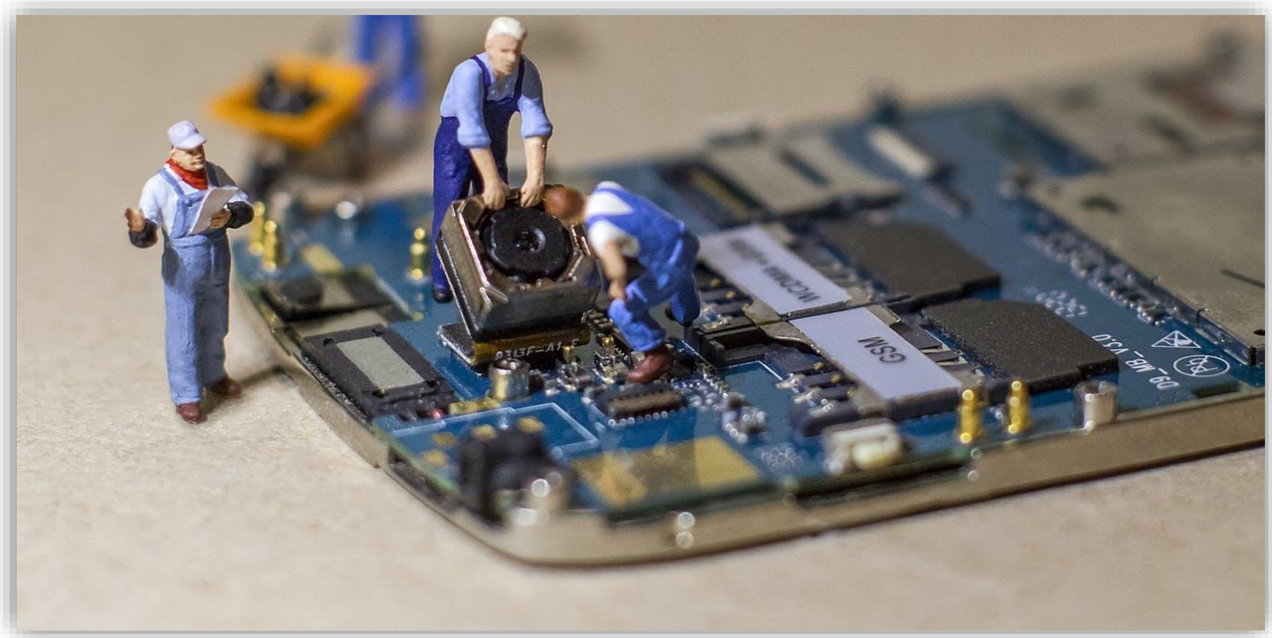
MODELS
&
ROBOTICS SECTION

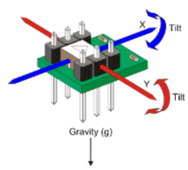
Study Material

Electronics



Sensors

1. Accelerometer:

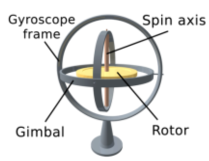


An accelerometer measures acceleration (change in speed) of anything that it's mounted on. How does it work? Inside an accelerator MEMS device are tiny micro-structures that bend due to momentum and gravity. When it experiences any form of acceleration, these tiny structures bend by an equivalent amount which can be electrically detected.

http://www.societyofrobots.com/sensors_accelerometer.shtml

https://learn.sparkfun.com/tutorials/accelerometer-basics

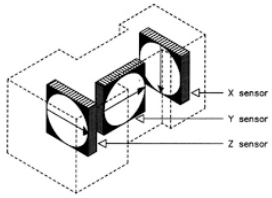
2. Gyroscope:



A **gyroscope** is a device used for measuring or maintaining orientation and angular velocity.[1][2] It is a spinning wheel or disc in which the axis of rotation is free to assume any orientation by itself. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum.

https://en.wikipedia.org/wiki/Gyroscope

3. Magnetometer:



The **digital compass** gives measurements based on Earth's magnetic field for robot navigation. Inside this commonly available MEMS are tiny nano-structures that bend due to electromagnetic fields. When this MEMS experiences any form of EM field, the tiny structures bend by an amount which can be electrically detected. Cheaper digital compasses usually have a resolution of around +/- 5 degrees, but newer and better ones can detect with a better accuracy.

