Embedded System Design with ARM
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Lecture – 40
Experiment Using Bluetooth

Welcome to lecture-40. So, in this lecture, firstly I will be interfacing with the STM board the Bluetooth module. So, I will show you how we can use Bluetooth using STM, any micro controller port in the here will take the example along with STM board. This is the first thing will I will do here in this lecture. Along with that in previous two lectures, we have introduced you with the device which is called accelerometer with that device as I have told you will be doing couple of experiment.

So, we will be showing you how we can find out the orientation of a device. Meaning of orientation is that whether the device is lying flat or is the device vertically up or it is vertically down or it is horizontally left or it is horizontally right ok. So, these are the few orientation, that we will find out how we can figure out the orientation of the device using the accelerometer ok.

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CONCEPTS COVERED

- ❑ Experiment with Bluetooth and accelerometer
- ❑ Demonstration

So, as I told you firstly we will do the experiment with Bluetooth. We will first show how we can connect Bluetooth with the microcontroller board. And we already know the connection how we can connect accelerometer, then we will figure out the orientation of any particular device, and we will determine that. And that will be displayed in a mobile phone, which I will be connecting through the Bluetooth module of with STM that is established between these two. And finally, we will show you the whole demonstration.

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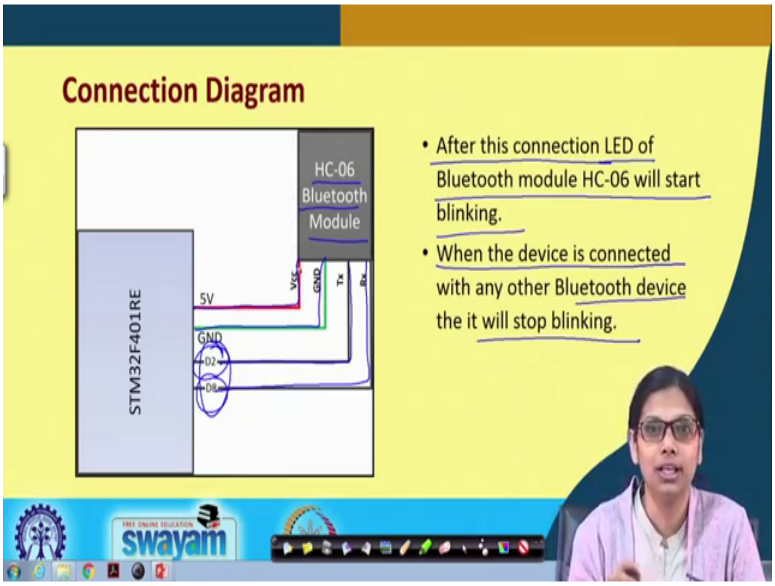

Connection Diagram

- After this connection LED of Bluetooth module HC-06 will start blinking.
- When the device is connected with any other Bluetooth device the it will stop blinking.

So, Bluetooth: what is Bluetooth? We have already discussed. Now, the Bluetooth module that we are using here is HC-06 ok, this is the Bluetooth module that we are using ok. So, the connection is fairly straightforward with the blue Bluetooth module. So, this is the VCC, which is connected to 5 volt. This is the ground, which is connected to ground pin off STM. The TX is connected to D 2, and RX is connected to D 8. Similarly, these two are made we have to built a serial connection between these two pins. So, we have to make one pin as RX, and another pin as TX ok. So, this is the straight forward connection.

Now, I have I will be showing you when the demonstration how exactly what will happen, when you connect a Bluetooth module. But, this is what you will understand, when you connected. After the connection that means, once you have a Bluetooth module with your device, which you will be connecting with the Bluetooth module that you have it in your mobile phone ok, so when you try to connect these two. First of all the Bluetooth module that you have interfaced with the STM. Once the connection is built, the LED of the Bluetooth module will start blinking. So, you will see that the LED will start blinking that means, there is a connection established that the Bluetooth module is working fine.

