Sensors

Types of Sensor

- **Propriocpetive:** Measures internal state of system. (Eg. Gyroscope)
- **Exteroceptive:** Measures external environment. (Eg. GPS)
- **Passive:** Measures ambient environment. (Eg. Camera)
- **Active:** Measures response of environment to energy emitted from a sensor. (Eg. Ultrasonic sensor)

Sensor Performance

Remember SCEAP!

- **Sensitivity:** Degree to which change in target input results in a sensor output.
- **Cross-Sensitivity:** Sensitivity to external disturbance from environment.
- **Error:** Deviation between actual and measured value
  2 main types of error:
  - Systematic: Errors that can be modeled and compensated for.
  - Random: Error that can be modeled probabilistically.

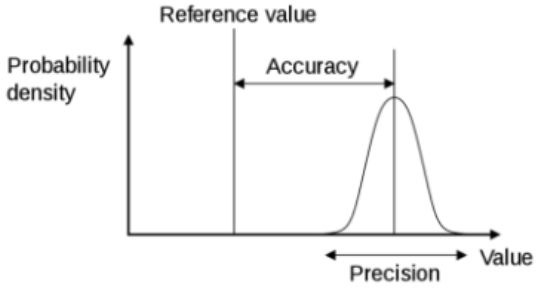
```
Error = m - v

m = measured value
v = actual value
```

- **Accuracy:** Conformity between actual value and measured value.

```
accuracy = 1 - (|error|/v)
```

- **Precision:** Degree of agreement between multiple measurements of the same environment state.

