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A capstone design project- Machine Vision System in Inspection Process

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Abstract

The purpose of this project is to design an automated inspection system that will identify, accept, or reject parts on a production line. The project simulates a major goal of industry—to monitor deviations in parts geometry. The project begins by integrating five components that work together as a system: a conveyor, a machine vision sensing device or camera, a robot, a programmable logic controller (PLC), and a pneumatic actuator. The conveyor belt moves parts to the inspection area, where the machine vision camera detects them. The camera makes an image of each part and displays that image within the software windows environment. The edge count and measurement distance sensors in the software identify each part as acceptable (PASS) or not acceptable (FAIL). The system, as it is designed, uses a PASS signal to recognize acceptable parts. That signal then is sent to and used by the robot to gather and assemble the acceptable parts in a central location. If the part is unacceptable, it is moved within reach of the actuator, which pushes it off the conveyor belt into a scrap bin. Five components, each performing a different function, are tied together into a system dedicated to ensuring that customers receive a quality product.

I. Introduction

College seniors in the Automated Manufacturing Technology Program are required to complete a capstone design project during their final semester. The program affords students the opportunity to develop their teamwork, communication, and problem solving skills, as well as the opportunity to put into practice many of the competencies learned in their program of study. Also, the students are afforded the opportunity to apply their individual technical know-how and knowledge on a real world project, which in this case is to design an automated inspection system utilizing a machine vision sensing device or camera, a robot, a PLC, and an actuator arm—all governed by computer hardware and software.

Automated inspection processes (AIP) are commonplace throughout industry and are used to ensure quality in products ranging from bottles to medicated pads to food items, as well as in the inspection of semiconductors, automotive parts, pharmaceutical products, and electronics in general. The machine vision sensing system can analyze scenes by extracting certain features from the image, such as accuracy of product dimensions, correct assembly of components, as well as identify the product as the correct product[1]. Virtually every manufacturing process can benefit from machine vision inspection.

The objective of this project is to demonstrate product recognition, identification, acceptance, or rejection. This AIP is very useful in industry, as it ensures timeliness and accuracy of product integrity. The machine vision sensing system is a tool that largely eliminates human error and the boredom and tedium of doing the same task over and over again. Also, it removes human beings from exposure to hazardous materials or environments, while at the same time accomplishing complex tasks quicker, more efficiently, more cost effective, and all without diminishing product quality. In some manufacturing scenarios, however, the inspection process serves a different function. Mass production may not allow constant changes in process, as the goal is continuous production. In this instance, an enormous quantity of parts can be made taking into account that some parts may not meet the established criteria. Because of the volume of parts produced, it is, in many instances, more cost-effective to keep a process continually going rather than to stop it. If the ratio of good to bad parts is relatively high, the machine vision sensing inspection system will eliminate the bad parts without having to slow down or stop the assembly system.

II. Automated Inspection Process

The flow chart depicted in Figure 1 shows the automated inspection process. The components that make up the AIP consists of a Mitsubishi RVN10 industrial robot with a input and output controller[2], an Allen Bradley Micrologix 1000 Programmable Logic Controller (PLC), a conveyor belt assembly, a pneumatic actuator arm, and a DVT Smart Image Sensor Camera with a I/O board[3]. The robot program activates the input/output controller, which sends and receives signals from the conveyor belt assembly, the DVT camera, and the pneumatic actuator arm. The Smart Image Sensor is a machine vision device that uses soft sensors to look for changes in contrast on a two-dimensional plane. The soft sensors are tools drawn on an image of an inspected part in order to carry out a specific task such as dimensional specification. For this project, the edge count and measurement soft sensors were utilized to make precise measurements.

The process begins when the robot places a part in a designated location on the conveyor belt. Then, the robot program activates the conveyor belt through robot controller output #1, which is illustrated in Figure 2. The conveyor belt transports the part to the inspection station, where the robot controller, output #9, sends a pulse to the DVT camera. The camera takes a picture of the part. The pre-programmed soft sensors in the camera collect data from the part and sends a PASS/FAIL signal back to input #9 of the robot. If the robot receives a PASS signal, the conveyor belt is activated, conveying the part to a specific location, where the robot will place it in a storage container. If the robot receives a FAIL signal, the conveyor belt is activated, conveying the part to the actuator, which pushes the part into a scrap bin. The actuator is controlled by a blast of air initiated by a line of robot program. The PLC is the go-between from the robot output and the motor that drives the conveyor belt. Robot controller output #1 and +24 volts terminals are connected to the I/O and +24 volts terminals on the PLC, respectively. The detailed wiring diagram of the different components is depicted in Figure 3.

