Paper ID #27584

Vision-based Object Tracking Experiment for Students to Perform Simple Industrial Robotic Automation

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Abstract

The paper describes the details of a student vision project at Drexel University for a robot to pick up parts from the conveyor belt and place them accurately into a drop-off fixture. In an effort to generate interest within the robotic program and from local industries, the Department of Engineering Technology at Drexel University responded to strength its curriculum by adding new innovative components in its robotics and automation course, such as machine vision. A key component in the robotics and automation course is the hands-on experience where student teams use and apply the vision systems hardware and software in an automated work-cell. In addition, the students are taught the principles of vision integration with other control devices, such as robots and Programmable Logic Controllers (PLCs). The experiment results make the students understand the vast use of sensor data, combining the power of the Jevois Smart Machine Vision camera. This data can be used by any autonomous robot to reach to the object of interest or for any user to find an object location. This project was embarked as a collaborative effort between the undergraduate students and a graduate student at Drexel University. Technical issues, collaborative efforts, and student learning outcomes in the execution of this project are discussed in the paper.

Introduction

This paper discusses an educational effort that incorporates vision-based object tracking concept for students to perform simple industrial robotic automation in robotics and mechatronics laboratory course at Drexel University. This project engages students in the implementation of vision camera for improving student laboratory activity in automation. This project entails designing, building, and testing a object sorting system that can be programmed to track a moving object autonomously. Manufacturing processes are becoming more autonomous, requiring less operator intervention in daily operations[1-3]. Industrial robots are good examples of flexible automation. Manufacturing engineers need to integrate other technologies with the objective of extracting from robots the flexibility they can offer. Vision systems have been introduced and implemented on industrial robots to improve productivity and flexibility of manufacturing systems. Some typical applications with vision systems are work piece identification, work piece positioning, work piece dimension measurement, position compensation, surface painting, and vision tracking. Therefore, there is a need to introduce vision system technology to the students who are interested in advanced manufacturing engineering and technology[4-5].

This paper will describe the vision-based object system design and lab activity setup to bring vision system technology in the course of Robotics and Mechatronics for students in the Department of Engineering Technology at Drexel University. A learning module of vision systems will be developed, the topics include types of images, image acquisition techniques, image processing techniques, system setup, introduction to vision system configuration, and programming. A lab activity module of the vision system integrated with a SCARA robot will be designed to provide hands-on experience to students[6-9]. The paper will demonstrate the hardware and software components of the vision system integration, camera setup, software configuration, system communication and programming methods that students will learn and practice with the robot vision system.

Design of Autonomous Object Tracking System

Ever since the emergence of computer vision as one of the major sought out skill in the job market, the amount of people leaning towards becoming experts in the field is still on the rise. We are dealing with a field which branches out into vast concepts and applications. Object identification, Object tracking, Autonomous driving, Facial Recognition, Biometrics are some of the areas in which computer vision plays an important role not only when it comes to designing an algorithm but in building a complete system. Real time object tracking is one of the most intriguing problem to work on as there are more innovations in the algorithms, hardware and programming every day. This object tracking can be implemented in manufacturing industries to track a package in line, to monitor the packaging of a product and to identify the flaws in the manufacturing process.

RFID tracking system can be used to keep track of the packages in an assembly line by using the free-range cooperative object tracking method[10]. This can also be implemented by high end machine vision cameras[11] and a more sophisticated software to handle its operation. In this paper we discuss about a simple object tracking tilt-head robot that uses the power of a Jevois Machine Vision camera and can monitor the movement of a desired object and move along its direction[12-14]. This simple robot can serve as a starter experiment for the students to set foot in learning concepts of computer vision through easier cost-effective implementations.

