Machine Vision and Robotics Laboratory

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The modern mechanical engineering technician/technologist must function in an increasingly automated world of design and manufacturing of today's products. The focus of this paper is on how to apply, not how to design, effective automated systems using some of the emerging building blocks of automated manufacturing systems. It will concentrate on the applied emphases of introductory and advanced courses in automated manufacturing systems that can be taken by associate and bachelor degree mechanical engineering technology students. These courses cover both theory and (hands-on) laboratory experiences in basic robots, switches, sensors, vision systems, digital logic, and PLCs used in today's industry. Many of these topics will not be covered here in order to address specifically the integration of machine vision with robotics applications. A short video showing the current automated manufacturing laboratory will be presented in conjunction with this paper.

Robots have been used for many years in applications of welding, painting, material handling, and assembly with more recent use in delicate assembly and inspection. Integration with machine vision has become a common partner more rapidly than expected. A machine vision system is not just a set of artificial eyes to permit a robot to see where it is going, navigate about its workplace or work as an object avoidance system. Such systems of the past bear little resemblance to today's machine vision systems, which may perform multiple manufacturing operations from inspection to measurement and small component assembly. Machine vision and machine vision systems will usually have specific assignments such as checking for proper part alignment, identifying parts, searching for specific defects, or checking alignment for assembly.[1] These procedures can be used advantageously with robotics systems to concentrate ways of employing integrated automated-vision systems for practical work.

Laboratory Facilities

The automated manufacturing laboratory in the Department of Technology, Kansas State University-Salina is built around seven laboratory and industrial robots and several flexible manufacturing systems. These include: two Scorbot ER VII laboratory robots, RobotVision/plus system, monitor, camera and two Motorola 68000 controllers; two Sankyo 5407 SCARA industrial robots with IBM controllers, IBM 386 control computers, AML/2 software and two SE 9100 vision sensors with monitors and cameras; two Unimation PUMA 550 robots, Unimation controllers with interface boards and VALII and Fast Talker software. All robot systems are equipped with their own teach pendant, 486 computer and dot matrix printers for both off-line and on-line programming.

The vision systems used in the lab can utilize 4 to 8 video cameras at a time. Programming in four different robot languages, Scorbase, ACL, VALII, and AML/2, along with equipment mentioned above, provide a flexible exposure to robotics and vision system interface. Hands-on operation and programming is provided each student working in small groups.

A Dolan-Jenner model 640 Investigation System (ALIS) with Sony color camera, Dalsa Line Scan camera, several B/W cameras, monitor, and various lenses are used to investigate lighting and optics configurations for different applications.

Additional equipment connected to this laboratory but not discussed here are: pick and place Armatrol-Mercury robot; PLCs, AB 154, 4-AB 100, 2-AB-SLC 500, and Square-D; several conveyors; vibrating bowls; numerous sensors types - switches, proximity switches, infrared, photoelectric, fiber optics, etc.

Laboratory Exercises

The AML/2 language used was intended to be a general language for robotic and other types of automated equipment. It is very similar to the popular, general-purpose computer language C. AML/2 provides for the use of subroutines and functions in C as well as vision system control instructions.

Machine vision functions can be divided into two general steps: (1) the gathering of the image into a machine readable form, and (2) the manipulation and analysis of that image to interpret it and accomplish the tasks desired. The digitization of image data is a classic example of analog to digital conversion that has application to other areas of manufacturing automation.

The interpretation and analysis phase is where specific objectives are being pursued with numerous techniques. Windowing to concentrate the analysis into a small field, thresholding used for image analysis, and histogramming to select appropriate light intensity levels are some of the phases useful in providing a most successful image. The shape identification is accomplished by a variety of clever techniques such as template matching, polygon approximation, local-features and edge detection.

