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Haptic Solutions for Agriculture

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***Abstract*—Haptics is a new technology which can be incorporated with many of the robotic control devices such that the operation of the device become more user friendly. In many cases, the control device will be in a remote place so the user will not get a proper idea about the device which is being controlled. Even if there is a video feedback, it may not give the proper information to the user, but while using the haptic device the user gets proper force and vibration feedback. So user will be more aware about the operation which is being carried out. This technology if we bring to agricultural field especially in the case of harvesting, sorting and packing, we can perform the task more effectively without damaging the fruit or vegetable. This paper is a study on the possibilities of using haptic technology in agricultural applications. And also about a prototype implementation of haptic device using Raspberry Pi board as a controller.**

Keywords—haptics, agricultural robotics, force feedback, sensors.

I. Introduction

In haptic technology it uses the sense of touch along with robotics. Nowadays all the industries related to agriculture are making use of the robotics technology to make their work more simple and productive. Also the number of people who are interested in farming job is less but the demand for production is more because of the increased population. In agricultural field also robotics has a very good role. Almost all the stages like planting, watering, weeding and harvesting is now has a robotic solution. But application of haptics is very rarely seen. Haptic technology can be used very effectively in agricultural field for controlling the robotic devices. Haptics has already introduced to many areas like medical field, defence, nuclear experiments and where ever there is a need for user to control from a distant place. In most cases the haptic system will have one master and slave part. The master part will be the part that the user is controlling. The slave part will have the end effector and sensors for feedback. The master part will be providing the force feedback to the user using some actuators according to the sensor information [1].

II. Various Applications of Haptics in Agriculture

For agricultural applications there are many areas where we can apply haptics. Main area is harvesting .There are many other areas where we can apply haptic technology like, planting, seeding, crop selection etc.

A. Crop Selection

There are many existing robotic systems that are used for identifying the crops. Most of them are wheeled robots which can move on the ground in between the plants. And it will be having multiple degree of freedom robotic arm with a high definition camera to identify and pick the fruits. In all of these systems the target size, shape and colours are identified by using image processing tools [2]. Another method is mimicking robotic arm controlled by a master device, the master device captures hand gestures of user using Kinect [3]. So in this case we can see that the ripe fruit is identified only by its colour and size. And in some cases target may be hidden in between the leaves. And for better efficiency and working, the plants has to be grown in a particular pattern such that the robot can move and reach in between the leaves and detect maximum number of fruits. The problem with existing methods is that it uses only the vision based techniques for automating the process. It does not use any other kind of sensors. Also for some crops we will not be able to grow the plants in a desired pattern. So the fruit may be hidden in between the leaves, the image processing method fails to identify the crop. In Such cases if we go for a haptic device, then we can search in between the leaves, we can identify the shape and size. Also we can hold the fruit and check whether it is ripe or not. The haptic device can give force feedback according to the force sensor readings at the end effector. So we can search the fruit in between the leaves.

B. Cutting

Next important task is cutting the crop from the plant. In normal cases it will be done by an expert farmer, he knows very well, how to apply force and where to apply it. For Some crops we need to cut the stem and for some fruit we need to pluck it by rotating or applying some amount of force. If it is a normal robotic arm it may not be intelligent, but in the case of haptic harvesting the user can easily do it with a touch feel on the control device. For example if we harvest coconut or if we cut its leaves or bunch of coconut we need to know exact force required for cutting and we need to apply the same required force. And if we consider the case of harvesting the fruits and vegetables, the cutting should be carried out very carefully without damaging the fruit and other parts of the plant. There is one other method used that is cutting the fruit using a laser light. For that they will be holding the fruit using a two fingered gripper which is having force sensors on it. The end effector will be holding the fruit and the sensor will measure the force acting on the gripper, so that the fruit will not get damaged. If we use multiple fingered gripper then it will be difficult to grasp the fruit without damaging the other parts of the plant. And the problem with laser cutting is that it can cut unwanted parts also [4]. If we use haptic technology in such cases, we would be able to harvest the fruit very effectively. Because we can feel the cutting process while performing the same. And with that sense of touch and force, we will be able to harvest the fruit remotely by applying the exact force required. Then the process will be more error free. The cutting tool can be attached with a force sensitive device, a current sensor, and a vibration sensor .The force sensor can measure the force which is being applied. And a vibration sensor can measure the amount of vibration happening while cutting. Sometimes the cutting tool may stuck at some obstacles, during that time the actuator at cutting side will draw more current, This condition can be measured by a current sensor. All these measured data can be transmitted to the haptic device and the haptic device can give proper feedback using corresponding actuators.

