CORC 3303

Exploring Robotics

Unit B:

Construction

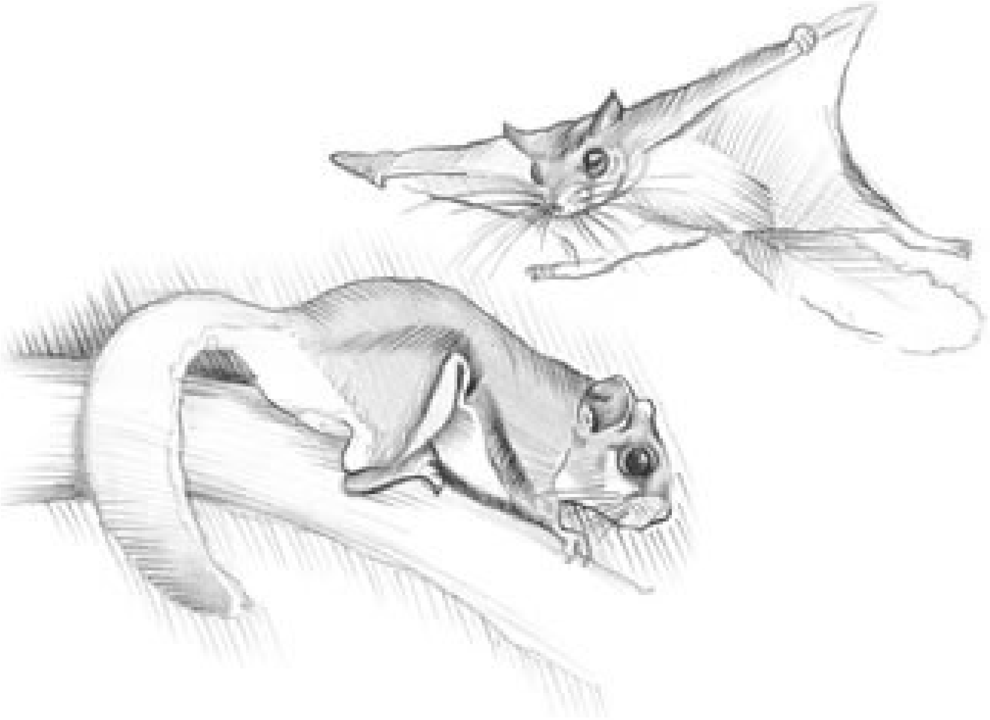
Effectors and Actuators

- An effector is a device on a robot that has an impact or influence on the environment.
- An actuator is the mechanism that enables the effector to execute an action or movement.
- In robots, actuators include electrical motors, chemically-sensitive materials and other technologies.
- These mechanisms actuate the wheels, tracks, arms, grippers and other effectors on robots.

Active vs. Passive Actuation

- Passive actuation utilizes potential energy in the mechanics of the effector and its interaction with the environment.
- In passive actuation there is no power consumption.
- An example of this in nature are the flying squirrels and their use of their flaps.

Passive Actuation



Active Actuation

- In active actuation an active consumption of energy for powering actuators takes place.
- One example is a gasoline car.
- Another example is the Lego Mindstorm rcx motors powered by a set of batteries.

