2017 ASABE Robotic Competition Report

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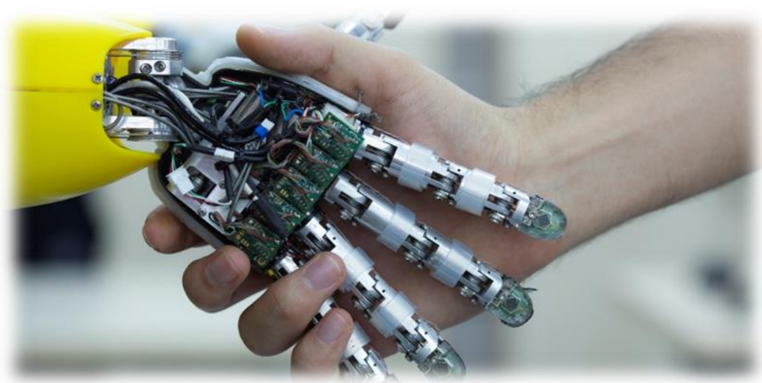

Abstract: The purpose of this study is to examine the robot created by Huskerbots Robotics Team for the 2017 ASABE Robotic Competition in great depth and to educate the future competitors that will be representing the University of Nebraska Lincoln about the process of this competition. The concept of creating machines that can operate autonomously dates back to classical times, however research into the functionally and the potential uses of robots did not grow substantially until the 20^{th} century. Robotic Technologies are used to develop machines that can substitute a function or a set of tasks for human beings. In today's world, Robotics is a rapidly growing field and a topic of discussion in many crowds. As technological advances continue; researching, designing, and building new robots serve various practical purposes, across different fields of study, one of which is Agriculture. According to research, agriculture account for 12% of Washington state's economy as it has a particularly large share of domestic raspberry crop, producing 95% of the nation's raspberries. A biennial raspberry crop is typically managed through manual pruning and herbicide application. As the farmers have the desire to cut labor costs and use less chemicals on their crops; this has opened many doors for new methods of accomplishing these necessary productions.

Keywords: Autonomously, Design, Research, Manual, Desire, Production.

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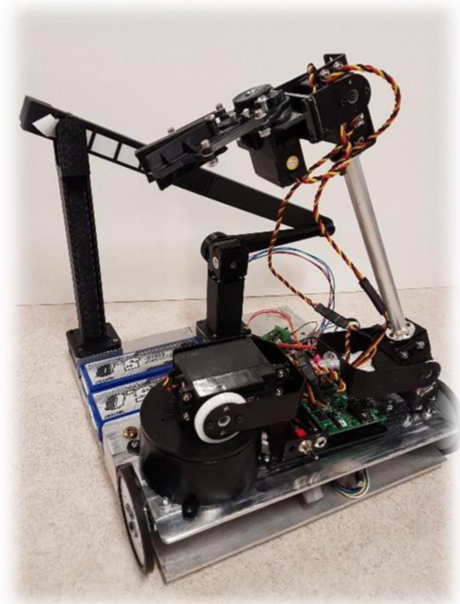
INTRODUCTION



This report follows the design and assembly of an autonomous robot developed by HuskerBots team for the ASABE Robotic competition which took place in Spokane, Washington on July 16th to 18th 2017. The challenge of this year's competition was to simulate a full raspberry primocane suppression and selective floricane removal pruning operation using autonomous robots. The competition required the participating teams to design robots which can identify raspberry primocanes and floricane, selectively cut irregularly distributed primocanes and floricanes to a given row density and remove the cut plant from the rows to clear debris. Basic Rules for the competition Include:

- Fully autonomous Robotic Mechanism
- Canes must be cut, not pulled, and removed from the board
- Robot must fit within a 12" cube before and after the competition
- Robot must stay on the board (Figure 1) at all times during the completions

Objective: The objective of this report is to study and understand the design of the mechanism. The robot can be divided into 3 main parts:

1. Image processing 2. Robotic Arm 3. Mobile platform

IMAGE PROCESSING

Image processing is a method that uses mathematical operations to convert an image into digital form in order to enhance that image or to extract some useful information from it. This is knows as a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image. Usually Image Processing system includes treating images as two-dimensional signals while applying already set signal processing methods to them. Images are also processed as three-dimensional signals with the third-dimension being time or the z-axis.

Image Processing is among the rapidly growing technologies in today's world with its applications in various aspects of a modern science as well as business while it also forms core research area within engineering and computer science disciplines too.

