Lecture 8: Inertial Sensing & Acoustic Attacks
Lecture Outline

- Logistics update
- Overview of Inertial Sensing
- WALNUT
- BackDoor
- MUTE
- Project meetings
Post-Mid-semester Grade Update

Reminder Re: Grading:

• 1 Course Project (60%)
• 1 Paper Presentation (10%)
• Participation (30%)
  • Includes submitting reviews before every lecture (15%)
  • Attendance is mandatory (15%)
  • May skip one review without affecting grade

Other logistics:

• 17 paper reviews => score = (# full reviews submitted) / 16
  • Get bonus points if you submit all 17
Types of IMUs?

- **Gyroscope** measures angular velocity $\omega$ in degrees/s

- **Accelerometer** measures linear acceleration $a$ in m/s$^2$

- **Magnetometer** measures magnetic field strength $m$ in $\mu$T (micro-Teslas).

Why is it called IMU?
History of IMUs

- Earliest use of gyroscopes goes back to German ballistic missiles (V-2 rocket) in WW2 for stability

- In the 1950s, MIT played a central role in the development of IMUs (Instrumentation Lab)
Uses/Applications of IMUs?
How Accelerometers Work

Mass on spring

How does it deform at rest?
Free fall?
Linear acc in x direction?

1g = 9.8 m/s²
How Accelerometers Work

What matters is the displacement
Newton's Law  

\[ F = ma \]

Hook's Law  

\[ F = kx \]

\[ = > a = \frac{k}{m}x \]

Why not simply use displacement to measure displacement?
Measuring Displacement

• How do we measure displacement?
• Most common approach is to use capacitance and MEMS (Micro electro-mechanical systems)
Measuring Displacement

• How do we measure displacement?
• Most common approach is to use capacitance and MEMS (Micro electro-mechanical systems)
MEMS Accelerometer

Mass
Capacitor

\[ C = \epsilon \frac{\text{Area}}{x} \]
2D Inertial Navigation in Strapdown System

\[
\begin{bmatrix}
    a_N \\
    a_E
\end{bmatrix} =
\begin{bmatrix}
    \cos\psi & -\sin\psi \\
    \sin\psi & \cos\psi
\end{bmatrix}
\begin{bmatrix}
    a_X \\
    a_Y
\end{bmatrix}
\]

Source: Basic Principles of Inertial Navigation
Seminar on inertial navigation systems
Tampere University of Technology
2D Inertial Navigation in Strapdown System

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\]

\[V_N(t) = V_N(t_0) + \int_{t_0}^{t} a_N(t)\,dt\]
\[X_N(t) = X_N(t_0) + \int_{t_0}^{t} V_N(t)\,dt\]

\[V_E(t) = V_E(t_0) + \int_{t_0}^{t} a_E(t)\,dt\]
\[X_E(t) = X_E(t_0) + \int_{t_0}^{t} V_E(t)\,dt\]