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A Proposal to Implement a Course on Vision Systems with Applications in Robotics at the Oregon Institute of Technology

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Abstract

Robotics, material handling systems, surveillance, object recognition, and component inspection in manufacturing are just a few of the areas where cameras and vision technology are being combined to design new processes and update existing ones. A problem arises from the wide range of skills and knowledge related to the mechanical set-up, electrical controls and software required to develop and successfully implement these systems. A class that introduces students to this subject matter so they can do projects and work in an industry setting is needed.

This paper proposes a course program of study that will be used to introduce Manufacturing and Mechanical Engineering Technology students to vision technologies at Oregon Institute of Technology in Klamath Falls Oregon. The main focus of this paper and what differentiates it from other proposals is that it identifies software and computer programming as one of the major barriers that keep Manufacturing and Mechanical Technology students from learning about vision systems and their use in automated/ robotic/ manufacturing applications.

Many lessons have been learned through collaborative projects with the computer science and computer software engineering students/faculty. In the past, MET and MFGET departments have worked on aspects of the projects and then turned them over to the computer department for software development. The authors take the approach that introductory "canned" programs can now provide basic functionality and tools, while some libraries of "code" functionality can be found on manufacturer's web sites and user forums. Finally, pure development of applications is available in a variety of applications programing interfaces "API" languages including Visual Basic, C++, C#, and others.

The expected benefits of this course are to provide a language and concept bridges that will allow more ET students to participate in the design and implementation of systems in conjunction with engineers from other disciplines. With the foundation built from this course and previous projects, the department will be able to grow and expand on the work completed each year. There is a need in industry for Mechanical/Manufacturing engineers and technologists with interdisciplinary skills and experience that they get as part of their college education.

Literature Review

Robot vision is a rapidly growing segment of robotics and computer engineering with application is numerous fields. It can be utilized in any situation where human vision is currently used. This field currently has many limitations, but improvements are being made on a continuous basis. Some of the primary areas of interest are Surveillance, inspection, obstacle avoidance, and guidance.

A lot of the work being done in the area of surveillance is focused on reducing the amount of processing power needed to do high quality object tracking and recognition. This allows for lower power consumption needed for mobile and small scale applications [1]. It also means that these systems can be produced more cheaply.

Automated visual inspection is something that is already being used in factories and processing plants. It allows for high speed inspection of every part where traditional inspection methods would only inspect samples of the product. Larger scale inspection is also being developed for bridge applications [3]. These same methods could be adapted for use in all kind of industrial and structural inspection situations were safety and consistency are concern.

Obstacle avoidance and guidance are closely related areas that are applicable to mobile robots. Guidance looks at the big picture and navigation from one point to another. Some specific applications are UAV guidance [4]. Many existing vision guidance systems rely on artificial markers for location purposes, but work is being done to develop ways of recognizing natural land marks for guidance purposes [4]. Collision avoidance deals more with small scale avoiding unexpected objects in the current path. Some of the work in this field involves systems that mimic insect nervous systems [2] because of their simplicity. These systems use relatively simple algorithms and hardware to avoid approaching object that are in the robot's path while giving very little reaction to objects that are in near collision positions[2].

The following is two more specific examples of how machine vision is being used. *An Autonomous Robotic System for Inspecting Substation Equipment* [5] presents Smart Guard, a completely autonomous robotic system that can inspect substation equipment. The vision based navigation system is applied when the robot patrols in a substation and inspect substation equipment. The method for inspection of substation equipment is to first analyze images and determine the ratio of distance, second is to compare current images to a reference image and to look at temperature using an infrared camera and match the two images.

Success in navigation requires success at the four building blocks of navigation; perception, localization, cognition, and motion control. In order to make these possible for navigation, it mentions three methods of navigation; magnetic guidance system, the integrated GPS-DR Navigation, and the omnidirectional Vision System. The omnidirectional vision system uses a camera installed on the robot to recognize four kinds of patterns or landmark which have different information and move forward following landmarks along the side of a road. Visual navigation may be a good way to reduce cost in the future, but there is still a lot of work needed to improve the positioning accuracy.

An Autonomous Mobile Robotic System for Surveillance of Indoor Environment [6] presents autonomous mobile robot used for surveillance of indoor environments by autonomously navigating with a monocular camera, a laser scanner, and an RFID device. For this surveillance vision system, laser-based mapping, safe navigation, global localization, and path planning are introduced. After area mapping is completed by using RFID Tags, the robot analyses the scene searching for abandoned or missing objects, RFID tags provide information about the surrounding region or instructions for the robot to perform a certain task. The proposed approach assumes that RFID tags are distributed throughout the environment, along with visual landmarks. As soon as a tag is sensed, the bearing of the tag relative to the robot is estimated. Bearing information is then used to trigger a rotational movement of an onboard camera, so that it is oriented toward the visual landmark associated to the tag.

