All Terrain Autonomous Robot for Rubber Tapping Using Siamese Networks

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Abstract - *A robot has been designed for rubbing tapping purposes. Using this method, the economic cost for rubber tapping can be reduced and the safety of humans can be ensured who used to do manual tapping. Raspberry Pi, used is the main component responsible for all mechanical actions. The robot is pre-trained using the Maze solver algorithm. After successful training by the user, this robot uses a GPS module for identification of the location of the tree. Siamese network is used for image processing. Motor driver(L293D) is used to drive the motors and four twelve-volt batteries are used to power up the device.*

Key Words: Raspberry Pi, Maze Solver Algorithm, GPS Module, Siamese Network, Motor Driver

1. INTRODUCTION

The robot designed is an all-terrain robot. Along with Raspberry Pi, four geared motors, two 5-volt motors, and three 3.3-volt servo motors have been used. An ultrasonic sensor is used for object detection and calculation of the distance between the object and the robot. IR sensor used to calculate the height of the obstacle. A camera sensor is used for image processing which is achieved through Siamese Network. The mechanical design of the robot, stress analysis, and the materials used have been mentioned along with the working and explanation of the robot in the further part. All the images mentioned in this paper are only for reference and not to scale.

2.1 STRUCTURE

The proposed idea of an all-terrain robot has the simplest structure, making it easy to manufacture and it is highly cost-effective compared to other designs that are currently in the service. 90% of the robot is made up of Aluminium and the rest of the materials used are stainless steel. Rubber products and other materials used are discussed further. The structure of the robot is divided into four categories namely, Housing Block, Front Axle, Rear suspension., and Tapper house.

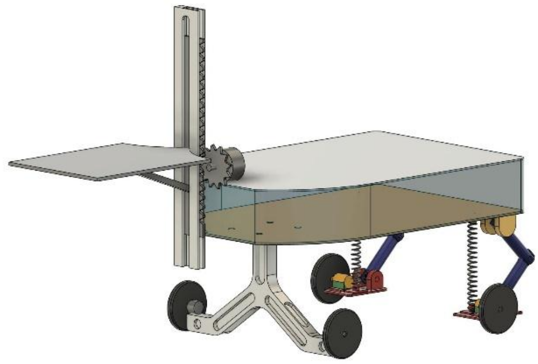

Fig -1: All Terrain Autonomous Robot for Rubber Tapping

2.2 HOUSING BLOCK

The Housing block of the robot is the epicenter area that connects all other divisions of the bot. The components present here are the top plate, bottom plate, and sheet metal cover.

The top plate and bottom plate are made up of aluminum which is of thickness 4mm. Isogrids are provided below the top surface of the plate to increase the structural rigidity of the plate. This has been done to resist the impact load which can fall on the bot unexpectedly, hence this provides great protection to the sensitive electronic components present inside the housing block. A guideway is joined to the bottom plate with the help of Intermitted Welds. At the rear side mounting, brackets at each end which are of U-shaped are provided with holes to mount the cylindrical links with the help of partially threaded bolts and fully threaded nuts of suitable diameter. Here the clamping region does not contain any threads and will be having a smooth curved surface. The entire Hosing block is covered with sheet metal of suitable thickness, except the region where rack and pinion arrangement is welded to the top and bottom plate. The sheet metal consists of ventilation holes for the circulation of atmospheric air to keep the interiors at optimum temperature. Stich wielding is done to join the sheet metal covering to the top and bottom plate throughout its perimeter.

Above the top plate, Servo motor which drives the pinion is placed and it is also provided with a cuboidal housing to safeguard it from external disturbances. Slotted holes are provided in the bottom plate to place the Electronic components according to their dimensions and they are provided with rubber seals and clamps so that they won't shake or vibrate during the movement of the robot. The bottom plate is provided with four holes at the guideway to assemble the front axle with the help of bolts and nuts of suitable diameter. Shock absorbers are present at the corners of the plate to absorb the shocks provided by Impact loads.

