L''Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes
Université Mohammed V

Implementation of Smart Jacket

Realized By

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Introduction

Nowadays each country seeks to improve its educational system because this later is the pillar of any society, that why they invest with their economic, human and pedagogic resources so as to search for the best way to achieve this great goal which societies can benefit a lot from it. These measures and efforts taken are just concentrated to boost methods of teaching, but it's still insufficient and limited to come up with excellent results because they aren't directed to give more importance to the psychology and physical of learners.

For that, we need to bring in some betterment which consist on taking into consideration the different attitudes and behaviors of the students in order to establish a good understanding of the problems which intervene in their school lives and which prevent the good learning.

So as to put this betterment into work, we ought to adopt an educational system which is different from the classical one because it would be difficult to achieve it while this system contains obsolete components. And that's where the role of "Smart Schools" come into play to contribute to the quality of teaching making the environment of students comfortable for good learning and performance.

In this context, we decide to acquire information about the behavior of students to orienting them towards adopting the best manner for their school lives, by using "Smart Jacket" conceived with advanced technologies including IoT and embedded system techniques.

Our solution could be interesting when speaking about quality of education, it provides accurate tracking from where we can find out easily their problems which can help us to analyzethem and finding better solutions to deal with them.

This report summarizes the work we have done. It is organized into chapters as follows:

Inthe first chapter,we present the Smart School with its structure and its role in student life and we show how the integration of Smart Jacket into Smart School could be beneficial.

After that, in the second chapter we will present the hardware and the software tools required for the carrying out of the project.Also, we will explain with great details how the design of Smart Jacket would be.

The final chapter contains the discussion, conclusion and the future work of the project.

Chapter 1

Introduction of Smart School and the advantage of Smart Jacket

Introduction

This chapter aims to analyze the different components of our project, namely the problematic that inspires us to create “Smart Jacket”. It presents first a global description about the modern educational system which is used by “Smart School”, thereafter we will describe how our solution “Smart Jacket” can bring in improvements to the modern system through different options that offers.

1-Presentationand description of Smart School

1.1 What is Smart School?

Smart School is an institution that integrates advanced technology-basedequipment to enhance the quality of learning, preparing learners for the information age. Moreover, teachers rely on a wide range of tools multimedia, including movies, photos, audio, slides, etc., to make the teaching and learning process more effective.

Figure 1– Modern Equipments in Smart School

It encourages active thinking process while its' environment motivates students to use personal computers (PCs), the internet and intranets as research and communication tools. Students are able to access online libraries, use electronic mail (e-mail) or combination of desktop video-conferencing and chat rooms for doing tutorials.

1.2 Structure of Smart School

The smart school is Fully equipped by Classrooms with multimedia courseware and presentation facilities , Media center for multimedia courseware presentation, Network resources like internet, Computer laboratory for teaching courses, Multimedia development center for creating teaching materials, Studio/Theatre for centralized teaching and video conferencing , Teachers' room with online access to courseware catalogues and databases, information and resource management systems , Administration offices for managing students' data and facilities for tracking student and teacher performance or resources , Server room to handle applications, management databases, and web servers.

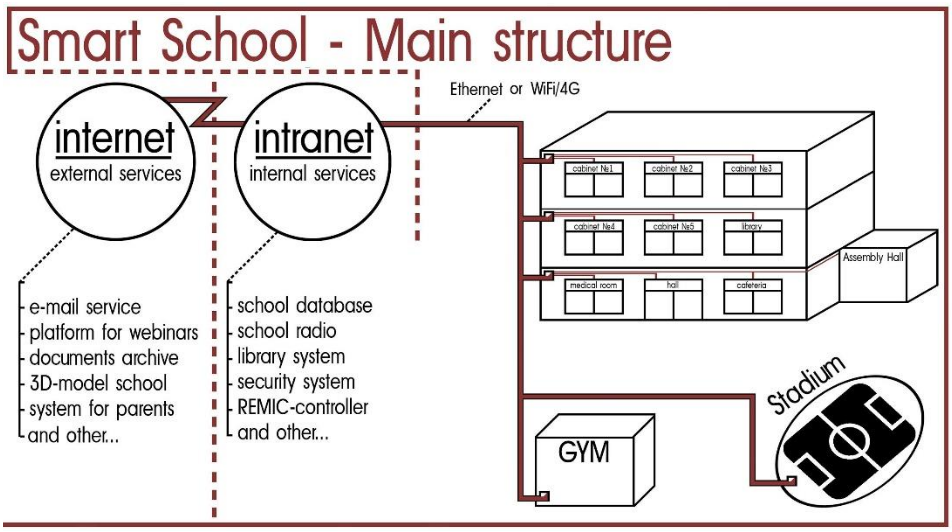

Figure 2–Example of the structure of the Smart School

In the context of innovation and development, the new IoT technology supports the "Smart School". It is based on a network that connects electronic objects, intended to exchange information between them.

