AUTOMATED COMPONENT-HANDLING SYSTEM FOR EDUCATION AND RESEARCH IN MECHATRONICS

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ABSTRACT

Mechatronic practitioners are engaged in the assembly and maintenance of complex machines, plants and systems in the engineering sector or in organisations which purchase and operate such mechatronic systems. Mechatronics, often described as the synergy of mechanical and computer systems together with electronic technologies, is increasingly being singled out as a core focus by both the education and business sectors. This international trend is also evident in South Africa and Engineering Faculties now have to provide students with the opportunity not only to acquire theoretical knowledge in Mechatronics but also to develop skills in implementing and designing mechatronics systems.

Key words: Automation, Component-handling, Education, Mechatronics

1. INTRODUCTION

Mechatronics offers a new degree of freedom in design. A particular function can be realised by pure mechanics in a traditional way or as a mechatronic solution with sensors, actuators and control. Education in mechatronics has an applied and project-oriented touch, and students are trained in the specification, design and implementation of mechatronic systems and products. The courses provide students with a fundamental understanding of how microcomputers are used in mechanical systems and the ability to design and program embedded microcomputer systems included in such products. Mechatronics brings together the areas of technology involving sensors and monitoring systems, actuation systems, analysis of the behaviour of systems and control systems.

The aim of the research project described in this paper is to develop an integrated Component-handling system that incorporates:

- a dual conveyor system,
- a machine-vision system for quality control,
- machine-vision systems to facilitate component handling and sorting,
- an industrial robot to be used for component transfer and simple assembly tasks,
- Automated Guided Vehicles (AGVs) that increase the flexibility while optimising the process of material handling within the system.

The purpose of the paper is to describe the composition and functioning of such an integrated component-handling system in an experimental, pseudo-industrial environment. This system can be used by students to acquire knowledge and skills related to mechatronics but it can also be used as a base for research projects within the mechatronics field. This project is an ongoing research project and it is therefore not a final solution to a Component-handling platform.

It is important that robotics be included in the mechatronics projects as robotics is a technology that is accepted by industry to improve factory quality, performance and efficiency. Robotics has for at least three decades been a key technology in engineering industries. Furthermore robotics is seen as a key technology which enables the creation of new, valuable products or which adds performance and functionality to automated machines.

The challenge is to develop component-handling systems with robotics embedded to achieve the needed high throughput and consistent productivity. These component-handling systems therefore lead to research in robotic control and the conception, design and evaluation of innovative mechatronic systems. Advantages of using robotics in component-handling applications include speed, payload capacity and consistent productivity. Increases in throughput are typically necessary to keep pace with production demands.

The paper is organised as follows. Section II gives a brief overview of the complete integrated component-handling system that forms the basis of the research platform, whilst section III entails a detailed description of the different elements of the component-handling system. Section IV describes the integration of the proposed new elements into the system, including the integration of modern monitoring technology into an Information Management System whilst section V details a brief summary of the topic under investigation.

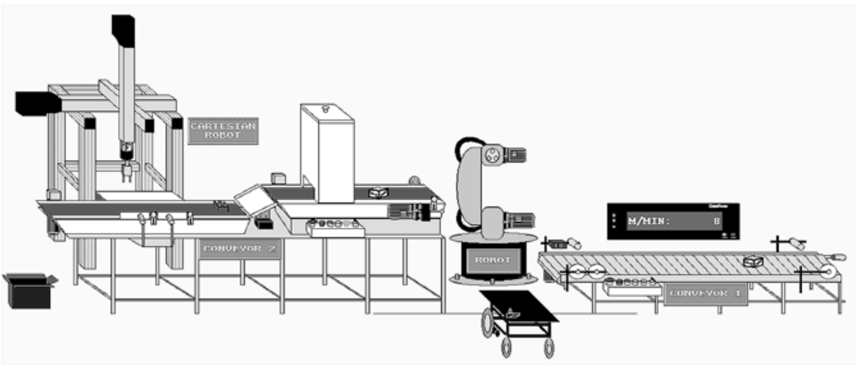

Fig. 1. Schematic representation of the current component-handling system.