C. Underground Harvesting

Till now we were discussing about the harvesting the crops above the ground level. When we see the underground harvesting there are few robotic solutions for harvesting, but now here haptics is used. One example is harvesting of white asparagus which requires highly skilled people for harvesting. The existing technology uses camera to identify the crop. The camera identifies the part above the ground level and after identifying an air spray system clears the dust and the griper will collect the crop [5]. The existing system may fail in identifying all the crops, because it may be hidden under the ground level. So a haptic device which can search for the crop in the sand will be an effective solution for this. If the crop is present then a needle like end effector with force sensor can give proper feedback through the haptic device. So in this case the vision based techniques will be a failure but using a force feedback end effector we can easily identify the crop.

D. Planting, Seeding and Digging

Currently available systems for planting and seeding are the robots which are moving on ground and they will be digging into the ground and it will be placing the plant or seed. There will be sensors to detect the edges and the correct path to move. At a particular distance gap the robotic arm will be placing the seed [6]. While sand digging is going on the end effector may be subjected to different range of forces because of the difference in the soil and may be because of the unwanted objects in the soil. Also we need to handle the plant or seed very softly. If the robotic arm used for this is haptic device then the user can very easily handle the same from a remote place. Doing this job on the farm manually during extreme climate condition is a difficult task. So remotely controlling using a haptic device will be a great advantage for the farmers.

E. Training of Farmers

Currently there are no agricultural tools that is having the haptic technology incorporated with it. And it is not yet used for the training purpose of the farmers. Now haptics has come to training applications also. We can see that haptics is used in many other fields for training people. One example is tweezer simulation for surface mounted device soldering. In this system they use a force sensitive resistor to measure the minute force acting on the tweezer. And this can be used to train the school children to develop soldering skill. In this system the feedback is given by a vibration motor [7]. Another example is a carpentry training tool which has a graphical user interface where we can select the tool and we learn how to use it. Virtually we can feel the force acting on it [8]. There are variety of tools and machineries used for farming. User can very easily study operation of all these using haptic technology. And incorporating haptics to all these to different applications will make the system more user friendly. The Main advantage is that the educated people will also interested in farming. Now that is the most important issue that we are facing. All farming community are getting educated and they go for other jobs. If we incorporate this to agriculture we can expect more people in this field. So for each tools we can have a master slave system where the farmer can control it from a remote place. For training purpose the haptic device can have a graphical user interface based system where the farmer can simulate all the tools for agricultural applications. He can select any tool from the graphical user interface and use it virtually.

F. Tissue Culture

In order to increase the production rate and quality most of the laboratories are being automated. Robotics has come to many of the biotechnology applications. But we can observe that there is no haptics involved in their applications. We can also incorporate haptics into biotechnology applications like tissue culture. The processes like cutting and transplantation can be very effectively done by using haptic devices. It can handle soft particles with required amount of force. Even we can use the technology to train the students. Main advantages are we can do the process without human interventions and it will become more contamination free.

G. Transplantation

Transplantation is one of the step in agriculture. Most of the time the transplantation has to be carried out during the initial growing stage itself. Which means we need to handle the plant very carefully. There is no existing system which measures the force for holding the same. But there are systems for transplanting the plants. One example is rice sprout transplanter. Which uses pluck and drop mechanism but there is no mechanism to take any haptic feedback [9]. Since we are handling with soft plant parts it is advisable to use haptic enabled plucking mechanism. So while it is collecting the plant it will give proper feedback to the user. We can use very sensitive force sensors at the plucking unit such that the plucking operation can be done safely without damaging the plant.

H. Floriculture

Flower harvesting requires a highly skilled and experienced labour. The skill includes identifying the flower, determine its quality, identifying the position for cutting and cutting then storing without damaging the flower. And it has to be done with minimum time [10]. There is a paper that discussing about the same where they use Stereo vision technology and Tomography for performing the same. And to Increase the process speed one solution is a Matlab based flower harvesting technology. After taking the picture they will do some pre-processing and image processing after that there will be some classification based on some parameters. After that they use some morphological process and finally the harvesting will be done [11]. There are lot of processes involved in floriculture like bulb removal, bunching the flowers, defoliating the flower. All these processes should be carried out very carefully. Without any touch feedback, if we rely on some automatic vision based techniques, there are chances that the flower may get damaged. So it is advisable to use a touch feedback using force sensor.

I. Quality Testing

Most of the existing methods are vision based methods, that will not be reliable all the time. One example is machine vision based quality testing [12]. They use high definition camera and some algorithms to take decisions. Completely depending on the image processing is not good. So it is better to go for a haptic enabled solution. Now the people are more interested in quality of fruits and vegetables. They are ready to pay more if the product is having high quality. We can use haptic tools to check the quality of the fruit. We can introduce a haptic enabled interface for checking the condition of the crop. Some of the fruits which are ripe will not stay long. And by holding the crop with specially designed haptic arm can identify whether it is ripe or not. A graphical user Interface can display the condition of the crop.

