XL CILAMCE
IBERO-LATIN AMERICAN CONGRESS ON COMPUTATIONAL METHODS IN ENGINEERING
NOVEMBER 11-14, 2019
Praiamar Natal Hotel & Convention
Natal, RN-BRAZIL

RAFT TELEMETRIC SYSTEM: A PROTOTYPICAL IMPLEMENTATION

Arthur Diniz Flor Torquato Fernandes
Prof. Carlos Magno de Lima
arthurdinizflor@gmail.com
cmagno@ufrnet.br
Federal University Of Rio Grande Do Norte
Campus Universitário - Lagoa Nova, 59078-970, RN/Natal, Brazil
Prof. Maria Christine Werba Saldanha
cwerbasaldanha@gmail.com
DEP-PPGEP-UFPB
Cidade Universitária , 58051-900, João Pessoa/PB, Brasil
Prof. William Fernandes de Queiroz
william@dem.ufrn.br
Pedro Henrique de Oliveira Freire
pedrofreirect@gmail.com
Anny Beatriz Pinheiro Fernandes
biaany@hotmail.com
Júlio César Silva Aprígio
julioaprigio8@gmail.com
Federal University Of Rio Grande Do Norte
Campus Universitário - Lagoa Nova, 59078-970, RN/Natal, Brazil

Abstract. This paper has as the main objective to help rafts to be stable and safe by doing a printed circuit board (PCB) based on the Arduino platform - with sensors as MPU6050 and NEO-6M GPS - which have the goal of sending data to a receptor base in an external computer, where this data is processed and analyzed, and shows the current rotation and location of the rafts. In this project, a phenolic sheet, Heat Exchangers and Photographic methods were used to manufacture a printed circuit board, the main object of the work. Also, a specific software was developed to process, analyze and show all the data collected by the sensors on the PCB. This software uses the C/C++ language with Arduino libraries and the Karman complementary filter, it is executed at the Arduino IDE and saved at the ATMega328p microcontroller and for the communication of the PCB with an external computer, the XBee module with ZigBee and SPI protocol using a 2.4GH frequency transmitted by a prototype was used.

Keywords: First keyword, Second keyword, Third keyword (up to 5 keywords)

1 Introduction

Rafts are small, handmade, boats that are very common fishing vessels on Brazilian northeast seaside area, particularly in the Rio Grande do Norte state. The process of making these vessels is one of large cultural significance for the region even becoming a subject of a research from Câmara Cascudo. Even though this practice is deeply rooted in Rio Grande do Norte's history and is the source of income to a large number of families, the practice of fishing in these rafts is becoming uncommon, probably due to low profitability of the practice and the increase of urban areas. In hopes of helping these practices to survive, the Federal University of Rio Grande do Norte (UFRN) alongside the Federal University of Campina Grande (UFCG) and the support of CNPq established the ProJangada project - with the orientation of Prof[a]. Dr[a]. Maria Christine Werba Saldanha - whose goal is to propose an alternative way to build rafts with attention to costs, safety and usability. And, with the objective of testing these prototypes, an alternative group was created, dedicated to developing an embedded system that'll help to manage tests in these rafts and validate their projects. With these objectives settled, a printed circuit board (PCB) was created based on the Arduino platform, with sensors as MPU6050 and NEO-6M GPS, that should read a range of different parameters, process the data, send it by antenna to an external computer and, at the same time, save this data on an SD card.

2 THEORETICAL BASIS

The development of systems that involve multidisciplinary practices requires the adoption of methodologies that can accelerate their development and implementation. The RAFT TELEMETRIC SYSTEM was implemented based on the Double Diamond Method of Design Thinking [1] which is divided into four distinct phases - Discover, Define, Develop and Deliver - the Double Diamond is a simple visual map of the design process.

With the identification and definition of needs, we began to explore the technologies necessary for their implementation. In boat design buoyancy and stability are critical to crew and cargo safety. From this premise we immediately identify the need for raft tilt angle measurement and for this we adopt inertial sensor technologies.

The category of inertial sensors based on MEMS (Micro ElectroMechanical Systems) is represented mainly by two devices: accelerometer and gyroscope. The magnetometer is applied to IMUs to improve the quality and accuracy of the inertial sensor output signal.