2.3 FRONT AXLE

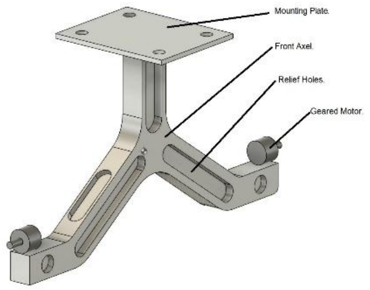

Fig -2: Front Axle

The Front Axle is one of the vital components in this robot. It is made of aluminum alloy which has a good amount of flexibility, which helps in crossing obstacles of inclined surface smoothly. The Front Axle consist of following parts, Y-shaped Axle, Rectangular plate, Geared motors, and Hose Clamps

The Y-shape indicates has 3-arms, one arm is connected to the bottom plate of housing block which is vertical to the surface and the other two arms are inclined 145° with each other and they are used to place the geared motor. Hose clamps are used to mount the geared motors to the horizontal surface on these arms. A Rectangular plate with four holes is welded above the top surface of the vertical arm. This is slid and locked with the help of bolts and nuts in the guideway present at the Housing Block. Rectangular slots with circular ends of suitable size are provided on every rectangular surface of Y-arm to reduce the weight of the Axle. Sharp edges are rounded to minimize stress concentration.

2.4 REAR SUSPENSION SYSTEM

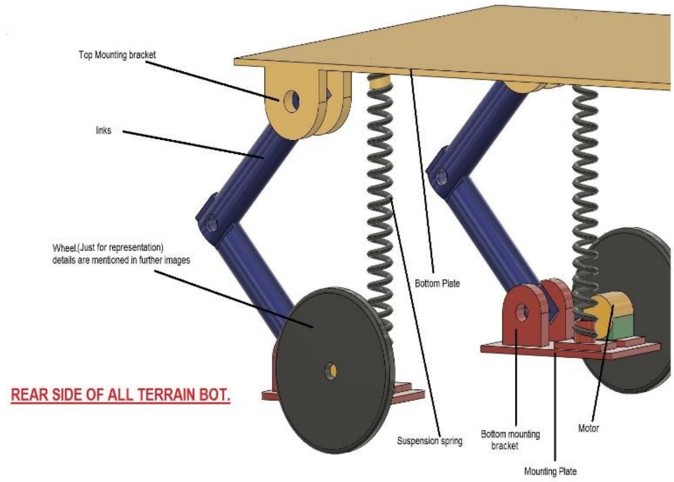

Fig -3: Rear Suspension System

The rear Suspension system is responsible to carry the rear wheels with a desired velocity and to give a smooth drive. The typical parts present in this division of the robot are geared motor, wheel, flat Plate compression spring, cylindrical links, mounting blocks, circular blocks for mounting spring, quarter circular blocks for mounting the geared motor, and U – shaped blocks for mounting the cylindrical links.

This system is connected to the bottom plate with the help of two cylindrical links which make 45° with the vertical initially. The length of both links remains same. When the wheel moves through the obstacle, the angle between the links will decrease and springs will undergo compression. The two cylindrical links will be connected with the help of partially threaded bolts and nuts providing a suitable circular smooth surface for small angular rotation. This is also true for the link connected to the mounting block below. The geared motor is connected to the wheel and the block as shown in the figure. The compression springs are having high free lengths, hence their stiffness is kept higher. The springs are of square and ground ends on both ends. The spring is of a tight fit to the circular block. The blocks have to be welded throughout the perimeter with the flat plate. The links are provided with rectangular slots or cut-outs for easy assembly.

2.5.1 TAPPER HOUSE

Tapper house is responsible for removing the woody surface present on the rubber tree to extract the latex from the tree. This can be subdivided into two parts Latex Extractor and Rack and pinion System.

