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2D Edge Detection through Manipulation of Non-Cooperative Featureless Payloads

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Abstract

In the manufacturing industry technological advances have led to the use of 2-dimensional programmable vision software for the inspection and location of parts. These operations have been completed using cameras and vision software that is programmed to look for distinctive features on the parts being inspected. However, a definitive solution to the problem presented by a featureless part has not been completed. The goal of this research is to advance the field of machine vision when used to process non-cooperative featureless parts through robotic manipulation. These findings have been presented to the funding corporation to be used in a processing line to improve the cycle time and quality of processing animal skins.

The solution consists of a two-part process. The first part of the process uses a segmented lighting technique consisting of a firewire camera from Point Grey Research [1] and a laser line supplied by Z-Laser [2]. The camera is interfaced with a KUKA [3] KR3 robot, so that after the program calculates the height at each point along the laser line, the robot is instructed to move to the highest point and pick up the payload. The second part of the process consists of the robot moving the payload in front of another firewire camera that determines where the bottom of the skin is located. Next, the payload is taken over to a fixed gripper that grips the payload by its bottom edge and advances it to the next stage of production. This process can be easily adapted to be used with other applications that involve featureless payloads including towels, sheets, and empty bags, etc; chamois were used in testing as an example application. The algorithm and methods will be presented along with the results and problems encountered along the way.

Introduction

Whether finding the edge of sheet goods on a conveyor or measuring product dimensions for quality purposes, the manufacturing industry has adopted edge finding techniques in many ways. Edge detection has proven useful in a manufacturing environment for part recognition, detection of debris or damage to a part, and bin picking operations, to name a few. Upon investigating literature in the field of edge detection, various methods can be found to find an edge of a payload. For example, one author describes a system that uses video and range sensors to aid in a bin picking operation [4]. The author describes the process of calculating a three dimensional image by computing the disparity between two images generated by a video sensor. Other common methods use a purely two-dimensional image and use sophisticated computer algorithms to determine the edge of the part [5].

These applications rely on proven edge-finding algorithms which count on reliable product features. When a product has no reliable features, these techniques are useless. Herein a method for finding the edge of a non-cooperative featureless payload, in our case chamois, is developed. The solution consists of using segmented lighting and a firewire camera to locate the highest point in a pile of chamois. Once that point is located and picked up with a robotic arm, the chamois is moved in front of another firewire camera where the length of the object is calculated and the edge location is determined from the length. Our laboratory prototype utilized two Flea2 firewire cameras from Point Grey Research [1], the KUKA [3] KR3 6-axis articulated robot, and VisionPro software from Cognex [6]. This project was a part of a much larger project that was awarded to several different organizations throughout the course of several years. The proof of concept was assigned to our group as well as several others. After our solution had reached completion, it was chosen to be taken to the next level. However, the remaining portions of the project, such as a simulation and modeling to predict success on a large scale, production prototype integration, and full scale integration, have been assigned to a robotics integrator, who is more capable of full scale integration of the system. Therefore, these aspects have not been included herein.

Location and Manipulation of Payload

Before we could locate the edge of the payload, we needed to locate and pick up only one chamois out of a pile of chamois. In order to complete this process we used a laser line, a form of segmented light, placed approximately one meter directly above the pile of chamois and a firewire camera placed at a 45-degree angle approximately one meter high and one meter to the side of the pile. The process begins when the camera takes a picture of the pile of chamois with the lined laser illuminating the pile as in figure 1.

