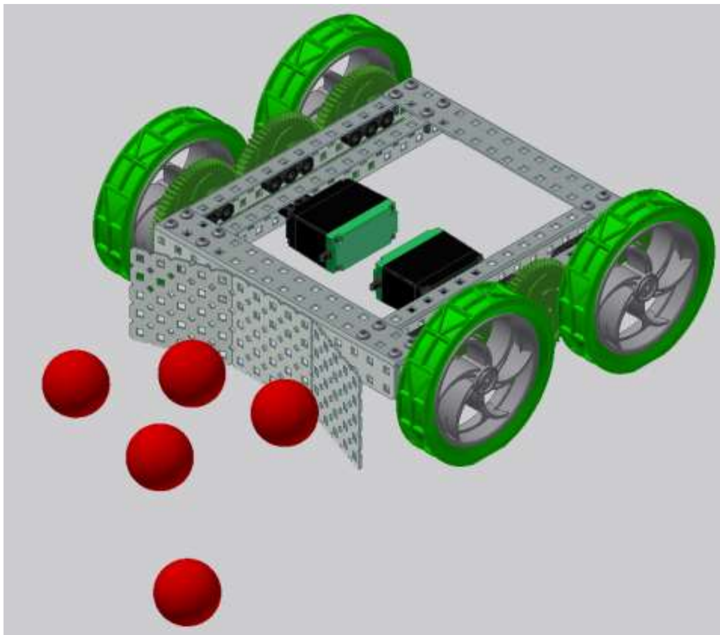
Robotics Refresher

1) Manipulator
    a. Plow
    b. Scoop
    c. Grabber
2) Accumulator
    a. Magazine
    b. Conveyor Belt
    c. Hopper
3) DC Motors
    a. Terms
    b. Characteristics
    c. Formulas
4) Mechanical Power Transmission
    a. Spur Gears
    b. Bevel Gears
    c. Worm Gears
    d. Helical Gears
    e. Planetary Gears
    f. Gear Ratios
    g. Formulas
    h. Rack and Pinion Gears
    i. Gear Box
5) Drivetrain Design.
    a. Car Steer
    b. Skid Steer
    c. Mecanum
    d. OmniCrawler
    e. Omni-Directional
6) Lifting Mechanisms
    a. Elevators
    b. Elevator Actuation and Loading
    c. Linear Slides
    d. Passive Assistance
7) Oddities
    a. Choo Choo
    b. Incredible
    c. Robot Fight Club

Manipulators

Plow:



Scoop: https://www.youtube.com/watch?v=ths6sWAKaDQ

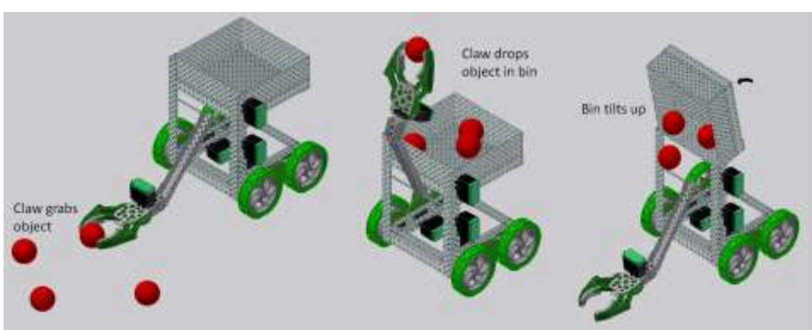
Grabber: https://www.youtube.com/watch?v=7_YZ1VJ7NzA

Accumulators

Magazine: https://www.youtube.com/watch?v=iEqg66PRwgE

Conveyor Belt: https://www.youtube.com/watch?v=v1Mpx2X4efM

Hoppers:



DC Motors

Terms:

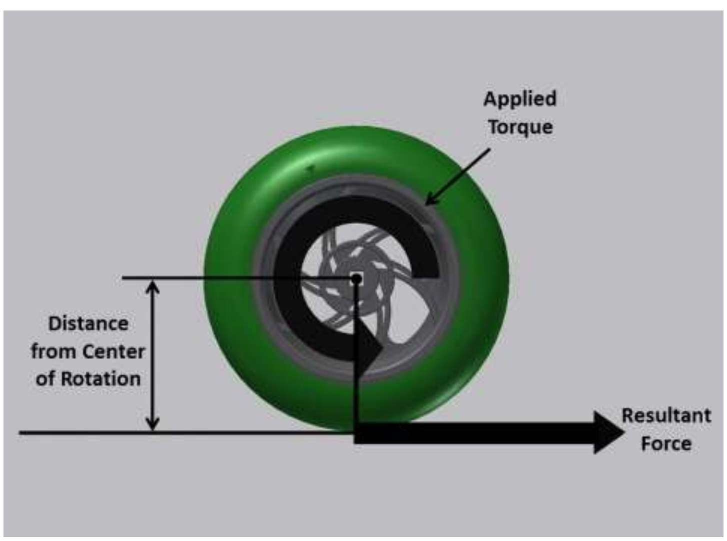
Speed – A measure of how fast an object is moving. This measure is given in units of distance per time (i.e. miles per hour, or feet per second.)

Rotational Speed – Speed can also be expressed rotationally. This refers to how fast something is moving in a circle. It is measured in units of angular-distance per time (i.e. degrees per second) or rotational cycles per time (i.e. revolutions per minute.)

Acceleration – A change in speed over a period of time is described as acceleration; the higher the acceleration the faster the change in speed

Force - Accelerations are caused by forces; they are influences that cause a change of movement, direction or shape. When one presses on an object, they are exerting a force on it. When a robot is accelerating, it does so because of the force its wheels exert on the floor. Force is measured in units such as Pounds or Newtons.

