Fabrication of Robotic Tree Climber Prototype

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***Abstract*—Traditional coconut harvesting is labor-intensive and hazardous, prompting the development of automated solutions. This machine aims to alleviate these challenges by employing hydraulic pistons to simulate the climbing action of human harvesters. The system comprises a sturdy frame equipped with adjustable hydraulic pistons, controlled by an integrated electronic interface. Through precise control of piston extension and retraction, the machine mimics the intricate movements required for efficient coconut climbing. Light weight frame and 3 hydraulic pistons, the movement of the machine is fast. With a 360 degree camera on top of the machine, it can sense obstacles along the path and clear its way. Safety features, such as sensors to detect obstacles and automatic shutdown mechanisms, ensure user protection**

Keywords—labor-intensive, hazardous, hydraulic pistons, sturdy frame, obstacles

I. INTRODUCTION

In agricultural heartlands, a groundbreaking initiative – a tree climbing robot designed to address the challenges of harvesting coconuts and areca nuts. This device aims to redefine agricultural practices. The core principle involves using hydraulic systems to ascend trees, reducing the need for manual climbing. Picture a world where farmers no longer face the arduous task of climbing tall trees. This robot isn't just a mechanical marvel; it signifies progress, efficiency, and cost-effectiveness for farmers. With coconut trees being a common sight, this device has the potential to transform the lives of farmers nationwide. The tree climbing robot utilizes Pascal's law, where changes in pressure applied to a fluid are transmitted undiminished. In our context, this means fluid force propels the robot up trees. The societal impact is significant, extending beyond technology and agriculture. By aiding farmers with tree climbing, the robot enhances safety and well- being in the fields. Its design reduces risks associated with climbing, making it a silent ally for those dedicated to agriculture. The social benefits go beyond efficiency gains; the robot inspires a new era of farming practices. Its introduction encourages farmers to embrace innovation, leading to a widespread adoption of technological solutions in agriculture. This could usher in a new age of productivity and sustainability. Importantly, the project aligns with renewable energy principles, marking a stride towards environmental consciousness. The use of renewable energy eliminates the need for external fuels, aligning with eco friendly practices. Minimal electricity required for operation underscores our commitment to sustainability. Currently, no other device allows controlled tree climbing from the ground. This technological gap presents an opportunity for our project to establish itself as a pioneer in agriculture technology.In summary, our project is more than a technological feat; it's a testament to innovation transforming age-old practices. By leveraging Pascal's law and fundamental robotics, our tree climbing robot aims to revolutionize coconut and areca nut harvesting. This initiative envisions a future. where farmer toil is reduced, risks minimized, and inspiration fuels a new wave of agricultural progress.

II. MOTIVATION AND PROBLEM STATEMENT

The process of climbing and harvesting coconuts from coconut trees is an inherently challenging and labor-intensive task. In regions like Kerala, where farmers often plant 70-100 coconut trees per acre, the financial burden on coconut farmers becomes significant. According to surveys, the +current practice involves hiring climbers, with farmers having to allocate an amount ranging from 50 to 100 rupees for each tree. This substantial cost per tree contributes to a considerable financial strain on coconut farmers, affecting their overall economic stability. Moreover, the risks associated with manual climbing are not only financial but also pose a threat to human life. Climbing coconut trees is a hazardous endeavor, and the shortage of devices that can be controlled from the ground exacerbates this challenge. The limited availability of such technology underscores the urgent need for innovative solutions to address the unique demands of coconut farming, especially considering the substantial market reliance on coconuts in our country. In this context, the development of a tree climbing robot becomes crucial. Such a device has the potential to alleviate the financial strain on coconut farmers by offering a cost-effective alternative to manual labor

The project addresses critical aspects of agricultural harvesting by prioritizing efficiency, safety, and remote operability. The device aims to expedite the harvesting process, making it not only faster but also safer than traditional methods. The incorporation of advanced technology, such as hydraulics and robotics, ensures precise control and minimizes the inherent risks associated with manual labor. Additionally, the inclusion of remote operation capabilities enhances the overall safety and flexibility of the harvesting operation. Through these objectives, our tree climbing robot emerges as a transformative solution with the potential to significantly improve agricultural practices. The technical feasibility of this product is a testament to its practicality and benefits for farmers.

III. OBJECTIVES

Efficiency in Harvesting: The central focus of our tree climbing robot is to revolutionize the harvesting of coconut and areca nut trees, aiming for a significant improvement in both speed and safety compared to traditional methods. Traditional approaches are often perilous and time-consuming. By replacing these methods with our device, we intend to elevate agricultural productivity by streamlining and expediting the harvesting process.

