Robotics Lecture: 01

Robot

- An automated electromechanical device that performs functions normally ascribed to humans, or a machine in the form of human. Robots are multifunction, re-programmable, automatic industrial machines design for replacing human in hazardous work. Example
    - Manipulator
    - Legged Robot
    - Wheeled Robot
    - Autonomous underwater Vehicle

What can Robots Do

- Perform jobs that are dangerous for human.
    - Decontaminating robot: cleans the main circulating pump housing in the nuclear power plant.
- Repetitive jobs that are boring, stressful, or labor intensive for humans
    - Welding Robots
- Manual task that human don't want to do

Advantages of Robots

- Can increase productivity, safety, efficiency, accuracy, quality, and consistency of products.
- Can work in hazardous environments such as radiation, darkness, hot and cold, ocean bottoms, space and etc.
- Can work continuously without tiring or fatigue or boredom, and not need any kind of medical treatment and vacations.

Disadvantages of Robots

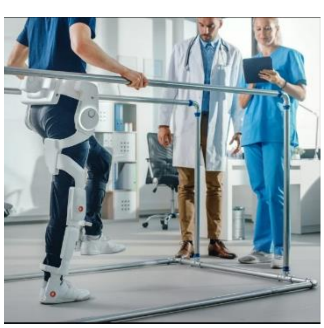
- Inappropriate or wrong responses
- Lack of decision making power, cognition, creativity, decision making, and understanding.
- Damage to the robots and other devices
- Limited degree of freedom and dexterity, (Sensor and vision system)

Categories of Robots

- Basic categories
  - Aerial (operational in air)(drown robot)
  - Ground (operational in ground)(jackal robot)
  - Water (operational under water or in water)(water snake robot)
- Operational categories
  - Autonomous (intelligent machines that can perform tasks and operate in an environment independently, without human control or intervention.)
  - Remote controlled (controlled via a remote)

Types of Robot

- Industrial Robots/Manipulators
  - The arm-like structure of an industrial robot is known as a robot manipulator. This component is responsible for completing the tasks the robot is programmed to perform. Also known as a robot arm, the manipulator mounts to the robot body and consists of multiple links and joints
- Mobile Robots
  - The basic functions of a mobile robot include the ability to move and explore, transport payloads, or revenue producing cargo, and complete complex tasks using an onboard system, like robotic arms.
  - There are two type of mobile robots
    - Wheeled mobile robot
    - Walking mobile robot
- Humanoid robots
  - A humanoid robot is a robot resembling the human body in shape. The design may be for functional purposes, such as interacting with human tools and environments, for experimental purposes, such as the study of bipedal locomotion, or for other purposes.
- Medical Robots
  - Medical robots assist with surgeries, streamline clinical workflow and hospital logistics, and enhance patient care and workplace safety.
- Exoskeleton
  - exoskeletons are considered wearable robotic units controlled



by computer boards to power a system of

motors, pneumatics, levers, or hydraulics to restore locomotion

- Drones
  - A drone is a flying robot that can be remotely controlled or fly autonomously using software-controlled flight plans in its embedded systems, that work in conjunction with onboard sensors and a global positioning system (GPS).

Criteria for a Robot

- Sense
  - Robot would have to be able to sense its surroundings. It would do this in ways that are not similar to the way that you sense your surroundings. Giving your robot sensors: light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), and taste sensors (tongue) will give your robot awareness of its environment.
- Act
  - A robot needs to be able to move around its environment. Whether rolling on wheels, walking on legs or propelling by thrusters a robot needs to be able to move.
- Energy/Power
  - A robot needs to be able to power itself. A robot might be solar powered, electrically powered, battery powered. The way your robot gets its energy will depend on what your robot needs to do
- Programmable
  - A robot needs some kind of "smarts." This is where programming enters the pictures. A programmer is the person who gives the robot its 'smarts.' The robot will

have to have some way to receive the program so that it knows what it is to do.

