NAZARBAYEV UNIVERSITY
SCHOOL OF SCIENCE AND TECHNOLOGY

Project Assignment #1

ROBT305 – EMBEDDED SYSTEMS

Fall Semester 2018

INTRODUCTION TO BEAGLEBONE BLACK BOARDS.
IMU SENSOR INTERFACING WITH BEAGLEBONE BLACK

DUE TIME AND DATE

- **Class presentation and report uploaded to Moodle on Thursday 11 September**

LEVEL OF COLLABORATION ALLOWED

You will be working in groups of two students

DELIVERABLES REQUIRED

You group is required to prepare and submit to Moodle system an MS Word report with Linux terminal screenshots for all major tasks and steps from this assignment prior to class demonstration on Thursday 28 September.

REFERENCES

Derek Molloy,"Exploring BeagleBone. Tools and Techniques for Building with Embedded Linux", Wiley, 2015 (available in Moodle)

INTRODUCTION

Do you want to detect the collision of a robot or to build a self-balancing robot? Or you have plans to build a drone? All these robots need sensors such as accelerometers, gyroscopes, magnetometers and IMUs. These small components are embedded into the robot to generate information about the different mechanical phenomenon such as acceleration, vibration, tilt, orientation in space, angular velocity, pitch or rotation.

These types of sensors with capabilities to measure the acceleration, tilt, angular velocity, and other mechanical phenomena are used in different devices including smartphones, gaming consoles or toys.

If an **accelerometer sensor** is designed to measure the acceleration and tilt, the gyroscopic sensor measures the angular velocity and orientation. The IMU sensor is a special one designed to combine the features of an accelerometer and gyroscope in order to display complete information about the acceleration, position, orientation, speed, etc. for a robot.

The accelerometer sensor measure acceleration in two different units including meters per second squared, or when the acceleration felt like a weight, in G-forces. The advantages of the accelerometer sensor include a high accuracy in applications with noises, as well the acceleration measurement down to zero Hertz. The biggest disadvantage of this sensor is the limited high frequency where the sensor works.

The **gyroscope sensor** is inexpensive and measures in degrees per second or revolutions per second the angular velocity. It's frequently used in robotic applications to measure the balancing and send corrections to motors or drones to stabilize the flight.

The **magnetometer sensor** are finding increasing use as compasses in consumer devices such as mobile phones and tablet computers

The **IMU or Inertial Measurement Unit** is a sensor that hosts three types of sensors.

ASSIGNMENT DETAILS

Read Chapter 1 of the "Exploring BeagleBone" textbook (available in Moodle)

GET FAMILIAR WITH THE SAFETY RULES ON PAGE 21 OF THE TEXTBOOK

TASK 1: CONNECTION BBB WITH PC AND SETTING UP INTERNET CONNECTION OVER USB CABLE

We will be connecting BeagleBone Black (BBB) boards to the host Ubuntu OS PC using USB cable. As an alternative, you can also opt to work from the Windows OS PC.

1. Connect BBB to a host PC.
2. By default, the host PC IP is 192.168.7.1 and the BBB board IP address is 192.168.7.2
3. Verify if the BBB board is connected by typing 192.168.7.2 in an Internet Browser window (optional). Please read Chapter 2 of the textbook for more details (page 27).
4. **Ubuntu OS PC:** For setting up Internet-over-USB connection, you need to activate Network Sharing in the host Ubuntu PC. Follow instructions on page 29 of the textbook.

   Windows OS PC: For setting up Internet-over-USB connection, follow instructions starting from 26 of the textbook.
5. **Ubuntu OS PC:** You will be communicating BBB boards using SSH connection. Read corresponding section on page 33 of the textbook and type instruction

   ```
   ssh -X root@192.168.7.2
   ```

   in the Ubuntu terminal window to access the embedded Debian Linux on BBB.

   Windows OS PC: Download and install PuTTY terminal program from http://www.putty.org/ Communicate with the BBB using SSH connection following the instructions on page 34.
6. Follow the instructions on page 43 to set up and verify the Internet connection on BBB.

TASK 2: TRANSFERRING FILES OVER SSH AND BASIC EMBEDDED LINUX OPERATIONS ON BBB

1. Follow the instructions and practice file transfer to BBB over SSH connection.

```
sftp root@192.168.7.2

sftp>> lcd /home/robot/temp
```

To transfer files, please use commands given in page 35.

2. Follow the steps from page 37 till 44 to practice basic Linux commands, file editing using Nano and updating Time settings on BBB.
3. Study Chapter 3 of the textbook for introduction to Embedded Linux and practice basic Linux commands on you BBB as shown on Pages 82 -89.
4. Study Linux Processes section (Pages 89 - 94), run HelloWorldSleep.c code on BBB.

TASK 3: BBB PROGRAMMING PRACTICE

1. Study Chapter 5 and practice C/C++ programming on your BBB on pages 167- 198.
2. Run makeLED.c, makeLEDs.cpp and other codes on your BBB.

