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SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

# UNIT IV – ROBOT CONTROL - SCSA1406

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# ROBOT CONTROL

**Unit 4 Robot Control**

Basics of control: Transfer functions, Control laws: P, PD, PID Non-linear and advanced controls

## Robot Control Systems

**Limited sequence control** – pick-and-place operations using mechanical stops to set positions

**Playback with point-to-point control** – records work cycle as a sequence of points, then plays back the sequence during program execution

**Playback with continuous path control** – greater memory capacity and/or interpolation capability to execute paths (in addition to points)

**Intelligent control** – exhibits behavior that makes it seem intelligent, e.g., responds to sensor inputs, makes decisions, communicates with humans

## Robot Control System

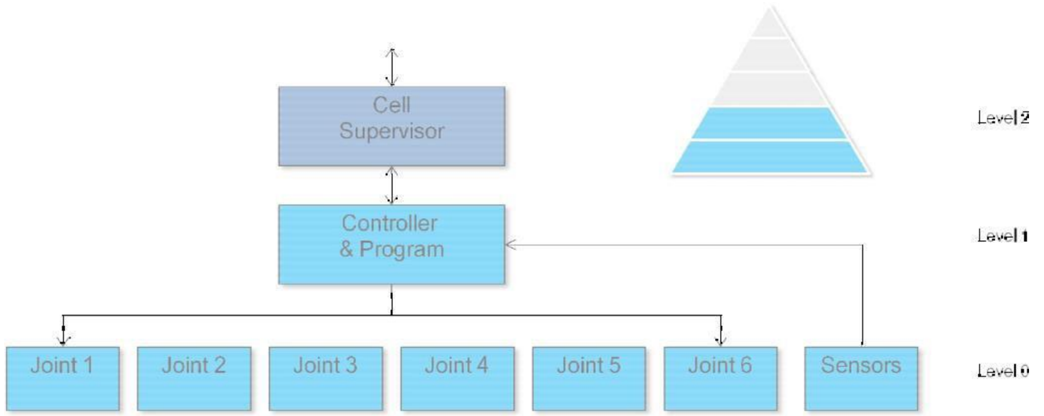


Fig 4.1 Robot Control system

## Motion Control

- Path control - how accurately a robot traces a given path (critical for gluing, painting, welding applications);
- Velocity control - how well the velocity is controlled (critical for gluing, painting applications)
- **Types of control path:**

  - Point to point control (used in assembly, palletizing, machine loading); - continuous path control/walkthrough (paint spraying, welding).

  - controlled path (paint spraying, welding)

-  Limited sequence control – pick-and-place operations using mechanical stops to set positions
-  Playback with point-to-point control – records work cycle as a sequence of points, then plays back the sequence during program execution
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**Robot Control System**

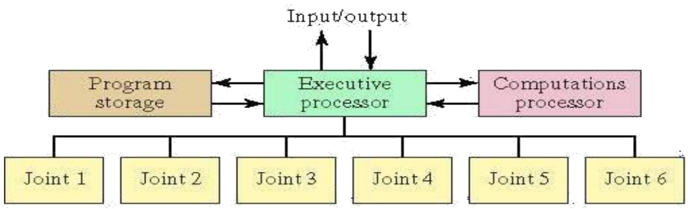


Fig 4.2 Robot Control System

Robot control consists in studying how to make a robot manipulator perform a task. Control design may be divided roughly in the following steps:

• Familiarization with the physical system under consideration,
• Modeling.

• Control specifications.
Control specifications Definition of control objectives: • Stability • Regulation • Trajectory tracking (motion control) • Optimization.