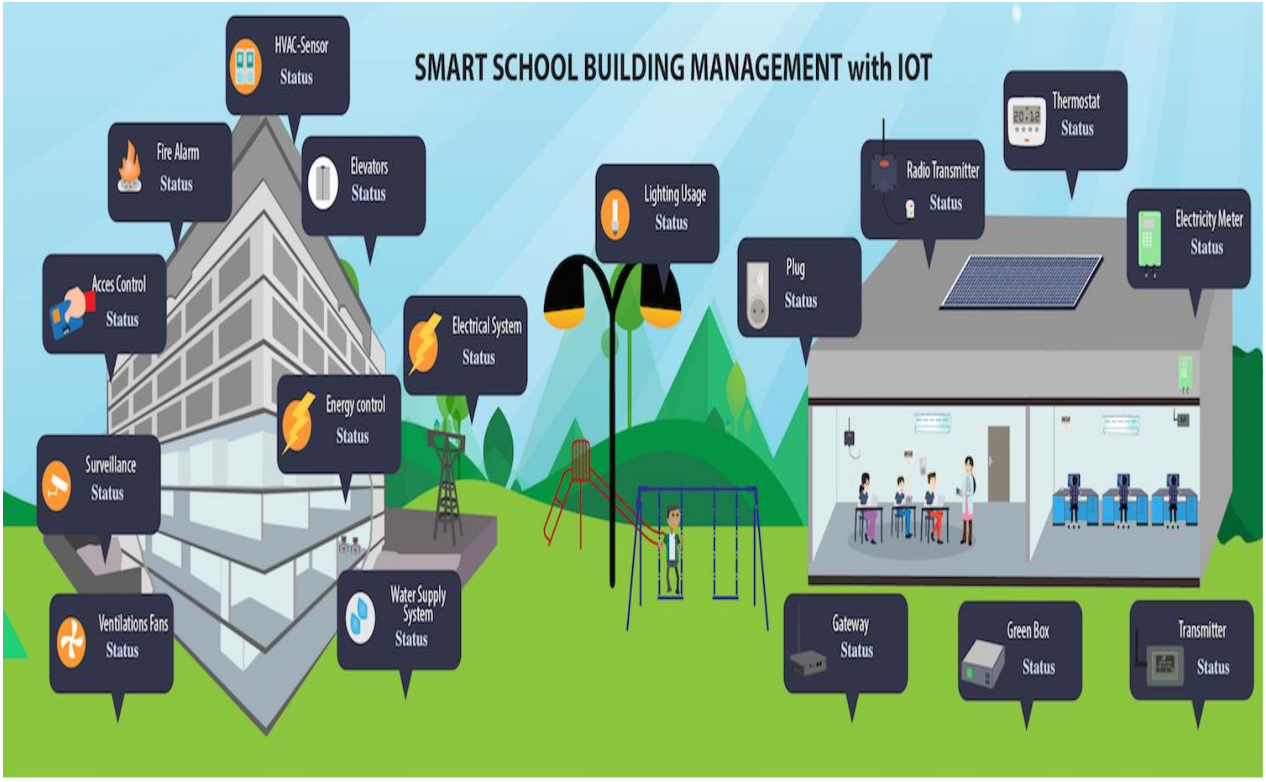

Figure 3– Smart School Building Management with IoT

Smart School by equipping itself with these smart objects based on IoT as it has the potential to redefine how students, teachers and administrators interact with their environment, thereby helping to improve the learning process and educational results.

1.3 Role of Smart School in student life:

Smart School invites, in the first place, to design an architecture and an educational environment that best serve and facilitate learning by integrating technology into teaching practices. This promotes the adaptation of students in this world of digitalization.

Indeed, the means of communication of information within the class play a crucial role in the understanding and the assimilation, that is why the transmission of the information with clarity by endowing the class with advanced equipment like interactive boards, tablets and other intelligent means will make learning more interesting, motivating, challenging and meaningful for students.

The smart school prepares the students to enter a more modern and worldwideenvironment successfully. The smart schools nourish the creative problem-solving skills in the new situations and the students are taught to have dare and courage in their decision-making and the responsibility assumptions, and for guaranteeing technical support and facility maintenance.

2- Smart Jacket

2.1 Problematic

Since the teachers meet a difficulty in the collection of information about behavior of students, we taught that the best solution to realize is Smart Jacket which will be based on developed means to acquire information concerning the body postures and attitudes since the body is a reflection of the mood and discomfort of the student. Also, because any behavior experienced by the student has a meaning and can play a crucial role in their understanding and their listening. Therefore, by having a better understanding of the student’s gestures and posture, it would be easy to intervene to guide student learning and it is through the consultation of its data that the right path of orientation is decided.

2.2 What is Smart Jacket?

Smart jacket is a fabric in which sensors are woven on it at strategic locations from where physical movements could be recorded.

We propose a concept that maintains a continuous follow-up on the postures of its wearer which is based in placing gyroscope sensors, accelerometer sensors at strategic location to collect the responses and treating them so as to determine problems of postures and correcting them.

Figure 4 : Example of Smart Jacket

2.3 Aim & Objectif

The project is based in principle on the different attitudes and behaviors of the students in order to establish a good understanding of the problems which intervene in their school lives and which prevent the good learning .

We will focus more particularly on the body that is a reflection of the mood and discomfort of the student. The latter in difficulty sends us body messages, signs that can be decrypted (aggressive behavior, inattention, lack of concentration, ...). These body postures and attitudes are to be considered as the expression of the malaise of the child in the classroom.

Any behavior experienced by the student is meaningful and may play a crucial role in their understanding and listening. Therefore, by having a better understanding of the student's gestures and posture, it would be easy to intervene to guide student learning.

Conclusion

Finally, to improve student education, we can collect information about their behavior through advanced techniques such as IoT. Thus, we can make students more comfortable in school for good concentration and a good school result.

Chapter 2

The main components of Smart Jacket, Conception& Assembling

1. Conception

The design consists more on actual planning of hardware part than the code to be created. A numberof software and hardware implementation techniques were used to design and develop the system. Fig. 5shows the block diagram of system.This section can be divided into many parts: Arduino ESP32 controller, MPU6050 sensors, multiplexer TCA9548A, Wi-Fi Module and the software Unity3D where the simulation is done. Block diagram is shows as below:

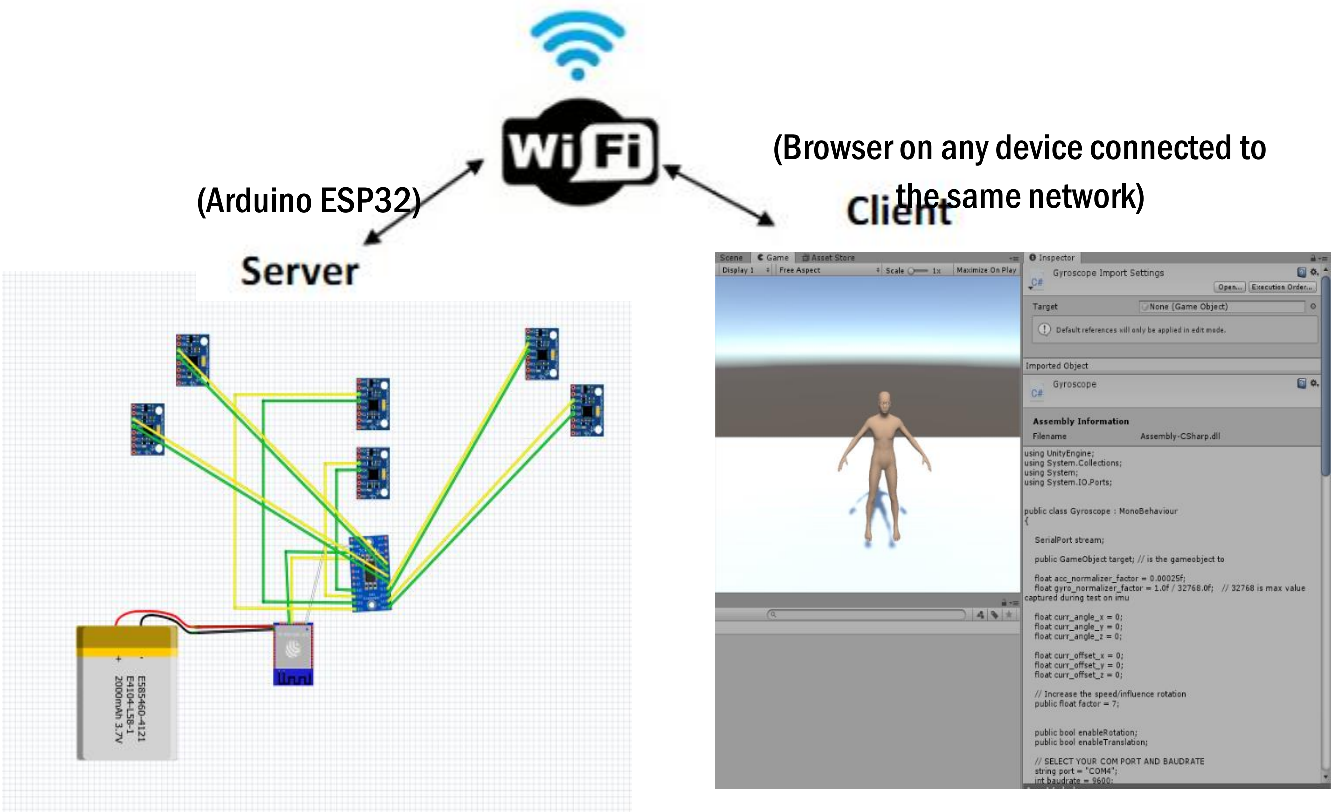

Figure 5 – Block diagram for our conception

Figure 6 – Motion track with Unity3D

In this work, we haveputted a set of Inertial Measurement Units (IMUs) attached at different parts of body to estimate 3D positions of arms, shoulders, back, we subsequently discuss how inertial sensors can be used to provide position and orientation information.Only the gyroscope was used for sensor position simulation. Data from all positions was recorded simultaneously and sent to a computer running Unity 3d software. The outputs of the software were angular velocity of body segments.

Six common positions shown in**Figure 7** are selected as the classification targets: (1) right arm; (2) left arm; (3) right shoulder; (4) left shoulder; (5) back.

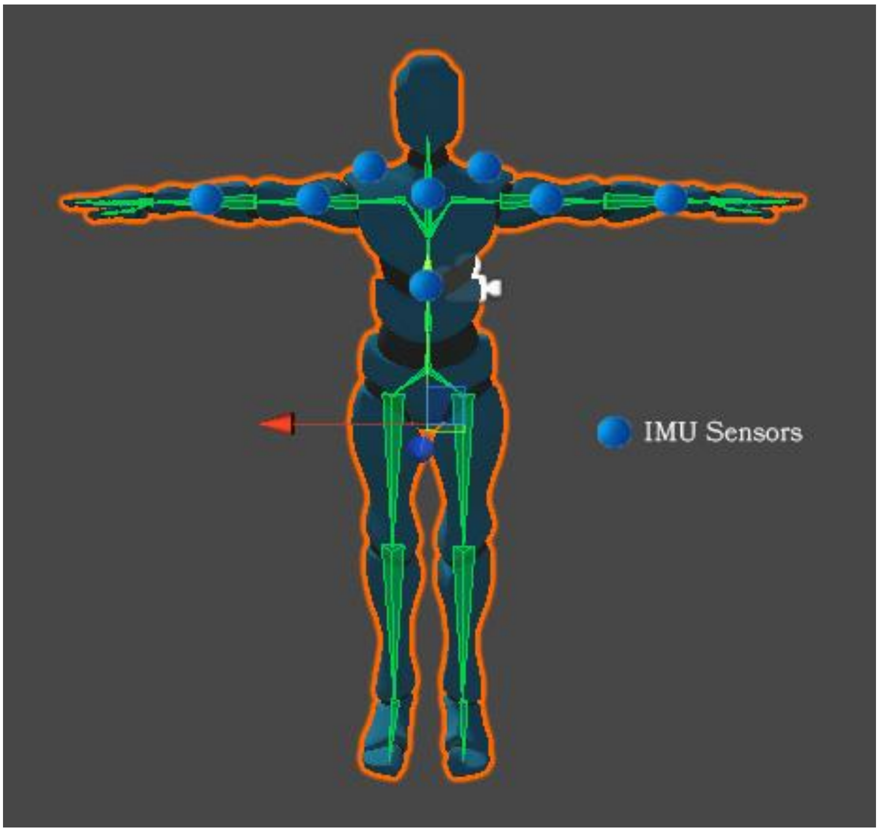

Figure 7: Positions target of IMUs

All these electronics will be wired between them using e-textile (electronic textiles) which are fabrics that feature electronics and interconnections woven into them, presenting physical flexibility. Components and interconnections are intrinsic to the fabric and thus are less visible and not susceptible of becoming tangled or snagged by surrounding objects.