For the sake of convenience, five parts are considered for inspection. Three of the parts are identical and indicate the good (PASS) parts. The other two parts are defective (FAIL) and contain defects such as missing legs and wide leg.

III. System Testing and Calibration

In order for the camera to recognize the difference between a good part and a defective part, the following must be done.

First, a good part must be placed under the camera to obtain the desired image. Next, soft sensors are located on the image of the good parts so that PASS/FAIL parameters can be defined. Then, a mixture of both good and defective parts are placed, one at a time, under the camera to ensure that the camera sends either a PASS or FAIL signal based on the condition of the part. The comparison of good and defective parts is illustrated in Figure 4.

Finally, the camera is secured to the conveyor belt assembly in order to see the speed at which the camera recognizes a good or defective part and how it interfaces with the other components of the system. Good parts are collected by the robot and stored at a central location, whereas defective parts are rejected and pushed off the conveyor belt into a scrap bin downstream of the camera by the pneumatic actuator arm.

IV. Assessment of Students and Outcomes

The department uses the capstone design project as an assessment tool to evaluate and validate program outcomes and students' achievements. Students are required to demonstrate scientific and technical knowledge and skills, and team work, and also be able to present the project both in verbally and in writing to the faculty and their peers.

Students are divided into teams with a maximum of four members per team. Each team selected a team leader who was responsible for managing all aspects of the project. The selection was based on academic achievement, technical skills and professional conduct. Each team member played a vital role in the design, assembly, testing and troubleshooting of the automated inspection process. One of the students, who acted as the Manufacturing Engineer, was responsible for programming a CNC milling machine in order to produce the parts to be inspected. Two other students, acting as Process Engineers, designed and installed the camera and actuator arm mounts and secured them to the conveyor belt assembly system. Also, they were instrumental in writing and modifying the robot program by inserting IF/ELSE statements, which activate different parts of the program to meet certain conditions. In addition, they were responsible for wiring and interfacing the various components of the automated inspection system and setting up the DVT sensor so that it could recognize the acceptable and unacceptable parts. The team leader, acting as the Operations Engineer, was responsible for overseeing the various stages of the project. He gathered documentation, ensured project logistics (parts and supplies), resolved problems and issues experienced by the team, and collected information from faculty for successful completion and operation of the automated inspection system.

V. Conclusion

Seniors implement general technical knowledge as the key to solving the current manufacturing problems in quality control. They learn how to install, program, operate, and troubleshoot each component of the system. Teamwork and group dynamics are other important parts of this project. They learn how to work and communicate together. The team leader coordinates the activities of the individuals who compose the project team. Students interact with faculty and faculty engage students in problem solving processes. The major challenge to this project is the integration and interfacing of the various components of the system as it relates to the overall process. With the exception of machining the parts, each component of the system must rely upon input from another component of the system. Each component provides the appropriate electronic response to indicate that a particular task has been completed. These signals are used to keep the process in motion, or to interrupt it when a defective product is detected. By properly integrating the individual components together, the system is able to detect defective parts. This project can be applied in industry to identify and inspect parts, determine position, orientation, location, visual guidance, and other applications related to quality control. Also, the project can be used in capstone course for assessment purposes.