There are two way for this system to recognize objects in the indoor environment. The first is to recognize abandoned or missing object detection by comparing the position of predefined objects or the presence of new ones, and the second is to use laser-based people detection and follow any intruder by reacting with predefined actions.

Introduction and Background

Machine vision is an area of industry that is growing rapidly and working its way into many engineering fields. The use of machine vision for guidance and inspection in manufacturing and assembly plants makes it necessary engineering technologists to have at least a basic understanding of the their function, capabilities, and limitations. This paper will outline some tools and methods that would be useful for teaching college undergraduates, studying engineering technology, how to use and program robotic vision systems. It will recommend an inexpensive kit that could be purchased for teaching the basic skills. A course outline will also be developed for a quarter system class that would provide basic understanding of the technology being used in industry.

The information in this paper will be largely based on the experience of the authors who have been doing graduate work in the field of robot vision from the perspective of Manufacturing Engineering Technology. The focus of this work was in the area of part inspection and automated material handling guidance systems. Many off the shelf products were used to develop basic systems for the identification of parts and part features using machine vision. Obstacle recognition and path planning was also performed using readily available software.

Software and computer programming knowledge are essential for implementing vision systems in a manufacturing environment. The main focus of this paper and what differentiates it from other proposals is that it identifies software and computer programming as the major barriers that keep Manufacturing and Mechanical Technology students from learning about vision systems. The first hurtle to teaching engineering technology students is making them familiar with a suitable software package. With an introduction to simple and inexpensive software and hardware, students can then explore the capabilities and limitation of machine vision.

Hardware

The camera is regarded as an eye of a robotic system, and is meant to capture an image and send it to a computer. The camera can be anything from the web cam on a laptop computer to a cell phone camera or digital still camera to a high end industrial camera. In most situations, a camera that can stream video would be used. Another consideration is that the higher quality resolution and sensitivity the camera is capable of, the better image recognition the system will have.

In some situation, the camera might be mounted far away from the objects, while others might require close up capability and still others might require weather proofing for outdoor use. When choosing a camera it is important to take all of the requirements into account. When it comes to lens, again, there are a variety of camera lens that can be used depending on the situation. To connect the camera to the computer, there are many options such as wireless, high definition cables, and USB cables. Each type has its own advantages and disadvantages, so depending on the situation and the type of camera, the kind of cable can be selected.

The computer that will be used is the next consideration. Again this will depend greatly on the application of the system, and some of the consideration for this are; will the system be mobile, will the computer need to be running other applications at the same time, what kind of image processing will be done, and what kind of environment will the system be operating in? The primary concerns when choosing a computer to perform image processing are the amount of RAM and Processor speed.

Software

Once a vision system has acquired an image and sent the data to the computer, a program is needed to perform target Acquisition, Recognition, and Analysis. These processes should be accomplished quickly and accurately to ensure proper function of the system. The image processing software should also be able to communicate with other program through an Application Programming Interface (API) so that actions can be taken based on what the vision system sees.

These are three kinds of representative vision application software for the image processing. OpenCV, called Open Source Computer Vision Library, is a library of programming functions mainly aimed at real-time computer vision, and has libraries for C, C++, C#, Visual Basic. It can be downloaded from Internet for free. One disadvantages of OpenCV is the fact that it requires a lot of knowledge and skills about C languages to build programs.

Halcon, which is commercial software, is the comprehensive standard software for machine vision with an integrated development environment (IDE) and is used worldwide. It provides the solution for the full range of applications in the field of machine vision and board, wafer & die inspection, medical image analysis, automotive and robotics, surveillance, and remote sensing. It also offers various language interfaces, such as a C++ and a native .NET interface. Using these interfaces, an operator can access all of HALCON's more than 1800 powerful functions from programming languages such as C, C++, C#, Visual Basic. Some disadvantages of Halcon are that it is expensive because it is a commercial product and it requires an operator with significant programming knowledge.