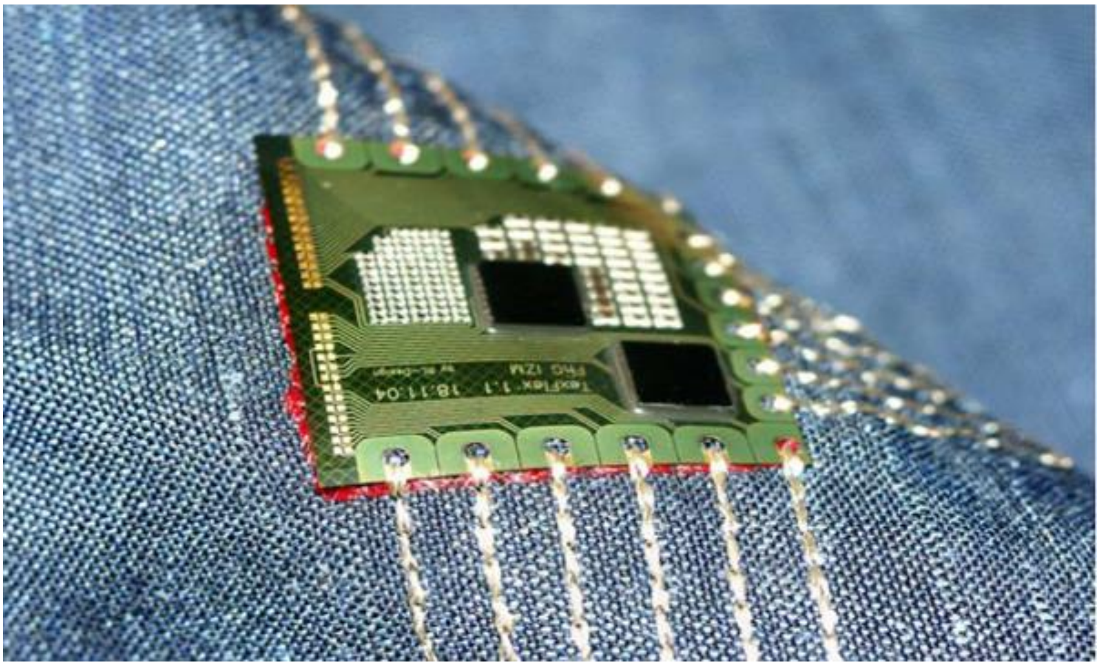

Figure 8 : Electronic woven into E-textile

2. Components Details

Different components of block diagram are described in details below:

No	Item
1	MPU6050
2	Multiplexer TCA9548A
3	ESP32
4	Battery
5	Unity 3D

2.6 MPU6050

The leading low-cost MEMS Motion Tracking Device is the Invensense MPU – 6050 which is a six-axis device (Gyro + Accelerometer). It is a sensor based on MEMS (Micro Electro Mechanical Systems) technology. Both the accelerometer and the gyroscope are embedded inside a single chip. This chip uses I^2C (inter integrated Circuit) protocol for communication.

A gyroscope measures the sensor's angular velocity, i.e. the rate of change of the sensor's orientation. An accelerometer measures proper acceleration, i.e. the rate of change of velocity.

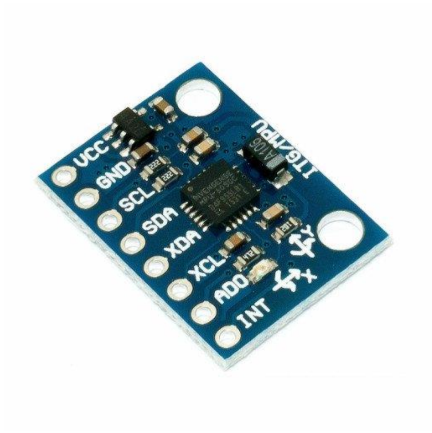

Figure 9 : GY-521 MPU6050

How does an accelerometer work?

There are many different types of accelerometers: mechanical, capacitive, piezoelectric. What interest us is the piezoelectric accelerometer. They have a crystal attached to a mass, so when the accelerometer moves, the masssqueezes the crystal and generates a tiny electric voltage as shown in the below image.

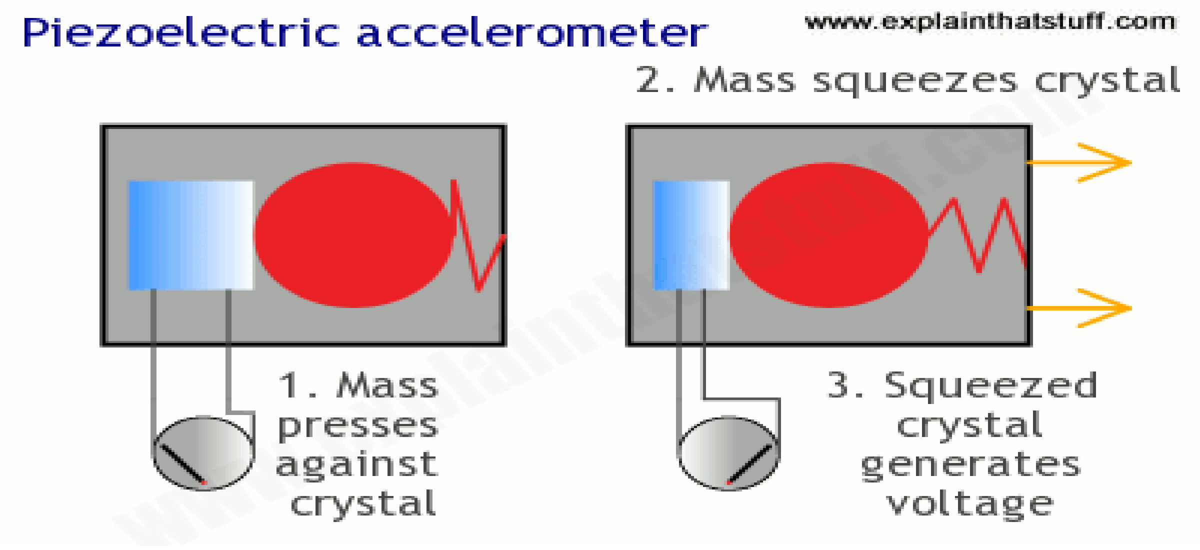

Figure 10: The basic concept of a piezoelectric accelerometer

How does a Gyroscope work?

