Introduction to Robotics

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Introduction

Robot can convey many different meanings. As per subject here, we mean an industrial robot: robotic arm or robotic manipulator

Robotic arm – roughly like human arm.

- Modelled using rigid bodies or links interconnected by flexible joints.

As per human anatomy:

- Chest , upper arm and forearm are rigid bodies or links
- Shoulder, elbow and wrist are joints

End of robotic arm is an end effector

- Tool, Gripper or hand with fingers.

History

Mass production assembly lines were first introduced at the beginning of the twentieth century (1905) by ford motor company.

- Used for high volume production of mechanical and electrical parts.

Hard Automation

- Require periodic modification of the production hardware each time a production cycle ends.
- Here machines and processes are often very efficient, but they have limited flexibility.

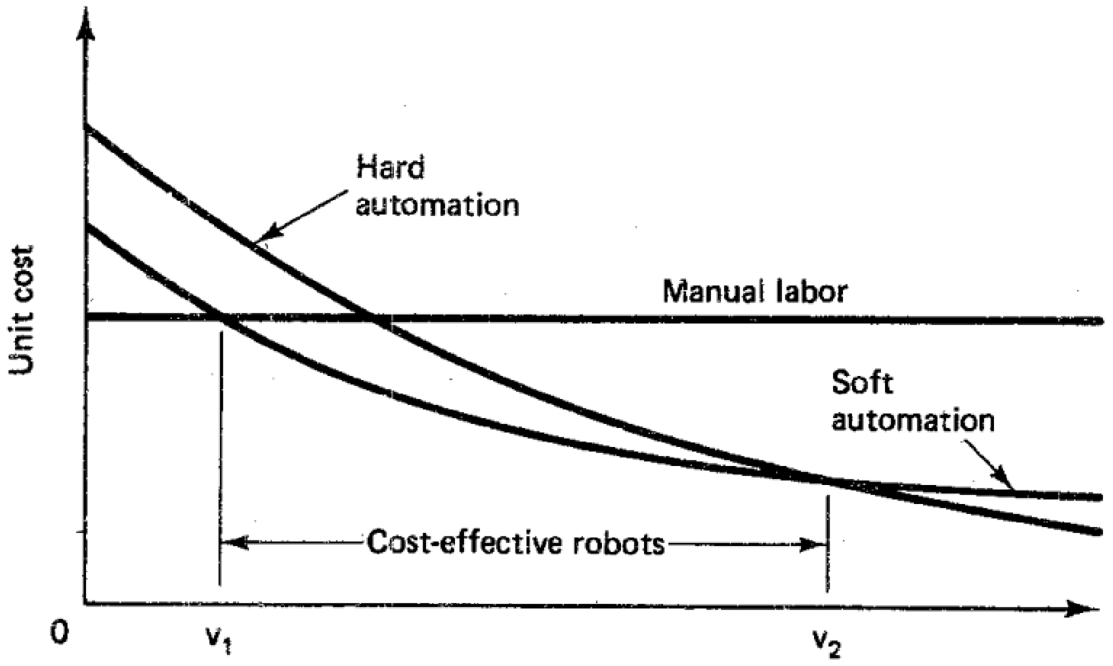
Soft Automation

- Flexible form of automation.
- Use of programming mechanical manipulators are used.
- Spot welding, Spray painting, material handling, and component assembly are some of the tasks.

Comparative analysis

A qualitative comparison of the cost effectiveness of manual labor, hard automation, and soft automation as a function of the production volume.

- Beyond v1, robots become more cost effective than manual labour.
- Beyond v2, Hard automation surpasses both manual labour and robots in cost effectiveness.



Definition

A robot is a software controllable mechanical device that uses sensors to guide one or more end effectors through programmed motions in a workspace in order to manipulate physical objects.

Remember:

- Today's industrial robots are not androids built to impersonate humans; indeed, most are not even capable of self locomotion.
- However, today's robots are anthropomorphic in the sense that they are patterned after the human arm. Thus, named as robotic arm or robotic manipulators.

Drive technologies

Schemes based on source of power used to drive the joints of robot.

- Electrical Drives
  - DC Servomotors, DC Stepper motors.
  - Used for low weight loads and precise motions.
  - Clean source of motion.
- Hydraulic Drives
  - Required for high-speed manipulation of substantial loads like molten steel handling, auto body part handling, hydraulic-drive robots etc.
  - Lacks cleanliness.
- Along with both above drives pneumatic tools or end effectors are used for gripping action(open-close).
- Pneumatic grippers exhibit built in compliance in grasping objects, as air is a compressible fluid. In contrast to mechanical grippers which can easily damage a delicate object by squeezing too hard.

