# Project #2: Orientation Tracking

## ESE 650: Learning in Robotics

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**Implementation Details:**

**Bias Estimation and scaling:**

The bias of the accelerometer and gyroscope is first measured by averaging the raw IMU data over the first 100 samples when the setup is stationary. The bias of the gyroscope is just mean of the readings. For accelerometer the mean of the first 100 samples will correspond to a vector g pointing down ie. [0; 0; -1]. Thus using this information and sensitivity from the dataset the accelerometer and gyroscope readings are processed to get 3D vectors.

**Synchronization of timestamps:**

The timestamps from the IMU unit, Vicon unit and Camera are first synchronized (synchronize_ts.m) by comparing difference between each pair of timestamps and choosing only those timestamps less than a threshold (0.001s since the IMU data comes at 100Hz).

**Algorithm**

Unscented Kalman Filter with 4 states consisting of unit quaternions was used for filtering the data.

**Process Model:** The gyroscope was assumed to be less noisy and in the process model directly. The sigma points were found by Cholesky decomposition of the State Covariance + Process noise covariance and were projected ahead in time.

**Measurement Model:** The measurement step consists of finding the difference between the measured accelerometer reading from the IMU data and the predicted measurement.

**Covariance Matrix initialization:**

State covariance matrix P (3x3) – Initialized to covariance of the entire accelerometer readings.

Process noise matrix Q (3x3) – Initialized to random diagonal matrix with elements between 0 and 1

Measurement noise matrix R (3x3) – Initialized to random diagonal matrix with elements between 0 and 1

**Result Comparison Setup & Sanity Check:**

The Vicon output, the raw accelerometer data converted to rotation matrix and the output from the UKF are plotted using subplot to visualize the results. In addition the raw gyroscope data is integrated over time and plotted as a sanity check. The raw accelerometer data is converted to rotation matrix by first solving for the roll, pitch and yaw angles corresponding to the general rotation matrix. The rotated vector in base frame must be [0; 0; -g]. Thus this gives only two angles and thus the other angle is arbitrarily fixed. **Hence singularities are observed in raw accelerometer plot which are observed to be corrected in the UKF output.**

## Image Stitching:

Firstly a big mosaic corresponding to the possible rotations is initialized (1500 x 3000). Here cylindrical coordinates are used to accumulate the images. The quaternion from UKF for each time step is converted to Euler angles. The Euler angles are then used to define an affine transform of the corresponding camera image to the respective position in the mosaic. Successive images are cross dissolved with a weight mask. Finally Gaussian smoothing is done to further enhance the blending.

## Results and Analysis:

UKF performance and image stitching performance are summarized in the table below.

| Parameters | Stats |
|---|---|
| Convergence of gradient descent for mean computation | 10-17 iterations (for within 0.001 norm of the final mean) |
| Average time taken for each time step for UKF | 6 milliseconds (real time) |
| Average time per time step for stitching images to mosaic | 14 milliseconds (real time) |

Stitched images of dataset1

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