Next when the device is connected, so the Bluetooth module will be used for communicating two device. So, when you will be connecting that Bluetooth module device, which you have connected with the STM board along with your mobile phone Bluetooth device, because these two will communicate with each other. So, when you do that action, then you will find that that the Bluetooth device it will stop blinking that means, the connection between the two device has been established ok.

So, these are the two things from which you can find out that in the first phase when you just connect the Bluetooth module with microcontroller, when it starts blinking that mean the connection is built ok. But, when it is connected with another device, then it will stop blinking. So, these are the two things when you connect with such module, you will find it out.

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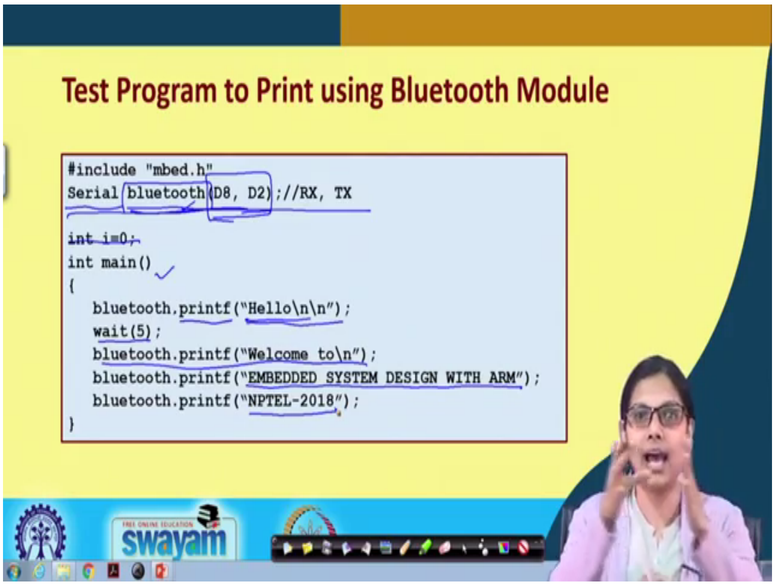

Test Program to Print using Bluetooth Module

```
#include "mbed.h"
Serial bluetooth(D8, D2);//RX, TX

~~int i=0;~~
int main()
{
   bluetooth.printf("Hello\n\n");
   wait(5);
   bluetooth.printf("Welcome to\n");
   bluetooth.printf("EMBEDDED SYSTEM DESIGN WITH ARM");
   bluetooth.printf("NPTEL-2018");
}
```

This is the first I will show you a test program, where I will be connecting the Bluetooth module with STM board along with my mobile phone Bluetooth module ok, and it will displace some text. Some text from the microcontroller board will be sent to my mobile phone through Bluetooth communication.

So, first of all we have to do the serial communication the name that I have given is Bluetooth the name of this connection, which is with these two pins that is D 8 and D 2 ok. This is the first thing, we have to initialize when we write the code. And then in the main what we are doing, actually we do not require this. In the main what we are doing, the connection which we have made with the name Bluetooth between D 8 and D 2. We will use this printf to print Hello.

So, once the connection is built with the Bluetooth module of STM along with the Bluetooth module of my mobile phone ok, then we will transfer the data. So, the transferring data takes place in this way, the object that we have created that is Bluetooth dot printer will print hello. Then will wait for 5 second. And then will print these few things welcome to embedded system design with arm, NPTEL-2018 ok, this is just a message that will get displayed.

Prior to this let me tell you that where I will be discussing everything when I demonstrate it, but let me briefly tell here itself that when we make when we will be making the connection of the Bluetooth, we will require some Bluetooth terminal to be installed in our mobile phone. So, make sure when you do the connection, you have in your mobile phone a Bluetooth terminal that a particular app, which will communicate through this STM Bluetooth enabled device.

So, your microcontroller along with that Bluetooth become one device, and your mobile phone is another device through which you will be making the connection. So, this is a straightforward code, where basically we have just made this connection making one TX and another RX. Accordingly, we are sending some messages here that is all we are doing. So, this is for the Bluetooth connection.

