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THE INTEGRATION OF INDUSTRIAL ROBOTS INTO CIM SYSTEMS

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ABSTRACT

Today we are seeing the beginning of Computer Integrated Manufacturing (CIM). However, we have yet to transform these concepts into practice engineering disciplines. The role of the robot in CIM is also new, and we are beginning to see robot manufactures and capabilities which will meet the challenges of CIM.

The robot is a major component of CIM technology. It appears to be the nucluous around which the technology is forming. Hence, the objective of this paper is to investigate the importance of the integration of industrial robots (IR) into CIM, thus clarifying one of the most important key technologies of the high level automated production within the Factory of the Future (FOF).

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INTRODUCTION

The Robotic Industrial Association (RIA) defines an Industrial Robot as "a reprogrammable multifunctional manipulator designed to move materials, parts, tools or specialized devices, through variable programmed motions for the performance of a variety of tasks. CIM will be a coordinate grouping of machines and equipment which perform tasks together to create a product, all under the control of a hierarchical authority. Each machine will be linked by a communication port to an hierarchical network of computer responsible for production flow and scheduling (1).

The key to CIM is the word INTEGRATED. Robots to some extent can be integrated and can interact with other components of the work cell. In fact, they must be capable of this if they are to be part of the FOF. IR systems have the ability to adapt to their environment. This implies powerful real time computer systems and advanced sensors. The sophisticated robots should have visual and tactile sensors. Various manipulators, multipled walking mechanisms and flexible hands with fingers. It may, also, have many actuators to be controlled at one with the help of optimal-position control system. Fig. 1 shows the four basic - available- IR's configurations: a- polar coordinate, b- cylindrical coordinate, c- joint arm coordinate, and d- cartesian coordinate (2,3).

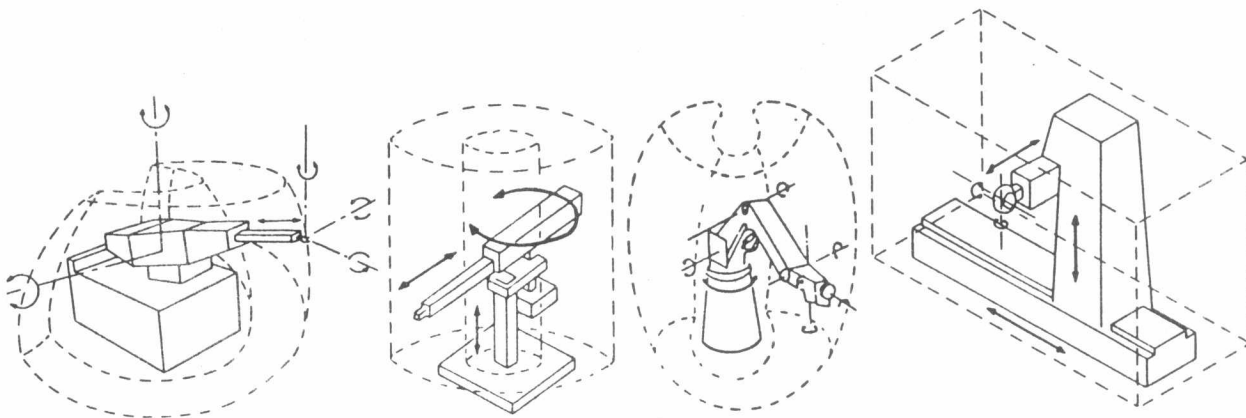


Fig. 1 Configurations of Industrial Robots

There are numerous technical features of an IR which determine its efficiency and effectiveness when it is integrated into CIM:

Degrees of freedom: There are up to six basic motions, or degrees of freedom, which provide the robot with the capability

to move the end effector through the required sequence of motions. Three degrees of freedom are associated with arm motion (i.e. vertical, radial, and rotational traverse); and three called wrist motions (i.e. wrist swivel, wrist band, and wrist yaw), as pictured in Fig. 2 for the polar-type robot.