Work-Envelope geometries

The end effector of a robotic manipulator is typically mounted on a flange or plate secured to the wrist of the robot. The gross work envelope of the robot is defined as locus of points in 3-dimensional space that can be reached by the wrist.

- Major axes: determine the position of the wrist.
- Minor axes: establish orientation of the tool.

The geometry of work envelope is determined by sequence of joints used for the major axes.

Types of Robotic joints

There are six types of joints:

- Revolute
- Prismatic or Linear joint
- Helical or Screw
- Cylindrical
- Universal
- Spherical

Robot work-envelopes

There are five types of robot work envelopes based on major axes. Also know as robotic configurations.

- Cartesian
- Cylindrical
- Spherical or Polar
- SCARA: Selective Compliance Assembly Robotic Arm
- Jointed Arm or Articulated.

Motion control methods

Another fundamental classification criterion is the method used to control the movement of end effector tool.

- Point to point motion
  - Spot Welding, pick and place, Loading and unloading etc
  - The tool moves in a sequence of discrete points in workspace.
- Continuous Path
  - Spray painting, Arc welding, Gluing
  - The end-effector must follow a prescribed path in 3-dimensional space and speed of motion along the path may vary.

Applications

Robotic applications often involve

- Simple/tedious, repetitive tasks : loading and unloading of machines
- Tasks with harsh and unhealthy environments: Spray painting, handling of toxic materials.
- See figure for details of US market.

Application	Percent
Material handling	24.4
Spot welding	16.5
Arc welding	14.5
Spray painting and finishing	12.4
Mechanical assembly	6.2
Electronic assembly	4.8
Material removal	4.5
Inspection and testing	2.9
Water jet cutting	2.7
Other	11.1

Distribution of world robot population

Country	Percent
Japan	44.1
U.S.A.	22.1
West Germany	8.8
Sweden	7.4
France	2.9
Great Britain	2.9
Italy	2.2
Others	9.6

Robot Specifications

Besides drive technologies, work-envelope geometries and motion control method are sufficient to classify robots, there are number of additional characteristics that specify robotic manipulators.

Characteristic	Units
Number of axes	—
Load carrying capacity	kg
Maximum speed, cycle time	mm/sec
Reach and stroke	mm
Tool orientation	deg
Repeatability	mm
Precision and accuracy	mm
Operating environment	—

Number of Axes

Axes	Type	Function
1–3	Major	Position the wrist
4–6	Minor	Orient the tool
7–*n*	Redundant	Avoid obstacles

Capacity and Speed

Load carrying capacity varies greatly between robots. It may be around 2.2 kg for educational robot or 4928 Kg for industrial robot.

Tool-tip speed also varies between manipulators. It may be around 92mm/sec to 9000mm/sec as per specific robots.

Cycle Time: The time required to perform a periodic motion like a simple pick and place operation.

In some cases, large load carrying capacity may not be necessary while in other cases accuracy may be more important than speed.

Reach and Stroke

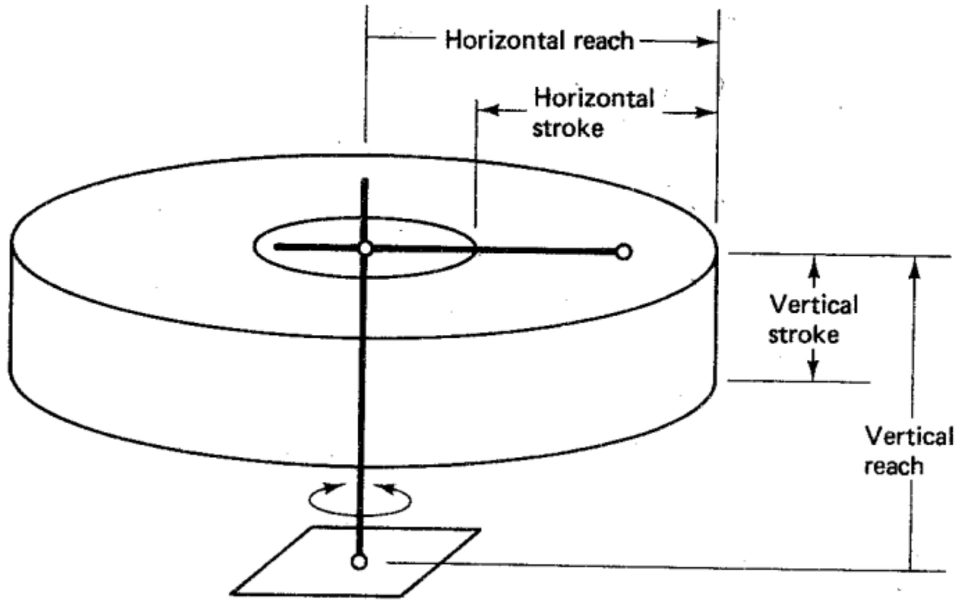
The reach and stroke of a robotic manipulator are rough measures of the size of the work envelope.

