IMU Calibration System Documentation

To run:

- First Run the CalibParams.m file
- Run the Simulink model (Imu_sensor_module).
- Finally run ImuCalibrationGui.m file for,
  - Capturing data for bias and scale factor estimation
  - Estimating calibration parameters.
  - Visualizing sensor outputs before and after calibration.
  - Saving calibration profiles for later use

Model Structure

The IMU calibration system consists of four interconnected subsystems:

Input Processing Subsystem:

- Accepts three primary inputs: Acceleration (3×1), Angular velocity (3×1), and Quaternion (4×1)
- Processes quaternions through normalization function to ensure unit magnitude
- Converts quaternions to Direction Cosine Matrix (DCM) for proper frame transformation
- Applies matrix multiplication to transform acceleration and gyroscope measurements

Accelerometer Model:

- Implements a 3-axis (X, Y, Z) accelerometer with error characteristics
- Each axis includes:
  - Gain blocks (Gain_X, Gain_Y, Gain_Z) for scale factor modeling
  - Constant bias blocks (0.01 m/s^2 default values)
  - Random noise generators (Noise_X/Y/Z)
  - Drift components with integrators to simulate time-varying errors
  - Summing junctions to combine all error components

Gyroscope Model:

- Implements a 3-axis (X, Y, Z) gyroscope with error characteristics

- Each axis contains:
    - Gain blocks (Gain_X/Y/Z_gyro) for scale factor modeling
    - Bias blocks for constant offsets
    - Noise generators to simulate random measurement noise
    - Drift components with integrators to model temporal instability
    - Summation blocks to combine true signal with error components

Calibration Subsystem:

- Processes raw sensor outputs (acc_out, gyro_out)
- Outputs both raw measurements (Accel_meas, Gyro_meas) to workspace
- Produces calibrated measurements (Calibrated_acc_output_x/y/z, Calibrated_gyro_output)
- Applies bias and scale factor corrections from calibration parameters

Calibration Process

The calibration process follows these steps:

1. **Simulation Setup**:
    - Configure simulation to run for 10 seconds (as seen in time settings)
    - Initialize sensor inputs from workspace or signal generators
2. **Sensor Error Modeling**:
    - Accelerometer and gyroscope measurements incorporate:
        - Scale factor errors (via Gain blocks)
        - Fixed biases (0.01 default values)
        - Random noise (Band-Limited White Noise blocks)
        - Temporal drift (through integrator chains)
3. **Error Parameter Estimation**:
    - Collect raw sensor measurements from simulation
    - Compute mean values to determine bias offsets

- Calculate measurement ranges to determine scale factors
- Apply correction algorithm: Calibrated = (Raw - Bias)/Scale

4. **Validation**:
    - Output signals include both raw and calibrated measurements
    - Visualization allows comparison between original and corrected signals

Assumptions

1. **Sensor Error Model**:
    - Linear error model with additive bias and multiplicative scale factor
    - Uncorrelated noise characteristics between axes
    - First-order drift characteristics (integrator-based)
2. **Coordinate Transformation**:
    - Quaternion-based attitude representation
    - Proper frame alignment through Direction Cosine Matrix conversion
3. **Calibration Limitations**:
    - Fixed bias and scale factor parameters (no temperature compensation)
4. **Implementation Constraints**:
    - 10-second simulation timespan
    - Sample rate determined by solver configuration
    - Noise parameters fixed during simulation

The model provides a comprehensive framework for IMU calibration with realistic sensor error characteristics and a structured calibration procedure.