Safety: The primary goal is to enhance safety in the agricultural sector by replacing manual labor with a climbing and harvesting robot. The design of our robot incorporates advanced hydraulic and robotic technology, offering precise control to minimize the risks of accidents and injuries associated with manual climbing. This transition to automated processes prioritizes the well-being of agricultural workers and contributes to a safer working environment

Remote Operation and Control: Another key objective of our tree climbing robot is to facilitate remote operation and control. By providing wireless remote control capabilities, operators can safely manage the robot from a distance, reducing direct exposure to potential risks. This feature not only enhances the safety of the operation but also introduces a level of precision and flexibility in controlling the harvesting process. The ability to operate the robot remotely adds an extra layer of adaptability, allowing operators to respond promptly to changing conditions and ensuring a more efficient and controlled harvesting operation.

IV. WORKING PRINCIPLE

The device's operational foundation lies in the principles of Pascal's law of hydraulics, coupled with basic robotics. The device's performance is mainly based on three parts: two clamping units and a motion unit containing two small horizontal pistons and one large vertical piston respectively. Both clamps are initially gripped to the tree trunk. Its functionality unfolds in a systematic manner: in the case of using a hydraulic system, upon initiation, the hydraulic pump from the hydraulic power unit (HPU) draws hydraulic oil from the reservoir and pressurizes it. This pressurized oil is then directed through 5/3 direction control valve to the horizontal piston cylinder which is connected to the upper clamp. Due to the flow of hydraulic oil to the inlet of the piston, it extends and releases the grip. In the next step, the pressurized oil is directed to the large vertical piston cylinder. Due to the flow of hydraulic oil to the inlet, the piston extends, enabling the upward motion of the device. Then, the switch is initiated to reverse the motion of hydraulic oil. The control valve or directional control valve is operated to redirect the flow of pressurized fluid from the actuators back to the reservoir. Likewise, by redirecting the flow of hydraulic oil on the upward cylinder piston, it retracts the piston at the upper clamp, and once more, it grips onto the tree. The same process for extending the upper horizontal piston is initiated for the lower one too, which enables the releasing of the lower clamp. Finally, the directional control valve reverses the flow of hydraulic oil in the piston cylinder at the motion unit, resulting in the retraction of the piston at the motion unit and further upward motion occurs. Then, reversing the flow of hydraulic oil on the lower horizontal piston enables gripping. Hence, a cycle of working is completed. This device can also work as a pneumatic system by replacing the HPU with a compressor and hydraulic oil with air. There is also a harvester setup consisting a arm and rotor enabling cutting motion. All these motions are controlled by Bluetooth wireless controller.

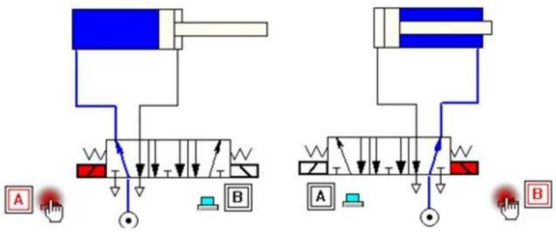


Fig.1 Showing flow of hydraulic fluid on the actuation of double acting cylinders, through 5/3 direction control valve.

V. DESIGN AND IMPLEMENTATION

This device consist of three sub systems: Robotic climber, Robotic harvester and Controller.

A. Robotic Climber

The subsystem responsible for climbing can be further classified in to three parts. Upper part, lower part, middle part. *Fig.1*.

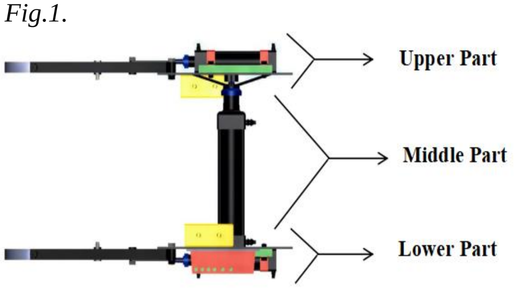


Fig.2.Robotic Climber

The upper part consist of a pair of grippers, horizontal hydraulic actuator connected to the solenoid valve, circuit board, and a power source. All these components are supported by a mild steel plate. The clamps made of mild steel with a diameter of 320mm and horizontal grippers (small) in size with specifications given in *Table.1*. The specifications regarding power supply for the device is given in *Table.2*.

Middle part consist of a double-acting vertical cylinder (large) with specifications given in *Table.3*.

