

Design of a Computer Vision Integrated Solid Handling System to Teach Manufacturing Automation to Third Year Undergraduate Students

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Abstract: This paper gives an overview of a solid handling system for flexible manufacturing processes performed by the Department of Mechanical and Chemical Engineering at the Islamic University of Technology (IUT). The basic concept of the system architecture and the work performed towards the development of the automated manufacturing process at IUT are described. The aim with the research initiative is the development of relevant skills in automated monitoring and controlling of manufacturing processes among the third year undergraduate students who specialise in manufacturing technologies. The flexible systems help students to understand how to increase productivity as well as reduce the total cost of the operation in manufacturing process. The overall system consists of a conveyor system, a robot system, a vision system, and a multitasking/multiprocessor computer system. The understanding of such a system would enable students to perform the entire production cycle for a variety of products.

Key words: manufacturing automation, solid handling, computer vision, conveyor, bucket

INTRODUCTION

A large proportion of effort regarding the automated manufacturing systems design is consumed and many works have been developed addressing the formalization of such systems. Despite of the application diversity and experience on the flexible manufacturing; the systematization, the theoretical grounds and the system design are developing day by day. As manufacturing environments become more and more competitive, small and medium manufacturing companies' approach becomes important for the productivity, quality, profitability and overall performance. Udoka (1991) overviewed the current body of knowledge on automated data capture technologies including bar coding, radio frequency identification, radio frequency communication, optical character recognition, voice recognition system, machine vision, electronic data interchange. The study explained that these techniques were critical to the success of automated manufacturing systems. The opening of world wide markets to many products enforce high level competition among manufacturer and has led to rapid developments in the areas of computer integrated manufacturing, flexible manufacturing, agile manufacturing and intelligent manufacturing etc. Chen and Su (1996) proposed an automated inspection system to enhance efficiency and flexibility of a computer integrated manufacturing system. The inspection system was equipped with closed loop feedback control architecture and produced a fully integrated production process. Enake and Dagli (1997) discussed the need of automated visual inspection systems in today's competitive environments. The development such automated system provide intelligent sensing and decision making systems capable of automatically performing many tasks traditionally executed by human beings.

The applicability of a vision system in educational and industrial application is wide. Chin and Dyer (1986) presented a comparative study on the model based object recognition for robot vision and provided insights of the progress toward future robot vision systems. Lu and Hsu (1995) described a computer vision system to reduce the human supervision of an existing automated storage retrieval system for a computer integrated manufacturing laboratory. The flexibility of the system was that it could be applied to other systems without further modification. Martin and Chiang (2003) developed algorithm to detect and to identify several mobile robots for successive frames using web cam based vision system. This led to a simple and cost effective way

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of performing image processing based on colour in real time. Winchester (2003) stated that manufacturer required exceptionally aggressive product development to survive in an industry where product life cycle is short. Therefore, well equipped initiative is required to deliver benefits in small and medium manufacturing plant using advanced automation. Kuren (2005) proposed a projection vision system integrated into an existing modelling framework to identify products and its surface for robotic processing. The system facilitated proper processing of used goods to meet current product demand. Kuren (2005) claimed that the application of projector-vision technology improves the accuracy of recovered material databases and improves the automated processing of used material streams. Rapid advancement of computer technology has enabled vision system, over other approaches, to act as high accuracy non-contact measurement tool. Huang and Lambert (1992) represented an integrated system using machine vision technique to shorten the product development cycle. The integrated implementation could provide manufacturing feedback during the product development stage. Ling et al. (2002) claimed vision system as the most desirable precision measurement tool. Through the experiment, they compared a high cost Charge Coupled Device sensor and a low cost Complementary Metal Oxide Semiconductor sensor respectively. The results revealed that the performance in speed and accuracy of the low cost sensor was compatible with high cost sensors.

