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Surf Logger

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Abstract—there are about 23 million surfers worldwide [1]. Many surfers are regular people wanting to ride the waves on their spare time and others are professionals, catching waves for a living. What they both have in common is the passion to learn and become better. We believe that our product is an opportunity to do just this.

Keywords—Surf logger, sensor box, rotation, acceleration

I. Introduction

The sport is not very popular in any of our countries, but more so in Porto, Portugal. Mutual talks about it has led to many questions, many ideas and consequently to choosing the topic "Travel Logging System" in relation to surfing. We would like to create something that you can measure and get more information about your surfing. This motivates us through the project.

A. Problem

When trying to create the surf logger, we had some problems. The main one is saving, reading, and visualizing the data. We decided to focus on the most important part, data storage. Before visualizing 3D, the data is saved to a SD card.
The designing of a waterproof case is another problem. When removing the SD card and using the USB entrance (to charge battery), there should not be any problems regarding possible water damaged. The possible water- tightness problem that can happen can cause a problem for electronics part.

B. Proposal

Secure Digital (SD) is a non-volatile memory card that is used for mobile phones and other portable devices. This is why we believe it is also suitable for our surf logger.

From a sustainability point of view, we decided to use a rechargeable battery. In comparison with a dischargeable battery, we can charge and recharge it many times. Therefore, we do not have to change the battery as often. Our goal was to use recycled materials for our parts but because the main gadgets of the logger are electronic parts, this was not possible. However, when we considered cover material we decided to use 'CORK'. Cork suits very well as a cover material for our product because it's lightweight and waterproof. The Cork industry is considered an environmental friendly industry. The sustainability of production and the easy recycling of the cork products are two other important properties that affected our decision. As a positive consequence, ecological footprint is reduced thanks to cork.

From a marketing angle, the surfers can compare their performance or show others how fast they were. A big advantage is, that there is no product like our already on the market. In addition our surf sensor is indispensable for a surf school because they can teach their customers in a very analyzing and objective way to improve their surfing skills. Another advantage of our product is that we can react spontaneous to several sports/ customer needs by adding sensors. Nowadays this is an aspect which is getting more and more important because of ephemerality. In conclusion our aim is to analyze and satisfy our customer needs so good that our sensor box will sell it on its own. Regarding the hierarchy of needs of Maslow our products satisfies self-fulfillment needs.

C. *Structure of the Paper*

We have already mentioned about problems and the proposals how we will solve our problems. In this paper, the main headlines are divided as follow. Related work mentioned about previous studies that are relevant with our product. Project development is where we present our components, architecture of our device, functionality properties. Project development involves the functional tests and result. Finally, conclusion presents our achievements and how it can be improved in the future.

II. RELATED WORK

A. *Android Sensor Box*

Android box is a tool that you can implement in your Android device. It uses many different sensors that can be used in your daily life with a click off a button. The device only detects changes. It may not show the correct temperature, proximity, light and pressure values if no changes occur. For better performances, sensors are usually used together [1].

B. *Twine Sensor Box*

Twine is a wireless sensor block tightly integrated with a cloud-based service. The durable, rubbery block has Wi-Fi, on-board temperature and orientation sensors, and an expansion connector for other sensors. The additional sensors can for instants detect floods, leaks, opened doors, and signals from your other home systems. Power is supplied by micro USB or two AAA batteries. By using web app makes it simple to set up and monitor your Twines from a browser. The Twine concentrates on to alert you to small problems before they become big problems [2].

C. *Sensor-packed SurfSens*

The research company Tecnalia and Spanish surfboard manufacturer Pukas have teamed up to create a surfboard that packs a gyroscope, accelerometer, GPS compass, pressure sensors and strain gauges to measure the flex of the board. Last year, four students from the University of California, San Diego, installed a computer and series of sensors on a surfboard with the goal of designing the “perfect” board. Being a student effort, the UCSD board wasn't as refined as the board created by Pukas and Tecnalia, which contains all the electronics within the board itself. The idea of the product is for professional riders to improve their styles using the data collected [3].

