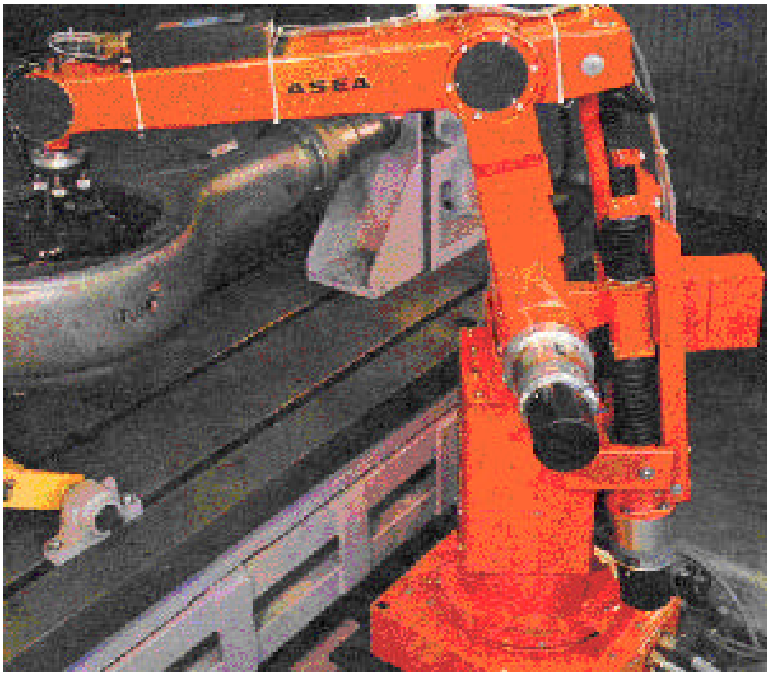
♦ Manipulator Arms

The common industrial manipulator is often referred to as a robot arm, with links and joints described in similar terms. Manipulators which emulate the characteristics of a human arm are called articulated arms. All their joints are rotary (or revolute). A representative articulated manipulators is the ASEA robot.



ASEA robot performing a mechanical assembly task.

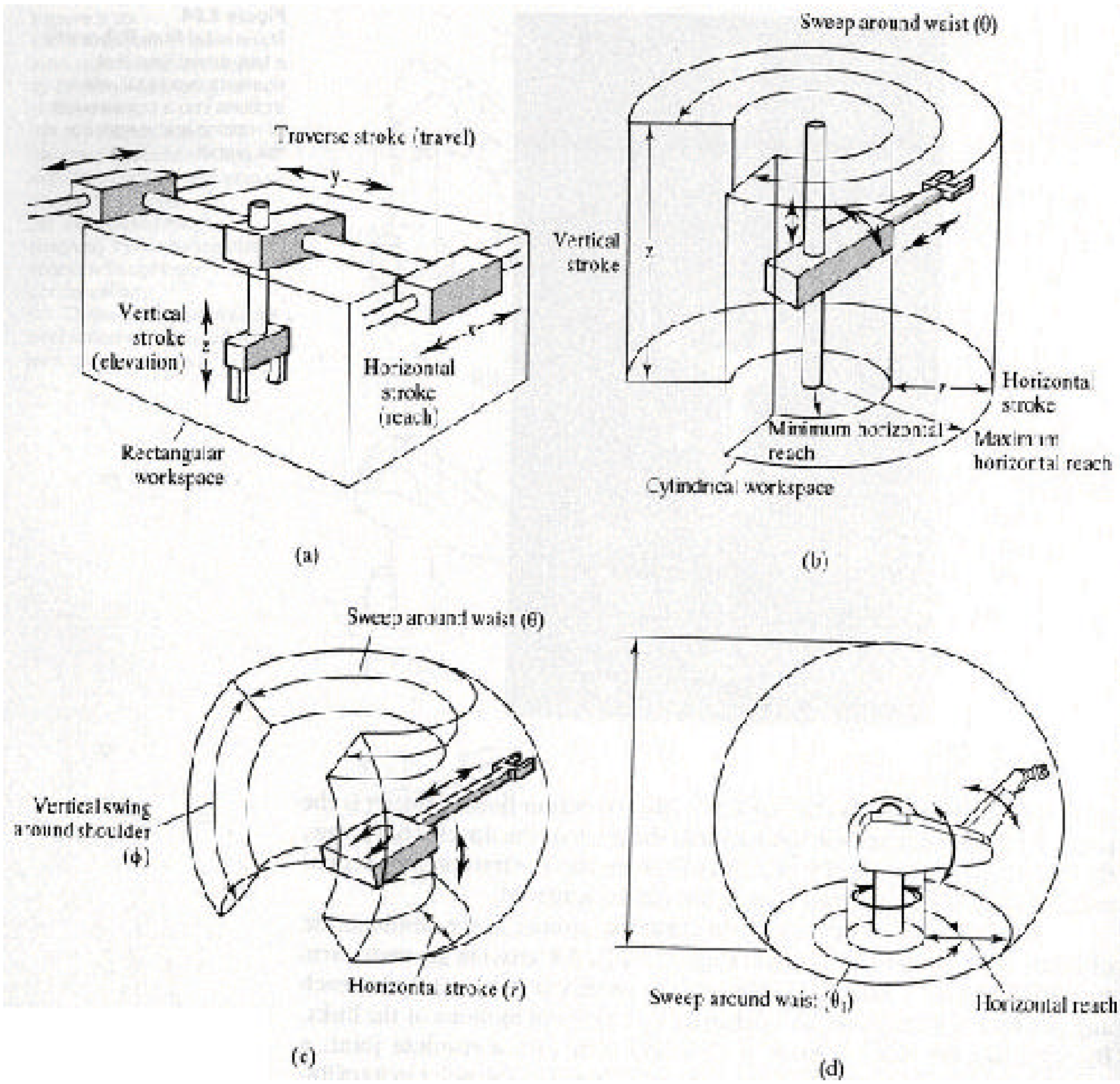
The motion of articulated robot arms differs from the motion of the human arm. While robot joints have fewer degrees of freedom, they can move through greater angles. For example, the elbow of an articulated robot can bend up or down whereas a person can only bend their elbow in one direction with respect to the straight arm position.