Abdullah *et al.* (2004) discussed image acquisition technologies namely the machine vision system and the computerised radar tomography using visible and non-visible band of radiation. The study showed the way to combine images produced by vision and sensors in order to adequately match the categories made by the experts in production line. Connolly (2005) reviewed the marking methods, the types of codes employed and the machine vision equipment used for part tracking in different industries. The study found that matrix code were being widely adopted for improving efficiency and quality of production line and the handling of any faults that appear during usage. Lindsay *et al.* (2000) proposed an advanced material handling system with improved travel and flexibility for computer integrated manufacturing. The proposed system formed part of a manufacturing assembly, interacted with overhead manipulators and part feeders and formed a comprehensive production system. Hashimoto (1993) described various approaches of automatic control of mechanical system using visual sensory feedback. Yee and Ventura (1999) described a method for finding optimal sequences in an assembly system. The method provided the selection of assembly sequences within all feasible assembly sequences. Robot vision system is mainly based on image based visual robot servoing. Pauli *et al.* (2001) applied visual servoing mechanism for handling object, camera calibration and object inspection. Through three different phases, namely calibration, inspection and assembly, the authors articulated the usefulness of image based servoing, optimal viewing and inspecting the objects, approaching and arranging the object to a goal place. Bone and Capson (2003) described the development of a vision guided robotic fixtureless assembly for automotive components with an aim to replace costly and inflexible fixtures. This was done with a programmable gripper to hold a wide range of part shapes without tool changing. The actions of the overall assembly were coordinated using a flexible distributed object oriented approach. Meng and Zhuang (2007) proposed a vision based self calibration method for a robot manipulator to measure the camera with a sequence of images of a calibration fixture without knowing the 3D data of the fixture in the reference coordinate system. The proposed method offered the robot calibration procedure more autonomous in a dynamic manufacturing environment by utilizing image sequences of a calibration object and a ground truth length (a given distance) within the reference frame. Gonzalez-Galvan *et al.* (2003) presented a vision based control methodology to perform accurate, three dimensional positioning and path-tracking tasks. Golnabi and Asadpour (2007) discussed the role of machine vision systems in industrial applications and reported a generic machine vision model.

The primary activity in this context is the development of a research platform by means of which students can develop their skills in practical process control in an automated manufacturing environment. The central theme of the activity is a multi-disciplinary, integrated approach to developing a physical system and applying these new techniques to flexible manufacturing processes. In this study, the platform consists of a conveyor system that transports small solid components through automated quality assurance by means of image processing and pick-up of different solid components using a pick and place robot. The solid components are placed on the bucket elevator for transporting the product to the storage locations. The functioning of the system is monitored via computer with data being sent. Manual control of identified activities of the system is also being incorporated.

Importance of the System:

Vision integrated automation systems have increased demand for efficient and flawless production process in the industrial plants. The greatest opportunities lie in improvements in product quality through automated

inspection of manufactured products. These days, almost all tasks that involve people in products inspection, can potentially be done partly or entirely by automated system. This system can be used to measure and count, and to detect flaws in products. It performs some tasks more effectively than people, especially tasks that involve highly repetitive inspection of products. Therefore, inspection processes are automated in order to lower inspection times, to minimize the mistakes coming from the labour in the quality control process, to bring flexibility in production system and to prevent the damage caused by control process. Products manufactured in millions have motivated the trend away from manual handling assisted by mechanical devices towards a fully-automated handling. Computer vision integrated handling technology is used to identify the quality and position of the products on conveyor system. The study demonstrates the building procedure of a flexible system using the combination of computer vision and handling technologies to the students who specialises in manufacturing technologies. This system can create ideas in students mind about their own processes and can easily be modified according to their needs with simple modifications.

Construction of System Hardware:

Followings are the list of hardware that has already been prepared by the students in the university workshop to incorporate with the system.

The Pick and Place Robot:

The material used for the manufacturing the robot is plastic, which is of 4 mm thick. Plastic body makes the robot light and nice. Plates of plastic were jointed with a special type of glue made of plastic dusts mixing with chloroform. It has employed mainly three different movements; waist movements, first arm movements, second arm movement. Figure 1 illustrates the demonstration unit of the pick and place robot prepared by Kabir *et al.* (2003) in IUT workshop.

The specifications of the manufactured robot are listed below

- Degree of freedom: 4
- Capacity: 500g
- Repeatability: ± 0.5 mm at the end of arm.
- Axis Capabilities:

	Maximum Angle (°)	Speed (Deg./sec)
Waist	360	0-27
First Arm	270	0-10
Second Arm	90	0-10

The Vision Interface:

The picture-capturing device as shown Figure 2 is capable of taking picture from any location on the conveyor by moving its face according to the request from the user. For the movement of the camera, it is mounted on camera holder. Parts of the camera holder are stepper motor, gear, metal plate, and plastic plate bar. The whole mechanism was developed by Alam *et al.* (2003) as a part of their undergraduate project work at IUT

two stepper motor is used. One is the azimuth control motor and other is the elevation control motor. There was a gear coupling with the azimuth control motor. Plastic plate bar is used to hold the elevation control motor on the gear of the azimuth control motor. The camera is mounted on a metal sheet that is rotated by elevation control motor. Azimuth control motor is capable of taking the load of elevation control motor along with the webcam mounted on it. All these parts are mounted on a metal plate. The circuit diagram used in the image processing is shown in Figure 3.

