

EPS Erasmus Project

The Smart Object

Hannes Harms¹, Toomas Juht², Anna Janaszekiewicz³, Jana Valauskaite⁴

¹Student, Technical University of Braunschweig, Germany

²Student, Tallinn University of Applied Sciences, Estonia

³Student, Technical University of Lodz, Poland

⁴Student, Vilnius Gediminas Technical University, Lithuania

Abstract– This paper describes the development of a Smart Object used as an interface for CAD-programs or computer games. The computer interfaces at the moment are bound to the table tops. For example, one of these products is the computer mouse. We want to change that with the freedom of movement that is offered by the Smart Object. That is achieved by using sensors that register movement (IMU), touch (touchscreen) and voice (microphone). The results are that this is achievable with the methods explained in this paper.

Keywords–IMU, Arduino, CAD-program, JAVA, 3D-Mouse

I Introduction

During the study in ISEP on the European Project Semester, we can choose a general theme from the proposed to develop a project. Our group chose to work on the Smart Object. Before we started working we had to answer some questions: what is a Smart Object and what should it offer to the user? A Smart Object is an object that can be used for a PC (Personal Computer) interface. Nowadays, everyone uses computers for working or entertainment. In our opinion, our project should give users freedom of movement. At the moment we have the computer mouse which gives us 2D movement freedom in x- and y- axis. We wanted to propose something further than this. We wanted to design a product which shows 3D movement freedom and, moreover, that will enable the user to turn it, rotate it, zoom in and out on a computer screen.

This paper is structured in six chapters. First we present the general problem, motivation, objectives and expected results. Then in the state of the art, the possibilities that can be used to solve the problems are explained. Next chapter is concerned with the project development. It includes the design and construction of the device and also the programming of the object, the data connection and the representation in a virtual

environment. In a following chapter we also present some aspects related to the possible commercial impact of our product and environmental sustainability. The fifth chapter - conclusion - is summary of all the project and team cooperation. In this part we included what problems we had, how we solved them and what we learn in Erasmus program.

II State of the art

Most of the technologies that will be used are part of modern electronic devices and part of a mass market.

A *Microcontroller:*

Arduino– Arduino is a popular open source single-board microcontroller, it is designed to make the process of using electronics in multidisciplinary projects more accessible. The hardware consists of simple open hardware design for the Arduino board with an Atmel AVR processor (it is a single chip microcontroller which was developed by Atmel in 1996) and on-board input/output support. The software consists of a standard programming language compiler and the boot loader that runs on the board.[1]

B *Sensors:*

IMU–IMU is an electronic device that measures and reports on crafts velocity, orientation and gravitational forces; it uses a combination of accelerometers and gyroscopes. Typically they are used to maneuver aircraft, including UAVs (unmanned aerial vehicles), among many others and spacecraft, including shuttles, satellites and landers. It is also the main component of internal navigation systems used in aircrafts, spacecrafts, watercrafts and guided missiles. In this capacity, the data collected from the IMUs sensors allows a computer to track a crafts position.[2] In the project the IMU is going to be used for sensing movement, that sensor input is translated so that it is applicable in a CAD-program.

Touch screen—Touchscreen is an electronic visual display that can detect the presence and location of a touch within the display area. The term generally refers to touching the display of the device with a finger or hand, it can also sense other passive objects such as a stylus. Commonly, the touch screens are in game consoles, all-in-one computers, tablet computers and smartphones. It has two main attributes. Firstly, it enables one to interact directly with what is displayed rather than indirectly with a pointer controlled by a mouse or touchpad. Secondly, it lets one do so without requiring any intermediate device that would need to be held in the hand (other than a stylus, which is optional)[3] In this project the touchscreen is meant to detect the touch of the users finger.

Microphone—A microphone is an acoustic-to-electric transducer or a sensor that converts sound into an electrical signal. Most present day microphones use different methods: electromagnetic induction, capacitance change, piezoelectric generation or light modulation to produce an electrical voltage signal from mechanical vibration. [4]

C Power supply:

To power a wireless device one could use solar panels or rechargeable batteries, other options would be too difficult to implement in this project. They would be too expensive and complex.

Lithium Polymer battery - LiPo battery— Li-Po batteries are rechargeable batteries, they are usually composed of several identical secondary cells in parallel to increase the discharge current capability. [5]

They are compact and ideal for small cordless devices. **Solar panels**—A solar panel is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. A photovoltaic system typically includes an array of solar panels, and inverter, sometimes a battery and or solar tracker and interconnection wiring.[6] Solar panels would cost too much. Besides, the object works when it is held by the user, which means that the users hand would cover the small solar panel. Also it should be cleaned often, because it comes in contact with human skin.