RoboRealm is a simpler software package for use in computer vision, image analysis, and robotic vision systems. Using an easy point and click interface, RoboRealm drastically simplifies vision programming. Image or video processing can be technically difficult. Homemade robots are continuously moving towards PC based systems (laptop, netbook, embedded, etc.) that have the power to support complex image processing functions. RoboRealm provides the software needed to get such a system up and running. It has compiled many image processing functions into an easy to use windows based application that operator can use with any digital image. RoboRealm acquires images of the robot's environment, and process the image, analyzes what needs to be done and send the needed signals to your robot's motors, servos, etc. It also has an

API function for access to and from C, C++, C#, and Visual Basic that can make a possible to communicate with other devices. Some advantages of RoboRealm are that it requires little programming skill to operators due to the built in functions, and it only costs about $50.00.

Imaging source software, which is called IC Imaging Control and made only for image acquisition using imaging source cameras, provides the operator with function and an API between C language and camera. This function in the IC Imaging Control is composed of basic things such as scroll/zoom, image capturing, saving, manipulating, image sequence, timestamps, and triggers which support programming environment such as C, C#, C++, Visual Basic.

Industrial Application Examples of Vision System

Vision systems are widespread and have been utilized in industry to increase the productivity. For instance, in the semi-conductor industry most products are complicated and too small to recognize with the naked eye, but utilizing a vision system the productivity can be increased because the camera can compare a captured image with an reference image and decide autonomously whether it has defects or not. Inspected products are stacked on a pallet by a robotic arm that senses product status with a camera, and then an automatic guided vehicle (AGV) can carry it to storage or shipping autonomously. All processes are executed by vision technology. It is also being adopted in the field of surveillance and robot guidance.

Application of Vision System for Education

Small Manufacturing Cell: Several examples mentioned above were adapted to a small manufacturing cell, which is a scaled down version of real systems that are widely used in industry. This small cell is composed of a vision system, robotic arm, milling machine, c-more control panel, variable frequency drive (VFD), a programmable logic controller (PLC), and a barcode scanner. The conveyor belt, operated by VFD through the PLC program, carries products to different stations that communicate with other machines such as a camera, a milling machine, and a robotic arm the PLC can control the entire process. The camera and RoboRealm software for the vision system is used for the image acquisition, recognition, and analysis. For instance, when the product passes in front of the camera, switches on the conveyor belt would be on and vision system would capture, recognize shapes, and analyze it by matching it to a reference image as soon as the product has stopped. If it has defects or appears different than the reference image, then the vision system sends information to the PLC which can then send signals to the robotic arm and milling machine. The robotic arm can then pick up the product and put it back in the milling machine for rework or place in a reject pile (Figure 1). The barcode scanner reads the bar code on top of the product and sends information to the computer to provide part information to the vision system and allow for faster image analysis. The C-more panel connects to the PLC through an Ethernet cable and provides GUI which provides control of the PLC through a touch screen. The data center computer is in charge of data management, communication interfaces.