• Stability. Consists in the property of a system by which it goes on working at certain regime or ‘closely’ to it ’forever’. – Lyapunov stability theory. – Input-output stability theory. In the case when the output y corresponds to the joint position q and velocity $\dot{q}$ . • Regulation “Position control in joint coordinates” •

Trajectory tracking “Tracking control in joint coordinates”

**Control Methods**

- ***Non Servo Control***
  - implemented by setting limits or mechanical stops for each joint and sequencing the actuation of each joint to accomplish the cycle
  - end point robot, limited sequence robot, bang-bang robot
  - No control over the motion at the intermediate points, only end points are known

- Programming accomplished by
  - setting desired sequence of moves
  - adjusting end stops for each axis accordingly

***Servo Control***

- Point to point Control
- Continuous Path Control
- Closed Loop control used to monitor position, velocity (other variables) of each joint
- the sequence of moves is controlled by a “squencer”, which uses feedback received

  from the end stops to index to next step in the program

- Low cost and easy to maintain, reliable
- relatively high speed
- repeatability of up to 0.01 inch
- limited flexibility
- typically hydraulic, pneumatic drives

**Point-to-Point Control**

- Only the end points are programmed, the path used to connect the end points are computed by the controller
- user can control velocity, and may permit linear or piece wise linear motion
- Feedback control is used during motion to ascertain that individual joints have achieved desired location
- Often used hydraulic drives, recent trend towards servomotors
- loads up to 500lb and large reach
- Applications
  - pick and place type operations
  - palletizing
  - machine loading

- In addition to the control over the endpoints, the path taken by the end effectors can be controlled
- Path is controlled by manipulating the joints throughout the entire motion, via closed loop control
- Applications:
  - spray painting, polishing, grinding, arc welding

**Sensors in Robotics**

Two basic categories of sensors used in industrial robots:

1. Internal - used to control position and velocity of the manipulator joints

2. External - used to coordinate the operation of the robot with other equipment in the work cell  Tactile - touch sensors and force sensors
    -  Proximity - when an object is close to the sensor  Optical -
    -  Machine vision
    -  Other sensors - temperature, voltage, etc.

-  Electric Drive system
    -  Uses electric motors to actuate individual joints
    -  Preferred drive system in today's robots
    -  Electric motor (stepper, servo, less strength, better accuracy and repeatability
-  Hydraulic Drive system
    -  Uses hydraulic pistons and rotary vane actuators
    -  Noted for their high power and lift capacity
    -  Hydraulic (mechanical, high strength)
-  Pneumatic Drive system
    -  Typically limited to smaller robots and simple material transfer applications
    -  Pneumatic (quick, less strength)

-  **Hydraulic** Drive system

  – High strength and high speed

  – Large robots, Takes floor space

  – Mechanical Simplicity

  – Used usually for heavy payloads

-  **Electric Motor (Servo/Stepper)** Drive system
  – High accuracy and repeatability

  – Low cost

  – Less floor space

  – Easy maintenance

-  **Pneumatic** Drive system
  – Smaller units, quick assembly

  – High cycle rate

  – Easy maintenance

**Electro hydraulic servo valves**

An electro hydraulic servo valve (EHSV) is an electrically operated valve that controls how hydraulic fluid is ported to an actuator. Servo valves and servo-proportional valves are operated by transforming a changing analogue or digital input signal into a smooth set of movements in a hydraulic cylinder. Servo valves can provide precise control of position, velocity, pressure and force with good post movement damping characteristics.

In its simplest form a servo or a servomechanism is a control system which measures its own output and forces the output to quickly and accurately follow a command signal, se Figure 1-1. In this way, the effect of anomalies in the control device itself and in the load can be minimized as well as the influence of external disturbances. A servomechanism can be designed to control almost any physical quantities, e.g. motion, force, pressure, temperature, electrical voltage or current.