The image or object is raster scanned in two dimensions by a black and white camera that gathers pixels which can be displayed on the monitor screen. The objective of a machine vision system is usually to discern a target feature, not to make a pretty picture. Switching to other cameras can add geometric representation in additional dimensions. The vision sensors define three kinds of images: "live", "binary", and "freeze" images. The "live" image is produced by the video signal received from one of the connecting cameras. The "binary" image is the binary coded "live" image in which each pixel has a value of black/white or zero/one. After the image acquisition is processed and stored to frame memory, it is a "freeze" image and is stored as a binary image.

After the students have been introduced to basic robot geometry, movement, and operations, they will program each type of robot in the lab. They will write two programs using at least two robot types. The student groups are then guided through exercises of operating machine vision through image acquisition (or capture) and image analysis techniques and lighting evaluation.

Several application experiments are then pursued using the vision sensors and robot arms, such as:

* Calibrate the Camera with Robot Arm
* Count Number of Objects and Assign a Specific Number
* Find the Location and Orientation of an Object
* Inspect a Gear for Missing Teeth
* Inspect a Number of Gears for Missing Teeth
* Measure a Rectangular Object with Two Holes
* Measure Dimensions of Circular and Elliptical Objects
* Identify the Shape and Parameters of Four-Sided Objects

Lighting is the most critical aspect of any machine vision application. Proper training on, how to choose the proper lighting scheme can result in increased accuracy and system reliability, and decrease response time. Because lighting is a unique problem to machine vision applications, we use the ALIS 640 Lighting Investigation System to select the specific lighting method from several options. Specific lighting methods utilize lens optics, polarizer/analyzers, filters and diffusers. Light sources used include: state-of-the-art, very high output (VHO) high frequency fluorescent, quartz halogen, laser diode, strobe and fiber optic ranging the spectrum from UV to near IR. This system allows rapid evaluation of target lighting in minutes, not hours or days. It affords users a means of quickly changing from one lighting strategy to another allowing for a thorough exploration of lighting in determining a final approach.

Several application experiments using the Application Lighting Investigation System (ALIS) have been or are under development. Titles of applications completed are:

* Setup and Use of Basic Lighting Techniques to Locate and Measure Part Features
* Edge Detection and Binary Effects Using Back Lighting
* Investigate & Design Lighting Configurations for Industrial Parts & Tasks
* Use of Strobe Lighting to Image Features on Moving Parts
* Laser and Fiber Optic Lighting

Due to the interdisciplinary nature of vision systems, these laboratory experiences include basic concepts in related fields such as: electronics, computers, production control, axis transformation, algorithms, pattern recognition, optics, lighting, and much more.

A final project for the first course is to develop a robotics program to incorporate the robot arm, sensors, and/or vision sensor to perform tasks with subroutines and decisions. Machine vision systems are used to let the robots identify, measure, and sort components. The final project for the second course is to design and implement an integrated system to produce a product.

Conclusion

The changing face of manufacturing applications requires continuous rethinking of the relevant experiences of the mechanical engineering technology curriculum. The engineering technologist must be able to apply the latest technology to effective and efficient solutions of today's manufacturing problems. This effort is part of an overall emphasis to produce technology specialists who can cross discipline boundaries and are capable of solving problems crucial to our nation's competitiveness and technical prowess.

Through these courses which include the processes of handling, inspecting, evaluation, and assembly of manufactured components the student designers will have learned important details about significant factors affecting individual parts and their relationship to the overall product.

Since its inception six and one-half years ago, student response is very positive to the courses titled "Automated Manufacturing Systems I" and "Automated Manufacturing Systems II" including the topics covered by this paper. These courses started out as
requirements for an automated manufacturing option in the mechanical engineering technology associate degree program and now has become required courses for both the associate and bachelor degrees in Mechanical Engineering Technology.

The presenter is constantly exploring more applications of robotics/sensors/vision system interface. This paper is written to suggest to educators in engineering technology, options to consider in instruction of automated manufacturing applications.

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