Kinect Based Wireless Robotic Coconut Tree Climber

Rajesh Kannan Megalingam, R Venumadhav, Ashis Pavan K, Anandkumar Mahadevan, Tom Charly Kattakayam, Harikrishna Menon T
Amrita Vishwa Vidyapeetham University, Amritapuri Campus, Kollam

***Abstract*—**The word coconut means the sitting sensation in the island paradise. In reality, a minimum of 5 - 6 billion coconut trees are harvested each year, with 12 million coconuts exported by Philippines and India, making them the largest exporters of coconut in the world. Also, coconut harvesting plays a very important role in the economy of many developing countries. Unfortunately despite its mass distribution and wide spread around the world, coconut harvesting is still done without proper safety measures which can lead to serious casualties. In this paper, we discuss various models for tree climbing and plucking. We have taken into account the safety, reliability, the ease of use which is capable of climbing trees, cutting down coconuts, cleaning the tree tops and spraying pesticides. This system is so designed that it can be controlled by anyone. A prototype of the arm has been designed and tested successfully, using Microsoft Kinect. The designed prototype responds to human gestures with negligible gap in the response time and hence can be implemented in real time**.**

***Index Terms*—**Kinect, Bluetooth, Wireless-camera, hexagonal structure, Ground Station, Robotic arm.

I. INTRODUCTION

COCONUT milk, coconut oil etc., are essentials in Indian households and the ingredients of most Indian as well as South East Asian delicacies. Coconut husk is used in the coir industry to manufacture carpets, ropes and similar items. With social status becoming a major concern in today's world, the percentage of population taking up coconut plucking as their means of living is steadily decreasing. Moreover coconut tree climbing involves a lot of risk. If the person slips, he will be falling from a great height. The accident might inflict irreparable damage to him and as well as his family as he might be the only bread earning member. Hence, coconut cutting is becoming a huge challenge for the agricultural industry. Our model is designed to suit and operate in any geographical terrain like seashores, mountaintops, or even valleys. The end product is fit to be used by any mediocre man with basic knowledge on operating an electronic device.

Our final model consists of six modules which are the ladder, a platform on which the ladder rests, the ground control, robotic arm with control logic, the camera and the cutter units. The chassis primarily consists of a platform which supports a ladder with a motion replicating arm.

Rajesh Kannan. Megalingam is with Amrita Vishwa Vidyapeetham University, Kerala, India (Ph: +91 476 2802305, rajeshkannan@ieee.org).
Venumadhav* (ak47.venu007@gmail.com), Ashis Pavan K, * (ashispavan@live.com), Anandkumar Mahadevan * andkmr93@gmail.com), Tom.Charly Kattakayam* (tomcharlyk@ieee.org), Harikrishna Menon.T* (harikrishnamenon@ieee.org) * All with Amrita Vishwa Vidyapeetham University, Kerala, India.

The ladder is adjustable with respect to the height of the tree and is manually controlled. The camera unit attached to the robotic arm continuously transmits video to the ground control unit, the robotic arm replicates the gestures of the hand of the user located at the ground control room with the help of the Kinect device. The platform is also movable in the horizontal direction and can be fixed at some pre-defined points.

II. MOTIVATION AND PROBLEM DEFINITION

Coconuts are still being harvested by a man simply climbing a tree without any protection. Although these people are quite good at what they do, there is still a 10 % chance of injury to these climbers. In addition, climbers (from 11 years and above) climb almost 30 to 45 trees per day making around 10 rupees per tree which sums it to 350 rupees (approx. 7 USD) a day which at present is not so promising. The seasonal nature of the job also extends uncertainties regarding job security. With millions of coconut trees within Kerala, there are only about a couple of hundreds of coconut climbers available, which at present is a big issue as coconut, in one form or the other, plays a vital role in most households.

The productivity of coconuts in India for the years 2008-09 and 2009-10 was 7747 nuts per hectare and 8303 nuts per hectare respectively. With the ever increasing demand for coconuts and the steadily decreasing percentage of manual cutters, this system provides a viable alternative. The risk factor involved in climbing coconut trees is reduced to a bare minimum. The system also aims at a low-cost and eco-friendly model which can be used even by illiterates and laymen. With effective use of this system, cost of coconuts can also be brought down thereby helping the common-man. This system paves way for technology in reducing economic and social hurdles.