http://www.societyofrobots.com/sensors_digitalcompass.shtml

Courtesy: Models and Robotics Section, STC, IIT Roorkee, uploaded by Mayankfph@iitr.ac.in,

4. IR Sensor (Proximity Sensor):

The Infrared emitter detector circuit is very useful if you plan to make a **line following robot**, or a robot with basic object or obstacle detection. **Infrared emitter detector** pair sensors are fairly easy to implement, although involved some level of **testing** and **calibration** to get right. They can be used for obstacle detection, motion detection, transmitters, **encoders**, and color detection (such as for line following).

http://www.societyofrobots.com/schematics_infraredemitdet.shtml

5. IR Distance Sensor:

The Sharp IR Range Finder works by the process of **triangulation**. A pulse of light (wavelength range of 850nm +/-70nm) is emitted and then reflected back (or not reflected at all). When the light returns it comes back at an angle that is dependent on the distance of the reflecting object. Triangulation works by detecting this reflected beam angle - by knowing the angle, distance can then be determined.

http://www.societyofrobots.com/sensors_sharpirrange.shtml

6. Ultrasonic Distance Sensor:

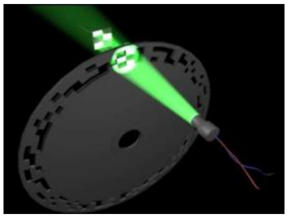
Everyone knows how sonar works. A sound gets emitted, then you 'see' your surroundings based on the sound coming echoing back. This is because sound takes time to travel distances. Farther the distance, the longer it takes for the sound to come back.

http://www.societyofrobots.com/sensors_sonar.shtml

7. Encoders:

The encoder is a sensor attached to a rotating object (such as a wheel or motor) to measure rotation. By measuring rotation your robot can do things such as determine displacement, velocity, acceleration, or the angle of a rotating sensor. A typical encoder uses optical sensor(s), a moving mechanical component, and a special reflector to provide a series of electrical pulses to your **microcontroller**. These pulses can be used as part of a **PID feedback control system** to determine translation distance, rotational velocity, and/or angle of a moving robot or robot part.

http://www.societyofrobots.com/sensors_encoder.shtml



8. Color Sensor:

The color sensor detects the color of the surface, usually in the RGB scale. Color is the result of interaction between a light source, an object and an observer. In case of reflected light, light falling on an object will be reflected or absorbed depending on surface characteristics, such as reflectance and transmittance. For example, green paper will absorb most of the reddish and bluish part of the spectrum while reflecting the greenish part of the spectrum, making it appear greenish to the observer.

http://www.societyofrobots.com/sensors_color.shtml

9. Bump Sensor:

Tactile Bump Sensors are great for **collision detection**, but the circuit itself also works fine for user buttons and switches as well. They usually implement a mechanical button to short the circuit, pulling the signal line high or low.

http://www.societyofrobots.com/sensors_tactbumpswitch.shtml

10. IMU:

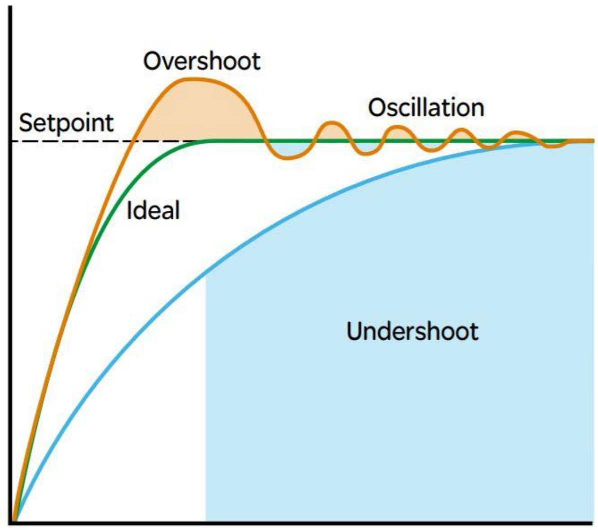
An **inertial measurement unit** (**IMU**) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. IMUs are typically used to maneuver aircraft, including unmanned aerial vehicles (UAVs), among many others, and spacecraft, including satellites and landers.

https://en.wikipedia.org/wiki/Inertial_measurement_unit

Algorithms & Filters:

1. PID:

A proportional integral derivative controller (PID controller) is a common method of controlling robots. PID theory will help you design a better control equation for your robot.