Torque – Force directed in a circle (rotating an object) is known as torque. Torque is a spinning force. If torque is spinning an object, the object will create a linear force at its edge. In the instance of a wheel spinning on the ground, the torque applied to the wheel axle creates a linear force at the edge of the tire where it contacts the ground. This is how one defines torque, a linear force at the edge of a circle. Torque is described by the magnitude of the force multiplied by the distance it is from the center of rotation (Force x Distance = Torque). Torque is measured in units of force*distance, such as Inch-Pounds of Newton-Meters.

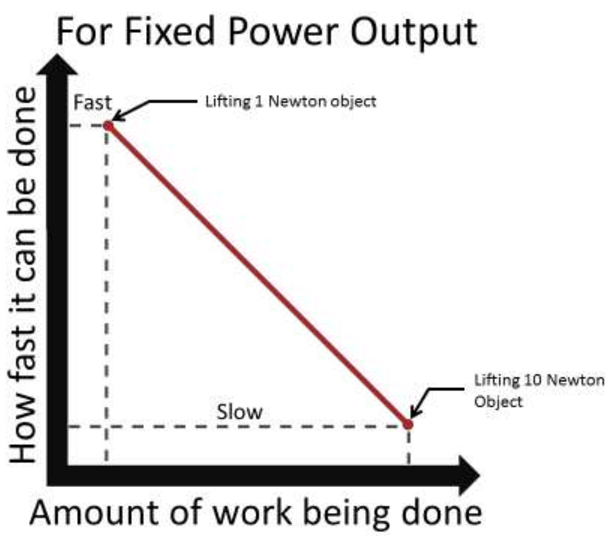


Work – The measure of force exerted over a distance is referred to as work. For instance, say it takes 10 pounds of force to hold an object. It would then take a certain amount of work to lift this object 10 inches, and it would take double that work to lift it 20 inches. Work can also be thought of as a change in energy.

Power - Power is defined as the RATE that work is performed.

Characteristics:

In robotics design it is handy to think of power as a limit, since competition robotic systems are limited in the amount of power they can output. If a robot needs to lift a 2 Newton weight (exerting a 2 Newton force) the amount of power the robot can output limits how FAST (the rate) at which the robot can lift it. If the robot is capable of outputting lots of power, it will be able to lift it quickly. If it can only output a small amount of power, it will lift it slowly (or not at all!)



Power is defined as Force multiplied by Velocity (how fast one can push with a constant force), and is frequently expressed in units of Watts.

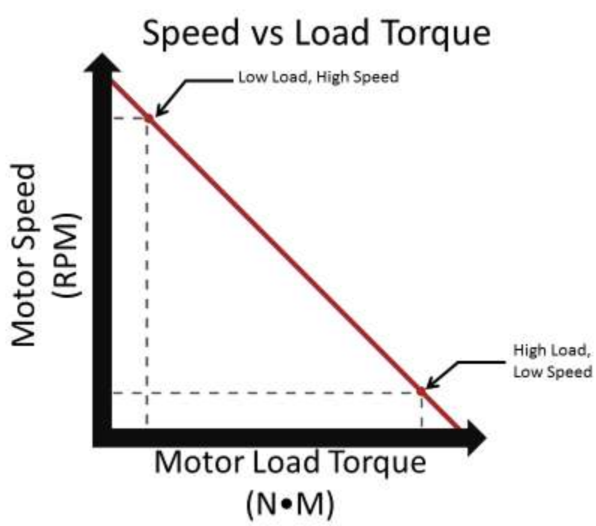
Power [Watts] = Force [Newton] x Velocity [Meters / Second]

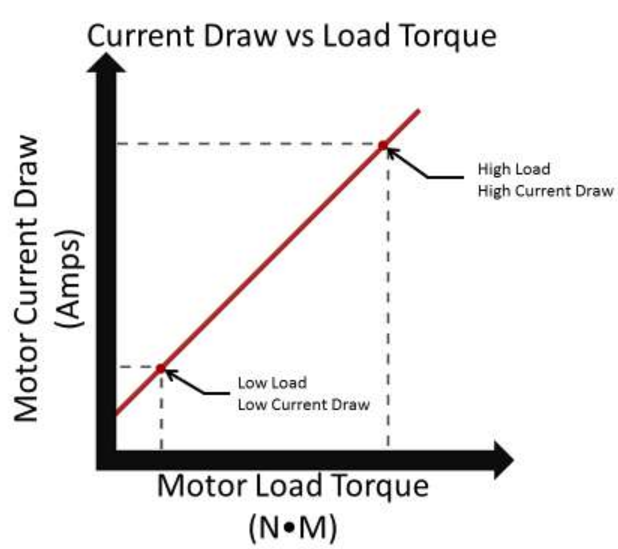
1 Watt = 1 (Newton x Meter) / Second

Motors convert electrical energy into mechanical energy through the use of electro-magnetic fields, and rotating wire coils. When a voltage is applied to a motor it outputs a fixed amount of mechanical power. The mechanical power is seen as the motor's output (usually some shaft, socket, or gear), spinning at some speed with some amount of torque.

Motor Loading - Motors only apply torque in response to loading. Ideally, with no loading on the output the motor will spin very, very fast with no torque. This never happens in real life, since there is always friction in the motor system acting as a load and requiring the motor to output torque to overcome it. The higher the load placed on the motor output, the more the motor will "fight back" with an opposing torque. However, since the motor outputs a fixed amount of power, the more torque the motor outputs, the slower its rotational speed. The more work one makes the motor do, the slower it spins. If one keeps increasing the load on the motor, eventually the load overcomes the motor and it stops spinning. This is called a STALL.