Inertial sensors are MEMS devices capable of monitoring linear or angular variations in velocity and acceleration, directly or indirectly, by converting inertial forces into some known physical change that can be captured by a corresponding transducer and converted into an electrical signal.

Obtaining data from accelerometer and gyroscope is the basis for the identification of angles, and it is still necessary to use mathematical filters to reduce the propagation of errors.

2.1 Accelerometer

According to Pereira [2] an accelerometer is defined as "a device that measures the vibration or static and dynamic acceleration of motion of a structure. They can be used to measure inclination, inertial forces (velocity, displacement or force) and shock or vibration". Usually they are used to measure acceleration in 3 orienting axes.

2.2 Gyroscope

Gyros are devices that measure orientation. A microelectronic gyroscope measures angular velocity (degrees per second) from which angular displacement can be calculated. To process the orientation, it is necessary to initialize the sensor to a known position using the accelerometer. From this it becomes possible to measure the angular velocity on the X, Y and Z axes by means of the gyro within a known time interval.

2.3 Mathematical Filters

In order to use the accelerometer, gyroscope, it is necessary to develop algorithms capable of capturing the signals of the sensors in the x, y and z axes. The output generated needs to be optimized using mathematical filters. The most cited algorithms in the literature, such as the Kalman filters and the Mahonny and Madgwick algorithm.

In our prototype we chose to use the Complementary Filter which is defined by Nudes et all [3] as a "simple mathematical linear combination, where a weight is defined for each input variable". This filter is a type of Kalman filter with an advantage of being less demanding on the machine but also being less precise (WALTER T. HIGGINS, JR. said on A Comparison of Complementary and Kalman Filtering [4]).

3 PROJECT SPECIFICATIONS

In order to optimize the time taken to develop this system, the project was structured in two modules, each one focused on building a different component of the system. They were the Hardware module and the Software module.

3.1 Hardware Module

The hardware module developed in this project used a set of sensors and materials that will be described in this section. The first step of developing a printed circuit board is to know what kind of sensors and types of equipment will be necessary to build the project. On this work, sensors were needed to capture angles, accelerations and positions; the chosen sensors were the MPU6050 motion tracking device and the NEO-6M GPS module. It was also necessary to have an equipment that is able to transmit all data captured and the XBee - PRO communication module was chosen in parallel with an ATMega328p microcontroller and an SD-card module to run and save the data, respectively. Below are described all the materials used during the project of the hardware module.

The MPU6050 Motion Tracking Device (Fig. 1a) integrated 6-axis Motion Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer, and a Digital Motion Processor^{TM} (DMP) all in a small 4 x 4x 0.9 mm package. According to its datasheet [5], this component uses the I^2C communication protocol which makes it directly accept input from an external 3-axis compass to provide a complete 9-axis Motion Fusion output. Features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs and three 16-bit ADCs for digitizing the accelerometer outputs. For precision tracking of both fast and slow motions, the parts feature a user-programmable gyroscope and accelerometer, the first one with full-scale range of $\pm$ 250, $\pm$ 500,$\pm$ 1000, and $\pm$ 2000°/sec and the second one with full-scale range of $\pm$ 2g, $\pm$ 4g, $\pm$ 8g, and $\pm$ 16g, being 1g equivalent to acceleration of gravity. For the power supply, the MPU6050 provides a VLOGIC reference pin (in addition to its analog supply pin: VDD), which sets the logic levels of its I2C interface. The VLOGIC voltage may be 1.8V $\pm$ 5% or VDD.

The XBee-PRO Communication Module (Fig. 1b) requires minimal power and provides reliable delivery of data between devices. According to its datasheet [6], this device operates within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other. The XBee-PRO uses a 2.8-3.4V power supply and has a 250mA transmit current. Through its serial port, the module can communicate with any logic and voltage compatible UART; or through a level translator to any serial device.

The NEO-6M GPS Module (Fig. 1c) is part of the GY-NEO6MV2 board which also contains a ceramic antenna and a built-in EEPROM. This board, according to its datasheet [7], uses a 3 to 5 V power supply range, a ceramic antenna, a backup battery, a LED signal indicator and EEPROM for saving the configuration data when powered off.

