Robotics 1 Lecture 2 Characteristics and Applications

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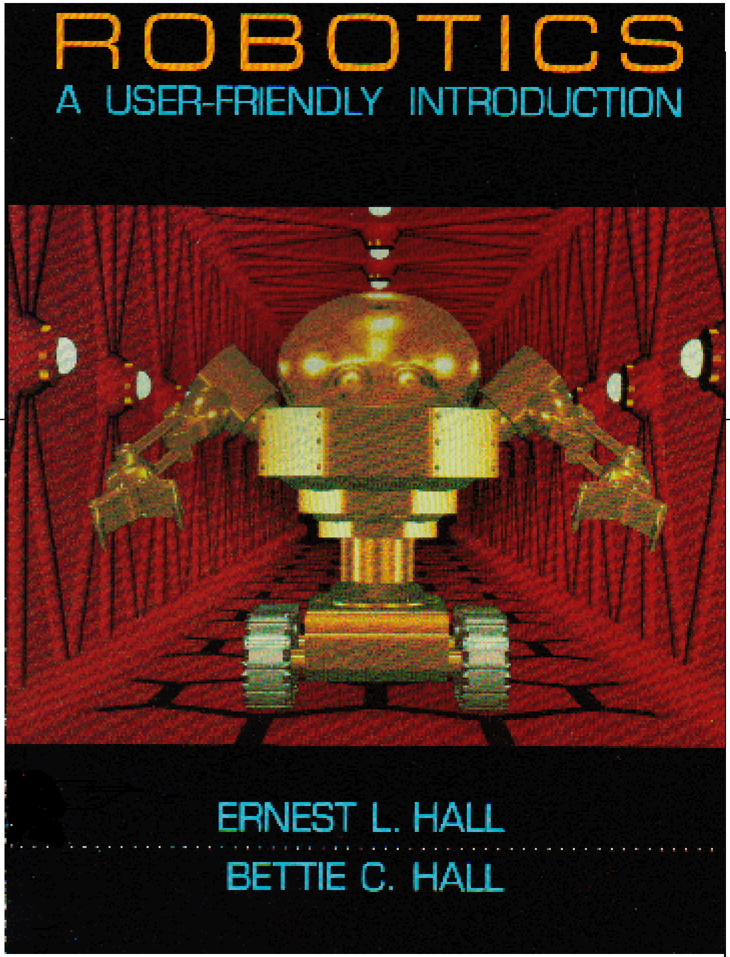
Robotics


ROBOTICS
A USER-FRIENDLY INTRODUCTION
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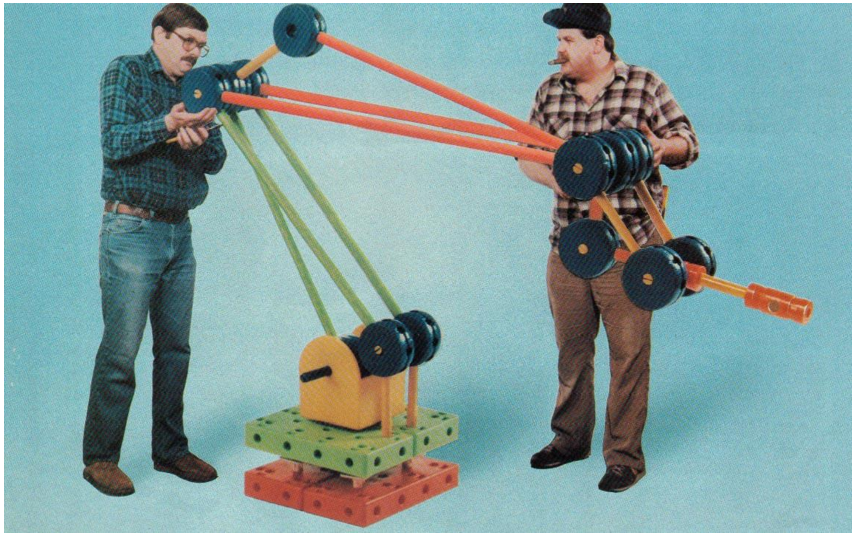
Course objective

- To provide a broad understanding of the use of industrial robots
- And an experience in specifying, designing and presenting a new robot application in oral and written formats.