Horizontal reach is defined as the maximum radial distance the wrist mounting flange can be positioned from the vertical axis about which the robot rotates.

Horizontal stroke represents the total radial distance the wrist can travel.

Vertical reach of a robot is the maximum elevation above the work surface that the wrist mounting flange can reach.

Vertical stroke is the total vertical distance that the wrist can travel.



Stroke ≤ Reach

Tool Orientation

If 3 independent minor axes are available then, then arbitrary orientations in 3D space can be defined.

To specify tool orientation,

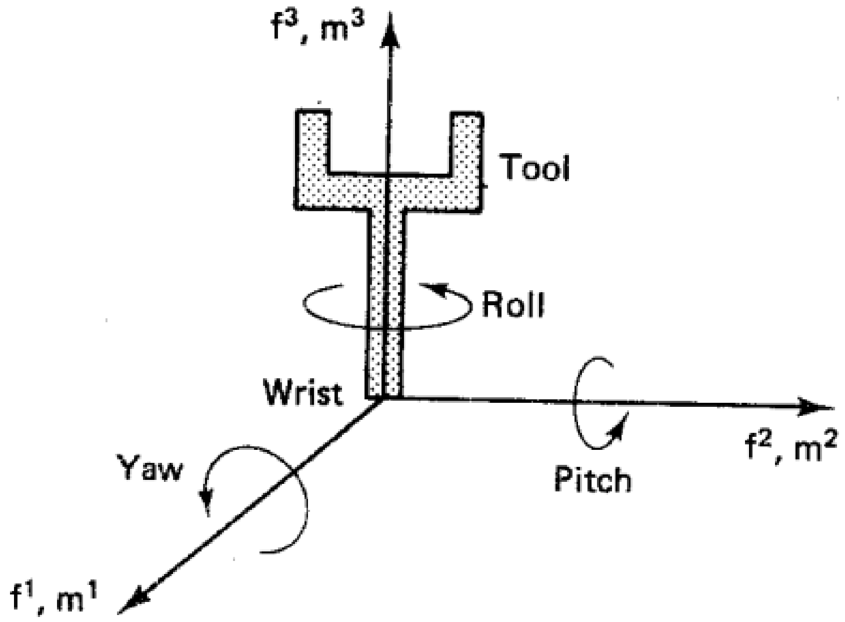
Consider,

Mobile coordinate frame M = {m1,m2,m3}

And fixed Coordinate frame F={f1, f2, f3}

The Yaw followed by pitch is not equivalent to Pitch followed by Yaw motion. Hence order of operation is of great importance.

Anticlockwise motions are taken as positive.

