REFURBISHING AND MODERNIZING A ROBOTIC MANUFACTURING CELL

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This scientific paper presents a laborious reverse engineering study aimed at elucidating the functionality of a more than 20-year-old Computer Integrated Manufacturing cell. The investigation focuses on understanding the intricacies of its constituent elements, which include a raw material storage system, an optical verification system, two Industrial Robots from Mitsubishi (RV-E3J and RV-E2) and conveyor belts. Through this endeavor, we aim to enhance our understanding of legacy CIM technology and provide valuable insights for future educational use.

KEYWORDS: CIM, Reverse Engineering, Manufacturing

1. Introduction

The faculty offered the opportunity to refurbish an old Computer Integrated Manufacturing (CIM) cell, initially used for training and research of technological manufacturing. The first steps were to identify the functionality of the systems and equipment as we did not have any inherited documentation. Additionally, we encountered the challenge of determining the compatibility of existing drive systems or, alternatively, exploring suitable alternatives.

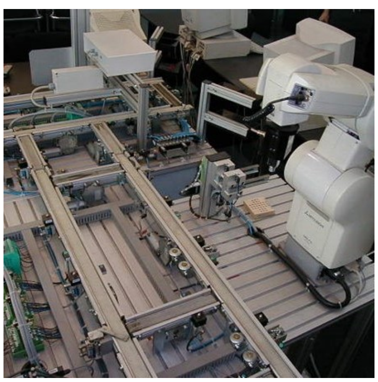

Fig. 1. Initial configuration of the CIM

Fig. 2. RV-E3 industrial robot

Fig. 3. RV-E2

2. General description of the IR

The manufacturing cell integrates two industrial robots of Mitsubishi make, model numbers Melfa RV-E2 and Melfa RV-E3J. They are part of the same family, with one having 6 degrees of freedom, the other only 5. Other similarities elements include repeatability, which is ±0.04mm, maximum composite speed (3500mm/s), and their same positioning system (architecture, operation ranges and dimensions).

The addition of the fourth, twist axis, allows the RV-E2 a higher degree of flexibility, allowing better positioning characteristics when compared to its 5-axis relative. This, however, reduces structural rigidity and therefore maximum operational radius (for the E3J, this is up to 630mm, while E2 can only reach 621mm). The original application utilized the pair in a cooperative manner, with one being used to load and unload a 3-Axis numerically controlled milling center, the other being used in pallet handling from adjacent conveyor belts. One of the goals of this project is to maintain the concept of cooperating IR's, while modernizing their functionality and better integrating them with modern hardware.

The robots' controllers were initially not in working order, predominantly due to passage of time and general wear. One of the first tasks undertaken was to clean the circuit boards using isopropyl alcohol, a thorough check of electrolytic capacitors (which are known points of failure) and cleanup of connectors, in order to avoid imperfect contacts. This brought one of the controllers back on-line but left the other still unresponsive. Through trial and errors (as controller manuals were not available), it was determined to be in a "configuration mode", accepting parameter modifications via the on-board buttons. By cycling between them, the proper combination was discovered, and the controller brough back to working order.

The teach pendants were still functional, as they represented very simple electronics, a far cry from what is considered current tech standard. They consist of an LCD screen, followed by a group of buttons, with multiplexed functionality: while in different menus, their functionality changes. The "dead man's trigger" mechanism is implemented by depressing the "step/move" key, after which motion of the robot is made available. Other functionality that has been explored when documenting the teach pendant was the ability to create new programs, delete and edit previous ones, as well as allow finer parameter entry and general maintenance. Homing of the robots is also achieved via a menu located on the teach-pendant, the reset procedure having been inferred from a recovered laboratory handout, which detailed the necessary steps.

After understanding the principles of the industrial robots, as well as the technical capabilities and limitations of the structures, the methods by which off-line programming could be achieved were studied. Utilizing the laboratory computers, it was able to access the robot's software, by means of the Cosimir integrated development environment. This allows for full off-line programmability, via graphical and textual means (the programming language is the easy to understand MoveMaster Command instruction set).

Since plenty of the CIM's functionality depends on timing of events and being able to react to external stimuli, the use of the controller's input-output (I/O) blocks was also studied. It was recognized that these I/O's are of the mechanical relay type, incapable of PWM or other functionality, but able to produce binary true-false conditions. This will prove useful in the future, as functions that would normally depend on the existence of a Programmable Logic Controller (PLC) can be offloaded into the robot's controllers, giving more flexibility to the designers and programmers of the cell. Interestingly, initially despite verifying that the commands would be issued from the robot controller, it was noted that no response would be obtained from the I/O boxes. It was theorized (a hypothesis which proved to be true) that the robot controller was acting as a current sink for the relays, requiring an external voltage to function correctly. After applying 24vDC to the I/O box's VCC pin, it was noted that the pins would act as programmed.

3. The pneumatic system

The Transfer/Transport System's is equipped with a pneumatic system that is electronically controlled. This system is composed of 5/2-way mono-stable electro valves, small pneumatic cylinders, and pressure regulators. The pneumatic cylinders, controlled via 5/2-way mono-stable electro valves, are positioned and have the role of stopping the pallet-carrier at the work station.