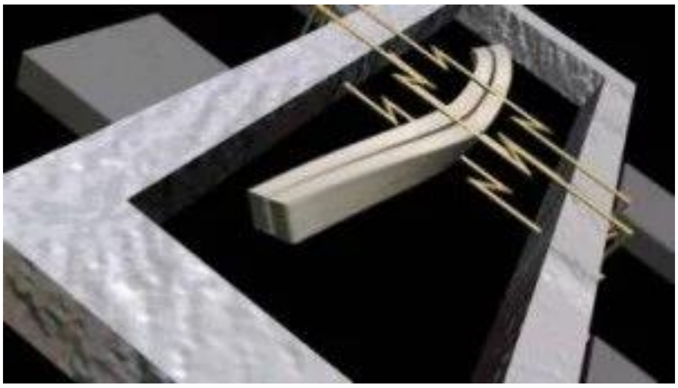

Figure 11: The principal work of gyroscope

It is held in place using piezoelectric crystals. Whenever you try to tilt this arrangement, the crystals experience a force in the direction of inclination. This is caused as a result of the inertia of the moving fork. The crystals thus produce a current in consensus with the piezoelectric effect, and this current is amplified. The values are then refined by the host microcontroller.

2.2 Multiplexer TCA9548A

A multiplexer, or MUX, is a device that selects one of several analog or digital input signals and then forwards the data or signal along that line into a single input. This means that multiple sensors can share the same data-line simultaneously and the multiplexer chooses which device to listen to based on the inputs of the selector bits on the MUX.

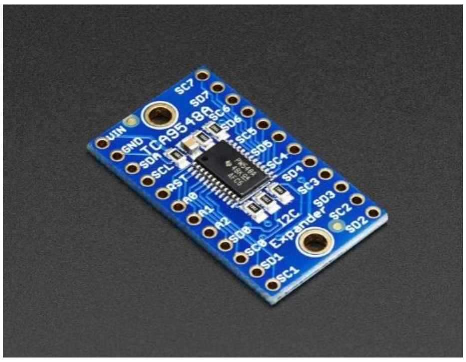

Figure 12: TCA9548A 1-to-8 I2C multiplexer

It is a way to get up to 8 same-address I2C devices hooked up to one microcontroller – this multiplexer acts as a gatekeeper, shuttling the commands to the selected set of I2C pins with your command.The multiplexer itself is on I2C address 0x70 and we simply write a single byte with the desired multiplexed output number to that port, and bam – any future I2C packets will get sent to that port.

2.3 ESP32

ESP32 by Espressif Systems is a popular low-cost microcontroller chip with a full TCP/IP and Wi-Fi stack. A number of features are supported, making it easy to interface with various hardware to put it online, making this inexpensive chip a prominent player in the emerging Internet of Things (IoT).

This chip integrates the following features:

- Wi-Fi (2.4 GHz band)
- ☐Bluetooth 4.2
- ☐Dual high performance cores
- ☐Ultra Low Power co-processor
- ☐Severalperipherals

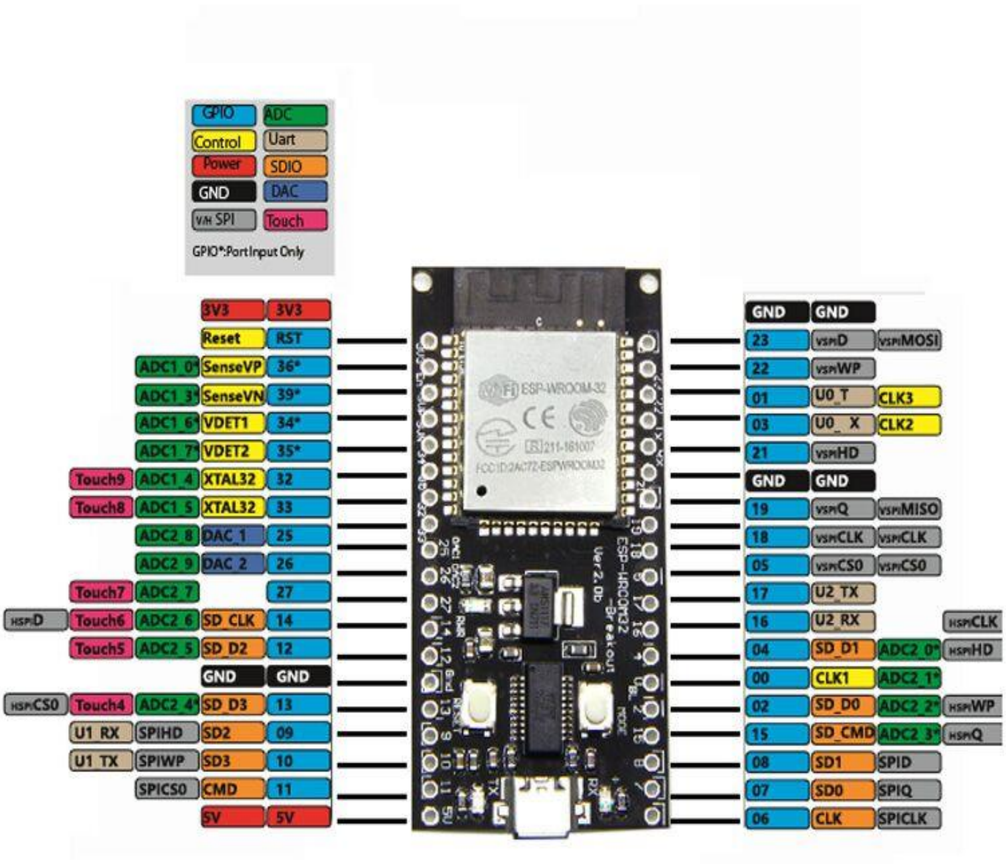

Figure 13: Schema of esp32-wroom-32

2.4 LiPo Battery

Figure 14: LiPo Battery for jacket

LiPo battery is new generation rechargeable battery to meet the demands of evolution to various, thinner and lighter battery.

LiPo battery is lightweight and thin portable information & communication devices such as portable phones, portable audio systems and PDA (personal digital assistants). LiPol Battery's liPo battery can be utilized in a wide variety of market products.

