EE565: MOBILE ROBOTICS

LAB # 5: AR DRONE SETUP WITH ROS AND SENSOR DATA FUSION USING AR DRONE'S ACCELEROMETER AND GYROSCOPE

IN-LAB WORK

This lab is composed of two parts, Hardware and Simulation. In Hardware experiment students shall acquire IMU sensors data from a real quadrotor, Parrot AR Drone. In the simulation experiment students will work with a gazebo quadrotor model in a virtual environment. **Quadrotors are really dangerous devices; be very careful and don't try to touch rotating propellers! If it fails in the air let it fall!**

HARDWARE EXPERIMENT:

1. Install ardrone_autonomy packages found at {url}.
    - **sudo apt-get install ros-indigo-ardrone_autonomy**
2. Use the following command to launch the quadrotor ROS driver, make sure wireless connection between AR-Drone and Computer is already established
    - **rosrun ardrone_autonomy ardrone_driver _realtime_navdata:=False _navdata_demo:=0**
3. Use ardrone/navdata topic to acquire sensor information such as orientation, linear and angular velocity
4. To view the live video stream
    - **rosrun img_view img_view /img_view:=/ardrone/front/image_raw**
5. Use ardrone/imu topic to acquire raw IMU sensor information, use following command to view a live plot
    - **rqt_plot /imu/orientation/x:y:z**
6. To take off and land send a std_msgs/Empty to ardrone/takeoff and ardrone/land respectively
7. To navigate AR-Drone after takeoff send geometry_msg/Twist on cmd_vel topic, value range: -1.0 to 1.0
    - -linear.x: move backward, +linear.x: move forward
    - -linear.y: move right, +linear.y: move left
    - -linear.z: move down, +linear.z: move up
    - -angular.z: turn left, +angular.z: turn right
8. Use rosbag to record IMU sensor and magnetometer topic in static condition and **<u>save it for use in lab assignment.</u>**
9. Play the recorded bag and write a node which subscribe to IMU topic and outputs accelerometer and gyroscope measurement.
10. Create a node to subscribe imu topic data, **<u>use the recorded bag file</u>**, and integrate the gyroscope measurements to calculate euler angles.
11. In the above node use accelerometer measurements to calculate roll and pitch angles

SIMULATION EXPERIMENT:

1. Install gazebo model for quadrotor {url}
    - **sudo apt-get install ros-indigo-hector-quadrotor-demo**
2. Launch gazebo simulation of a quadrotor in a virtual environment and get yourself familiarize with Rviz and gazebo nodes implementing a quadrotor simulation

- **roslaunch hector_quadrotor_demo outdoor_flight_gazebo.launch**

3. The preferred method of quadrotor navigation is using a joystick, make sure the joystick is connect with the PC
   - **roslaunch hector_quadrotor_teleop xbox_controller.launch**
4. We can also navigate the simulated quadrotor using the keyboard
   - **rostopic pub ardrone/cmd_vel geometry_msg/Twist -1 -- [0,0,0.1] [0,0,0] && roslaunch teleop_twist_keyboard teleop_twist_keyboard.py**
5. ROS has a built-in node for 3D pose estimation using extended Kalman filter called robot_pose_ekf {url} if by default it is not installed use following command to install it
   - **sudo apt-get install ros-indigo-robot-pose-ekf**

   It performs a loosely coupled integration of odometry, IMU and visual odometry data for pose estimation. Download the odometry publisher node **(ardrone_odometery.cpp)** from LMS required to implement robot-pose-ekf. Modify the launch file as per given instructions.

Lab Assignment

1) To get the understanding of Kalman filer we shall implement it in a simple case where the quadrotor is stationary. Suppose we wish to filter accelerometer value which is almost constant except some small random noise. Therefore, the process model is as follows

$$x_t = x_0 + \mathcal{N}\left(0, \sigma_p^2\right)$$

   Accelerometer measurements are also subjected to random noise, therefore, the measurement model is as follows

$$y_t = x_t + \mathcal{N}(0, \sigma_m^2)$$

   Write a simple node which can subscribe to IMU topic and able to separately filter the three accelerometer values using Kalman filter methodology. Publish the estimated state and variance as a custom message consists of two fields. Using rqt_plot plot the published message.

   a) Record the accelerometer measurements and measure the variance of accelerometer readings.
   b) Since the measurement variance is fixed, observe the behavior of filter using different process noise variance
   c) Now observe the estimated state and its variance using different initial values of the state and its variance.

2) Calculate Euler angles for an Attitude and Heading Reference System (AHRS) using gyro-rate sensor, accelerometer and magnetometer.

   a) Calculate the Euler angles from gyroscope's body-rate measurements as follows

$$\begin{bmatrix}\phi\\ \theta\\ \psi\end{bmatrix}_t = \begin{bmatrix}\phi\\ \theta\\ \psi\end{bmatrix}_{t-1} + \begin{bmatrix}1 & sin(\phi)tan(\theta) & cos(\phi)tan(\theta)\\ 0 & cos(\phi) & -sin(\phi)\\ 0 & sin(\phi)\,/cos(\theta) & cos(\phi)\,/cos(\theta)\end{bmatrix}\cdot\begin{bmatrix}g_x\\ g_y\\ g_z\end{bmatrix}\cdot\Delta t$$

   b) The roll and pitch angle from accelerometer can be calculated as follows

$$\begin{bmatrix}\phi\\ \theta\end{bmatrix} = \begin{bmatrix}atan2(ay, ax)\\ -atan2\left(ax, \sqrt{a_y^2 + a_z^2}\right)\end{bmatrix}$$

   c) The yaw angle from the magnetometer readings can be calculated as follows

$$y = m_y\cos(\phi) - m_z\sin(\phi)$$
$$x = m_x\cos(\theta) + m_y\sin(\theta)\sin(\phi) + m_z\sin(\theta)\cos(\phi)$$
$$\psi = -atan2(y, x)$$