J. Sorting and Packing

After harvesting and testing the quality of the crop, it has to be sorted and packed very carefully there are different sorting methods for different fruits and vegetables. One example is neural network based machine vision system for pomegranate harvesting in this system. In this method first image acquisition is carried out, then using wavelet de-noising, quality of the image is upgraded, then spatial and frequency parameters are taken. Finally if we compare the results of spatial and frequency components, results from frequency components is more favourable. But the accuracy depends on the sample images that we have taken [13]. During the process of sorting and packing, if we rely only on image processing there is a chance of getting the crop damaged. The system may not be intelligent enough to calculate the exact force that has to be applied. If haptics also incorporated in that then person can directly do the operations. He can feel the force which is acting on the crop. So the user will have a very good control over the same. So he can decide how much force he need to apply for the same.

III. THEORY AND DESIGN

Normally the haptic system will be having two sections. One master device and a slave device. Master device will be the one which the user is going to deal with. And it will be the controlling part. The slave device will be working according to the commands from the master. Fig. 1 shows the block diagram of the master slave system which we developed and tested. At each side to control the operations, we have central processing units. We are using Raspberry pi as central processing unit. And for communication purpose we are using Wi-Fi. The advantage of using Raspberry pi is that, it has inbuilt Wi-Fi module. And to take encoder readings we are connecting arduino board to both central processing units. Arduino alone cannot be used for data processing and plotting graph. For that it needs a central processing unit. So we use a combination of both Raspberry pi and arduino at both side. Master side encoders will be reading the position values and the master arduino will send the values to the slave arduino. These values will be sending through Bluetooth. At Slave side when these arduino gets the position values, the servo motors will start working to reach the final destination. So the slave robotic arm will be working as per the position values from the master. Since the Bluetooth communication is password protected unauthorised access is prevented.

Along with the operations the vibration sensor attached at the slave side will be continuously measuring the vibration and if it crosses a threshold it will send command to the master. Whenever it gets that command, we get a vibration feedback at the master haptic device. For that there is a vibration actuator at the master side. So user can feel the exact vibration that is there at the slave side. Also we are measuring the current at the end effector. If slave device hits on any obstacle then the actuator will get extra load and it will be drawing more current. This variation in current can be detected by the current sensor. So that the user can identify what is happening at operating side which is not clearly visible to the user.

And to reduce the error in controlling the arm we are attaching rotary encoders at slave side, it will be sending the values corresponding to the servo motor angle. The rotary encoders at master side will be transmitting the angle values to the slave. And at slave side, to ensure that whether it reached correct angle or not, we have another set of rotary encoders. That values will be transmitted back to the master side. So that both values can be compared to detect error in position. Since both arduino boards are connected to the raspberry pi, we can access both board from a remote place and even we can change the code in arduino. If we want to plot the sensor values as a graph we can change the code in arduino by accessing the raspberry pi through Wi-Fi. It can be done from our mobile phone or from our personal computer all should be connected to the same Wi-Fi network. And after changing the code in arduino we can see the sensor value plot at the master side monitoring screen. There will be a camera at the slave side for video streaming. The video can be also monitored at master side. And to give force feedback to the user the master device is having a servo motor gripper to restrict its motion. There is a distance sensor attached to the slave, if there is any obstacle it will send a command to the master. When this command is received the griper will turn on and we will not be able to move the haptic device. This gripper at master side will be closed when any obstacle is detected at the slave side. So the user cannot move the haptic device, this will be acting as a force feedback in the device. At slave side we have robotic arm with servo motors which are controlled by the slave central processing unit. We have current and vibration sensors attached in this part.

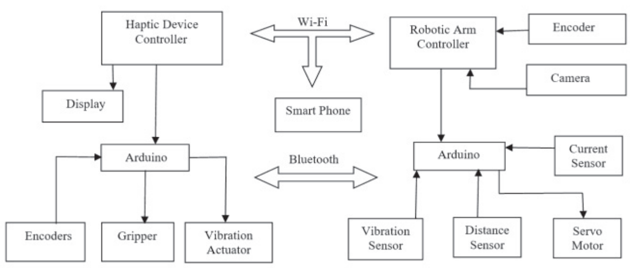

Fig. 1. Block diagram

IV. RESULTS

Using the master slave system we are able to control the robotic arm very easily and also we are able to receive the live video. We can see both sensor value reading and live video feedback of the slave side operation. Similarly we can see all sensor values at ground station as a plot with x axis represents the time and y axis represents decimal value equivalent of the voltage measured by sensors.