- Autonomous*
    - intelligent machines that can perform tasks and operate in an environment independently, without human control or intervention

Components of a Robot

- Sensors
    - A sensor is a device that detects and responds to some type of input from the physical environment. The input can be light, heat, motion, moisture, pressure or any number of other environmental phenomena.
    - Sensors
        - Camera
        - Touch
        - Laser scanner etc.
- Controller
    - The robotic controller is often referred to as the “brains” of a robot. This is because it interrupts coding that serves as the program for a given robotic application. The controller deciphers the code into instructions for the articulated robot to use in order to operate and carry out the steps of the application.
    - Example
        - Microcontroller
        - Arduino
        - Raspberry Pi
- Actuators
    - Produces a motion by converting energy and signals going into the system. The motion it produces can be either rotary or linear.
    - Example
        - End-effectors
        - Motors

  - Valves
  - Cylinders

Laws of Robotics

Issac Asimov proposed his three "Laws of Robotics", and he later added a "zeroth law"

- Zeroth Law
  - A robot is not allowed to injure humanity, or, through inaction it allows humanity to come to harm.
- First Law
  - A robot cannot injure a human being, or, through inaction it allows a human being to come to harm, unless it would violate the higher order law.
- Second Law
  - A robot should follow the orders given it by human beings, except when such orders given by humans would conflict with a higher order law
- Third Law
  - A robot is allowed to protect its own existence as long as such protection would not conflict with a higher order law.

Robotics Lecture: 03

- A robot consists of links and joints, every joint connects exactly two links. Actuators will provide forces and torques and causes the links to move. Ideally, the actuators are of lower speed and high torque, but available actuators have speeds in the range of thousands of RPMs (revolution per min), and speed reduction and torque amplification using gears.
- Robots can be open-chain serial or closed-chain with closed loops.

Configuration Space of a Robot

- The configuration of a robot is a specification of the position of all points of the robot.
- A space of all configurations of the robot is called the configuration space or C-space of the robot.
- The configuration of the robot is a point in its C-space

Degree of Freedom

- The term degrees of freedom is widely used to define the motion capabilities of robots, including humanoid robots. In this context, the term generally refers to the number of joints or axes of motion on the robot.
- there are 2 fundamental means of movement:
    - Translation
        - Translation can be further broken into 3 kinds of movements
            - Forward – backward
            - Left – right
            - Up – down
    - Rotation
        - Rotation can also be further broken into 3 kinds of movements
            - Pitch
            - Yaw
            - Roll

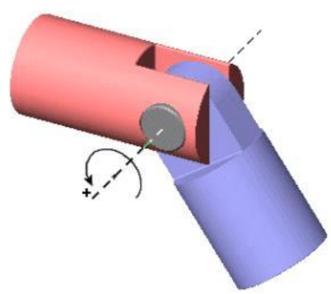
- Degrees of Freedom of a Rigid Body in a 3D Space
  - A rigid body in three-dimensional space has six degrees of freedom (DOFs)
  - Three of them are for position motion along x, y,z axis and three are for orientation roll, pitch and yaw.

- Degrees of Freedom of a Rigid Body in a 2D Space
  - The rigid body in 2D space has three degree of freedoms, two linear degree of freedoms and one rotational degree of freedom.

- Robot Joints Put Constraints on the Motion of the Robot Links Reducing Their Degrees of Freedom (DOFs)

Types of Different Joints Used in Robots

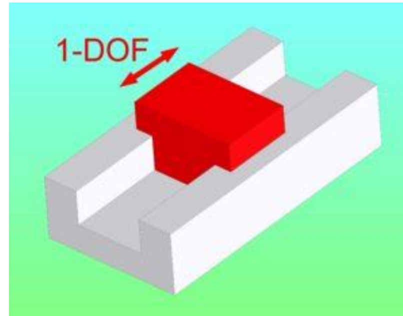
- The main types of robot joints are:
  - Revolute (Rotary) joints
    - A joint that has one rotational degree of freedom. The joint constrains the motion of two arbitrary frames that connect to the base and follower frames of the joint to pure rotation about a common axis. The axis of rotation is aligned with the z-axis of the joint base frame.



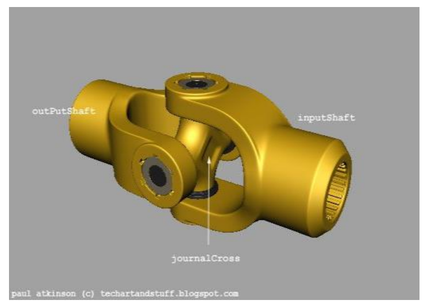
    - 1 degree of freedom

  - Prismatic or linear (sliding) joints
    - A prismatic joint is a connection between two objects that allows relative motion along a single axis. This means the joint

has one degree of freedom (1-DOF). A prismatic joint allows only linear motion along a single axis. Often prismatic joints are driven by rotary motors with a transmission that converts rotational motion to linear motion, such as a ball screw or a rack and pinion



  - 1 degree of freedom
- Universal Joints
  - Universal joint provide two degree of freedom, which is two revolute joints with joint axes orthogonal to each other. Provide two rotational degree of freedom around roll and pitch axes that are x and y axes.