SYLLABUS

TOPIC

1. Realistic and Safe Use of Robots
2. Applications of Industrial Robots
3. Economic Justification; Project Assigned

Excel Template

4. Robot Implementation
5. Arm Configurations
6. Wrist Configurations
7. End Effectors and Tooling
8. Methods of Actuation
9. Non-servo Operation
10. Servo Controlled Robots
11. Cell Control, Hierarchical Design
12. Performance Measures

Sample Report 1 - Welding
Sample Report 2 - Painting
Sample Report 3 - Soldering
Sample Report 4 - Batch Manufacturing
Sample Report 5 - Machine Loading

13. Joint Control Programming
14. Path Control Programming
15. High Level Languages
16. Simulation and Programming
17. Vision and Sensor Systems
18. Work Cell Interfacing; REPORT DUE
19. Intelligent Robot Cells
20. Flexible Manufacturing
21. FINAL ORAL EXAM

Some web resources

- www.robotics.uc.edu
- http://www.robotics.org/body.cfm
- http://www.robotics.org/public/articles/index.cfm?cat=6
- http://www.sme.org/cgi-bin/membhtml.pl?/memb/mservices.html&&&SME&
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Realistic and Safe Use of Robots

- An intelligent industrial robot is a remarkably useful combination of a manipulator, sensors and controls.
- The use of these machines in factory automation can improve productivity, increase product quality and improve competitiveness.
- Robots have been created to perform a wide variety of tasks spanning from educational robots in classrooms, to arc welding robots in the automobile industry, to teleoperated robot arms and mobile robots in space.

Objective

- Provide an overview of the proven applications of industrial robotics
- At the end of the presentation the students should be able to describe the major robot applications

What is a robot?

- Definition - The Robot Industries Association (RIA) has defined an *industrial robot* as "a reprogrammable, multi-functional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks."

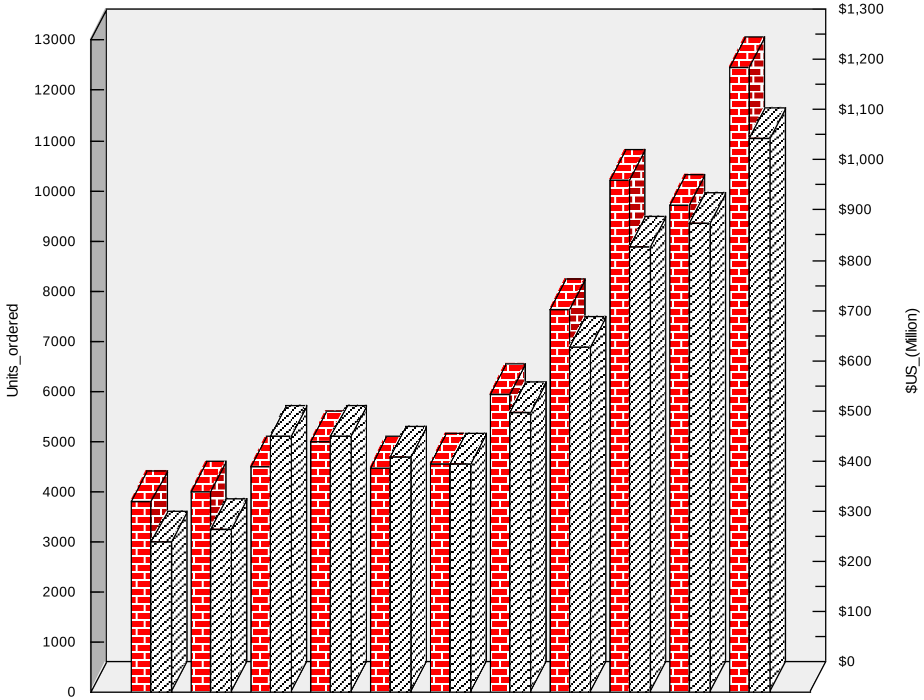
Benefits of robots

- Introducing robot technology into factories improved plant productivity, quality, and flexibility above what could be realized on the basis of hard or fixed automation structures.