IV. COCONUT AS PERVASIVE INGREDIENT

Coconuts are regarded to add flavor to all South Indian dishes especially chutneys and other traditional curries. Coconut milk, coconut oil and grated coconut are used in many dishes not only in India, but also in many South East Asian nations to enhance their taste and nutritional content. Many small scale industries in South India make handicrafts out of coconut shells and coconut husk, which are sold in the global market. Coconut tree leaves are used to prepare brooms which are quite cheaper and are used in many Indian households instead of plastic broomsticks. Most people from economically backward class utilize coconut leaves for roofing their homes. Coconut husk supports the coir industry which manufactures mats, ropes, carpets and exports them to the global market. The water inside the tender coconut, popularly known as *ilaneer* is regarded as a health drink in South India and consumed by people to restore the blood glucose levels during diarrhea.

III. RELATED WORKS

Although there are many existing tree climbing robots, there are currently no robotic devices for climbing and harvesting coconut trees in specific. Worcester Polytechnic Institute came up with a basic tree climbing robot with a six legged design where they also tried comparing the various robots used for climbing trees and walls [1]. MIT graduate students also developed a device to harvest bananas in a class known as "2.009" which is slightly more related to our project [2]. One drawback of these robots is that they take much longer time to climb a tree than humans. In India too, we have a coconut harvesting device, which ensures the user's safety and speeds up the process. However, this device still requires a person to physically climb the tree and therefore does not properly address the need of the hour.

IV. COCOBOT MODELS

After analysing the previous research works on this topic [3], we came up with the indigenous models – the Hexagonal wired model, the Hexagonal Kinect based model and the Kinect Based Ladder models. Certain modules are common to all these Coco-bot models:

1) Ground Station:

The wireless video camera attached to the robotic arm continuously transmits live video of the coconut position. The user can perfectly position the cutter of the arm to cut the coconut by monitoring this video. Power supply for all the modules including the cutter control is provided from 230V mains. The whole system can be monitored solely by a person.

2) Robotic arm:

The robotic arm system consists of mainly two components- the arm unit and the controller unit. The arm unit consists of robot base, links, joints, motors, joint detecting sensors and end effecter. The control unit consists of microcontroller, motor drivers, joint detecting sensors, power unit, and a processing unit that allows an operator to program the robot and control the actuators accordingly.

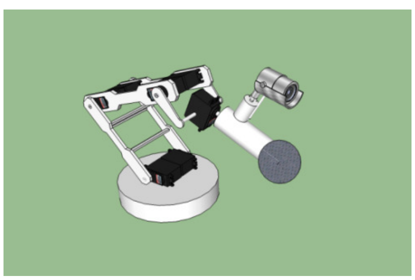

Fig.1 Robotic Arm

3) Camera Unit with Wireless Transmitter:

The camera used in the robotic arm is having a wireless transmitter and receiver which avails Bluetooth technology. The video transmitted by the model is received at the ground station where it is connected to a monitor. The image of the coconut is clearly projected on the monitor. It helps to decide when to move the hand and triggers the cutter. Bluetooth system provides efficient transmission up to 50m. The following paragraphs describe the modules which are used only in the corresponding models.

A. Hexagonal Wired Remote Controlled Fixed Ground Station Model (Cocobot1)

1) Modeling of Hexagonal Structured Climber:

As the name indicates, it is hexagonal structured, where each side of the hexagon consists of a motor and a wheel. Grippers are attached to it so that it would be fixed to the tree trunk. The climber unit consists of a hexagonal base, adjustable links and adjustable joints whereas the controller unit consists of a microcontroller, motor drivers, power unit and a command signal which is used for the direct movement of the climber.

B. Hexagonal, Wired, Kinect Controlled, Fixed Ground Station Model (Cocobot2)

Even though there are various methods for controlling a robotic arm like using a joy stick, glove based sensor control, both of the former methods requires carriage of loads of cables, heavy contact devices should be worn and generally expensive sensors that connect the device to a computer respectively. The approach we have used here is the vision based technique, that neither requires sensors nor wearing heavy contact devices on human body parts. Instead, it uses camera, infrared sensors and image processing techniques to interpret the received image. The hexagonal structure is used for the climber because it is adjustable to each coconut tree. We can even use voice commands to move the hexagonal structure up, down or stop its movement.

