ECET - 330

Application of Computer in Process Control

Course Instructor

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What is an Industrial Robot?

An **industrial robot** is defined by ISO as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. The field of robotics may be more practically defined as the study, design and use of robot systems for manufacturing (a top-level definition relying on the prior definition of robot).

Typical applications of robots include welding, painting, assembly, pick and place (such as packaging, palletizing and SMT), product inspection, and testing; all accomplished with high endurance, speed, and precision.
Robot Types and Feature -1/2

The most commonly used robot configurations are articulated robots, SCARA robots and Cartesian coordinate robots, (aka gantry robots or x-y-z robots). In the context of general robotics, most types of robots would fall into the category of robotic arms (inherent in the use of the word *manipulator* in the above-mentioned ISO standard). Robots exhibit varying degrees of autonomy:

*The **SCARA** acronym stands for Selective Compliant Assembly Robot Arm or Selective Compliant Articulated Robot Arm.*
1. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. These actions are determined by programmed routines that specify the direction, acceleration, velocity, deceleration, and distance of a series of coordinated motions.

2. Other robots are much more flexible as to the orientation of the object on which they are operating or even the task that has to be performed on the object itself, which the robot may even need to identify. For example, for more precise guidance, robots often contain machine vision sub-systems acting as their "eyes", linked to powerful computers or controllers. Artificial intelligence, or what passes for it, is becoming an increasingly important factor in the modern industrial robot.
Parameters of Robot

1. **Number of axes:** Two axes are required to reach any point in a plane; three axes are required to reach any point in space. To fully control the orientation of the end of the arm (i.e. the *wrist*) three more axes (yaw, pitch, and roll) are required. Some designs (e.g. the SCARA robot) trade limitations in motion possibilities for cost, speed, and accuracy.

2. **Degrees of freedom:** Which is usually the same as the number of axes.
3. **Working envelope:** The region of space a robot can reach.

4. **Kinematics:** The actual arrangement of rigid members and joints in the robot, which determines the robot's possible motions. Classes of robot kinematics include articulated, cartesian, parallel and SCARA.

5. **Carrying capacity or payload:** How much weight a robot can lift.
6. **Speed**: How fast the robot can position the end of its arm. This may be defined in terms of the angular or linear speed of each axis or as a compound speed i.e. the speed of the end of the arm when all axes are moving.

7. **Acceleration**: How quickly an axis can accelerate. Since this is a limiting factor a robot may not be able to reach its specified maximum speed for movements over a short distance or a complex path requiring frequent changes of direction.
8. **Accuracy**: How closely a robot can reach a commanded position. When the absolute position of the robot is measured and compared to the commanded position the error is a measure of accuracy. Accuracy can be improved with external sensing for example a vision system or Infra-Red. See robot calibration. Accuracy can vary with speed and position within the working envelope and with payload (see compliance).
9. **Repeatability**: how well the robot will return to a programmed position. This is not the same as accuracy. It may be that when told to go to a certain X-Y-Z position that it gets only to within 1 mm of that position. This would be its accuracy which may be improved by calibration. But if that position is taught into controller memory and each time it is sent there it returns to within 0.1 mm of the taught position then the repeatability will be within 0.1 mm.
Accuracy and repeatability are different measures. Repeatability is usually the most important criterion for a robot. ISO 9283 sets out a method whereby both accuracy and repeatability can be measured. Typically a robot is sent to a taught position a number of times and the error is measured at each return to the position after visiting 4 other positions. Repeatability is then quantified using the standard deviation of those samples in all three dimensions. A typical robot can, of course make a positional error exceeding that and that could be a problem for the process.
Moreover the repeatability is different in different parts of the working envelope and also changes with speed and payload. ISO 9283 specifies that accuracy and repeatability should be measured at maximum speed and at maximum payload. But this results in pessimistic values whereas the robot could be much more accurate and repeatable at light loads and speeds.
Repeatability in an industrial process is also subject to the accuracy of the end effector, for example a gripper, and even to the design of the 'fingers' that match the gripper to the object being grasped. For example if a robot picks a screw by its head the screw could be at a random angle. A subsequent attempt to insert the screw into a hole could easily fail. These and similar scenarios can be improved with 'lead-ins' e.g. by making the entrance to the hole tapered.
10. **Motion control:** For some applications, such as simple pick-and-place assembly, the robot need merely return repeatedly to a limited number of pre-taught positions. For more sophisticated applications, such as welding and finishing (spray painting), motion must be continuously controlled to follow a path in space, with controlled orientation and velocity.
11. **Power source**: Some robots use electric motors, others use hydraulic actuators. The former are faster, the latter are stronger and advantageous in applications such as spray painting, where a spark could set off an explosion; however, low internal air-pressurization of the arm can prevent ingress of flammable vapors as well as other contaminants.
12. **Drive:** Some robots connect electric motors to the joints via gears; others connect the motor to the joint directly (*direct drive*). Using gears results in measurable *'backlash' which is free movement in an axis.* Smaller robot arms frequently employ high speed, low torque DC motors, which generally require high gearing ratios; this has the disadvantage of backlash. In such cases the harmonic drive is often used.
13. Compliance: This is a measure of the amount in angle or distance that a robot axis will move when a force is applied to it. Because of compliance when a robot goes to a position carrying its maximum payload it will be at a position slightly lower than when it is carrying no payload. Compliance can also be responsible for overshoot when carrying high payloads in which case acceleration would need to be reduced.