Applications

- Robots are now being used in many applications including: welding, sealing, and painting; material handling, assembly, and inspection; and in non-automotive industries such as electronics, consumer products, pharmaceutical, and service [Weil, 1994].

Market



Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Units_ordered	3,800	4,000	4,500	5,000	4,488	4,561	5,942	7,634	10,198	9,709	12,459
$US_(Million)	$300	$325	$510	$510	$470	$456	$559	$688	$887	$934	$1,104

500,000 robots in the world

- Record breaking shipments from US manufacturers in 1997 totaled 12,459 robots, valued at $1.1 billion. This represents a 172% increase in robotic systems, and a 136% increase in revenues since 1992. According to new statistics released by the Robotic Industries Association, the world's population of installed robots at the end of 1997 exceeded 500,000. The country that has the largest population of industrial robots is Japan (400,000), followed by the USA (80,000), and the other Western European nations (120,000).

Applications by use

Application	Percent
welding	53.0
material handling	24.0
assembly	10.0
spray coating	8.5
inspection	1.0
other	3.5

Robot Characteristics

- **1. Manipulator -** The mechanical structure that performs the actual work of the robot, consisting of links and joints with actuators.
- **2. Feedback devices** - Transducers that sense the position of various linkages and/or joints that transmit this information to the controller.
- **3. Controller -** Computer used to generate signals for the drive system in order to reduce response error in positioning and applying force during robot assignments.
- **4. Power source -** Electric, pneumatic, and hydraulic power systems used to provide and regulate the energy needed for the manipulator's actuators.

Manipulator configuration

- There are six basic motion degrees of freedom to arbitrarily position and orient an object in a three-dimensional space (three arm and body motions and three wrist movements).

Arm and wrist

- The first three links, called the major links, carry the gross manipulation tasks. Examples of robots that use the major links include arc welding, spray painting, and water jet cutting applications. The last three links, or the minor links, carry the fine force and tactile manipulation tasks.

Redundant DOF's

- Robots with more than six axes of motion are called redundant degree of freedom robots. The redundant axes are used when greater flexibility is required, such as obstacle avoidance in the workplace, parts assembly and machining applications.

R-P joints

- Typical joints are either revolute (R) joints, which provide rotational motion about an axis, or prismatic (P) joints, which provide sliding (linear) motion along an axis. Using the R-P notation, a robot with three revolute joints would be abbreviated as RRR, while one with two revolute joints followed by one prismatic joint would be denoted RRP.

Major mechanism designs

- There are five major mechanical configurations commonly used for robots: Cartesian, cylindrical, spherical, articulated, and SCARA (Selective Compliance Articulated Robot for Assembly). Workplace coverage, particular reach and collision avoidance, are important considerations in the selection of a robot for an application.

Configurations fit applications

- Cartesian
- Application – assembly and machine loading
- Configuration – PPP
- Percentage – 18
- Advantage – equal resolution, simple kinematics
- Disadvantage – Poor space utilization, slow speed

Cylindrical

- Application – assembly and machine loading
- Configuration – RPP
- Percentage - 15
- Advantage – good reach, simple kinematics
- Disadvantage – variable resolution

