BRAC UNIVERSITY
Inspiring Excellence

Course Name : Introduction to Robotics
Course : CSE461
Class Note
Chapter 1 (Introduction to robotics basics)

What is a robot?

An embodied agent that can be programmed to perform physical tasks. An embodied agent is an AI system that has a physical presence and can be programmed to perform physical tasks in the environment it is situated in.

What are the laws of robotics:

The laws of robotics were first introduced by science fiction writer Isaac Asimov in his 1942 short story "Runaround" and later expanded upon in his "Robot" series of novels. They are a set of three (or sometimes four) ethical guidelines intended to govern the behavior of intelligent robots:

1. **A robot may not injure a human being, or through inaction, allow a human being to come to harm** : This law requires that robots prioritize the safety and well-being of humans above all else. It means that a robot should not intentionally harm a human, and it should take action to prevent harm from coming to a human if it is within the robot's power to do so.
2. **A robot must obey orders given to it by human beings, except where such orders would conflict with the first law :** This law establishes that robots must obey human instructions as long as those instructions do not conflict with the first law. It means that a robot cannot be programmed or instructed to harm humans.
3. **A robot must protect its own existence as long as such protection does not conflict with the first or second law:** This law allows robots to take action to preserve their own existence, but only if doing so does not conflict with the first two laws. Essentially, it means that a robot should not sacrifice its own safety or well-being in order to protect humans or follow human orders.
4. **A robot should always have a kill switch:** This "law" is not an official part of Asimov's original Three Laws, but it is sometimes added as an additional guideline for robot safety. A kill switch is a mechanism that allows a human operator to shut down a robot in case of an emergency or malfunction. The idea is that the robot should always be under human control and should never be allowed to cause harm without a way to shut it down quickly.

What is 4D in robotics and how can robotics be useful in handling this term?

The 4D (Dull, Dirty, Difficult, and Dangerous) concept refers to tasks that are tedious, hazardous, or physically demanding, making them unsuitable or even impossible for humans to perform. Robotics technology is ideally suited for performing such tasks, as it allows for automation and remote control of equipment, thus reducing the risk to human operators.

Here's how each of the 4D categories can be applied to robotics:

Dull: Tasks that are repetitive and monotonous, such as assembly line work, can be automated using robots. This reduces the risk of errors and allows humans to focus on more creative and strategic tasks.

Dirty: Tasks that involve exposure to hazardous materials, such as cleaning up radioactive waste or handling toxic chemicals, can be performed by robots. This protects human workers from exposure to dangerous substances and reduces the risk of contamination.

Difficult: Tasks that require physical strength or agility, such as lifting heavy objects or working in tight spaces, can be performed by robots. This reduces the risk of injury to human workers and increases efficiency by allowing robots to perform tasks that would be difficult or impossible for humans.

Dangerous: Tasks that are hazardous to human life, such as working in mines, handling explosives, or conducting search and rescue operations in disaster zones, can be performed by robots. This reduces the risk of injury or death to human workers and allows robots to perform tasks that would be too dangerous for humans to attempt.

Overall, the 4D concept highlights the value of robotics in automating tasks that are dull, dirty, difficult, or dangerous, thus improving safety, efficiency, and productivity in various industries.

Thumb Rules on the decision of a Robot Uses:

1. The first rule to consider, what is known as the Four D of Robotics, i.e. is the task dirty, dull, dangerous, or difficult? If so, a human will probably not be able to do the job efficiently. Therefore, the job is appropriate for automation or for robotic labor.
2. The second rule is that a robot may not leave a human jobless. Robotics and automation must serve to make our lives more enjoyable, not miserable.
3. A third rule involves asking whether you can find people who are willing to do the job. If not, the job is a candidate for automation and Robotics.
4. A four rule of thumb is that the use of robots or automation must make short-term and long-term economic sense.

Uncrewed Vehicle:

An uncrewed vehicle is a vehicle that is capable of performing tasks or operations without a human operator or crew on board. These vehicles are often controlled remotely, either by a human operator on the ground or through an autonomous system that allows the vehicle to navigate and make decisions on its own.