$$precision = \frac{range}{\sigma} \propto \sigma^{-1}$$

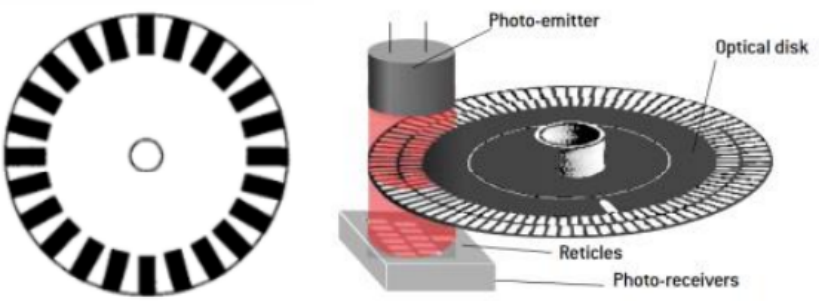


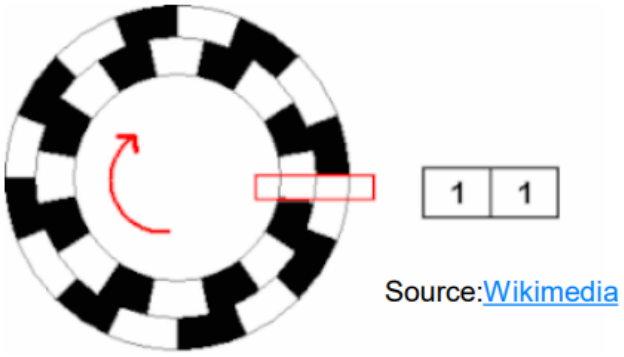
Sensors

Wheel Encoders

Optical Encoder

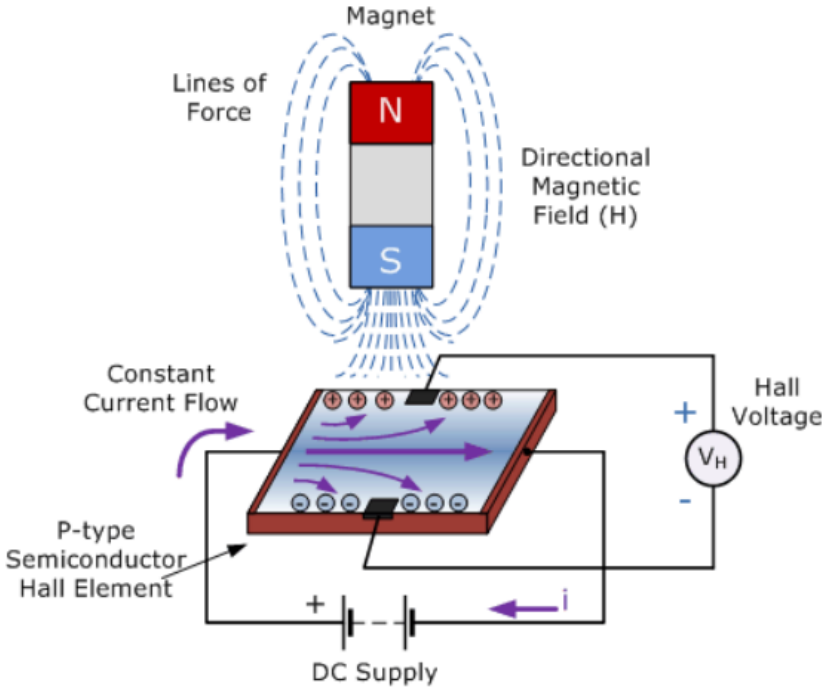
Disk attached to the wheel shaft with periodic pattern of opaque and transparent regions. Light source on one side of disk with a sensor on the other. Wheel rotation produces a series of pulses proportional to the rate of rotation. To get direction a Quadrature incremental encoder is used. This has 2 patterns that are 90 degrees out of phase.





Digital Compass

Uses Hall effect or Flux gate.
Hall effect:
- Voltage induces current across semiconductor.
- Magnetic field perturbs electrons, inducing a second voltage difference perpendicular to the flow.



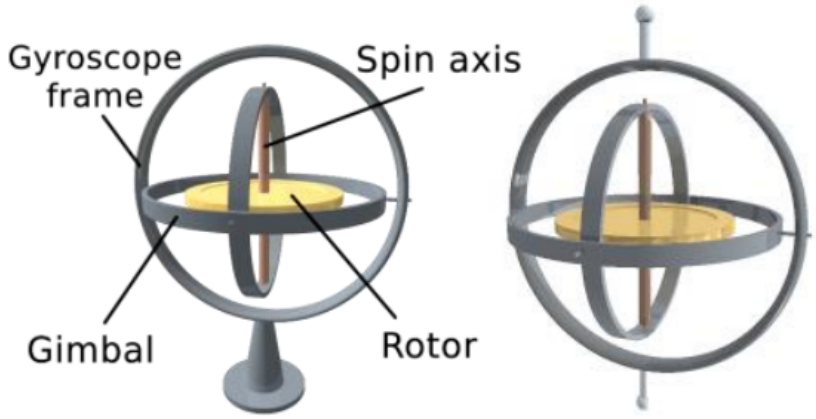
Gyroscopes

Provides orientation or angular velocity (Rate Gyro).

Mechanical

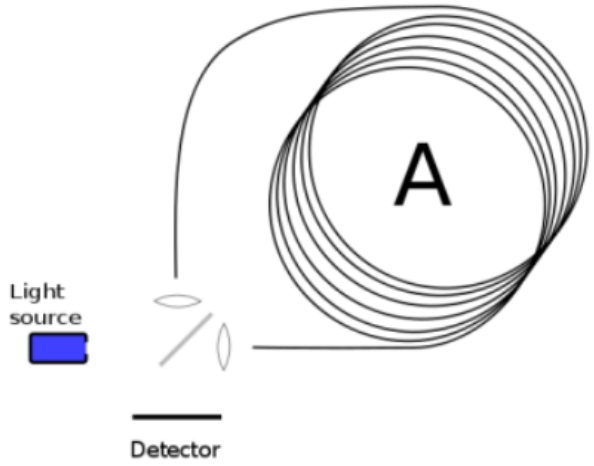
- Spinning proof mass.

- Maintains orientation due to conservation of angular momentum.