Image processing basically includes the following three steps:

1. Importing the image with optical scanner or by digital photography.

2. Analyzing and manipulating the image which includes data compression and image enhancement and spotting patterns that are not to human eyes like satellite photographs.

3. Output is the last stage in which result can be altered image or report that is based on image analysis.

The Robot developed by Huskerbots team does the task of image processing using an RGB camera. More specifically an (Raspberry Pi Camera Module v2, Raspberry Pi Foundation) is used to take a top view image of one zone at a time. In order for the camera to be moved to the desired position to capture the image of the canes, the team had designed a crank arm capable of contracting back and forth to fit to the dimension of the robot. After the crank arm has moved the RGB camera to about 9 inches above the surface level, Image processing algorithm is used to detect empty spots, and the canes. Color based segmentation and classification is used to classify the canes into green (weak) and yellow (strong) canes. Once the color of the canes is determined, an array with 4 rows and 6 columns is created with the information about all 24 points in the grid. The camera intrinsic are used to estimate the extrinsic parameters with respect to the cane grid. This information is used to calculate the coordinates of the canes relative to the robot arm. The Coordinates are then sent to the robotic arm so they may be cut if they follow the rules that have been defined in cutting the canes. The process is then repeat at each zone.

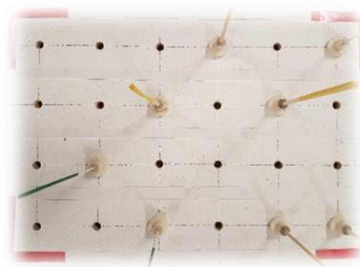


Figure 1. Point of view of the RGb camera

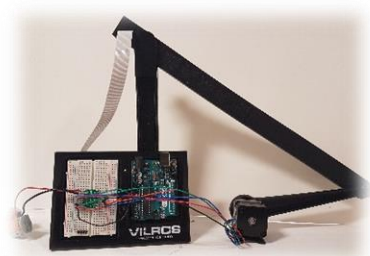


Figure 2. The crank arm

It is worth mentioning that in modern sciences and technologies, images has gained much broader scopes due to the ever growing importance of scientific visualization . Examples of such include microarray data in genetic research, or real-time multi-asset portfolio trading in finance. Microscope image processing specializes in the processing of images obtained by microscope.

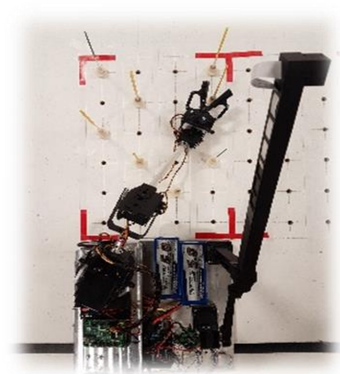


Figure 3. Crank arm working with the Robotic arm

Robotic Arm


Figure 4. An articulated six-axis robot

A robotic arm is a programmable manipulator that is comprised of segments connected by rotary and linear joints. These joints allow for controlled movements. Tasks that utilize robot arms depend on accuracy and repeatability. These applications typically require repetitive motions.

There are several types of robotic arms. The most flexible design is articulated and has between four and six axes. Articulated robot models boast a variety of work envelope sizes and maximum payload capacities. Tooling is attached to the end of the robot arm to move, position, and otherwise manipulate a part. The work envelope is the area a robot arm can reach within its normal range of motions. Maximum payload is the highest amount of weight a robot arm can safely carry and manipulate. It includes the weight of any additions to the robot arm, including the tooling.

Articulated six-axis robot arms are available in a range of sizes. Heavy-duty articulated arms perform applications such as spot welding and automotive assembly. They deliver consistent results with pinpoint accuracy. Smaller tabletop arms are integrated into material handling applications such as electronic assembly. The versatile mid-range robot arms perform other applications, such as arc welding and painting.

