Robot Programming

The 3 Basic Robot Programming Methods

1. The Teach Method
2. Hand Guiding/Lead-Through Programming
3. Offline Robot Programming

Robot Cell Design and Control

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INTRODUCTION

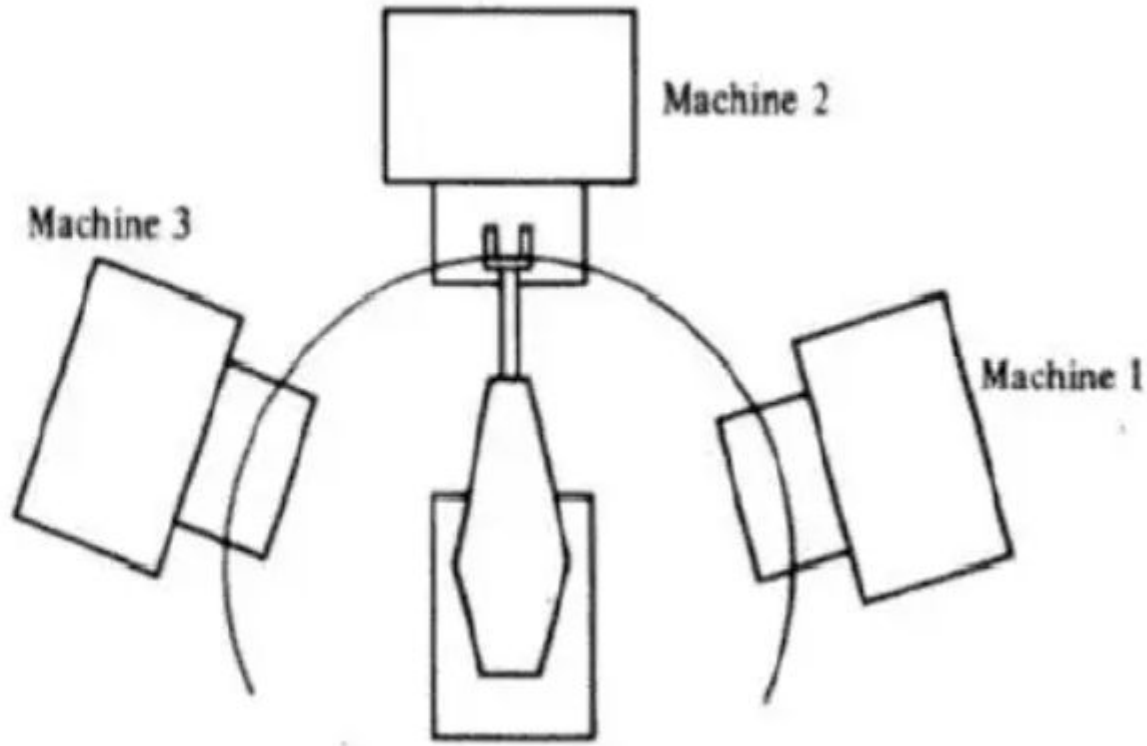
- Industrial robots generally work with other pieces of equipment. The pieces of equipment include conveyors, production machines, fixtures, and tools. The robot and the associated equipment form a workcell.
- Actually, the robot workcell or simply cell is a defined area of space through which a robot can move. It is also known as the work envelope.

ROBOT WORKCELL LAYOUTS

- Robot cells can be arranged into various arrangements or layouts. The layouts are:
  - Robot-centered cell
  - In-line robot cell
  - Mobile robot cell

