3D Orientation using Sensor Fusion

NAME: Pranav Ganore (pranavbganore@gmail.com) **Date : 03/01/2019**

[Note – The App activity is scrollable and Also Consider the Final fused Pitch, Roll and Yaw values displayed w.r.t. the Mobile Device as the Point of Reference for rotation (as the user may get confused about these values after calibrations).

Algorithm for 3D Orientation :

1. Get the raw sensor values from Accelerometer $(x_a,\ y_a,\ z_a)$, Gyroscope $(x_g,\ y_g,\ z_g)$ and Magnetometer(x_m, y_m, z_m) .
2. OnSensorChanged –> calculate $PITCH_{acc}, ROLL_{acc}$ and YAW_{acc} using Accelerometer and Magnetometer data using following formula:

   $$PITCH_{acc} = arcsin\left(\frac{-y_a}{\|\vec{a}\|}\right)$$

   $$ROLL_{acc} = arcsin\left(\frac{x_a}{\|\vec{a}\|}\right)$$

   $$YAW_{acc} = \arctan2(y, x)$$

   $$where \rightarrow x \text{ and } y \text{ are calculated as follows :}$$

   $$y = (-x_m) \times cos(ROLL_{acc}) + z_m \times sin(ROLL_{acc})$$

   $$x = X_m \times \sin(PITCH_{acc}) \times \sin(ROLL_{acc}) + y_m \times \cos(PITCH_{acc}) + z_m \times \sin(PITCH_{acc}) \times \cos(ROLL_{acc})$$

3. OnSensorChanged – calculate $PITCH_{gyro}$, $ROLL_{gyro}$, YAW_{gyro} using Gyroscope data using following formulae : **The gyroscope data is integrated every timestep with the current angle value.**

   $$PITCH_{gyro} = PITCH_{gyro} + \left((-x_g) \times \Delta t \times \left(\frac{180}{3.14}\right)\right) \% 360$$

   $$ROLL_{gyro} = ROLL_{gyro} + \left((y_g) \times \Delta t \times \left(\frac{180}{3.14}\right)\right) \% 360$$

   $$YAW_{gyro} = YAW_{gyro} + \left((-z_g) \times \Delta t \times \left(\frac{180}{3.14}\right)\right) \% 360$$

   $$Here, \% \rightarrow represents\ 'modulous' operation\ used\ in\ order\ to\ get\ the\ rotation\ along\ 360°.$$
   $$We\ can\ choose\ to\ get\ the\ rotation\ in\ 90°\ but\ inorder\ to\ correctly\ rotate\ the\ image\ I\ have\ chosen\ to\ keep\ rotation\ angles\ here\ around\ 360°.$$

4. Create a complimentary filter to fuse $PITCH, ROLL, YAW\ from\ 'acc'\ and\ 'gyro'$ together to get $PITCH_{fused}$, $ROLL_{fused}$, YAW_{fused} using formulae :

   $$PITCH_{fused} = (PITCH_{gyro} \times 0.98) + (PITCH_{acc} \times 0.02)$$
   $$ROLL_{fused} = (ROLL_{gyro} \times 0.98) + (ROLL_{acc} \times 0.02)$$
   $$YAW_{fused} = (YAW_{gyro} \times 0.98) + (YAW_{acc} \times 0.02)$$

AND, thereby 3D Orientation is given by these three units (Which are displayed in the app).

5. Rotate the IMAGE by applying the above calculated $PITCH_{fused}$, $ROLL_{fused}$, YAW_{fused} in step 4.

About the Complimentary Filter :

The complementary filter gives us a "best of both worlds" kind of deal. On the short term, we use the data from the gyroscope, because it is very precise and not susceptible to external forces. On the long term, we use the data from the accelerometer, as it does not drift. Thus relying 98% more on gyroscope and only 2% on accelerometer.

About the Calibration :

I have chosen to reset the mobile image and all the angles to 0 on calibrate so as to give user the new contextual frame of reference every time they click on calibrate in various changed positions.
One can also choose to set the gyro angles equal to accelo angles to set the calibration w.r.t. relative frame of reference and not absolute which gyroscope gives.