D Wireless data connection:

Wi-Fi—Wi-Fi is a technology that allows an electronic device to exchange data wirelessly over a computer network. It includes high-speed internet connection. There are a lot of devices that can use Wi-Fi, such as a PC, video game console, smartphone, tablet or digital audio player. All of these can connect to a network resource such as the Internet via a wireless network access point. In indoor use the range is about 20 meters and outdoors its greater. Access point coverage, also called hotspot, can comprise an area as small as a single room with walls that block radio waves or as large as many square miles - this is achieved by using multiple overlapping access points.[7]

Bluetooth—Bluetooth is a widely spread wireless connection option. It can be found on PCs, smartphones, laptops and other devices. It is used for exchanging data over short distances from both fixed and mobile devices. Bluetooth creates personal area networks (PANs) with high levels of security.[8]

ZigBee—ZigBee is intended to be simpler and less expensive than other WPANs (wireless personal area network) such as Bluetooth. It is targeted at radio-frequency applications that require low data rate, long battery life and secure networking. ZigBee is best suited for periodic or intermittent data or single transmission from a single transmission from a sensor or input device.[9]

E Related Projects and Products

For the same purpose one can use 3Dconnexion's 3D mouse. The user can rotate, zoom, turn and pan the object when using it. The 3D mouse resembles a joystick a device that is placed on a table. On the products homepage one can find this sentence: Its a level of control thats simply not possible with a traditional mouse and keyboard. They launched their first product in 2009. 3Dconnexion has 5 different products that can be used for the same purpose; the difference is in segmentation.[10]

F Conclusions

Bluetooth is used for wireless data transfer because it is built in most of the computers and smartphones. When using ZigBee the users should buy a software and a receiver for that. Wifi would consume the biggest amount of energy so it is excluded because of that. For the microcontroller a Arduino board that has Bluetooth already built in is used. For the user interaction

three sensors were chosen: IMU, touchscreen and microphone.

The main competitor is the 3D mouse, the company that produces it has several products segmented for different customer groups. They differ in size and in the functions that the product offers. The differences are that the bigger products have built in LCD screens and they have more functions, but they also cost more. The smallest one has only the Controller Cap and two interface buttons.

III Project Development

This chapter describes the state of our product development, this includes the system architecture and hardware specifications. The main part of the object is an Arduino microcontroller. The board is connected to different sensors. Main part of the sensor system is an IMU, to get a full 6 degree of freedom measurement of the position of the object. The sensor data is transmitted to a PC over a wireless data connection. On the PC the object is modelled in a virtual environment. The programming language for this part is Java.

A System Architecture

All the parts are inside the outer shell except the touch screen. The outer shell is made from acrylic glass that is machined and bent to the needed shape. There are several holes and openings machined in for bolts and parts, the corners of the object are bent. The shell is screwed together because we are making a prototype and there might be a need to reopen the shell. Also the parts and components are bolted together.

A.1 Hardware Specifications

Typical modern wireless devices contain the following building blocks: A controlling platform with a CPU, sensors, wireless communication interface, memory and a power source. In this project we chose these blocks considering the following constraints: price, ease of use, flexibility and energy consumption.

Arduino BT—The Arduino BT is a microcontroller board based on the ATmega328 and the Bluegiga WT11 bluetooth module. Main features are: wireless serial communication over bluetooth, 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator, a 32 KB Flash Memory and 2 KB SRAM.[11]

IMU Digital Combo Board - ITG3200/ADXL345—The IMU offers a 6 degrees of freedom measurement.

The communication is solved over I2C with the Arduino. **ITG-3200 Integrated Triple-Axis Digital-Output Gyroscope**— The Gyroscope is single-chip, digital-output, 3-axis MEMS gyro optimized for gaming, 3D mice, and motion-based remote control applications. It features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyro outputs and a Fast-Mode I²C (400kHz) interface. The Digital-output X-, Y-, and Z-Axis angular rate sensors have a sensitivity of 14 LSBs per °/sec and a full-scale range of 2000°/sec.[12]

Digital Accelerometer ADXL345— The ADXL345 is a small and ultra low power 3-axis accelerometer. It measures the static acceleration of gravity, as well as dynamic acceleration resulting from motion or shock. The measurement is done with a high resolution (13-bit) at up to ±16 g. The data is formatted as 16-bit twos complement and is accessible through a I2C digital interface. The resolution of 3.9 mg/LSB) enables measurement of inclination changes less than 1.0°.[13]

Information flow from the sensors the the PC The movement of the object is registered by an IMU. After that the electronical data is converted by a logical level converter. At last the Arduino board sends the data via bluetooth to a PC. The microphone registers the voice input and sends it to the Arduino. The Arduino sends the data to a PC via bluetooth. The touch pad detects the input (touch) and sends it to breakout board. In the end the data is sent to the Arduino and from there its sent to the PC via bluetooth.