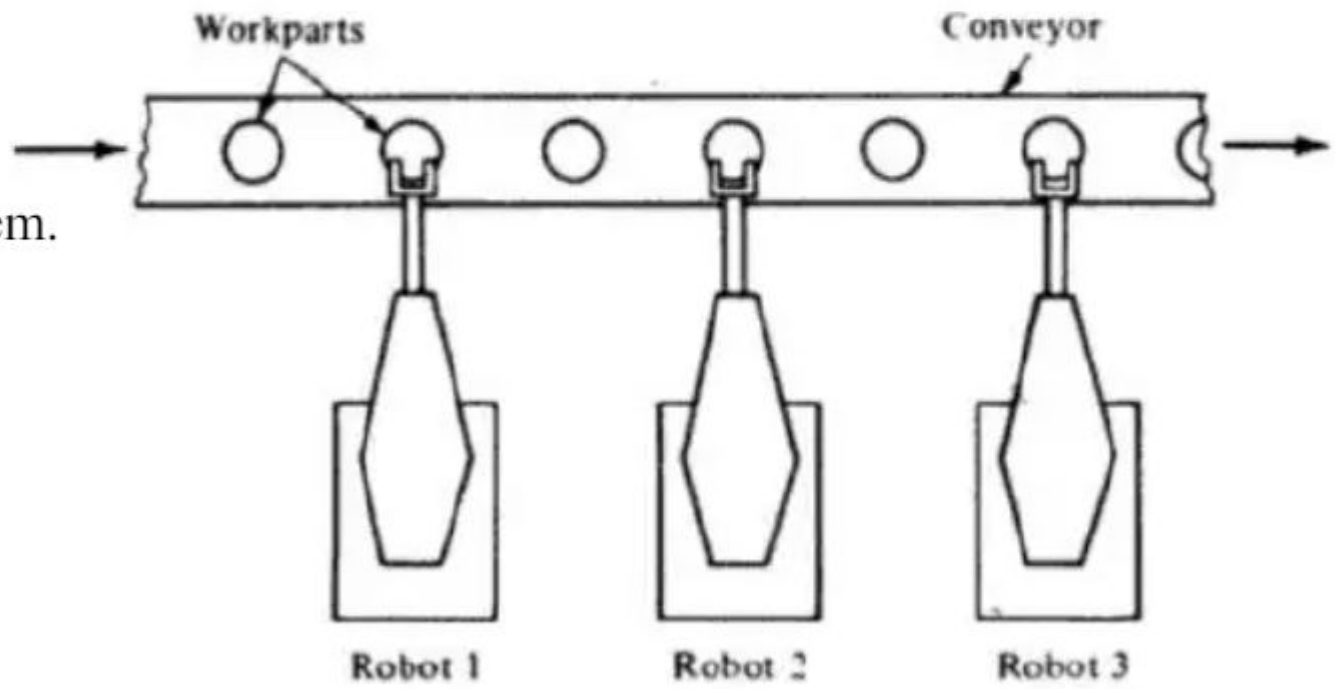
ROBOT-CENTERED CELL

- In robot-centered cell, the robot is located at the center of the cell and the equipment is arranged in a partial circle around it.
- During 1960s, one robot used to perform a single operation, either serving a single production machine, or performing a single production operation. This was causing the low utilization of the robot.
- To increase the utilization, the workcell concept was developed in which one robot services several machines as shown in the figure.
- Conveyors, parts feeders, and pallets are used for delivering the workpart in and/or out of the cell.
- This type of layout is used for the operations like arc welding, die casting, plastic moulding, machining, etc.



IN-LINE ROBOT CELL

- In this layout, the robot is situated along a moving conveyor and performs a task on the product as it travels past on the conveyer belt.
- Here, more than one robot is placed along the moving line. This layout finds its application in a car body assembly plant.
- The in-line robot workcell has the following transfer systems:
  - Intermittent transfer system,
  - Continuous transfer system,
  - Non-synchronous transfer system.



INTERMITTENT TRANSFER SYSTEM

- In this system, the parts can be moved from one workstation to the next along a line with a start and stop motion.
- It is also known as a synchronous transfer system because all the parts are moved simultaneously and registered at their next respective workstation.
- Here, the robot is stationary and forms a position along the line at which a part stops for processing.
- The main advantage of this system is that the part can be registered in a fixed location and orientation with respect to the robot during the robot's work cycle.

CONTINUOUS TRANSFER SYSTEM

- In this system, the parts are moved continuously along a line at constant speed. This means that the position and orientation of the part change continuously with respect to the robot which is fixed along the line.
- Here, the registration of the part relative to the robot becomes a problem. This problem can be solved by any of the following two methods:
  - Moving base line tracking system
  - Stationary base line tracking system

MOVING BASE LINE TRACKING SYSTEM

- This tracking system involves the movement of the robot along a path parallel to the line of travel of workpart while the operation is performed on the part. Thus, the relative position of the part and the robot remain constant during the work cycle.
- These are the following problems associated with this arrangement:
  - An additional degree of freedom is required for the robot to move.
  - Collision and interference between the two adjacent robots.
- These problems can be avoided as follows:
  - The solution for an additional degree of freedom involves a high capital investment for constructing a system (cart or rail) on which the robot can be mounted.
  - The collision and interference between the two adjacent robots can be avoided by providing a sufficient space between them.

