Drive Systems for Robots

Capt Geeth Karunarathne

Joint Drive Systems

- Electric
  - Uses electric motors to actuate individual joints
  - Preferred drive system in today's robots
- Hydraulic
  - Uses hydraulic pistons and rotary vane actuators
  - Noted for their high power and lift capacity
- Pneumatic
  - Typically limited to smaller robots and simple material transfer applications

Actuators

- Actuator is the term used for the *mechanism that drives* the robotic arm.
- There are 3 main types of Actuators
    1. Electric motors
    2. Hydraulic
    3. Pneumatic cylinder
- *Hydraulic* and *pneumatic* actuators are generally suited to driving *prismatic joints* since they produce *linear* motion directly
- Hydraulic and pneumatic actuators are also known as *linear actuators.*
- *Electric motors* are more suited to driving *resolute joints* as they produce rotation

Hydraulic Actuators

- A car makes use of a hydraulic system. moderate force applied to the brake pedal is sufficient to produce enough force to stop the car.
- The underlying principle of all hydraulic systems was first discovered by the French scientist Blaise Pascal in 1653. He stated that "if external pressure is applied to a confined fluid, then the pressure is transferred without loss to all surfaces in contact with the fluid”
- The word fluid can mean both a gas or a liquid
- Where large forces are required we can expect to find hydraulic devices (mechanical diggers on building sites, pit props in coal mines and jacks for lifting cars all use the principle of hydraulics.

Hydraulic Actuators

- Each hydraulic actuator contains the following parts:
  - Pistons
  - Spring return piston
  - Double acting cylinder
  - Hydraulic transfer value
  - And in some cases a hydraulic accumulator

- Advantages of the hydraulic mechanism
  - A hydraulic device can produce an enormous range of forces without the need for gears, simply by controlling the flow of fluid
  - Movement of the piston can be smooth and fast
  - Position of the piston can be controlled precisely by a low-current electrically operated value
  - There are no sparks to worry about as there are with electrical motor, so the system is safe to use in explosive atmospheres such as in paint spraying or near inflammable materials

Pneumatic Actuators

- A pneumatic actuator uses air instead of fluid
- The relationship between force and area is the same in pneumatic system compared to a hydraulic system
- We know that air is compressible, so in order to build up the pressure required to operate the piston, extra work must be done by the pump to compress the air. This means that pneumatic devices are less efficient
- If you have ever used a bicycle pump you may have noticed that it becomes hot as it is used. The heat produced by the mechanical work done in compressing the air. Heat represents wasted energy.

Pneumatic Actuators

- Advantages ol the Pneumatic system:
  - less expensive than an equivalent hydraulic system.
  - Small amount of air leakage is acceptable
  - A pressure relief valve can be incorporated to release pressure when a force is exceeded
  - Pneumatic devices are faster to respond compared to a hydraulic system
  - as air is lighter than fluid.

- Disdvantages
  - cannot produce the enormous forces like hydraulic systems
  - As air is compressible heavy loads on the robot arm may cause the pistons to move even when all the valves on the cylinder are closed.

Electric Motors

- Not all electric motors are suited for use as actuators in robots
- There are three basic characteristics of a motor, when combined will determine the suitability of a motor for a particular job.
- The 3 characteristics are power, torque and speed. Each of these characteristics are interdependent, that means can not alter one without affecting the others.