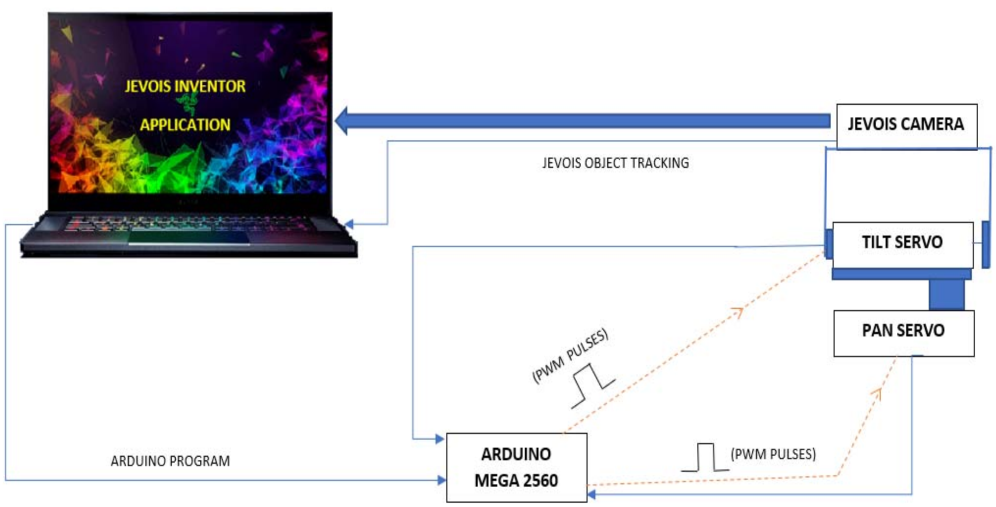


Figure 1. Block diagram of the Object Tracking System using Jevois camera and Arduino

This project aims to design, build, and test an autonomous 3D sorting system through the use of an object tracking system and the Arduino microcontroller as the center of the whole system. It is equipped with a Jevois camera that is used to locate the object's position and navigate towards a destination by controlling its tilt and pa motor as shown in Figure 1. This project aims to design and build a prototype model for an autonomous 3D sorting system that would be designed to help those that would need it the most. This experiment is designed for the students to have a hands-on experience in building a tilt head robot mounted with a Jevois A22 Machine Vision Camera to track objects in real time. The following equipment are used in building the robot: Arduino Mega 2560, Jevois A22 machine vision camera, two DS3218 20KG large torque digital servos, housing for the servos, and connecting wires.

Figure 2 shows Arduino Mega 2560 Rev 3 used in the project. The MEGA 2560 is designed for more complex projects. With 54 digital I/O pins, 16 analog inputs and a larger space for the robotics 3D sorting project. The advanced Arduino model compared to Arduino Uno, Arduino Mega 2560 not only has more input ports but carries higher RAM and sketch memory and is flawless to operate with the Jevois machine vision camera[15]. This version of Arduino houses the 8 bit ATMEGA 2560 microcontroller which is a high performance low power RISC based microcontroller that is capable of executing a million instructions per MHz.

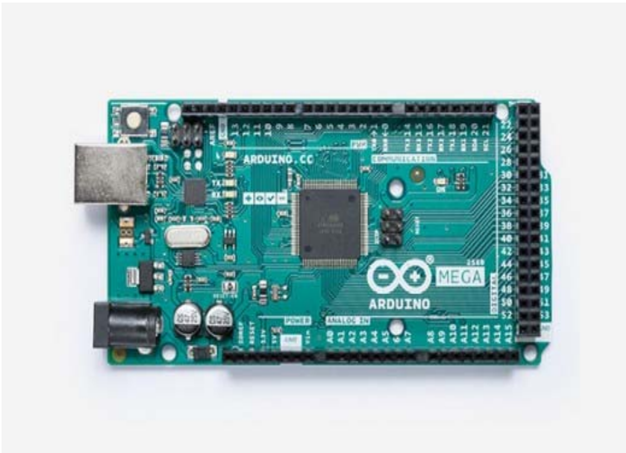


Figure 2. Arduino Mega 2560 Rev 3

Figure 3 shows a kit of Jevois Machine Vision Camera. Jevois is an open source machine vision camera with a video sensor, quad-core CPU, USB video and serial port all contained in a 1.7 cubic inches package weighing 17 grams[12]. This tiny camera houses a microSD card that can be loaded with any provided open source models such as OpenCV 4.0.0 beta, TensorFlow, Caffe, and others. Jevois also made an interactive software platform, Jevois Inventor to communicate with Jevois camera directly. This will provide the user with access to several modules ranging from Saliency detection to Face detection and Object tracking modules.