TASK 4. IMU INTERFACING

Your group will interface an inertial measurement unit (IMU) to the BBB board using I^2C synchronous communication bus.

The Pololu MinIMU-9 v3 www.pololu.com/product/2468 is an inertial measurement unit (IMU) that packs an L3GD20H 3-axis gyro and an LSM303D 3-axis accelerometer and 3-axis magnetometer onto a tiny 0.8″ × 0.5″ board. An I^2C interface accesses nine independent rotation, acceleration, and magnetic measurements that can be used to calculate the sensor's absolute 3D orientation. The MinIMU-9 v3 board includes a voltage regulator and a level-shifting circuit that allows operation from 2.5 to 5.5 V.

Some groups will receive the Pololu AltIMU-10 v4 unit (https://www.pololu.com/product/2470) that is exactly the same as the MinIMU-9 but contains an additional LPS331AP digital barometer sensor for altitude measurements (is not used in this assignment).

I^2C Communication

The L3GD20H's gyro and the LSM303D's accelerometer and magnetometer can be queried and configured through the I^2C bus. A detailed explanation of the protocols used by each device can be found in the L3GD20H and the LSM303D datasheets (available in Moodle).

The L3GD20H and LSM303D each have separate slave addresses on the I^2C bus. The following table shows the slave addresses of the sensors:

Sensor	Slave Address (default)
L3GD20H (gyro)	1101011b (0x6B)
LSM303D (accelerometer and magnetometer)	0011101b (0x1D)

To connect the sensor to the BBB:

1. Study principles of general purpose input/output (GPIO) interfacing to BBB in **Chapter 6 of the textbook (pp. 201 - 203).**
2. Study relevant section of **Chapter 8 of the textbook (pp. 275 - 290)** and connect the IMU to the BBB board similar way as in Figure 8-1b (p. 277) using the following connections:

   IMU pin / BBB input/output
   SCL – 19
   SDA – 20
   GND – 1
   VDD – 3
   VIN – disconnected.

3. Follow the textbook and test i2c-tools: **i2cdetect**, **i2cdump** and **12cget**, in the BBB terminal.

4. Observe that the IMU gyro, accelerometer and magnetometer sensors are all off by default and do not provide orientation measurements. Use sensor datasheets to learn correct data register addresses, e.g. 8-bit registers **OUT_X_L (0x28)** and **OUT_X_H (0x29)** provide 16-bit X-axis gyro measurement data (L3GD20H sensor). The register reading commands examples are **i2cget 0x6B 0x28** and **i2cget 0x6B 0x29**.

5. In order to turn the IMU on, sensor configuration registers have to be set to the normal mode of operation. This can be done by sending, for example, the following control worlds to the corresponding configuration registers as given in the table below using **i2cset** command, e.g. **i2cset 0x6b 0x20 0x0F**

L3GD20H		**LSM303D**	
Register (address)	Control word	Register	Control word
CTRL1 (0x20)	0x0F	CTRL1	0x57
CTRL2 (0x21)	0x20	CTRL2	0x18
		CTRL5	0x64
		CTRL6	0x20
		CTRL7	0x00

6. Learn the meaning of the control words using sensor datasheets and modify if necessary the corresponding accelerometer, magnetometer and gyroscope sensor control registers and set the sensors to following settings:

	L3GD20H	LSM303D	
	Gyroscope	**Accelerometer**	**Magnetometer**
Data output frequency	50Hz	50Hz	6.25Hz
Range of output frequency	$\pm$245 deg/sec	$\pm 2g\ (2\ x\ 9.81 m/s^2)$	$\pm 4\ gauss\ (2x10^{-4} Tesla)$

   Provide your modified control words in the report.

7. Use the program example from Listing 8-1 on page 286 of the textbook (the code is available in Moodle) and write a program for setting the configuration registers and reading measurement data from x, y and z axes of all of the IMU onboard sensors. Note that the 16-bit data word for each measurement axis is obtained by combining readings from two 8-bit data registers (low and high).
8. Using the IMU sensor datasheets you are required to prepare a register map similar to Table 8-2 on page 283 of the textbook containing information about configuration and data registers. Please be able to explain the meaning of the sensor control words during the class presentation.

TASK 5. IMU SIGNAL PROCESSING

1. Study, download, and implement an open-source IMU sensor measurement fusion algorithm in C code developed by Sebastian Madgwick from http://www.x-io.co.uk/open-source-imu-and-ahrs-algorithms/

2. Interface your IMU sensor measurement data program with the algorithm code and obtain orientation estimations in the terminal window when running on the BBB (**no need** for threaded implementation and graphical user interface at this point).

GRADING CRITERIA

Demonstration and grading of your working BBB&IMU setups and program solutions (with questions/answers) will be done during the class lab session on Tuesday 11 September.

Please prepare a detailed report with program code and submit it to the project folder in Moodle by the end of Tuesday 11 September.

This project evaluation will be done using individual grading depending on the level of participation and understanding of the project assignments.

Program quality with implemented additional features and report quality may add bonus points.

Late submission penalty – 10% per day