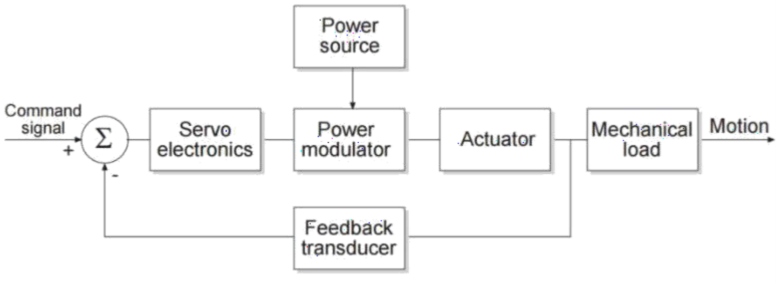


Figure 1-1: Basic servomechanism

Fig 4.3 Basic Servo Mechanics

Capabilities of electro-hydraulic servos When rapid and precise control of sizeable loads is required an electro-hydraulic servo is often the best approach to the problem. Generally speaking, the hydraulic servo actuator provides fast response, high force and short stroke characteristics. The main advantages of hydraulic components are.

- Easy and accurate control of work table position and velocity
- Good stiffness characteristics
- Zero back-lash
- Rapid response to change in speed or direction
- Low rate of wear

There are several significant advantages of hydraulic servo drives over electric motor drives:

♦ Hydraulic drives have substantially higher power to weight ratios resulting in higher machine frame resonant frequencies for a given power level.

♦ Hydraulic actuators are stiffer than electric drives, resulting in higher loop gain capability, greater accuracy and better frequency response.

♦ Hydraulic servos give smoother performance at low speeds and have a wide speed range without special control circuits.

♦ Hydraulic systems are to a great extent self-cooling and can be operated in stall condition indefinitely without damage.

♦ Both hydraulic and electric drives are very reliable provided that maintenance is followed.

♦ Hydraulic servos are usually less expensive for system above several horsepower, especially if the hydraulic power supply is shared between several actuators.

**End Effectors Types**

1) Standard Grippers (Angular and parallel, Pneumatic, hydraulic, electric, spring powered, Power-opened and Spring-closed)
2) Vacuum Grippers (Single or multiple, use venturi or vacuum pump)
3) Vacuum Surfaces (Multiple suction ports, to grasp cloth materials, flat surfaces, sheet material)
4) Electromagnetic Grippers (often used in conjunction with standard grippers)
5) Air-Pressure Grippers (balloon type)
    1. Pneumatic fingers
    2. Mandrel grippers
    3. Pin grippers
6) Special Purpose Grippers (Hooking devices, custom positioners or tools)
7) Welding (MIG /TIG, Plasma Arc, Laser, Spot)
8) Pressure Sprayers (painting, water jet cutting, cleaning)
9) Hot Cutting type (laser, plasma, de-flashers-hot knife)
10) Buffing/Grinding/De-burring type
11) Drilling/Milling type
12) Dispensing type (adhesive, sealant, foam)

**Mechanical Grippers**

Mechanical grippers are used to pick up, move, place, or hold parts in an automated system. They can be used in harsh or dangerous

**VACUUM GRIPPERS:** for non-ferrous components with flat and smooth surfaces, grippers can be built using standard vacuum cups or pads made of rubber-like materials. Not suitable for components with curved surfaces or with holes.

**Vacuum grippers**

Vacuum-grippers become in suction cups, the suctions cups is made of rubber. The suction cups are connected through tubes with under pressure devices for picking up items and for releasing items air is pumped out into the suction cups. The under pressure can be created with the following devices:

The vacuum grippers use suction cups (vacuum cups) as pick up devices. There are different types of suction cups and the cups are generally made of polyurethane or rubber and can be used at temperatures between -50 and 200 °C. The suction cup can be categorized into four different types; universal suction cups, flat suction cups with bars, suction cups with bellow and depth suction cups as shown in figure 3.