Uncrewed vehicles can be categorized into several different types based on their mode of operation, design, and intended use. Here are some common categories of uncrewed vehicles:

1. Unmanned Aerial Vehicles (UAVs) or Drones: These are aircraft that operate without a human pilot on board. They can be controlled remotely or can fly autonomously based on pre-programmed flight plans. UAVs are commonly used for aerial photography, surveillance, delivery, and scientific research.
2. Unmanned Ground Vehicles (UGVs): These are ground-based vehicles that operate without a human operator on board. They can be remotely controlled or operate autonomously. UGVs are commonly used in military and defense, logistics, transportation, and agriculture.
3. Unmanned Surface Vehicles (USVs): These are vehicles that operate on the surface of water without a human operator on board. They can be remotely controlled or operate autonomously. USVs are commonly used for oceanographic research, environmental monitoring, and defense.
4. Unmanned Underwater Vehicles (UUVs): These are vehicles that operate underwater without a human operator on board. They can be remotely controlled or operate autonomously. UUVs are commonly used for oceanographic research, underwater exploration, and defense.

The three primitives of robotics are:

1. Sense: The ability of a robot to perceive its environment through various sensors such as cameras, microphones, or touch sensors. Sensing allows the robot to gather information about its surroundings and make decisions based on that information.
2. Plan: The ability of a robot to use the information it has gathered through sensing to create a plan of action. This involves analyzing the data and determining the best course of action to achieve a particular goal.
3. Act: The ability of a robot to carry out its planned actions through physical movement or manipulation. This involves controlling motors, actuators, or other physical mechanisms to interact with the environment and achieve the desired outcome.

These three primitives are fundamental to the operation of most modern robots, whether they are industrial robots used in manufacturing, service robots used in healthcare or hospitality, or autonomous vehicles used in transportation. By sensing, planning, and acting, robots are able to interact with the world in increasingly sophisticated ways, and are becoming increasingly important in many aspects of our lives.

The three paradigms of robotics are:

1. **Hierarchical/Deliberative Paradigm:** This paradigm involves a robot that uses a model of the world to plan its actions based on a specific goal. The robot processes sensory input, generates a plan, and then executes the plan to achieve the desired outcome. This approach is often used in industrial applications, where robots are programmed to perform a specific task in a structured environment.

Robot Primitives	INPUT	OUTPUT
SENSE	Sensor Data	Sensed Information
PLAN	Information [sensed and/or cognitive]	Directives
ACT	Directives	Actuator Commands

2. **Reactive Paradigm:** This paradigm involves a robot that responds to its environment in real-time without building an explicit model of the world. The robot reacts to sensory input by selecting an appropriate behavior or action from a predefined set of options. This approach is often used in mobile robotics and autonomous vehicles, where the robot needs to navigate a complex and dynamic environment.

Robot Primitives	INPUT	OUTPUT
SENSE	Sensor Data	Sensed Information
PLAN		
ACT	Sensed Information	Actuator Commands

3. **Hybrid Paradigm:** This paradigm combines elements of both the deliberative and reactive paradigms. The robot builds a model of the world and uses it to plan its actions, but also responds to sensory input in real-time to adjust its plan as necessary. This approach is often used in

complex environments where the robot needs to be able to adapt to changing conditions, such as search and rescue missions or space exploration.

Each of these paradigms has its strengths and weaknesses, and the choice of which paradigm to use depends on the specific application and the requirements of the robot. By understanding these different paradigms, researchers and engineers can design robots that are better suited to perform specific tasks and operate effectively in different environments.

