by lumberjacks and uses a wheel-based driving system for vertical climbing. Aracil [8] proposed a climbing robot, i.e.,

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climbing parallel robot (CPR), which uses a Stewart–Gough platform to maneuver. RisE V2 [9] is a wall climbing robot that imitates the movement of an insect, using six legs to maneuver.

The goal of this project was to build a tree-climbing robot to satisfy the various requirements. The robot works on two sub-mechanisms: (a) Gripping (b) Climbing. The movement of the machine is like an ape climbing the tree. First, the upper pair of arms grip the tree then the body moves up then the lower pair of arms grip the tree then the upper pair leaves the contact and the body moves up.

II.SYSTEM MODEL AND WORKING

There are two types of motion in climbing classified as; continuous and discrete type. In the continuous type, energy consumption is reduced and speed is increased. But it is difficult to implement continuous motion, thus discrete motion is adopted in this project. Mechanically the tree climbing robot consists of two segments top and bottom segment [3]. The two segments are joined by a threaded rod [2]. Two DC motors are provided for each segment and a single DC motor is used for rotating threaded rod in order to achieve the linear motion. Movement of a pair of legs are controlled by dc motor in each segments. First tree climbing robot is attached to the trunk with the aid of grippers. The motors used for climbing overcome the moments caused by weight.

Mechanical units consists of two segments, joined by a spine which can be extended or retracted. Each segment have four legs with very sharp points as feet. To climb, the legs on the top segment would pinch together and the sharp feet would dig into the bark, securing the robot. Then the spine would be retracted, pulling up the bottom segment. The legs on the bottom segment would then grip the tree, and the top segment would release. Finally, the spine would extend, pushing the top segment upwards, and the process would repeat. The climbing sequence is similar to the way an inchworm climbs. The general design of the robot consists of mainly two parts.1.Legs for gripping 2.Body for climbing. The legs are formed by an Al bar bend into U shape and fitted with very sharp T pins. The legs are some of the most important parts of this robot, because their design determines whether or not the robot can grip onto trees. We decided to have four pairs of legs, each pair controlled by one motor. To make the legs, cut four 8.5” lengths of the aluminum bar. Mark the segments 2.5” from each end. At those marks, bent the aluminum at a right angle, to make a U shape. The proper gripping mechanism is provided by a sharp feet which is attached to the each pairs of legs. To move up and down a tree, the robot extends and contracts by spinning a threaded rod which is coupled to another DC motor using a nut and glue. This method of locomotion is most suited because the threaded rod is easily available, cheap and can be coupled to the motor easily. When the rod is spun clockwise, the two segments are pulled together, and they are pushed apart when it spins counter clockwise. To spin the rod, need a relatively high-torque low-speed motor that would run at 12V. So the threaded rod is coupled to a high torque DC motor to actuate the spine.

Electrically the Tree climbing robot has two modules, one for transmitter and another for receiving and controlling. An RF module is a small electronic device used to transmit and receive radio signal on one of a number of carrier frequencies. Several carrier frequencies are commonly used in commercially available RF modules, including 433.93 MHz, 868 MHz and 915 MHz .

III. BLOCK DIAGRAM OF THE SYSTEM

The block diagram of the transmitter is given in fig.1. The main parts are power supply, microcontroller and RF transmitter. The power supply section provide +5V for the transmitter section to work. This section transmits the binary data to space in a particular range based on the antenna used. This signal is received by the receiver and it performs the sequence of motion required to climb up/ down the tree.

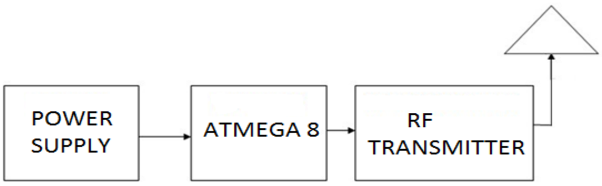

Figure 1: Block diagram of transmitting section

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The block diagram of the receiver is given in fig 2. The main parts are RF receiver, power supply, microcontroller, sensing &controlling unit. The robots power at the receiving section is provided by two different sources. The microcontroller and the motor control circuitry are powered by a 9V battery through an IC voltage regulator. The power supply section which provide +5V for the transmitter section to work, IC LM7805 is used for providing a constant power of +5V, while the motors are powered by an appropriate 12 v Li-Po battery unit.