Spherical

Application - automotive manufacturing

Configuration – RRP

Percentage - 10

Advantages - excellent reach; very powerful w/ hydraulic drive

Disadvantages - complex kinematics; variable resolution

Articulated

Application - spray coating

Configuration – RRR

Percentage - 42

Advantages - maximum flexibility; large work envelope; high speed

Disadvantages - complex kinematics; rigid structure; difficult to control

SCARA*

Application - assembly & insertion

Configuration – RRP

Percentage - 15

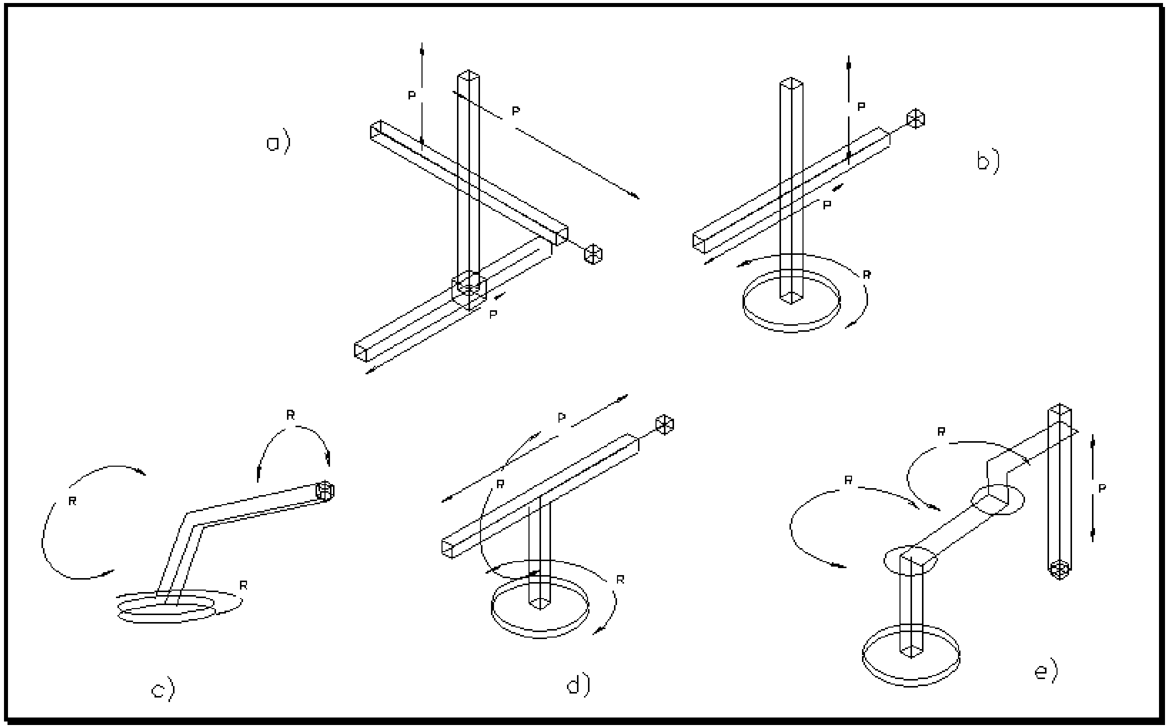
Advantages - horizontal compliance; high speed; no gravity effect

Disadvantage - complex kinematics; variable resolution; limited vertical motion

* **S**elective **C**ompliance **A**rticulated **R**obot for **A**ssembly

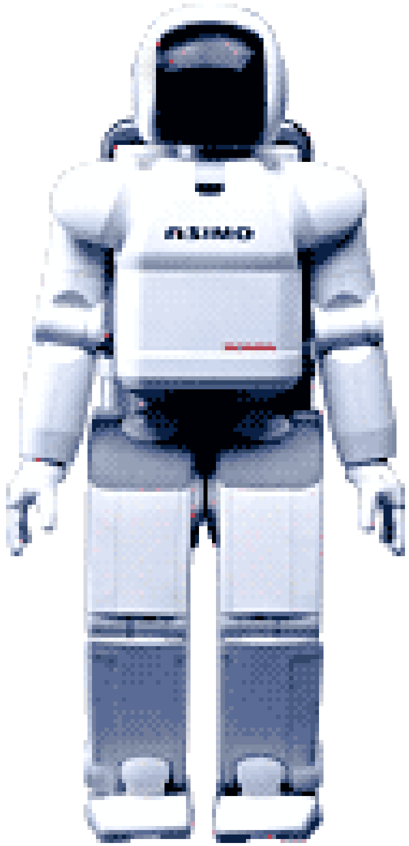
(Source for the percent of use: V.D. Hunt, Robotics Sourcebook, New York: Elsevier, 1988.)