Actuator Output = Kp * (distance from goal) + Kd * (change in error) + Ki * (accumulative error)

http://www.societyofrobots.com/programming_PID.shtml

2. Moving Average:

In statistics, a **moving average** (**rolling average** or **running average**) is a calculation to analyze data points by creating series of averages of different subsets of the full data set. It is also called a **moving mean (MM)**[1] or **rolling**

mean and is a type of finite impulse response filter. Given a series of numbers and a fixed subset size, the first element of the moving average is obtained by taking the average of the initial fixed subset of the number series. Then the subset is modified by "shifting forward"; that is, excluding the first number of the series and including the next value in the subset.
https://en.wikipedia.org/wiki/Moving_average

3. Low Pass Filter:

A **low-pass filter** (**LPF**) is a filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The exact frequency response of the filter depends on the filter design. The filter is sometimes called a **high-cut filter**, or **treble-cut filter** in audio applications. A low-pass filter is the complement of a high-pass filter.
https://en.wikipedia.org/wiki/Low-pass_filter

4. High Pass Filter:

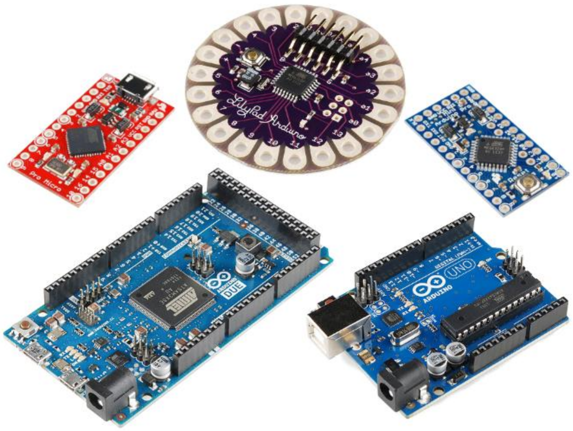
A **high-pass filter** (HPF) is an electronic filter that passes signals with a frequency higher than a certain cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency. The amount of attenuation for each frequency depends on the filter design. A high-pass filter is usually modeled as a linear time-invariant system. It is sometimes called a **low-cut filter** or **bass-cut filter**.[1] High-pass filters have many uses, such as blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices. They can also be used in conjunction with a low-pass filter to produce a band pass filter.
https://en.wikipedia.org/wiki/High-pass_filter

5. Complementary Filter:

Idea behind complementary filter is to take slow moving signals from accelerometer and fast moving signals from a gyroscope and combine them.
Accelerometer gives a good indicator of orientation in static conditions.
Gyroscope gives a good indicator of tilt in dynamic conditions.
So the idea is to pass the accelerometer signals through a low-pass filter and the gyroscope signals through a high-pass filter and combine them to give the final rate.
This principle can also be used for filtering signals of other co-related sensors.
y[n]=(1-alpha) * x[n] + alpha * y[n-1]   //use this for angles obtained from accelerometers
x[n] is the pitch/roll/yaw that you get from the accelerometer
y[n] is the filtered final pitch/roll/yaw
https://sites.google.com/site/myimuestimationexperience/filters/complementary-filter

Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board.



Here are some links which will be useful to you for introduction to Arduino:
https://learn.sparkfun.com/tutorials/what-is-an-arduino
https://learn.sparkfun.com/tutorials/installing-arduino-ide
https://learn.sparkfun.com/tutorials/data-types-in-arduino

Arduino Tutorials YouTube:

Jeremy Blum https://www.youtube.com/playlist?list=PLA567CE235D39FA84
https://www.youtube.com/playlist?list=PLPK2l9Knytg5s2dk8V09thBmNl2g5pRSr

Some Basic Arduino Based Projects:

https://programmingelectronics.com/category/project-based/

Raspberry Pi

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

YouTube Tutorial Links:
https://www.youtube.com/playlist?list=PLQVvvaa0QuDesV8WWHLLXW_avmTzHmJLv
https://www.youtube.com/playlist?list=PLPK2l9Knytg67nkvpnnl81ossAHfOgmqU

