21M.370 Digital Instrument Design
IMUs

1. IMU, MARG, acc, gyro, magnetometer
    1. Naming:
        1. IMU : inertial measurement unit
        2. MARG: Magnetic, angular rate, gravity
    2. 6Dof vs 9 DoF
        1. Degree of Freedom: unique qualities of motion
        2. Acceleration XYZ
        3. Rotation XYZ (Gyroscope)
        4. Position relative to Magnetic North XYZ (Magnetometer)
    3. Accelerometer: acceleration
    4. Gyroscope: angular velocity
    5. Magnetometer: position relative to magnetic north
        1. magnetometer is slow
        2. can be laggy
2. what do we want to measure?
    1. movement
    2. amount, direction
        1. position
        2. absolute or relative
    3. (angle) / tilt
        1. yaw pitch roll
    4. quality of motion (straight/curved)
    5. recognize postures
    6. recognize gestures
3. Qualities of movement
    1. static position
    2. velocity - constant movement

3. acceleration - change of velocity

4. jerk - change of acceleration

5. acc + gyro don't give us what we want: angle (position) and velocity

4. Signal processing

    1. scaling

        1. change range of values

        2. change curve of values

        3. clip to prevent values from exceeding a range

    2. differentiation, integration

        1. differentiation: output = input - prevInput

            1. change in signal values removes offsets (static values)

            2. differentiation order: position->velocity->accel->jerk

        2. integration: output = input + prevInput

            1. integrates errors in the signal, which must be compensated for

            2. integration order: jerk->accel->velocity->position

5. accelerometer

    1. Positive qualities: responsive, direct, jitter, but no drift

    2. But doesn't give us velocity without integrating acceleration

    3. acceleration is both movement and gravity

        1. accel due to gravity is often used for tilt, but axes interact

        2. can we remove gravity?

            1. calculate jerk and then reintegrate

            2. but instantaneous changes in angle will reintroduce gravity. . .

    4. more accurate tilt

        1. calculate angle between

    5. overall magnitude

    6. vector angle

7. velocity:
   1. integrate acc measurements
   2. lots of drift
8. position
   1. integrate velocity
   2. unusable
9. jerk
   1. 1st derivate of acceleration
   2. change of acceleration
   3. used to detect sudden movements

6. gyroscope
   1. measure angular velocity, or speed of rotation
   2. [Gyroscope - learn.sparkfun.com](https://learn.sparkfun.com/tutorials/gyroscope/all)
   3. low jitter, good resolution
   4. integrate to determine angle
      1. very higher drift, unusable as is
      2. use high pass filter to remove drift

7. sensor fusion
   1. combine gyro and accel
      1. kalman filters
      2. complementary filters
         1. gyro * gyroWeight + accel * (1-gyroWeight)

8. output signals
   1. raw accel and gyro
   2. tilt
   3. velocity
   4. velocity magnitude