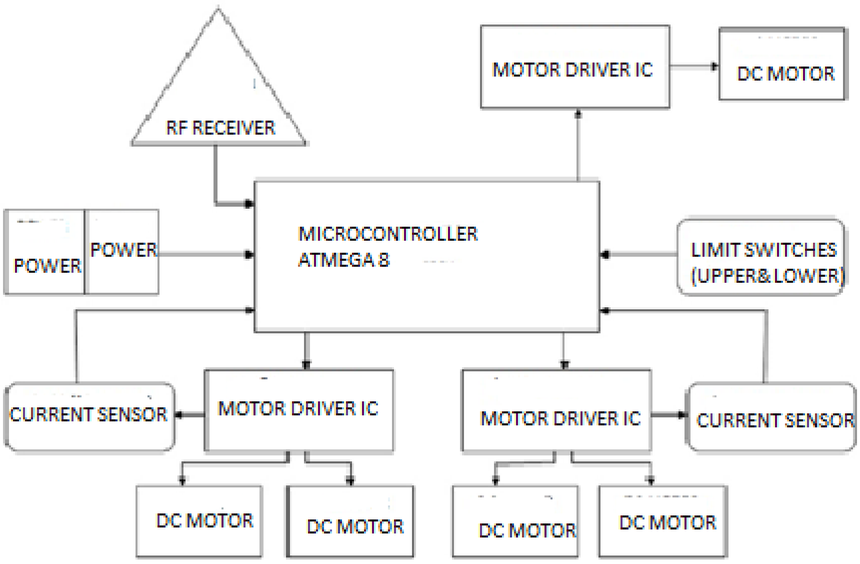

Figure 2: Block diagram of receiving section

Three separate control boards are used to control the motors in the top and bottom legs and the central body. The climbing unit consist of a centre shaft DC motor directly coupled to the threaded rod. For controlling this motor a separate H-bridges used. The controlling signals are sent to the motors through the motor drivers by a microcontroller. The tree gripping unit consist of 4 Dc motor. Each motor actuate a pair of legs. There are 2 pairs of legs on both top and bottom segment. The working of the motor can be explained with the help of block diagram. It consists of 5 DC motors among 4 of them are used for the movement of the leg and the other one is used to climb up and down. The DC motor are made to run in both direction by an H-bridge[7]. For the working of the tree climbing robot, first the top segment grips the tree Bottom segment releases form the tree, then the spine contracts, pulling the bottom segment up towards the top segment Bottom segment grips the tree, top segment releases from the tree Spine extends, pushing the top segment upwards, and the cycle can start over again.

In order to achieve a closed loop control system, there needs to be sensor feedback from the robot. The first issue to address is whether or not a gripper is correctly placed against the tree before allowing its claws to close and clamp onto the bark. To know when this occurs, we can provide a push-button the palm area of each gripper. Being simple binary devices consisting of only an on or off state, the buttons are the most efficient method for sensing contact. In order to sense the force on a gripper, the current drawn by the motor which drives the gripper needs be measured. To do so the circuit below was designed. It measures the current going through the motor directly by adding a shunt resistor in series with the motors ground lead. The voltage drop is then measured across this resistor, and is converted to current using Ohms Law, V=I R.

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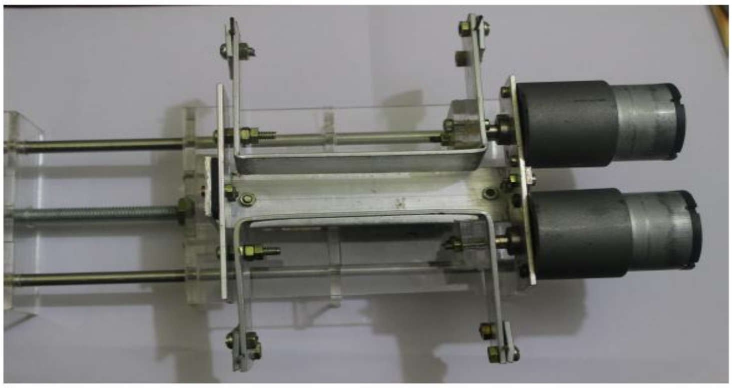

Fig 3: Legs driven by Motor

Fig 3 shows the legs and motors coupled together and motor drive the legs directly.

IV. MOTION PLANNING ALGORITHM AND FLOWCHART

Here we use Micro controller (ATmega8) to control the DC motor modules. When the switch is activated, the sequence of rotation of the motor for upward motion will be initiated [6]. To climb up a tree, the robot goes through a simple series of motions(fig 4). First, the top segment grips the tree and the bottom segment releases form the tree. Then the spine contracts, pulling the bottom segment up towards the top segment. Next the bottom segment grips the tree, and afterwards the top segment releases from the tree. Finally, the spine extends, pushing the top segment upwards, and the cycle can start over again. For ease of programming, a function is written corresponding to each basic motion. These are as follows: Start, open all, Stop, close all .Close Top, Close Bottom, Open Top, Open Bottom, Shrink and Stretch. By combining these functions in the proper order, the robot can be made to ascend or descend trees. Opening the legs is very simple. The legs turn outwards from the tree until the current sensor value reach a predetermined level set in the program. Then power is cut off to the motors. Closing the legs on the tree, however, is a little bit more complex. Since trees vary in diameter, the legs need to be able to grip a wide variety of diameters without reprogramming the robot for each size. To figure out when to cut off power to the motors, the controller must sense the current continuously and send to the analog to digital converter (ADC) pin of the microcontroller. If the value obtained is greater than 30 (Digital value-obtained through testing), the controller cuts of power to the motors, to prevent them from stalling out, or damaging themselves, the motor controller or the gearboxes (but actually we are providing a pulse of 10% duty cycle with PWM technique in order to ensure secure gripping).