LiPol Battery has developed, and introduces a liPo battery that achieves an ultra-thin under 1mm with high performance through its own original technology and high reliability employing a complete gel-type electrolyte.

2.7 Unity 3D

Figure 15: Logo of Unity

Unity gives users the ability to create games and experiences in both 2D and 3D, and the engine offers a primary scripting API in C#, for both the Unity editor in the form of plugins, and games themselves.

3. Assembling

The Hardware setup of our system consist of an Arduino micro controller with onboard power supply,wireless communication and data collection form IMU clusters. We had to use multiple IMUs in 8 different positions so as to obtain the whole movement of body but since all sensors will be at one address, we have to use a multiplexer for I^{2}C busso the processor can then talk to this sensor alone without affecting the others.

The system was designed to estimate the shoulder and elbow joint angles by using clusters of one or more IMUs, shoulder and wrist. The raw data from each of the cluster is collected by an Arduino ESP32. This data is sentwirelessly to the computer, which initially estimates the absolute orientation of each cluster separately and then takes the difference between the absolute orientations in order to estimate the joint angle involved. The results are displayed in real time on a virtual mannequin created in Unity 3D. This provides for visual validation of the data. Since IMUs are known to have drift, data from multiple IMU within a cluster will be fused so as to get a better position estimate.

Figure 16: principle of conception

3.1 Wiring MPU6050 with Arduino

The wiring for this project is shown below :

- GY-521 Vcc pin -> ESP32 3V3 pin
- GY-521 Gnd pin -> ESP32 Gnd pin
- GY-521 SDA pin -> ESP32 SDA pin
- GY-521 SCL pin -> ESP32 SCL pin

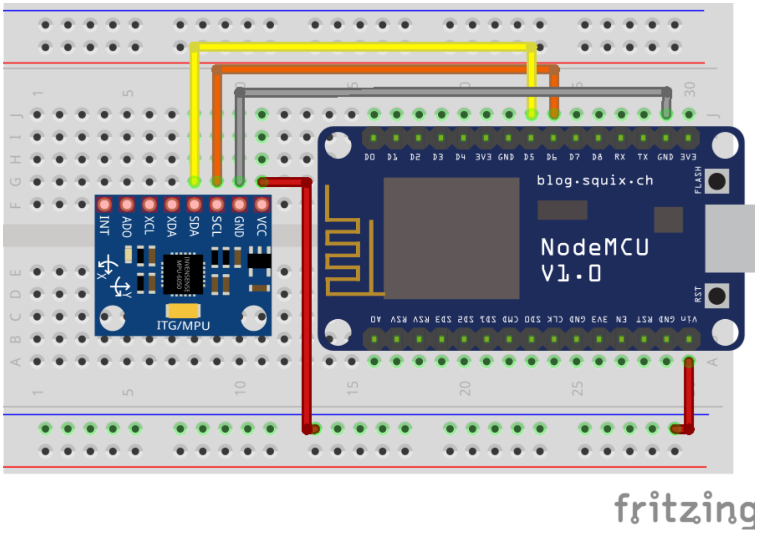

Figure 17: wiring esp32 with MPU6050

3.2 Basic communication

When the MPU is powered on it initially is in sleep mode. To take our measurements we will need to wake up the MPU. To wake up the MPU we need to write to the register which address is(0x6B). This register configures both the power mode and the clock source. It also can disable the temperature sensor and reset the entire device. Initially we will set this entire register to 0. This will wake up the MPU, keep the Temperature sensor on and use it's internal clock.

Now we should be able to read the accelerometer, gyro and temperature signals. The way that we do this is by starting a transmission, then writing the starting register, then requesting how many bytes we want to read, then reading them. All of the measurements we are interested in are 16bits numbers, meaning they take up two registers and we need to combine them when we read the values.

In the loop function, seven sensor values (3x accelerometer, 1x temperature, and 3x gyro) are requested from the GY-521 module. The MPU-6050 has many registers which can be read. Fourteen of these registers contain the sensor values that we need. As a first step, we tell the GY-521 module where we are going to start reading ("Wire.write(0x3B);"). Then, we request to read 14 registers ("Wire.requestFrom(MPU_ADDR, 7*2, true);"). If you are wondering, why 14 registers are read instead of 7 registers, the reason is quite simple: Each sensor value has a size of 2 byte. As each register has a size of one byte, a single sensor value must be retrieved by accessing two registers. The first register contains the so-called "high byte" and the second register contains the "low byte". Next, all values are retrieved and printed out to the serial connection. At the end of the loop function, a delay of one second is added in order to avoid flooding the serial monitor with messages.

```
#include "Wire.h"

const int MPU_addr=0x68; // I2C address of the MPU-6050

int16_t AcX,AcY,AcZ,Tmp,GyX,GyY,GyZ;

void setup() {
Wire.begin();
Serial.begin(115200);

check_I2c(MPU_addr); // Check that there is an MPU

Wire.beginTransmission(MPU_addr);
Wire.write(0x6B); // PWR_MGMT_1 register
Wire.write(0); // set to zero (wakes up the MPU-6050)
Wire.endTransmission(true);
}

void loop() {

Wire.beginTransmission(MPU_addr);
Wire.write(0x3B); // starting with register 0x3B (ACCEL_XOUT_H)
Wire.endTransmission(false);
Wire.requestFrom(MPU_addr,14,true); // request a total of 14 registers
AcX=Wire.read()<<8|Wire.read(); // 0x3B (ACCEL_XOUT_H) & 0x3C (ACCEL_XOUT_L)
AcY=Wire.read()<<8|Wire.read(); // 0x3D (ACCEL_YOUT_H) & 0x3E (ACCEL_YOUT_L)
AcZ=Wire.read()<<8|Wire.read(); // 0x3F (ACCEL_ZOUT_H) & 0x40 (ACCEL_ZOUT_L)
Tmp=Wire.read()<<8|Wire.read(); // 0x41 (TEMP_OUT_H) & 0x42 (TEMP_OUT_L)
GyX=Wire.read()<<8|Wire.read(); // 0x43 (GYRO_XOUT_H) & 0x44 (GYRO_XOUT_L)
GyY=Wire.read()<<8|Wire.read(); // 0x45 (GYRO_YOUT_H) & 0x46 (GYRO_YOUT_L)
GyZ=Wire.read()<<8|Wire.read(); // 0x47 (GYRO_ZOUT_H) & 0x48 (GYRO_ZOUT_L)
Serial.print("AcX = "); Serial.print(AcX);
Serial.print(" | AcY = "); Serial.print(AcY);
Serial.print(" | AcZ = "); Serial.print(AcZ);
Serial.print(" | Tmp = "); Serial.print(Tmp);
Serial.print(" | GyX = "); Serial.print(GyX);
Serial.print(" | GyY = "); Serial.print(GyY);
Serial.print(" | GyZ = "); Serial.println(GyZ);

delay(500); // Wait 0.5 seconds and scan again
}

byte check_I2c(byte addr){
// We are using the return value of
// the Write.endTransmisstion to see if
// a device did acknowledge to the address.
byte error;
Wire.beginTransmission(addr);
error = Wire.endTransmission();

if (error == 0)
{
Serial.print(" Device Found at 0x");
Serial.println(addr,HEX);
}
else
{
Serial.print(" No Device Found at 0x");
Serial.println(addr,HEX);
}
return error;
}
```