15. End of Arm tooling (EOAT) design considerations.
Some Factors and Considerations

1. Programming
2. Robot types and applications – soft automation versus hard automation
3. End of Arm tooling (EOAT) design considerations
4. Product delivery systems
5. Robotic cell design
6. Cell guarding standards
7. Vision
8. Conveyor tracking
A 6-axis industrial robot

MOTOMAN HP3C
HP3C – 6 Axis Industrial Robot

The Motoman HP3C is a compact, high-speed robot that requires minimal installation space. Due to its compact design, it can be floor-, wall-, or ceiling-mounted. It comes with a Compact controller (485 x 183 x 300 mm) mounts horizontally or vertically. The HP3C yields extraordinary production results while requiring minimal capital investment.
HP3C – Coverage / Cell Range

The HP3C features a 701 mm (27.6") reach and offers the widest work envelope in its class. The coverage of its movement is shown as below. All dimensions are metric (mm) and for reference on the diagram.
HP3C - Features

- Power Consumption: 1 kVA
- Controlled Axes: 6
- Payload: 3 kg (6.6 lbs)
- Vertical Reach: 1,163 mm (45.8")
- Horizontal Reach: 701 mm (27.6")
- Approximate Mass: 37 kg (81.6 lbs)
- Brakes: All axes
- Structure: Vertical jointed- arm type

<table>
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<th>Maximum Motion Range</th>
<th>S-Axis (Turning/Sweep)</th>
<th>±170°</th>
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<tr>
<td></td>
<td>L-Axis (Lower Arm)</td>
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<tr>
<td></td>
<td>U-Axis (Upper Arm)</td>
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<tr>
<td></td>
<td>R-Axis (Wrist Roll)</td>
<td>±190°</td>
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<tr>
<td></td>
<td>B-Axis (Bend/Pitch/Yaw)</td>
<td>±125°</td>
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<td>T-Axis (Wrist Twist)</td>
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<table>
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<td>L-Axis</td>
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<td>U-Axis</td>
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<td></td>
<td>R-Axis</td>
<td>375°/s</td>
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<tr>
<td></td>
<td>B-Axis</td>
<td>375°/s</td>
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<td></td>
<td>T-Axis</td>
<td>500°/s</td>
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<tr>
<th>Allowable Moment</th>
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<td>B-Axis</td>
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<td></td>
<td>T-Axis</td>
<td>5.21 N•m</td>
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NXC100 Controller

The NXC100 controller is one of the smallest controllers in its class. It features a Windows® CE programming pendant with color touch screen, high-speed processing, unmatched memory (60,000 steps (taught points), 10,000 ladder (concurrent I/O) instructions), built-in Ethernet, and a robust PC architecture. In addition, the NXC100 features best-in-class path planning that dramatically reduces teaching time.

Fig.1: The Teach Pad
NXC100 Controller - Features

Controller:
- Approximate Mass 15 kg (33.1 lbs.)
- Primary Power Requirements Single-phase, 200/220 VAC at 50
- Position Feedback Absolute encoder /60 Hz
- Program Memory 60,000 steps and 10,000 instructions
- Interface Ethernet, RS-232C

Pendant / Teach Pad:
- Pendant Display 6.5 inch full-color touch screen, 640 x 480 (VGA)
- Pendant Weight 1.34 kg (2.96 lbs.)
- Coordinate System Joint, rectangular, cylindrical, tool, 24 user-coordinate frames
- Windows® Menu Driven User-selectable touch screen
- Interface Compact flash slot for backup
- Highly flexible Fieldbus support, and connectivity through standard network options for DeviceNet, ControlNet, Profibus-DP, EtherNet/IP, and many others.
NXC100 Controller - I/O Expansion

The NXC100 supports I/O expansion via the following:

- Remote I/O
- ControlNet
- Profibus-DP
- Remote I/O
- Analog output

- Discrete I/O, NPN/PNP
- DeviceNet
- Other networks available
- EtherNet/IP
HP3C - Applications

By only changing the end of the arm tool (EOAT), the HP3C can be used in the following applications,

- ASSEMBLY
- DISPENSING
- HANDLING
- MACHINE TENDING
- PACKAGING
Few other Robots -1/2

Motoman SDA10D Assembly Robot:
Axis: 15 (7 axes per arm, plus a single axis for base rotation).
Payload: 10 kg /Arm
Applications: Assembly, packaging, material handling, machine tending, part transfer

ABB IRB 5500 – Flex Painter: (Car body exterior paint robot)
Axis: 6
Reduced air handling volumes for ventilation, emissions from booth exhausts, machine programming efforts, in time and personnel requirements

Motoman ES165D | ES200D Robot with Spot Harness: (Spot welding robot)
Axis: 6
Payload: 165 kg | 200 kg
Few other Robots -2/2

**ABB IRB 360 Flex Picker Parallel axis robot:**
- Axis: 4
- Picking range of 800mm, greater reach of 1130mm, payload up to 3kg,
- Superior tracking performance

**Motoman MPL160 Palletizing Robot**
- Axis: 4
- Payload: 160 kg (352.8 lb)
- 3,024 mm (119.1") vertical reach; 3,159 mm (124.4") horizontal reach; ±0.5 mm (±0.02") repeatability

**Schunk Radio Sensor System:**
- Consists of a transmitter (RSS-T2) with two mechanical switches and one receiver (RSS-R1) with an external antenna.
QUESTIONS?