STATIONARY BASE LINE TRACKING SYSTEM

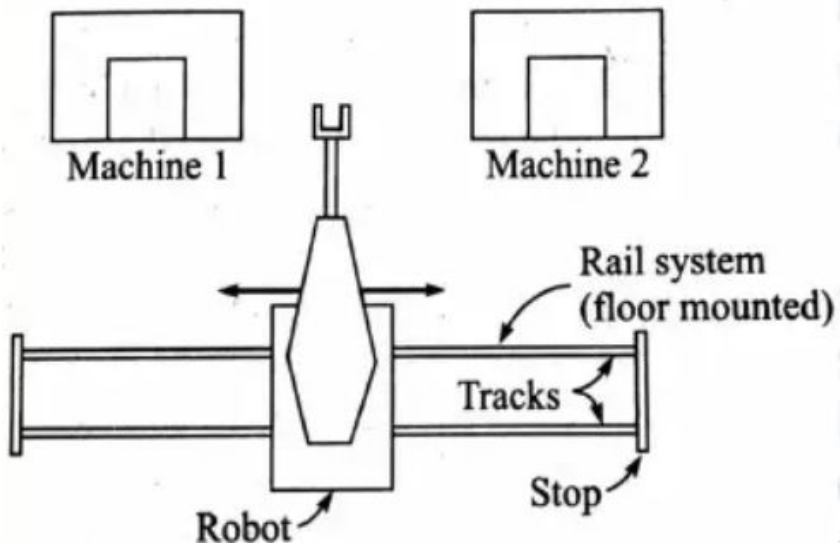
- This tracking system involves the robot in a stationary position along the line, but its manipulator is capable of tracking the moving part.
- 'Tracking' means that the robot is capable of maintaining the positions of programed points, including the orientation of the end-effector and the motion velocities in relation to the part even though the part is moving along the conveyor.

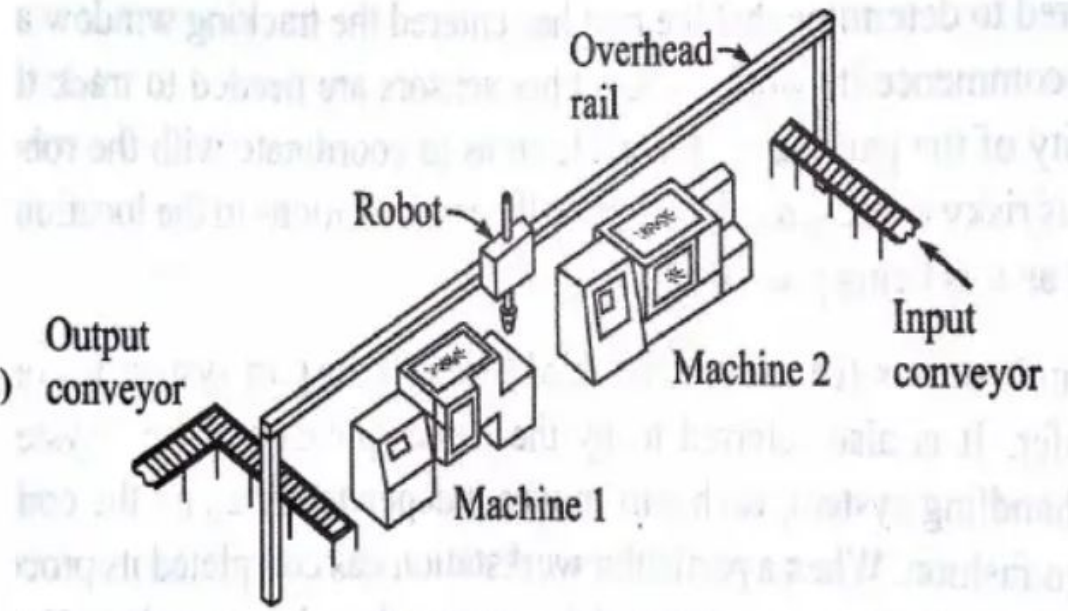
NON-SYNCHRONOUS TRANSFER

- This is a third type of transport system, also known as ‘power-and-free’ system.
- It involves the movement of the each part independently along the conveyor in a stop-and-go manner. When the processing of the part gets completed at one workstation, it moves to the next station on the line.
- Thus, at any given moment, some parts are being processed while others are located between the two successive stations.
- The design and operation of this system are more complicated than the other two transfer systems because each part must be provided with its own independently operated moving cart.
- For irregular timing of arrivals of the parts, sensors must be provided to indicate the robot for performing its operations.