http://www.kipr.org/curriculum/rcx/Botball_RCX_Start.html

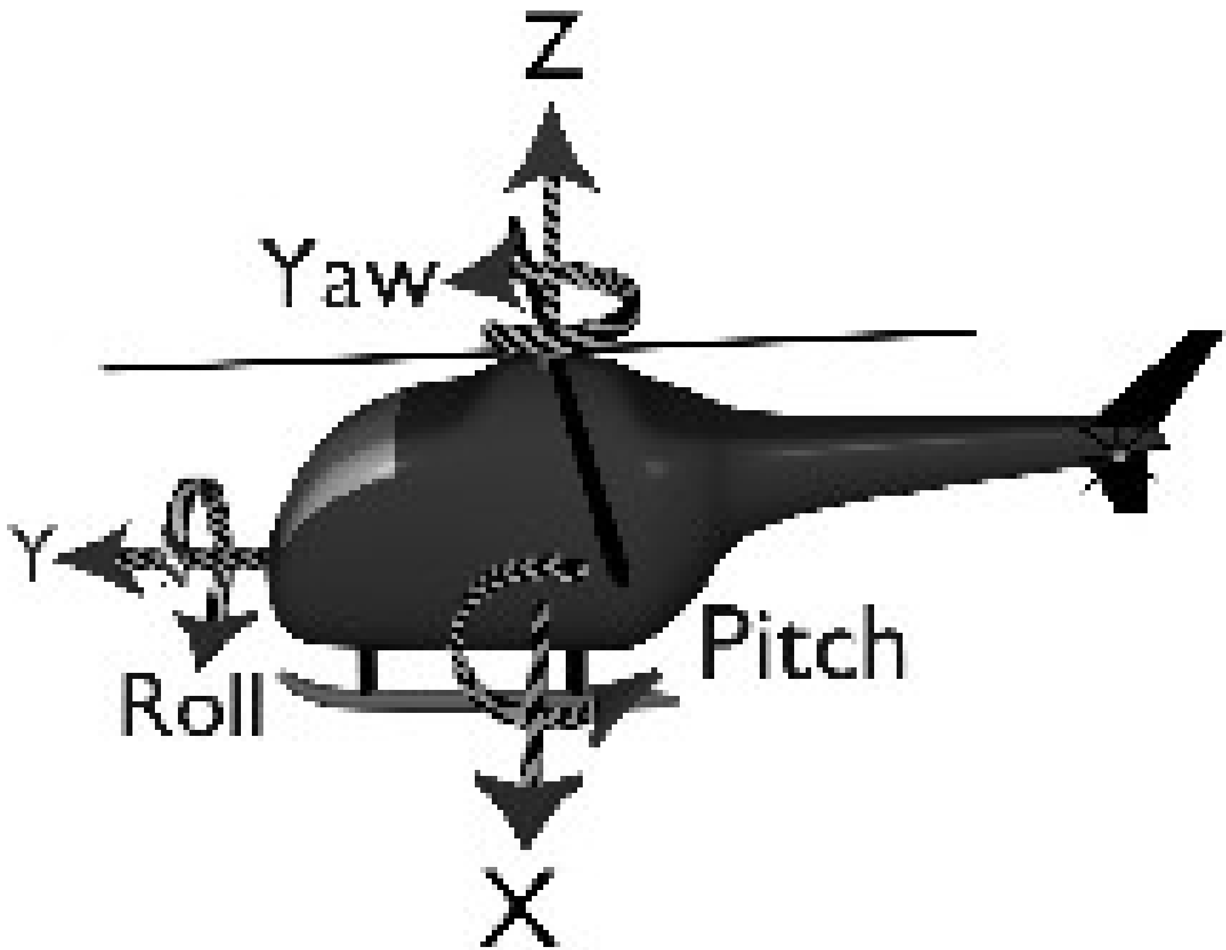
Effectors and DOFs

- A degree of freedom (DOF) is any of the minimum number of coordinates required to completely specify the motion of a mechanical system.
- Informally, this is akin to the way in which the robot can move.
- Knowing how many DOF a robot has is important in determining how it can impact its world and how well it can accomplish its task.

Degrees of Freedom

- A free body in 3D space has a 6 degrees of freedom.
- 3 of these are for describing position on the plane (Translational DOF) : x, y, z.
- The other 3 are for orientation (Rotational DOF) : roll, pitch, yaw.
- Note: joints introduce more degrees of freedom.