Common configurations



New designs

- While all of the above configurations are rigid serial links, a parallel robot configuration, known as Steward platform, also exists. There are also lightweight, flexible robot arms for faster speed and lower energy consumption.
- Humanoid robots



Direct drive

- Industrial robots can be direct-driven arms (DDArm) and indirect driven arms. Most industrial robots used today are indirect-drive-geared mechanisms. However, this drive mechanism may suffer from poor dynamic response under heavy mechanical load and gear friction, and backlash.

Robot Control Strategies

- Robot manipulators typically perform a task repeatedly with high accuracy. Yoshikawa [1990] defines the fundamental elements of tasks performed by robots as:
- **1. Gross manipulation**: to move the end-effector, with or without a load, along a desired path (*position control*).
- **2. Fine manipulation**: to exert a desired force on an object when in contact with it (*force control*).

Motion trajectory problem

- One of the major objectives of a robot is to position its tool from one point to another along a planned trajectory. This is called controlled path motion, or the *motion trajectory problem*.

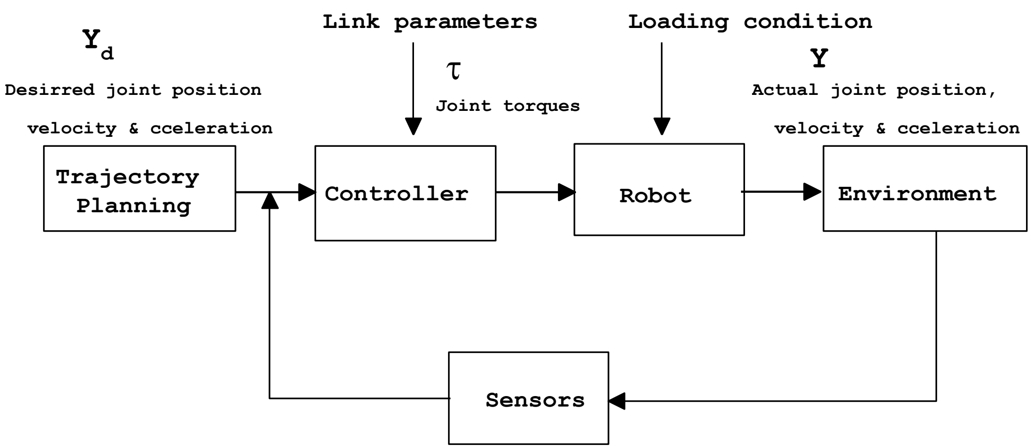
Non-linear system

- Describing the motion of an industrial robot generates a set of highly nonlinear differential equations.

Complex torque functions

For an end-effector to move in a particular trajectory at a particular velocity, a complex set of torque functions must be applied by the joint actuators. Instantaneous feedback information on position, velocity, acceleration, and other physical variables can greatly enhance the performance of the robot.

Basic control block diagram



Motion control

- With increasing demands for faster, more accurate, and more reliable robots, the field of robotics has faced the challenge of reducing the required on-line processor power, calibration time, and engineering cost while developing new robot controllers.

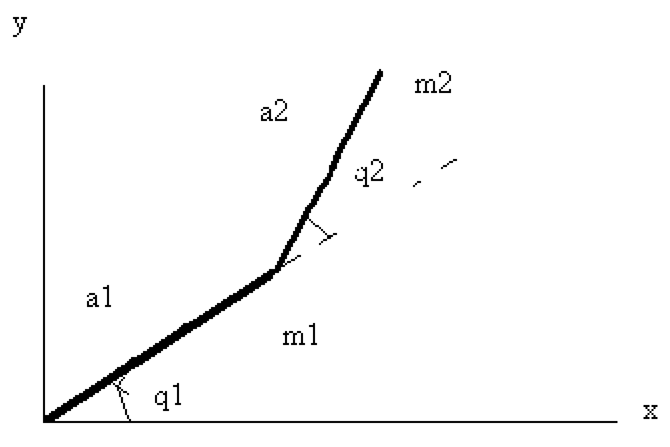
Robust control

- If the robot is to be controlled in real time, the algorithms used must be efficient and robust; otherwise we will have to compromise the robot control strategies.