Current Draw - The motor draws a certain amount of electrical current (expressed in units of amps) depending on how much load is placed on it. As the load increases on the motor, the more torque the motor outputs to overcome it and the more current the motor draws.





Varying Power with Voltage - The Power output of a DC Motor varies with the voltage applied. This means that the more voltage is applied, the more power is available and the faster the motor can do work.

If a motor is under a fixed amount of load, and the voltage is increased (resulting in an increase of power), what will it do? It will spin faster! There is more power available to accomplish the same amount of work.

This means that the above motor characteristics change depending on the Voltage applied to the motor, and as such they need to be listed at a given Voltage (i.e. "Tested at 12V".) In fact, the four characteristics above vary proportionally with applied voltage. For example, if one knows a motor has a free speed of 50 RPM at 6V, if the voltage is doubled to 12V the free speed doubles also, and can be calculated to be 100 RPM.

Multiple Motors - When an application requires more power than a motor can handle, a designer has three options:

1. Deal with it, and change the requirements of the problem so that lower power is acceptable.
2. Switch to a more powerful motor.
3. Use more than one motor in the application.

What happens when multiple motors are used on one application? Simple – they balance the torque load between them. If 2 N-m of torque is applied, each motor will have a torque load of 1 N-m, and react accordingly.

Formulas:

Speed = Distance / Time

Rotational Speed = Rotational Cycles / Time

Rotational Speed = Degrees / Time

Torque = Force x Distance

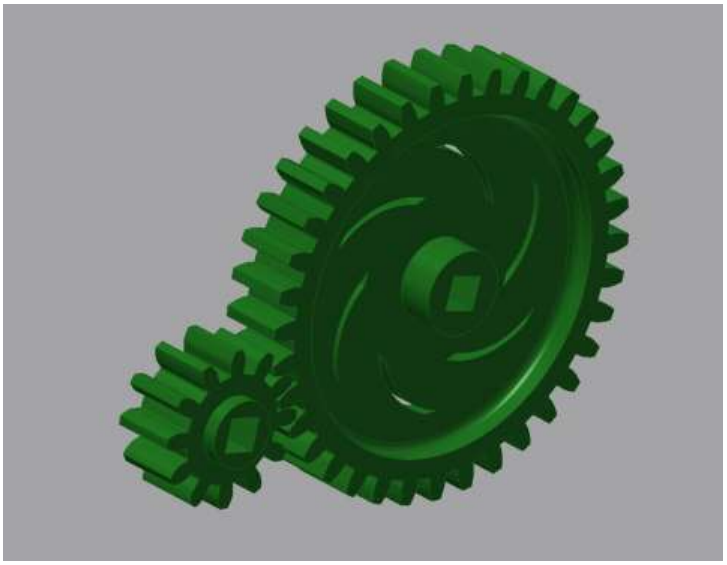
Force = Torque / Distance

Power = Force x Velocity

Mechanical Power Transmission

Spur Gears:

The most common type of gear is called a spur gear. Spur gears transfer motion between two shafts running parallel to each other. Spur Gears are characterized by their teeth, which are straight and parallel to the gear's axis of rotation.



Bevel Gears: https://www.youtube.com/watch?v=vP85dB82C-Y

Bevel gears are conically shaped, and transmit power between shafts that have intersecting axes of motion. Bevel gears can transmit power between shafts at a variety of angles, but are most commonly used to transmit power 90-degrees as seen in the above example.

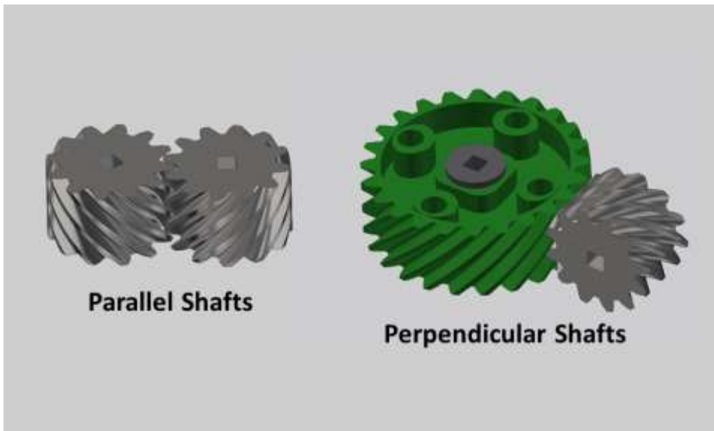
Worm Gears: https://www.youtube.com/watch?v=Z5m2J-wlLuk

Worm gears come in pairs: worm gears and worm wheels that mate together to transfer power between perpendicular shafts that have axes of rotation offset from each other.

Worm gears resemble screws; as they spin, they turn their mating worm wheel. This type of gear pair is very useful for creating a high mechanical advantage in a small form factor. In this type of gear pair, the worm gear can drive the worm wheel forward, but it is very difficult for the worm wheel to drive the worm gear. For this reason, these gears are useful for applications where the designer doesn't want a mechanism to be back-driven.