Figure 3. Jevois Machine Vision Camera with the microSD card and power cable

As shown in Figure 4, two DS3218 digital servos of 20 kg payload capacity were installed inside the housing based on the object tracking algorithm in Jevois inventor[14]. This is a high torque, water proof digital servo with a 180^{o} control angle and dimensions 40 x 20 x 40.5 mm. Metal housings are used to hold the servos on top of one another. The servos are setup in such a way that one servo accounts for the pitch measurement while the other servo corresponds to the yaw measurement.

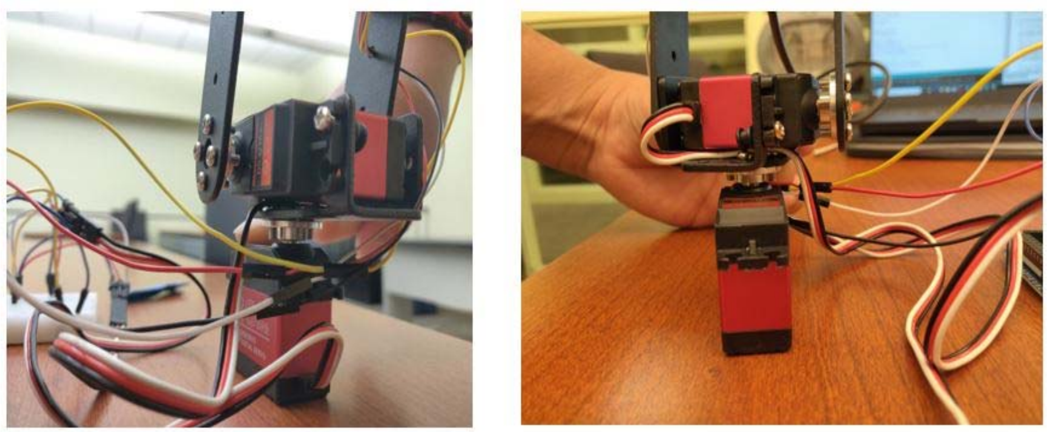


Figure 4. Two DS3218 20KG servos arrangement inside the housing

Design of Object Tracking System

The main aim of the experiment is to build a simple pan/tilt head robot to track an object of interest using the Jevois machine vision camera. The Jevois machine vision camera is placed over the top of the servo housing and is powered by the USB power cable and data transfer takes place through the data cable both connected to the laptop. With this setup, the camera moves along the motion of the servo. The Arduino is used to control the motion of the servo and is integrated to the Jevois machine vision camera to receive information about the position of the object being tracked through serial communication. To demonstrate the method used for tracking and movement of the tilt head robot, the Jevois's color-based object tracking method is used to detect and track the object of interest. This color-based tracking module adopts the concept of isolating pixels within a given HSV range (Hue, Saturation, Value) and extracts the object contour.

Once the object of interest is detected the Jevois sends the coordinates of the object center to the Arduino using serial communication[13]. The script.cfg file of this module can be edited to change the camera settings every time the module is loaded. The camera captures the live video feed and for every frame of the video data is sent over the serial communication. These standardized serial messages sent by the camera focuses on the location information of the obejcts being detected. The user can alter the serstyle parameter of the jevois::StdModule to format the serial messages being received. The precision of the serial message being sent can be changes by using the serprec parameter of the StdModule with serprec being 0 for integer, 1 for float numbers with one decimal position and 2 for precision up to two decimal points[4]. A walkthrough about programming in JEvois and about the above-mentioned serial communication is provided to the students.