Subsystem:

In robotics, subsystems are often divided based on the different functions they perform. Three common subsystems in robotics are:

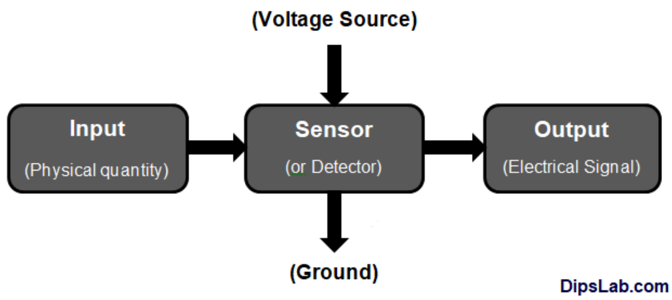
1. **Motion subsystem:** This subsystem is responsible for controlling the motion of the robot. It includes components such as motors, actuators, and sensors that allow the robot to move in a controlled manner. The motion subsystem is often responsible for tasks such as position control, velocity control, and trajectory planning.
2. **Recognition subsystem:** This subsystem is responsible for sensing and recognizing the environment around the robot. It includes components such as cameras, lidar, and other sensors that allow the robot to detect objects, people, and other features in the environment. The recognition subsystem is often responsible for tasks such as object detection, tracking, and identification.
3. **Control subsystem:** This subsystem is responsible for controlling the behavior of the robot. It includes components such as processors, controllers, and software that allow the robot to make decisions and carry out actions based on the input from the motion and recognition subsystems. The control subsystem is often responsible for tasks such as path planning, decision making, and coordination.

These subsystems are interdependent and work together to enable the robot to perform its intended function. For example, the recognition subsystem might detect an object, and the control subsystem might use that information to plan a path for the robot to move around the object, while the motion subsystem controls the robot's movements to follow that path. By dividing the robot into these subsystems, engineers can design and optimize each subsystem independently, which can lead to more efficient and effective robotic systems.

Recognition Subsystem:

Sensor :

A sensor is a device or subsystem that detects and responds to a physical stimulus, such as light, temperature, pressure, or motion, and converts it into an electrical or mechanical signal that can be processed, analyzed, or used to control other devices or systems. Sensors are essential components of many electronic, mechanical, and robotic systems, and are used in a wide range of applications, such as automotive, aerospace, medical, environmental monitoring, and consumer electronics. They can be classified based on the physical phenomenon they detect, the type of output they provide, and their operating principles. Some common types of sensors include temperature sensors, pressure sensors, proximity sensors, optical sensors, and motion sensors.



Types of sensors:

Active and passive sensors are two different types of sensors used in various applications.

1. **Active sensors:** Active sensors emit energy or radiation to measure the properties of an object or environment. They require a power source to operate and can be used to gather data in situations where passive sensors are unable to function. Some examples of active sensors include radar, lidar, and ultrasonic sensors.

Radar sensors emit radio waves that are reflected back by objects in their path. By measuring the time it takes for the waves to return and the intensity of the reflection, radar sensors can determine the location, distance, and speed of objects.

Lidar sensors use laser beams to scan an area and create a 3D map of the environment. They measure the time it takes for the laser beams to reflect off of objects and return to the sensor, allowing them to create highly detailed and accurate maps.

Ultrasonic sensors emit high-frequency sound waves that bounce off objects and return to the sensor. By measuring the time it takes for the waves to return, ultrasonic sensors can determine the distance and location of objects.

2. **Passive sensors:** Passive sensors detect and measure the energy emitted by objects in the environment without emitting any energy themselves. They do not require a power source to operate and are often used in situations where active sensors may interfere with the environment or other sensors. Some examples of passive sensors include infrared sensors and optical sensors.

Infrared sensors detect the heat energy emitted by objects and convert it into an electrical signal that can be processed or displayed. They are commonly used in temperature measurement, motion detection, and other applications.

Optical sensors use light to detect and measure various physical properties, such as color, intensity, and wavelength. They can be used in applications such as image sensing, position sensing, and spectroscopy.

LIDAR:

LIDAR (Light Detection and Ranging) is a remote sensing technology that uses laser light to measure the distance to objects in its field of view. LIDAR technology has many applications, including autonomous vehicles, surveying, mapping, and atmospheric monitoring.