D. *Push Snowboarding (Nokia and Burton)*

Nokia, a company incorporating wearable sensors into snowboarding, witch communicates with a smartphone through Bluetooth in real-time. With Nokia’s smartphone’s as a platform for capturing and analyzing data, the mobile application uses the phone’s GPS capabilities along with the data collected from four sensors implemented in the snowboard to provide snowboarders with live tracking of their ride including speed, heart rate, airtime, rotation and a measure of how excited a rider was while snowboarding [4].

III. PROJECT DEVELOPMENT

A. *Components*

Table.1 List of materials

METARIAL	NAME	MODEL
Control Panel	Arduino Uno Rev.3	UNO-REV3
Shield Module for Bluetooth	Arduino Wireless SD Shield	ARDU-0019
Bluetooth Radio	RN41-XV Bluetooth Module - Chip Antenna	INM-0553
Sensor Stick(Accelerometer , gyroscope, magnetometer)	9 Degrees of Freedom - Sensor Stick	INM-0431
Battery	Polymer Lithium Ion Battery-2000mAh	INM-0138
Converter and charger for the battery	Power Cell – LiPo Charger/Booster	INM-0496
Temperature Sensor	TMP36 - Temperature Sensor	INM-0428
Cork Block		

Control Panel

In addition to all the features of the previous board, the Uno uses an ATmega16U2 instead of the 8U2 found on the Uno (or the FTDI found on previous generations). This allows for faster transfer rates and more memory. No drivers needed for Linux or Mac and the ability to have the Uno show up as a keyboard, mouse, joystick. [5]

The Uno R3 also adds SDA and SCL pins next to the AREF. In addition, there are two new pins placed near the RESET pin. One is the IOREF that allow the shields to adapt to the voltage provided from the board. The other is a not connected and is reserved for future purposes. The Uno R3 works with all existing shields but can adapt to new shields, which uses these additional pins [6].

Shield Module for Bluetooth

The Wireless SD Shield allows an Arduino board to communicate using a wireless module. It is based on the Xbee modules from Digi, but can use any module with the same footprint. The module can communicate up to 100 feet indoors or 300 feet outdoors (with line-of-sight). It can be used as a serial/ USB replacement or you can put it into a command mode and configure it for a variety of broadcast and mesh networking options [7].

If we would need to cover a larger distances we could use the XBee Pro model instead. These radios can get up to 1.5 km communication in line of sight. The on-board voltage regulator can supply enough current to power these radios. The shields breaks out each of the Xbee's pins to a through-hole solder pad. This shield is also compatible with other radios using the same socket.

Included on the board is a SD card slot accessible through the SD Library. When using the SD Library to access the card, Pin 4 is CS and cannot be used otherwise. SPI also relies on pins 11, 12, and 13 for communication [8].

Bluetooth Module

The RN41XV is a small form factor, low power Bluetooth radio module offering plug-in compatibility for the widely used 2 x 10 (2mm) socket typically used for 802.15.4 radio modules. Based on the popular 2 x 10 (2mm) socket footprint often found in embedded applications, the Roving Networks' RN41XV module provides Bluetooth connectivity in legacy and existing designs that have been based upon the 802.15.4 standard [9].

The RN41XV is built upon Roving's RN41 low power Bluetooth module. The module has an embedded Bluetooth stack and supports multiple interface protocols and profiles including the commonly used SPP and HID profiles [10].

Sensor Stick

The 9DOF Sensor stick or put in another way a sensor board with 9 degrees of freedom. Includes the ADXL345 accelerometer, the HMC5883L magnetometer, and the ITG-3200 MEMS gyro has a I2C interface in the followings we show the specifications of all the sensors [11].