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Biographical Information

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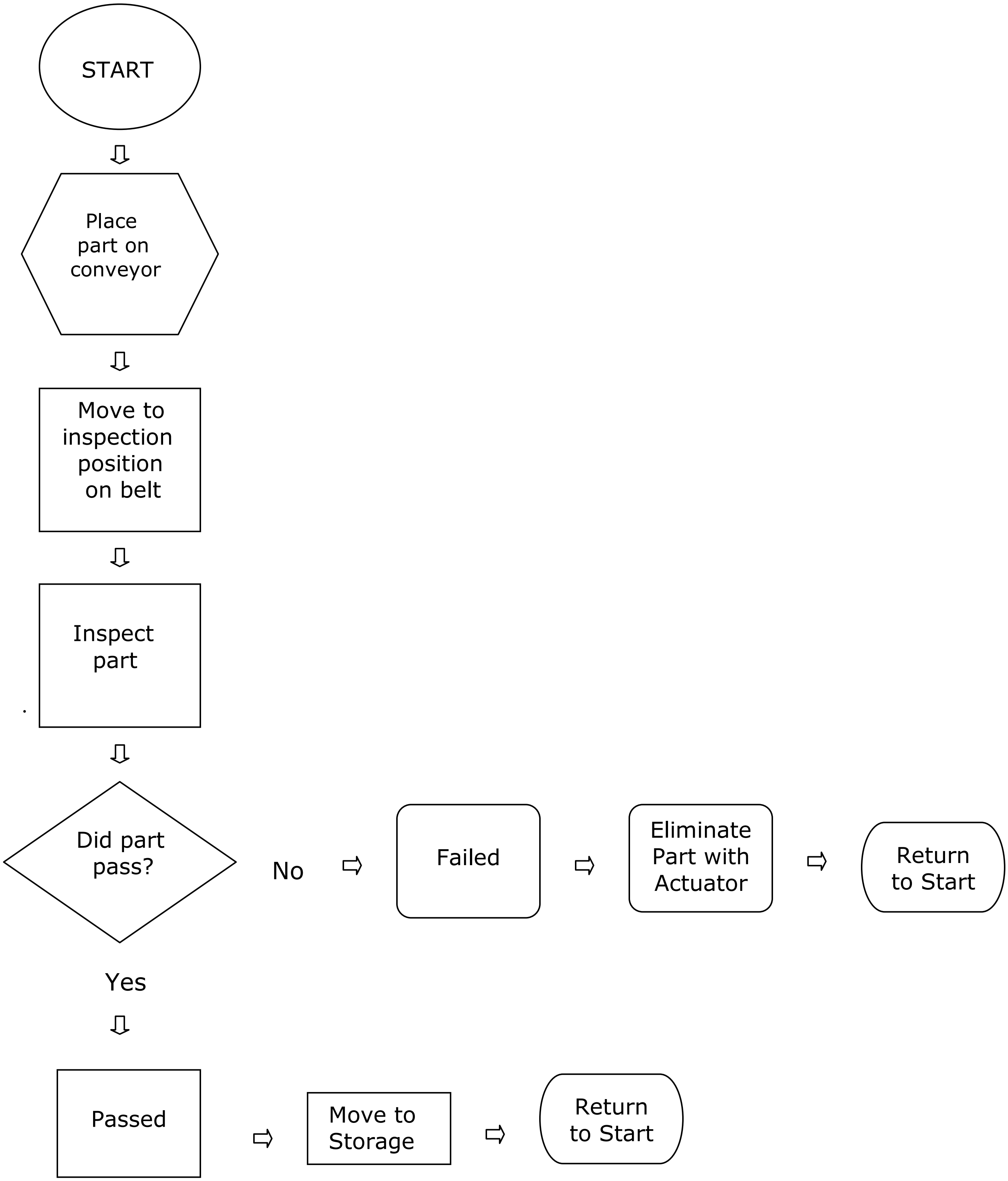

Figure 1. Inspection process flow chart

Cam = camera - Con = conveyor - Fail = part failed - Pass = part passed - Rbt = robot

	<u>Program Instruction</u>	**<u>Process Explanation</u>**
Rbt	**040 IF IN 10 = 1 GOTO 50 ELSE GOTO 40**	
	050 MOV P50	Home position
	100 MOV P100	Position arm over part
	125 HND 1=1	Grab part
	160 MOV P150	Position part at belt
	165 HND 1=0	Place part
	175 MOV P50	Back to home
Con	**180 OUT 1=1**	Conveyor on
	190 DLY 2	
	195 OUT 1=0	Conveyor off
Cam	**200 OUT 9=1**	Send signal to camera
	225 DLY 2	Take picture/inspect
	250 OUT 9=0	
	275 DLY 3	
	300 IF IN 9=1 GOTO 400 ELSE GO TO 600	
Pass	**400 OUT 1=1**	Conveyor on
	425 DLY 2	
	450 OUT 1=0	Conveyor off
	460 MOV P200	Move above part
	465 HND 1=1	Grab part
	485 MOV P250	Part move to collect point
	500 HND 1=0	Place part
	525 DLY 1	
	550 GOTO 725	
Fail	**600 OUT 1=1**	Conveyor on
	625 DLY 2	
	650 OUT 1=0	Part stop at actuator
	665 DLY 1	
	675 HND 2=1	Actuator out
	685 DLY 1	
	700 HND 2=0	Actuator in
	725 GOTO 40	