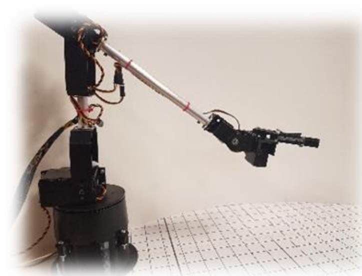


Figure 5. The robotic arm

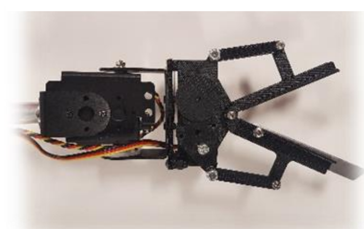


Figure 6. The cutting mechanism

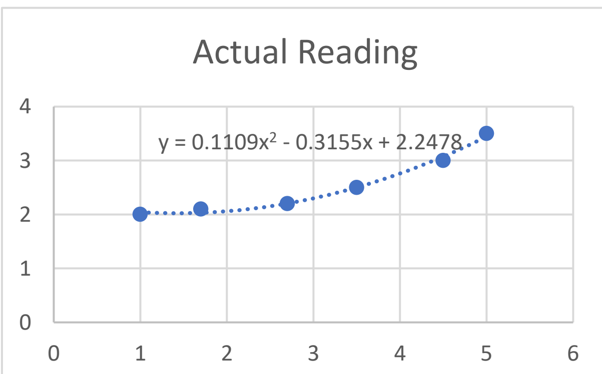
The Robotic arm that is used for the competition is a Lynxmotion AL5D. This mechanism is driven by five hobbyist servos, and a custom-designed cutting tool, all powered with a 5V lithium batteries. Motors are controlled using a Lynxmotion servo controller, and commands are sent to this board via serial communication from the Arduino Mega Board.

To accomplish the pulling of canes, the following tasks are necessary:

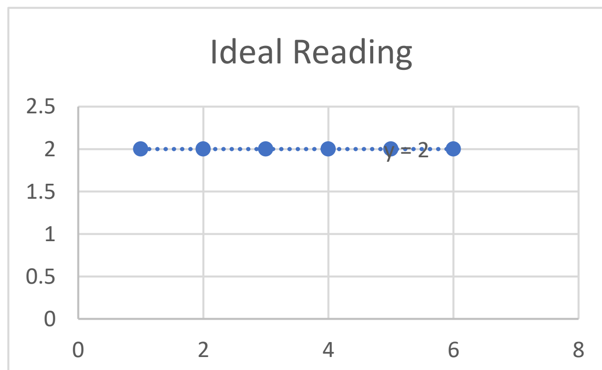
- Data representing the canes present in the adjacent zone is received by the Arduino Mega from the vision system.
- Cane data is analyzed to determine which canes can and cannot be pulled
- A kinematic model of the robot is used to solve for robot joint angles (servo positions) necessary to reach the desired point in space of each cane to be pulled
- Robot servo positions are translated to the data format readable by the servo controller and sent, executing the process of cane removal

Calibration of the Robotic Arm:

In order to be assured that the robotic arm would reach the desired position of each cane and perform the cutting process, we had to perform several calibrations. Calibration in measurement technology and metrology is the comparison of measurement values delivered by a device under test with those of a calibration standard of known accuracy. Such a standard could be another measurement device of known accuracy, a device generating the quantity to be measured such as a voltage, or a physical artefact, such as a meter ruler. As you can see in the graphs below the ideal reading when the arm is commanded to move only in the Y & Z-axis would be a straight line which depicts a straight path. However, our actual reading suggested that as the arm moves in the Y-direction there will be a decrease in the Z-coordinates which would be more likely due to the loadings on the arm. To overcome this problem, we had to use a different approach and make several changes to the inverse Kinematics of the arm so that every time there is an decrease in the Z-axis, it calculates the amount of error and so increase the Z-axis by that amount so the arm moves in a straight path just as it would on an ideal reading.



Graph 1. The Actual reading of the robotic arm's position



Graph 2. The Ideal reading of the robotic arm's position

The outcome of the comparison can result in no significant error being noted on the device under test, a significant error being noted but no adjustment made, or an adjustment made to correct the error to an acceptable level. Strictly, the term calibration means just the act of comparison, and does not include any subsequent adjustment.

Inverse Kinematics

In order to understand what inverse kinematics is, it is good to know what forward kinematics is all about first. Calculating the current coordinates of a robot's hand is easy. Forward kinematics refers to the use of the kinematic equations of a robot to compute the position of the end-effector from specified values for the joint parameter. To do this, we just need to look at each segment of a robot's arm–the coordinates of the segment's base, the direction of the joint's axis, the angle between this segment and the next one, and the length of the segment–in order to calculate where the end of this segment is. Repeating this with each segment and we would determine the hand's position. This is called forward kinematics.

Now the robot's arm must adjust each joint's angle in order to move its hand over the cup. This is quite the opposite of the previous calculation - here, we start with a given position and want to know how to rotate each segment of the arm. It turns out that this is much harder than the forward case, however there are several different approaches available for solving such problems, which are as follow:

1. The algebraic approach: This basically works by solving matrix equations.

2. The geometric approach: The idea is to combine knowledge about the robotic arm's geometry with suitable trigonometric formulas.