Figure 1: The view from the camera of the pile of chamois

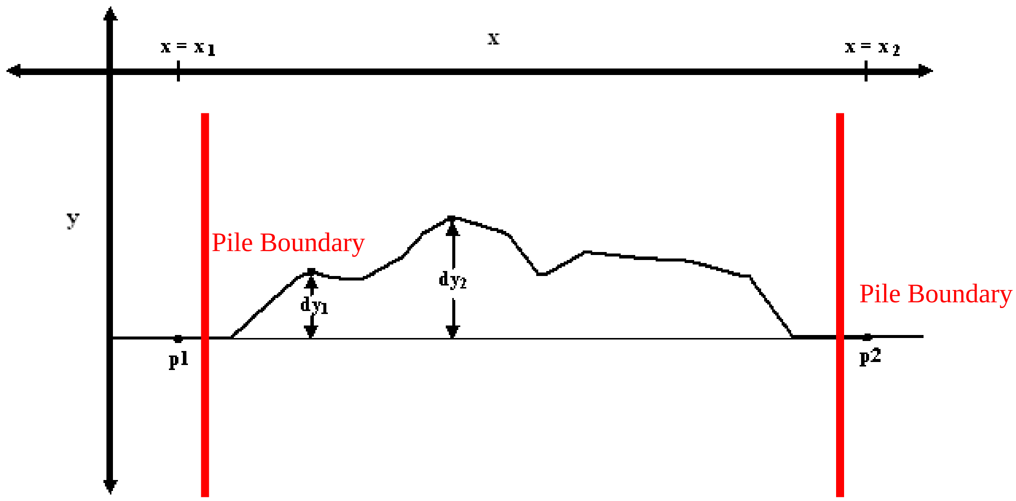

Figure 2: Image mathematic definitions

The algorithm then calculates the highest point of the pile along the line of the laser as follows. First, the algorithm creates a straight line between p_1 and p_2 as in figure 2, where the x value of p_1 and p_2 are predefined to be x_1 and x_2. This assumes that these two points were on the table and not the pile. The vertical red lines represent the boundaries for the pile of chamois. Given the angle of the camera with respect to the laser, the algorithm then calculates the height (dy_n) of each point along the laser line. This height (dy_n) is defined as the distance along the y-axis from the laser line to the line formed between p_1 and p_2. As seen in figure 3, the laser over the pile of chamois is identified by the algorithm using a color segmentation tool and indicates this by turning it green. The color segmentation provides the remaining algorithm with a binary image. Figure 4 shows the overall algorithm in the VisionPro software by Cognex.

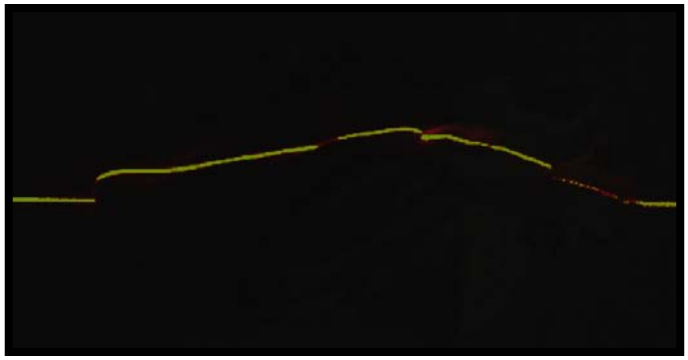

Figure 3: Laser image after color segmentation

Step one segments out the laser so all that is seen in the next step is a binary image including only the laser. The LeftSideLaserReferenceLocator and the RightSideLaserReferenceLocator are two functions that locate the position of the laser line on the table (p_1 and p_2 in figure 2) or other reference points at the same height as the base of the chamois, whether it is a table or a conveyor bed. The PixelHeightMeasurmentAlgorithm function is the main file that works on the image.