MOBILE ROBOT CELLS

- The mobile robot cell is the one in which the robot is capable of moving to the various machines within its workcell.
  - This can be accomplished by mounting the robot on a mobile base rail system. The rail system may be either the tracks fastened to the floor or an overhead rail system as shown in the figures.
  - The overhead rail system has an advantage over the floor-mounted track system that it occupies less floor area. Meanwhile, it has a disadvantage of high capital investment for its construction.





WORKCELL CONTROL

- There are various activities which occur sequentially and simultaneously in the robot cell. To coordinate and control these activities, we use a device called the **workcell controller** or **workstation controller.**
- The functions performed by a workcell controller can be divided into three categories:
  1. Sequence control
  2. Operator interface
  3. Safety monitoring
- If the control requirements to operate the cell are simple and easy, the robot controller is employed to perform these activities.
- If the control requirements to operate the cell are complicated, a higher-level control device, such as a programmable logic controller (PLC), is employed to perform these activities.

SEQUENCE CONTROL

- The workcell controller performs **the sequence control function** during the regular automatic operation of the workcell. It comprises the following control functions:
  1. Control of sequential activities in the workcell.
  2. Control of simultaneous activities in the workcell.
  3. Making decisions to proceed with the work cycle based on the events that occur in the workcell.
  4. Making decisions to stop or delay the work cycle based on events that occur in the workcell.

OPERATOR INTERFACE

- The operator interface provides a means of interaction between the human workers and workcell operation. It is required in some of the important situations like:
  1. The human is an integral part of the workcell.
  2. Emergency stop conditions.
  3. Program editing by the operator.
  4. Data input by the operator.
- In a robot workplace, the human operators will have various works to be done along, the robot like part loading and unloading, and more. At this time, the start and stop controls may be used by the workers in order to protect them from physical damages.

SAFETY MONITORING

- Sometimes, the human workers may be injured severely while performing too close with the robots. To overcome this problem, several safety steps are studied by implementing sensors. Moreover, a workcell controller should have the ability to monitor its individual function for hazardous situations. It is known as hazard or safety monitoring.

INTERLOCKS

- An interlock is a method which prevents the continuation of the work cycle sequences until a certain condition or set of conditions are satisfied.
- It is a feature of workcell control which plays a vital role in regulating the sequence in which the various elements of the work cycle are processed.
- It can be used for the following purposes:
  1. To ensure that a raw workpart was at the pick up location on the conveyor or not before the robot tried to grasp the part.
  2. To determine when the machining cycle was completed before the robot attempts to load the part into the fixture.
  3. To indicate that the part has been successfully loaded, so that the automatic machining cycle can begin.

TYPES OF INTERLOCKS

- Interlocks can be divided into two basic categories:
  1. **Output interlock:** An output interlock uses a signal sent from the workcell controller to one of the machines or other devices in the workcell to commence the automatic cycle. It corresponds to the SIGNAL programming statement.
  2. **Input interlock:** An input interlock uses a signal sent from the one of the machines or other devices in the workcell to the workcell controller to indicate that a certain condition or set of conditions have been satisfied and the work cycle sequence can continue. It corresponds to the WAIT programming statement

USES OF INTERLOCKS

- The interlocks are used not only to prevent the workpart from **inaccurate positioning,** but also to protect the components in the workcell from **being damaged**.
- In addition, the interlocks also consider **the failures and irregularities** that occur in the cell. If a malfunction takes place in a robot workcell, the application engineer must find out a technique to recognize the malfunction and should take a suitable action for the solution.
- Subsequently, interlocks are used to obtain the **series control** and **safety monitoring** in both irregular and regular work cycles.
- Moreover, advanced type sensors can be used to gain more accurate performance in the work cycle.