The system makes use of the 2D coordinates of the serstyle parameter which specifies the 2D location of a point in interest in the 2D space. The terse T2 x y is used to communicate the 2D location of the object to the Arduino. We specify the HSV value of the object to be tracked. Once the machine vision module identifies the object to be tracked, it marks the contour of the object and as the object moves the module still tracks the object and marks its contour in real time[7]. As the object is being tracked the camera sends serial messages to the Arduino with message type being a 2D and id parameter is set to blob and the x, y parameter carries the location of the object's center and the standardized object size also. Changes are made in the script.cfg file to track a violet strip, which is our object of interest. This can be interactively one through the Jevois Inventor Software[5].

The Arduino is programmed to control the pan and tilt servos[8] based on the serial data received from the Jevois camera. The angle of the servos is controlled by a gain value which is set to 0.1*(target value/SCALE) where the scale is a constant value multiplied with every pan and tilt values (x and y increments or decrements). This gain is updated every single frame as there will be movement in object in every frame. Thus, when the user moves the object along a direction the pan/tilt head also moves and points at that direction tracking the object of interest. Other object tracking algorithms can also be implemented through OpenCV by programming the Jevois camera in C++ or Python[18-19].

This process is displayed to the students explaining them how difficult it was in earlier days to implement such an object tracking system that comes with a burden of high cost. The students not only learn about the interesting field of robotics and machine vision, but they get to experiment and find themselves how easy it is to build a complicated system with the help of an Arduino and a Jevois machine vision camera. This is essentially implemented in the Robotics and Mechatronics Laboratory in an attempt to introduce the concept of integrating machine vision and robotics. The students also get an idea of how this can be used in industrial automation.

Connection from Arduino to Jevois

The TTL level hardware serial port of Jevois camera supports 3.3 V and 5 V logic, we use the 5 V supply from the Arduino. The connection from Arduino to Jevois A22 camera is shown in Figure 5. The IOREF and GND wires are connected to 5 V supply and GND (Red and Black) respectively and TX and RX wires (Yellow and White) are connected to TX1 and RX1 for the Arduino Mega 2560.

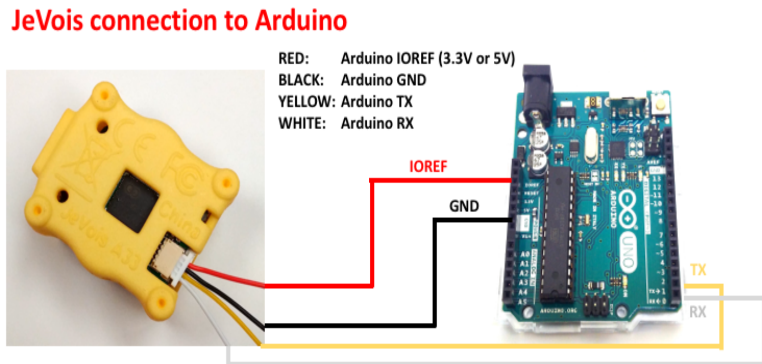


Figure 5. Arduino to Jevois connection. *Pic source: Jevois official manual*

The servos are controlled by Arduino on connecting them to the PWN pins 3 and 5. The pan servo (bottom servo) is connected to the PWM digital pin 3 and the tilt servo (top servo) is connected to the PWM digital pin 5. The servo IOREF and GND are connected to the Arduino pins 5V and GND respectively. The below Figure 6 shows the complete connection setup. The students are made into groups and are provided hands on training to come up with the connections for the circuit.