Miscellaneous Links (For Advanced Study):

PWM: https://learn.sparkfun.com/tutorials/pulse-width-modulation
https://learn.sparkfun.com/tutorials/integrated-circuits
https://learn.sparkfun.com/tutorials/analog-vs-digital
https://learn.sparkfun.com/tutorials/logic-levels
http://www.arduino.cc/en/Guide/Introduction
http://learn.sparkfun.com/tutorials/how-do-i-power-my-project
Serial Communication: https://learn.sparkfun.com/tutorials/serial-communication
I2C: https://learn.sparkfun.com/tutorials/i2c
ADC: https://learn.sparkfun.com/tutorials/analog-to-digital-conversion
https://learn.sparkfun.com/tutorials/pcb-basics

Mechanical and Design

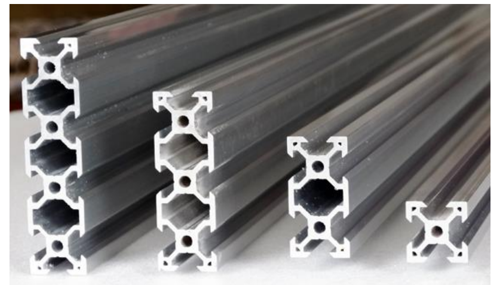
Chapter1
Mechanical Accessories

1. Structural Parts

1.1 Square Channels or square pipes:
These are hollow square extrusions which are used in making physical structure of the robot or any machine. They come in various sizes and materials according to requirement in terms of size and strength respectively.

1.2 V extrusions:

These are customized cross sectional extruded structural parts used in making robots. One of their main advantages over regular square pipes is their enhanced strength and that presence of several accessories that makes construction of structure, using V extrusion, easier.



[Extrusion : YouTube video link]

[Extrusion 2 : YouTube Video Link]

1.3 Shafts

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The various members such as pulleys and gears are mounted on it.

1.4 L-plates

These are the mechanical parts that are used to provide strength to the structure and also make the structure planar.

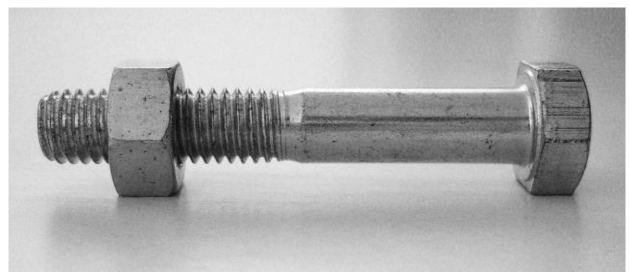
[L plates use : YouTube video link]

1.5 Angle Brackets

These are the mechanical parts that are used to provide strength to the structure and also used to join two square pipes perpendicular to each other.

2. Fasteners

2.1 Nuts and Bolts



Nuts and bolts are the mechanical parts that are used to join or fasten various structural parts.There are different types of nuts and bolts present today that have different designs according to different applications.

2.2 Washers

A washer is a thin plate (typically disk-shaped) with a hole (typically in the middle) that is normally used to distribute the load of a threaded fastener, such as a screw or nut.

[Bolts : YouTube Video Link]
[Nuts : YouTube Video Link]
[Washers : YouTube video Link]

3. Bearings

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis.

3.1 Ball Bearings

The purpose of a ball bearing is to support or facilitate rolling motion by reducing rotational friction and support radial and axial loads.

Bearing : Link YouTube

3.2 Linear sliders or bearings

The purpose of a linear sliders or bearing is to support or facilitate rolling motion by reducing rotational friction between guide and rail and support corresponding loads.

Linear Sliders or Bearings : Link YouTube

Linear Sliders or Bearings 2 (watch only initial 4 minutes): Link YouTube

4. Gears

A gear or cogwheel is a rotating machine part having cut *teeth*, or cogs, which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source.