Fibre Optic

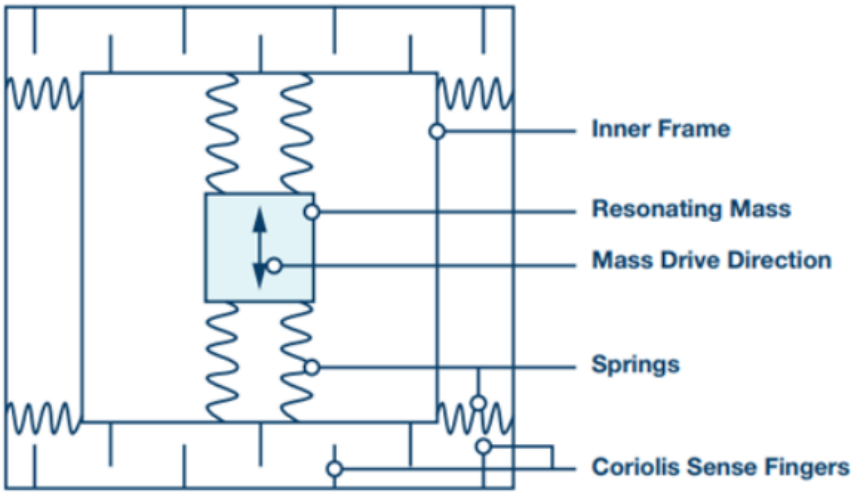
- Based off Sagnac effect.
- Coherent laser is passed simultaneously though opposite ends of a fibre optic.
- Rotation causes path shortening opposite to direction of rotation.
- Path shortening causes a phase shift.



MEMS

MicroElectroMechanical System are small scale IC based angular velocity sensing gyros.

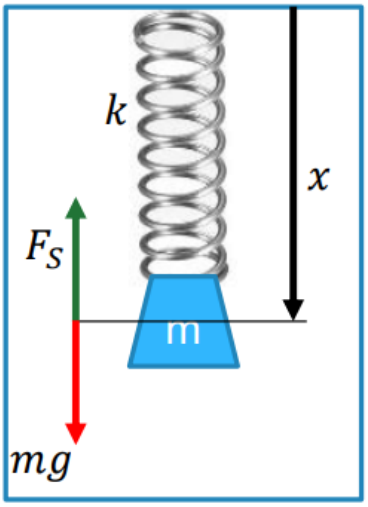
- Vibrating mass to sense Coriolis acceleration in direction of rotation.
- **Coriolis sense fingers** measure the capacitive transduction do to deflection of the inner frame relative to the outer frame



Accelerometers

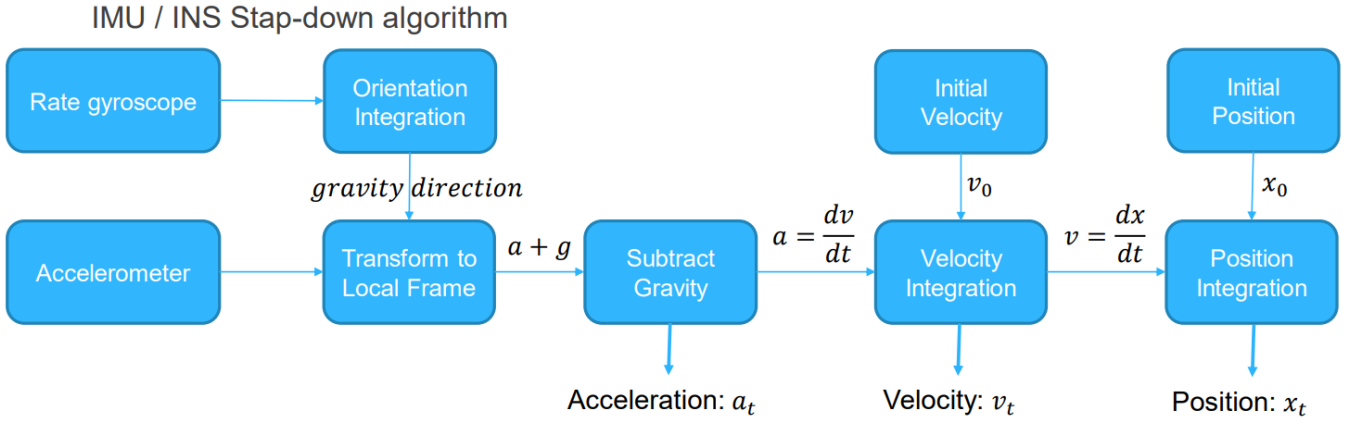
Measure linear accelerations using something similar to a spring-mass-damper.

```
k = spring constant
x = displacement of mass
a = acceleration of accelerometer
g = acceleration due to gravity
m = mass of proof mass

a + g = kx/m
```