Figure 2. Robot program

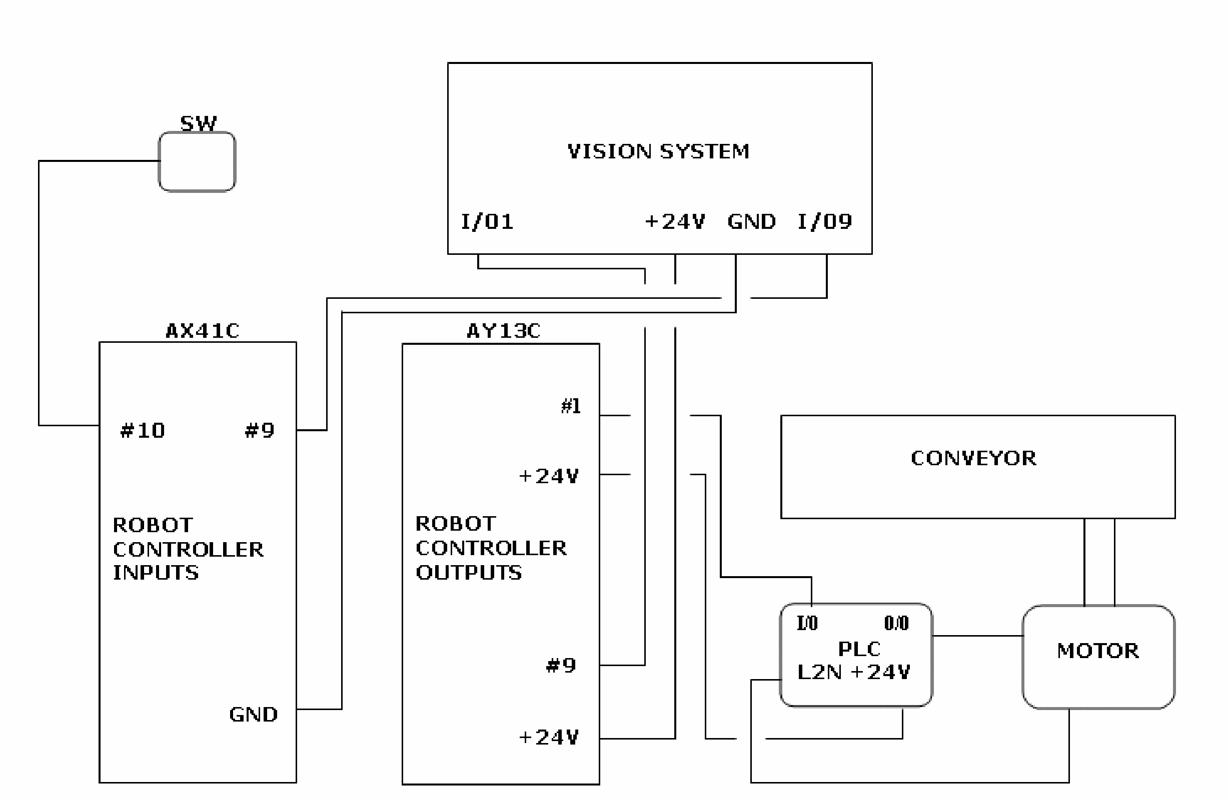

Figure 3. Wiring diagram

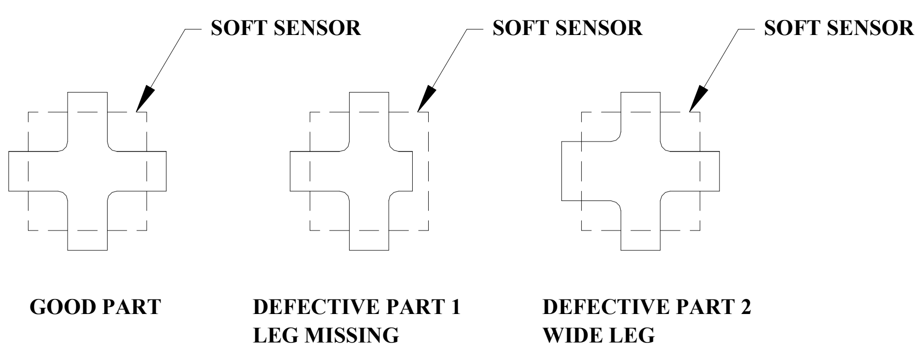

Figure 4. Comparison of good and defective parts