2.5.2 LATEX EXTRACTOR

The latex extractor is one of the simple mechanisms which can be used to remove the wood material from the Rubber tree.

2.5.3 RACK AND PINION SYSTEM

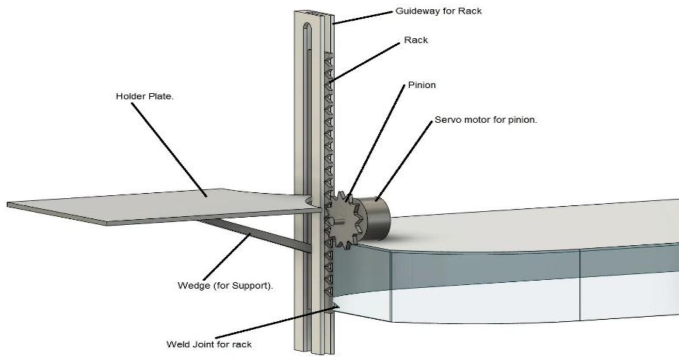

Fig -4: Rack and Pinion System

The Rack and Pinion system is used for vertical movement to position the cutter at a certain height. The Servo motor for pinion is present on the top of the top plate. The Rack and Pinion have a greater number of teeth's which helps them to position the cutter precisely. The Rack is placed inside the guideway. At the contact region of rack and guideway, there is a presence of rubber material that has high friction co-efficient. This is made to avoid the slip of the rack from the guideway while removing the material. The Pinion is also responsible to provide extra reaction force to keep the rack in position. The Rack is connected to a Holder plate on which the components of latex extractor are present. The holder plate is a small rectangular projection which is placed inside the small slot present in the Rack. They are joined with the help of the weld joint. A wedge connecting the holder plate and the rack is joined with weld joints to provide extra support so that the connection between rack and holder plate doesn't break.

2.5.4 FEA ANALYSIS OF HOLDER PLATE

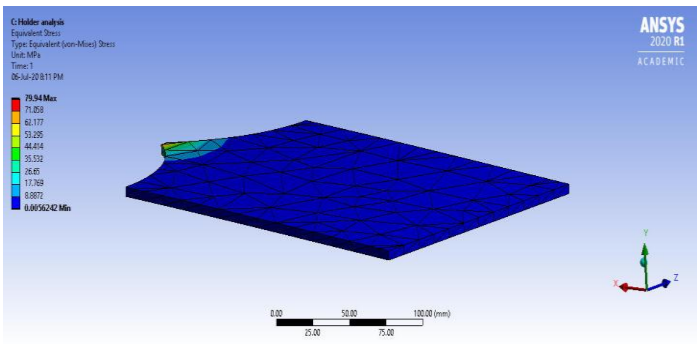

Fig -5: FEA Analysis of Holder Plate

2.5.5 CUTTING KNIFE

The cutting knife is made up of stainless steel with sharp edges. The hardness value of the knife varies from 58-62 Hrc (Rockwell hardness C-scale).

2.6 WHEEL DESIGN

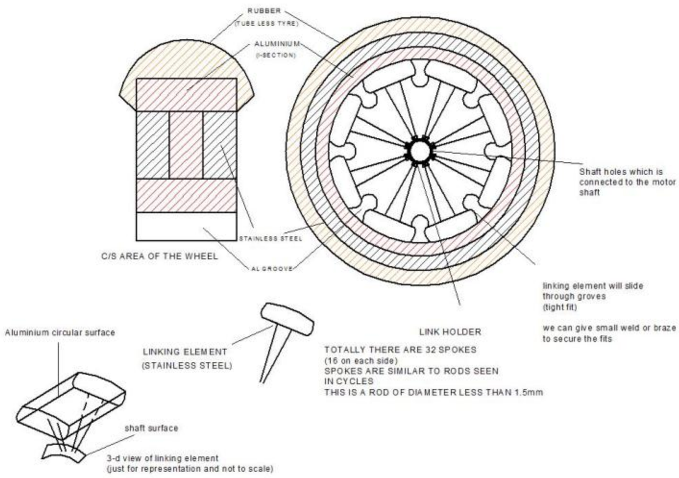

Fig -6: Wheel Design

3. WORKING AND EXPLANATION

The robot will be first trained. During the training period the robot will be trained according to the Maze solver algorithm and using a camera sensor the positions of the rubber tree will be trained, here positions refer to the coordinates of the trees.