The ATMega328p (Fig. 1d), according to its datasheet [8], is a low-power CMOS 8-bit microcontroller that achieves throughputs approaching 1 MIPS per MHz allowing the designed system to optimize power consumption versus processing speed. This component features 32K bytes of in-system programmable flash with read-while-write capabilities, 1K bytes EEPROM, 2K bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire serial interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable watchdog timer with internal oscillator and five software selectable power saving modes.

The SD Card User Module (Fig. 1e), according to its datasheet [9], allows you to access PC compatible files on six different flash card form factors. It allows basic operation with as few as four PSoC pins. Depending upon the card type and card socket, you can use additional pins to support write protect, card insert, and others. This user module allows you to access SD and MMC cards using a simple C interface and using the SPI data mode to address the card.

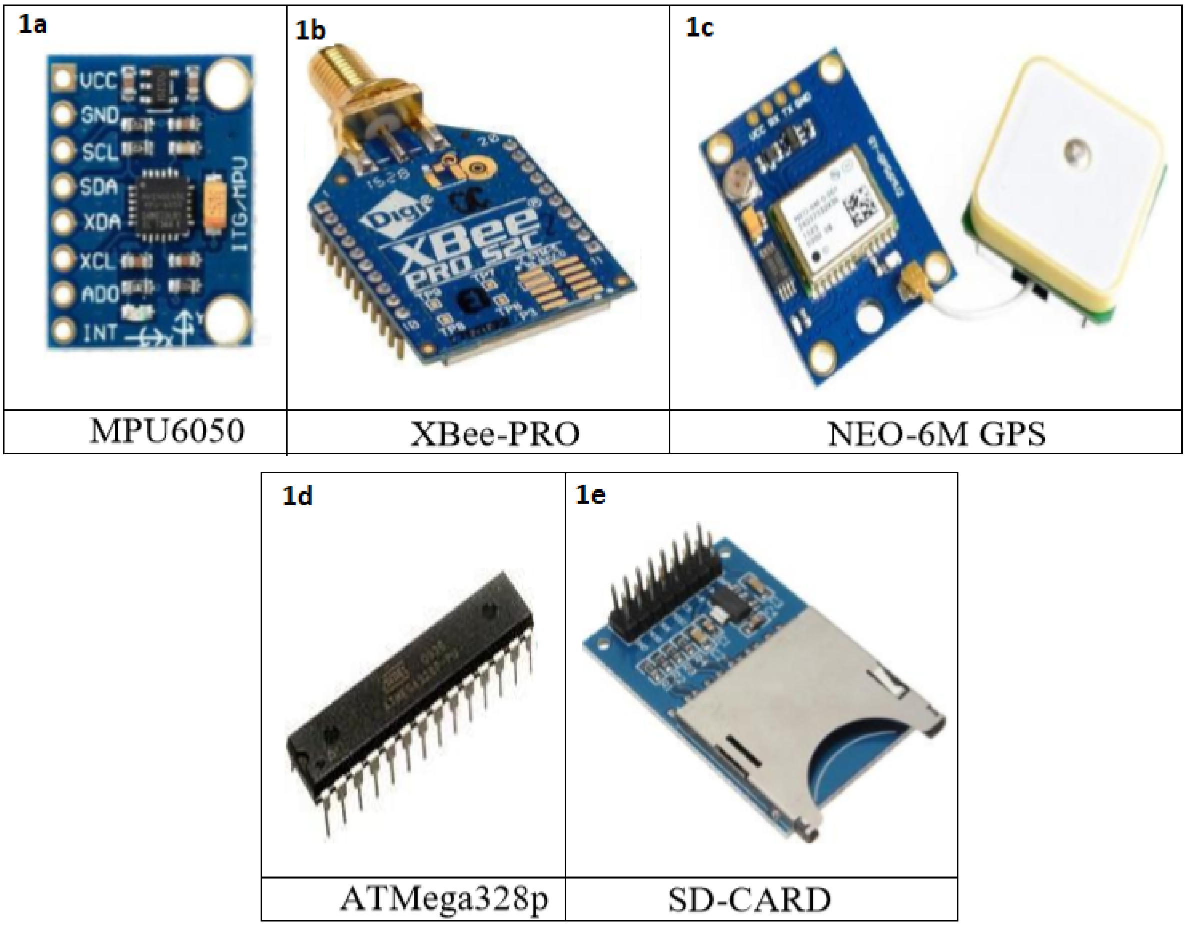

Figure 1. Components of the hardware module

After having this knowledge, the next step of the hardware to be taken is to develop the circuit schematics to be simulated at some software capable of this. The board itself was designed using a CAD Software and using a previously built schematic as basis. We choose to manufacture the PCB using a photographic method.

3.2 Software Module

The measurement of angles work using a complementary filter that is defined by "Eq. (1)". With θ representing the measured angle, G_y the angular velocity and Acc the linear acceleration.

$$\theta = 0.88(\theta + G_y dt) + 0.02Acc \tag{1}$$

This filter is a type of Kalman filter with an advantage of being less demanding on the machine but also being less precise (WALTER T. HIGGINS, JR. said on A Comparison of Complementary and Kalman Filtering [4]).

After the angles are obtained, they are recorded in a Sheet file on the SD card. After 1 minute of angle measurements, the program stops and attempts to get the current location by GPS network. If it is succeeded, the system sends it to be recorded on a different sheet file on the SD card and send it by Zigbee network.

The software module was developed using the C/C++ language with the standard Arduino Library [10]. It also uses the SD, Wire, Software Serial, MPU6050_tockn and tiny GPS libraries provided by the community.

4 TESTS AND RESULTS