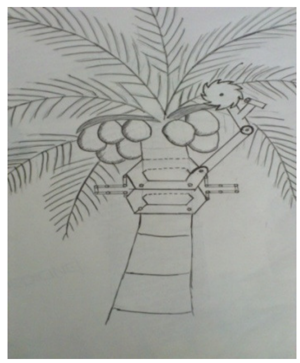

Fig.2 Hexagonal, Wired, Fixed Ground Station Model

1) Kinect capturing the arm position:

The position of the arm is detected using camera system. The distance will be calculated with reference fixed to a point which would be analogous to the base of arm. Instead of using two cameras we have used the Kinect module which measures x and y coordinates using RGB camera and measure z coordinates using Infrared sensors which will calculate the depth. The skeletal data acquired by Kinect is accessed using the Kinect SDK from Microsoft Corporation.

2) Working of Climber:

The Kinect recognizes the motion command from the user and differentiates between move-up, move-down and stop signals. The microcontroller receives the signal from the transmitter following which; the receiver part generates signals to control the actuators. For example, if the command "up" is given, all the motors will move in the counter clockwise direction and the climber unit moves up. To get accurate results, noise should be removed using speech recognition.

3) Kinect controlled Robot Arm:

The Kinect infrared sensors capture the frame-wise information about the user from the sensor. The RGB camera captures the movements of the user. This information is used calculate the joint angles by using forward and inverse kinematics. Once the joints angles are obtained this data will be transmitted to robot and the receiver would analyze the transmitted signal. The microcontroller generates signals to control the actuators. The transmission and reception is done through wired cables.

C. Kinect Controlled Fixed Ground Station Model with Adjustable Ladder (Cocobot3)

Both of the previously proposed models, had the disadvantage of a hexagonal model, which is much too heavy for climbing and the system is mostly wired which makes it expensive to install and maintain by common man. Hence we go for this model which puts forth a manually controlled adjustable ladder in place of the hexagonal climber which is controlled by means of a crank. The adjustable ladder along with the Kinect, module the efficiency over control and compactness of the model can be multiplied.

1) Coco-bot Model Details

The model consists of a stationary ground station, an adjustable ladder fixed on a platform, a hand with a cutter fixed on the ladder, a camera with a wireless transmitter and receiver, and power supply.

2) The Adjustable Ladder with the Arm

For implementing the ladder model, the platform on which the ladder is placed should have a wide base, which can support it. The ladder has a manually adjustable crank alongside it for it's up and down motion. It is designed to be adjustable to each tree as each tree has different shape and hence cannot be automated keeping in mind the structure of a single tree. The platform rests on wheels which makes it easily transportable. The ladder is adjusted to the tree manually.

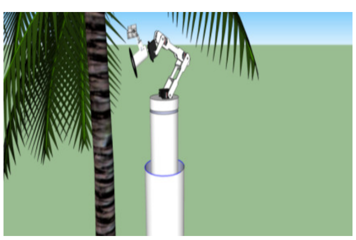

Fig.3 Adjustable Ladder Model with Fixed Ground Station

D. Kinect Controlled Mobile Ground Station Model with Adjustable Ladder (Cocobot4)

1) Movement of the ground station along with ladder*:*

If the ground station is implanted, it would be difficult to transfer data using Bluetooth as its range is about 50 meters. It would be highly improbable to move the power unit every time we move to the next coconut tree. Hence, the ground station is fixed to the ladder, which adds more weight to the ladder unit.

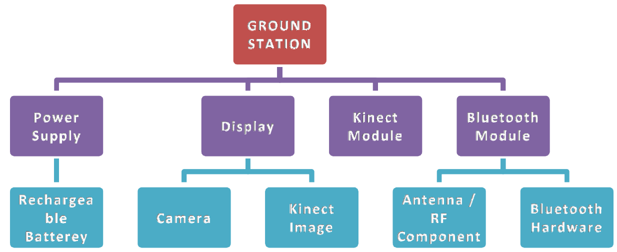

Fig.4 Complete Block Diagram of the Ground Station

To reduce the weight factor, we are going for high performance, light weighted batteries like lithium ion batteries. The rest of the model design is similar to that of the previous one which doesn't require any modification.