IV Programming the Smart Object

The programming part of the SO can be divided in two sections. On the device side we have the Arduino program, written in C. The programming language on the PC side is Java. To get a powerful amount of functions we use a Java OpenGL engine called "jmonkeyengine" [14]. To develop the Java program we use the open source software Eclipse [15]. Figure 1 gives an overview over the software architecture. The Java application is separated in three parts. A data management thread for the serial Bluetooth connection, a thread to visualize the 3D-environment and the cube and a thread for plotting the sensor data.

A The Arduino Program

The program is structured like the typical Arduino application in a Setup and a Loop part. In the Setup the Serial Connection is established. Furthermore all the digital and

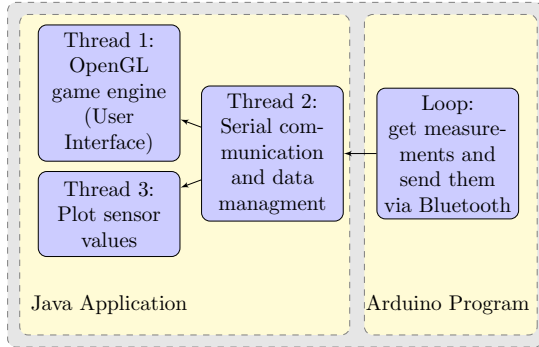


Figure 1: Software Architecture

analog ports, which are connected to the sensors, are defined. At least an array of double values is allocated for saving the sensor values. After the Setup the Loop starts to run. The first step in the Loop is to check, if a connection to the PC exist. If not, the Arduino has to do nothing. If a connection exist, the values from each sensor are called. For the IMU a open source library called "FreeIMU" [16] is used. The library was very helpful and makes the IMU easy to use. Inside this software, the gyro values and acceleration values are fused together to calculate a more stable position. As one result it is possible to get directly the Euler Angles of the sensor. The touchpad is directly connected to an analog port, but it is not possible to read x- and y-position at the same time, because a special pin configuration is necessary. After reading the touchpad position, the microphone value is read, which is also a analog read.

B Data Management Thread

The thread is used to create the connection to the SO. The used Bluetooth profile is a serial connection. If the Bluetooth connection is working, all incoming data is stored in 3 different FIFOs (First In First Out). The FIFOs are declared as public. The implemented data structure is thread save, to avoid data crashes. This is necessary because multiple threads have to access the data.

C Game Engine Thread

The Game Engine Thread implements the OpenGL game engine. After setting up the world and creating the cube the thread tries to get data from the data management thread. If data is available a loop is started to permanently update the visualization. To detect the zoom, the touch pad data is analysed in a separate function. If the

values are decreasing or increasing the zoom value is calculated new. By analysing the acceleration data for big changes in a short time period, a shake of the object can be detected. With this information two modes are implemented. In the first mode the cube can be rotated. In the second mode the camera around the cube can be rotated. For both modes the three Euler angles from the IMU are used to change the rotation of the cube or camera. Figure 2 shows the structure of the Algorithm.

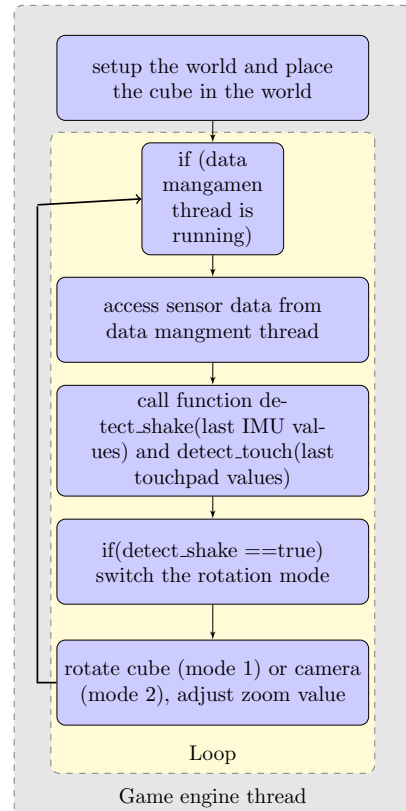


Figure 2: Game Engine Thread

D Plot Thread

The thread is used to plot the sensor data in real time. If a new value is added to the FIFO of the data management thread, the plot thread adds a time stamp to each value and refreshes the plot. Each plot is added to tab of a tabbed pane in the Java application, so the user can easily switch between the different plots or the object visualisation.