Types of gears:

Spur
Helical
Double helical
Bevel
Spiral bevels
Hypoid
Crown
Worm

Types of Gears : YouTube video Link

Watch these videos in order to get an idea of mechanical accessories

Courtesy: Models and Robotics Section, STC, IIT Roorkee, uploaded by Mayankfph@iitr.ac.in,

1. Manufacturing Video 1
2. Manufacturing Video 2

Chapter 2
Actuators

4.1 DC Motors:

From the start, DC motors seem quite simple. Apply a voltage to both terminals, and *weeeeeeee* it spins. But what if you want to control which direction the motor spins? Correct, you reverse the wires. Now what if you want the motor to spin at half that speed? You would use less voltage. But how would you get a robot to do those things autonomously? How would you know what voltage a motor should get? Why not 50V instead of 12V? What about motor overheating? To know the answers follow the link.
http://www.societyofrobots.com/actuators_dcmotors.shtml

4.2 Brushless DC Motors:

In order to make the operation more reliable, more efficient, and less noisy the recent trend has been to use brushless D.C (BLDC) motors. They are also lighter compared to brushed motors with the same power output. The brushes in conventional D.C motors wear out over the time and may cause sparking. As a result the conventional D.C motors require occasional maintenance. Controlling the brush sparking in them is also a difficult affair. Thus the brushed D.C motor should never be used for operations that demand long life and reliability. For this reason, BLDC motors are used in most of the modern devices. Efficiency of a BLDC motor is typically around 85-90%, whereas the conventional brushed motors are only 75-80% efficient. BLDC motors are also suitable for high speed applications (10000 rpm or above). The BLDC motors are also well known for their better speed control.
http://www.societyofrobots.com/actuators_brushlessmotors.shtml

4.3 Servo Motors:

A **servomotor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration.[1] It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servo motors.
http://www.societyofrobots.com/actuators_servos.shtml

4.4 Solenoids:

Solenoids are actuators capable of linear motion. They can be electromechanical (AC/DC), hydraulic, or pneumatic driven - all operating on the same basic principles. Give it energy and it will produce a linear force. They are great for pushing buttons, hitting keys on a piano, valve operators, and even for jumping robots. DC solenoids operate on the same basic principles as a **DC motor**.
http://www.societyofrobots.com/actuators_solenoids.shtml

4.5 Stepper Motors:

Stepper Motors work under a very similar principle to DC motors, except they have many coils instead of just one. So to operate a stepper motor, one must activate these different coils in particular patterns to generate motor rotation. So stepper motors need to be sent **patterned commands** to rotate. These commands are sent as high and low logic over several lines, and must be pulsed in a **particular order** and **combination**. Steppers are often used because each 'step,' separated by a set step angle, can be counted and used for **feedback control**. For example, a 10 degree step angle stepper motor would require 36 commands to rotate 360 degrees.
http://www.societyofrobots.com/actuators_steppers.shtml

Stepper Motors : YouTube Video Link

4.6 Pneumatics & Hydraulic Actuators:

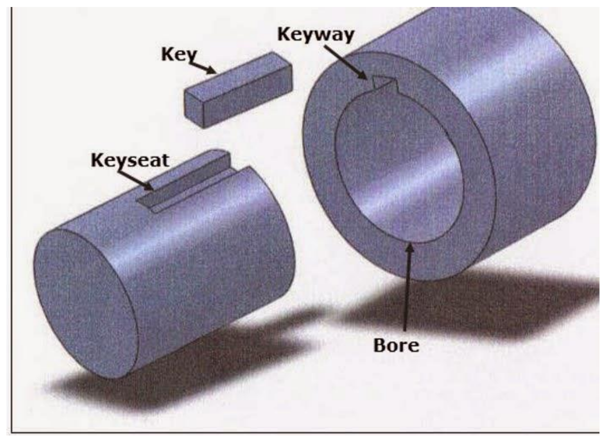
A **pneumatic control valve actuator** converts energy (typically in the form of compressed air) into mechanical motion. The motion can be rotary or linear, depending on the type of actuator.
Similarly Hydraulic actuators use liquid(typically water) for energy transfer.

http://www.robotplatform.com/knowledge/actuators/types_of_actuators.html

Pneumatics tutorials (a bit longer video but clears all the fundamentals of Pneumatic actuators): video Link YouTube

Chapter 3
Power Transmission

2.1 Key and Key slot



A key is a machine element used to connect a rotating machine element to a shaft. The key prevents relative rotation between the two parts and may enable torque transmission. For a key to function, the shaft and rotating machine element must have a keyway and a key seat, which is a slot and pocket in which the key fits. The whole system is called a keyed joint. A keyed joint may allow relative axial movement between the parts.

