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What is a robot?

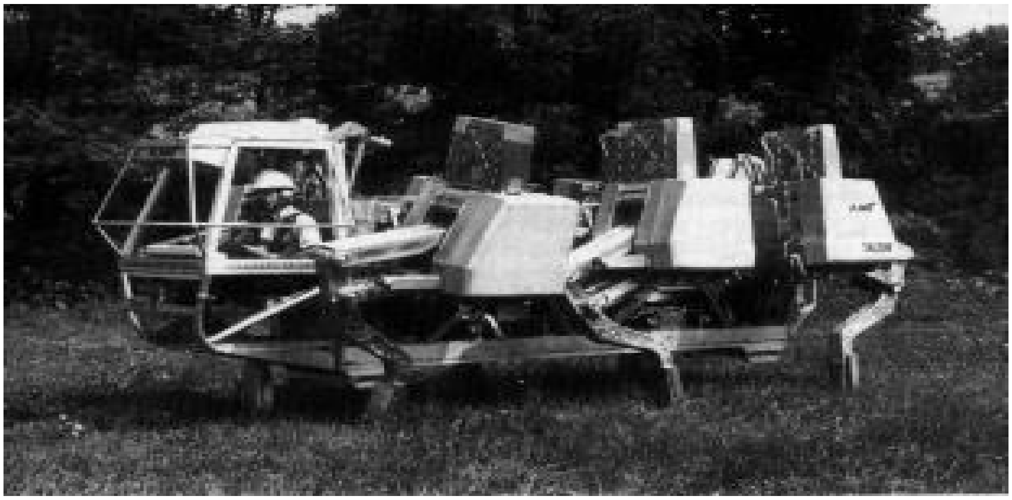
The Webster defines a robot as

An automatic apparatus or device that performs functions ordinarily ascribed to
Humans or operates with what appears to be almost human intelligence.
The Robotics Institute of America defines a robot as follows:
A robot is a reprogrammable multifunctional manipulator designed to move material, Parts, tools or specialized devices through variable programmed motions for the Performance of a variety of tasks.

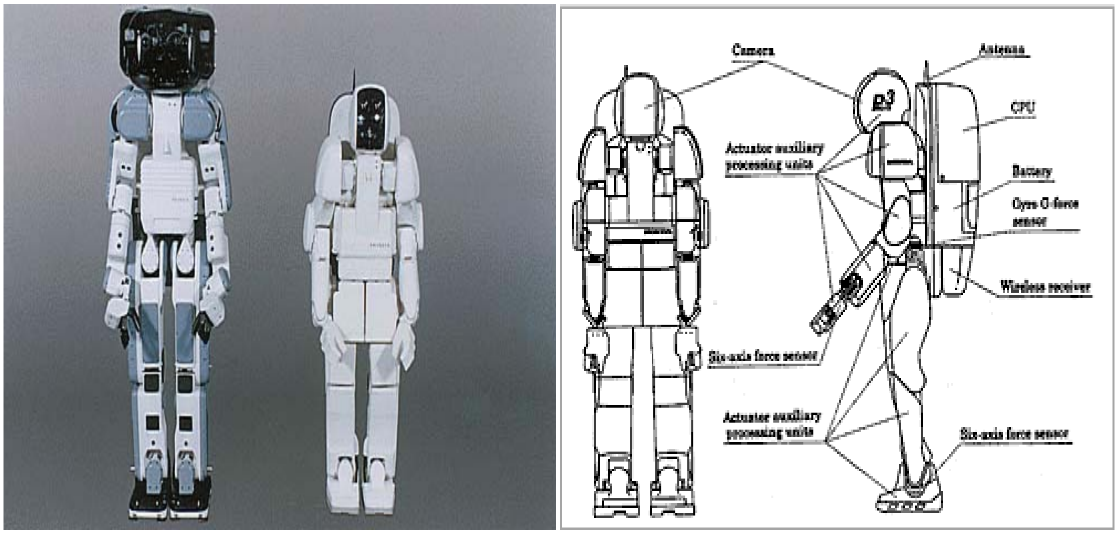
Definition of a robot revisited

The robot is a computer-controlled device that combines the technology of digital
Computers with the technology of servo-control of articulated chains. It should be easily reprogrammed to perform a variety of tasks, and must have sensors that enable it to react and adapt to changing conditions. Most industrial robots satisfy this definition. They basically serve to eliminate the need of high cost, specialized equipment in the Manufacturing industry. However, as we will see, they may require expensive, specialized tooling. A lay person, perhaps guided by Asimov's science fiction and Hollywood's movies, might argue that a robot must have sensing and be able to make decisions and act based on this sensory information, just as human beings do. It is this lay Peron's definition of a robot that is the goal of much of the research and development in robotics. As we will see, industrial robots are very successful at simple repetitive tasks that are typical of

assembly lines, but they do not meet the layperson’s conception of a robot.