E Building and assembly

E.1 Building angle brackets

The plan was to buy the angle brackets that suited the best with our needs. Unfortunately we couldnt get them. The angle brackets were made from an aluminium alloy L-profile. The L-profile had to be cut in 20 mm wide pieces and then two holes had to be drilled into each angle bracket for the screws. The first hole drilled was 2 mm in diameter and the second one was in 3 mm in diameter. Files were used to make the edges surfaces smoother, because a metal saw was used for the cutting. Angle brackets for the bottom part had to be smaller from the 2 mm hole side so that the Arduino could be taken out if needed. Thous angle brackets were grinded to size.

E.2 Bending the Acrylic glass parts

For bending acrylic glass some heat source was needed. ISEP doesnt have a machine or some other device meant for that. In the Electro Mechanics laboratory the university had some devices that could be used for this purpose. Before bending, the parts were cut into size and some small cuts were made where the bending line should run, the cut was 0,3-0,5 mm deep. The small cut should be made on the side that is going to be inside of the bent corner. This cut relieves stress that the bending causes. A voltage regulator was used to heat up a wire that was fastened between two clamps. The wire was couple of mm (3 mm) hire then the piece of acrylic sheet. At those circumstances, after testing, was found that the best bends can be made with 3.1 V and 11,8 A, at this point the wire was around 400 deg C. This suited best with the 3 mm thick acrylic glass sheet that was used and the heated part didnt have any bubbles. There was also a problem with the wire it started to bend because the material elongated when the temperature grew. The solution for that problem was that it had to be held under tension manually to avoid that.

E.3 Machining the acrylic parts

The holes for the screws were drilled after bending the acrylic parts, this was done to achieve higher precision. Chamfers were made so that the screw heads would be at the same level as the acrylic. A drilling machine was used for this purpose. Also some holes were made for the touchscreen connector and the hole for the USB cable to charge the assembled device. The top and bottom parts were cut into size, the sides and corners were grinded and filed. Then the holes for the screws were drilled. Chamfers were also made to hide the screw heads.

E.4 Assembly

To assemble everything different screws, washers and nuts are used. The angle brackets hold together 4 acrylic glass parts that form the shell. Two types of screws are used to fasten the angle brackets to the acrylic: metal screws and M3 screws. The metal screw is screwed straitly in the angle brackets 2 mm diameter hole. The M3 screw goes through the 3 mm diameter hole and is fastened with a nut. To fasten all the electrical things to the acrylic M3 screws, rubber washers and M3 nuts are used. The M3 screw is fastened to the acrylic with a nut. This method should relieve some stress from the electrical parts. Then the electrical parts are fixed between 2 rubber washers and to hold them in place another nut is used. The last nut is loosely fastened on the screw to keep the hardware in place. The Touchscreen is taped onto one side of the shell. The touchscreen pin goes through the hole that was made before into the acrylic glass. The connector is placed inside the shell. Figure 3 shows the Smart Object with all assembled parts.



Figure 3: The Smart Object with all assembled parts

V Marketing

After developing the Smart Object we intend to put it in the market. Nowadays in order to sell the product it is not enough to produce it. It is important to concentrate on meeting the needs of our customers. Moreover an observation of the market is necessary to recognize changes on the market. Therefore a market environment analysis

was done.

A *The market environment analysis*

There are two types of market environments distinguished: micro and macro. Firstly, we will analyze the micro environment, secondly we will analyze the macro environment. Our product will be made of high quality materials and we are trying to get a modern and innovative solution. Furthermore, it is important to know, that there are no identical products in the market. In the first phase of the project our supplier is ISEP. If the product goes in production we are going to address a mass market. When we are introducing the object to the market we will need some suppliers. We have to remember that all companies cooperating with us are going to be checked carefully. Important things are the price and quality of resources and time of delivery.