Electric Motors

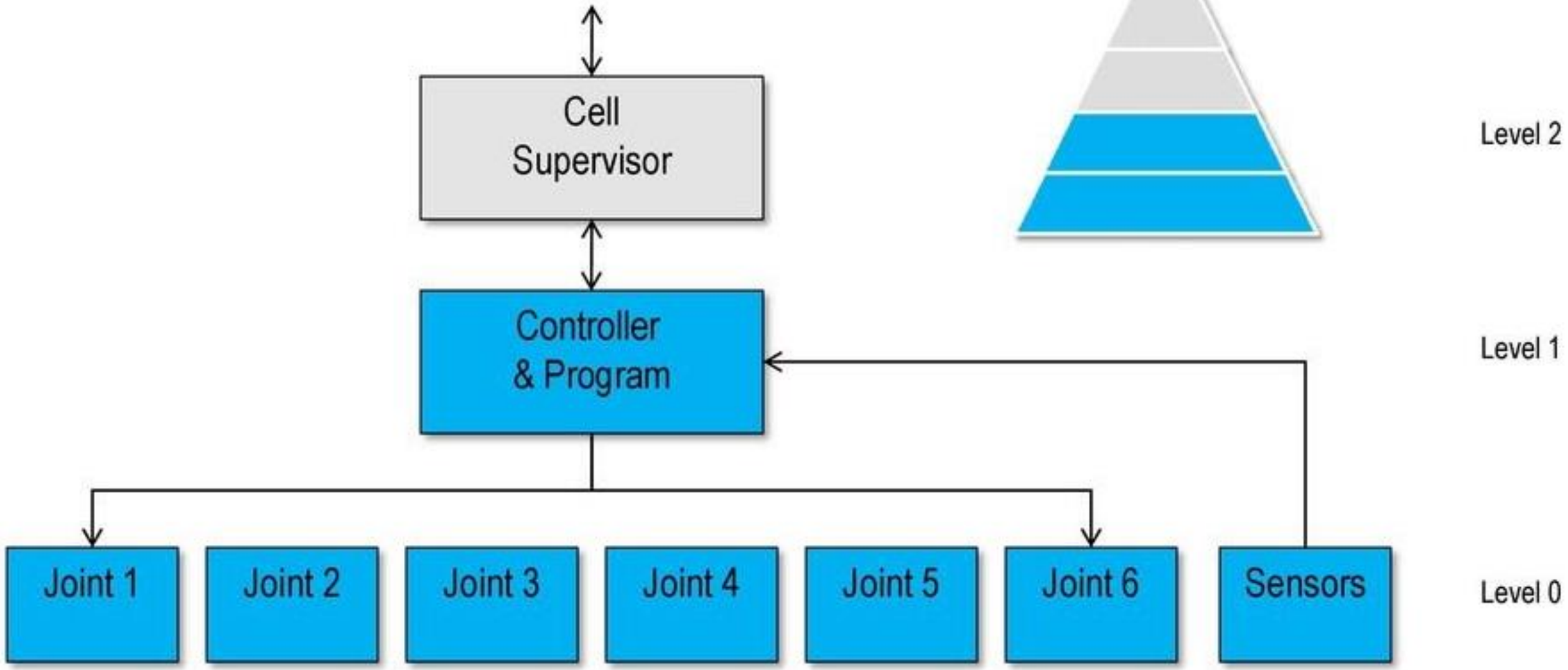
- Two types of power: electrical and mechanical, both are measured in watts.
- Torque is how strong a motor is or how much turning force it is able to produce and is measured in newton-metres.
- The speed is measured in revolutions per minute and is rotation of the motor
- There are 3 different types of motors
  1. AC motor which operates by alternating current electricity
  2. DC motor which operates by direct current electricity
  3. Stepper motors which operates by pulses of electricity

  Any type of electric motor could be used for a robot as long as it is possible to electronically control the speed and power so that it behaves the way we want.
- DC motors and Stepper motors are commonly used in robotics

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



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

- *Non Servo* Control

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

Servo Control

- *Servo Control*
  - Point to point Control
  - Continuous Path Control
- Closed Loop control used to monitor position, velocity (other variables) of each joint

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

Continuous Path Control

- in addition to the control over the endpoints, the path taken by the end effector 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

Robot Programming

- Typically performed using one of the following
  - On line
    - teach pendant
    - lead through programming
  - Off line
    - robot programming languages
    - task level programming

Robot Programming

- Leadthrough programming
  - Work cycle is taught to robot by moving the manipulator through the required motion cycle and simultaneously entering the program into controller memory for later playback
- lead the robot physically through the required sequence of motions
- trajectory and endpoints are recorded, using a sampling routine which records points at 60-80 times a second
- when played back results in a smooth continuous motion
- large memory requirements