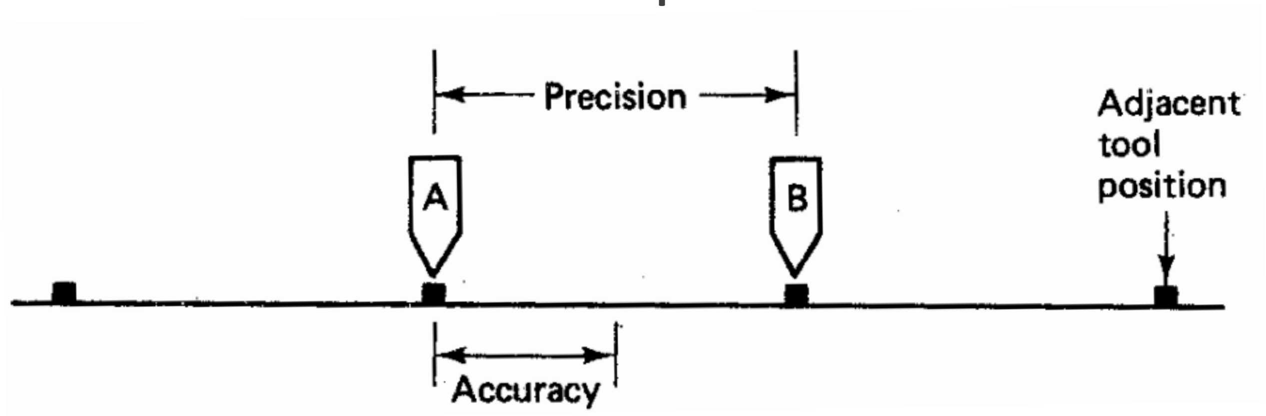


Operation	Description	Axis
1	Yaw	f^1
2	Pitch	f^2
3	Roll	f^3

Repeatability and Precision

Repeatability is the ability of the robot to position the tool tip in the same place repeatedly. Due to backlash in gears and flexibility in the links, there will always be some repeatability error. Usually in range of millimeters.

Precision is the matter of spatial resolution with which the tool can be positioned in the work envelope



Accuracy

The accuracy of a robotic manipulator is a measure of the ability of robot to place the tool tip at an arbitrary prescribed location in the work envelope.

It is not as easy as to analyze precision. Accuracy depends on

- Backlash in gears
- Elastic deformations in links due to loading

However, Inaccuracy or error can be set by this formula

$$\text{Error} \geq \frac{Precision}{2}$$

To maintain reasonable accuracy, robots are periodically reset or zeroed to a standard hard home position using limit switch sensors.

Operating Environments

Operating environment depends on nature of task

- Harsh, dangerous and unhealthy environment
  - Transport of radioactive materials, spray painting, welding, and loading and unloading of furnaces.
  - Temperature and contamination are major issues.
  - Joints can be jammed by contaminants.
- Clean room robots
  - Robots that handle Semiconductor ICs, photomasks etc.
  - Here temperature , pressure and humidity are carefully controlled.

Classification of Robots

Industrial robot: These are most existing robots;

Service robots: There are hardly any yet;

Biomedical robot: A quite new and promising application field to robotics;

Experimental or Scientific robots: The second most popular type of real robot.

Industrial Robots

The industrial robots can also be further divided into:

- robot manipulator arms and
- mobile robots.

Industrial mobile robots are often called automatic guided vehicles (AGVs), and they are used to transport components and materials in factories.

The manipulator arms are fixed in position, and used to spray paint, make solder joints, assemble components, and manipulate and transport objects.

They are programmed to do specific task and can’t adapt, modify or change according to circumstances.

Industrial robots are large powerful machines that can even kill people if something goes wrong.

Service Robots

The Service robots are robots that mainly work outside the factory and are normally supposed to provide direct services to people.

There are still very few real service robots in the world, but the most popular applications or proposed applications are floor cleaning, security patrol, mail delivery, and other kinds of delivery tasks.

Most service robots are mobile. But there are, however, machines that exist today that we might also call service robots, though they are not mobile robots. The automatic car washing machines, the kind you drive into, might also be thought of as a kind of robot that provides a service to people.

Biomedical Robots

Robots that assist doctors in planning, training and performing surgery.

Robots that assist patients in reducing the effects of impairments caused by a trauma. This effect reduction could be replacing a lost limb, helping the patient move the impaired limb or as a part of a rehabilitation program for the impaired limb.

Finally, we can also include autonomous wheelchairs in this category.

For most people, a robot is a machine that can make its own decisions about what it ought to do, and that can react to internal and external events and respond to changes in the surrounding environments. But as the robotic reasoning capacity is very low, and the failure probability is high, with biomedical robots it is not possible to let the robot be autonomous.

Experimental Robots

Experimental or scientific robots are robots used for robotic research purposes or other scientific applications.

Teleoperated Robots receives instructions for what it had to do from Master Like Vyomitra, a space robot. These systems are used to undertake tasks in hostile environments for humans such as in mines, outer space, areas of high radioactivity, bomb disposal sites, underwater, etc. In these situations, the master robot is kept in a safe zone while the slave performs the desired task in the remote hazardous environment.

Haptic arms: A haptic device is a mechanism designed to interact with humans, allowing a tactile connection with a remote or virtual environment. These devices allow providing the user with additional information of the working environment through the sense of touch. A special example of kinesthetic haptic device is the so-called exoskeleton.