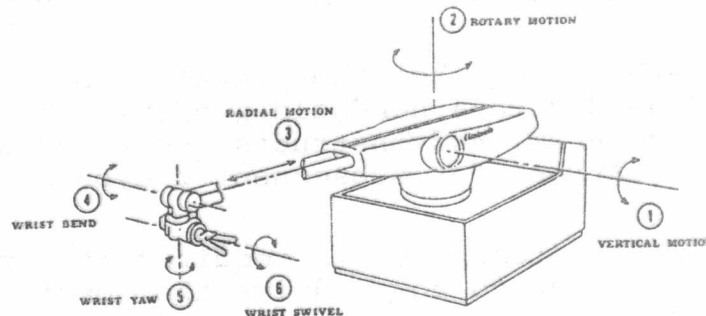


Fig. 2 Typical six degrees of freedom in robot motion

Motion control systems: The motion control systems of IRs can be classified as either point-to-point (PTP) or contouring (also called continuous path). PTP robots would be capable of performing certain kinds of productive operations, such as machine loading and unloading, pick-and-place activities, and spot welding. Contouring robots are used in certain industrial operations as paint spraying, continuous welding processes and grasping objects moving along a conveyor.

Work volume: Refers to the spatial region within which the end of robot's wrist can be manipulated.

Precision of movement: Refers to the robot's ability to accurately move to a programmed location and to repeat that move in successive cycles. Many assembly operations must be performed with a very high level of precision, with other operations such as spray painting do not have nearly the same accuracy and repeatability.

Speed of movement: The speed with which the robot can manipulate the end effector ranges up to a maximum of 1.5 m/s.

Load capacity: The load capacity of robots ranges from a few grams up to several hundreds kilo-grams.

Type of drive system: There are three basic drive systems used in available robots namely: hydraulic, electric, and pneumatic driven.



Memory capacity: The memory capacity of the robot determines the length and complexity of the work it can perform.

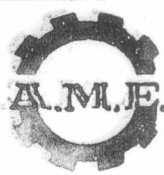
Type of programming: The concept of programmability is implicit in the definition of a robot. Closely related to the type and capacity of the robot's memory is the procedure required to program the robot. Computer controlled IR are usually programmed by:

- Walkthrough method; requires the operator to direct the robot's arm and hand with a handheld pendant through the sequence of movements, and instructs the robot control to record these locations for subsequent playback during work-cycle.
- Leadthrough method (teach-mode); requires the programmer to use a control pendant to power drive the robot through its motion sequence. Each motion is recorded into memory for future playback in work cycle.
- Off line programming; is a new technology for robots and will be required in the FOF. It provides the ability to create or modify a robot program without interrupting the robot's activity. Many computer languages such as VAL, HELP and AML may be used in a robot program.

ADVANTAGES OF ROBOTS

IR systems have been found to be tremendously effective tools for replacing human in dull repetitive tasks or hazardous environments in manufacturing and material handling industries (4). The following are the major application areas which tend to make the installation of a robot in a CIMS economical and practical:

- Welding robots: plants dealing with sheet metal and structural metal products find perfect applications for welding robots working in CIM. Both point-to-point controlled and continuous path controlled robots are widely used.
- Machine loading and unloading with robots: robotised loading and unloading operations in CIM provide the unmanned solution to material handling tasks. In the typical application, robot would grasp a raw workpart from a conveyor and load it into the machine. In some cases, the robot holds the part in position during processing; when processing is completed, the robot unloads the part from the machine and place it onto another conveyor.
- Tool changing: robots might be used to change cutting tools



on NC machines. A robot could be dedicated to this task at a single machine, where it might also load and unload parts as well as change tools, or a travelling robot might change tools on several machines.