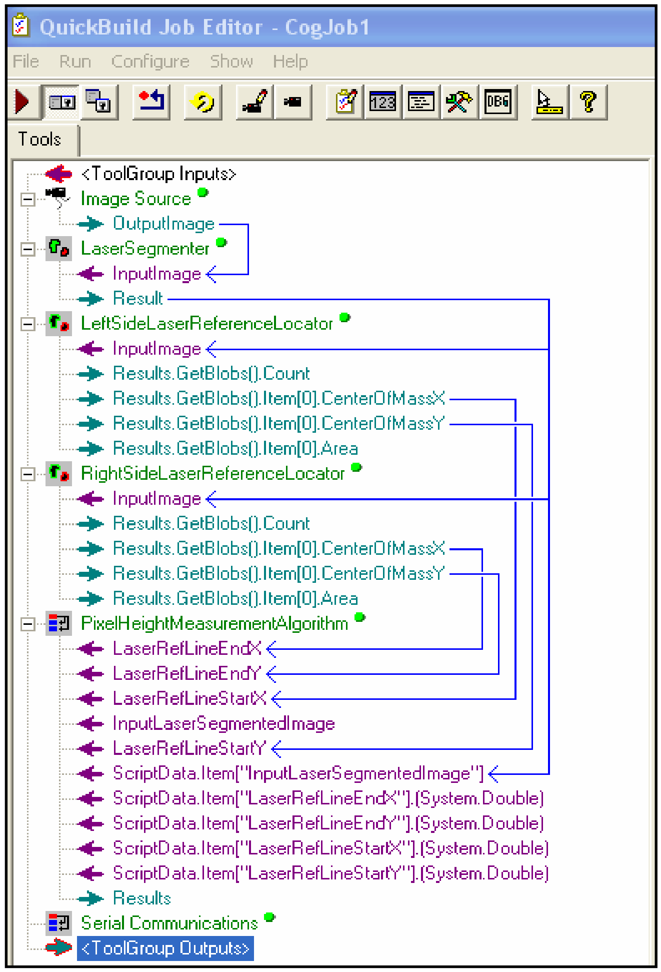

Figure 4: VisionPro Algorithm

This algorithm takes the laser-segmented image along with the reference points and determines the height of the chamois at each pixel along the laser line. Since dy_1, dy_2 … dy_n are now known, the highest point can be determined and is represented by the largest distance, dy_{max}. The highest point is therefore, (x,y,z) = (x value at the highest point, the predetermined location of the single laser, calculated based on the height measured). This (x, y, z) coordinate is then transmitted to the robot via a RS-232 serial link and the robot responds by moving to the point and picking up the chamois.

Camera Calibration

In order for the algorithm to be accurate, the camera needs to be calibrated for lens aberrations. To calibrate the camera in the x-and-y-directions, incremental marks were made on the table. When the picture is taken, we know the spacing of the marks and can note the perceived distances and calibrate accordingly. In order to calibrate the camera in the z-direction, several objects of known height are used and measured by the algorithm. Once again, the perceived height is noted and calibration is carried out accordingly. The second camera, as described below, is calibrated only in the z-direction and is done by making incremental marks, noting the perceived spacing and correcting for the error.

Edge Detection Process

Our edge detection method relies on the simple fact that it is not likely that the robot will pick up the payload at the exact center. Therefore, gravity will cause an edge to drop to the bottom. Once the payload is in a vertical position, the second algorithm can be run. A firewire camera is set up approximately one meter in front of the payload, allowing the camera to view of the bottom half of the material. The first task our algorithm performs is a color segmentation of the captured picture of the material. To allow for easy detection of the light-colored material being picked up, a black background is used. This enables us to train the color segmentor to create a binary image of the material and background. To make sure that the camera did not detect any small false positives, the color segmentor erodes any area smaller than a specified size; this size can be adjusted based on lighting conditions in order to get the best picture of the material.

After this task is performed, the binary image is processed by another piece of the algorithm. This task begins from the bottom by searching pixel by pixel across each row, searching for a white pixel. Once a single white pixel is found, the algorithm begins to count how many consecutive white pixels are in each row until a row containing at least ten white pixels is found. After finding at least ten pixels, the algorithm counts back five pixels, selecting a pixel which is very near the bottom and center of the material, providing a value for the bottom edge of the material. The algorithm can then determine the distance of the material from the end of the robot's gripper to a second gripper that can grab the bottom edge of the material. This value is then sent to the robot holding the material. This second gripper is fixed to a table nearby and is shown in figure 5. Once this fixed gripper has the material by the edge, it can then feed it into the next part of the process.