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Fig.5 The Proposed Adjustable Ladder Model

V. POWER SUPPLY

There are two modes of power supplies - wired and wireless mode. In case of fixed ground station model, 230v AC supply is the main source of power, whereas in the mobile Coco-bot model we have rechargeable batteries for power supply. The power is used to operate the Kinect module, the cutter as well as the wireless transmitter and receiver of the camera.

VI. ANALYSIS OF DIFFERENT COCO-BOT MODELS

A. Cocobot 1:

The Initial cost of implementation of this model is less. The chassis is fixed on the trees which make it easier to maintain its balance and further manipulation is done using the joy stick. Since this model is a wired model, maintenance cost of this system will be high. Also the speed of the climber is not at all appreciable. Moreover wires, cables and components require more space for implementation. Internal damages in the wires will be difficult to diagnose and also if the model gets stuck on top of the tree, it has to be brought down manually, making it very difficult for the user.

B. Cocobot 2:

The joy stick model used for coco-bot 1 required lot of wires making it difficult to handle. When replaced with a Kinect module, it not only reduced the wiring but also improved the interaction between user and the robotic arm making it much more user friendly. Mobility of this model gets restricted due to wires and hence it is not ideal for provisional network setup. The speed of this model is a major concern where it takes about 15-20 min to climb the tree making it time consuming for the user.

C. Cocobot 3:

The adjustable ladder model can be easily controlled and operated as compared to the hexagonal model which has to be wired all the way down to the ground station. The hexagonal model which was too slow in propagating is made faster when replace with this model. The ladder model is comparatively faster, as it is manually controlled and can also be adjusted to the structure of the tree. The ground station being immobile gives out the strength of the wireless signal transmission only up to a few meters, which is not feasible.

D. Cocobot 4:

Since the ground station is mobile, wireless data transmission and reception becomes easier. Similarly the Power consumption is also very less making it feasible for the user. The major attraction of this model is that it is very easy to maintain and the speed of the propagation is very high compared to other 3 models.

TABLE I
COMPARISON OF VARIOUS COCOBOT MODELS

	Cocobot1	*Cocobot2*	*Cocobot3*	*Cocobot4*
Mode of control	Wired	Wired	Wireless	Wireless
Power consumption	Very High	High	Low	Low
Speed	Very Slow	Slow	Fast	Faster
Cost	Moderate	Moderate	Low	Low

VII. COMPARISON OF WIRELESS TECHNIQUES

Wireless area networks have different categories like personal area networks (WPANs), Local Area networks (WLANs) [9], Wide Area Networks (WWANs), Metropolitan Area Networks (WMANs) [10] and Global Area Networks (WGANs). IR transmission [8] uses light in the Infrared region of the spectrum for transmission purposes. Transmission is possible only if transmitter and receiver are in line of sight, low data transmission range, cannot penetrate opaque objects. Wi-Fi has a range of about 20m indoors and a greater range outdoors [4]. WWANs such as GSM, CDMA have wider reach as compared to that of the local area networks [5]. WIMAX, a fourth generation technology, aims at giving high bit rates of 30-40 Mbps with the latest update providing upto1Gbps. Bluetooth [6] has a range which is dependent on power, based on which it is divided into different classes. Different data rates as per version [7]: Version 1.2- Up to 1 Mbps; Version 2.0 + EDR - Up to 3 Mbps; Version 3.0 + HS - Up to 24 Mbps.

VIII. HEXAGONAL, WIRELESS, KINECT CONTROL

The final model of the Coco-bot incorporates all the features required for hassle free and efficient performance of the setup. This setup can be implemented in all the models except Cocobot1, and is adaptable to any contingencies. The model described here consists of a similar chassis as described in the above design. The advantage of this design is the better control we have over the robotic arm that is controlled using Microsoft Kinect. This improves the dexterity of the entire model as the arm is designed to imitate the gestures of the controller's arm. The design can be segregated into three modules.

A. Kinect data processing

At the ground station unit, the gesture data to be send to the Coco-bot is obtained through the joint position obtained from the Microsoft Kinect. The device tracks 20 essential joints out of which tracking 4 joints enable the controller to stimulate locomotion of arm of the Coco-bot.

Kinect gathers the color and depth information using the RGB and Infra-Red camera respectively. The Kinect SDK then uses this data to recognize a human blob. It then creates an approximate skeleton of all the limbs of the blob detected. From this, the Kinect can make out the location of the various joints (hands, neck, head, etc.) of the human body. The SDK then provides this information about the joints in an event that is fired regularly based on the camera frame-rate. The data from the Kinect SDK is processed using Microsoft Visual Studio 2010.