LIDAR systems typically consist of a laser scanner, a receiver, and a data processing unit. The laser scanner emits laser pulses that travel through the atmosphere and bounce off objects in their path. The receiver detects the reflected laser pulses and measures their time of flight and intensity. The data processing unit then uses this information to create a 3D map of the environment.

There are two main categories of LIDAR systems, including:

1. **Airborne LIDAR:** These LIDAR systems are mounted on aircraft and are used for mapping large areas, such as forests, coastlines, and urban areas. Airborne LIDAR systems can cover large areas quickly and provide high-resolution maps.
2. **Terrestrial LIDAR:** These LIDAR systems are used for mapping smaller areas, such as building interiors, archaeological sites, and construction sites. Terrestrial LIDAR systems are mounted on tripods and can provide high-resolution 3D maps.

LIDAR technology has revolutionized many industries by providing accurate and detailed 3D maps of the environment. It has become an essential tool for autonomous vehicles, robotics, and remote sensing applications. However, LIDAR systems can be expensive and require skilled operators to operate and maintain.

Control Subsystem:

Control hardware in robotics refers to the controller that continuously reads from sensors like motor encoders, force sensors, or even vision or depth sensors, and updates the robot’s movements accordingly.

Microcontroller: Microcontrollers can interact with the physical world through sensors and actuators. Sensors are devices that detect and respond to changes in the environment, such as temperature, light, or motion. The microcontroller can read data from sensors and use it to make decisions or trigger actions. Actuators, on the other hand, are devices that can move or control a mechanism or system. The microcontroller can send signals to actuators to control their behavior.

For example, in a temperature control system, a temperature sensor might detect the current temperature and send that information to the microcontroller. The microcontroller can then compare the current temperature to a desired setpoint and send a signal to an actuator, such as a heater or fan, to adjust the temperature accordingly.

Arduino : Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs from various sources such as sensors or buttons and turn them into outputs such as activating a motor or turning on an LED.

Motion Subsystem:

Manipulator :

In robotics, a manipulator is a robotic arm that is designed to move objects or perform tasks in a specific environment. The manipulator is typically made up of a series of rigid links that are connected by joints or axes, allowing the arm to move in different directions and perform a variety of tasks. The end of the manipulator often includes an end effector, which is a tool or device that is used to interact with the environment.

Manipulators are used in a wide range of applications, from manufacturing and assembly to construction and surgery. They are often used in situations where it is difficult or dangerous for humans to perform tasks, or where precision and accuracy are critical. For example, in manufacturing, manipulators can be used to move heavy objects or perform repetitive tasks that would be difficult for humans to do for extended periods of time.

End Effector

In robotics, an end effector is a tool or device that is attached to the end of a robotic manipulator, such as a robotic arm. The end effector is designed to interact with the environment in order to perform a specific task, such as grasping an object, cutting a material, or welding two pieces together.

The end effector is typically designed to meet the specific requirements of the task at hand, and can vary widely in terms of size, shape, and functionality. For example, a robotic arm used for welding might have an end effector that includes a welding torch and a wire feeder, while a robotic arm used for assembly might have an end effector that includes grippers or suction cups to hold and manipulate parts.

End effectors are often designed to be interchangeable, so that the same manipulator can be used for multiple tasks by simply swapping out the end effector. This allows for greater flexibility and efficiency in robotic systems, as the same robotic arm can be used for a variety of tasks without needing to be reconfigured or replaced.

Actuators :

In robotics, an actuator is a component that is used to convert energy into motion or force. The actuator is responsible for moving the robotic system or its components, such as the manipulator or end effector, in a controlled manner. There are several different types of actuators that are commonly used in robotics, each with its own strengths and limitations.

Electric Actuators: Electric actuators are the most common type of actuators used in robotics. They convert electrical energy into motion or force, and can be controlled precisely using software or other control systems. Some examples of electric actuators include DC motors, stepper motors, and servo motors. Electric actuators are typically lightweight, compact, and easy to control, making them a popular choice for a wide range of applications. However, they may not be as powerful or able to generate as much force as hydraulic or pneumatic actuators.

