MTRN4110 – Project 1, Part A

The objective of this task is obtaining experience about using our sensors' data. This type of processing is intended to be performed in real-time (i.e. when it is actually needed). However, in Project 1, we start playing in an off-line fashion, i.e. we use data we recorded before, and we process it under no real-time constraints. In subsequent projects, you will adapt and use these programs for processing sensors' data in an on-line fashion (i.e. when the action actually occurs).
Project 1 is divided in two parts. Part A focuses on integrating the gyroscopes (initially, in a simplified context). Part B involves processing images from a 3D camera. Both sensors are intensively used in subsequent projects and are instrumental for the robot's perception component.

Part A

Intro: In this part of Project 1 you are required to estimate the attitude of a platform, uniquely based on integrating the gyroscopes' measurements (provided by an IMU).
As during that experiment (when the data was collected) the platform did operate in a flat and horizontal context (i.e. in an almost 2D context); we assume that the attitude does respect the condition "roll=0; pitch=0". Consequently, all the action does occur in the heading (φ_z component of the attitude, a.k.a. yaw); which simplifies our problem: We just integrate the angular rate ω_z.

Given the data provided by the gyros of an IMU device, you are asked to implement the following programs:

a) Load the provided data and plot the angular rates against time.
b) Integrate (numerically) the angular rates for estimating the attitude. Plot the obtained result.
c) Assuming that the sensor's body was kept stationary during the first 5 seconds of the experiment, estimate the BIAS of the sensor.
d) Apply process (b) using the unbiased data (using the bias, which was estimated in (c)).

Note: For facilitating visualization, you should express the final results and plots in degrees (avoid showing results in radians or other units).

Item (a) is already solved by the example file "LoadandShowGyros4110.m". You should inspect that program in order to understand how to read the data from the files.

Item (b) should usually involve properly integrating the angular rates, whose local version is provided by the 3D gyros of the IMU sensor. As the sensor was rotated just on the (horizontal) Z-plane (only the yaw was modified, keeping roll $\varphi_x \cong 0$, $\varphi_y \cong 0$), you can solve (b) by just integrating the measurements provided by the gyro ω_z. You need to implement the program for performing the numerical integration of $\frac{d\varphi_z}{dt}$ (the yaw rate). In this very particular condition the rate $\frac{d\varphi_z}{dt}$ is identical to ω_z (you can verify this fact by using the equations provided in the lecture notes).
You may assume that at time 0 the unit is oriented at $\varphi_z = 0$ (i.e. assume that the initial orientation is aligned with the fixed coordinate frame).
Apply the integration process, using the datasets provided. Verify that the results are consistent (similar, but not necessarily identical) with the results shown in the file "ResultsTask1a.pdf".

Item (c) ask you to exploit the fact that during some initial period of time the sensor was not moving; consequently, the sensor should measure nil angular rate during that interval of time. However, the

measurements present readings different than zero, mainly due to randomly fluctuating noise and to certain offset (bias).
This offset can be estimated by averaging the read values, during an interval of time during which we are sure the sensor was static.
The estimated bias can be used for removing the bias in subsequent readings (e.g. when the sensor is actually moving), for improving results. Before using the measured angular rate, we remove the estimated bias, e.g.

$$\omega_{improved}(t) = \omega_{measured}(t) - B$$

For instance, for estimating the heading of the platform in which the sensor is installed,

$$\theta(t) = \theta(t_0) + \int_{\tau=t_0}^{t} \omega_{real}(\tau)\cdot d\tau \approx \theta(t_0) + \int_{\tau=t_0}^{t} \omega_{improved}(\tau)\cdot d\tau = \theta(t_0) + \int_{\tau=t_0}^{t} \left(\omega_{measured}(\tau) - B\right)\cdot d\tau$$

Note: we are integrating only the gyro Z, assuming $\frac{d\varphi_z(t)}{dt} = \omega_z(t)$, because we know that the platform operated on an almost flat surface and that the IMU is installed aligned to the platform.

As we are not able to sample at infinite rate but at a "fast enough" rate, i.e. 200Hz, we need to implement the integration in a numerical way.

Given certain rate $\alpha(t) = {dA(t)}/{dt}$, then its associated integral relation is $A(t) = A(t_0) + \int_{\tau=t_0}^{t} \alpha(\tau)\cdot d\tau$. The continuous process can be approximated by the following discrete-time process:

$$A(t_n) = A(t_0) + \sum_{i=1}^{n} \alpha(t_{i-1})\cdot(t_i - t_{i-1}).$$

This approximation is valid in cases in which $(t_i - t_{i-1})$ are small enough. The integration process can also be expressed in a recursive fashion, as follows,

$$A(t_k) = A(t_{k-1}) + \alpha(t_{k-1})\cdot(t_k - t_{k-1}).$$

This recursive process can be easily implemented in a computer program, and can be exploited for integrating the heading rate in our problem.

Available data: *ImuData\IMU_001\IMUdata.mat* and *ImuData\IMU_002\IMUdata.mat*

This task should be solved during weeks 2, 3 and 4, jointly with Part B.
You will give a demonstration of your program, on week 4 (during your lab session) and submit you're the same day of your demonstration. The submission will be done, electronically, through Moodle. Instructions about the format of the submitted files will be given in week 3.
This part is released in week 1; however, you should wait for the lecturer's explanation of the necessary concepts, before solving it; or you may read the lecture notes related to this topic, in advance.
This assignment is INDIVIDUAL work (it is not to be solved in groups.)

If you have questions, ask the lecturer via Moodle's Forum, or by email (Email: j.guivant@unsw.edu.au)