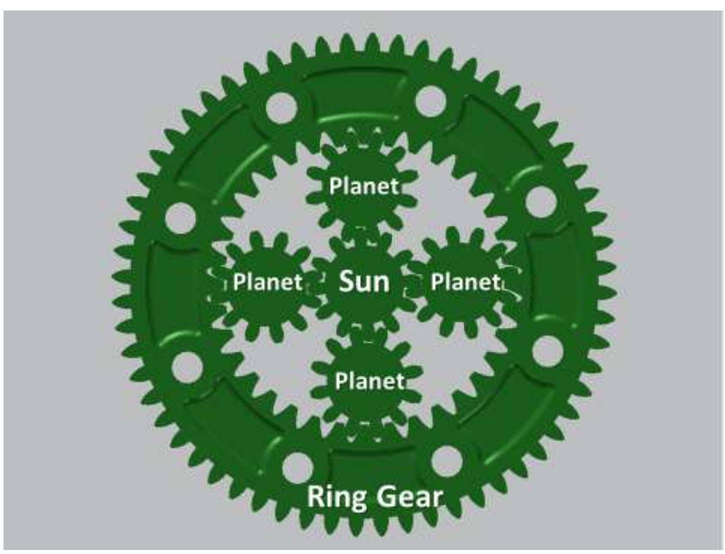
Helical Gears: https://www.youtube.com/watch?v=V5J7uhYmPpk

Helical gears resemble spur gears, only their teeth are curved in the shape of a helix. These gears can be used to transmit power between two parallel axes of motion, or between perpendicular non-intersecting axes of motion.



Planetary Gears:

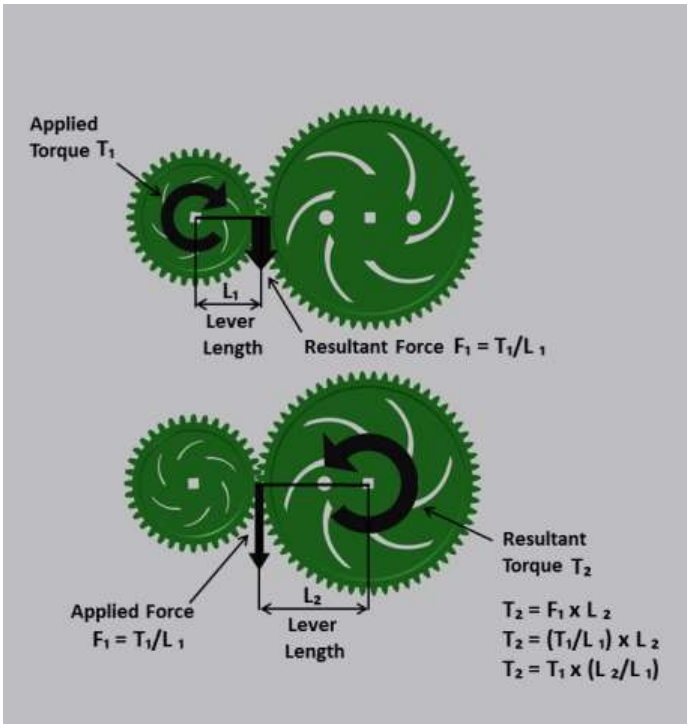
A planetary gear set consists of one or more planet gears moving along an outer ring gear as a central sun gear drives them. As the planet gears are driven, they typically move a planet carrier plate along with them.



Interestingly, planetary gears can be used in a variety of ways with different gears serving as the inputs and outputs. For example, one might use the sun gear as the input and the planet carrier as the output while the ring gear is held stationary, or one might use the ring gear as the input and the sun gear as the output while the planet carrier is held stationary. The overall mechanical advantage of a planetary gear set changes depending on the configuration used.

Gear Ratios:

Gears are not just used to transfer power, they also provide an opportunity to adjust the mechanical advantage of a mechanism. There are cases where a motor itself is powerful enough for an application but the motor's output characteristics are not well suited to the application. A motor that is VERY fast but has only a little bit of torque would not be suitable to lift a heavy load; in these cases it is necessary to use gear ratios to change the outputs to a more appropriate balance of torque and speed.



Formulas:

Gear Ratio = (Driving Gear Teeth):(Driven Gear Teeth)

Gear Reduction = Driven Gear Teeth / Driving Gear Teeth

Output Torque = Input Torque x Gear Reduction

Gear Reduction Required = Output Torque / Input Torque

Output Speed = Input Speed / Gear Reduction

Gear Reduction Required = Input Speed / Output Speed

Compound Gear Reduction = Gear Reduction 1 x Gear Reduction 2 x Gear Reduction 3 x (all other gear reductions)

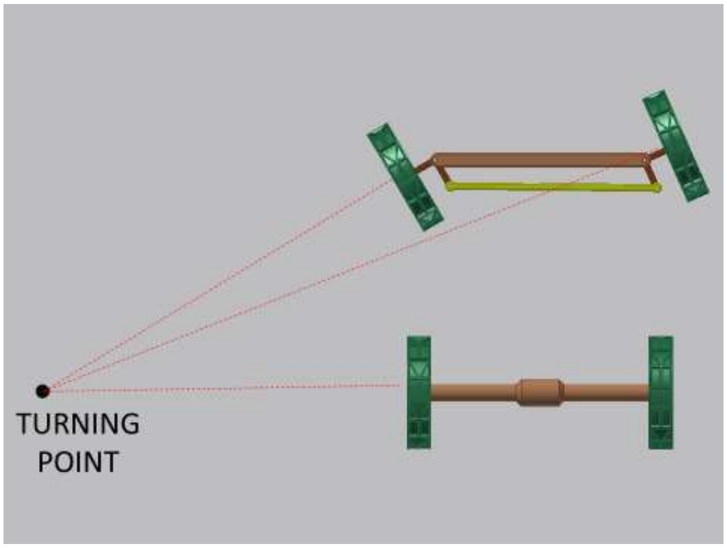
Rack and Pinion Gears: **https://www.youtube.com/watch?v=zAEA0H9aIEc**

Gear Box: https://www.youtube.com/watch?v=sMT3u_4lRgo

https://www.youtube.com/watch?v=vlYg92q5LM8

Drivetrain Design:

Ackermann "Car Style" Steering:

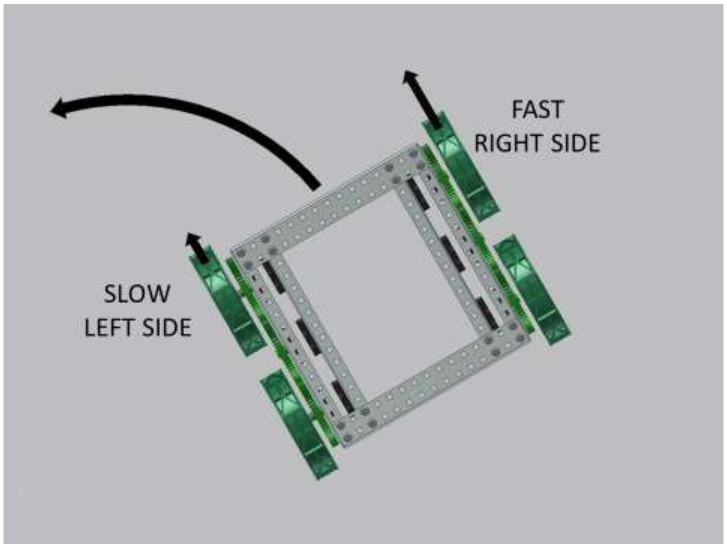


In this type of drive, all the wheels move in the same direction: forward or backwards. Steering is accomplished by turning the wheels such that all the wheels are positioned in an arc around a single turning point.

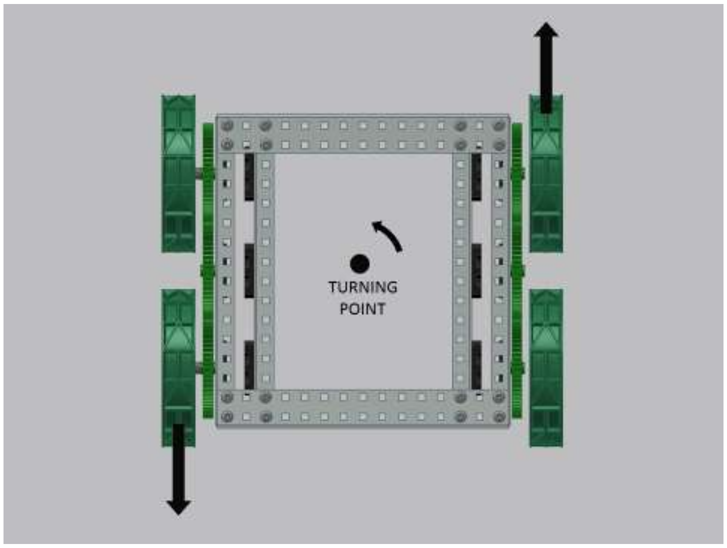
One of the benefits of this configuration is that there is no turning scrub when it is properly set up. However, a major drawback for this type of drive is its inability to perform a zero radius turn.

Skid Steer:

This is the most common type of competition robotics drivetrain. This style is sometimes referred to as "tank drive" since it is commonly used on tanks. In this type of drivetrain, the wheels on the right side and the left side of the drive are powered by separate motors. These wheels are locked pointing forward/backward, and do not steer. Steering is accomplished by varying the speed of the different sides (i.e. if the right side goes forward very fast, and the left side goes forward slowly – the robot turns left).



This type of drivetrain is capable of zero radius turns; the robot driver would simply power one side forward and the other side in reverse.



Mecanum Drivetrain:

https://www.youtube.com/watch?v=Ne09Y72zW_Y

https://www.youtube.com/watch?v=K1yDDmkbaq4

Omni-Crawler Drivetrain:

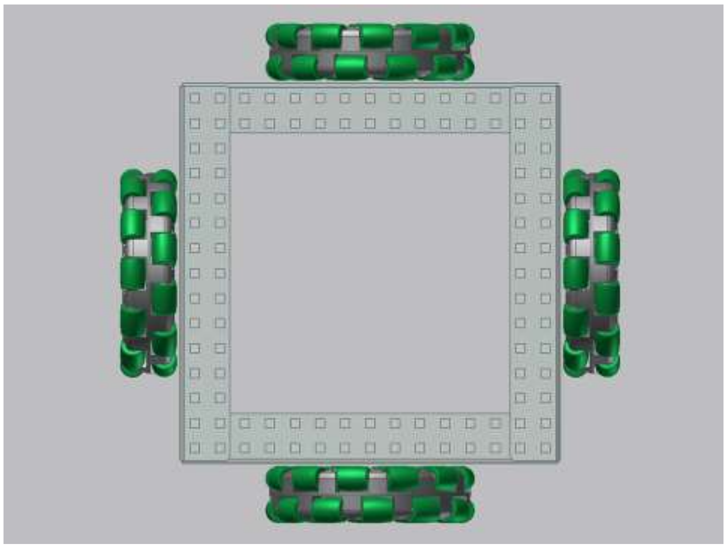
https://www.youtube.com/watch?v=BTp2UAaihaI