Adaptive Suspension Vehicle



The Honda Humanoid

Anatomy of a robot

The basic components of a robot system are:

- The mechanical linkage
- Actuators and transmissions
- Sensors
- Controllers
- User interface
- Power conversion unit

The manipulator linkage

The manipulator consists of a set of rigid *links* connected by *joints*. The joints are typically *rotary* or *sliding*. The last link or the most distal link is called the *end effectors* because it is this link to which a gripper or a tool is attached. Sometimes one distinguishes between this last link and the end effectors that is mounted to this link at the *tool mounting plate* or the *tool flange*.

The manipulator can generally be divided into a *regional structure* and an *orientational structure*. The regional structure generally consists of the joints (and the links between them) whose main function is the positioning of the manipulator end effectors. These are generally the proximal joints. The remaining distal joints are mainly responsible for orienting the end effectors. Figure 5 shows an example of an industrial robot whose regional structure produces a roughly spherical *workspace*.

The actuators are used to drive the joints of the manipulator. Note that all joints may not be powered and some may be passive. For example, if you look at Figure 6, the elbow extension is achieved using a linear actuator (a telescoping link or a cylinder) and the elbow joint is a passive joint.

Actuators

The actuators are typically linear or rotary actuators. Also they may be electric, pneumatic or hydraulic. Typically, electric actuators or motors are better suited to high speed, low load applications while hydraulic actuators do better at low speed and high load applications. Pneumatic actuators are like hydraulic actuators except that they are generally not used for high payload. The main reason they are used in industry is because shop air is readily available. However, the maximum pressure is generally 100 psi. In contrast, hydraulic actuators may run as high as 3000 psi.

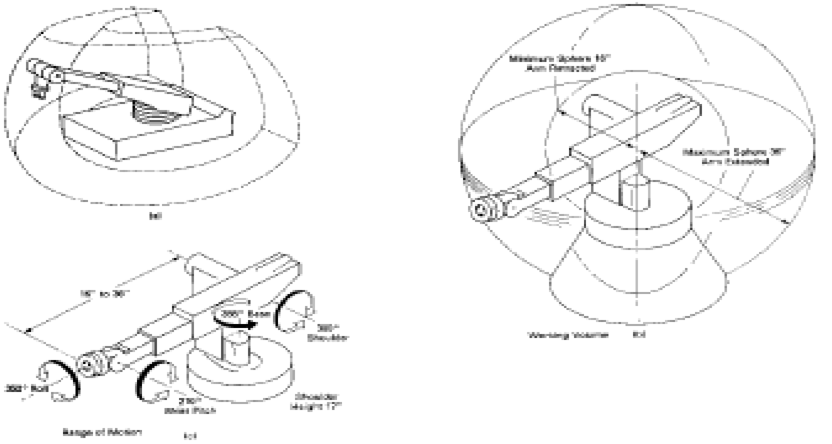


Figure 5 An industrial robot with a spherical workspace [KCN, page 16]

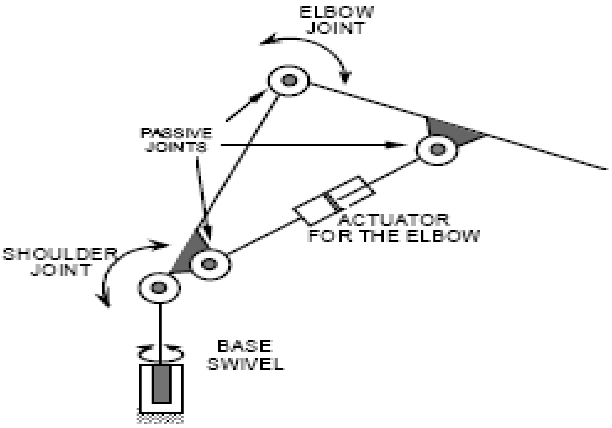


Figure 6 The regional structure for the Cincinnati Milacron T3 robot

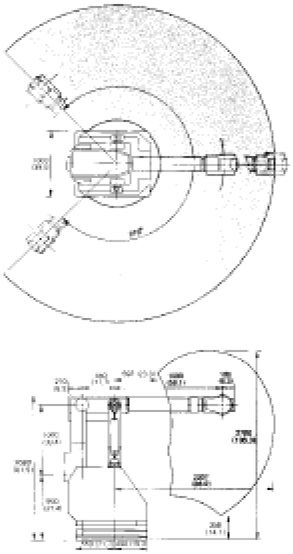


Figure 7 An industrial robot with a parallelogram drive arrangement [KCN, page 21]

Transmissions

Transmissions are elements between the actuators and the joints of the mechanical linkage. They are generally used for three reasons.

1. Often the actuator output is not directly suitable for driving the robot linkage. The high speed DC motor (running at say 3000 rpm) may not be suitable for running a robot at lower speeds. However, with appropriate gearing or transmission, the speed may be reduced to 30 rpm (1/2 rotation per second), which is reasonably fast. In addition, the rated torque at 3000 rpm is amplified by a factor of 100 (assuming a highly efficient gearbox).
2. The output of the actuator may be kinematically different from the joint motion. For example, in Figure 6, the linear actuator is kinematically different from the elbow

joint it drives. Thus the linkage consisting of the three passive joints and the linear actuator may be viewed as a transmission that converts the linear motion of the actuator to the rotary motion of the elbow joint.