Battery

Rechargeable lithium polymer battery that provides our device with the energy we can see the specification and the safety performances in the followings table specifications and safety performance

The speciation of the output of our battery is 3.7 V, so we need to change this voltage to an accurate one for our arduino board. We can make it by using two batteries in series and using the voltage regulator of the arduino board Input Voltage (recommended) 7-12 V or using a boost regulator to 5v and connected to the arduino board without using the regulator of the board.

Convertor and Charger for the Battery

The PowerCell board is a single cell LiPo boost converter (to 3.3V and 5V) and micro-USB charger in one. The features are MCP73831 Single Cell LiPo charger at 500mA,TPS61200 Boost Converter, 3.3 or 5V selectable output voltage(5V @ 600mA max, 3.3V @ 200mA max), under voltage lock out at 2.6V (with disable jumper), Quiescent current(less than 55uA), JST connector for LiPo battery, micro-USB connector for charge power source, 4.7uH, 1.2A Sumida CDRH2D18 inductor, over temperature protection [14].

Temperature Sensor

The TMP36 is a low voltage, precision centigrade temperature sensor. It provides a voltage output that is linearly proportional to the Celsius temperature. The features are 2.7 V to 5.5 VDC voltage input, 10 mV/°C scale factor, ±2 °C accuracy over temperature, ±0.5°C linearity, −40°C to +125°C operating range [15]

Micro SD Memory Card

Kingston 8GB Class 10 micro SD memory card is used for saving data.

Cork Block

To cover the surf logger, cork is used because it is a flexible, impermeable, buoyant and compressible material. As much as fire resistant, it is also a thermal insulator. Cork suits very well as a cover material for our product because it's lightweight and waterproof. The Cork industry is considered an environmental friendly industry [16].

Conclusion

In terms of both price and functionality, these materials are one step further than the other options. Total price of all these (cork included) is 189 EUR.

B. Architecture

Power Architecture

The power supply in our project comes from Li-Poly 2000 mAh battery. This battery has a nominal voltage of 3.7 V. We will convert this voltage with the battery charger and boost it uptil 5 V. The output of the booster is directly connected to the arduino 5 V. voltage input then the Arduino linear regulator and the wireless shield linear regulator take care of providing the sensor stick and the Bluetooth radio the right amount of voltage (3.3 V). The TMP 36 temperature sensor is fed at 5 V. by the arduino output in the following sketch we have the electrical architecture as well as the power consumption in mA.

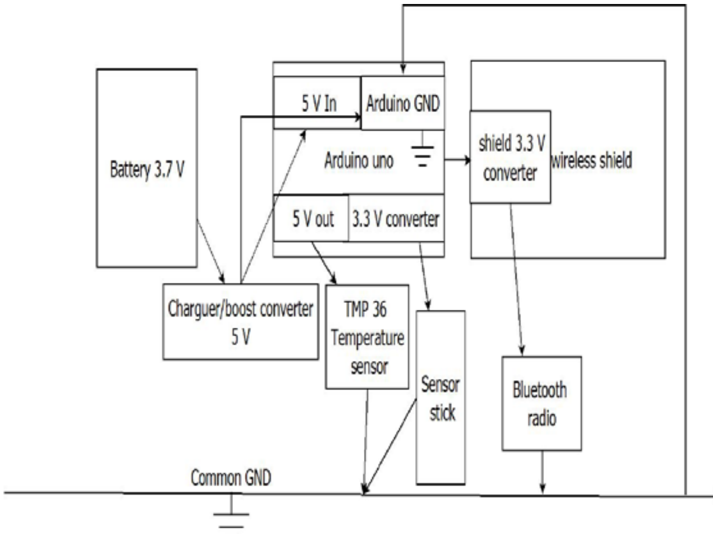

Figure.1 Power architecture of surf logger

Signal Architecture

The 9 Degrees of freedom-sensor stick is communicating with an I²C interface with the Arduino Uno. I²C is a multi-master serial single-ended computer bus invented by the Philips semiconductor division. I²C uses only two bidirectional open-drain lines, Serial Data Line (SDA) and Serial Clock Line (SCL), pulled up with resistors as we can see in the following sketch it's not necessary for us to add the pull up resistors because they are included in the mate.