Raspberry Pi will be powered on and it will check the geo-location (location of the nearest rubber tree) using GPS module and parallelly it will check the status of the battery, if the battery status is less than 20% a message will be played using the using speaker attached to the robot, telling the person that battery is low and ask them to Charge.

It checks the location, if the location doesn't match with previous locations that are stored during the training process, it will tell the user to train the robot because it's a new location to it. If the location was present in previous locations, it will load that map to the cache for further prosses. Once the map is loaded it will follow the path which is loaded and it will start creating a very displeasing sound indicating the movement of the robot.

Along with that it also checks the intensity of the external environment if it's dark it will power on high intensity led to avoid the harm caused by the animals on the robot and vice versa.

It has 2 ultrasonic sensors which are attached to 3.3 v servo motor which can rotate 180 degrees. One of them will be present on the front side and other in the backside of the robot for object detection and it calculates the distance between the object and the robot and it works similarly to the sonar. Only one ultrasonic sensor will be active at a time to minimize battery usage. For example, if the robot is moving in a forward direction only the front ultrasonic sensor will be activated.

If an object is detected camera sensor will be activated and it collects the images and Raspberry Pi will process this image and check whether it's a tree or not. If it's not a tree, the camera sensor will be deactivated and the IR sensor which is present near the bottom is activated and it checks the height of the object.

If it is small which the robot can climb, the robot will climb and move forward. If it's large which the robot can't climb it then the robot will move backward using another ultrasonic sensor which is present at the backside, till that object can't be recognized from the front sensor and from that point it uses bellman-ford algorithm to find another shortest distance to the next tree and using this it will reach the next tree.

If the robot wants to move towards the left side, left motors present both at the front and backside will rotate forward and both right side motors present at the front and back will rotate backward.

Similarly, when the robot wants to move towards the right side, both right side motors present at the front and back will rotate forward and the left motors present both at the front and backside will rotate backward.

Once it reaches the tree it will calculate the diameter of the tree using image processing and also it will check for the leaf shape of the tree and make sure that it reaches the correct destination after this it will activate the servo motors of the arm and place the arm on the tree and the arm taps the tree using the cutting tool.

