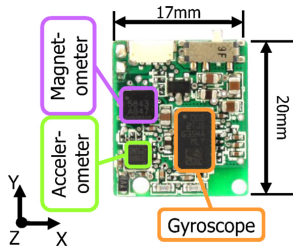


IMU – Inertial Measurement Unit

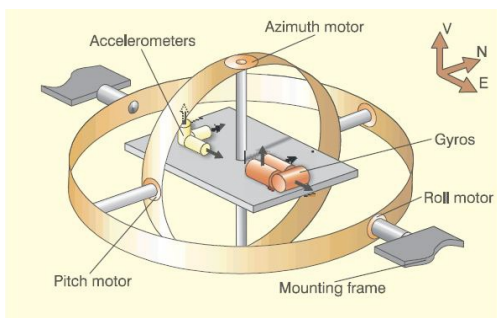


What is in an IMU?

- Gyroscopes -> Angular Velocity (radians/s)
- Accelerometer -> Linear Acceleration (m/s² or g)
- Magnetometer -> Magnetic field strength (micro-Tesla or Gauss)

In addition, sometimes, barometric or GPS measurements are integrated in an IMU as well.

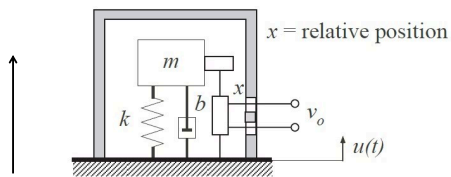
IMU – Inertial Measurement Unit



IMU: Principle of Operation

1. An object either remains at rest or continues to move at a constant velocity, unless acted upon by a force.
2. The vector sum of the forces **F** on an object is equal to the mass **m** of that object multiplied by the acceleration **a** of the object: **F = ma**.
3. When one body exerts a force on a 2nd body, the 2nd body simultaneously exerts a force equal in magnitude and opposite in direction on the 1st body.

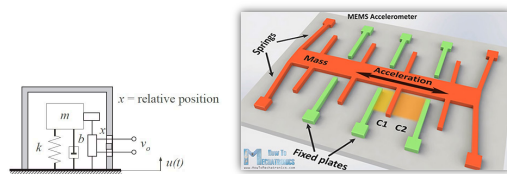
Accelerometer



When m accelerates, it will experience a force, which will cause spring K to move. The displacement of k can be measured through sensor x , and the force F can be sensed as a result. Given F and m , the acceleration \ddot{x} can be measured based the Newton's 2nd law.

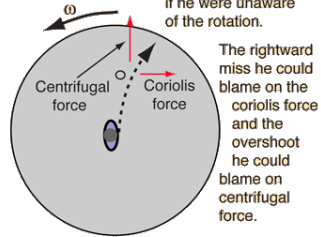
$$\ddot{x} = F/m$$

Accelerometer



Coriolis and Centripetal Forces

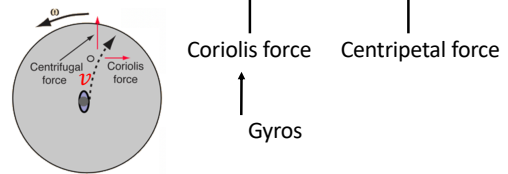
A golfer who is putting the ball from the center of a rotating platform would tend to miss to the right and overshoot the hole if he were unaware of the rotation.



Coriolis and Centripetal Forces

$$\vec{a}_i = \vec{a}_r + 2\vec{\omega} \times \vec{v}_r + \vec{\omega} \times (\vec{\omega} \times \vec{r}_r)$$

$$m\vec{a}_i = m\vec{a}_r + 2m\vec{\omega} \times \vec{v}_r + m\vec{\omega} \times (\vec{\omega} \times \vec{r}_r)$$

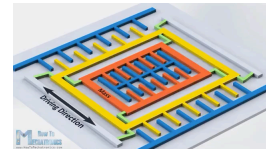
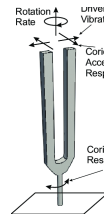


Gyroscope or Gyro



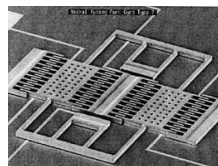
Newton's first law of motion states: a body in motion will remain in motion unless it is acted upon by an external force.

Gyroscope: tuning fork design



Tuning fork design uses two tines that resonate (\vec{V}). Coriolis force is detected either as differential bending of the tines or as a torsional vibration of the tuning-fork stem, along direction that is orthogonal to the main vibration. From the Coriolis force, angular velocity ($\vec{\Omega}$) can be calculated.

Gyroscope or Gyro



Three gyroscopes along three principal axes provide three angular velocities whose integration results in angular change (odometry). Modern gyros are built with MEMS (right).

Gyroscope applications



Gyros are responsible for UAV control, ESC (electronic stability control) for cars to prevent rollovers, Wii by Nintendo, video games on smart phones, etc.



Summary

- IMU uses gyroscopes to measure angular velocities and accelerometers to measure accelerations, about the three axes.
- Integration of angular velocity over a short time interval provides angular change.
- Double integration of acceleration over a short time interval provides linear change.
- IMU is inexpensive but requires calibration and is subject to ambient noise in environments.

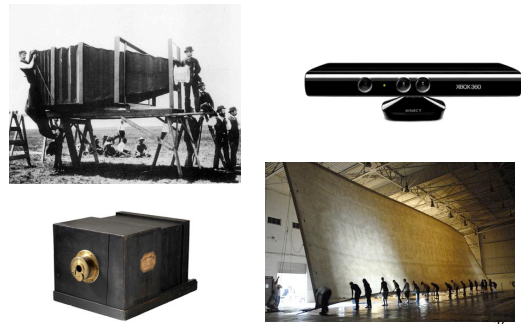
Cameras and Images

- Why camera?
- Images and Pixels
- Image formation
- Coordinate frames: image, camera, and world (map)
- Camera calibration: intrinsics and extrinsics

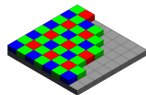
Why camera?

- Vision provides rich information about the world in which a robot operates (humans derive 80-90% of information from vision).
- Types of information computed with vision in robotics:
 - Geometry of a scene (SfM, single-image depth, surface normal)
 - Robot motion (visual odometry)
 - Object detection (pedestrians, cars, doors, windows, etc.)
 - Object classification (scene semantics)

Cameras



Images and pixels



- A camera captures either color or grayscale images.
- Each grayscale image is a matrix of N columns and M rows (e.g., 640x480).
- A color image consists of three separate images, one for each color component or channel (e.g., RGB).
- A color image can be captured with one array of lighting sensing elements covered with a Bayer filter mosaic or three separate arrays.
- Each element of an image array is called a picture element or pixel, indexed by its column and row number.
- The intensity (grayscale or a color channel) value of a pixel is encoded typically in 8-bits (0-255).
- Therefore, a grayscale image is just an array of 8-bit numbers, which a computer vision algorithm processes to extract info.

Images and pixels