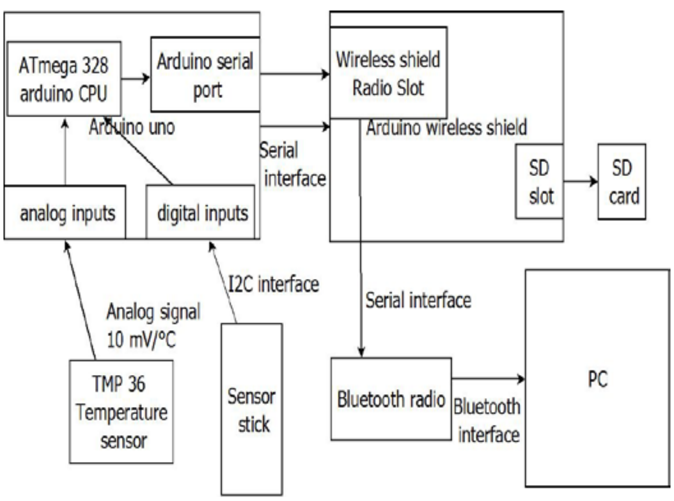

Figure.2 Signal arthitecture of surf logger

Design of the Case

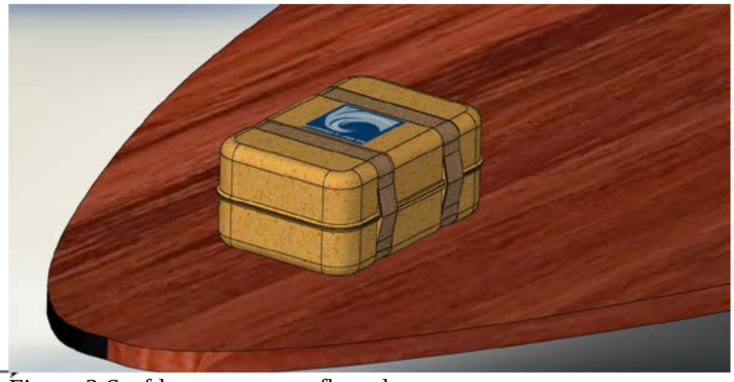

Figure.3 Surf logger on a surfboard

The box made of cork and with two straps that keep the box together. There is rubber tightening in between the two halves and this makes the box waterproof.

C. Functionalities

Read and Process the Data from the Sensor Stick

As explained in the section of software development, reading and visualization the data collected from the sensors is based on the razor-9dof-ahrs firmware. The first thing to get working is that the software is supposed to read the data from the sensor stick that includes the ADXL345 accelerometer, the HMC5883L magnetometer and the ITG-3200 MEMS gyro. The second thing to work on is to get the data from all sensors. It uses I²C interface (as explained in signal architecture).
In order to read I²C signals, the Software uses the wire library that allows communicating with I2C / TWI devices to the Arduino. For using the wire library it's necessary to know the addresses of each device that are provide in the datasheets of the devices. With the wire library, the rate is adjusted to 50Hz (25Hz bandwidth) because the main loop runs at 50Hz and the data from the sensors are read with a 6 byte resolution (2 each axis).

Once the code has read the information from the sensors the readings are corrected with the Sensor calibration, scale and offset values. We want to know the exact orientation of the surfboard. This means we need the yaw, pitch and roll angle.