Many applications do not require arms with articulated (or revolute) geometries. Simpler geometries involving prismatic or sliding joints are often adequate. Prismatic and revolute joints represent the opposite extremes of a universal screw. In a revolute joint, the screw pitch is zero, constraining the joint to pure rotation. In a prismatic joint, the pitch is infinite, constraining the joint to pure sliding motion. Revolute joints are often preferred because of the strength, low friction and reliability of ball bearings. Joints that allow a combination of translation and rotation (such as lead screws) are not normally used to join the links of robot arms.

Manipulators are grouped into classes according to the combination of joints used in their construction. A **Cartesian geometry arm** (sometimes called a gantry crane) uses only prismatic joints, and can reach any position in its rectangular workspace by Cartesian motions of the links. By replacing the waist joint of a Cartesian arm with a revolute joint, a **cylindrical geometry**

arm is formed. This arm can reach any point in its cylindrical workspace (a thick-shelled cylinder) by a combination of rotation and translation. If the shoulder joint is also replaced by a revolute joint, an **arm with a polar geometry** is formed. The workspace of this arm is half a thick spherical shell, and end effector positions are best described with polar coordinates. Finally, replacing the elbow joint with a revolute joint results in a **revolute geometry, orarticulated arm**. The workspace of an articulated arm is a rather complex thick walled spherical shell. The outside of the shell is a single sphere, but the inside is a set of intersecting spheres.

Motions of an articulated robot arm.



Workspaces for different robot geometries: (a) Cartesian geometry; (b) cylindrical geometry ; (c) polar/spherical geometry; (d) revolute geometry/articulated arm, (from [McKerrow]).

Comparison of robot configuration (from [*McKerrow*]).

Robot	***Joints***	***Coordinates***
		Advantages
Cartesian	prismatic waist prismatic shoulder prismatic elbow	. linear motion in three dimension . simple kinematic model . rigid structure . easy to visualize . can use inexpensive pneumatic drives for pick and place operation. *Disadvantages* . requires a large volume to operate in . work space is smaller than robot volume . unable to reach areas under objects . guiding surfaces of prismatic joints . must be covered to prevent ingress of dust
		Advantages
Cylindrical	revolute waist prismatic shoulder primatic elbow	. simple kinematic model . easy to visualize . good access into cavities and machine openings . very powerful when hydraulic drives used *Disadvantages* . restricted work space . prismatic guides difficult to seal from dust and liquids . back of robot can overlap work volume
		Advantages
Spherical	revolute waist revolute shoulder prismatic elbow	. covers a large volume from a central support . can bend down to pick objects up off the floor *Disadvantages* .complex kinematic model . difficult to visualize
		Advantages
Articulated	revolute waist revolute shoulder revolute elbow	. maximum flexibility . covers a large work space relative to volume of robots . revolute joints are easy to seal . suits electric motors . can reach over and under objects *Disadvantages* . complex kinematics . difficult to visualize . control of linear motion is difficult . structure not very rigid at full reach

Workspace considerations, particularly reach and collision avoidance, play an important part in the selection of a robot for an application. All manufacturers give detailed specifications of the work space of their robots and associated equipment.