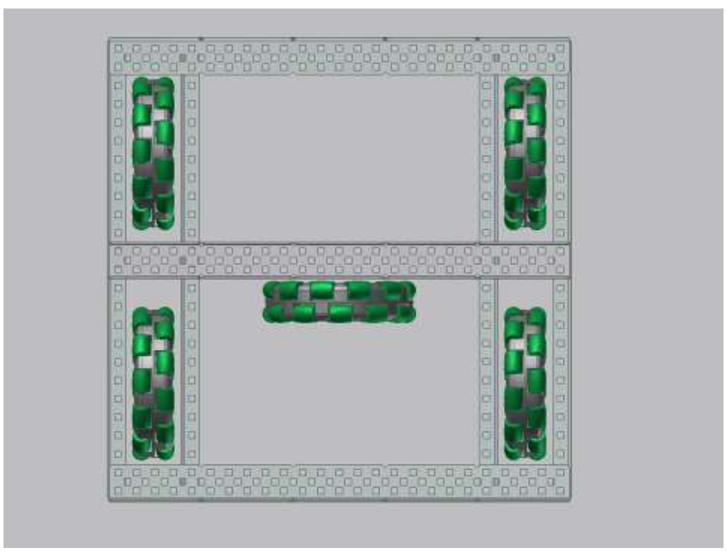
Omni-Directional Drivetrain:

https://www.youtube.com/watch?v=Z0lUTMBbu9A

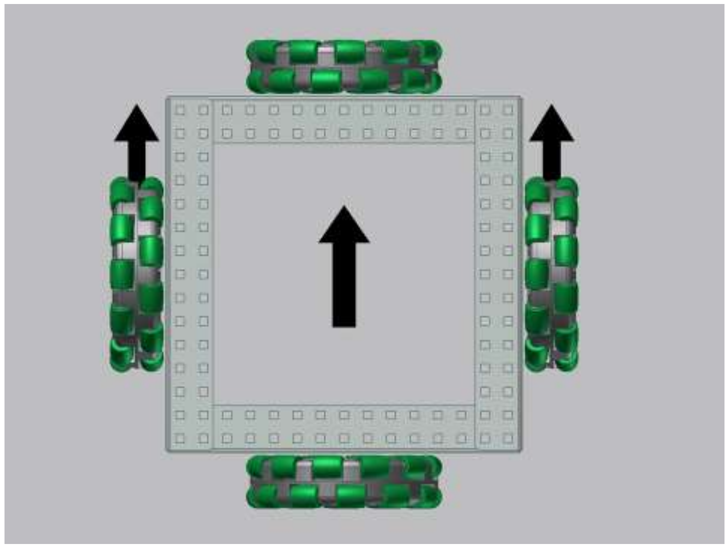
https://www.youtube.com/watch?v=BwGTNHplb5k

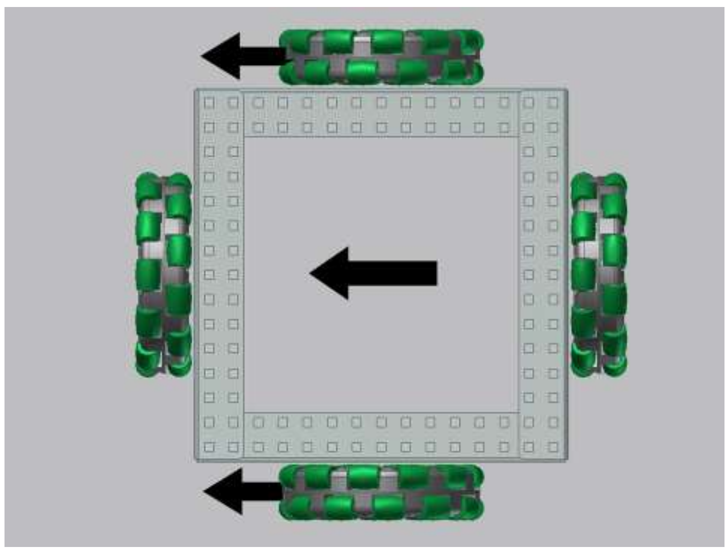
These wheels can be used in a variety of configurations to allow for omni-directional driving. Two common configurations are shown below:

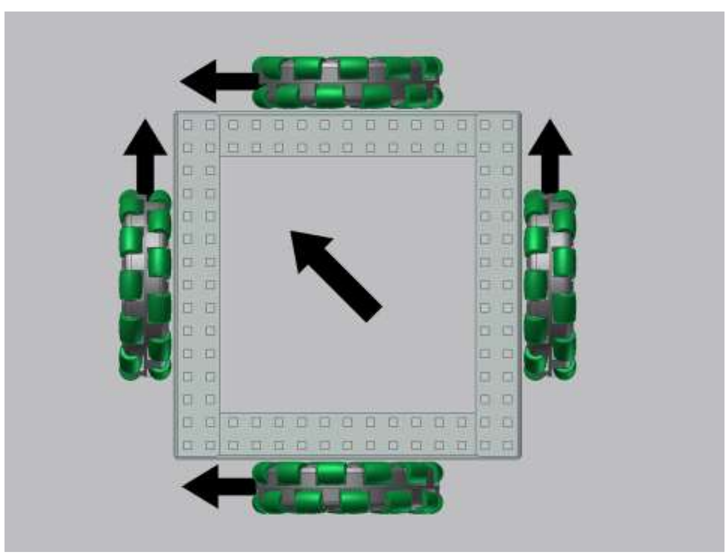




Since omni-wheels don't have any sideways friction, the wheels facing forward/backward can drive without the wheels facing right/left dragging. By powering both sets of wheels, the robot can move in any direction.