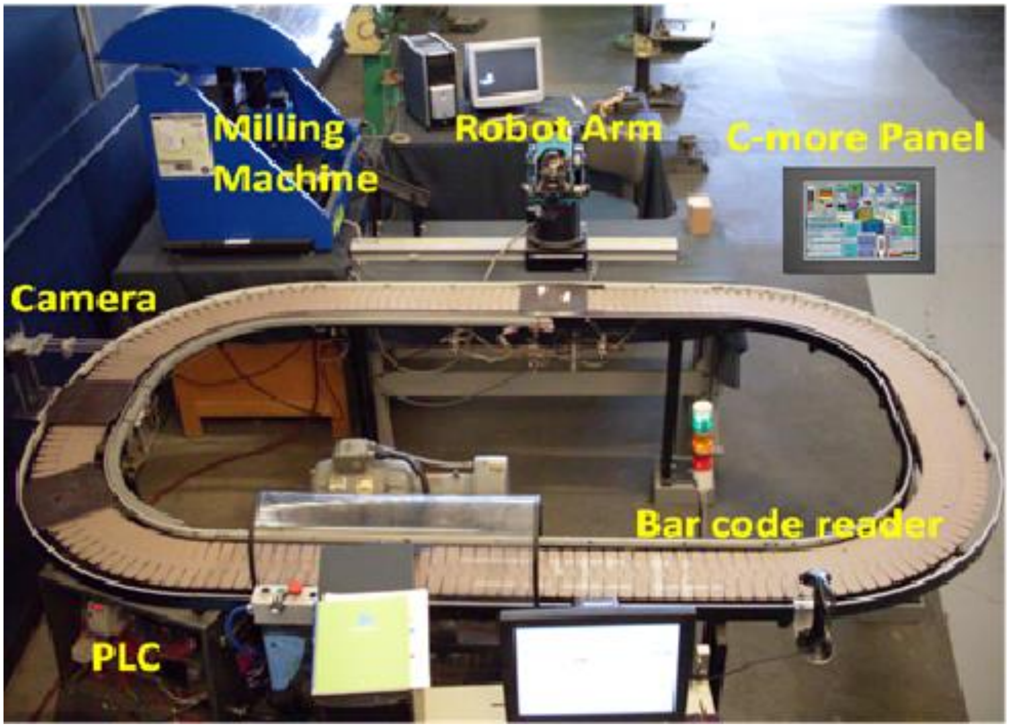


Figure 1: CIM Cell with vision station incorporated

There are three types of shapes representing different product (figure 2). There is a circle, a square, and a triangle. Each shape has some small circle inside representing part features. If there are an incorrect number of circles or the circles are an incorrect size, the product is regarded as defective (figure 3).

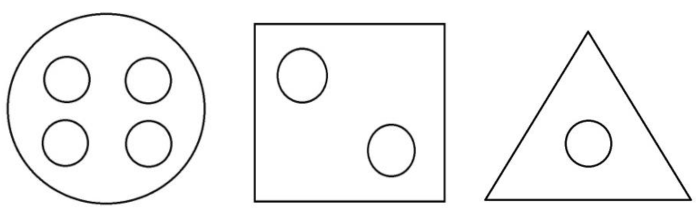


Figure 2: Shapes used for testing camera/software

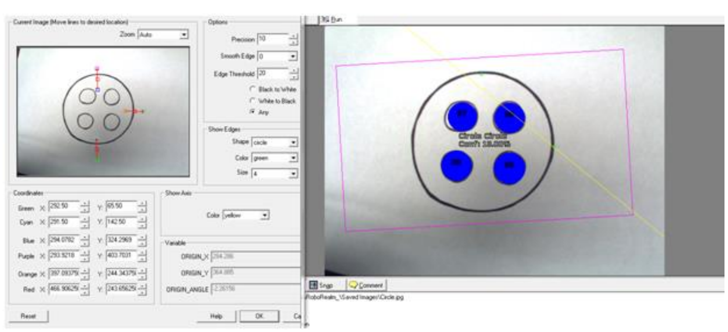


Figure 3: Identification of known errors (# and location of holes)

Table 1 shows the function for shape recognition

Object Recognition if OBJECT_NAME = "Circle_circle" then ·· Origin_Probe ·· Canny ·· Circles ·· if CIRCLES_COUNT = 4 then ··· Timer ··· Write Images ·· end_if end_if :	: if OBJECT_NAME = "Square_circle" then ·· Origin_Probe ·· Canny ·· Circles ·· if CIRCLES_COUNT = 2 then ··· Timer ··· Write Images ·· end_if end_if :	: if OBJECT_NAME = "Triangle_circle" then ·· Origin_Probe ·· Canny ·· Circles ·· if CIRCLES_COUNT = 1 then ··· Timer ··· Write Images ·· end_if end_if

Smart Robotic Warehouse: A vision system was adapted to a simulated smart robot warehouse. This smart robot warehouse is composed of vision system with a camera installed on the ceiling to observe objects on the floor, in this case toy cars, and obstacles. The three toy cars are different colors; red, blue, and green. In this case the obstacles are black so that the vision system can recognize the difference between the toy cars and the obstacles. After that, it develops a path having each car move from point A to point B and produces X and Y coordinates for car's start and end positions (figure 4). Then it would transmit coordinate data to the moveable robot through the API in real time so that robot can get from place to place while avoiding obstacles. A manual control G.U.I. have been developed for the robots that will be used in the continuation of this research. This G.U.I. and a portion of the robot control code are shown in figures 5 and 6.