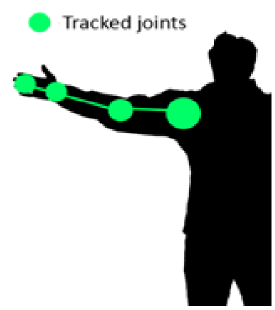

Fig.6 Joints tracked for robotic-arm control

The program is such that it identifies the shoulder-elbow joints, elbow-wrist joints and wrist-hand joints as three-dimensional vectors. Various joints are shown in Fig.6. The program is run at a frame-rate equal to that of the Kinect camera and the angle between these vectors, obtained using dot-product, and gives the angles that the joints of the humanoid should move. These angles are then driven to the Arduino board through a serial port. The Arduino board is connected to a Wi-Fi shield. The controller-side is equipped with monitors for analyzing the visual data send from Coco-bot through the dedicated Wi-Fi network setup in the area.

B. Structural Design

The body consists of a hexagonal chassis with 6 wheels and 6 motors for climbing up the tree. The chassis has a semi-circular track on which the arm in mounted. This enables the arm to rotate about circumference of the tree trunk to chop-off coconuts hanging at any orientation.

The initial design of the Coco-bot was carried out by designing of the arm and successful testing of the arm in laboratory. The response lag while using Kinect to control the arm was found to be negligible.

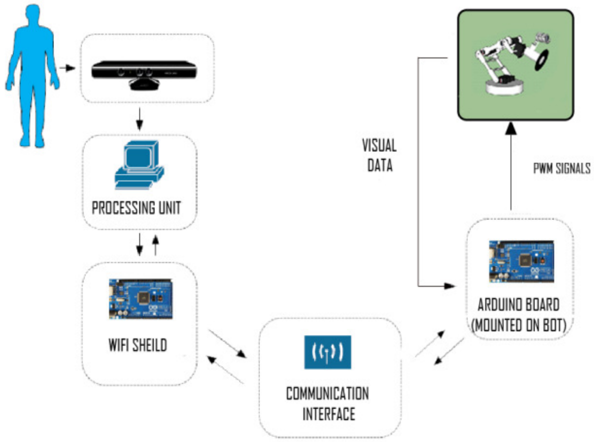

Fig.7. Hexagonal, Wireless Kinect Controller System

1) Prototype

The prototype arm was built using aluminum plates cut in shape of rectangles and L-angles as shown in Fig.8. The plates are connected at the required positions using 3mm diameter screws. The joints of the arm are replicated using servo motors i.e. three servo motors at the shoulder for the three degrees of freedom; two motors one at elbow and the other in between the elbow joint and shoulder joint to account for the twisting of the elbow.

Fig.8 Prototype of the arm to be mounted on the Coco-bot

The blade to be attached to the wrist of the arm is a driven by a DC motor of high rpm. Cameras are aligned close to the blade to provide a better view of the orientation of the coconuts.

C. Communication interface

The interaction module acts as the link between the controller and the humanoid side. It is required to setup a dedicated network for transfer of control signals from the controller-side to the humanoid-side simultaneously with the collection of visual and other analog data from the humanoid cameras and sensors and make it available for the controller-side for analysis. Wireless interaction enables remote functionality of the robot.

IX. CONCLUSION

Constraints present in models are overcome gradually and Kinect Controlled Mobile Ground Station Model with Adjustable Ladder is supposed to be the best among all models. The adjustable ladder is much easily controlled and operated as compared to the hexagonal model, which has to be wired all the way down to the ground station. The ladder model is comparatively faster, as it is manually controlled and can be adjusted to be apt for the structure of each tree. The advantages are low maintenance and minimal power consumption. Low power consumption of the module is helpful for us in the operation of our model. Since our machine has to continuously work for hours, it should have components which consume the minimum power. The Kinect module justifies its selection by enabling a faster and easier arm control methodology. It simplifies the process of the motion of joints. The Bluetooth wireless technology consumes less than 15mA which is best suited for our need and transmission is done with the help of short wave-length radio waves in the ISM band from 22.4-2.48GHz.

X. ACKNOWLEDGMENT

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