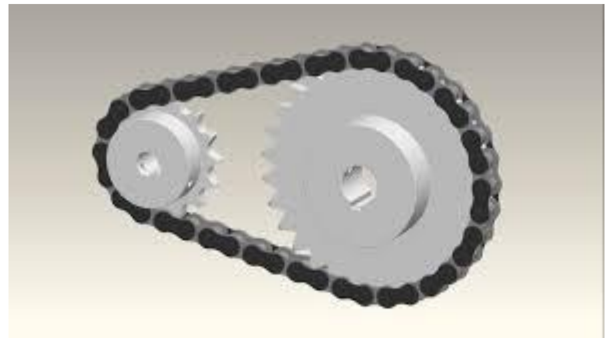
2.2 Gear Train:

The *rotational* motion of one shaft is transmitted to another with the help of gears. The transferring of power can be either in intersecting or parallel shafts. It is the most frequently used mechanical transmission system in the robots. The added advantage of the gears is that the speed can be *decreased or increased* according to the operation.

Gear trains in robotics : YouTube video link

2.3 Chain Sprockets

Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, and other machinery either to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc. Perhaps the most common form of sprocket may be found in the bicycle, in which the pedal shaft carries a large sprocket-wheel, which drives a chain, which, in turn, drives a small sprocket on the axle of the rear wheel . Early automobiles were also largely driven by sprocket and chain mechanism, a practice largely copied from bicycles.



Chain and Sprockets : YouTube Video Link

2.4 V belts

A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts may be used as a source of motion, to transmit power efficiently, or to track relative movement. Belts are looped over pulleys and may have a twist between the pulleys, and the shafts need not be parallel.

V belts : YouTube Video Link

2.5 Timing Belts

A toothed belt; timing belt; cogged belt; cog belt; or synchronous belt is a flexible belt with teeth molded onto its inner surface. It is designed to run over matching toothed pulleys or sprockets. Toothed belts are used in a wide array of in mechanical devices, where high-power transmission is desired.

Timing Belts : YouTube Video Link

Chapter 4
Wheels and Drives

3.1 Omni Wheels

Omni wheels or poly wheels, similar to Mecanum wheels, are wheels with small discs around the circumference which are perpendicular to the turning direction. The effect is that the wheel can be driven with full force, but will also slide laterally with great ease. These wheels are often employed in holonomic drive systems.

3.2 Mecanum Wheels:

The Mecanum wheel is a design for a wheel which can move a vehicle in any direction. It is sometimes called the Ilon wheel after its inventor, Bengt Erland Ilon, who came up with the idea when he was an engineer with the Swedish company Mecanum AB.

It is a conventional wheel with a series of rollers attached to its circumference. These rollers typically each have an axis of rotation at 45° to the plane of the wheel and at 45° to a line through the center of the roller parallel to the axis of rotation of the wheel.

3.3 Differential Wheels

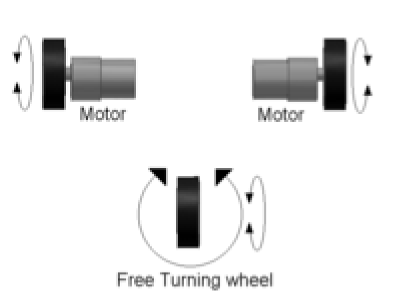
Differential Wheels are the normal Wheels that are used in various day to day appliances.

3.4 Castor Wheels:

A caster (also *castor* according to some dictionaries) is a wheeled device typically mounted to a larger object that enables relatively easy rolling movement of the object. Casters are essentially special housings that include a wheel, facilitating the installation of wheels on objects.

Various Types of Drives

3.1 Two wheel Differential:

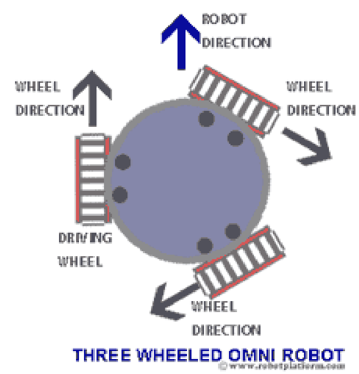


A differential wheeled robot is a mobile robot whose movement is based on two separately driven wheels placed on either side of the robot body. It can thus change its direction by varying the relative rate of rotation of its wheels and hence does not require an additional steering motion.