Lower part consist of pair of grippers, horizontal hydraulic actuator connected to the solenoid valve and hydraulic power unit which specifications are given in *Table.4*

Name	Specifications
Outer diameter	35mm
Inner diameter	30mm
Pressure	7-10bar
Stroke length	120mm

Table.1. Specification of piston cylinder (small)

Name	Specifications
Power supply	12V 7 amp
Run time	40 min

Table.2. Specification of Battery

Name	Specifications
Outer diameter	55mm
Inner diameter	50mm
Pressure	7-10bar
Stroke length	160mm

Table.3. Specification of piston cylinder (large)

Name	Specifications
Usage/Application	Industrial
Power	2HP
Voltage	220V
Material	Mild Steel
Phase	Single Phase

Table. 4. Specification of HPU

B. Robotic Harvester

The incorporation of a sophisticated robotic arm, coupled with AI-driven cognitive capabilities, signifies a transformative leap in agricultural automation. By harnessing the power of machine learning, the system adeptly navigates the complex visual landscape of the coconut tree environment, culminating in swift and discerning coconut selection. Such technological prowess not only streamlines harvesting operations but also underscores a commitment to innovation-driven sustainable agriculture. In concert with its 360-degree mobility, the system represents a change in coconut harvesting methodologies, poised to elevate productivity while minimizing resource expenditure. In the prototype model the harvester is installed with cutter and arm which the arm can only move in 2 directions. Shown in *Fig.3.*

Specification of cutter installed is given in *Table.5.*

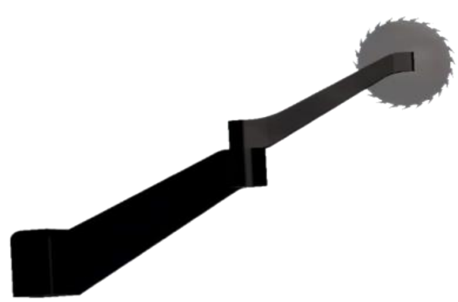


Fig 3. Robotic Harvester

Name	Specifications
DC supply	12V 90W
RPM	60
Gear type	Spur gear

Table 5. Specification of DC Gear Motor

C. Controller

In the described device, electronic integration plays a crucial role in orchestrating its various functions seamlessly. The Bluetooth receiver serves as the interface between the user and the device, allowing for remote control and operation. It receives signals wirelessly from a Bluetooth-enabled controller, enabling the user to initiate and regulate the device's movements and actions from a distance. The Arduino board acts as the central processing unit, interpreting the commands received from the Bluetooth receiver and coordinating the operation of different components accordingly. It serves as the brain of the system, executing pre-programmed instructions to control the direction of hydraulic or pneumatic flow, activate relays, and manage the overall functioning of the device. Relays act as switches, facilitating the transition between different modes of operation and controlling the flow of power to various actuators and components. They help regulate the timing and sequence of actions, ensuring precise and coordinated movement. The power supply provides the necessary electrical energy to drive the device's electronic components, ensuring continuous operation and responsiveness to user commands. Together, these electronic elements given in *Fig.4* enable efficient and user-friendly control of the device, and usability in forestry applications.

