Sichuan University - Pittsburgh Institute

ME 1042

Mechatronics Lab

Inertial Measurement

Revised April

2021

Mechanical Engineering Department

Lab 3: Inertial Measurement

Figure 0: Precise attitude measurement is instrumental to the control of unmanned aerial vehicles

This lab explores acceleration, rotation, and magnetic field measurements using an Inertial Measurement Unit (IMU) sensor. In particular, roll, pitch, and yaw measurements will be determined using the output of the accelerometer and gyroscope sensors. Also, earth's magnetic field direction will be approximated using the magnetometer.

Learning Objectives

After completing this lab, you should be able to complete the following activities:

1. Identify components of an Inertial Measurement Unit
2. Estimate roll and pitch using an accelerometer
3. Estimate yaw by integrating the output of a gyroscope
4. Analyze gyroscopic drift
5. Approximate earth's magnetic field direction using a magnetometer

6. Determine magnetometer offset

Required Tools and Technology

Platform: NI ELVIS III	✓ View User Manual http://www.ni.com/en-us/support/model.ni-elvis-iii.html
Hardware: Quanser Mechatronic Sensors Board	✓ View User Manual http://www.ni.com/en-us/support/model.quanser-mechatronic-sensors-board-for-ni-elvis-iii.html
Software: LabVIEW Version 18.0 or Later Toolkits and Modules: • LabVIEW Real-Time Module • NI ELVIS III Toolkit	✓ Before downloading and installing software, refer to your professor or lab manager for information on your lab's software licenses and infrastructure ✓ Download & Install for NI ELVIS III ✓ http://www.ni.com/academic/download ✓ View Tutorials ✓ http://www.ni.com/academic/students/learn-labview/

Expected Deliverables

In this lab, you will collect the following deliverables:

- ✓ Record raw accelerometer data
- ✓ Examine and calculate roll and pitch angles using accelerometer output
- ✓ Examine yaw angle polarity
- ✓ Measure maximum and minimum magnetometer outputs
- ✓ Determine magnetic North
- ✓ Estimate gyro drift
- ✓ Estimate magnetometer offset
- ✓ Observe and estimate Euler singularities when determining roll and pitch

Your instructor may expect you to complete a lab report. Refer to your instructor for specific requirements or templates.

1 Experimental Procedure

1.1 Measuring Pose and Magnetic Field using an IMU

The VI used to examine the behavior of the IMU is shown in Figure 1.