2. COMPOSITION OF THE CURRENT COMPONENT-HANDLING SYSTEM

The system is designed to transport components that are placed on a conveyor system through the different "modules" of the complete system. These modules do the following:

- Picking up and placing of differently categorised components by an industrial robot either onto a next conveyor system or AGV for transportation of the component to a permanent storage area;
- Quality assurance of the specific component utilising image processing of components with respect to size, shape and surface characteristics;
- Mass and friction determination by means of a "weigh-slide". Although dynamic mass determination enjoys high priority in modern manufacturing processes [1] this facility is not considered in this paper;
- Picking up and placing (sorting) of differently categorised components by a Cartesian robot;
- Monitoring and recording of complete system;
- Quality control to ensure every shipping container has the correct number of components.

The functioning of the complete system is monitored and recorded remotely by a supervisory control and data acquisition (SCADA) system, providing data for logging purposes and the production of different types of reports. A simplified, schematic representation of the complete system, as depicted by the SCADA, is shown in Fig. 1 – with the component-flow being from right-to-left.

3. FUNTIONING OF DIFFERENT ELEMENTS OF SYSTEM

The different elements of the system will now be discussed in detail.

A. Hinged Steel Belt Conveyor

This conveyor (Conveyor 1 in Fig. 1) is the starting point of the system and components will eventually be loaded automatically onto the conveyor.

B. Robot Arm

Increasingly robotic applications require machine vision for guiding robot movement for automated component-handling, as well as for quality control. Machine vision can replace human vision with video cameras and specialised computers, and can improve on human vision where precise and repeatable visual measurements and inspections are required.

For automated component-handling, components are selected and placed on a transportation system by a robot or motion mechanism. A visionless robot requires accurately positioned components to be able to access the components correctly. This requires expensive and often unique fixtures to position each component type and assembly. A robot with vision capabilities can use less costly and more general fixtures and can be taught to find and place components on the assembly. Visual guidance can also compensate for some variations in the components, permitting the completion of tasks impossible with blind placement. Such vision systems can be either fixed, or mounted on the robot arm.

In the case under consideration use is made of a Digital Video Technology (DVT) machine vision system to provide this facility. It is mounted with an overhead light box, ensuring lighting levels on the work area that are substantially higher than the ambient lighting. This enables accurate determination of component's exact position, physical features and orientation which is required by the robot.

The current system is provided with a Kuka KR6 robot arm which is capable of handling payloads of up to 6 kilograms. This robot is used to pick components from the first conveyor and place them either on the second conveyor, on an Automatic Guided Vehicle (as indicated in Fig. 1) or in a variety of alternative, predetermined locations. The robot will be fitted with a DVT vision system to be able to compensate for variations in component orientation as stated earlier.

C. Material Belt Conveyor

This conveyor is host to the vision-based quality control module. The components are loaded by the robot and then the quality assurance system checks the quality and identifies the components on the conveyor. The characteristics of the components will determine the position where the components are to leave the conveyor and influence the functioning of the component-handling equipment. This conveyor is marked as "Conveyor 2" in Fig. 1.

D. Vision-based Quality Control

Machine vision systems are increasingly replacing human vision for quality control inspection of manufactured or natural objects because these inspections are often required at levels too fast or precise for human vision [2]. These requirements can be met with high speed machine vision systems, integrated into the flow of the manufacturing process, either as part of robot guidance or at a station specifically designed for inspection. In either case, the manufacturer benefits, producing higher quality products with less waste and, therefore, at lower cost [3].

The parameters of a machine vision system might differ from one application to the next, but the basic parameters will be the same [4].

The determination of the limitations of an automated vision inspection and the design of such are difficult and expertise in many technical areas is required [5]. Illumination, camera characteristi cs, computer interfacing, programming and image processing are amongst these.