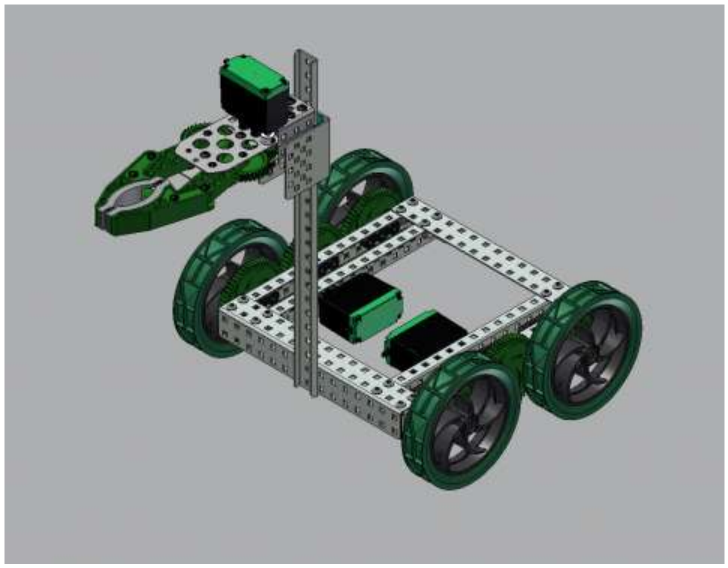


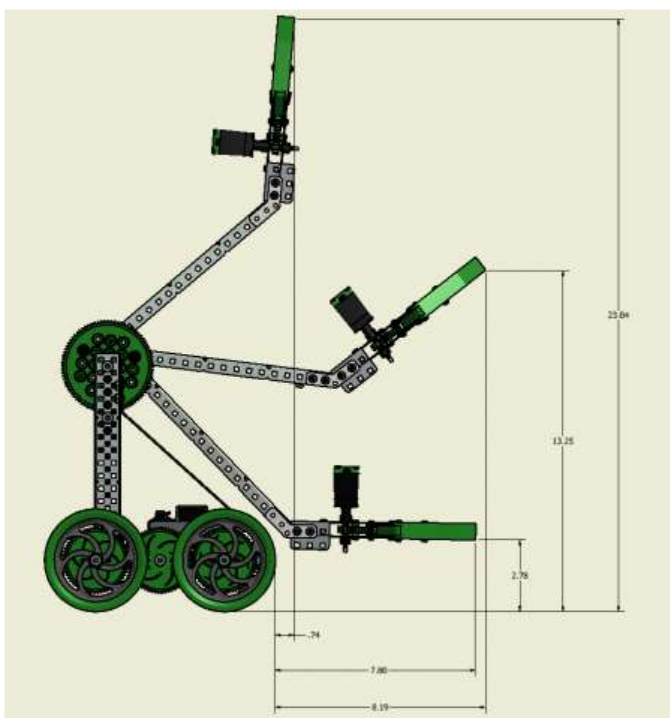


LIFTING MECHANISMS

Elevators: https://www.youtube.com/watch?v=3YOWj3JFZBk

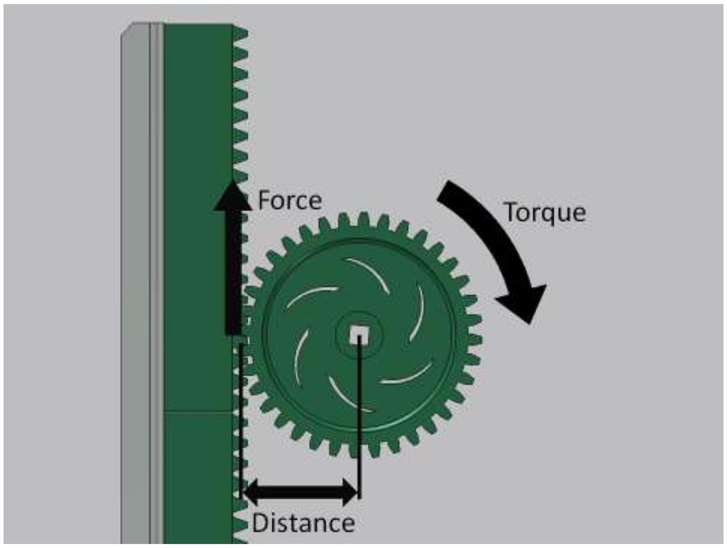
https://www.youtube.com/watch?v=0UO4Zu-gdHQ



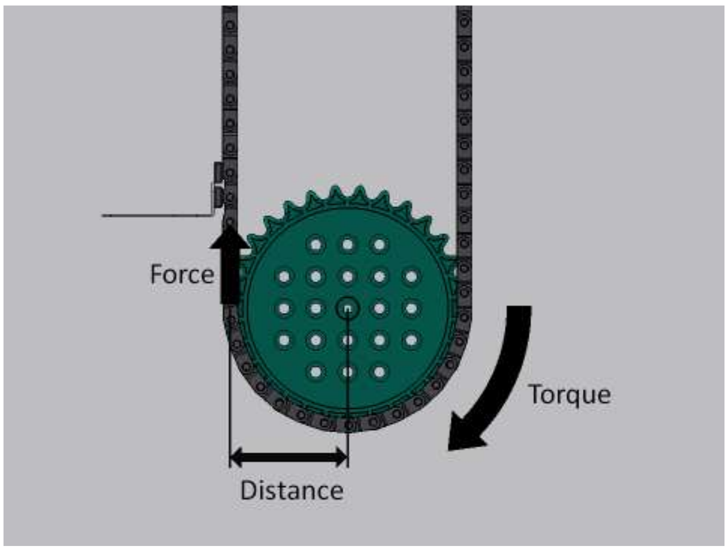


Elevator Actuation & Loading:

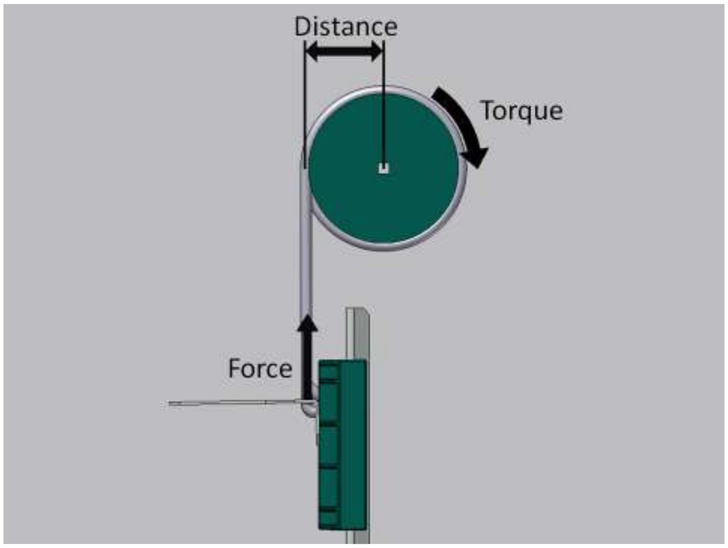
Actuation of a linear elevator is a little different than a rotating joint. Unlike a rotating joint, an elevator somehow must convert the rotary motion of a motor into the linear motion required to drive the elevator. There are several ways this is commonly accomplished.