To balance the robot, additional wheels or casters may be added.

Two Wheel Differential Drive : YouTube Video Link

3.2 Three wheeled Omni Drive:

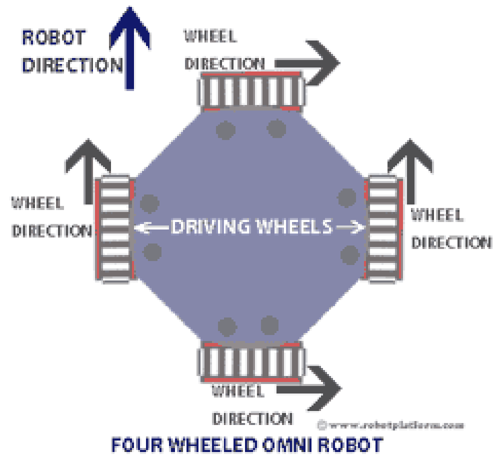


A three wheel design offers greater traction as any reactive force is distributed through only three points and the robot is well balanced even on uneven terrain. This design also reduces an additional wheel compared to a 4 wheeled robot which makes it cost effective (yes, these wheels are expensive). In few instances, I have see that designing a three wheeled Omni robot is simpler and can drive more straight than a four wheeled robot, although I would still vote for a 4 wheeled robot.

Few designers add two wheels parallel to each other and one wheel perpendicular to the two wheels which is a better design or a compromise between three and four wheeled Omni-drive robots.

3 wheel Omni Drive : YouTube video Link

3.3 Four Wheeled Omni Drive:

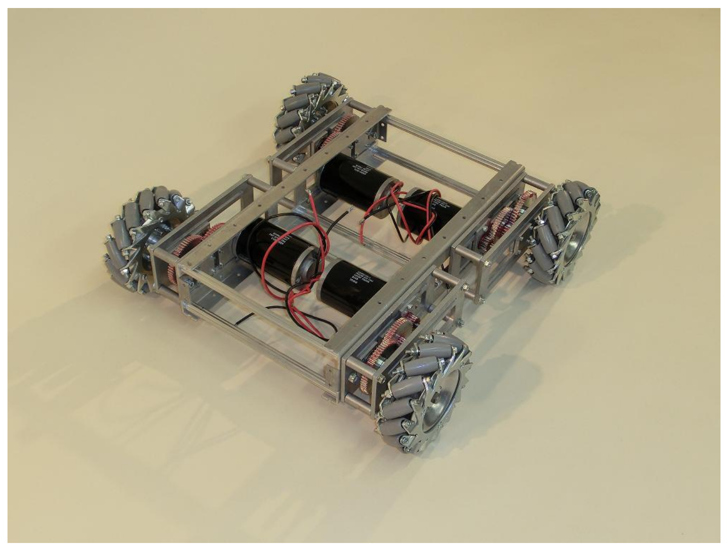


In 4 wheel design, 4 Omni wheels are attached at 90° to each other. This means any two wheels are parallel to each other and other two wheels perpendicular. The first and the major benefit is the simplified calculation. Since there are two pairs of wheels, each pair requires only one calculation and all four wheels require only two calculations. Also at any point there are two driving wheels and two free wheels. This makes the two driving wheels 100% efficient and drivers the robot at higher speed compared to 3-wheel design.

4 wheel Omni Drive : YouTube Video Link

3.4 Four Wheel Mecanum Drive:

Mecanum drive is a type of holonomic drive base; meaning that it applies the force of the wheel at a 45° angle to the robot instead of on one of its axes. By applying the force at an angle to the robot, you can vary the magnitude of the force vectors to gain translational control of the robot; aka, the robot can move in any direction while keeping the front of the robot in a constant compass direction. This differs from the basic robot drive systems like arcade drive, tank drive, or shopping cart drive require you to turn the front of the robot to travel in another direction.



Mecanum Days Video Link YouTube

Designing in Solidworks:
Complete Solidworks Tutorial

GitHub Link for previous year MaRS projects:

https://github.com/marsiitr