Figure 18: Codefor communication with MPU6050

The connection of Arduino ESP32 with MPU6050 using serial communication is shown below:

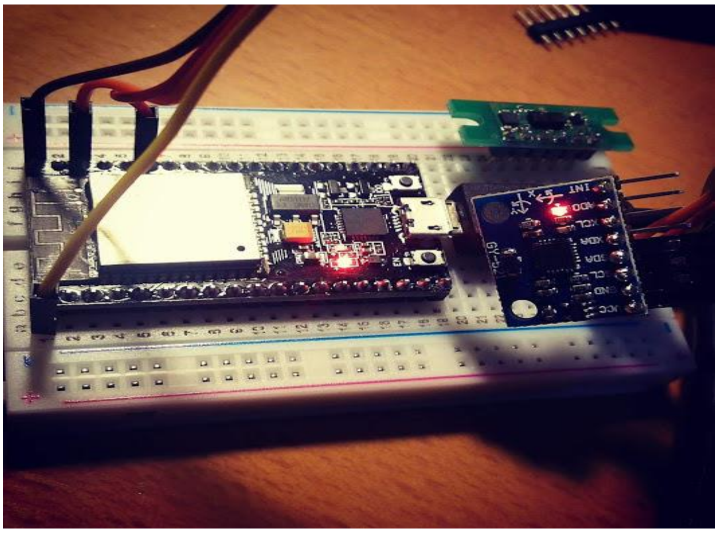

Figure 19: Test of MPU6050 with ESP32

The output that we produced is shown below:

```
aX =  -7064 | aY =  10176 | aZ =  11208 | tmp = 29.75 | gX =   -904 | gY =      5 | gZ =   -322
aX =  -7196 | aY =   9824 | aZ =  11336 | tmp = 29.75 | gX =   -285 | gY =   -180 | gZ =   -188
aX =  -5780 | aY =   2368 | aZ =  14544 | tmp = 29.75 | gX = -22301 | gY =   2625 | gZ =  -5303
aX =  -1696 | aY =     44 | aZ =  16544 | tmp = 29.85 | gX =   -420 | gY =   -350 | gZ =    -85
aX =  -1716 | aY =     20 | aZ =  16588 | tmp = 29.80 | gX =   -434 | gY =    -81 | gZ =    -70
aX =  -1724 | aY =     12 | aZ =  16632 | tmp = 29.85 | gX =   -439 | gY =   -107 | gZ =    -54
aX =  -1660 | aY =    172 | aZ =  16564 | tmp = 29.71 | gX =   -413 | gY =    -96 | gZ =    -60
aX =  -1568 | aY =   -760 | aZ =  16488 | tmp = 29.75 | gX =   -457 | gY =   -106 | gZ =     -9
aX =  -1740 | aY =    156 | aZ =  16676 | tmp = 29.75 | gX =   -425 | gY =   -102 | gZ =    -78
aX =  -1780 | aY =     28 | aZ =  16616 | tmp = 29.85 | gX =   -432 | gY =    -81 | gZ =    -68
aX =  -1632 | aY =     -4 | aZ =  16696 | tmp = 29.85 | gX =   -397 | gY =    -26 | gZ =    -69
aX =  -1692 | aY =     32 | aZ =  16488 | tmp = 29.75 | gX =   -421 | gY =    -95 | gZ =    -54
aX =  -1736 | aY =     44 | aZ =  16596 | tmp = 29.80 | gX =   -425 | gY =   -105 | gZ =    -74
aX =  -1716 | aY =    -12 | aZ =  16624 | tmp = 29.80 | gX =   -418 | gY =    -88 | gZ =    -63
aX =  -1736 | aY =     12 | aZ =  16452 | tmp = 29.85 | gX =   -418 | gY =   -102 | gZ =    -67
aX =  -1700 | aY =     76 | aZ =  16680 | tmp = 29.80 | gX =   -413 | gY =   -118 | gZ =    -70
aX =  -1660 | aY =   5384 | aZ =  13644 | tmp = 29.80 | gX =  26935 | gY =  -4916 | gZ =    757
aX =  -7680 | aY =  10880 | aZ =   9840 | tmp = 29.85 | gX =   -538 | gY =   1631 | gZ =  -2064
aX =  -6208 | aY =   5252 | aZ =  10824 | tmp = 29.89 | gX =  -7468 | gY =   2253 | gZ =  -1185
aX =  -7420 | aY =   6228 | aZ =  11792 | tmp = 29.89 | gX =   1150 | gY =   7089 | gZ =  -4492
aX =  -7164 | aY =   7072 | aZ =  13156 | tmp = 29.80 | gX =    667 | gY =  -4435 | gZ =   -698
aX =  -6980 | aY =   9336 | aZ =  11836 | tmp = 29.85 | gX =   -674 | gY =   -227 | gZ =    107
aX =  -8120 | aY =   9440 | aZ =  10828 | tmp = 29.89 | gX =    290 | gY =   -799 | gZ =   -514
aX =  -8568 | aY =   9448 | aZ =  10476 | tmp = 29.85 | gX =   -323 | gY =    500 | gZ =     53
aX =  -9764 | aY =   7460 | aZ =  11016 | tmp = 29.80 | gX =  -1829 | gY =  -2223 | gZ =   1124
aX =  -8448 | aY =   8592 | aZ =  11128 | tmp = 29.89 | gX =    800 | gY =   -709 | gZ =  -1364
aX =  -9324 | aY =   8556 | aZ =  10416 | tmp = 29.85 | gX =   -483 | gY =   -283 | gZ =   -736
aX =  -9936 | aY =   9472 | aZ =   8284 | tmp = 29.89 | gX =   1336 | gY =   2446 | gZ =    748
aX = -10212 | aY =   8968 | aZ =   9508 | tmp = 29.80 | gX =   -243 | gY =    -95 | gZ =   -377
aX = -10424 | aY =   8992 | aZ =   8956 | tmp = 29.75 | gX =   -539 | gY =   -185 | gZ =     46
aX = -10308 | aY =   9140 | aZ =   8676 | tmp = 29.85 | gX =   -401 | gY =   -377 | gZ =   -482
aX = -10068 | aY =   8968 | aZ =   9152 | tmp = 29.89 | gX =     96 | gY =     87 | gZ =     -1
aX =  -8272 | aY =   2276 | aZ =  15480 | tmp = 29.89 | gX =  -9084 | gY =  -5002 | gZ =  -2562
aX =  -1900 | aY =     36 | aZ =  16560 | tmp = 29.80 | gX =   -396 | gY =   -166 | gZ =    -77
aX =  -1820 | aY =     16 | aZ =  16708 | tmp = 29.85 | gX =   -417 | gY =   -109 | gZ =    -64
aX =  -1752 | aY =     40 | aZ =  16696 | tmp = 29.89 | gX =   -438 | gY =   -121 | gZ =    -69
aX =  -2780 | aY =    220 | aZ =  18852 | tmp = 29.85 | gX =     -2 | gY =   -925 | gZ =     46
aX =  -1812 | aY =    144 | aZ =  16544 | tmp = 29.85 | gX =   -415 | gY =   -118 | gZ =    -82
```