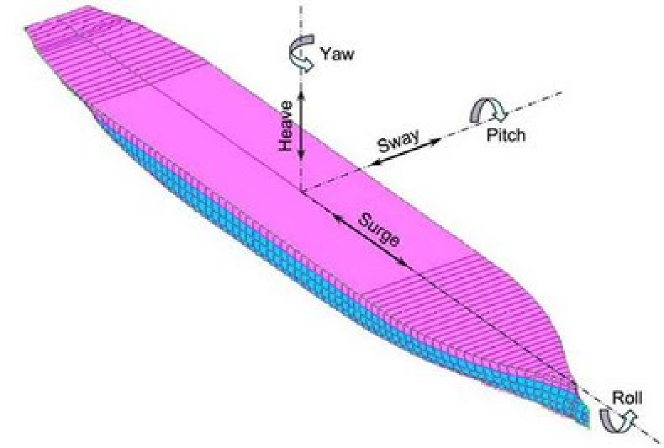

Figure 4 Explanation pitch yaw and roll on the surf board [ ]

http://salvador-nautico.blogspot.pt/2011/09/cabeceio-pitch.html //

Accelerometer and gyroscope are hard to use separately to measure the angle position. Angle position is derived from the accelerometer. It has noise, while the gyroscope is showing the drift. Though accelerometer gives noisy output, its measuring error is conservative. On the other side, gyroscope gives relatively noise immured output for short time duration, though its error will be diverged for long time period. With these characteristics, we can see that two sensors are in complementary relationship. If gyro drift can be corrected by accelerometer, the output angle can have reliability. Likewise, improved output can be calculated by the combination of two complementary sensors. The magnetometer gives as a yaw correction by measure the magnetic north.

Internally the fusions of accelerometer, magnetometer and gyroscope data are done to use a Direction Cosine Matrix (DCM) algorithm. The algorithm also takes care of handling sensor noise and numerical errors. It is based on a paper by William Premerlan on the theory and implementation of a direction-cosine-matrix (DCM).

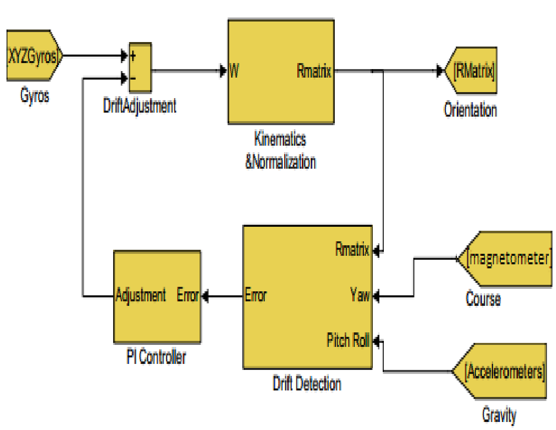

Figure.4 Block diagram of the DCM

Posture data (Euler angles) of the board are get from the gyro. For the roll, pitch, and yaw, three rotation matrices X, Y, and Z can be calculated:

$$X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix}, Y = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}, Z = \begin{bmatrix} \cos\varphi & -\sin\varphi & 0 \\ \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

DCM= Z.Y.X matrix is representing orientation of surfboard in 3-dimensional space.

Proportional plus integral feedback controller is used to apply the rotation correction to the gyros because it is stable and the integral term completely cancels gyro offset. Also if we consider thermal drift there is zero residual orientation error.

Sensor Calibration

The firmware also implements some settings options to improve precision and responsiveness for sensor calibration. If the sensors are not calibrated, they may effect like:

-Drifts in yaw when applying roll to the board.

-Pointing up does not really result in an up attitude

To calibrate the sensor stick we have to know that the definition of the axes differs from info that is printed on the board. The firmware uses:

- X axis pointing forward (towards the short edge with the connector holes)
- Y axis pointing to the right
- Z axis pointing down

To calibrate the gyroscope, we wanted to know the average noise of the gyro on all three axes. So, the sensor stick was laid on the table. The gyro was sent values. The average of every four values was calculated. (Table.2)

Axe	*Average*
X	30.30
Y	115.50
Z	27.17

To calibrate accelerometer, sensor stick was put each direction for each axes(x, y, and z). It was let just pure gravity and got minimum and maximum values of the gravity acceleration on each axis. In the following table we have collected the values:

Axe	Max	Min
X	254	-264
Y	265	-255
Z	242	-270

The extended calibration consists for *hard* and *soft iron* errors. To compensate hard and soft iron errors, processing sketch is used. It found the magnetic ellipsoid in the magnetic environment which our device was.