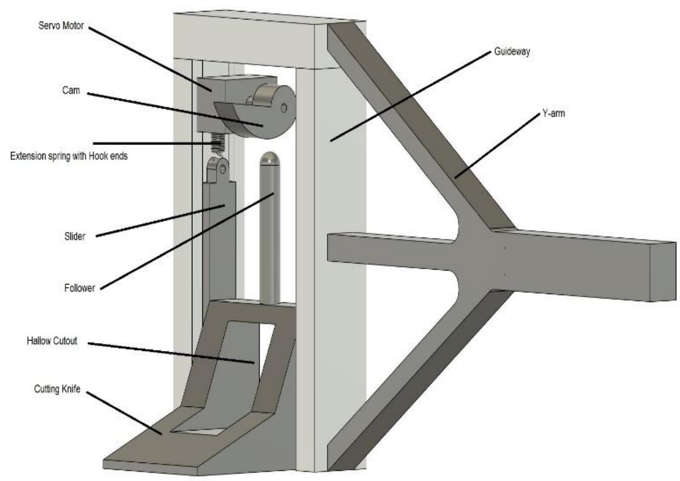

Fig -7: Cutting Tool

The cutting tool consisting of Cam, Follower, Guideway, Slider, Cutting Knife, Servo motor, and Extension spring. The follower is connected to cutting Knife through a weld joint. The guideway is in U- shape, the sliders are present on either of the guideway. A hallow cut-out is provided on cutting knife so that the removed material slides out through cutting Knife. One hook of the extension spring is placed at the top of the guideway while the other is placed on top of the slider. There will one extension spring per slider. Servo Motor is placed on one end of the guideway. As the cam rotates, the follower slides down, and work is done to extend the spring. This implies the cutter is ready to remove the material. After removing the material, the cam is rotated in opposite direction. Hence the follower will move up with the help of energy stored in extension spring.

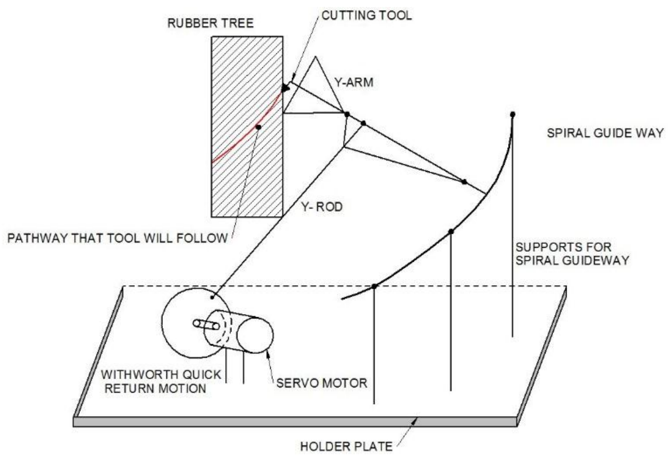

Fig -8: Line diagram of Latex Extractor

The latex extractor uses a spiral guideway with a low friction coefficient to move the cutting tool spirally which helps in the collection of latex efficiently. The spiral guideway is mounted to the holder plate with the help of three support pillars of different lengths. These are joined with welds. The spiral guideway and the cutting tool are connected with the help of an arm which has three spokes and these spokes are used to connect the tool. The tool is connected with the help of welded joints. To pull the entire tool, a Y-shaped rod is used.

Whitworth quick return mechanism is used as the drive mechanism. As the crank rotates, it will start pulling the rod and at the same time the cam will start rotating and will stop after rotating 85^0, but the rod will continue pulling and hence the wood material will start tearing off from the trunk. This operation is performed with low rpm to obtain smooth cuts. As the cutting is completed, the entire tool retraces its original path with a greater velocity. After this, the rack will move slightly downwards to remove the further material, and this operation repeats.

Once it's done the arm will be removed from the tree and placed back to its original position. The robot continues to move to other trees until the status of the battery reaches 20% or less than that. Once it reaches this condition the robot starts moving towards the starting point. If the status of the battery reaches 5% the robot will send coordinates of the current location to the owner using the GSM module.

Here we have used Siamese networks for image processing and load on the motor is continuously monitored using an ammeter. Initially, we give 50% of the power to the motors using the PWM (Pulse width modulation). If the load increases (when robot moving towards higher altitude) the voltage is increased till the current is in normal condition Also the voltage will be decreased when the load is very less (robot moving towards lower altitude) to save the battery power. The concept of multithreading is used for monitoring and controlling all the devices at the same time. Motor driver(L293D) to drive the motors and four twelve-volt batteries are used to power up the device.

4. CONCLUSION

The proposed idea of rubber tapping is using basic structural features and simple mechanisms to extract latex from the rubber tree. This Autonomous bot is different when compared to other products related to latex extraction which are available commercially. These products use one latex extractor per tree while this autonomous bot uses only one latex extractor for all the trees present on the farm. The maintenance of this bot is also easier and easily repairable with the basic tools available in remote areas. Hence the overall cost of extraction is reduced.

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