Degrees of Freedom



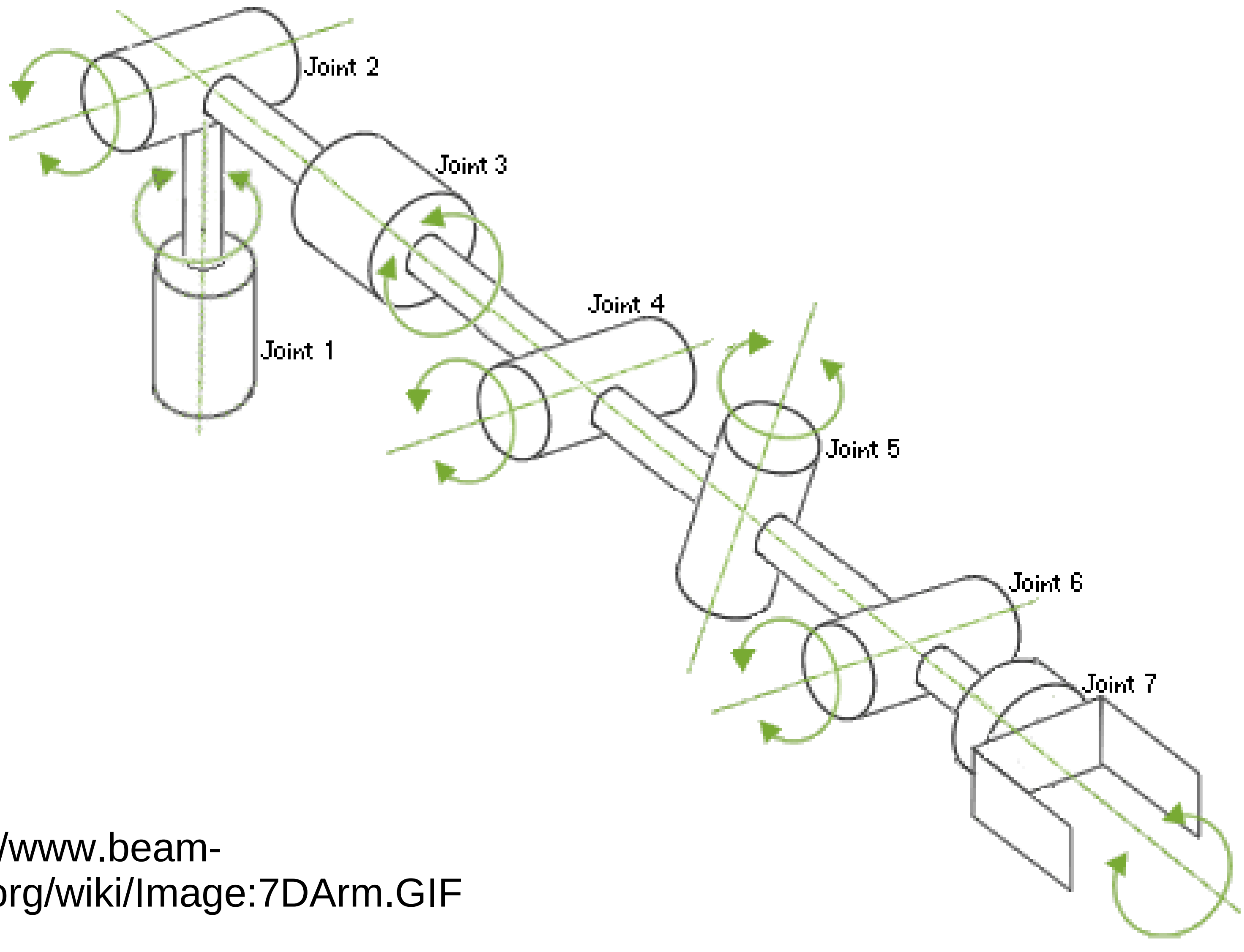
Degrees of Freedom

- If a robot has an actuator for every DOF, then all of the DOF are controllable.
- If Controllable DOF = Total DOF then the robot is said to be **holonomic**.
- If CDOF < TDOF then the robot is said to be **nonholonomic**.
- If CDOF > TDOF then the robot is said to be **redundant**.

DOF Human Arm Example

- A human arm, not including the hand, has seven DOF.
- The shoulder gives you pitch, yaw and roll.
- The elbow allows for pitch.
- The wrist allows pitch and yaw.
- Elbow and wrist allows for roll.