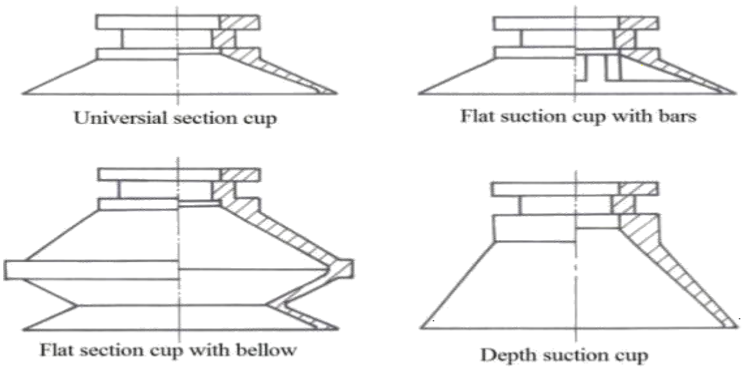


*Figure 3 Different types of suction cups, picture taken from [5] page 204*

Fig 4.4 Suction Cups

The universal suction cups are used for flat or slightly arched surfaces. Universal suction cups are one of the cheapest suction cups in the market but there are several disadvantages with this type of suction cups. When the under pressure is too high, the suction cup decreases a lot which leads to a greater wear. The flat suction cups with bars are suitable for flat or flexible items that need assistance when lifted. These types of suction cups provides a small movement under load and maintains the area that the under pressure is acting on, this reduces the wear of the flat suction cup with bars, this leads to a faster and safer movement. Suction cups with bellows are usually used for curved surfaces, for example when separation is needed or when a smaller item is being gripped and needs a shorter movement. This type of suction cups can be used in several areas but they allow a lot of movement at gripping and low stability with small under pressure. The depth suction cup can be used for surfaces that are very irregular and curved or when an item needs to be lifted over an edge. [5] Items with rough surfaces (surface roughness $\leq 5$ μm for some types of suction cups) or items that are made of porous material will have difficulty with vacuum grippers. An item with holes, slots and gaps on the surfaces is not recommended to be handled with vacuum grippers. The air in the suction is sucked out with one of the techniques described earlier, if the material is porous or has holes on its surface; it will be difficult to suck out the air. In such cases the leakage of air can be reduced if smaller suction cups are used. Figure 4 shows different types of suction cups.

**Magnetic Gripper:** used to grip ferrous materials. Magnetic gripper uses a magnetic head to attract ferrous materials like steel plates. The magnetic head is simply constructed with a ferromagnetic core and conducting coils. Magnetic grippers are most commonly used in a robot as end effectors for grasping the *ferrous* materials. It is another type of handling the work parts other than the mechanical grippers and vacuum grippers. Types of magnetic grippers:

The magnetic grippers can be classified into *two common types*, namely:

Magnetic grippers with


Fig 4.5 Magnetic Gripper

**Electromagnets:**

Electromagnetic grippers include a *controller unit* and a *DC power* for handling the materials. This type of grippers is easy to control, and very effective in releasing the part at the end of the operation than the permanent magnets. If the work part gripped is to be released, the polarity level is minimized by the controller unit before the electromagnet is turned off. This process will certainly help in *removing the magnetism* on the work parts. As a result, a best way of releasing the materials is possible in this gripper.

**Permanent magnets:**

The permanent magnets do not require any sort of external power as like the electromagnets for handling the materials. After this gripper grasps a work part, an additional device called as *stripper push – off pin* will be required to separate the work part from the magnet. This device is incorporated at the sides of the gripper.

The advantage of this permanent magnet gripper is that it can be used in hazardous applications like *explosion-proof apparatus* because of no electrical circuit. Moreover, there is no possibility of *spark production* as well.

**Benefits:**

This gripper only requires *one surface* to grasp the materials. The grasping of materials is done *very quickly*.

It does not require *separate designs* for handling different size of materials.

It is capable of grasping materials with *holes*, which is unfeasible in the vacuum grippers.

**Drawbacks:**

The gripped work part has the chance of *slipping out* when it is moving quickly. Sometimes *oil* in the surface can reduce the strength of the gripper.