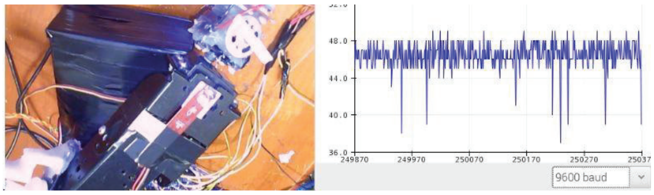

Fig. 2. Vibration sensor output without vibration

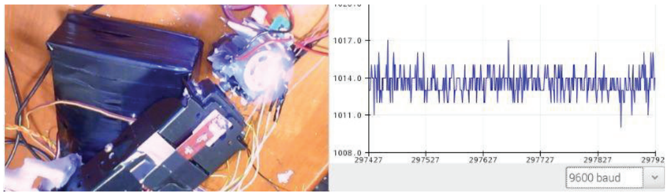

Fig. 3. Vibration sensor output with vibration

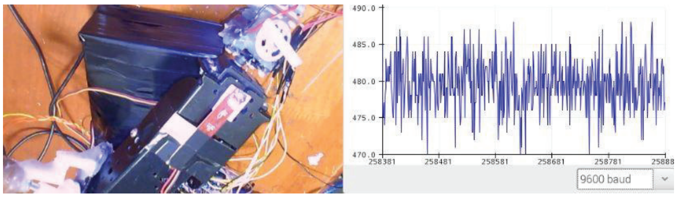

Fig. 4. Current sensor output with less current reading, load not applied

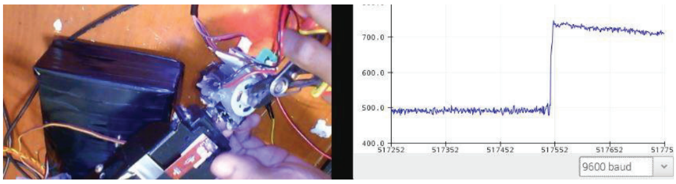

Fig. 5. Current sensor output with more current reading, load applied

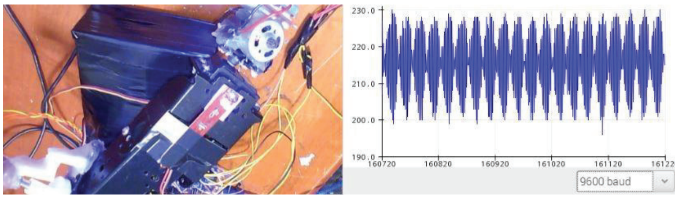

Fig. 6. Obstacle sensor reading without obstacle

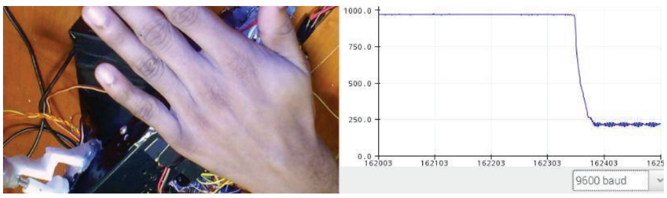

Fig. 7. Obstacle sensor reading with obstacle

The voltage value will be between 5 volts and 0 volts. There is an analog to digital converter inside arduino. It is a 10 bit analog to digital converter. So it will be mapping the 0 to 5 volt value to 0 to 1023. This value will be shown on the y axis of the plot. Here in Fig. 2 we can see vibration sensor gives low output voltage, there is no vibration. And gives high output voltage when there is vibration, it is shown in Fig. 3. Here the value shown is more than thousand, it means it is nearer to 5 volts. Similarly when load current increases current sensor output voltage increases. When we apply load on actuator the current drawn will be more, we can see this in Fig. 5 where we are applying load on the actuator and the current reading is more. But in Fig. 4 there is no load applied and current reading is very low. Apart from current sensor we have obstacle sensor to detect any obstacle in front of the robotic arm. Current sensor can detect any obstacle after hitting with it ,by measuring variation in load current. So to detect the presence of obstacle before hitting we use obstacle sensor. Fig. 6 shows the slave side monitor when there is no obstacle in front of the robotic arm and Fig. 7 shows the values of obstacle sensor with obstacle.

V. Future Works

In this paper we have discussed some of the possibilities of applying haptics in agriculture. And we have seen one prototype of a haptic device where we tested the force feedback and sensor value streaming via wireless communication. In future we are aiming for a complete haptic device which is having proper force feedback and a user friendly graphical user interface. And using the same technology farmer can very easily control the device from a remote place. For that we need a higher level processing unit and a good software platform like robotic operating system (ROS). So the next level implementation will be using ROS. And we will be able to interface more number of sensors to the system.

VI. Conclusion

As we have conducted a study on haptics in agriculture especially in harvesting application, we could see that it is very rarely used in this field. But it is having so many advantages and future scope. And with this technology user can very effectively control any harvesting device from a distant place. And he can feel like as he is really using the device. Finally the agricultural robots incorporated with haptics technology will be able to handle the crop with minimum damages.

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