Conveyor Belt:

The main components of the conveyor belt are pulling member (belt), idler rollers, centering device, drive units (pulley, motor and transmission gear between the motor & pulley), mechanical (screw-type) or counterweight (gravity-type) take-up, discharge device (tripper), belt cleaners, conveyor frame. Some of the components were ordered according to the model specifications. The others were manufactured in the



Fig. 1: Pick and Place Robot with Gripper Hand (Kabir *et al.*, 2003)

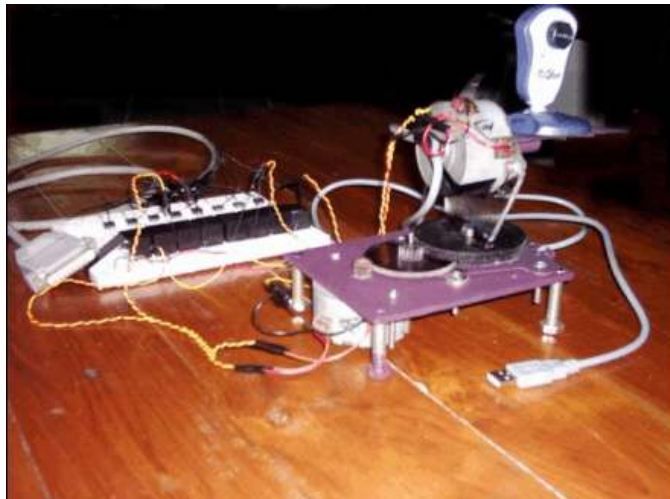


Fig. 2: The Camera Mounting (Alam *et al.*, 2003)

University workshop. The schematic view of the conveyor belt designed by Islam *et al.* (2003) in the IUT workshop is shown in Figure 4. The specifications of the manufactured conveyor belt are given below

- Capacity: 1.5 tons per hour
- Belt length: 1.1 meter
- Belt width: 200 mm
- Belt length: 1100mm
- Belt thickness: 7.3mm
- Roller diameter: 78 mm
- Roller face (Length): 400 mm
- Driving pulley shaft diameter: 30 mm
- Driving pulley bore bearing diameter: 30 mm
- Driven pulley shaft diameter: 25 mm
- Driven pulley bore bearing diameter: 25 mm
- Frame height: 600 mm
- Length: 1400 mm
- Width: 410 mm

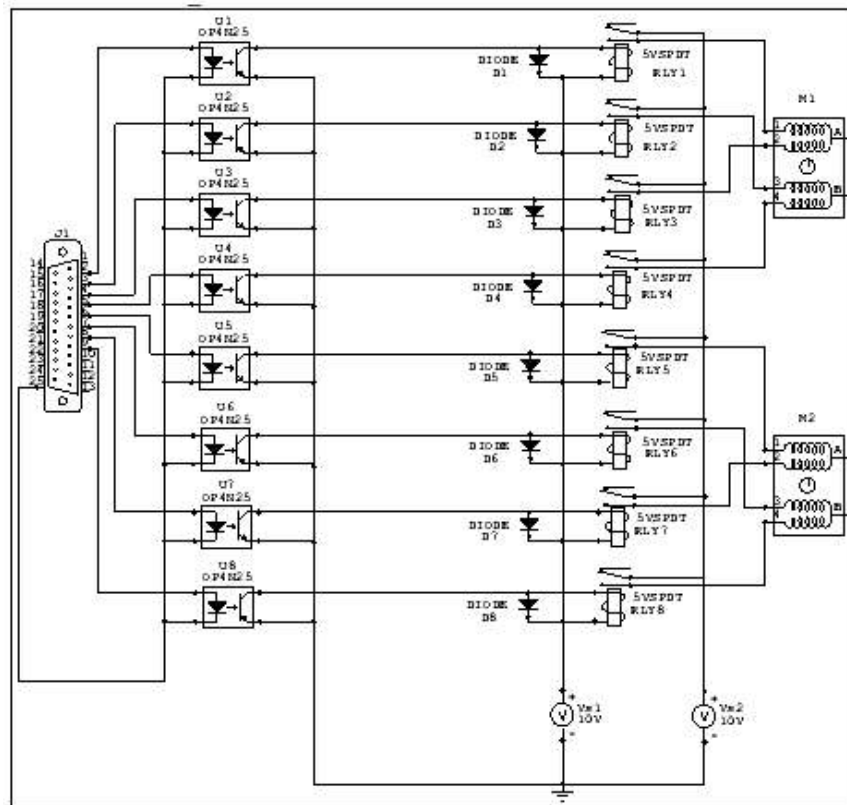


Fig. 3: Interface Circuit for Image Processing (Alam *et al.*, 2003).