3. The actuators are usually big and heavy and often it is not practical to locate the actuator at the joint. First, big actuators have large inertias and they are harder to move around in space than the links that comprise the mechanical linkage. So it is desirable to locate them at a fixed base. Second, because of their size, they can impede the motion of one or more links of the robot. Thus, it is not uncommon to find linkages or gear trains that transmit the power from the actuator over a large distance to the joint. A parallelogram drive is shown in Figure 7. This drive allows the joint actuators to be placed on the base (as opposed to placing them in the moving forearm or upper arm) thus reducing the inertia and weight of upper arm.

Sensors

In order to control a robot, it is necessary to know the position of each joint in the mechanical linkage. Therefore it is necessary to instrument the joints3 of the robot with position sensors (encoders, potentiometers, resolvers, etc.). Velocity sensors (e.g., tachometers) and acceleration sensors (accelerometers) may also be used. In addition to the position, it may be necessary to know the forces and moments exerted by the end effector or simply the torques/forces exerted by each actuator. Six axis force/torque sensors that mount between the tool and the distal link measure the forces encountered by the tool or the gripper. Pressure sensors may be used to measure the force exerted by a hydraulic or pneumatic actuator. In addition, the robot system may be commanded using sensory information from vision sensors (cameras, laser range finders), acoustic sensors (ultrasonic ranging systems) or touch sensors (optical or strain based).

Controller

The controller provides the intelligence that is necessary to control the manipulator system. It looks at the sensory information and computes the control commands that must be sent to the actuators to carry out the specified task. It generally includes:

- Memory to store the control program and the state of the robot system obtained from the sensors
- A computational unit (CPU) that computes the control commands
- The appropriate hardware to interface with the external world (sensors and actuators)

The hardware for a user interface

The user interface

This interface allows use a human operator to monitor or control the operation of the robot. It must have a display that shows the status of the system. It must also have an input device that allows the human to enter commands to the robot. The user interface may be a personal computer with the appropriate software or a teach pendant.

The power conversion unit

The power conversion unit takes the commands issued by the controller, which may be low power and even digital signals and converts them into high power analog signals that can be used to drive the actuators. For example, for an electric actuator, this power conversion unit may consist of a digital to analog converter and an amplifier with a power supply. For a pneumatic actuator, this may consist of a compressor, the appropriate servo valves for regulating the flow of air, an amplifier and a digital to analog converter. For a hydraulic robot, you will have a pump and a cooler instead of a compressor. A possible implementation of a robot controller is shown in Figure 8.

We will discuss each of the building blocks in greater detail at some point during the course. Specifically, we will cover the following subjects:

- The kinematics and geometry of mechanical linkages
(notes, [CRA 92, pg. 133:144])
- Actuators
([CRA 92, pg. 42:48, 144:149])

Examples:

Pittman dc servo motor, Comp motor stepper motor, electro pneumatic actuator tested, hydraulic actuators of the ASV, NSK Mega torque direct drive motor, Kollmorgen servo disc motor)

- # Transmissions

([CRA 92, pg. 48:51])
gear trains, spur and bevel gears, harmonic drives, cable-pulley systems, lead screws,
rack and pinion systems, belt and pulley linear drives, the Roh'lix mechanism, slider
crank mechanism, cam-follower systems, four-bar linkage, flexible shaft couplings,
intermittent mechanisms (Geneva mechanism and walking beam)

- Sensors

potentiometers, resolvers, LVDTs, optical encoders, tachometers, accelerometers,
strain gages, pressure sensors, proximity devices, ultrasonic, sensors, electromagnetic
sensors, tactile sensors, computer vision systems, bar code readers, counters, timers

- Controllers

On/off control [KCN 89, pg. 176], continuous control, real-time controller

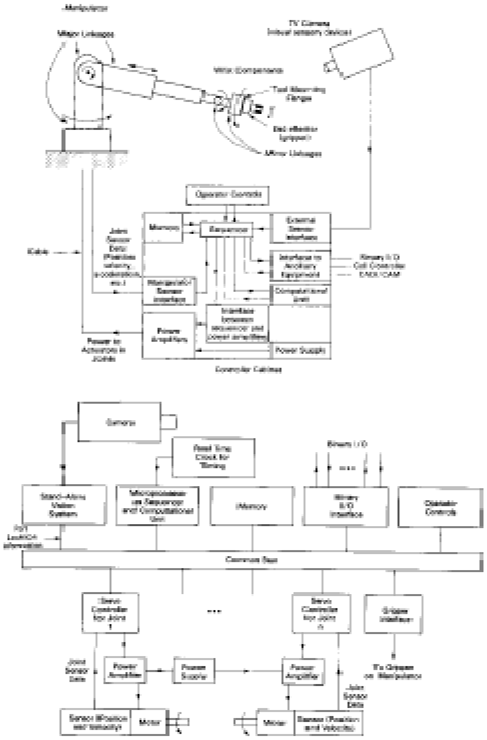


Figure 8 Possible implementation of a robot controller [KCN 89, page 89