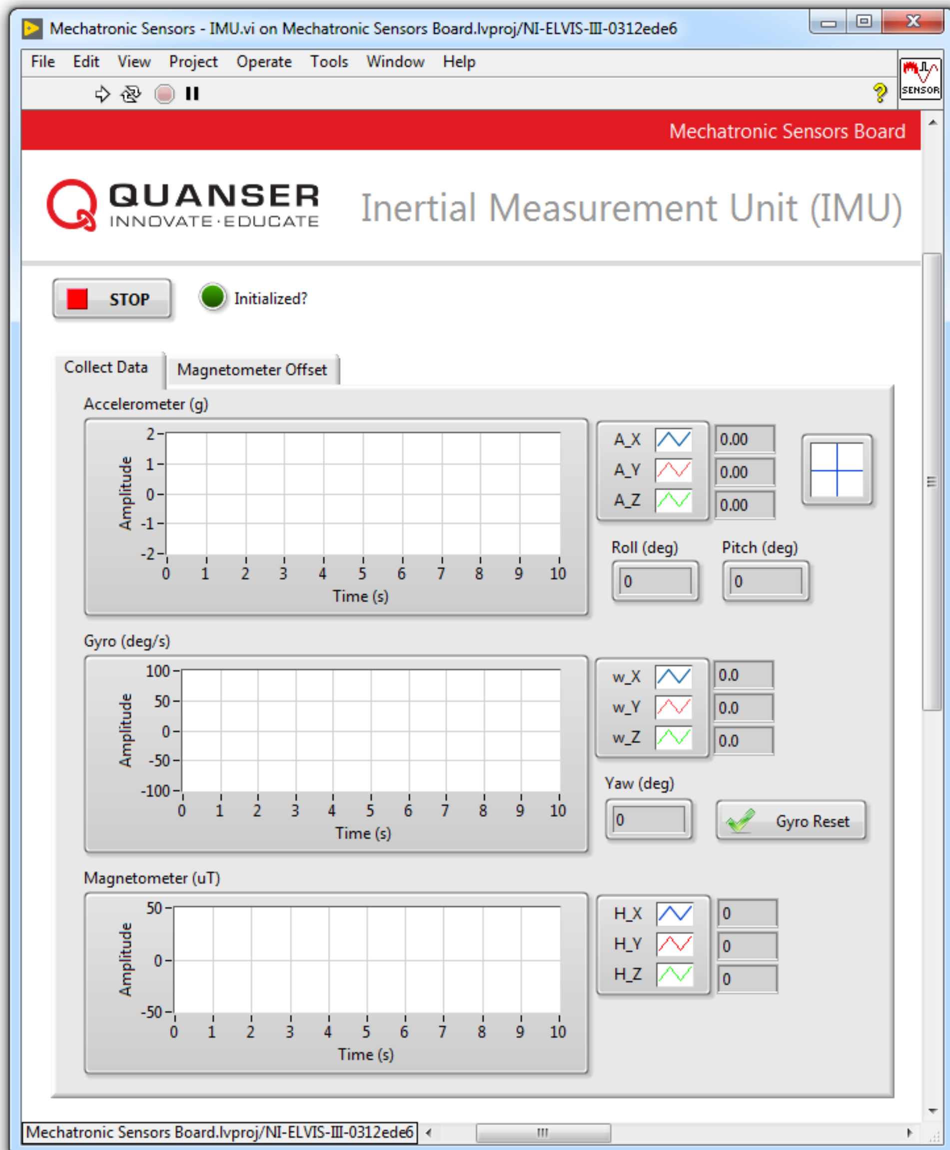

Figure 1: VI used for measuring the output of the IMU

1.1.1 Raw Accelerometer Output

1. Open **Mechatronic Sensors Board.lvproj**
2. From the **Project Explorer** window, open **Mechatronic Sensors – IMU.vi**
3. Click on the **Collect Data** tab.
4. Run the VI.
5. Wait for the **Initialized?** LED indicator to turn on.
6. The direction of the axes of the accelerometer is silk screened on the IMU sensor. Hold the IMU sensor such that the accelerometer X-axis is pointing vertically upward. Record the value displayed in the **A_X** numeric indicator in Table 1.
7. Hold the IMU sensor such that the accelerometer X-axis is pointing vertically downward. Record the value displayed in the **A_X** numeric indicator in Table 1.
8. Repeat steps 7 and 8 for the accelerometer Y and Z axes and record your results in Table 1.

Table1: Raw accelerometer output

Accelerometer Axis Direction	Raw Output (g)
X upward	
X downward	
Y upward	
Y downward	
Z upward	
Z downward	

1.1.2 Examine Roll Angle

9. The VI implements Equation 1 to estimate the roll of the sensor. Hold the sensor in the horizontal plane with the accelerometer Z-axis pointing vertically upward. The **Roll (deg)** numeric indicator must output a value of **0**. Slowly roll the sensor

sideways (about the accelerometer's X-axis) and examine changes in the **Roll (deg)** numeric indicator. Does the indicated roll angle polarity match the diagram shown in Figure 2?

Equation 1

$$\varphi = atan2\left(\frac{A_Y}{A_Z}\right)$$

10. Holding the sensor at a +45 degree roll angle. Make note of the **A_Y** and **A_Z** accelerometer outputs and use Equation 1-1 to estimate the roll angle. Does your calculation agree with the roll angle displayed in the VI?

