EC4.404: Mechatronics System Design

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General Information

Mechatronics: Study of the integration of mechanical hardware, electrical/electronic hardware with computer hardware and software. Named by Tetsuro Mori from Japan when working with Yaskawa Electric Coorporation.
Applications: Robotics, Aerospace industry, automotive industry, process industry etc.

Course Objective: To introduce the design and development of a mechatronic system.
Instructors: Harikumar Kandath and Nagamanikandan Govindan.

Sensors in Ground Robot

- Wheel Encoder
- Magnetometer
- Inertial Measurement Unit (IMU): contains Accelerometer and Gyroscope.
- Global Positioning System (GPS)
- Range measuring sensor (LIDAR, ultrasonic, camera)

Sensors in UAV

- Inertial Measurement Unit (IMU) contains Accelerometer and Gyroscope.
- Altimeter
- Airspeed sensor
- Magnetometer
- Global Positioning System (GPS)
- Range measuring sensor (LIDAR, ultrasonic, RADAR, camera)

Sensors in Robotic Manipulator

- IMU
- Encoder
- Force-Torque sensor
- Camera

Wheel Encoder

- Hall effect sensor
- Ring magnet

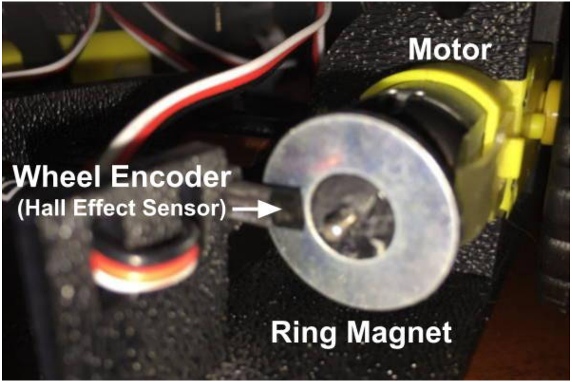


Figure: Wheel-Encoder

Hall Effect Sensor

$$V = \frac{R_H}{t} IB \tag{1}$$

$R_H=$ Hall coefficient (m^3/C), $t=$ thickness (m), $I=$ current (A), $B=$ magnetic flux density (T).

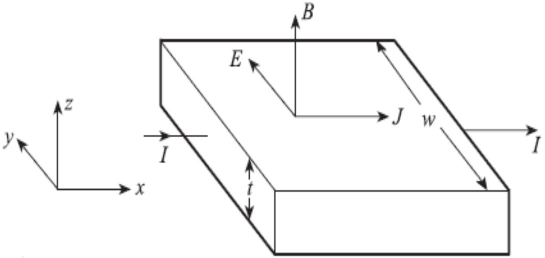


Figure: Diagram explaining Hall effect

Ring Magnet

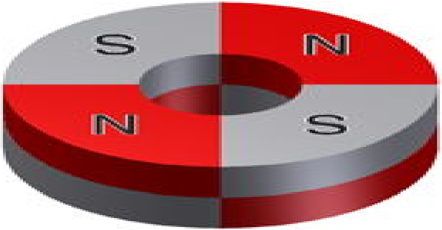


Figure: Ring Magnet

Distance and Speed Calculation

Motor gear ratio $(1:N)$, robot wheel radius r (m),number of magnetic poles P, Distance moved by robot D (m) per pulse.

$$D = \frac{2\pi r}{NP} \tag{2}$$

Number of pulses per second N_p. Speed of robot V in m/s.

$$V = DN_p = \frac{2\pi r N_p}{NP} \tag{3}$$

Position Estimation (Odometry)

$$\frac{dx}{dt} = v_x = V \, cos \, \psi \tag{4}$$

$$x(t) = \int_0^t V \, cos \, \psi \, dt + x(0) \tag{5}$$

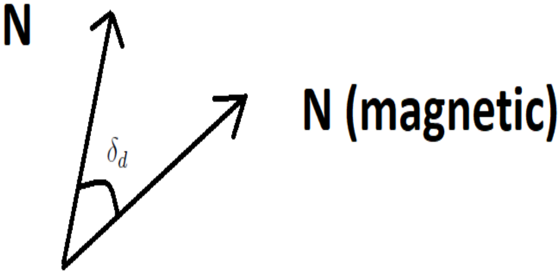
$$\frac{dy}{dt} = v_y = V \, sin \, \psi \tag{6}$$

$$y(t) = \int_0^t V \, sin \, \psi \, dt + y(0) \tag{7}$$

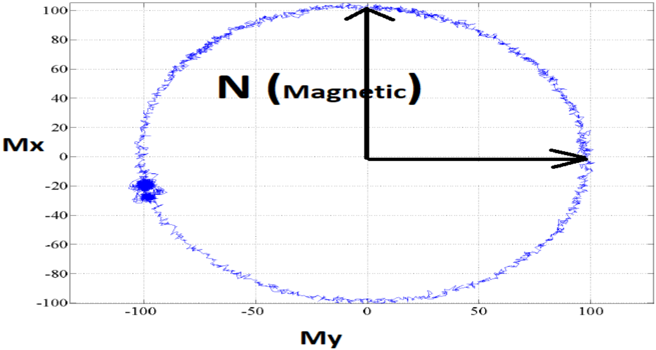
NB: Errors in the measurement of V and ψ will lead to error in the above-mentioned position estimate.

Magnetometer

Magnetometer measures the strength of the magnetic field based on Lorentz force (current carrying conductor experiences a force proportional to the magnetic field).
Magnetic field of earth varies from 0.25 to 0.65 Gauss. The true north direction of earth and magnetic north of earth varies by the angle of declination δ_d as shown below.



Magnetometer Reading



Two axis magnetometer reading is plotted above when rotated from 0^o to 360^o. If the above given axis is taken as the inertial XY axis for the robot motion (X along N (magnetic), then yaw angle ψ is given by

$$\psi = tan^{-1}(\frac{M_y}{M_x}) \tag{8}$$

Limitations of using only wheel encoder and magnetometer for odometry

- The angle ψ will not change when computed using magnetometer if the robot can move sideways without changing the orientation.
- Error in wheel encoder based speed estimation during wheel slip. Slip is a condition where wheel rotates without changing the position of the robot as observed in the normal case (i.e. one complete rotation of the wheel does not corresponds to a distance of $2\pi r$) .

THANK YOU