The *machining chips* may stick to the gripper during unloading.

PID is acronym for **Proportional Plus Integral Plus Derivative Controller.It** is a control loop feedback mechanism (controller) widely used in industrial control systems due to their robust performance in a wide range of operating conditions & simplicity.In This PID Controller Introduction, I have Tried To Illustrate The PID Controller With SIMPLE Explanations & BASIC MATLAB CODE To Give You

Idea About P,PI,PD & PID Controllers

For PID control, the actuating signal u(t),consists of proportional error signal added with derivative and integral of error signal e(t).

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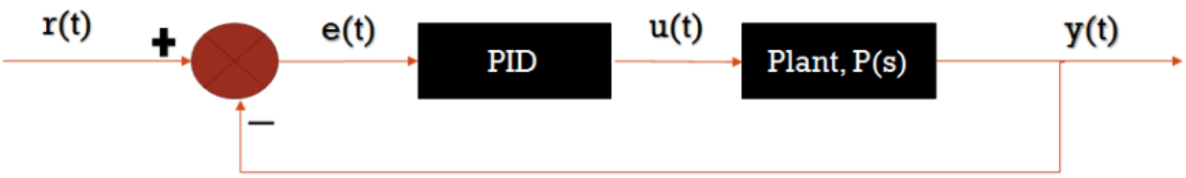
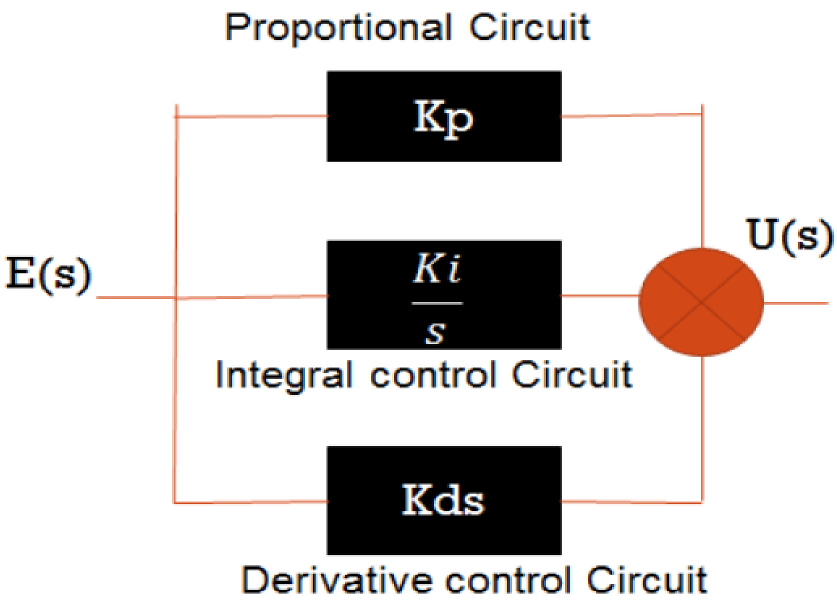



The Plant P is controlled by input u(t) which is represented as

$$u(t) = K_p e(t) + K_d \frac{e(t)}{dt} + K_i \int e(t)\, dt$$

## Physical Realisation of PID Controller




Physical realization of PID Controller

1. A **proportional controller** (Kp) will have the effect of reducing the rise time and will reduce, but never eliminate, the steady-state error.
2. An **integral control (Ki)** will have the effect of eliminating the steady-state error, but it may make **the transient response worse**.
3. A **derivative control (Kd)** will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response but little effect on rise time

4. A **PD Controller** could add damping to a system, but the steady-state response is not affected.(steady state error is not eliminated)

5. A **PI Controller** could improve relative stability and eliminate steady state error at the same time, but the settling time is increased(System response sluggish)

But a **PID controller removes steady-state error** and decreases system settling times while maintaining **a reasonable transient response**

**TEXT/REFERENCE BOOKS**:

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