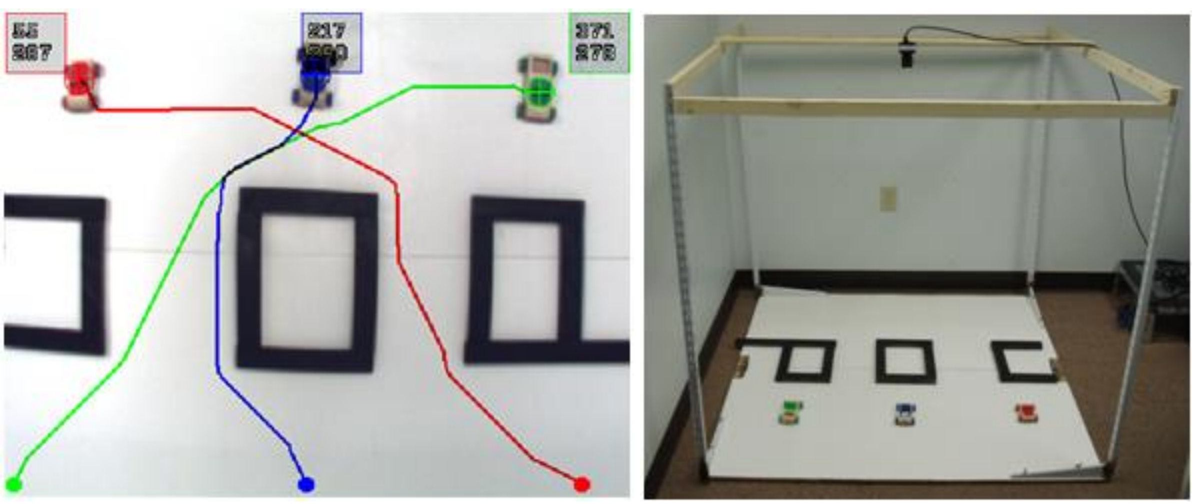


Figure 4: Prototype warehouse set up for testing

Table 2 shows the function for path planning

	:	:
Radial_Distortion	Marker[Red]	Dilate 15
Crop 63,6 - 480,346	Color_Filter	Center of Gravity
Marker[Corrected]	Dilate 15	Marker[Revert]
Color_Filter	Center of Gravity	Auto Threshold
Dilate 15	Marker[Revert]	Erode 12
Center of Gravity	Auto Threshold	Math Revert Current
Marker[Revert]	Erode 12	Path_Planning
Auto Threshold	Math Revert Current	Display_Variables
Erode 12	Path_Planning	Math Current Red
Math Revert Current	Display_Variables	Math Current Blue
Path_Planning	Marker[Blue]	Watch_Variables
Display_Variables	Color_Filter	
:	:	