D. Tests and Results

In order to prove the functionalities that were explained above, some tests were designed to know if the device was working as expected. The environment of the proves was in most of the cases a worktable EPS classroom, except for the range test and the waterproof test which took place in others environments which were subsequently described.

The tested materials were the ones we had put in the material list was purchased by ISEP to inmotion.pt. The pc used to check the Bluetooth connection and run the processing sketch is a Toshiba PORTÉGÉ Z930-15E.

Bluetooth Range Taste

This test took place outside. For testing the Bluetooth range, it was started to sending data to the PC in a short distance and then gradually the device is moved away from the computer. Every five steps, some test movements were made to find out if the Bluetooth connection is still working. To measure the path length until the Bluetooth stops working, a string was used. Following the specs that were given by the Bluetooth standards and the manufacturer range of the antenna over open air should be approximately 100 meter.

Because the cork box attenuates to Bluetooth signal, two different tests is performed. They are:

a) Without the case

b) With the case

Autonomy Test by Measure the Current

To verify the calculations that performed on the battery, the maximum current draw could be measured. This current should not exceed the $108.64\ mA$. Also, an ammeter is needed to test it.
Assembly will follow the same pattern as the rest of the tests but the ammeter was placed between the battery and the boost converter as shown below:

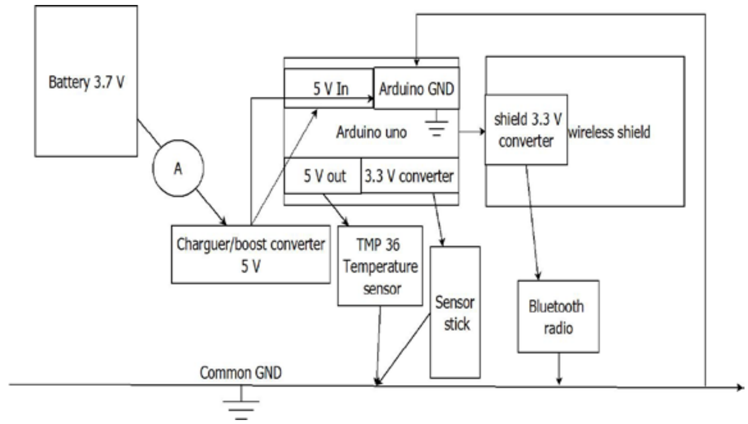

Figure.5

Battery Time and Temperature Test

During the discharging process a constant value of the voltage is necessary. The mAh of all the batteries shown in their characteristics (in this case it is 2000 mAh).

Autonomy is tested when the device is running. To perform the test, the device is been running steadily and sending data to the PC. The test started with full-charged battery. Start time was checked and written down. The device was started to run. When it shut down, the time was recorded again. The battery should last approximately 19 hours.

This test run in parallel with battery time test and consisted in measuring the temperature inside of the box with an external thermometer while the device was running and sending data to the computer. The temperature was measured every 10 minutes until it reached thermal equilibrium.

Waterproof Test

To check the waterproof properties of the cork case, it was put in water without electronic parts. After 10 seconds it was taken out and checked if there is any water inside.
At first the presence of water was checked by visual inspection and we putted some paper inside the case.

More tests were conducted with liquid contact indicators. A liquid contact indicator (LCI) is a small indicator that turns from white into another color after contact with water They are usually use to have a lead to the cause of a defect in electronic devices and also avoid discussions about liability and warranty.

Figure 6 Waterproof test

Results from Water test

There was coming water into the case because the seal was not tight enough. This was a manufacture problem, because the prototype was hand-made. In serial production, the case with the seal will be made more accurate because it will be made by machines.