There are a variety of commercial capturing systems (image acquisitioning boards), Smartcams and Compact Vision Systems (CVS) available. Capture systems must be installed on a computer placed in the inspection environment. A Smartcam is a camera with integrated capturing hardware. The CVS is a stand-alone, rugged unit which is used widely in industry and the Component-handling Platform (CHP) is provided with such a system. It is a National Instruments product with software that is compatible with Vision Builder for Automated Inspection, LabVIEW and OCR software. The implemented system and setup is shown in Fig. 2 [6].

The versatility of the technology, its ability to be configured to application specifications and its ability to be integrated into the production process make the implementation process and transition to full automation a lot easier with minimal impact on production downtime.

E. Picking and Placing using a Cartesian Robot

The component orientation and placing subsystem incorporates:

- a component-sorting subsystem with three possible outputs for differently characterised components depending on the output of the quality assurance camera subsystem, and
- a second machine-vision system to ensure proper guiding and control of the Cartesian robot.

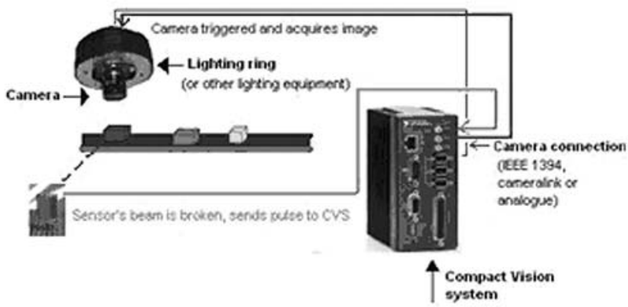

Fig. 2. Depiction of triggered acquisitioning

This required the mounting of this machine vision system onto the arm of the Cartesian robot. However, since only components meeting known and specified criteria are handled in this application, 3-D sensing is not required and back illumination suffices as a means of determining the position and outline of the components to be handled by the linear robot. The robot and accompanying machine vision system make use of DeviceNet for communication with the placing PC which has been programmed using LabVIEW 7.1 [3].

To facilitate successful handling of components by the robot and gripper, it has to adjust automatically to the optimal position, orientation and height depending on the shape and position of the component exiting the system. Consequently it was decided to use a 200-step stepper motor – controlled by a dedicated PIC-controller - in collaboration with the camera mounted on the robot's arm, to realise this capability.

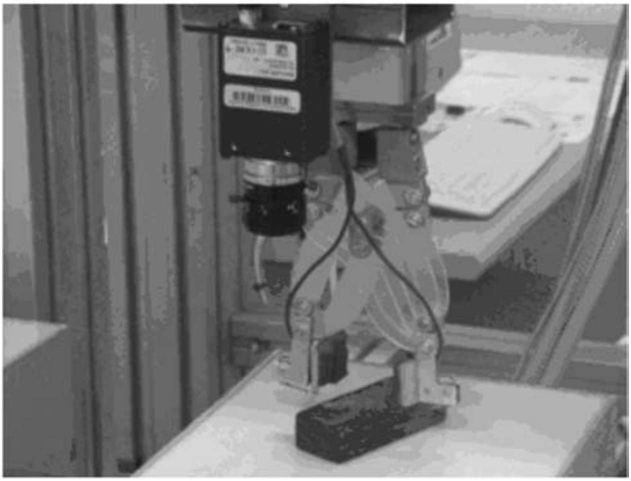

Fig. 3. Arrangement of camera and robot gripper

This configuration ensures a step size of 1.8 degrees - or a maximum displacement of approximately 0.6mm with 40mm grippers - per step [3]. This proved suitable for the application. The components are then transferred to predetermined areas for further handling and/or storage.

