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A Survey on Robotic Coconut Tree Climbers – Existing Methods and Techniques

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Abstract: As the coconut palm growers are struggling with the acute shortage of human coconut tree climbers to climb and harvest the coconuts, many are working towards possible alternatives to help them handle this situation. In this study paper we analyse the problems associated with the shortage of human coconut tree climbers in -depth. We also present details of various existing mechanical models available in the market and have not yet solved this issue. Along with this we discuss how robotics and automation could be a possible solution for this entire problem. In this context we discuss about the features of such robotic system and also give suggestions on various unmanned robotic models that can be designed and implemented.

Keywords: coconut tree climbing, harvesting, agricultural robotics

1. INTRODUCTION

Coconut is one of the cash crops in India. India is one among the top players of coconut producers in the world. But the coconut farmers and home grown coconut tree growers face lot of difficulties in getting manual coconut tree climbers to harvest the coconut. There is acute shortage of human coconut tree climbers not only in India but all over the world. Traditionally this job is taken up by the socially and economically backward people in India. As the literacy rate increases and India is growing economically, there are several high paid jobs which people move to. It also a risky job in which an accident might be fatal in some cases. Without proper insurance coverage, this could be a blow to the entire family if the climber is the lone person to earn and take care of the family. It is also found that people engage in this job for several years develop issues related to their skin.

So better solutions has to come to harvest coconuts since it is very risky job. The purpose of this paper is to discuss about various existing solutions available, their limitations and suggest solutions that could possibly be a complete one. The conventional way of harvesting is by climbing the coconut tree and cutting it. Because of the difficulties in climbing and harvesting process different methods have been developed. One is to use a mechanical aid to climb, another method is to use a robot for climbing and cutting. Robots are used for many purposes

and they are mainly used to replace human being while doing difficult and dangerous task. Now the technology has reached a level in which we can design variety of robotic system which can do different kinds of tasks like picking and placing, cutting, climbing, flying and swimming. This paper is a study paper that deals with climbing robot particularly coconut tree climbing robots. As coconut tree climbing is a tedious job robots can play a very good role in finding a permanent solution. There are different developments and progresses in this research field. The paper is arranged as follows – section II presents the motivation and the problem statement in detail whereas section III elaborates the recent research work in the area of coconut tree climbing and harvesting, all over the world. Section IV explains about the existing methods and section V gives suggestions on how robotics and automation could bring in a change in this field.

2. PROBLEM STATEMENT

Coconut and coconut products find variety of uses. Coconut and coconut milk is used for cooking. Coconut water is a healthy and refreshing drink. Coconut shells and husk can be used to make different household and flooring materials. Coir and stuffed mattresses are made from coconut husk. Coconut oil is another major product. It has a major role in Ayurveda treatment. Most of the ayurvedic medicinal oils are made from coconut oil. And we have plenty of coconut trees in our country and all over the world. The problem that we are facing is the harvesting the coconuts .The structure and height of the tree is the problem. It requires skilled labour to climb and also it is very risky job. If the person climbing the tree loses the hold on the tree or if he fails to grip when he reaches the top side, there is a chance that he may fall from the top. There comes the importance of a proper gripping mechanism that helps people to climb.

It is time that we look for alternate solution in which we can harvest coconuts without man power. Robotics and Automation could be a possible solution. We have to solve several issues like how the robots hold the tree, how much user friendly, how much durable etc. Different mechanisms has to be applied. Designing a vertical climbing robot is a difficult one than normal rover bots. And also the structure of the tree is also an important parameter to be considered. Tree cross sectional area may vary in each tree and it may vary in same tree from top to bottom. Height of the tree is another parameter which plays an important role in the case if we are controlling it from the ground. Proper communication channels has to be chosen for controlling the robot. Likewise there are so many parameters that has to be considered while designing such a system. This paper deals with different possibilities and mechanisms for harvesting coconuts.

3. RELATED WORKS

Manual harvesting is the traditional form of the coconut harvesting. Due to the height and the tree structure, coconut tree climbing is a very difficult job. It is only done by the trained professionals. The educated youth is not interested in this risky job. That's why the availability of the labour and labour cost became a severe problem for coconut tree farmers. There are so many coconut climbing machines available in the market, which includes sitting type and standing type. A person has to sit or stand in the machine fastened to the tree and exert considerable physical effort to operate the machine to take him/her up the tree. Traditional

coconut climbers use rope loop for the climbing. In both these types of devices the control and lifting has to be carried out manually.