In order to analyze failures in the prototype, a series of laboratory tests took place, they were divided into Hardware Tests and Software Test.

4.1 Hardware Tests

These tests were made in order to analyze any hardware failure that may occur, during these tests it was verified that the Microcontroller is receiving the correct voltage, that the programming circuit is working properly and that each component is receiving their correct voltage. In the current version of the board, no project failures were detected. But due to a lack of refinement on the manufacturing process, some boards do not work properly.

4.2 Software Tests

To test the software system, a small model of a raft was made. This model is deployed in a water reservoir alongside the system. During this test, weight loads are deployed in different sectors of the model and the data is collected. After that, it is verified if the software is working properly, it is checked if the data is being recorded, the quality of these data and also if it is being sent by the antenna. Some of the results are displayed below in figure 2(a), 2(b), 2(c). In the current software version, some inconsistencies were being detected with the data right after the measurement of the GPS signal.


```
"EulerAngles":
[
{
"AngX": "0.200286",
"AngY": "-0.268693",
"AngZ": "-1.60305e-007",
"Time": "0.15"
},
```


a


```
{
"AngX": "0.231956",
"AngY": "-0.450584",
"AngZ": "-3.36412e-005",
"Time": "1.44"
},
```


b


```
{
"AngX": "0.389387",
"AngY": "-0.38694",
"AngZ": "0.000251672",
"Time": "2.72"
},
```


c

Figure 2. Data results from algorithm

The data collected is transferred and displayed in real time on an 3D environment.

4.3 3D Environment

After PCB manufacturing, testing, verification and analysis of the collected data, this information was transmitted through the communication system based on the X-bee PRO comunication module.

Provided with antenna the prototype communicates directly with a server, which in real time sends the raft positioning data, allowing from a three-dimensional CAD model in a viewing environment (see figure 3) to observe in detail the movements of the raft finds in a test tank being subjected to localized loads.

This visualization enables a real-time analysis of the raft's behavior, and the data captured and recorded on an SD card is used for further analysis of the vessel's stability.

To build the three-dimensional environment we use the software Processing, connected in real time with the PCB.