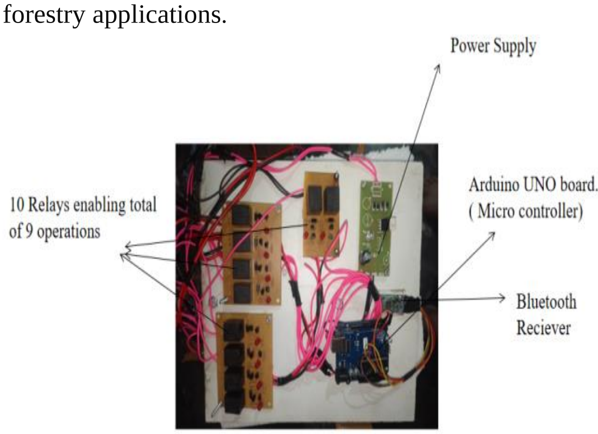


Fig 4.Circuit Board

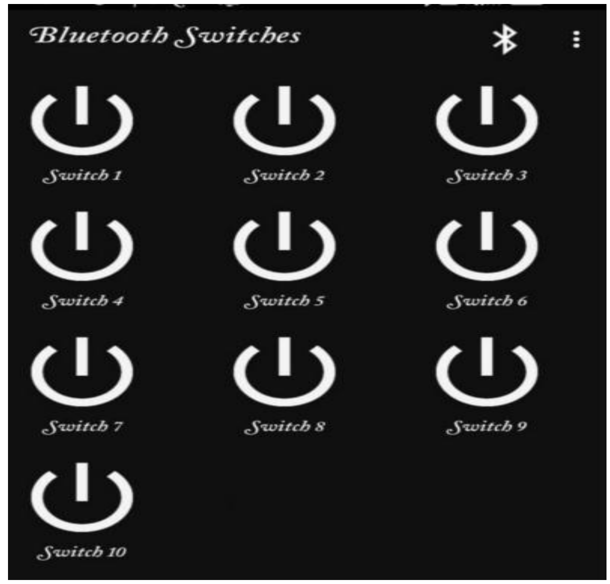
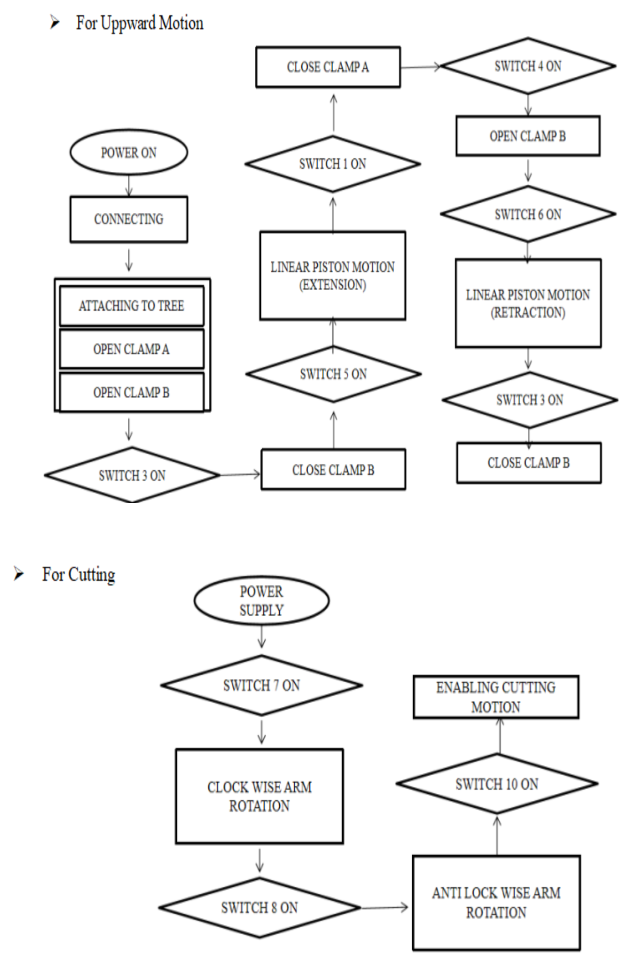


Fig 5.Control Panel

Operations and data flow is given in *Fig.6*



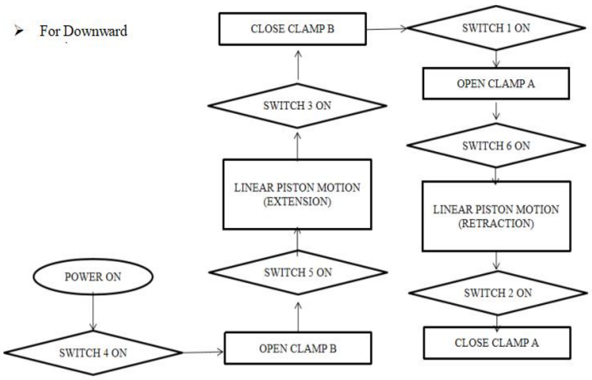


Fig.6. Operation and Data flow

VI. ANALYSIS

Analyzing the stress distribution in the device described using ANSYS software involves simulating the mechanical behavior of its components under various loading conditions. The device's frame, constructed from mild steel, and the piston cylinders, made of steel, are subjected to forces and pressures during operation. By importing the CAD model of the device into ANSYS, engineers can define material properties, boundary conditions, and loads to simulate real-world scenarios accurately. Through finite element analysis (FEA), ANSYS calculates stress, strain, and deformation within the structure, highlighting potential weak points or areas prone to failure. Factors such as clamping force, hydraulic pressure, and dynamic forces from motion contribute to the stress distribution. Engineers can iteratively refine the design based on simulation results to optimize structural integrity, minimize weight, and enhance overall performance. ANSYS facilitates comprehensive stress analysis, aiding in the development of a robust and reliable device capable of withstanding the demands of forestry applications.