In the above example a rack and pinion mechanism is used to drive the elevator. The pinion gear spins at some speed with an applied torque. This torque then applies a linear force at the gear's pitch circle, which drives the mechanism.



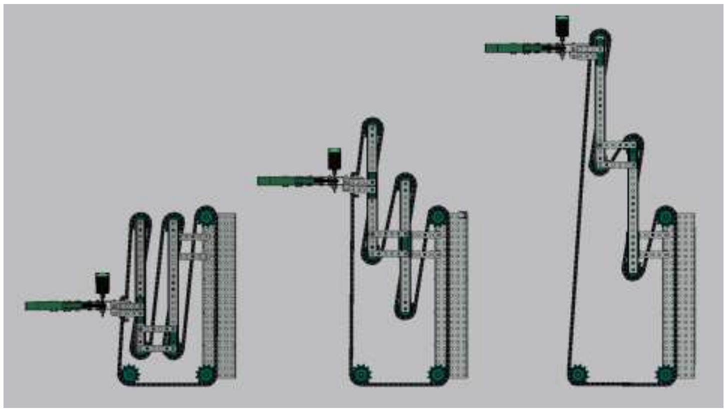
The above image shows how chain and sprockets can be used to drive a linear elevator. The torque on the driving sprocket spins the chain. The chain is attached to the linear elevator, and exerts a linear force to drive the mechanism.



In the above example, a winch is used to drive a linear elevator. A motor applies torque to the winch which provides a linear force along a rope, which then drives the mechanism.

Linear Slides:

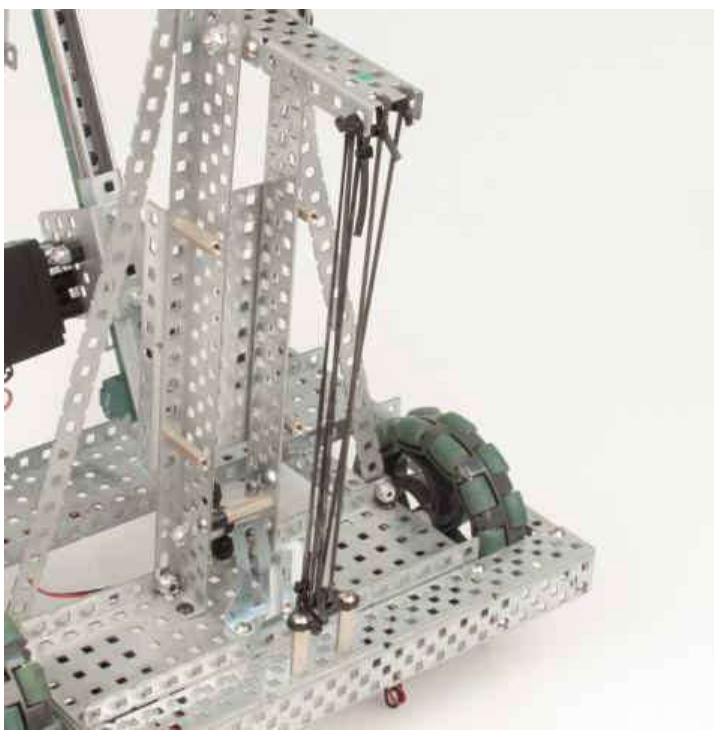
Single stage elevators are able to lift up only one extension of their length. That is, if the elevator is one meter tall, it will be able to lift a claw from the bottom to the top, a total of one meter. However, multiple stage mechanisms are also possible. By stacking multiple linear elevators together, one can create a mechanism which will reach up much higher than their own height.



https://www.youtube.com/watch?v=utKWU4w4M2A

https://www.youtube.com/watch?v=Pga6n5ZsJoA

Passive Assistance:



Oddities

Choo-Choo: https://www.youtube.com/watch?v=LooSBjSCGmE

Incredible: https://www.youtube.com/watch?v=Bi0Z8bZRHMQ

Robot Fight Club: https://www.youtube.com/watch?v=qsJ1JmxGMK8

Gladiator Fight: https://www.youtube.com/watch?v=qLp4phGL41s

FIRST Relic Recovery: https://www.youtube.com/watch?v=tNPvKb7-3xE

Thoughts that Will Destroy a Team

Analysis Paralysis – Don't be afraid to start just because victory is not assured. Be bold and take a step of faith. Successful people are those who forge a trail.

Groupthink – Don't be so afraid of offending or contradicting others that you go along with bad ideas. If you think that it is bad…it probably is.

Law of Triviality – Don't focus on the trivial just because it's easy. It is easy to mount a wheel but difficult to build a linear slide. Once you mount the wheel, move on and build the slide. If you do not know how to build a slide, then don't be afraid to ask for help.

Design by Committee – Don't lose sight of the big picture. We are here to solve a problem. Projects are often delayed in their inception due to too much information. Think about the information and if it is bad, move on.