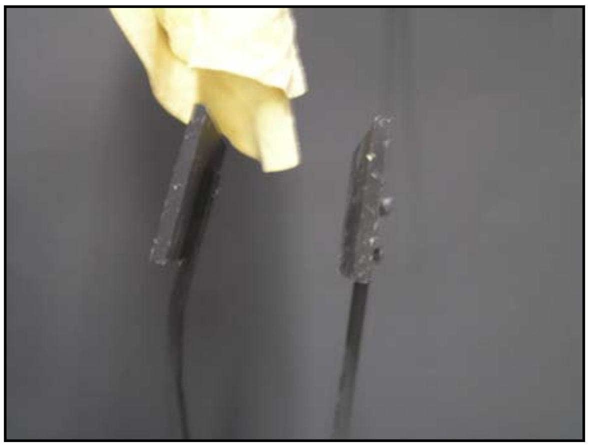

Figure 5: The fixed gripper with material edge waiting to be gripped

Process

Overall the process can be simplified into eight simple steps. The steps are outlined below in figure 6. The process begins with the first camera capturing an image of the pile of chamois with the laser line on the pile. That image is then sent through an algorithm where the height of the pile is determined. After the height is determined, the robot will move to pick up a single chamois at the highest point and move it in front of a second camera. The second camera will then capture an image that is used to calculate the length of the chamois, in order to determine where to place it in the fixed gripper. Once the chamois is placed in the fixed gripper, the gripper will close and the robot will move the chamois over the conveyor and release it. Lastly, once the free end of the chamois is on the conveyor the fixed gripper will release the chamois to continue to the next step of the manufacturing process. This process repeats while there are objects beneath the laser line.

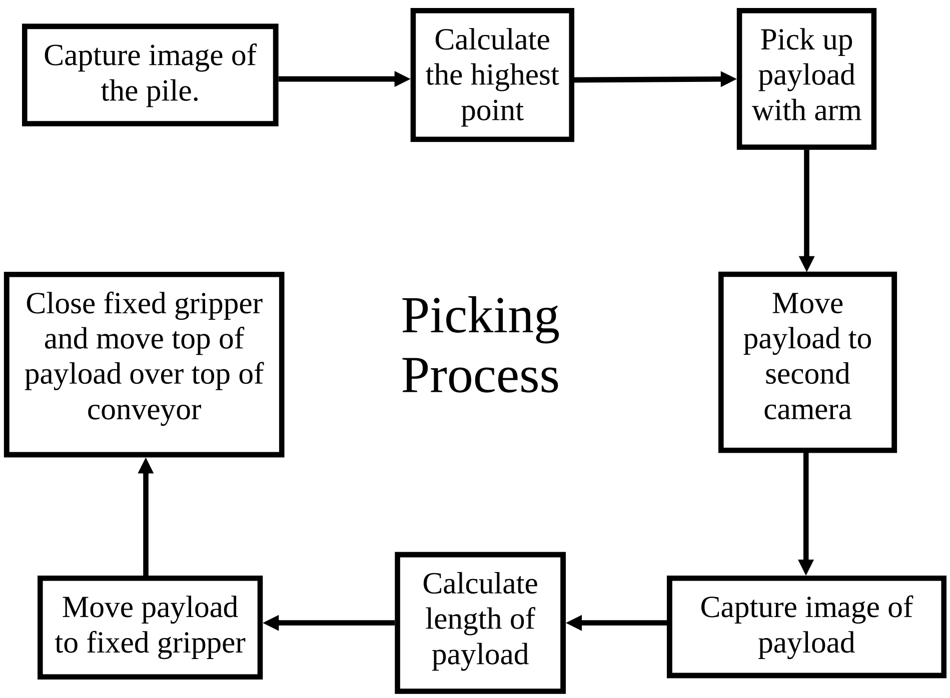

Figure 6: The entire picking process in eight steps

Problems that Occurred

Throughout the testing phase of this project, we encountered several problems with our solution, many of which we were able to overcome or provide a potential solution.