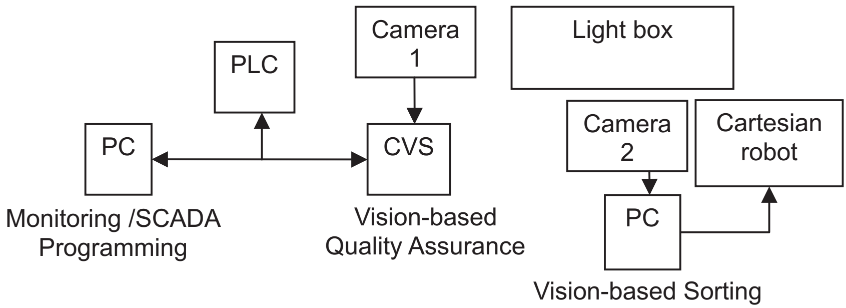

Fig. 4. Components deployment diagram

The arrangement of the camera and gripper is shown in Fig. 3. In Fig. 4 the interfacing of the different components of the vision-based subsystems is illustrated.

F. Monitoring and Recording of Complete System

It is probably safe to say that most organisations with a significant capital investment in plant equipment are now employing some form of condition monitoring technology in order to predict at least some failures. However it is likely that the frequency at which monitoring is taking place – and the quality thereof - is far from optimal. Reliability-centred maintenance (RCM) principles indicate that the primary determinant of frequency of a condition-monitoring task is the lead time to failure. This is the time from which an incipient failure can first be detected, until functional failure occurs. A typical manufacturing condition monitoring system is shown in Fig. 5.

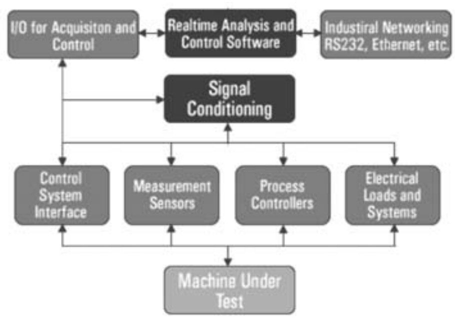

Fig. 5. Structure of a typical condition-monitoring system

Hardware components include sensors, controllers, data acquisition I/O and networking interfaces. Software components include analysis and control tools.

The CHP is provided with various condition monitoring sensors - including pressure, temperature and positional sensors - which provide input signals to a controller. This information is used to diagnose platform problems, product jams, or mechanical failure enabling the introduction of reliability-centred maintenance for the complete system.

The ideal, enhanced condition-monitoring system will improve asset management by providing an early warning system that allows organisations to move beyond simple calendar-based maintenance, into a proactive, asset-performance-based maintenance environment. Consequently, the deployment of maintenance resources and material requirements can be planned in a more efficient and cost effective manner.

This approach also empowers operators by providing the ability to track maintenance activity associated with an asset, without leaving the operational environment. The operator could, for example, view in real time how effectively equipment is performing in relation to expected or ideal conditions and trigger immediate corrective action if required. This constitutes automated feedback of the outcomes of the manufacturing process and condition monitoring on the different components of the system, to be able to derive relevant data for the maintenance plan that includes automated maintenance scheduling.

A representation of the overall functioning Supervisory, Control and Data Acquisition (SCADA) system is shown in Fig. 1. Each part of the system has its own page in the SCADA with more detail of the specific component of the system. In Fig. 6 the page of the first conveyor is shown and more detailed information of Conveyor 2 is displayed.

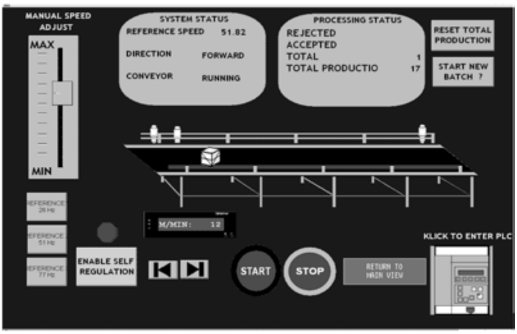

Fig. 6. Detailed SCADA diagram for Conveyor 2

The SCADA system consists of the Operator Station (PC), a PLC (Allen-Bradley Micologix 1500), a Compact Vision System (NI 1450), an AC Motor Drive (Allen-Bradley Powerflex 40) and the OPC (Object Linking and Embedding (OLE) for Process Control) network. In the current system OPC Server and OPC Client applications are used to make the data available over the Ethernet. The current SCADA system is shown in Fig. 7.