Kinematics and dynamics

- The robot arm position control is a complex kinematic and dynamic problem that has received attention for many years. During the last several years, most research on robot control has resulted in algorithms that are adaptive to non-linearities and structural uncertainties but require a great deal of processing resources.

Two link manipulator



Torque 1 equation

$$\tau_{1.1} = \left[(m_1 + m_2) \cdot a_1^{\,2} + m_2 \cdot a_2^{\,2} + 2 \cdot m_2 \cdot a_1 \cdot a_2 \cdot \cos(q_2) \right] \cdot \frac{d^2}{dt^2} q_1$$

$$\tau_{1.2} = \tau_{1.1} + \left(m_2 \cdot a_2^{\,2} + m_2 \cdot a_1 \cdot a_2 \cdot \cos(q_2) \right) \cdot \frac{d^2}{dt^2} q_2$$

$$\tau_{1.3} = \tau_{1.2} - m_2 \cdot a_1 \cdot a_2 \cdot \left[2 \cdot \frac{d}{dt} q_1 \cdot \frac{d}{dt} q_2 + \left(\frac{d}{dt} q_2 \right)^2 \right] \cdot \sin(q_2)$$

$$\tau_1 = \tau_{1.3} + (m_1 + m_2) \cdot g \cdot a_1 \cdot \cos(q_1) + m_2 \cdot g \cdot a_2 \cdot \cos(q_1 + q_2)$$

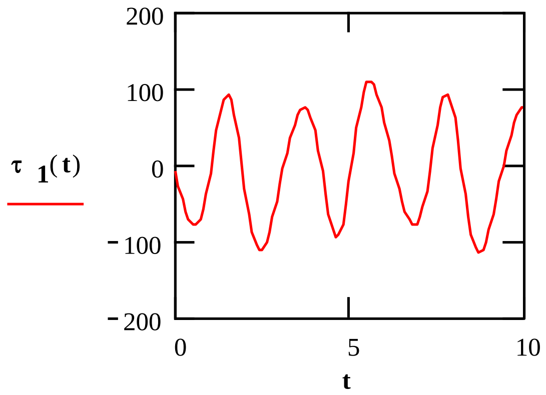
Torque 2 equation

And for the second torque

$$\tau_{2.1} = \left(m_2 \cdot a_2^{\,2} + m_2 \cdot a_1 \cdot a_2 \cdot \cos\left(q_2\right) \cdot \frac{d^2}{dt^2} q_1 \right) + m_2 \cdot a_2^{\,2} \cdot \frac{d^2}{dt^2} q_2$$

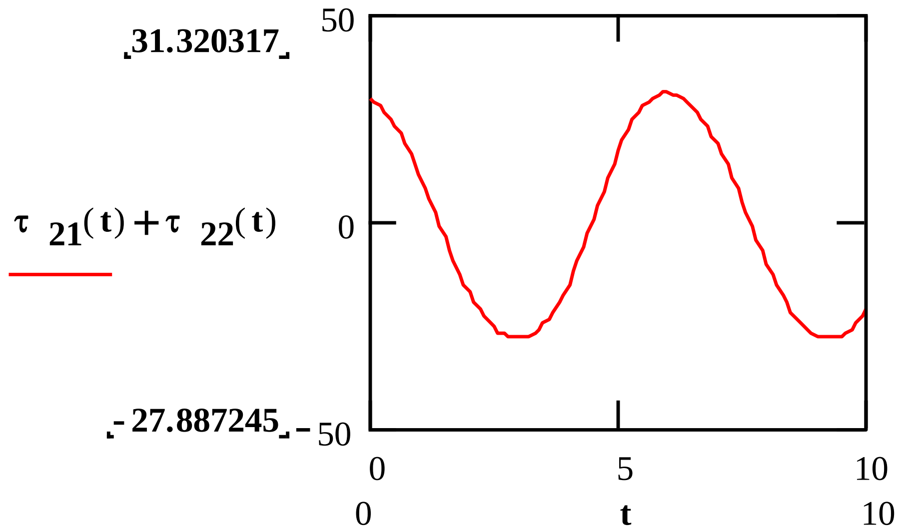
$$\tau_2 = \tau_{2.1} + m_2 \cdot a_1 \cdot a_2 \cdot \left(\frac{d}{dt} q_1 \right)^2 \sin\left(q_2\right) + m_2 \cdot g \cdot a_2 \cdot \cos\left(q_1 + q_2\right)$$