1. Two problems occurred when the gripper closed on a chamois that was in the pile. There were times when multiple chamois would be gripped by the robot. This occurred when the

gripper moved down too far into the pile causing the chamois to press together, which led to a multiple pick. Other times, the gripper did not always close on a chamois because the gripper did not move far enough into the pile. The solutions to these problems were related; if the gripper moved too far into the pile, it may have griped multiple chamois. Similarly, if the gripper did not move far enough into the pile, it may have completely missed the chamois. Therefore, we set up the algorithm to move into the pile far enough so that there was only a 5% chance of missing a chamois and a 12% chance of gripping multiple chamois simultaneously (see table 1 for percentages of these occurrences.) This is adjustable depending on the process for which the solution is to be used. This problem partially arose because the gripper was a two-finger gripper. It is recommended that a four-finger gripper be used to better insure a pick and to reduce multiple picks. Although not yet tested, it is believed that a four-finger gripper would reduce these issues to 1-3% total.

2. Occasionally the chamois would be gripped very near the middle, causing the fixed gripper to close on two edges instead of one single edge. This problem was not of the greatest concern, because the process that follows our solution can still handle a folded piece but reduces quality. We felt that it was better, for throughput reasons, to be certain the gripper had a chamois than no had chamois at all.

3. In order for the robot to be efficient, the robot needs to be run at full speed. With the speed of the robot and weight and length of the chamois, the chamois would sway when placed above the fixed gripper. Therefore, the robot would have to pause for a long period of time before an accurate measurement could be made. The solution to this problem was to mount a C-shaped anti-sway device above the fixed gripper. The device did help prevent swinging by bringing the chamois up through the device. With this addition we are able to calculate accurate measurements immediately after the chamois entered the field of view of the camera and then lower the chamois directly into the fixed gripper without many problems.

4. Once the anti-sway device was installed however, it created yet another problem. At times the chamois would get caught on the C when it began to be lowered to the fixed gripper. While this rarely happens, it would require an operator to remove the product and decreases up-time of the system. The solution for this problem is to place the anti-sway device onto a retractable cylinder. Though we did not test this concept, we are confident that this will prevent the chamois from getting caught up.

Table 1: Problem statistics (100 iterations)

	Rate of occurrence
Failure to Pick	5%
Multiple Pick	12%
Caught on anti-sway device	1%
Missed second gripper	1%

Conclusion

From the research completed herein, the task of finding the edge of a non-cooperative featureless payload is not as difficult when the process is broken down into two steps; the first step being separating out multiple parts, which permits the processing of only one part at a time. Once one part is isolated, the second step uses a second camera with a different algorithm to measure the length of the part, therefore locating the edge of the part. This proof-of-concept development research led the funding organization to order a production prototype from a third-party robotics integrator so that full scale adoption of the process could be further studied on the actual product.

References

[1] Point Grey Research, www.ptgrey.com , 11/10/2007.
[2] Z-Laser, www.z-laser.com , 11/10/2007.
[3] KUKA Robotics, www.kuka.com , 11/10/2007.
[4] Boughorbel, F., et al. "Laser ranging and video imaging for bin picking", Assembly Automation, March 2003.
[5] Davies, E.R., *Machine Vision, Theory, Algorithms, Practicalities*, 3rd Edition, 2005.
[6] Cognex, www.cognex.com , 11/10/2007.

Biography

TREVOR ROBINSON is currently a senior in the Department of Technological Studies at Ohio Northern University pursuing a B.S. in Technology Education. He plans to obtain a PhD in Technology Education.

ADAM STIENECKER teaches electronics and applied control systems courses at Ohio Northern University in the Department of Technological Studies. He holds undergraduate and doctorate degrees in Electrical Engineering from the University of Toledo in Ohio. His areas of research include 2D-and 3D-vision-guided industrial robots.