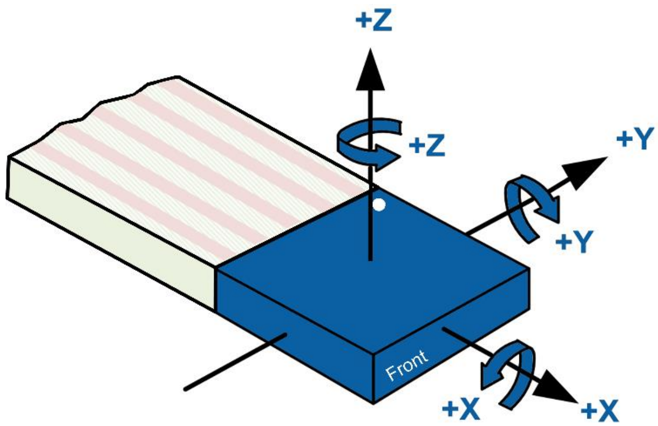

Figure 2: Orientation of axes of sensitivity and polarity of rotation for the accelerometer and gyroscope

1.1.3 Examine Pitch Angle

11. The VI implements Equation 2 to estimate the pitch of the sensor. Hold the sensor in the horizontal plane with the accelerometer Z-axis pointing vertically upward. The **Pitch (deg)** numeric indicator must output a value of **0**. Slowly pitch the sensor downward (about the accelerometer's Y-axis) and examine changes in the **Pitch (deg)** numeric indicator. Does the indicated pitch angle polarity match the diagram shown in Figure 2?

Equation 2

$$\theta = atan2\left(-\frac{A_X}{A_Z}\right)$$

12. Pitch the sensor downward holding it at a +45 degree angle. Make note of the **A_X** and **A_Z** accelerometer outputs and use Equation 2 to estimate the pitch angle. Does your calculation agree with the pitch angle displayed in the VI?

1.1.4 Examine Yaw Angle

13. The VI estimates the yaw angle by integrating the Z-axis component of the gyro output. Hold the sensor in the horizontal plane and click the **Gyro Reset** button to zero the yaw angle.
14. While keeping the sensor level in the horizontal plane, slowly yaw it sideways. Examine changes in the **Yaw (deg)** numeric indicator. Does the indicated yaw angle polarity match the diagram shown in Figure 2?

Equation 3

$$\psi = \int \omega_Z \, dt$$

1.1.5 Find Magnetic North

15. Determine magnetic North by holding the sensor in the horizontal plane with the magnetometer's Z-axis pointing downward. Slowly rotate the sensor about the Z-axis and examine the **H_Y** numeric indicator. Determine the maximum and minimum values indicated by the **H_Y** numeric indicator. The direction of the Y-axis at which maximum **H_Y** value occurs points toward magnetic North.
16. Validate your finding with a device that indicates magnetic North (e.g. a compass).
17. Stop the VI.

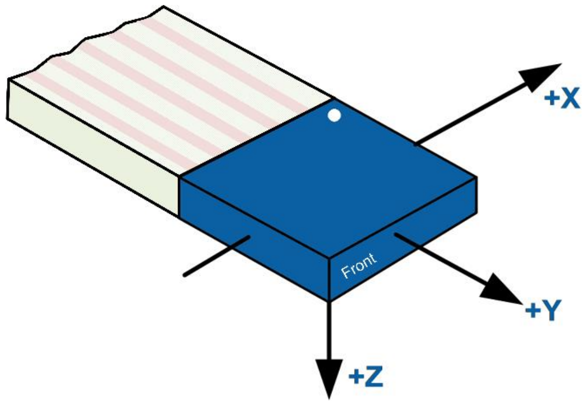

Figure 3: Orientation of axes of sensitivity for the magnetometer

2 For the Report

The report format will be a MEMO. Be sure to include:

1 The raw accelerometer data you recorded in Table 1.

2 When examining roll angles in Step 9, did the roll angle polarity match the diagram shown in Figure 2?

3 What are the A_Y and A_Z accelerometer outputs noted in Step 10? Using these values and Equation 1, calculate the sensor's roll angle. Show your calculations. Did your calculation agree with the roll angle displayed in the VI?

4 When examining pitch angles in Step 11, did the polarity match the diagram shown in Figure 2?

5 When examining yaw angles in Step 14, did the polarity match the diagram shown in Figure 2?

6 What are the maximum and minimum H_Y values recorded in Step 16? Did you successfully validate your magnetic North finding?