In paper [1] the authors are proposing a standing type tree climber which weighs about 5-9 kg, a low-cost model, which is made up of mild steel, steel rope wire and rubber pad. In this climber the top and the bottom of the climber are looped with the steel rope wire. The user has to stand on the climber and lift it manually using steel rope. As the height of the tree increases the risk of using this climber is also high. The authors in paper [2] discuss about the prototype that they have developed for automatic coconut harvester, which contains a triangle structure with an arm and a cutter. Two springs are used for adjusting with the diameter variation of the tree. Only a prototype for climbing is developed and the testing of the arm is not demonstrated satisfactorily. In paper [3] a semi-autonomous coconut tree harvesting robot is proposed. There is no prototype but only the CAD model of the entire system is presented. There is no actual hardware implementation discussed. In paper [4], the design of an autonomous robot to climb the tree like an inchworm by using minimum sensors is elaborately discussed. The optimal path is selected with the sensors. An autonomous climbing algorithm is used guide the robot. Its mechanical construction is such a way that it can climb a tree of an irregular shape [4]. But this model is not suitable for coconut tree climbing robot as the proposed design discuss only about a robotic structure to climb a tree without carrying any load.

An image processing technique used for building a robotic model to spray pesticide on the top of the coconut tree is discussed in [5]. The coconut climbing robot discussed in this paper is holding the spraying system with 4 wheels of which two are used for support and 2 wheels for moving. This robot can accommodate only slight changes in the diameter. This can be only useful for spraying pesticides, not for coconut harvesting. A single prototype of this robot is developed but not a successful model. George et al. (2012) reported that a total of 35.5% (78 cases out of 220 climbers) fell down from coconut trees while doing their job. A 7.9% (19/240) of the tree climbers in the study area withdrew from their traditional profession and remained unemployed. Among them, only 5.3% (1/19) stopped climbing trees due to health problems and 94.7% (18/19) withdrew because of casualties that happened during their occupation [7]. An ergonomic coconut climbing device is developed in which the user can sit comfortably during climbing. Normally in these types of climbing devices, the centre of gravity of the user shifts outside of the body and hence the user feels uncomfortable and not shaky. This problem is avoided in the proposed model by modifying the upper frame of coconut climbing device and the downward inclination is obviated [6]. In the proposed device in [8] there exists two portions each of which contains a T gripper. Manual effort is required for the upward movement. The speed depends on the effort exercised by the user. An additional pedal is assembled in each section to hold the leg of the user. In addition to the T gripper a rope is also used [8]. The risk of using this climber increases with height. Autonomous tree climbing and pruning 9 DOF robot with 5 DOF puma arm is discussed in the paper [9]. This is only a concept paper in which there is no actual implementation discussed. The paper [10] proposed a palm climbing robot with fork arm for spraying insecticides or picking dates. The upward movement is controlled by 3 pneumatic actuators. Only the prototype details of the body is presented in this paper. There are no details about the implementation and testing of the arm.

4. EXISTING METHODOLOGIES

Manual harvesting is the traditional method for coconut harvesting. They use coir loop to hold the tree. There are two types of manual climbing, the front foot and frog-foot type. The front foot technique is very similar to rock climbing. The second method is frog-foot method in which the climber places the legs like a frog on two sides of the trunk. Multi-utility elevator platform, aerial access hoist are also used for coconut harvesting. The lack of availability of the labour and labour cost became a severe problem for coconut tree farmers. To avoid this problem so many climbing devices are developed and are available in the market. We discuss some of them here.

4.1 Tree walker - Standing type coconut tree climber

This is a standing type coconut tree climber. It is specially designed for the professional climbers. By using steel wire rope, it is possible to adjust with the diameter variation of the tree. So it can be also useful for climbing Areca nut to Palmyra Palm or even Silver Oak & Similar forestry trees. By using hands and legs one can move upward. These types of climbers are highly durable, anti-corrosive and dimensionally accurate. Full body safety is confirmed by additional steel ropes. For these type of products, maintenance is very low. This product can be used only by trained personnel and hence labour and labour cost problems still exist.