Intertial Measurement Units

IMU's (aka INS) combines 3 gyros and 3 axes accelerometers to calculate relative position, velocity, and acceleration. Can also contain GPS to combine several mesurements for better results. Can be used in a GPS outage.



Global Navigation Satelite System

System of satellites that transmit positioning and timing data to recievers.

- Satellites transmit synchronised signals based on accurate clocks
- Signal is a 1023 pseudo random number (PRN)
- Reciever computers propagation time by evaluating shift of PRN relative to time t=0

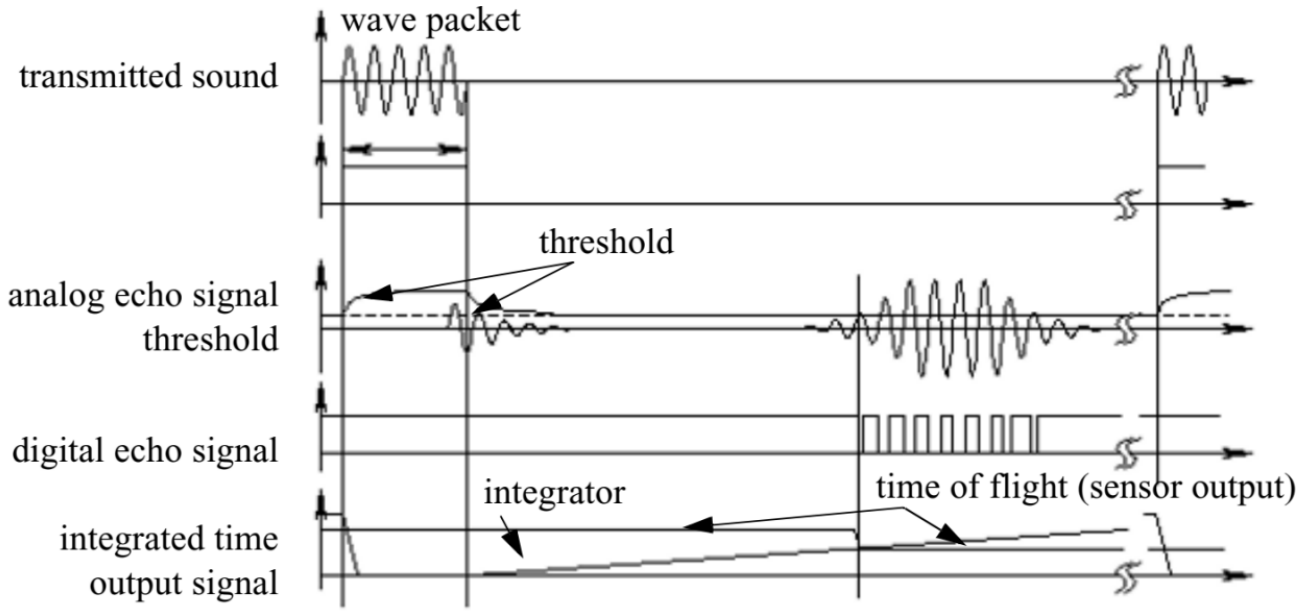
```
d = ct

computing d for multiple satellites allows trilateration of position
```

- 3 satellites for position plus one for time sync

Ultrasonic Sensors

Emits ultrasonic waves and computes distance based on RTT. Low frequency = higher range. Can have poor angular resolution and low bandwidth.