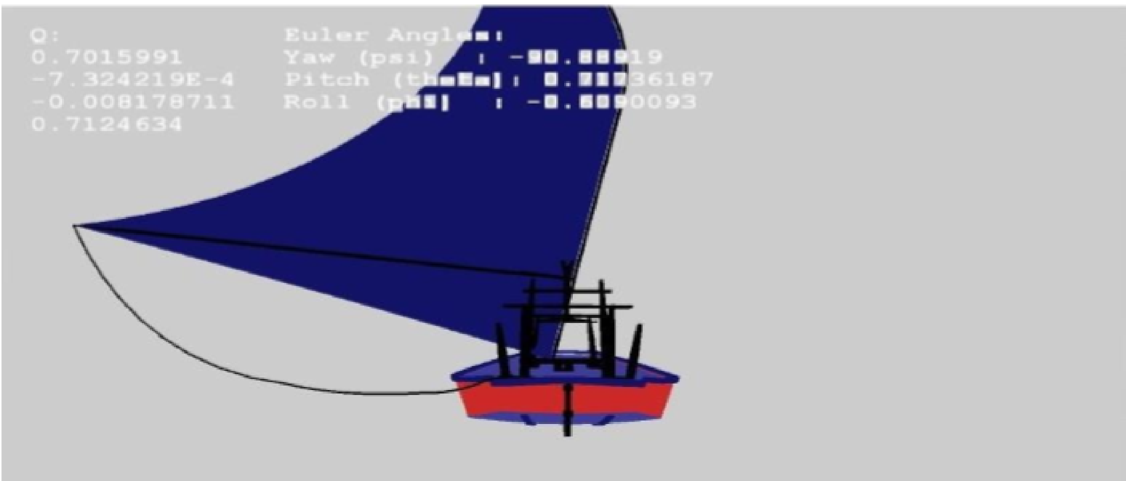

Figure 3. 3D Environment - The raft prototype

5 Conclusions and Future Works

During the development of the system it was essential to adopt the Double Diamond methodology as a way to optimize time and ensure that the system actually met the needs of the project. After the analysis and simulation of the data obtained from the complementary filter it was observed that the data presented with acceptable precision. In addition, tests in a three-dimensional visualization environment were useful in validating the prototype vessel when its stability was analyzed. For future work, we look forward to improving and optimizing the PCB software and manufacturing process. Just as we expect to introduce GPS in real-time raft monitoring while they are offshore.

Acknowledgements

The authors gratefully acknowledge the support of the Brazilian National Council for Scientific and Technological Development (CNPq - Process 485961/2013-0)

References

[1] Council, D., 2019. Double diamond model. `https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond`. [Online; accessed 16-July-2019].

[2] Pereira, M., 2018. Acelerômetros. `https://repositorio.pgsskroton.com.br/bitstream/123456789/20996/1/07Acelerometros.pdf`. [Online; accessed 16-July-2019].

[3] Lage, V., Rêgo Segundo, A. K., & Vargas Barsante e Pinto, T., 2018. O uso de giroscópios e acelerômetros para modelagem matemática de uma plataforma com dois graus de liberdade. In *CBA 2016*.

[4] Higgins, W. T., 1975. A comparison of complementary and kalman filtering. *IEEE Transactions on Aerospace and Electronic Systems*, vol. AES-11, n. 3, pp. 321–325.

[5] Inc, I., 2013. Mpu-6000 and mpu-6050 product specification revision 3.4. https://store.invensense.com/datasheets/invensense/MPU-6050_DataSheet_V3204.pdf. [Online; accessed 16-July-2019].

[6] International, D., 2009. Xbee®/xbee-pro® rf modules - product manual v1.xex - 802.15.4 protocol. https://www.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Datasheet.pdf. [Online; accessed 16-July-2019].

[7] UBlox, 2011. Neo-6u-blox 6 gps modules datasheet. https://www.openimpulse.com/blog/wp-content/uploads/wpsc/downloadables/GY-NEO6MV2-GPS-Module-Datasheet.pdf. [Online; accessed 16-July-2019].

[8] Atmel, 2015. Atmega 328p datasheet. http://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf. [Online; accessed 16-July-2019].

[9] Corporation, C. S., 2012. Sdcard datashee v 1.2. http://www.fecegypt.com/uploads/dataSheet/1480848837_sdcard_001-13589.pdf. Online; accessed 16-July-2019.

[10] Arduino, 2019. Standard arduino libraries. https://www.arduino.cc/en/reference/libraries. [Online; accessed 16-July-2019].