Figure 20: Output of MPU6050

Conclusion

This jacket is a prototype for the first design to achieve human posture data collection using sensors. The design principles applied here can be applied to collect data using fabric sensors which are the new technology.

Preliminary design was to establish the connection and data collection modules in place. This has been done successfully as mentioned abovein the paper. Our next step would be applying the artificial intelligence algorithms to identify the psychology of the wearer based on his comportments.

Chapter 3

This chapter contains the discussion, conclusion
And the future work of the project

1. Discussion

During the whole period of the project we gained of lot of knowledge on the Arduino UNO R3 and ESP32, gyroscope and accelerometer sensors. If we talk about the achievements out of the project when starting to do theproject it was to control sensor MPU6050with Arduino UNO R3 and transmit that data via serial communication. Then we managed to use ESP32 so as to send that data via wireless technology and collecting them using a script with C# in order to simulate the movements collected with sensors on Unity3D an engine used to create three-dimensional, two-dimensional, as well as simulations and other experiences.

The main achievements that we gained out of the projectwere that we got to learn programming in Arduino IDE and could learn how to program using embedded C.Another main achievement was we could learn and understand the Arduino technology, the wide applicationsof Arduino and IoT. There are lots of many other areas where the Arduino could be used for educational applications and that are the reasons for us to choose this project.

2. Conclusions

To get to the aim of a project there will be always a set of objectives, to achieve that objectives we needto know how where and with what resource is the step towards completing the objectives taken. Now in thisproject too to get to the aim of the project there was a set of objectives, which gradually changed as the projectresearch was completed and then while testing a certain technology the objectives again changed due to thefailure of the method. Now the first thing of the project is a good research, we had to do a wide and a strongresearch before we started to put our objectives as some technologies were new in market.Each stage of the project was tested after every part of it was completed and then moved on to the next one.During the course of the project we gained knowledge of embedded Cwe also gained knowledge of Arduinotechnology and what this small microcontroller is capable of.

The challenges that we faced during the course of the project were that of the time constrain, as we had to learnabout interfacing with Arduino and the engine of simulation Unity 3D and then learn about IOT . If given an opportunity to work again on a project, we will try to learn an advanced technology than Arduino which is Raspberry Pi as its has more fields of applications sowe would be happy to take it up.

3. Future Work

Many different adaptations, tests, and experiments have been left for the future due to lack of time and materials (i.e. acquiring real data are usually very time consuming, requiring meeting with some psychologist). Future work concerns deeper analysis of particular mechanisms, new proposals to try different methods. There are some ideas that we would have liked to try during our tests but the lack of time and materials prevent us from doing them, so the following ideas could be tested:

Measuring the heart rate: Heart rate data is an empowering tool that can help you be more aware of your heart health .

Textile Temperature Sensor: Body temperature is an important physiological signal in terms of heat, cold stress and comfort aspects. The aim of this study was to develop weft knitted temperature-sensing fabric along with application of welding technology. Temperature sensing structures have been realised by knitting conductive yarns into the textile structure. The working principle of knitted sensors is based on the inherent tendency of conductive yarn to respond changes in temperature according to its electrical resistance.

[https://www.researchgate.net/publication/296704872_DEVELOPMENT_OF_TEXTILE-BASED_TEMPERATURE_SENSOR]

Textiles generating electricity: If clothing were packed with thermoelectric generators, body heat could be turned into electricity.

https://www.youtube.com/watch?v=H7SEz80f2gQ

This development is extraordinary and a continuous process which demands more accurate sensibility of sensors. Sensors will continue to be miniaturized until they reach micrometre and even nanometre scale. They will then be able to be deeply integrated into material fibres. Another fact of progress is the energy sector. These sensors need to be self-sufficient. There are currently three approaches being explored, recovering mechanical energy (from the body's movements), recovering heat from the body, and generating solar power. It's impossible to determine a list of potential uses for upcoming technology at the moment because the possibilities are endless.