Consideration of the motions involved in assembly has led to the development of a simpler arm geometry for use in assembly applications, known as the **SCARA** (Selective Compliance Automatic Robot Arm) geometry. While all SCARA robots have the same geometry the name SCARA does not have a geometric basis. Most assembly operations involve building up the assembly by placing parts on top of a partially complete assembly. A SCARA arm has two revolute joints in the horizontal plane, allowing it to reach any point within a horizontal planar workspace defined by two concentric circles. At the end of the arm is a vertical link which can translate in the vertical direction, allowing parts to be raised from a tray and placed on to the assembly. A gripper placed at the end of this link may be able to rotate about the vertical axis of this link, facilitating control of part orientation in a horizontal plane.

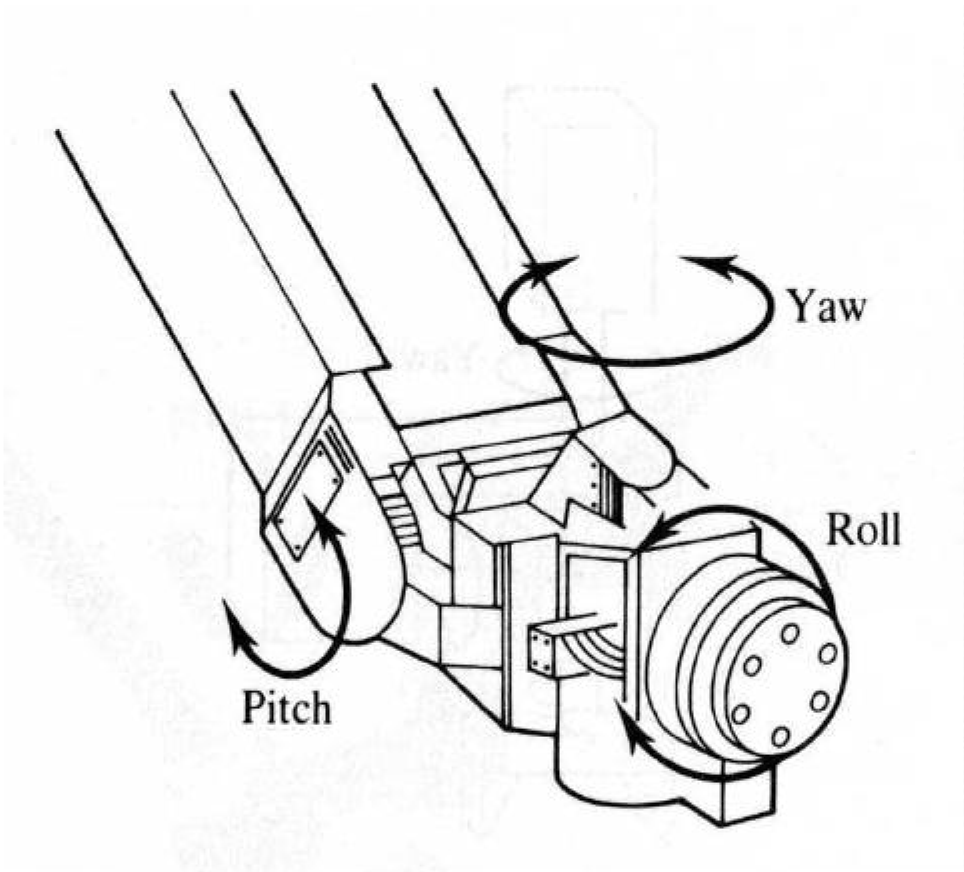
♦ Wrists

The kinematic structure of the robot arm allows to postion its end point at any (x,y,z) location in the 3D space (…. within the robot's working space)

In order to provide for the proper orientation of the hand/end-effector the robot arm should have *a wrist*. Typically a robot wrist provides the same 3D rotations as a human hand: roll, pitch, and yaw. A wrist where the three axes of rotation intersect is called a *spherical wrist*. These have the advantage that the mathematical model used to calculate the wrist joint angles from their position and orientation in space is soluble.

One problem in achieving spherical wrist design is the physical difficulty of fitting all the components into the available space. The size of the human wrist is small because the muscles which power it are located in the forearm, not in the wrist. Wrist design is a complex task, involving conflicting goals. Desirable features of a wrist include :

- small size
- axes close together to increase mechanical efficiency
- tool plate close to the axes to increase strength and precision
- soluble mathematical model
- no singularities in the work volume
- back-driving to allow programming by teach and playback
- decoupling between motions around the three axes
- actuators mounted away from the wrist to allow size reduction
- paths for end effector control and power through the wrist
- power proportionate to the proposed task
- rugged housing.



Robot wrist