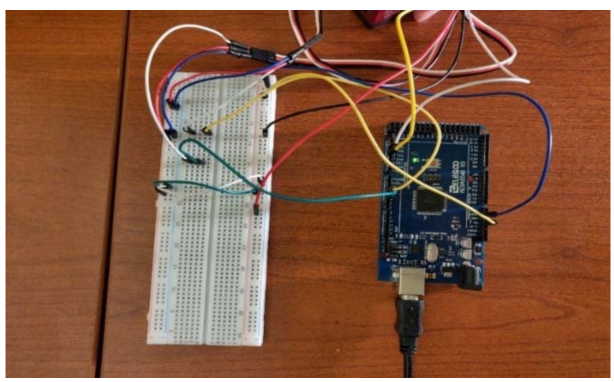


Figure 6. Connection setup of Arduino, Servos and camera on a breadboard

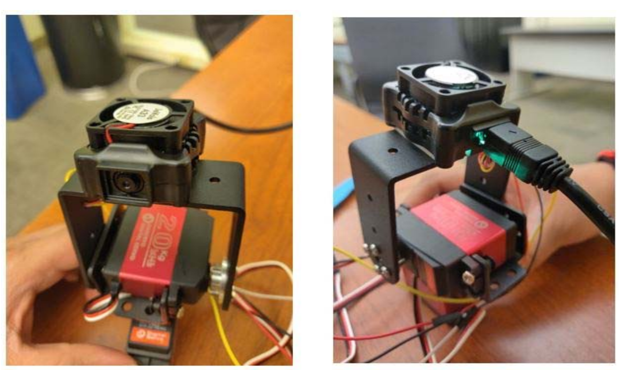


Figure 7. Jevois camera setup (left) and Jevois powered through USB cable by laptop (right)

Figure 7 shows the mounting of Jevois camera to the servo (left) and also the right figure shows that the machine vision camera is powered by laptop through the USB cable. The students are provided the run-through of the program in Arduino and also the Jevois Inventor's object tracker as shown in Figure 8.

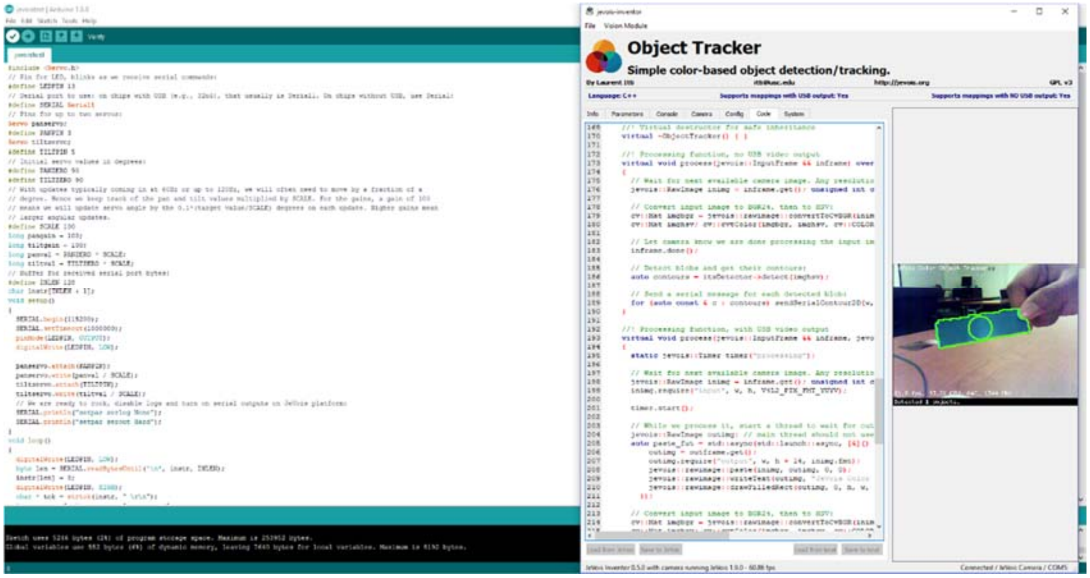


Figure 8. Laptop running Jevois inventor and Arduino code

Experimental Results

The experiment is carried out by bringing the violet strip as a test object before the camera to get detected. The HSV values set in the script.cfg file matches the HSV values of the object and hence the contour is detected as shown in Figure 8. The object is later moved to make sure the tilt and pan servos turns the camera in the direction of movement of the object. As the user moves the object around, the camera tracks the movement and sends serial input to the Arduino and this input is converted to gain values that are fed as pulses to the pan and tilt servos by the Arduino.