4.2 Coconut Tree Climber - Standing type climber with additional steel rods and safety

This is another type of product available in the market. It is almost similar to tree walker but the main difference is that in this 3 rods are used in two halves design discussed in previous model. Steel ropes are used for tying with the coconut tree. These type devices weigh about 10 kg. Unskilled persons can climb the coconut trees using this device.

4.3 Coconut Tree Climber - Simple single piece model

These type of climbers are only used by the professionals. In this adjustable belts are used for tying with the coconut tree. The safety is very less in these types of climbers. The upward movement is carried out by applying force to the pedal.

4.4 Appachan's coconut tree climber

Mr. Joseph also known as Appachan developed a coconut tree climber which is one of the successful models existing in the market. It can be used to climb coconut, palm, and areca-nut and can also be used to spray pesticides, harvest fruits and for experiments. It also works as the climbing tool for electricity department. This climber has high demand in South East Asian countries, Indian sub-continent countries, the Middle East Asian countries, African countries, southern Indian states, Oceania countries and Australia. This is safe and easy to use with fine gripping.

4.5 Coconut tree climber - Sitting type

In these type of climbers, the user can sit and control. Any person can use this machine. Ropes are used for tying with the coconut tree. The diameter of this loop can be adjusted using screwing mechanism. The weight of these types of devices is very high. The speed of the climbing device depends on the performance of the user. By applying force on the pedal the climber moves upward.

4.6 Multi-tree climber - Sitting, frame type

The multi-tree climber is sitting type coconut tree climber. This climber is operated manually by hands and feet. There are two metallic frames, one upper and one lower used for climbing up and down. Rubber grippers are used to get proper grip between the tree and the frame. It is a low weight sitting model coconut tree climber. This can be used by any person without special training. This device is durable, strong and easy to use. This climber can bear 100Kg weight capacity and can be used both in coconut and palm trees.

4.7 Multi-tree X5 climber (sitting type, manually operated)

This multi-tree climber can be used for climbing all kind of pole trees such as coconut, areca-nut, silver oak and palm without any risk. The climber can sit and manually operate the climber. This can be used even by nonprofessional climbers.

4.8 Multi Tree Climber XL Series

This is a sitting model coconut climber. The optimum quality multi climber is manually operated by hand and foots. Any unskilled person can use this. This lightweight climber is strong and easy to use. This is the simplest model of sitting type coconut tree climber. Sitting in this tree climber is not that much comfortable.

4.9 Advanced Coconut Tree Climber - Sitting, manually operated

This is a sitting type manually operated coconut tree climber. It has two parts upper and lower part. The user has to coordinate these two parts simultaneously by using hands and legs to climb. The sitting in this type of climber is very difficult for a normal person

5. FUTURE DIRECTIONS

Undoubtedly, there is a wide range of scope in the development of the many mechanical models of coconut tree climbing machines discussed earlier. Research can go into this area of making it an automated one which would not be so easy and soon, but can be of great help if achieved. Moreover, the latest advancements in the field of Robotics and Automation can be of a great help to achieve this task of taking the mechanical models to the next level. This transformation would meet some of the limitations and risks associated with the mechanical models. If the machine gets breakdown after reaching certain altitude of the tree, then the person travelling in it would have to face consequences. In addition to this risk, there is the need of human effort to make the machine. The mechanical work that needs to be done by a human to ascend the tree via the machine is too much. The advantage that the requirement of a skilled labor who has expertise in climbing coconut trees and bring coconuts down, falls short when effort of the person travelling is taken into account.

As per the Forbes New Industrial Revolution report, Dec 2015, Robotics is one of the top 5 technology trends that is driving innovation. Feb 2016, Fortune report the worldwide spending on Robotics will nearly double in 2019 and will hit $135 billion. Silliconangle.com reports that, “the agricultural industry is ripe for robotic revolution”. Robotics can provide a permanent and everlasting solution to the long standing issues associated with coconut tree climbing and harvesting. In this direction, we provide certain suggestions regarding the possibilities of the solutions when using Robotics and Automation to solve this issue. These suggestions are provided based on affordability, usability, durability, serviceability and safety.