Degrees of Freedom



http://www.beam-wiki.org/wiki/Image:7DArm.GIF

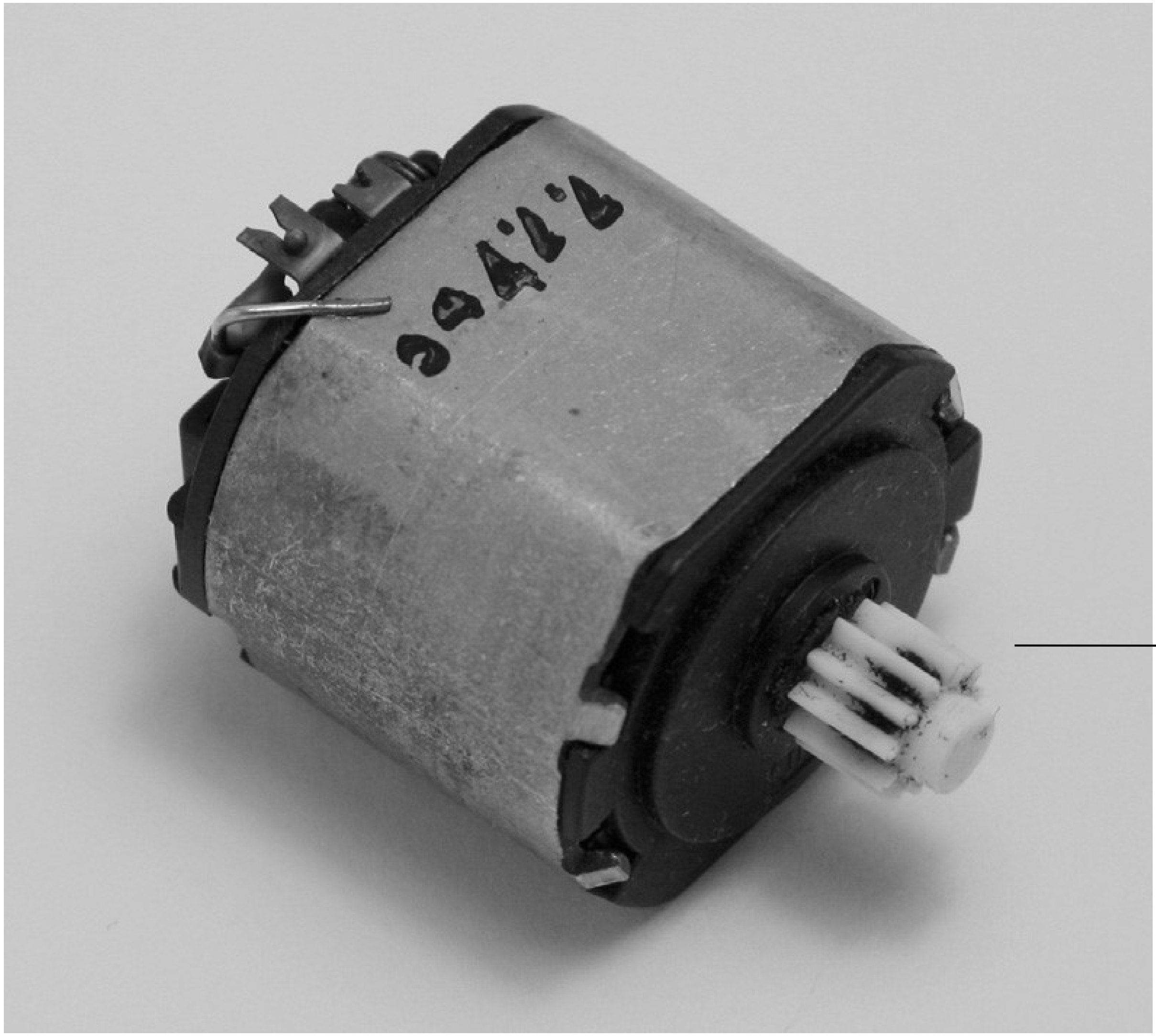
Motors

- Motors are the most common actuators in robotics.
- Motors provide rotational movement - roll.
- They are well suited for rotating wheels.

Direct-Current (DC) Motors

- DC motors are simple, inexpensive, easy to use and easy to find.
- Different sizes and packing methods provide accommodation to a variety of robots and tasks.
- Note: a good robot design matches all parts to the task to be performed.

Direct-Current (DC) Motors



Shaft

Direct-Current (DC) Motors

- To make the motor run, you need to provide it with electrical power in the right voltage range.
- If the voltage is low, but not too low, the motor will run but with less power.
- If the voltage is high, power of the motor is increased but it will succumb to ware and tear much sooner.
- With a good constant voltage in the right range, the motor will draw current in the amount proportional to the work it is doing.

Direct-Current (DC) Motors

- The more current the motor uses, the more Torque (rotational force) is produced at the motor shaft.
- The amount of power a motor can generate is proportional to its Torque and to the rotational velocity of its shaft.
- Amount of power : Torque x Rotational Velocity.
- If the motor is spinning with nothing attached to its shaft then Rotational Velocity is at its highest but Torque is zero. Hence output power is also zero.