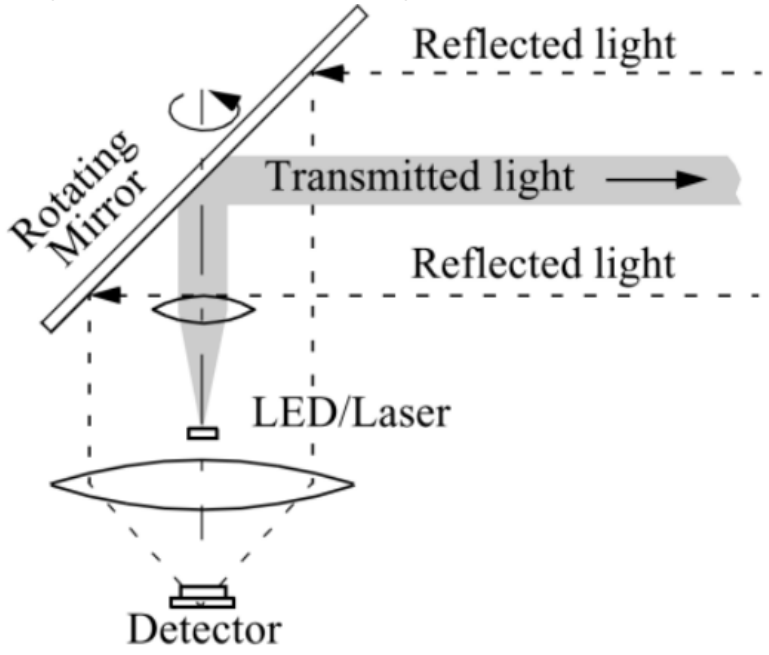
```
d = (ct)/2
c = 343m/s
t = time
```



Lidar

Calculates distance based on a ToF sensor.

- Emits laser pulse
- Laser pulses reflect from the scene
- High speed system measures RTT
  Rotating a 2D lidar system or combining multiple lasers can achieve a 3D scan.



RGBD

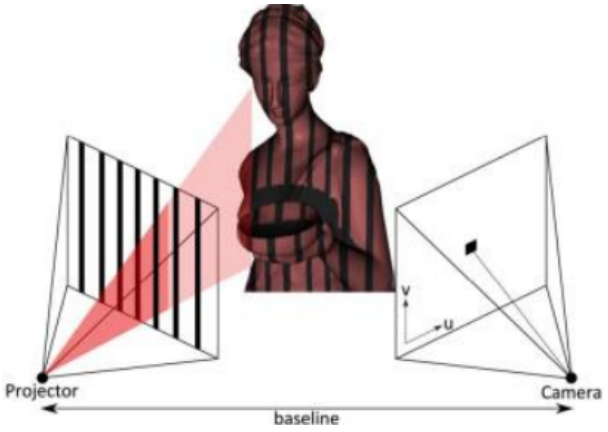
Red Green Blue Distance. Used to enable depth sensing with cameras.

Structured Light

Image data combined with IR camera data. Based on optical triangulation. Bypasses feature maching though projecting a known pattern. Depth is determined by:

```
d = (bf)/m
b = baseline
f = focal length
m = desparity
```

- Low cost, high FPS
- Sunlight causes interferance. ToF limited to spatial resolution.
- Used in Kinect V1



ToF

Uses high speed near infrared (NIR) light source. Sensor measures reflected illumination. Light is pulsed at period Δt. Every pixel samples in 2 out of phase time windows C1 and C2.

$$d = \frac{1}{2} c\Delta t \left(\frac{Q_2}{Q_1 + Q_2} \right)$$

c: speed of light

Q_i: charge collect in integration window C_i