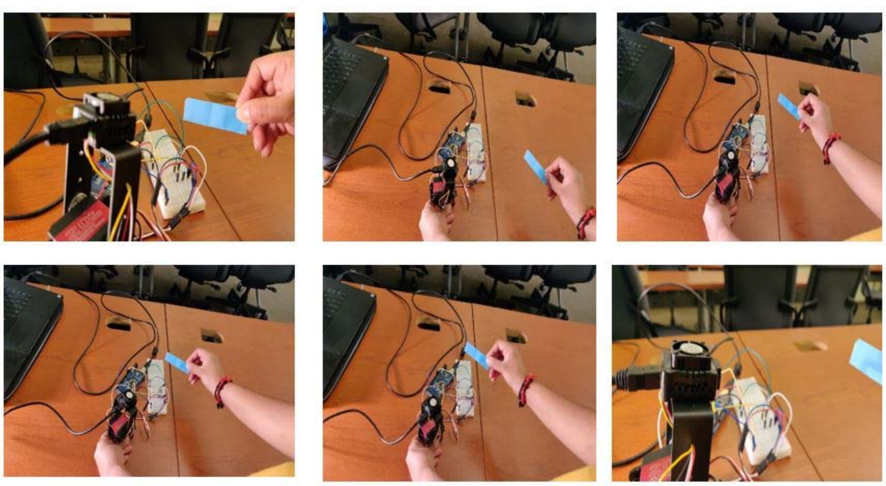


Figure 9. Working and results of the object tracking

Now on getting the pulses from the Arduino the pan and tilt servo moves and thereby moving the Jevois camera attached to the top of the mount. This is shown in Figure 9. The live tracking can be viewed through the Jevois inventor in laptop which shows what the Jevois machine vision camera exactly sees in the environment as shown in Figure 10. Students are asked to move the object and they monitor the Jevois inventor live feed to see how accurate the tracking is implemented.

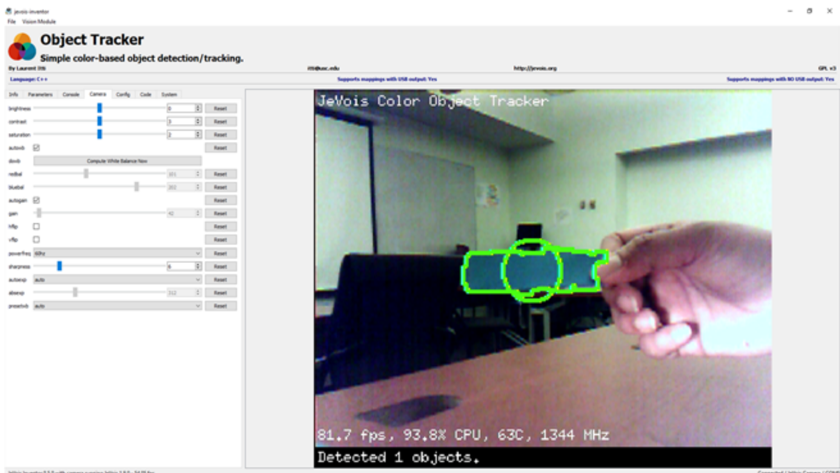
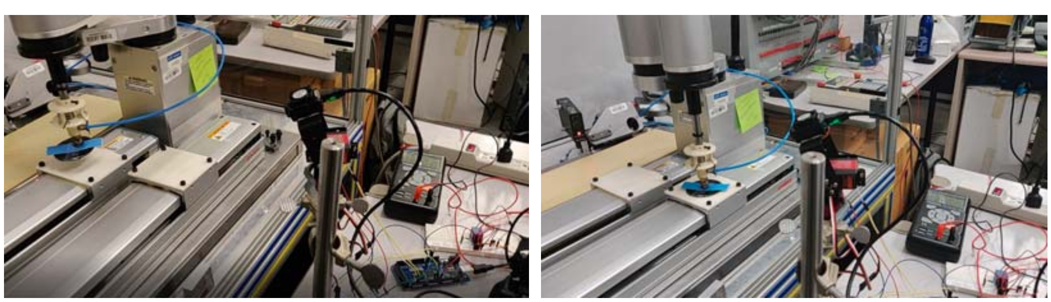