Sample torque 1



Note that the maximum value of about 200 Nm would let one size the motor correctly. Also, the shape appears quite simple.

Sample torque 2



Today

- Today, most robots have joint controllers that are based on traditional linear controllers and are ineffective in dealing with the nonlinear terms such as friction and backlash.

Computed torque control

- One popular robot control scheme is *computed-torque control* or *inverse-dynamics control*. Most robot control schemes found in robust, adaptive, or learning control strategies can be considered special cases of computed-torque control. This techniques involve the decomposition of the control design problem into two parts [Koivo, 1989]:

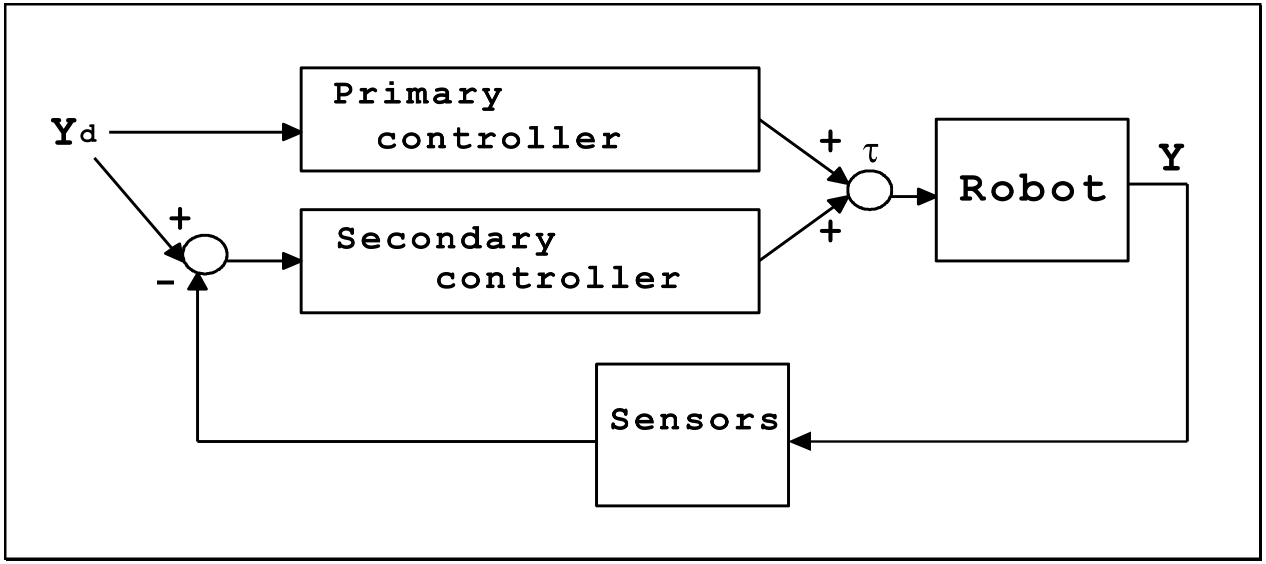
Primary controller

- 1. A primary controller, a feedforward (inner-loop) design to track the desired trajectory under ideal conditions.

Outer loop control

- 2. A secondary controller, a feedback (outer-loop) design to compensate for undesirable deviations (disturbances) of the motion from the desired trajectory based on a linearized model.

Concept of high level controller



Artificial Neural Networks

- Potential for major improvement in flexibility and learning capability of both stationary and mobile robots.

Any questions?