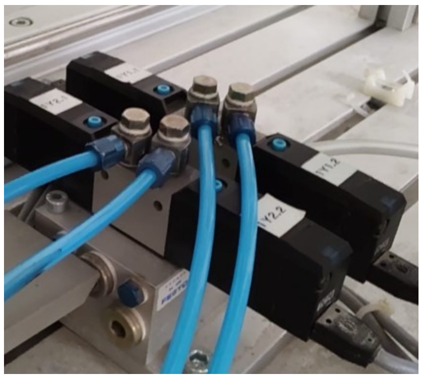

Fig. 4. 5/2-way mono-stable electro valves

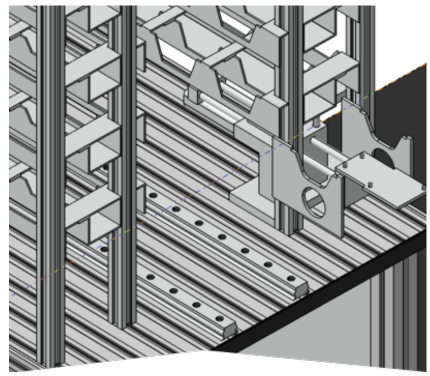

Fig. 5. Pallet loading and unloading system

Connected to the Transfer/Transport System is the automated rack. The pallet carrier is arrested at the fore of the rack, then elevated to the loading and unloading system. The pallet is then transferred into the rack by means of a pinion gear mechanism. The Load/Unload System for the pallets is composed of 2 pneumatic cylinders and two 5/2-way mono-stable electro valves and a pressure regulator. The small cylinder traverses the boom vertically, the long cylinder ensures axial movement, with the end goal being the transfer from the pallet carrier and into the pick-up area. Working pressure has been established to be 2.5bars, with electronic commands being issued by the rack's integrated PLC.

Reprogramming of this PLC has been determined to be an unfeasible endeavor, as the means to achieve it are lost to time: by studying the reference manual, it was found that the main means of programming is via a memory card, which is used to transfer programs into the internal battery backed-up RAM. Therefore, the decision was taken to consider the electronics of the rack a black box, with efforts going into understanding the means of commanding it.

The main interface to the other cell's components is a 4-bit electrical I/O port. By applying logic level high voltages to each of the bits, commands can be issued. Understanding the rack is still a work in progress, however initial tests have proven that both the electronics and mechanical parts are functional. A special program was developed in python, to automate sending of the 4-bit commands, which resulted in an initial indexing of positions within the stack. Further research is required on this topic, however time constraints restricted our ability to further delve into the subject.

Gaskets in the cylinders have worn down over time and become brittle. During our testing, while the pneumatic cylinders were observed to function, after a number of cycles failure was observed, as pressure was rapidly lost in the system. At the current time, efforts to replace the cylinders are underway, however the possibility of taking the pneumatics of the rack off-line and replacing their functionality with the 5-axis IR has been taken into account.

4. Electronic peripherals

The system incorporates specialized modules designed for the detection and identification of pallet carriers. This is done utilizing two sensors: an inductive proximity sensor, which detects the presence of a pallet carrier, and a capacitive identification sensor, which reads the unique identifier from a small built-in plastic tab. Both sensors are interfaced with special local-control modules, which aggregate signals, while transmitting information about their state over the RS-232 bus to the main PLCs. Reverse engineering of both these sensors and the local control centers proved to be a tedious process, which required connecting a logic analyzer to first identify what protocol was in used, then the structure of data sent over the bus.

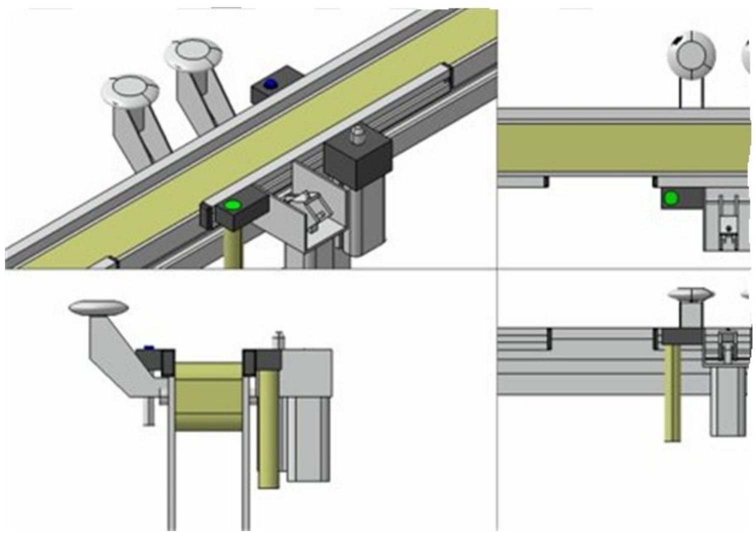

Fig. 6. CAD model of capacitive and inductive sensors

5. Conclusions

As was proceeded with the reverse engineering process, it was successfully discovered how to work with some of the available systems and components of the cell. At current time, the robots, the optical verification system and the pneumatic components are fully functional, with all that remains being to determine how to control the stack.

Further work concerns both documenting all that has been researched (recognizing that the CIM's purpose is first and foremost an educational one) and development of a new, flexible fabrication system. Building on the foundation of what has been achieved, we wish to create an application that both serves an industrial and an educational purpose, breathing life into an abandoned but still valuable piece of technology.

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