If it comes to competition, at the moment the product we are offering does not exist in the market. But the market for smart electronic devices, which simplify life, is huge and rapidly growing. Nevertheless, one competitor for our product can be the 3D mouse. 3D mouse devices generally function through ultrasound and provide at least three degrees of freedom. On the market there are a lot of companies producing 3D mice. The other competitive product is the Wii Remote. It is not our direct competitor, but the product uses some of the same components and it can be used for the same purposes. The Wii remote is used for games. It is the primary controller for Nintendo's Wii console. Wii Remote has a motion sensing capability, which allows the user to interact with the game and manipulate items on screen via gesture recognition and pointing through the use of accelerometer and optical sensor technology. Another feature is its expandability through the use of attachments. The attachment bundled with the Wii console is the Nunchuk, which complements the Wii Remote by providing functions similar to those in gamepad controllers. Another product is the typical gamepad. It is a type of game controller, held in two hands, where the fingers (especially thumbs) are used to provide input.

However, these two products can be used only for gaming. So our product can be distinguished from the existing product, because it gives more possibilities and can be used for a professional purpose and also for having fun. Macro environment includes demographic, economic, natural, technological, political and cultural forces. We have to still observe changes in these forces

and answer to them.

B *Market segmentation*

Market segmentation is to make a distribution of the market into a relatively homogeneous group of consumers, because of the similarities of characteristics reveal a similar demand. Knowing the target segment will help us to prepare a product that meets the needs of our clients and helps us to obtain advantage in the market. We see opportunity to sell our product in two segments:

- People who are working with engineering programs meant for drawing. They are designers, architects, engineers, also teachers and students who use engineering programs. They spend a lot of their time using computers to draw sketches, diagrams, plans and models. Our product can facilitate the implementation of these activities.
- Young people (17-35 years) who use their computers or mobile phones to play games.

C *Basic marketing strategy*

Marketing strategy comprises actions and producing plan, the sales of the product and dealing with problems. The prototype is produced for ISEP, but the product can be sold in open market. Firstly we are planning to produce Smart Object for one segment, after one year we are planning enter the second market, market for younger people. If we think about the long-term strategy (three years) we would like to develop a product line. For example we can develop a product for professionals with very precise sensors and a support for many engineering softwares. Another aspect is the aesthetics of the product. It is possible to extend the color variations of the product, change shape or do our product smaller to better fit a woman's hand and to meet the need of young consumers. We extend our offer also for various types of connections to the computer object, it need not be only Bluetooth, but we can use WiFi or ZigBee.

D *Marketing MIX*

Marketing mix is a business tool used for marketing products. It is composed of four Ps/Cs:

D.1 *Product / Customer*

One can use the Smart Object as an input device for CAD-programs. By using the device one can turn the model (with the sensor data) in the program 3D space,

zoom in and out (with touch pad) and use some voice commands (microphone). With the acceleration data the program decides if the Smart Object is held in hand or lies on the table. The wireless connection is achieved via Bluetooth.

D.2 Price / Cost

We do not know yet how much our product will cost exactly, but the price includes: cost of materials, cost of packaging, distribution costs, advertising costs and labor costs. If we have production lines we will buy materials in bulk so price of material will be lower. Advertising costs will be spread over more units so that the price of the product in mass production will be lower. As for the price of the product, we can give only the costs incurred for materials and it is around 300 (VAT included) for the prototype.

D.3 Promotion and Communication

We would like to do in this phase of project some posters and leaflets. When we generate a web page we are going to put a description of the product there along with photos, videos illustrating the use of the product. The web page will be available in Portuguese, English and German language. We will pay for position in Google, because for the clients it will be easier to find us. We want to design two types of it: for professionals and after one year for people playing games. First one should be more professional and factual. Second one can be modern and less official. To attract the attention of customers we would like to send our product to four of the biggest professional magazines. The readers will have independent opinion about the product.

D.4 Place convenience

We want to sell our product in the Internet. It is better because we do not have to pay rent for the shop. It is more convenient for the client because he/she can do his/her shopping seven days a week, twenty four hours a day without leaving home. To distribute our product we use logistic companies. Moreover we need some special packages to carry the product. This package should prevent damage. They send us their order and after five days they have the product in their house. If our product do not meet customer needs, he/she can return product within fourteen days.

VI Conclusion

In this paper, a context-aware smart object for communication with a virtual environment is presented. This described object consists of three parts: (1) Arduino microcontroller, which connects with board of sensors, (2) an IMU (inertial measurement system) that gets a full 6 degree of freedom measurement of the position of the object, and (3) a wireless data connection and a virtual environment which is programmed in JAVA.