Figure 10. Jevois Camera output on how it tracks the object of interest

Students were exposed to the concept of Machine Vision and its uses in the Industrial Automation process. Concepts such as basic image acquisition and processing is first taught the students, followed by which the students we given the opportunity to use a Smart Machine Vision Camera, Jevois A33. This smart machine vision camera is built-in with several vision modules thus making it easy for the students who do not have prior experience in programming. Arduino integration with the Smart Vision camera is shown to the students and the Pan and Tilt servo setups are also taught. Students practice the concept of Collaborative Robots, where they integrate two Robots (a SCARA robot and 1-Axis robot) using the Digital Inputs and Outputs to establish communication between them and to perform a desired task. Now the machine vision camera which is integrated through the Arduino is used to communicate with the SCARA robot by connecting it as one of the input peripherals of the SCARA robot.



(a) Point A (b) Point B

Figure 11. Vision-based tracking for a SCARA robot to picks and place an object from Point A to Point B

For the entire automation, the student programs the SCARA Robot using a MPB pendant to move from Point B to Point of destination and also the One-Axis robot is programmed using an HPB pendant to move from Point A to Point B as shown in Figure 11. The student also programs the Arduino to control the tilt-head servos based on the output of the Jevois camera and also arduino is programmed to send out a high 24V pulse using the relay switching circuit when the object is first tracked.

Students' Hands-on Laboratory Learning Experience with Machine Vision

The students' first experiment the collaborative robots' concept by using the Photoelectric sensor as peripheral that tells the SCARA when the one-axis platform reaches the desired location. Then, the student group integrate the one-axis robot directly with the SCARA to perform the collaborative automation. They calculate the cycle time taken for different speeds of the two robots. Finally, the Student experiment the same Collaborative robot automation, but this time using the Machine Vision Camera as a peripheral that keeps tracks of the object of interest. Concept of not only automation, but also the basics of machine vision and Arduino embedded system building is learned by the students. Thus, this lab was very beneficial to the students to get introduced to the field of Machine Vision. Some students who had doubts regarding this experiment owing to their coding skills found the use of Jevois module and Arduino programming to be simple and also interesting.