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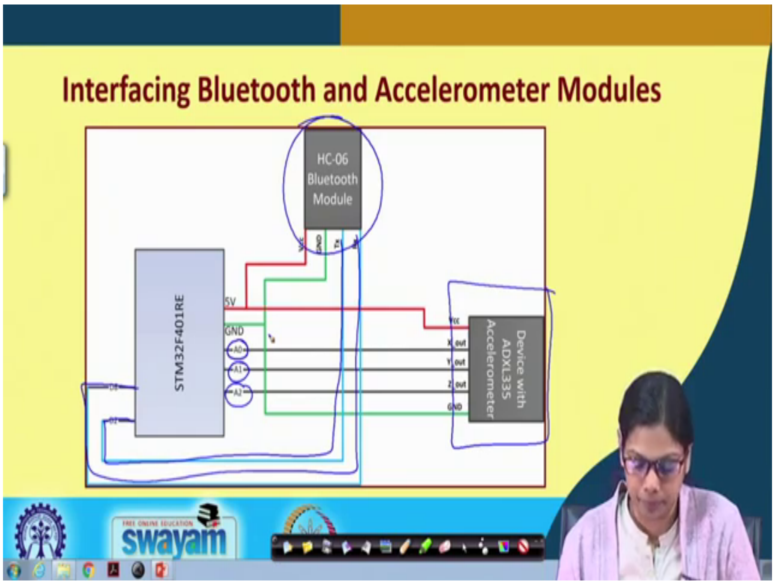

Interfacing Bluetooth and Accelerometer Modules

Now, we will go ahead with the interfacing Bluetooth and the accelerometer module. So, this is fairly straightforward, because we have already discussed about the Bluetooth. We have already discussed about the Bluetooth, that Bluetooth module connection this is the Bluetooth module connection that I have already discussed with you.

I have already discussed with you the accelerometer connection. So, we can make this connection, which is connected to analog port A 0, A 1, and A 2. And with the Bluetooth module, it is connected to DT 2 with the TX, and D 8 with the RX. And VCC ground for the Bluetooth module, and VCC ground for the accelerometer is connected here, this is all about the socket diagram.

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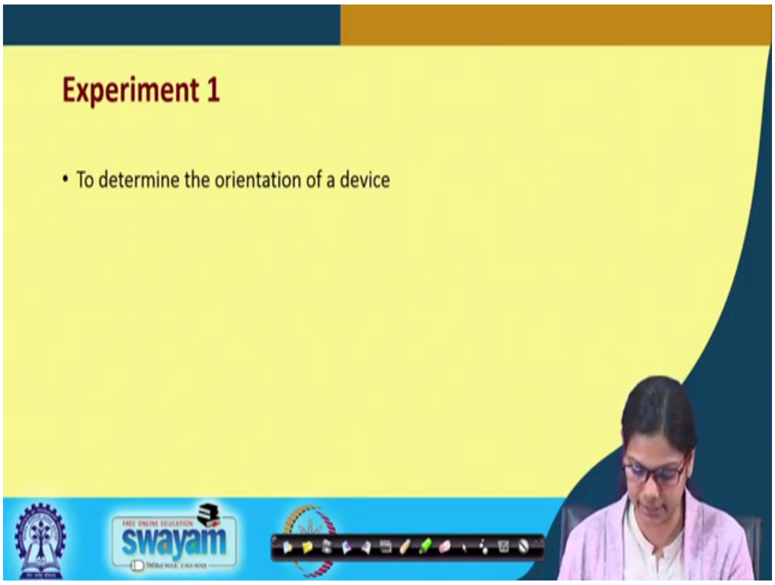

Experiment 1

- To determine the orientation of a device

Next, the first experiment; so, I will be discussing the codes first, and then I will demonstrate. So, in the first experiment will determine the orientation of the device ok. So, recall our experiment that we conducted the previous lecture. In the previous lecture, we have shown you that we are receiving some values right that is a 32,000 or 35,000. Some x, y, z coordinate values we are getting. Based on that based on that coordinate values, what we have to do that we have to test. When I put accelerometer along with a device, and we make it vertically straight, then what changes happens in which coordinates that is what we need to check.