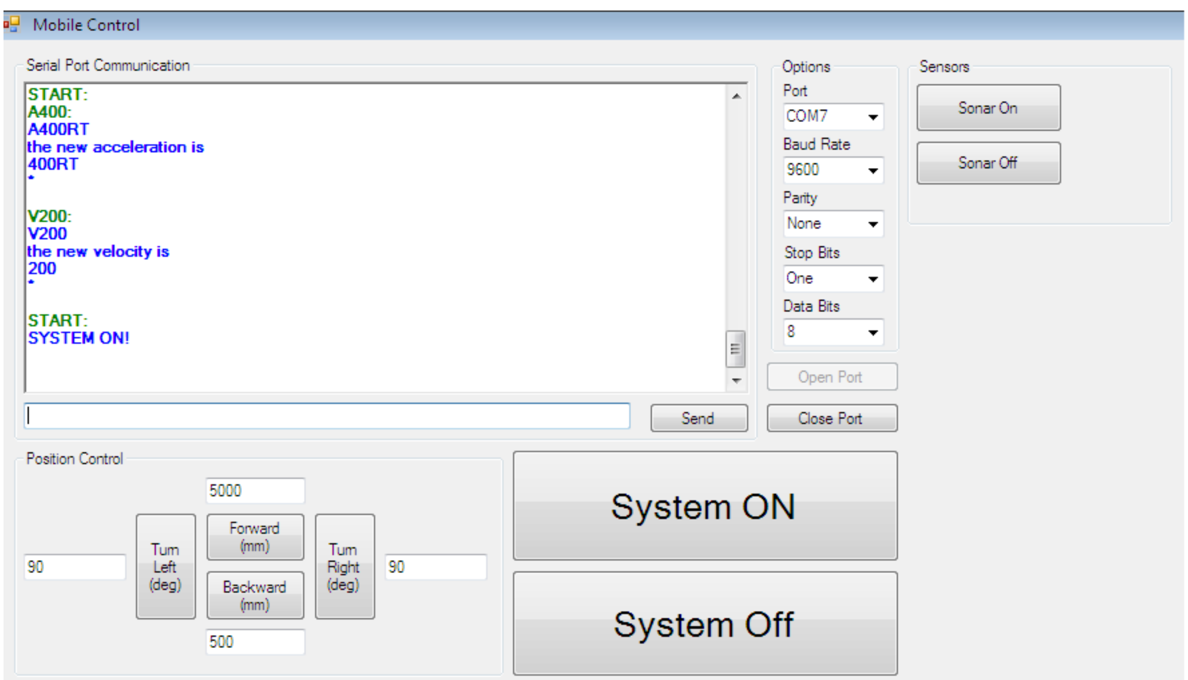
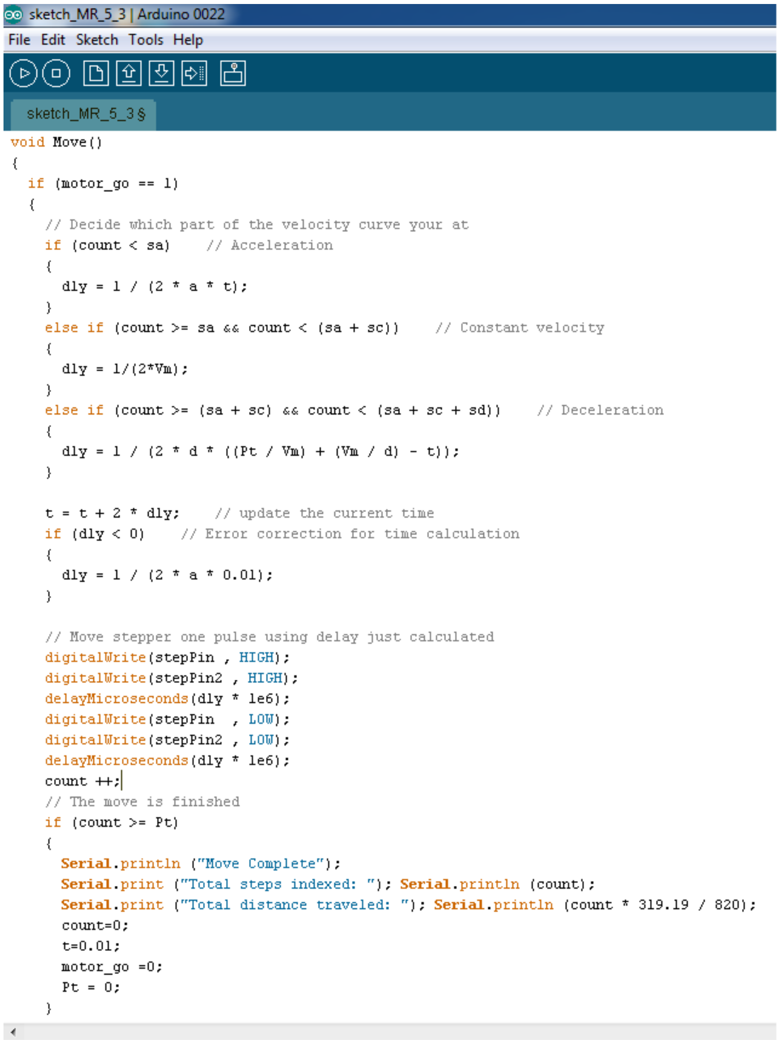


Figure 5: Functions and programming environment for Roborealm




```
void Move()
{
  if (motor_go == 1)
  {
    // Decide which part of the velocity curve your at
    if (count < sa)     // Acceleration
    {
      dly = 1 / (2 * a * t);
    }
    else if (count >= sa && count < (sa + sc))     // Constant velocity
    {
      dly = 1/(2*Vm);
    }
    else if (count >= (sa + sc) && count < (sa + sc + sd))     // Deceleration
    {
      dly = 1 / (2 * d * ((Pt / Vm) + (Vm / d) - t));
    }

    t = t + 2 * dly;     // update the current time
    if (dly < 0)     // Error correction for time calculation
    {
      dly = 1 / (2 * a * 0.01);
    }

    // Move stepper one pulse using delay just calculated
    digitalWrite(stepPin , HIGH);
    digitalWrite(stepPin2 , HIGH);
    delayMicroseconds(dly * 1e6);
    digitalWrite(stepPin  , LOW);
    digitalWrite(stepPin2 , LOW);
    delayMicroseconds(dly * 1e6);
    count ++;
    // The move is finished
    if (count >= Pt)
    {
      Serial.println ("Move Complete");
      Serial.print ("Total steps indexed: "); Serial.println (count);
      Serial.print ("Total distance traveled: "); Serial.println (count * 319.19 / 820);
      count=0;
      t=0.01;
      motor_go =0;
      Pt = 0;
    }
```

Figure 6: Sample program for the robot control

Low Cost Educational Kit

The following is a sample kit that could be used for education of engineering technology students. The kit will be kept as inexpensive as possible in order to minimize financial concerns when implementing the proposed program. Existing school computers should be sufficient for educational image processing because high speed and accuracy are not necessary.