Direct-Current (DC) Motors

- When the motor is stalled (e.g. rcx robot is pushing against an unmovable wall), Torque is at its maximum but Rotational Velocity is zero. Here again output is zero.
- On average an of the shelf DC motor have free-spinning speeds in the range of 50 to 150 revolutions per second (rps).
- This means they produce high speed but low Torque (Rotational force), hence they are suited for driving light objects that rotate very fast.

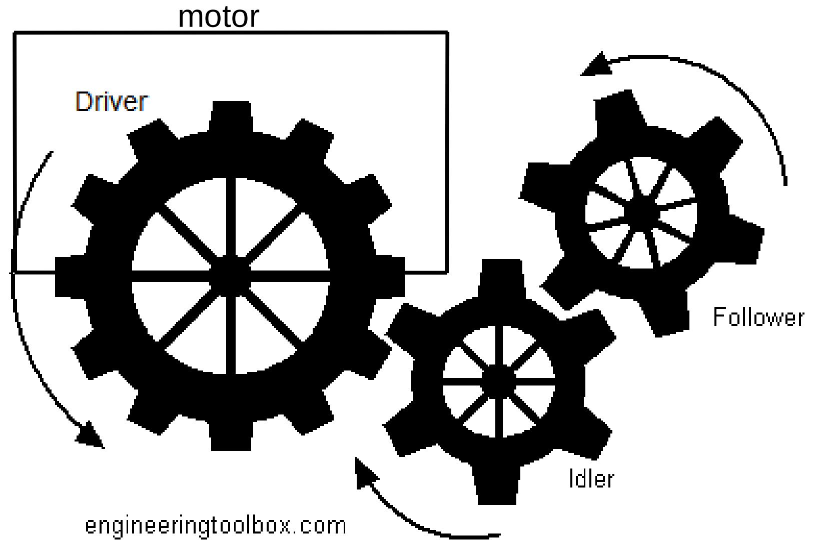
Gears

- Most of the times, robots need to pull the loads of their bodies, turn their wheels and lift their manipulators which amounts to a considerable quantity of mass.
- So, how do we use these motors which are suited for driving light objects to drive heavier things?
- Through the usage of gears you can change the force and torque output of motors.
- The force generated at the edge of a gear is the ratio of the Torque to the Radius of the gear.
- Combining gears with different radii is a way of manipulating the amount of force and Torque that is generated by a motor.

Gear Terminology

- A gear that is connected to a power source (e.g. a motor) is called a **driver** or **input gear**.
- A gear that is connected to a wheel or other effector is called a **follower**, **output** or **driven gear**.
- A gear that is located between two other gears, transferring power from one to the other, is called an **idler gear**.

Gear Terminology



Note: Adjacent gears rotate in opposite directions.

Function of Gears

- Gears can change planes of rotation.
- Gears can transfer motion.
- Gears can increase/decrease speed (gearing up, gearing down).
- Gears can increase/decrease power Torque
- Gears can change direction. Idler gear only changes direction. It does not affect gear ratio (speed).

Gear Ratios and Torque

- You can calculate the “gear ratio” by using the number of teeth of the “driver gear” divided by the number of teeth of the “follower gear”.
- If driver gear has 8-teeth and follower gear has 24-teeth, the gear ratio of these two gears is 3:1.
- Remember that Torque is a measure of how much a force acting on an object causes that object to rotate.
- Torque must overcome friction (and gravity if in an incline) to move the wheels of a vehicle.

Gearing and Torque

- When a small gear drives a large one, Torque is increased and speed is decreased.
- Using gears to make your robot go slower is called **gearing down** where small small gear is the driver and large gear is the follower. If your robot is going uphill, you will need more Torque.
- When a large gear drives a small one, Torque is decreased and speed is increased.
- Using gears to make your robot go faster is called **gearing up** where a large gear is the driver and a small gear is the follower.

Tradeoffs

- Robot design often requires compromises among conflicting factors in order to achieve the desired results.
- A larger wheel can yield an increase in linear velocity, but results in less force pushing the robot forward.
- “gearing down” produces an increase in Torque but also causes a decrease in rotational speed.
- “gearing up” produces an increase in rotational speed but also causes a decrease in Torque.