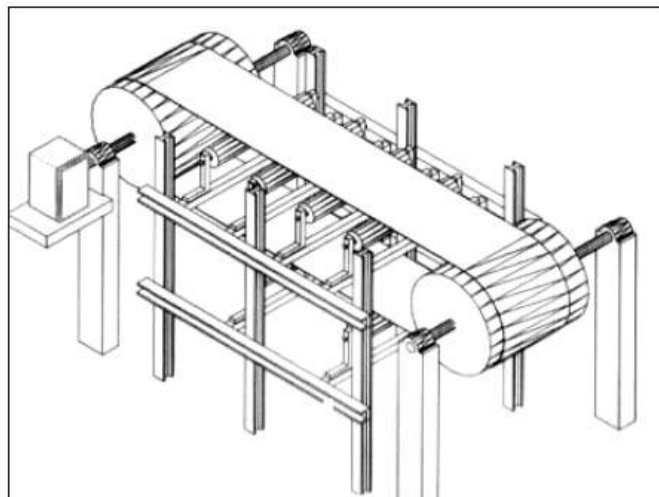


Fig. 4: Schematic View of the Conveyor Belt (Islam *et al.*, 2003)

- Motor power: 0.5HP (0.372 kW)
- Motor RPM: 56

Bucket Elevator:

Bucket elevators are specified for the conveyance of various solid components. Transverse compactness, ability to raise loads to considerable height and capacities ranging from 5 to 160 m³/h are the main merits of manufactured bucket elevator. The main components are buckets, pulling member (belt), shaft, drum

pulley, casing, base, hold back brake, take ups, elevator boot, drive unit (gear type motor and belt). There are 11 buckets and the gap between the buckets is 0.3m. Each bucket has the capacity to about 215 GM. The schematic view of the bucket elevator manufactured by Islam *et al.* (2003) in the IUT workshop is shown in Figure 5.

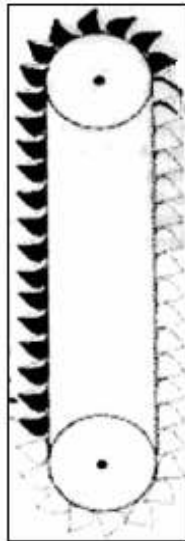


Fig. 5: Schematic View of a Bucket Elevator (Islam *et al.*, 2003)

The specifications of the manufactured conveyor belt are given below

- Belt Width: 152.4 mm
- Belt Length: 3.33 m
- Width of the Bucket: 127 mm
- Height of the Bucket: 120.65 mm
- Bucket spacing: 301.62 mm
- Inner diameter of Drum pulley: 38 mm
- Outer diameter of Drum pulley: 254 mm
- Power transmission Belt: A-40
- Inner diameter of motor pulley: 12 mm
- Outer diameter of Motor pulley: 92 mm
- Motor: 3-Phase AC Motor
- Motor power: 0.5 hp = 0.272 KW
- Inner diameter of Power transmission Pulley = 25 mm
- Outer diameter of Power transmission Pulley = 120 mm
- For upper shaft,
- Inner diameter of Ball Bearing: 25 mm
- Outer diameter of Ball Bearing: 50 mm
- For lower shaft,
- Inner diameter of Ball Bearing: 30 mm
- Outer diameter of Ball Bearing: 60 mm

System Overview and General Structure:

The system is designed to transport solid components that are placed on the conveyor. The conveyor is governed by microprocessor based logic controller. Various sensors including speed and positional sensors provide input signals to the controller. The program in the controller makes decisions based on the input signals and control the output signals to activate the different devices interfaced to the outputs of the controller. It is however not only for controlling of the system that the program logic controller is used but also for monitoring the complete system. The quality assurance on the specific solid component is done using image processing. The components are directed to the correct exit, are picked up from the exit area and are placed

on the bucket elevator using pick and place robot for transportation of the component to a permanent storage area. Figure 6 illustrates a schematic of the overall system.