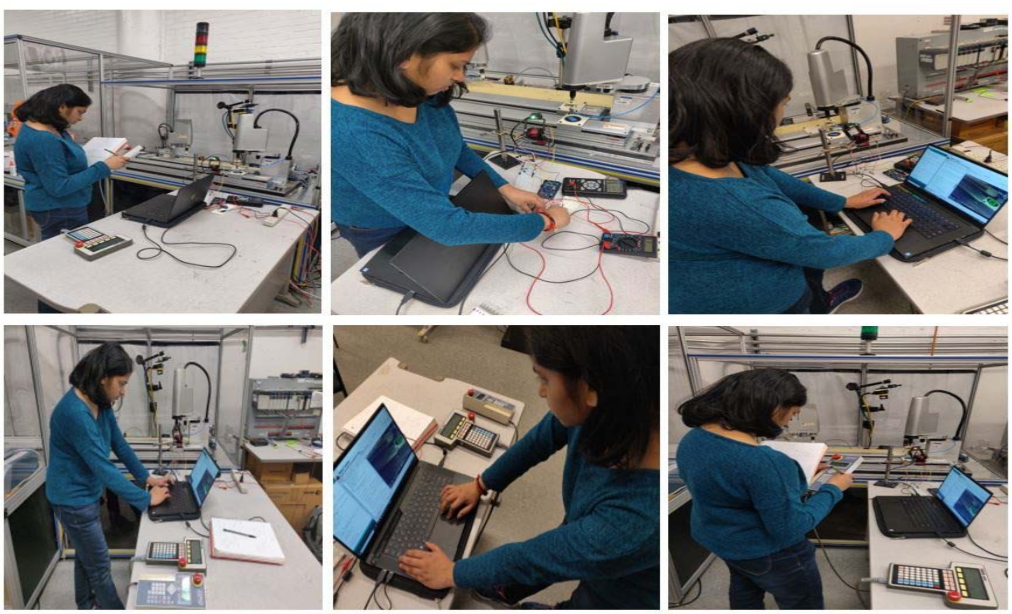


Figure 12. Student working on the machine vision camera experiment

Conclusion

This successful implementation is made possible through the vast information support available in the Jevois manuals. To further this project, the vision information of an object can be obtained from the Jevois imaging data processed by the Object Tracker in real time, along with the location of the moving object in real world. The entire laboratory experiment was very much inspiring to explore a real-time object tracking project that the students can build on their own. Students learned how to showcase an advanced version-based tracking system involving robotic pick-and-place for automation. Students were able to develop and implement a manufacturing robotics application with a vision-based object tracking system integrated in the laboratory project. Students also learned the different vision system technologies, understand their advantages and disadvantages, and know the key issues and technology challenges in developing and implementing vision systems in manufacturing robotics applications.

References

1. Zhuang, H., Sudhakar, R., "Development of a Machine Vision Laboratory," 2003 ASEE Conference, Nashville, TN.
2. Floyd, M., Kim, H., Culler, D.E., "A Proposal to Implement a Course on Vision Systems with Applications in Robotics at the Oregon Institute of Technology," 2013 ASEE Conference, Atlanta, GA.
3. Yeh, C., Hammond, H., "An Industry Based Student Project: Implementing A Machine Vision Systems For Robotic Application," 2002 ASEE Conference, Montreal, Canada.
4. Otieno, A.W., Mirman, C. R., "Machine Vision Applications within a Manufacturing Engineering Technology Program," 2002 ASEE Conference, Montreal, Canada.
5. Sirinterlikci, A., "Development of a Comprehensive Industrial Controls Course in a Manufacturing Engineering Program," 2006 ASEE Conference, Chicago, IL.
6. Sirinterlikci, A., "Practical Hands-on Industrial Robotics Laboratory Development," 2012 ASEE Conference, San Antonio, TX.
7. Richard Chiou, Yongjin Kwon, and Prathaban Mookiah, "Manufacturing E-Quality Through Integrated Web-enabled Computer Vision and Robotics," The International Journal of Advanced Manufacturing Technology, Volume 43, Numbers 7-8, pp. 720-730, August, 2009.
8. Yongjin Kwon and Richard Chiou, "Automated Vision Inspection in Network-based Production Environment," The International Journal of Advanced Manufacturing Technology, Volume 45, Numbers 1-2, pp. 81-90, November, 2009.
9. Richard Chiou, Michael Mauk**,** Robin Kizirian, and Yueh-Ting Yang, "Noncontact Surface Roughness Testing for E-Quality via Vision Method Using LabVIEW**,"** American Society for Engineering Education for the 117th Annual Conference & Exposition, Louisville, Kentucky June 20 - 23, 2010.
10. RFID Assisted Object Tracking for Automating Manufacturing Assembly Lines - IEEE International Conference on e-Business Engineering (ICEBE'07)
11. A Machine Vision Application for Industrial Assembly Inspection - 2009 Second International Conference on Machine Vision
12. Jevois smart machine vision camera – jevois.org
13. Jevois serial port user-guide - http://jevois.org/doc/UserSerial.html
14. Jevois inventor software - http://jevois.org/doc/JeVoisInventor.html
15. Arduino Mega 2560 - https://www.arduino.cc/en/main/arduinoBoardMega2560?setlang=en
16. Jevois Object Tracker - http://jevois.org/moddoc/ObjectTracker/modinfo.html
17. Arduino servo library for control - https://www.arduino.cc/en/reference/servo
18. Video tracking methods - https://en.wikipedia.org/wiki/Video_tracking
19. Object tracking algorithms - https://www.learnopencv.com/object-tracking-using-opencv-cpp-python/
20. Light Detection and Ranging - https://docs.px4.io/en/sensor/lidar_lite.html