Testing Device in the Water

The final tests will be conducted when the case is waterproof. Liquid contact indicators will be glued to the parts. In order to know if the water comes into the case. The test was taken place in the real environment in which our surf logger was used, the sea. It was fixed to a surf board. This will help us to test if :

- The range was enough to have a good surf experience and not lose the Bluetooth conection
- The cork was isolating components and there was no evidence that water has entereing the device
- That it was useful to improve surf skills

IV. CONCLUSION

Visual Interface

In order to have a visual representation of the exact orientation of the surfboard, the output data was computed by the Arduino Uno. It means that roll yaw and pitch angles were used to rotate a 3D model of the sensor stick.

The part of the code that handles is the processing sketch which is also provided with the AHRS firmware.

Processing is an open source programming language and development environment. The language builds on the Java language but uses a simplified syntax and graphics programming model. Processing is useful for making other computers "talk" with an Arduino.

To receive the data from the Arduino, the sketch was used the serial interface. Also to achieve that, it is necessary to import the serial processing library, the serial data may come from the USB port (universal serial port) or wirelessly by Bluetooth (see Bluetooth communication) or other wireless technologies. It is necessary to fix baud rate to the rate that Arduino Uno is issuing: 57600.

Bluetooth Communication

Instead of using WI-FI we use a Bluetooth antenna because of the low power consumption. This antenna can receive and send data to the output of our system. The data is sent by serial interface to the PC, Rx and Tx pins of the Arduino Uno and take care of this, for configuring the Arduino and make the calibrations we have used the USB as a serial port but we also have the option of using Bluetooth as a serial port.

In order to receive the angles by Bluetooth we have to adjust the baud rate of the antenna from the 115200 fixed by default to the baud rate of the Arduino code 57600.

Write Data on the SD Card

The wireless SD shield also allow to the Arduino board to communicate with a SD card using the SPI interface. Serial Peripheral Interface (SPI) is a synchronous serial data protocol used by microcontrollers for communicating with one or more peripheral devices quickly over short distances. SPI relies on pins 11, 12, and 13 for communication. Additionally when using the SD Library to access the card, Pin 4 is CS and cannot be used otherwise [17]

In order to achieve this we will use The SD library that allows for reading from and writing to SD cards. The angles will be saved on the SD card to have a copy of every surf session. The data will also be written when Bluetooth communication is interrupted. During this operating mode the Bluetooth connection is trying to be restored but in the progress no data will be lost [18], [19].

Future Development

With our device, you can write data on SD card and can get data with Bluetooth. But it is not possible to get these data both ways. You can only use one option at a time; write on SD card or get data with Bluetooth. If we work on the possibility that use them together, we believe it can be achieved.

In the future, the device could be produced together with a surfboard manufacture. This allows us to reach the market together. Thanks to this idea, sensor box and surfboard do not have to be bought separately and the costumer doesn't have to spend money for each one. We want to provide a product of good quality at an appropriate price. Our intention is, that the advertisement informs buyers about all the possible benefits which can be gained as a result of its use, but also about the most important technical details of the device, so that the customer will be able to determine their compliance with their requirements and make an informed choice, consistent with their expectations.

If the market research reveals an attractive market within the snowboard and skateboard industry, we will adopt our product for those markets by creating a fitted marketing plan.
In addition we can increase the quality of our case regarding waterproofness by designing a deeper channel for the seal.
Furthermore we will develop a website with the issues which are already mentioned in the marketing mix.
Finally we are going to improve the erosion of the case by varnishing it with water resistant ecological paint. As a special benefit for our costumer they will be able to create their own design of the box.

Features for future would be to make the temperature sensor to make all components switch off in the event the temperature inside the case is too warm. Furthermore, to improve the visual appearance when you want to check how your surfing was. For this we could develop an app so it’s easier to watch the stats from your surf session.

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