ERROR DETECTION & RECOVERY

- Error detection and recovery can be defined as the capability of the robot and other automated equipment to detect the errors and malfunctions occurred in the cell and to take the necessary action to restore the system to the normal operation.
- By the name, error detection and recovery comprises two components:
  1. **Error detection:** The detection problem involves the use of suitable sensors to identify the error occurred during the operation. It also includes the associated intelligence to read the sensor signals so that errors can be properly identified and classified.
  2. **Error recovery:** The error recovery system offers a proper plan to the robot to correct the existing malfunction or irregularities in the workcell. Generally, a specific recovery plan is prepared for dealing with each type of error that is recognized during the error detection.

TYPES OF ERRORS

- The errors that commonly occur during a manufacturing operation are as follows:
  1. **Random errors:** These errors are resulting from stochastic events, and they are described with the help of their statistical nature.
  2. **Systematic errors:** These types of errors are described by some preconception that takes place in the operation.
  3. **Illegitimate error:** These errors are obtained either by the mistake of a human worker or equipment.

GRAPHICAL SIMULATION OF ROBOT WORKCELLS

- Simulation can be defined as the technique of building a model of a real or proposed system so that the behavior of the system may be studied.
- In the case of robotic work cells, graphical simulation is usually employed. It aims at visualizing and verifying the performance of a robot in a manufacturing cell, determining features such as reachability and workspace. Furthermore, in the case of robotic cells, the graphical simulation software is also used for off-line programming.

- Among the features that a graphical simulator must provide, there are:
  - Module and robot builder;
  - 3D graphical task simulation;
  - "Universal" inverse kinematics;
  - Full dynamics models;
  - Trajectory and task planning;
  - Off-line programming.

ADVANTAGES

- The possibility of viewing the process in a graphical simulator brings a number of advantages to the robot programming operation.

1. It is possible to verify the **robot trajectory and detect collisions** with other objects of the working cell. This is particularly true for the case of working cells where two or more robots are moving simultaneously with interception among their working volumes.
2. **Reduction in production times:** With the help of simulation, it is possible to determine the time of each operation, detect bottlenecks, and seek for best trajectory solutions.
3. **Verification of accessibility:** Graphical simulators come with libraries composed of a large range of commercial robot models. Therefore, it is possible to test the access and reach of different robots and compare solutions without having the robots or building the work cells.
4. **Programming reuse and flexibility:** It is possible to modify and reuse programmed operations. Regular and symmetric parts can be programmed using the mirror function.

HISTORY/RESEARCH IN GRAPHICAL SIMULATION

- *f*The graphical simulation of robots was born with the need of off-line programming. With the invention of robots and their widespread acceptance in the manufacturing floor, there was a basic need for off-line programming, similar to CNC machine tools, of the robots in order to improve their utilization and productivity.
- In the 1960's and through the 1970's, off-line programming languages such as AL, AUTOPASS, RAIL, VAL, etc. were used for programming the robots.

- In the late 1970s, virtual reality software packages appeared for the purpose of constructing manufacturing cells, planning the robot path, detection of robot collision with other equipment in the cell, and obtaining off-line programs for the robots. These software packages were based on wire frame graphics which are difficult to visualize and have no automatic collision detection capabilities.
- In the 1980's, with the increase of computer power and particularly the appearance of powerful workstations with powerful graphical capabilities, new virtual reality software packages appeared in the market that were based on solid model graphics and efficient intelligent algorithms.
- Several vendors have developed virtual reality software. University of Nottingham developed GRASP, McDonnell Douglas Manufacturing Industry Systems Company developed PLACE, etc.

THE PLACE SYSTEM

- The PLACE graphic simulation package consists of four modules. They are as follows:

- **PLACE:** It was the very first released module. PLACE stands for **Positioner Layout and Cell Evaluation**. It is used to construct a three-dimensional model of the workcell in the CAD/CAM database and to evaluate the operation of the cell.
- **BUILD:** It is used to construct models of the individual robots that might be used in a workcell.
- **COMMAND:** It is used to create and debug programs off-line that would be downloaded to the robot to save on-line programming time.
- **ADJUST:** It is used to calibrate the differences between the computer graphics model of the workcell and the actual workcell.