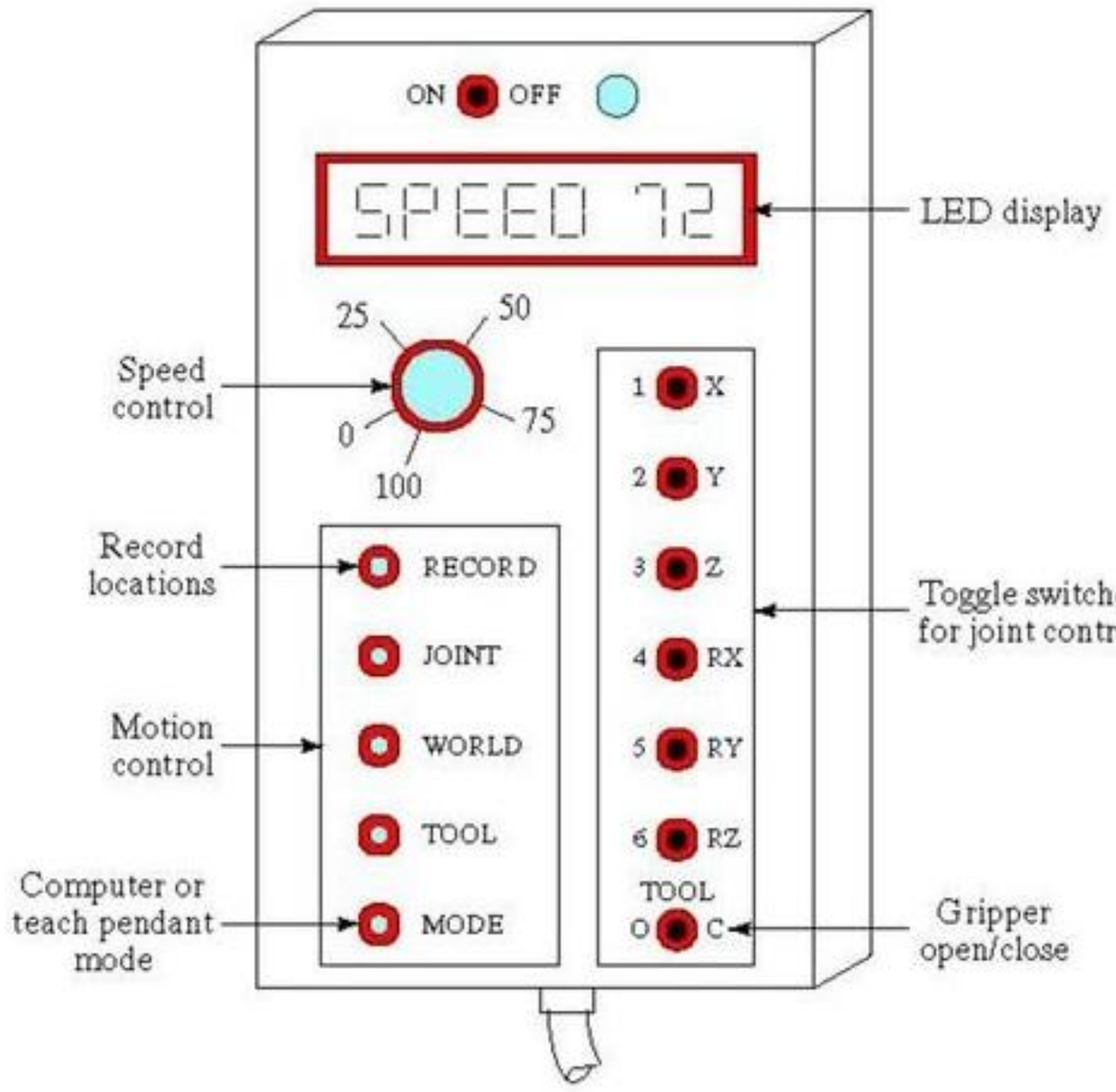
Leadthrough Programming

Powered leadthrough

- Common for point-to-point robots
- Uses teach pendant

Manual leadthrough

- Convenient for continuous path control robots
- Human programmer physical moves manipulator



Use of Teach Pendant

- Hand held device with switches used to control the robot motions
- End points are recorded in controller memory
- Sequentially played back to execute robot actions
- Trajectory determined by robot controller
- Suited for point to point control applications
- Easy to use, no special programming skills required
- Useful when programming robots for wide range of repetitive tasks for long production runs
- RAPID

Leadthrough Programming Advantages

- Advantages:
  - Easily learned by shop personnel
  - Logical way to teach a robot
  - No computer programming

- Disadvantages:
  - Downtime during programming
  - Limited programming logic capability
  - Not compatible with supervisory control

Robot Programming

- Robot programming languages
  - Textual programming language to enter commands into robot controller
- Simulation and off-line programming
  - Program is prepared at a remote computer terminal and downloaded to robot controller for execution without need for leadthrough methods

Robot Programming

- Textural programming languages
- Enhanced sensor capabilities
- Improved output capabilities to control external equipment
- Program logic
- Computations and data processing
- Communications with supervisory computers

Programming Languages

- Motivation
  - need to interface robot control system to external sensors, to provide "real time” changes based on sensory equipment
  - computing based on geometry of environment
  - ability to interface with CAD/CAM systems
    - meaningful task descriptions
    - off-line programming capability
- Large number of robot languages available
  - ROS, Python, Matlab, C++ etc. (200+)
- Each robot manufacturer has their own robot programming language
- No standards exist
- Portability of programs virtually non-existent

Example

- A robot performs a loading and unloading operation for a machine tool as follows:
  - Robot pick up part from conveyor and loads into machine (Time = 5.5 sec)
  - Machining cycle (automatic). (Time = 33.0 sec)
  - Robot retrieves part from machine and deposits to outgoing conveyor. (Time = 4.8 sec)
  - Robot moves back to pick up position. (Time = 1.7 sec)
- Every 30 work parts, the cutting tools in the machine are changed which takes 3.0 minutes. The uptime efficiency of the robot is 97%, and the uptime efficiency of the machine tool is 98% which rarely overlap.
- Determine the hourly production rate.