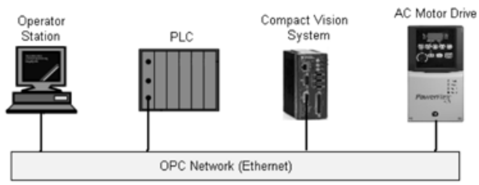

Fig. 7. Structure of components in SCADA system.

4. ENVISAGED NEW ELEMENTS OF SYSTEM

A. Enhancements on Hinged Steel Belt Conveyor

A module for loading the components automatically onto the conveyor is not developed as yet and is one of the projects that will be started soon.

B. Inspection of Shipped and Assembled Components

It sometimes happens that, within an assembly process, not all components get fitted onto a specific product. Major problems are caused if the part is shipped to the customer and it is incomplete. Also the problem of parts being lost or stolen between the packaging area and the shipping area arises. This can also create problems in ascertaining whether the part was misplaced during shipping, or if it was lost by the customer. Such problems caused the following two projects to be initiated.

The hinged steel belt conveyor will also host a vision system that will inspect containers which are divided into compartments, ensuring that there are components within each compartment. This will ensure that stolen or lost parts will be noticed before shipping of incomplete containers of products to the client.

Another vision system will be used to ensure that all components that were part of the assembly process are placed onto/into the specific part. This will form part of the quality system of the assembled components.

C. *Information Management System*

To achieve a sustainable competitive advantage, manufacturing systems must be reconfigurable and able to adapt quickly to market changes [7]. This makes the timely collection and distribution of reliable information to the plant's decision-makers critical. The ability to collect and securely store process data from a manufacturing system is therefore very important. This data can be analysed and transformed into useful information, and then presented to the plant users to improve efficiency and profitability.

The function of the Information Management System will be to do the following but will not be limited to it:

- Capture data from different sources
- Production data
- Condition-monitoring data

- Run times of each component of system
- Secure storing of all data
- Preventative maintenance scheduling
- Quality assurance data
- Communication platform to AGVs
- Providing data to business system

Therefore, the Information Management System should be a unique system that will be able to optimally access and manage production and maintenance data of the particular plant. It can be applied to a Reconfigurable Manufacturing System in order to decrease ramp-up times and to ensure an effective preventative maintenance plan with input from all relevant subsystems.

This system will also be able to provide data for analysis of the system. Independent software has been developed to enable the remote preparation and printing of statistical tables and process charts as effective tools for monitoring and recording the functioning of the complete component-handling system.

5. SUMMARY

Educational and research projects in mechatronics by the research group of our Faculty have centred around aspects related to the design and development of this Component-handling Platform. Collaboration with universities abroad has been established and collaboration is currently active with universities in Germany. The objective of the collaboration is to establish contact with colleagues in Germany doing research in similar fields, to set up collaborative research projects and to investigate education programmes currently adopted by German universities.

The number of research projects currently being studied in mechatronics has increased exponentially over the last few years. Structured project supervision, state-of-the-art equipment and motivated research students have been the main contributing factor to this success.

An experimental component-handling system is discussed in the paper. Preferably, this system should be rationalised by integrating the different functions and adding an information management system. However, it proved to be a suitable platform to facilitate initial research into mechatronics as well as providing an excellent platform for education within the mechatronics field. It must however be noted that this is ongoing research and therefore an open-loop system of which the final implementation cannot be indicated.

6. REFERENCES

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