- Machining robot: machining robot is a relatively new application for the rapidly expanding robot application. Just as welding and spray painting, the processing operation is performed by a specialized tool attached to the robot's wrist as its end effector. Some of the processing operations which have been performed by IRs include drilling, riveting, grinding, polishing, chamfering, deburring, and waterjet cutting (5).
- Robotised assembly: there is huge potential for flexible automation in assembly, and although the problems are great, it is now practical to install small system (6). Batch type assembly operations seem to offer the most promise for using robot. The reason for this is based on economics and technological capabilities, a robot would probably be too slow for mass production, and one of the robot's most important attributes, its programmability, would hardly be used. What is basically required for batch production is a flexible assembly system or adaptable-programmable assembly system (APAS), and robot-type arms constitute an important component of these systems.
- Inspection: like assembly, inspection is a relatively new area for the application of IRs (7). With ever-increasing emphasis on quality in manufacturing, there is a trend toward automating the inspection process and toward the use of 100% inspection by machine instead of sampling inspection by human beings. An important role in this area of inspection will be played by IRs; robots equipped with mechanical probes, optical sensing capabilities, or other measuring devices can be programmed to perform dimensional checking and other forms of inspection operations.

IRs WITHIN CIM SYSTEM

A CIM may be defined as a system dealing with high level distributed data processing and automated material flow using computer controlled machines, assembly cells, IRs, inspection machine and so on, together with computer integrated materials handling and storage systems. A relatively recent innovation in the design of CIM system involves the use of IRs to perform a portion of the parts handling chore. It has been estimated that 75% of all rotational parts can be accommodate in a machine cell which use a robot as the handling mechanism (8).



High efficiency and more productivity from the investments require over night operations of the machining system. But on the other hand, an operator for over night operations could not hardly be found without difficulties. Furthermore, more profitability in day shift operations by less operators is also desired. These requirements motivate the progressive automatic machining system with an IR.

On line factory inspection is a task that human beings probably should not have to perform. Although it is not dangerous job, it can be tedious and unrewarding, and it is difficult, if not impossible, to maintain concentration on the small details of fast-moving objects for hours at a time, a day after day (9). Even the most adapted human workers simply cannot keep up with the speed of the modern production line; therefore, several inspectors may be required, or a limited sampling for quality control may be all that's possible.

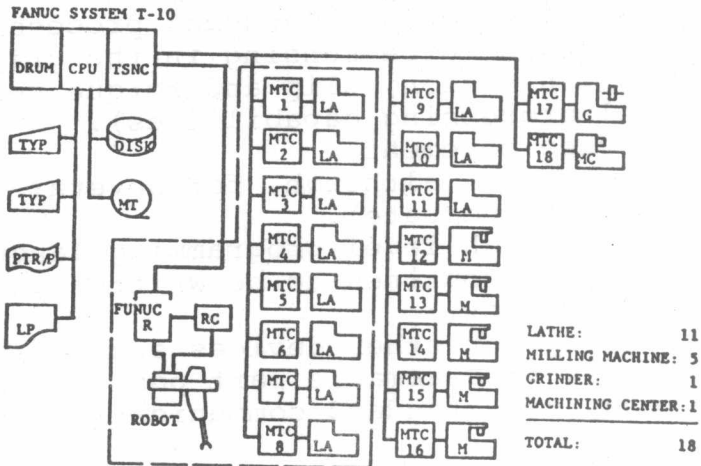
A robot-controlled production group includes one or more robots. This does away with the need for buffer storage between the machines and considerably reduces the throughput time. Furthermore, it often increases the capacity of the production group so that any waiting ahead of the group is eliminated. The high precision, compact design and high-capacity program memory of robot are vital factors. Having a robot-controlled production group will result in the reduction of capital tied down in machine tools and work in-progress as well as a higher rate of production.

The large program memory and high reliability of robots allow a production group to be operated almost entirely unmanned. Some examples for the general integration of robots within CIM systems are shown in Fig. 2.