In the future the product has to be made more marketable, at the moment the prototypes shell is made of acrylic glass. This material is not suitable for mass production. When the Smart Object is going to hit the market the shell should be made from a moldable material like ABS- plastic. A lot of appliances and electronic devices have enclosures made from ABS-plastic. The material is tough and has a good impact resistance. The material can be easily molded with proper machines. Also the outer design should be more attractive, at the moment it looks like a box where we can put our hardware. Also the product can be made smaller. At the moment Arduino BT is used as a microcontroller it is ideal for prototyping. The microcontroller can be also a lot smaller because it is specially made to fill the given tasks. Also the battery can be more compact to take as few space as possible.

VII Acknowledgment

First of all, we would like to thank Instituto Superior de Engenharia do Porto for this opportunity to attend this project and program. We would like to thank all the supervisors (António Ferreira da Silva, Manuel Santos Silva, Maria Benedita Malheiro, Maria Cristina Ribeiro, Nídia Sá Caetano, Paulo Ferreira, Pedro Barbosa Guedes) for helping us, answering to all our questions and helping to solve some of the problems we had. Also we want to thank the teachers who helped us develop our deliverables, teamwork skills, communication skills and more- Ana Margarida Barata, Luis Caeiro Castanheira, Francisco Jose Vieira, Roger Nylund, Luis Cardia Lopes, Maria Alexandra Costa.

References

- [1] Wikipedia The Free Encyclopedia, Arduino. [Online]. Available from: <http://en.wikipedia.org/wiki/Arduino>[Accessed: April, 2012]

- [2] Wikipedia The Free Encyclopedia, Inertial measurement unit. [Online]. Available from: http://en.wikipedia.org/wiki/Inertial_measurement_unit [Accessed: April, 2012]
- [3] Wikipedia The Free Encyclopedia, Touchscreen. [Online]. Available from: <http://en.wikipedia.org/wiki/Touchscreen> [Accessed: April, 2012]
- [4] Wikipedia The Free Encyclopedia, Microphone. Online. Available from: <http://en.wikipedia.org/wiki/Microphone> [Accessed: 30th May, 2012]
- [5] Wikipedia The Free Encyclopedia, Lithium-ion Polymer battery. [Online]. Available from: http://en.wikipedia.org/wiki/Lithium-ion_polymer_battery [Accessed: April, 2012]
- [6] Wikipedia The Free Encyclopedia, Solar panel. [Online]. Available from: http://en.wikipedia.org/wiki/Solar_panels [Accessed: April, 2012]
- [7] Wikipedia The Free Encyclopedia, Wifi. [Online]. Available from: <http://en.wikipedia.org/wiki/Wi-Fi> [Accessed: April, 2012]
- [8] Wikipedia The Free Encyclopedia, Bluetooth. [Online]. Available from: <http://en.wikipedia.org/wiki/Bluetooth> [Accessed: April, 2012]
- [9] Wikipedia The Free Encyclopedia, ZigBee. [Online]. Available from: <http://en.wikipedia.org/wiki/ZigBee> [Accessed: April, 2012]
- [10] 3D connexion, What is 3D mouse. [Online]. Available from: <http://www.3dconnexion.com/products/what-is-a-3d-mouse.html> [Accessed: April, 2012]
- [11] Arduino, Arduino BT. [Online]. Available from: <http://arduino.cc/it/Main/ArduinoBoardBluetooth> [Accessed: April, 2012]
- [12] ITG-3200 Integrated Triple-Axis Digital-Output Gyroscope, .[Online]. Available from: <http://www.invensense.com/mems/gyro/itg3200.html> [Accessed: April, 2012]
- [13] Analog Devices, ADXL345: 3-AXIS, 2 G/4 G/8 G/16 G Digital accelerometer. [Online]. Available from: <http://www.analog.com/en/mems-sensors/mems-inertial-sensors/adxl345/products/product.html> [Accessed: June, 2012]
- [14] Java OpenGL Engine (April, 2012) [Online]. Available from: <http://jmonkeyengine.com/>. [Accessed: April, 2012]
- [15] JMonkey Engine(April, 2012):[Online]. Available from: <http://jmonkeyengine.com/> [Accessed: April, 2012]
- [16] FreeIMU library(April, 2012):[Online]. Available from: <http://www.varesano.net/topic/freeimu>