3. The numeric approach: Take a guess and look how far we are off, It then moves one or more segments to locally minimize the error. The Process is repeat.

In order to get the desired coordinates, the geometric approach was used. For this case, the team derived the geometric equations by hand using the laws of cosines and law of sines. The numerical approach was also used for improving the accuracy of the robotic arm's position.

MOBILE PLATFORM

The frame that supports an artificial object in its construction is known as the chassis. Chassis also provide protection as well as stronghold for the components to be placed at. An example of a chassis is the underpart of a motor vehicle, consisting of the frame. If the running gear such as wheels and transmission, and sometimes even the driver's seat, are included, then the assembly is described as a rolling chassis. In an electronic device, the chassis consists of a frame or other internal supporting structure on which the circuit boards and other electronics are mounted.

The mobile platform in the robot developed by Huskerbots team consists of two high power high reduction geared DC brushed motors with encoders and one free-to-rotate steel casters to provide sturdy foundation and enhance the motion smoothness. By moving with encoder feedback, allowing the platform to move with precision in term of displacement and straightness, the encoder feedback also allows the platform m to steer and turn with differential rotation across the two motors. The high reduction provides high resolution up to 10,884.47 encoder counts per revolution with high output torque up to 23 kg-cm.

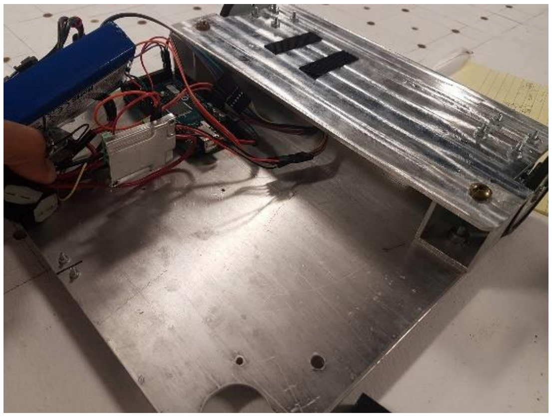


Figure 7. Chassis of the robot

RESULTS AND DISCUSSIONS

The robot designed by the Huskerbots robotics team accomplish the task of simulating a full raspberry primocane suppression and selective floricane removal pruning operation by first diving the entire area to separate zones. After moving the to the chosen zone, the crank arm expands so that the attached RGB camera uses the image processing operation to find the coordinates of the canes that needed to be cut. For this Raspberry Pi microprocessor combines the pictures and analyzes the data. Each cane that requires cutting receives a position relative to the robotic arm. The coordinates are then sent to the Arduino microprocessor that is connected to the robotic arm. Following that, Arduino communicates with the arm and tell the motors to move to the position needed so the arm may cut the required canes and place them on the chassis. The process is then repeated until all the required canes are cut.

An alternative method that we could have used

As It was mentioned the displacement of the robot is achieved by two high power high reduction geared DC brushed motors with encoders as well as a free-to-rotate steel casters to provide sturdy foundation and enhance the motion smoothness. However, the initial approach to this case was to make a line follower robot. The workings of a line follower robot are pretty straight forward. These robots have the capability to detect a black/dark line on a lighter surface depending on the contrast. They estimate whether the line underneath them is shifting towards their left/right as they move over them. Based on that estimation, they give respective signals to the motors to turn left/right to maintain a steady center with respect to the line.

These robots usually use an array of IR (Infrared) sensors in order to calculate the reflectance of the surface beneath them. The basic criteria being that the black line will have a lesser reflectance value (black absorbs light) than the lighter surface around it. This low value of reflectance is the parameter used to detect the position of the line by the robot. The higher value of reflectance will be the surface around the line. So in this linear array of IR sensors, if the leftmost/rightmost IR sensor presents the low value for reflectance, then the black line is towards the left/right of the robot correspondingly. The controller then compensates for this by signaling the motor to go in the opposite direction of the line.

CONCLUSION

The branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing is robotics. There are many types of robots; they are used in many different environments and for many different uses, although being very diverse in application and form they all share three basic similarities when it comes to their construction:

- All the Robots have a mechanical construction. That is they all have a frame, form or shape designed to achieve a particular task
- Robots have electrical components which power and control the machinery. That power comes in the form of electricity from a power source such as a battery.
- All robots contain some level of computer programming code. A program is how a robot decides when or how to do something. Many programmers use C/C++ or Python to commands their robots with their desired tasks.

Robots have replaced humans in performing repetitive and dangerous tasks which humans prefer not to do, or are unable to do because of size limitations, or which take place in extreme environments such as outer space or the bottom of the sea.