And accordingly will write the program. So, if that x coordinate value is in between this and this or the y coordinate value is in between this and this or to z coordinate value is in between this and this, then it is vertically up or vertically down ok. So, in this experiment firstly will look into the orientation of the device. So, this connection diagram with Bluetooth module, and with accelerometer will be the same.

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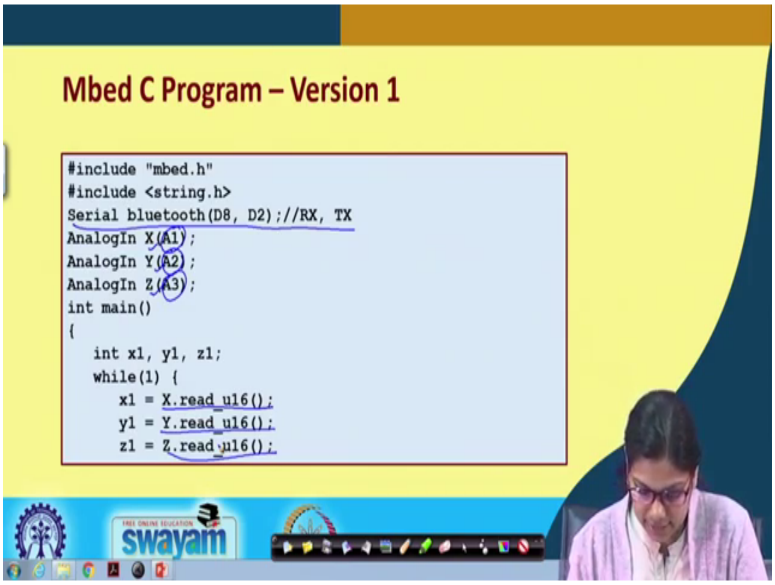

Mbed C Program – Version 1

```
#include "mbed.h"
#include <string.h>
Serial bluetooth(D8, D2);//RX, TX
AnalogIn X(A1);
AnalogIn Y(A2);
AnalogIn Z(A3);
int main()
{
   int x1, y1, z1;
   while(1) {
      x1 = X.read_u16();
      y1 = Y.read_u16();
      z1 = Z.read_u16();
```

This is the Mbed code. Let us discuss this is the serial connection for transferring the data. So, in the Bluetooth module, it will be displayed whether it is vertically up or it is vertically right. Then we will be connecting X, Y and Z coordinate to A 0, A 2, and A 3 ok. In this case, I have connected to A 1, A 2, and A 3, you could connect to any port of the any analog port, this is first thing.

Then what we are doing, we are reading the value ok. We are reading the three values that is X dot read, Y dot read underscore U16, and Z dot read underscore U16. So, we are doing the following things to read the value. After reading the value, we need to check. Let us see, what we will do next?

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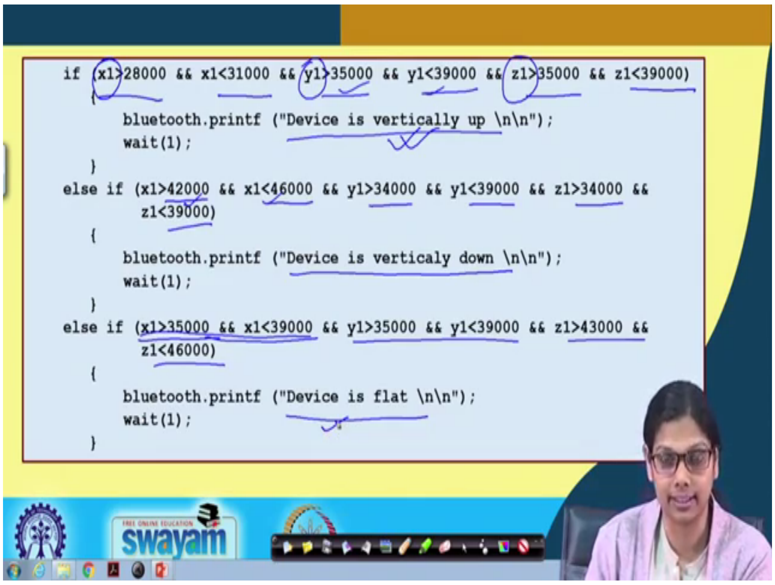

```
if (x1>28000 && x1<31000 && y1>35000 && y1<39000 && z1>35000 && z1<39000)
    {
        bluetooth.printf ("Device is vertically up \n\n");
        wait(1);
    }
else if (x1>42000 && x1<46000 && y1>34000 && y1<39000 && z1>34000 &&
        z1<39000)
    {
        bluetooth.printf ("Device is verticaly down \n\n");
        wait(1);
    }
else if (x1>35000 && x1<39000 && y1>35000 && y1<39000 && z1>43000 &&
        z1<46000)
    {
        bluetooth.printf ("Device is flat \n\n");
        wait(1);
    }
```