Fig 4 shows a greatly simplified flowchart of the program. Here only the motion planning is depicted. The actual algorithm is slightly complicated which involve so many user defined functions. The last piece to the programming puzzle is the method of controlling the robots actions. One start and one stop functions and corresponding switches at the transmitter end are provided to manually control the behavior of the robot so that the robot can be easily removed from the tree surface. Otherwise it become difficult to remove the robot from the tree since, we can see from the program that robot is always gripping the tree. While the switch start is pressed (circuit open), the robot keeps its legs open. Once the switch stop is turned on, all legs of the robot starts to grip the tree and the robot begins its climbing cycle after pressing the up/down button. To remove the robot from the tree, the switch is turned back to the off position, and both sets of legs release.

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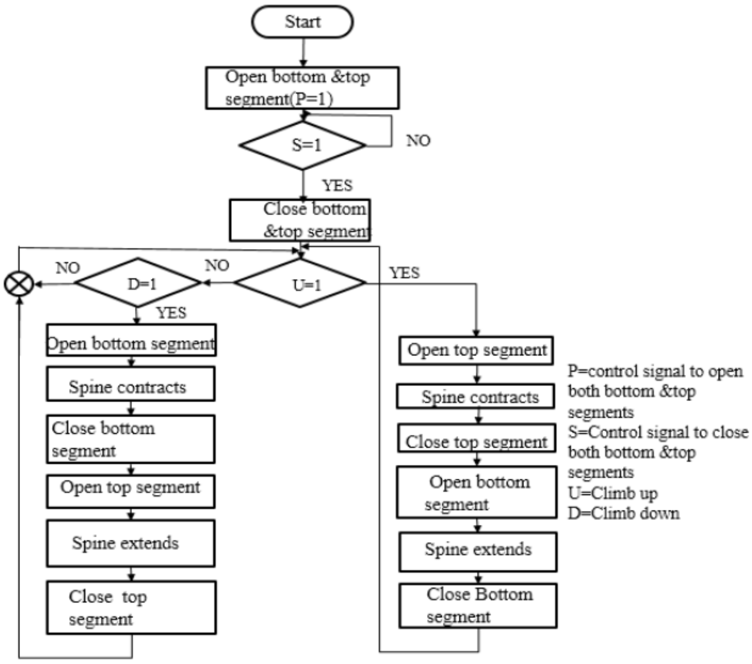

Fig 4: Simplified flowchart for a single pulse operation

V. EXPERIMENTAL SETUP AND RESULTS

As seen in Fig 5, the final revision that we tested for our robot was able to hold onto a tree trunk securely. This proved that our design was able to hold its own weight on a tree and could be controlled to climb up. It was determined that the robot is a self-powered robot since it is able to carry on board power source. The final testing was done on a branch less tree, a PVC pipe and on a vertical steel pipe. The results shows:

1. The robot can climb trees having diameters between 10 and 20 cm
2. The robot can climb various branch less trees.
3. The robot has a load carrying capacity of 0.75 kgs.
4. The robot can climb on man-made structure such as steel, PVC pipes etc. which gives lots of other applications.
5. The measured value of current is 140mA or 30 in digital read
6. The robot takes 8 minutes to cover vertical distance of half meter

Table 1 shows the various results obtained during the testing of the tree climbing robot implemented.

Features	Measured value
Current during gripping	140 mA (30 digital value)
Playload capacity	About 0.75 kg
Diameter of tree	10-20cm
Speed of motion	1m/8min

Table 1: Test results

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Fig 5: Experimental setup.

VI. CONCLUSION AND FURTHER WORK

This paper presents about an autonomous tree climbing robot. The mechanical structure and control algorithm of the tree climbing robot was designed and implemented successfully. The tree climbing robot moves along branchless tree by its arms using legs and spike system and moves vertically in a constant velocity using screw mechanism. An RF based remote is provided to control the motion of the robot. Several experiments are carried out on natural structure as well as man-made structure to evaluate the proposed algorithm. The proposed motion planning strategy is able to guide Tree climbing robot to climb on the tree. The robot is simple in construction and cost than the robots that are described in the literature survey.

Further research into the mechanical design of the legs or body would allow for the final project to be more effective in completing our list of objectives. Further work in a control system would allow for the robot to react to its surrounding and allow for easier and more intuitive controls for the end user. This project can be extended to replace humans from plucking coconut as it reduces risk of accidents. Further modifications like branch selection, incorporation of vision based sensors like video camera for observation, special arms for harvesting purposes etc. with extended degrees of freedom can also be incorporated in the near future to meet the various requirements associated with tree climbing.

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