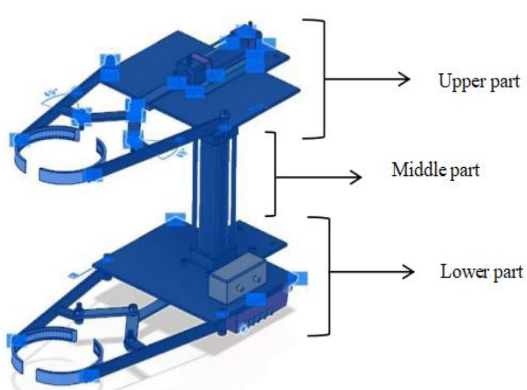


Fig.7.Frame of device

A. Stress Analysis On Upper Part

The stress analysis conducted at the upper part of the device using ANSYS software yielded reassuring results, indicating its structural integrity under operational conditions. With a maximum load specification of 15kg and a maximum stress threshold of 0.003 MPa, the analysis revealed that the device operates well within safe limits

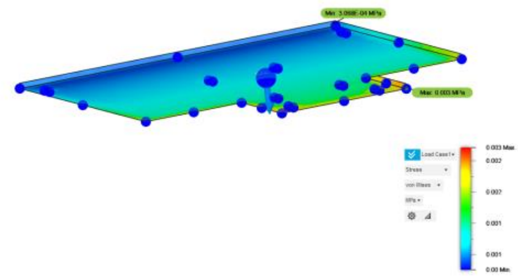


Fig 8.Stress analysis on upper part

B. Stress Analysis On Middle Part

The stress analysis conducted at the middle part of the device using ANSYS software provides valuable insights into its structural integrity and performance under load. With a maximum load capacity of 15kg and a maximum stress of 24.474 MPa, the analysis indicates that the device can withstand significant forces without compromising its functionality. Despite operating near the upper limit of stress, the device exhibits only millimeter-level deformation, showcasing its robust design and resilience under pressure.

Fig 9.Stress analysis on middle part

A. Stress Analysis On Lower Part

The stress analysis conducted on the lower part of the device using ANSYS software yielded insightful results regarding its structural integrity and performance under load. With a maximum load capacity specified at 15kg and a maximum stress threshold set at 0.002MPa, the analysis aimed to assess whether the device could withstand operational stresses within acceptable limits. The ANSYS simulation indicated that even under the maximum load condition, the stress experienced by the lower part of the device remained well below the specified threshold, ensuring that it operates within safe parameters. Additionally, the result highlighted that the deformation observed in the lower part due to the applied load was minimal, measuring only at the millimeter level.

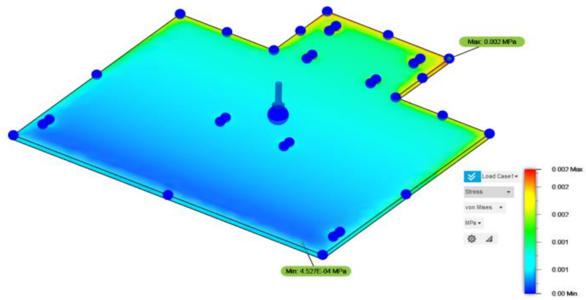


Fig 10..Stress analysis on Lower part

VII. FABRICATED PROTOTYPE

The completed prototype of the forestry device is a noteworthy accomplishment, seamlessly merging hydraulic principles with basic robotics for a versatile tool. Originally planned with a hydraulic power unit, cost constraints led to a switch to a pneumatic system, maintaining functionality while reducing expenses. Similarly, the robotic harvester evolved from a complex 360-degree arm to a simpler 2-DOF version for cost-effectiveness. Despite these changes, the core operational principles remain intact, utilizing pistons for gripping and maneuvering around tree trunks. The detailed 3D design preserves the essence of the hydraulic system and robotic arm. Incorporation of a Bluetooth controller allows remote operation, enhancing field usability. In summary, the prototype effectively marries hydraulic and robotic technologies, offering a practical, cost-conscious solution for forestry tasks.

Fig.11. Assembled Prototype

VIII. CONCLUSION

The "Fabrication of Robotic Tree Climber Prototype" project represents a groundbreaking advancement in agricultural technology, specifically targeting the challenges of coconut and areca nut harvesting. Combining hydraulic and robotic principles, the device prioritizes efficiency and safety for farmers. Strategic modifications and integration of electronic components ensure cost-effectiveness and usability. Though not flawless, its successful ascent marks a promising start, signaling potential for future improvements. Overall, this project exemplifies innovation and collaboration, offering hope for transformative change in agricultural practices, benefiting farming communities nationwide. nationwide.

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