Software

RoboRealm should be used for image processing because it is easy to use and cost approximately $50. This software can be purchased from the RoboRealm's website (WWW.roborealm.com) and is available for a free 30 day trial (figure 7).

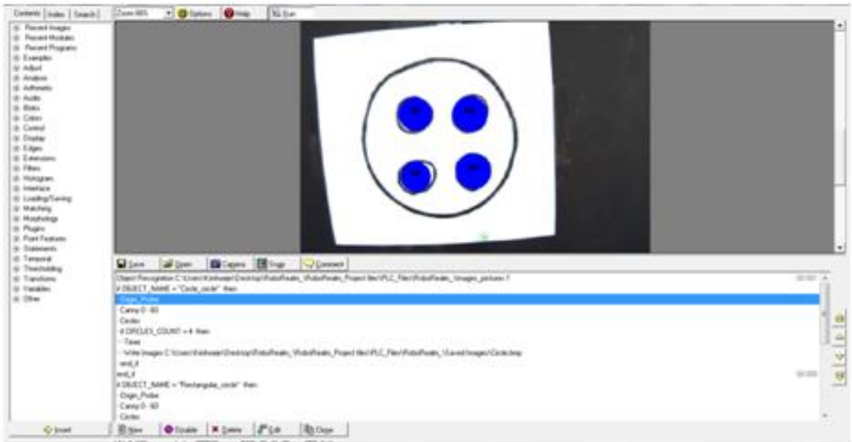


Figure 7: RoboRealm software inteface

Hardware

For a camera, it is recommended that a webcam is used. Webcams are available anywhere that computer accessories are sold and can usually be found for under $20. The camera should come with any drivers that are required to operate it, as well as a USB cable or wireless antenna to connect it to the computer.

White paper and colored markers will also be needed. These materials will be used for simple shape and color recognition. It is recommended that they are purchased from the office supply store with best prices. A ream of printer paper costs about $5 and enough markers for a whole class should cost about $30.

Other useful object that could be purchased would be toys, tools, and other miscellaneous object that could be used to perform more complex analysis. It would also be possible to use object that are already available at the school such as pencils, book, or any other educational tools that are already in the class room.

Course Program Outline

Table 3 below shows the proposed class schedule for a course in robot vision systems.

Weeks	Subject	Content	Note
1	What is robot vision	Discuss basic components of a robot vision system	
2	What is a vision system	Discuss how the components of a vision system work together	
3	Introduction to RoboRealm	Get familiarized with the RoboRealm user interface and available functions	
4	Shape recognition	Use RoboRealm to recognize basic shapes squares, circles, and triangles	
5	Compare shapes	Use RoboRealm to compare shapes and images, and recognize a human face	

6	Recognize color	Use RoboRealm to recognize color in combination with shapes	
7	Path planning	Use RoboRealm to navigate from point A to point B while avoiding obstacles	
8	Motor outputs	Use RoboRealm to send signals to motors for motion control	
9	RoboRealm API	Interface RoboRealm with other software using the API	
10	Review and Project	Work on team projects to use robot vision to accomplish a goal	

Discussion & conclusion

The information given in this paper shows that a class that teaches the basics of robot vision would be useful, practical, and achievable. The primary obstacle of computer programing can be minimized by the proper selection of processing software, and possibly requiring a programing for engineers class as a pre-requisite. Equipment for the class can be very inexpensive because high speed and accuracy are not required for educational purposes. A course in robotics is already offered by the school, so the course in visions systems could be offered as a second class in a series. The attended school also has 2 Fanuc LR Mate 200 *i*C robotic arms, in educational enclosures, that are equipped with cameras and I/O capability for communication with other systems (figure 8). These could easily be integrated into the class.