Let us see, what we are checking. What we are checking x 1 is the x out value, y 1 is the y out value, and z 1 is the z out value. We have seen that the coordinate when we are getting x 1 in between this and this, y 1 in between this and this, and z 1 in between this and this, then the devices is consider to be vertically up ok.

After doing this, the Bluetooth dot printf device will print the devices vertically up. Similarly, the next condition if we get x 1 value in the range of 42000 to 46000, y 1 value in the range of 34000 to 39000, and z 1 value in the range of 34000 to 39000. Then we can see that the vertical the device is vertically down.

So, basically when the it is vertically up, so these coordinates if you see is the most when it is vertically down, then these coordinates are having high value ok. So, this is just a representative thing that we have done it. When you do it, I have already shown you that how you will be looking into the values, you can if you use Arduino, you can see it in the serial monitor else you use cool term where all these values will get displayed, then you do the experiment. You hold the device vertically up, and see what value of x, y, z coordinate you are getting ok.

So, accordingly you can have the code written. So, this is the code written for our experiment through the way we got the values ok, you might get something different. So, you have to try it out, and figure it out. Similarly, there are few more condition for if the devices lying flat, when it is lying flat you see x coordinate value, and y coordinate value are to some extent same, but the z coordinate value is the highest ok, when it is lying flat. So, when this is there, then the device is flat. Let us move on.

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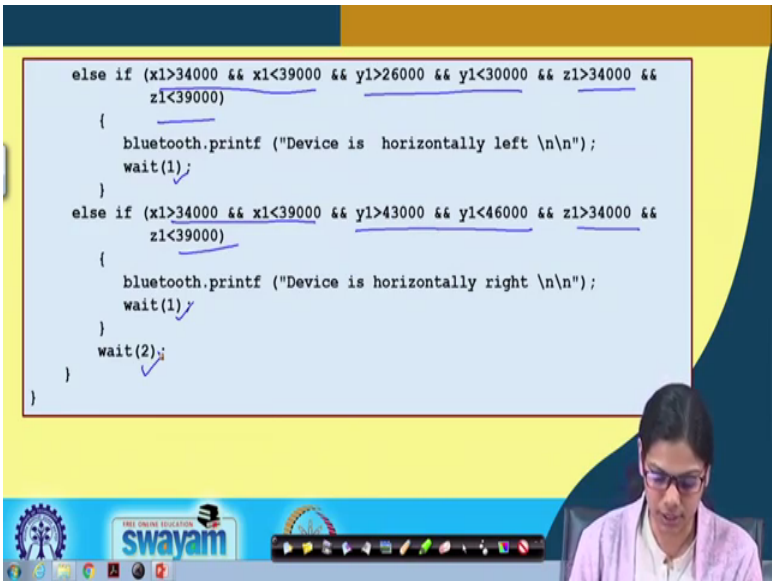

```
    else if (x1>34000 && x1<39000 && y1>26000 && y1<30000 && z1>34000 &&
            z1<39000)
      {
         bluetooth.printf ("Device is  horizontally left \n\n");
         wait(1);
      }
    else if (x1>34000 && x1<39000 && y1>43000 && y1<46000 && z1>34000 &&
            z1<39000)
      {
         bluetooth.printf ("Device is horizontally right \n\n");
         wait(1);
      }
      wait(2);
   }
}
```