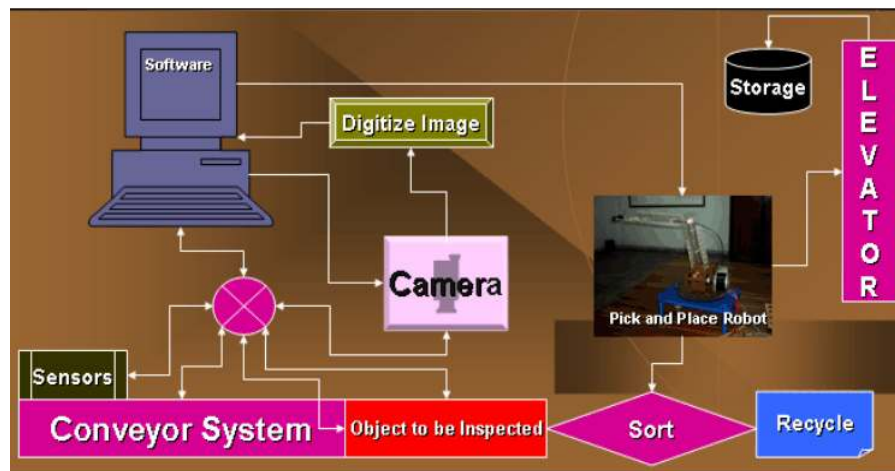


Fig. 6: Schematic illustration of the overall system

In this setup there can be maximum one product in one line over the conveyor. The product is feed to the system manually from the left side. When the product passes through the sensor, the sensor triggers the camera after a certain delay according to the speed of the conveyor. At the same time the sensor triggers the encoder and the encoder starts to count the pulses that are equal to the distance between the sensor and the reference position of the robot. After a delay the camera takes the image of the products, and evaluates it according to the given specifications. In the setup, it is preferred to classify the products according to their colours. It can also be done according to the products diameter, tolerance, and surface texture; but since it is a demonstration unit, it is determined to identify the colour attribute to let students easily realize the system. The image processing software investigates the position of a product in the line or in the bucket. After that the vision system investigates the colours of the products in each bucket. Then the camera makes these evaluations and sends the results to the PC for storage. And the system leaves for its reference position before other products come to the reference point.

System Algorithm:

After the system starts, the initialization of the camera is done and the system remains in waiting state. To acquire image, the system waits for the trigger which is a signal coming from computer. When it sets (means make an inspection), the system grabs one image. The image is normally in RGB (red-green-blue) format. It may be converted to HSV (Hue-Saturation model) colour model to better discriminate the colour components. The image is divided into two regions (two halves, one top to mid, one mid to bottom). These regions correspond to slots and in the image they are always treated as different regions. If an object is found then the system looks at other image with similar threshold and morphological operations. Then the system decides on the colour of the object. Decision depends on the place at the Hue scale and saturation. When the system decides on the object presence and colour, it sends this information to let system to pick and clears the image for the next waiting state. The system contents a simple user interface, which always shows the last results, the cumulative number of all the processed objects, commands for initializing the camera and stopping the system. The approach for describing the shape inspection and object assembly are based on the autoregressive model described by Pauli *et al.* (2001). Unwanted noisy effects can be reduced by applying simple morphological operations.

Automated Positioning and Handling of Components:

Solid components transported and walked out from a functioning conveyor belt system are positioned and handled automatically, depending on its physical characteristics. The first students' activity involved in this process is to do image recognition of the components. Shape recognition is also a part of preliminary quality assurance processes. This is done through a real-time image processing technique where digital images of components moving along the conveyor are accessed and processed. Inspection by means of a computer-driven

image recognition opens up a field where measurements of specified criteria are performed tirelessly at high speed and with high accuracy. These measurements are compared to the image of an ideal artifact stored in computer memory and determine a pass / fail result. Quality control in production line environments historically relied on visual inspection of manufactured goods to ensure that they meet required specifications. Here, through the digital image processing, students understand the tireless, high-speed automated inspection of production lines with low error count. Camera positioned relative to the subject send a digital signal to a computer-based frame grabber. It captures images which are analysed by the software and calibrated to real world units. The characteristics of the components determine the position where the components are to leave the conveyor and influence the functioning of the materials handling equipment. When exiting the conveyor belt system, the components are taken by the pick and place robot with a gripper mounted on it. These components are transferred by the bucket elevator to pre-determined areas for further handling and/or storage. With the familiarity of the overall system, students also gather and extend available knowledge in the fields of image recognition and machine vision.

Conclusion:

The study describes the design of a solid component handling system and demonstrates a realistic approach to the undergraduate students who specialise in manufacturing process. This approach builds on the progress already made in manufacturing automation and aims to enhance the conceptual flexibility of solid handling systems to the students. The system will provide a comprehensive research platform by means of which industries and students of can develop skills in component handling system for automated manufacturing process environment.

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