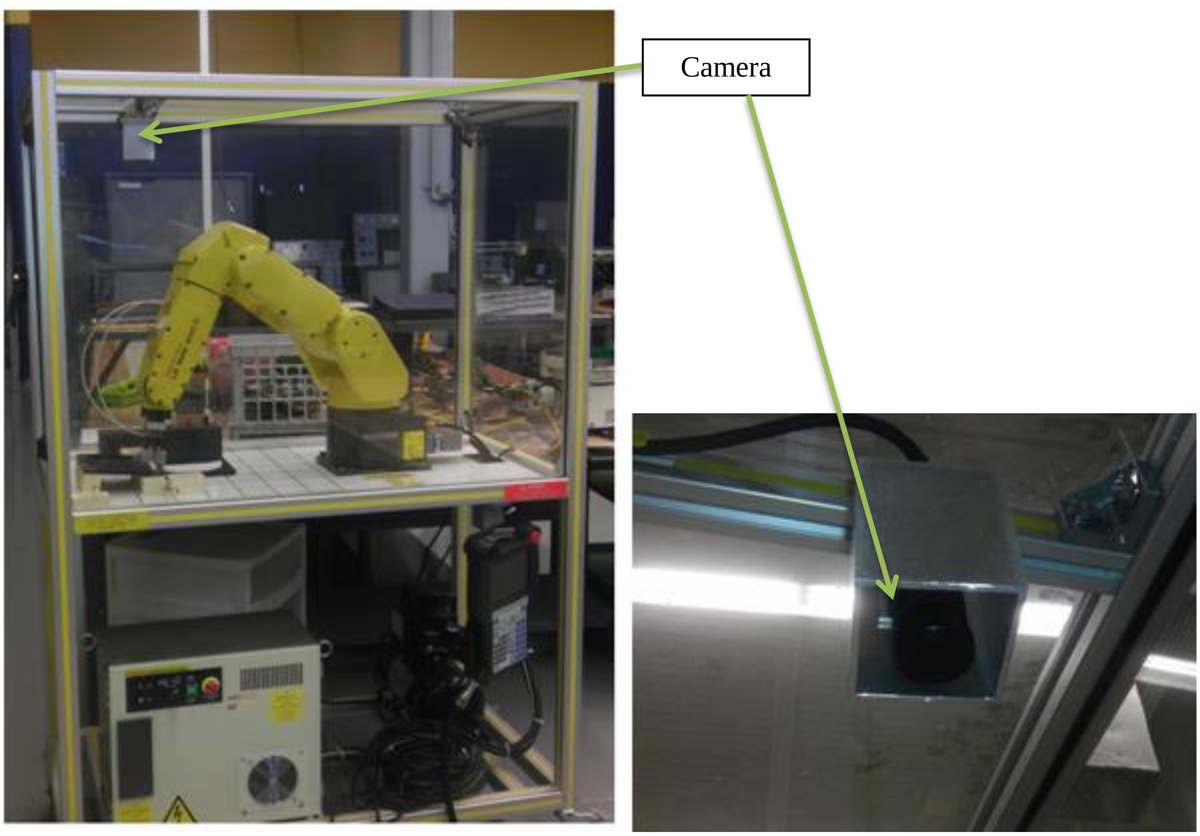


Figure 8: Current capabilities include cameras in the Fanuc CERT training cart.

The increase in the use of automation and specifically robot vision systems in a variety of industries means that companies will be looking for engineers with the skills and knowledge required to design and maintain these systems. In order to accommodate that need, the attended school should offer the proposed class as an engineering technology elective. This will give graduates a valuable advantage in an increasingly competitive job market.

Reference

[1] Hagiwara, H., Asami, K., Komori, M.: FPGA Implementation of Image Processing for Real-Time Robot Vision System. Communications in Computer and Information Science 206, 134-141 (2011)

[2] Okuno, H., Yagi, T.: A robot vision system for collision avoidance using a bio-inspired algorithm. Lect. Notes Comput. Sci. 4985, 107-116 (2008)

[3] Oh, J., Jang, G., Oh, S., Lee, J., Yi, B., Moon, Y., Lee, J., Choi, Y.: Bridge Inspection Robot System with Machine Vision. Automation in Construction 18, 929-941 (2009)

[4] Cesetti, A., Frontoni, E., Mancini, A., Zingaretti, P., Longhi, S.: A Vision-Based Guidance System for UAV Navigation and Safe Landing using Natural landmarks. J Intell Robot Syst. 57, 233-257 (2010)

[5] Wang, Binhai (Electric Power Robotics Laboratory, Shandong Electric Power Research Institute, Jinan, 250002 Shandong, China); Guo, Rui; Li, Bingqiang; Han, Lei; Sun, Yong; Wang, Mingrui **Source:** *Journal of Field Robotics*, v 29, n 1, p 123-137, January-February 2012, *Applied Robotics for the Power Industry*

[6] Di Paola, Donato (Institute of Intelligent Systems for Automation (ISSIA), National Research Council (CNR), Bari, Italy); Milella, Annalisa; Cicirelli, Grazia; Distante, Arcangelo **Source:***International Journal of Advanced Robotic Systems*, v 7, n 1, p 19-26, March 2010