We have few more conditions, when the device is horizontally left ok. When it is horizontally left, when we have the value of x 1, and of course z also we can see in the range of 34000 to 39000, and y coordinate value is less here. Similarly, here it will be the opposite this value is in this range, but y coordinate value is highest, then it is horizontally right. So, it depends on how you are putting the accelerometer in the device also. So, you have to see that and you have to write your program accordingly.

Then for every after every display there is a weight of 1 second 1 second and after this there is a weight of 2 second, and everything is run once again ok. The so this program what we have demonstrated basically, it is like it is showing what is the device orientation ok. This is one application you can think of which you can experiment.

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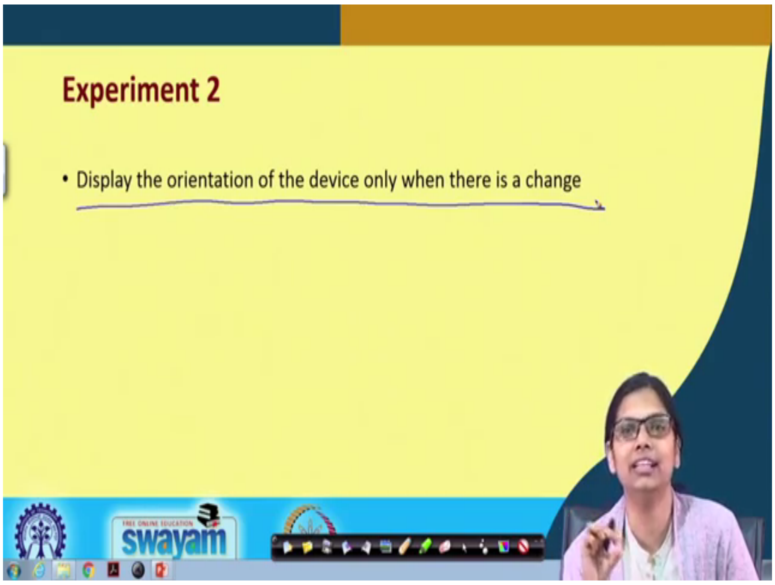

Experiment 2

- Display the orientation of the device only when there is a change

Let me go to another experiment. In the previous experiment, it is the it we have done it in a fashion that whenever the device changes, and after every 2 second the it is displaying that the device is flat, the device is vertically down, device is vertically up. So, after 2 second, it is getting displayed ok.

So, here we have just made one change, where it will display the orientation of the device only when there is a change that means, if the device is flat, it will remain flat. If there is a change from flat to vertically up or vertically down, then only it will get displayed in the Bluetooth module. So, we have just done our little program change to incorporate this particular change. So, let me let me show you, what change basically I have done here.

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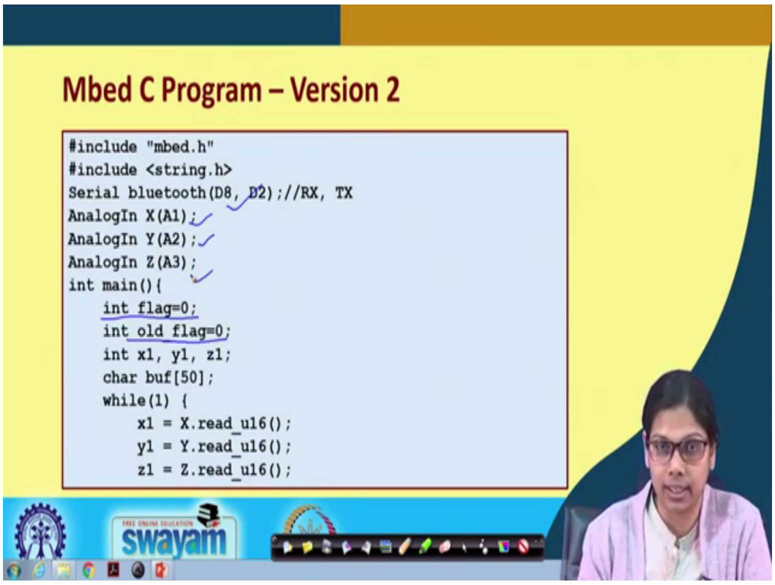