Unlike paddy and staple foods that are grown only by farmers in fields, coconut trees are grown almost in all houses in southern India, except in cities. Many houses have backyards where sometimes 20 to 30 coconut trees are grown and the least, 1 to 3 coconut palm. So any solution to this issue should not only encompass the farmers growing coconut trees, but also the people growing this palm at homes. They too suffer from the same issue. The first and foremost feature of the robotic device is that it should be affordable. This is a very challenging issue for the designers and builders of this kind of robots. When advanced robotic systems are built, the Human-Computer Interface (HCI) is also going to be very advanced. This means that only trained personnel can operate such robots. So the HCI must be as simple as possible, easily comprehensible and rugged. In addition users should be able to learn with minimum training if required. Care should be taken to see that the users spend more on fixing several issues with the system rather than putting it to use. It shouldn't be a daily affair of the users to keep fixing the broken parts. As it is true with any product, the user should be able to see profit in buying and using this robotic system. At the end of the year, the user must not have spent more money in repairing and fixing issues with the robot than the original cost.

Any system built is prone to break down and wear and tear. This might be due to several reasons including human error, power system failure, low quality materials used etc. A system can be considered completely successful only if service can be provided so that any issue can be fixed. The user should not keep the system rusting away due to some minor issues. There must be proper service options available to the users to deal with any type of failures in the system. The design and implementation of this robotic system must be in such a way that it is safe for the users. Safety should be considered in two aspects – safety of the system and safety of the user. Service has to be carried out regularly to make sure the system is intact and doesn't break down and fall while climbing the tree. Safety measures must be strictly followed and user must have awareness about these measures. Considering the second safety aspect, the user must always operate the system at a safe distance so that even if the system breaks and falls down from the top of the tree, there is no injury caused to any person. In addition, this would also make sure the coconut bunches falling down doesn't harm anyone.

Taking into consideration all the points discussed earlier we propose that Robotics and Automation as a viable solution. The robot can be unmanned and sent to the top of the tree with a robotic arm attached which can cut the branch of coconuts. Cutting individual coconuts would increase the complexity of the system and a huge time consuming work. So this robotic arm should cut the stem of the coconut bunch attached to the tree. The robotic arm can be controlled using wireless technology so that the user need not be in the vicinity but can control from a safe distance or from a control cabin. Few methods to achieve this are presented here.

5.1 Telescopic Ladder Method

We have proposed similar model in our paper earlier [11] in which a telescopic type ladder is raised or lowered using a manual crank attached to it. At the top of the ladder is attached a robotic arm which can be controlled in wireless way using a smart phone or a wireless joystick device. The user can position the arm to which a cutter is attached to the stem of the coconut bunch. This could be one of the cheapest methods as no complex sensor technology or image processing technology is required. It could be easily transported and the user need no special

training to attach this system to the tree as it is going to operate independent of the tree. In this method, the stability analysis must be carried out and taken care as the ladder should not fall when it is raised to higher level.

Fastening Body Method

In this method an unmanned robotic climber body is designed which can be attached to the tree or detached from the tree. A robotic arm can be attached to this body and can be controlled using smartphone or joystick controller using wireless technology. The body climbs up or down along with the robotic arm to which a cutter is attached. A wireless camera can be attached to the body which can beam live video to a smart device on the ground so that the user can see the coconut tree structure at the top, with the coconut bunches. This can be extremely useful when used in taller trees. The cost of this model could be significantly higher as sophisticated actuators and embedded system based control circuit is required for the body to operate.

5.2 Closed Loop Control Method

This is similar to the Fastening Body Method with the exception that this is a closed loop system in which sensors are used to get feedback from the arm by the user so that the user is aware of what is going on at the top of the tree. This can even be called as haptics approach.

5.3 Fully Automated Method

In this approach the entire system is completely automated except that it has to be attached or detached to tree manually. With image processing technologies, the video of the coconut tree top with the coconut bunches attached to the stem can be used to find the depth and position of the stem of the coconut bunch. With this information and inverse kinematics the robotic arm can automatically cut the stem without the intervention of the user. If implemented with advanced image processing algorithms, this method could achieve very good results.

6. CONCLUSION

As agricultural robotics is bringing revolution in agricultural sector in all the developed countries, the developing nations like India should not miss out the opportunity to make use of such technologies and keep pace with innovations in agricultural sector. In this context we presented the study of various issues associated with human coconut tree climbers, which are the existing manual mechanical models available in the market, what are the limitations associated with them, how robotics and automation could possibly find permanent solution to all issues and finally some suggestions on the design of unmanned robotic coconut tree climber and harvester.

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