Hydraulic Actuators: Hydraulic actuators use pressurized fluid, typically oil or water, to generate force and motion. They are often used in applications that require high levels of force or power, such as heavy-duty construction or industrial equipment. Hydraulic actuators can generate a lot of force and are able to maintain a constant force over long periods of time. However, they may be more complex and expensive to maintain than electric or pneumatic actuators, and may require a separate hydraulic system to operate.

Pneumatic Actuators: Pneumatic actuators use compressed air or other gasses to generate motion and force. They are often used in applications that require quick movements or high levels of precision, such as in assembly lines or robotics research. Pneumatic actuators are typically lightweight, easy to control, and able to generate force quickly.

Motors:

DC Motor:

Advantages:

- Simple and easy to use.
- Provides high starting torque.
- Low cost compared to other types of motors.
- Can operate over a wide range of temperatures and environments.

Limitations:

- Cannot maintain a constant speed under varying loads.
- May experience reduced efficiency at low speeds.
- Requires regular maintenance to ensure proper operation.
- No angular control

Uses:

- DC motors are useful when you need a simple, low-cost motor that can provide high starting torque and speed control.
- They are commonly used in applications such as electric vehicles, industrial machinery, and robotics.

Servo Motor:

Advantages:

- Provides accurate and precise control over position, velocity, and acceleration.
- Can maintain a constant speed under varying loads.
- Low electrical noise output.

Limitations:

- May require more complex control circuitry.
- Sometime slow
- Can be sensitive to vibration and shock.
- Limited angle of rotation.
- Requires precise calibration to achieve optimal performance.

Uses:

- Servo motors are useful when you need accurate and precise control over the position, velocity, and acceleration of the motor.
- They are commonly used in applications such as robotics, industrial automation, and aerospace systems.

Stepper Motor:

Advantages:

- Provides precise control over positioning and speed.
- Can maintain a constant speed under varying loads.
- Low cost compared to servo motors.
- Provides high torque output at low speeds.
- Easy to use and control.

Limitations:

- Less efficient than DC motors at high speeds.
- Limited speed range.
- Can experience increased electrical noise output.

Uses:

- Stepper motors are useful when you need precise positioning control, such as in CNC machines, 3D printers, and robotics.
- They can also be used in applications where low-speed torque is required, such as in surveillance cameras or robotics.

Transmission systems:

Transmission systems are essential components of robots and other machinery that convert rotational motion into linear or angular motion to achieve the desired output. Four common types of transmission systems used in robotics are belt transmission, chain transmission, gear transmission, and link mechanism transmission.

Belt Transmission: Belt transmission systems use flexible belts made of rubber or other materials to transfer rotational motion from one pulley to another. They are commonly used in applications of energy transmission , such as in conveyors, printing presses, and agricultural equipment. Belt transmission systems are simple, cost-effective, and easy to maintain, but they may slip under heavy loads or high speeds.

Chain Transmission: Chain transmission systems use roller chains to transfer power between two or more sprockets. They are commonly used in high-power, high-torque applications, such as in motorcycles, bicycles, and heavy machinery. Chain transmission systems are durable, long-lasting, and able to handle high loads and speeds. However, they may require regular lubrication and maintenance to prevent wear and tear.

Gear Transmission: Gear transmission systems use meshing gears to transmit rotational motion and power between two or more shafts. They are commonly used in applications that require magnification or reduction of speed. It also helps to attain precise speed and torque control, such as in automobiles, airplanes, and machine tools. Gear transmission systems are highly efficient, compact, and able to transmit large amounts of power.

In summary, the choice of transmission system will depend on the specific requirements of the application, including factors such as speed, torque, precision, and environmental conditions. Each type of transmission system has its own strengths and limitations, and it is important to choose the right type of transmission system for the application in order to achieve optimal performance and efficiency.