  - 2 degree of freedom
- Spherical Joints
  - 2 degree of freedom
- Cylindrical Joints
  - 2 degree of freedom
  - Count occurrences of each word in given text file
- Helical joints
  - 1 degree of freedom

Grubler's Formula

- Grubler's formula to find the degree of freedom of any mechanism including the robots
- dof = m(N – 1 – J) + $\sum_{i=1}^{J} fi$
- N = no of bodies or links including ground
- J = no of joints
- if m is the number of degrees of freedom of a single body, that is six for spatial bodies and three for planar bodies:

- m = 6, for spatial bodies
- m = 3, for planar bodies

Task Space and Work Space of Robot

- Work Space
  - The workspace of a robot is a specification of the reachable configurations of the end-effector. Or
  - The workspace of a robot is the set of all positions that it can reach. This depends on a number of factors including the dimensions of the Robot.
- Task Space
  - Task space (or Cartesian space) is defined by the position and orientation of the end effector of a robot
  - We should only know about the task and not the robot to find the task space, and it is possible that the robot cannot reach some configurations

Manipulator

- Robot arms can be used to automate the process of placing the goods or products onto pallets, by automating the process, palletizing becomes more accurate, cost-effective, predictable and also free humans workers from performing tasks that are risky.
- We call the robot arm a manipulator, as the robot arm doesn't always look like a human arm.
- Robot arm = manipulator , Joints + Links = manipulator
- Joints are the part of the manipulator that allows movement. Joints are powered and controlled using motors.
- Links are those parts that connect joints together.

- End Effector

- Is a peripheral device that attaches to a robot’s wrist, allowing the robot to interact with its task.
- Most end effectors are mechanical or electromechanical and serve as grippers, process tools, or sensors and these are basic types of end effector.
- Humble Gripper
  - The most common robot of end effector, it allow you to pick up and manipulate objects and use for, pick and place, assembly, and machine tending.
- There are vacuum grippers, magnetic grippers, needle gripper as well.
- You can also attach a sensor to use the robot as a programmable sensor orientation device.
- Many sensors can serve as an end effector, including ultrasonic sensors, laser scanners, 2D and 3D cameras, and infrared sensors.

Kinematic Diagram

- A kinematic diagram illustrates the connectivity of links and joints of a mechanism or machine rather than the dimensions or shape of the parts, links and joints are connected together when all of the joint variables have a value of 0.
- Often links are presented as geometric objects, such as lines, triangles, or squares, that support schematic versions of the joints of the mechanism or machine

Coordinate Frame

- A Cartesian coordinate frame consist of x, y and z axis.
- In order to drive equations from kinematic diagrams, we need coordinate frames.

- We need at least one coordinate frame as a base frame, the frame that represents real-world or the ground to which the robot is attached.
- We need one frame for the end effector of the robot.
- To draw frames on the kinematic diagrams, we need to follow four rules known as the "Denavit-Hartenberg" rules.
- **Denavit-Hartenberg Rules**
  - Rule # 1 : The z-axis must be the axis of rotation for a revolute joint or the direction of the motion for a prismatic joint
  - Rule # 2 : The x-axis must be the perpendicular both to its own z-axis, and the z-axis for the frame before it
  - Rule # 3 : All Frame must follow the right hand rule
  - Rule # 4 : Each x-axis must intersect the z-axis of the frame before it (this rule doesn't apply to frame 0 as there is no frame before it)

Robotics Lecture: 04

Orientation of an End-effector:

- In Cartesian space, a robot orientation is decided by a combination of rotations in X, Y, and Z direction, and we can have a 3-by-3 rotation matrix for each orientation.
- We describe the position of an end-effector using the displacement vector.
- The orientation of an end-effector is described using the rotation matrix.

$$R_X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & -sin\theta \\ 0 & sin\theta & cos\theta \end{bmatrix} R_Y = \begin{bmatrix} cos\theta & 0 & sin\theta \\ 0 & 1 & 0 \\ -sin\theta & 0 & cos\theta \end{bmatrix}$$

$$R_Z = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

ROS (Robot operating System)