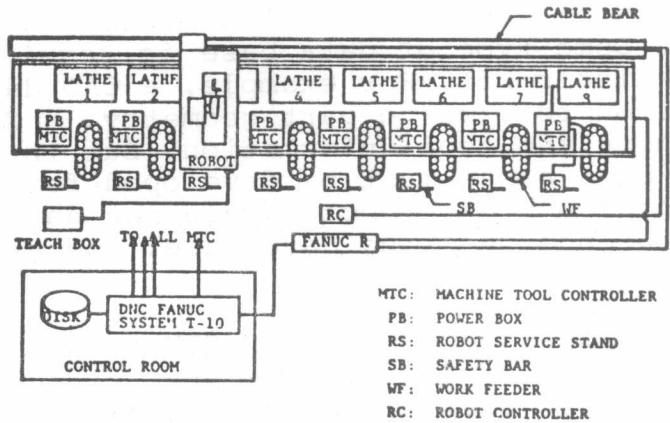
FEATURES OF A CIM ROBOT

Until very recently, robot application have not been in a CAM environment. Except for large scale automotive installations and in specific types of jobs such as die casting (10). The IR was conceived and designed for flexibility and nonobsolescence. Such design criteria define the main features of a CIM robot which include:

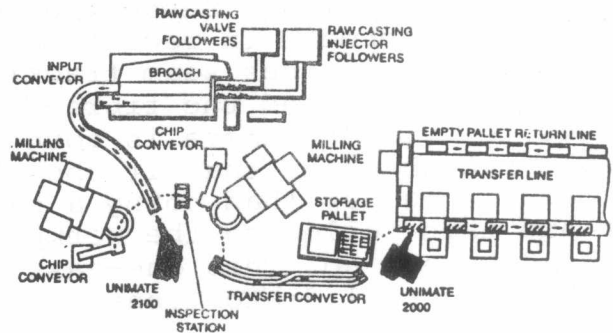
- Enough degrees of freedom to perform in the human environment.
- High position accuracy, i.e. approximately ± 0.1 mm or better.
- Relatively large number of I/O signals capable of monitoring each arrival and departure, and the gripper status from the



A total of 18 NC machines including 11 lathes are employed in the machining of a large variety of pulse motor parts.



Eight of the lathes are loaded and unloading by a single robot travelling on overhead rail and position system.



The robots are equipped with random program selection for changing to an alternate program if desired

Fig. 2 Examples of robots in CIM.



robot program.

- Capacity for real-time sensory feedback processing (i.e. a minimum requirement is force sensing in the gripper, which can be extended with vision, slip and torque sensing, and optional parallel processing capabilities).
- Fast, vibration-free movement.
- Continuous path control (although, for several jobs, point-to-point robots are adequate).
- A powerful, modular high level programming language, allowing parameterized subroutines to be written and not just programming by teach box.
- Interfacing facility for other devices such as other robots, computers, sensors, programmable part positioning and orienting devices, via standard communication interfaces.

For a maximum efficiency, a robot in manufacturing work cell should obtain its task program directly from a supervisory control via a hardware interface. This link enables rapid changeover of workcell activities with minimum distribution of production time. Some type of data base is required to define task for an off-line robot. For example, a CAD data base can provide information related to part geometry, a CAM data base can provide machine and tool information. But in most cases, new or enhanced data bases must be developed for off line programming of robots such as: robot simulation data base, clearance and interference checking data base, and specific robot process data base.

DEVELOPMENTS AND TRENDS OF CIM ROBOT

Robot application and programming methods have progressed for beyond merely handling components as seen above since their controllers and sensors have evolved the capability to communicate with other intelligent devices. Sensors particularly have been the focus of much development in recent years. The robot vision system, for example, provides seam tracking. The fibre-optic output of the laser light and the fibre-optic input leading to a solid state television camera is found in robot arm. It is one pass system, which means that it observes the welding process as it occurs, rather than doing a part alignment verification first and then following the workpiece with the welding gun, as other systems do. This one-pass method is faster and ensures that thermal distortions are compensated in real time.



CONCLUSION

IRs have a very wide range of potential applications in CIM systems because they are reprogrammable, flexible devices themselves. The increasing power of their sensory feedback processing system allows them to work at a high level of intelligence. However, robots are not yet capable of solving most materials handling, assembly or inspection tasks in CIM systems. At present, a relatively low proportion of robots are capable of communicating at a high level with other robots and computers, and their sensory systems are usually expensive compared to their performance. A considerable amount of R&D work is therefore still required.

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