Mbed C Program – Version 2

```
#include "mbed.h"
#include <string.h>
Serial bluetooth(D8, D2);//RX, TX
AnalogIn X(A1);
AnalogIn Y(A2);
AnalogIn Z(A3);
int main(){
    int flag=0;
    int old flag=0;
    int x1, y1, z1;
    char buf[50];
    while(1) {
        x1 = X.read_u16();
        y1 = Y.read_u16();
        z1 = Z.read_u16();
```

So, this part of the code is straightforward is the same basically, but we have taken two variables. One is flag, we have initialized it to 0. Another is old flag, which is also initialized to 0 ok. So, these are the two things that we have done. For all other things, it is pretty similar we have built a serial connection, then A 1, A 2, A 3 we have made the analog port, we have connected with X, Y, Z out of the accelerometer.

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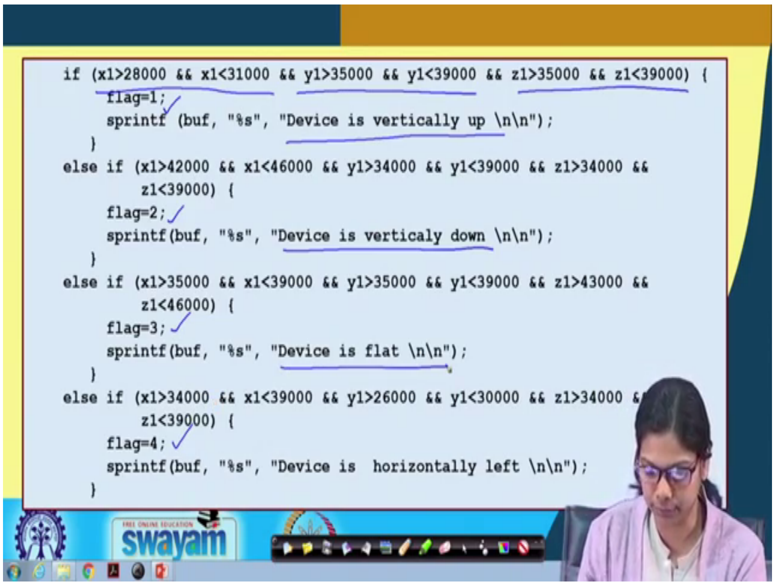

```
    if (x1>28000 && x1<31000 && y1>35000 && y1<39000 && z1>35000 && z1<39000) {
        flag=1;
        sprintf (buf, "%s", "Device is vertically up \n\n");
    }
else if (x1>42000 && x1<46000 && y1>34000 && y1<39000 && z1>34000 &&
            z1<39000) {
        flag=2;
        sprintf(buf, "%s", "Device is verticaly down \n\n");
    }
else if (x1>35000 && x1<39000 && y1>35000 && y1<39000 && z1>43000 &&
            z1<46000) {
        flag=3;
        sprintf(buf, "%s", "Device is flat \n\n");
    }
else if (x1>34000 && x1<39000 && y1>26000 && y1<30000 && z1>34000 &
            z1<39000) {
        flag=4;
        sprintf(buf, "%s", "Device is  horizontally left \n\n");
    }
```

And then let us see the program here, what we are doing basically that the condition would be pretty same, if you see one. Whenever we have either it is vertically up or it is vertically down, what is basically done is that we are initializing a flag ok. So, in the first case the flag is 1. In the next case, the flag is 2. In the third case, the flag is 3. And flag is four and depending on it is vertically up, vertically down, flat horizontally left.

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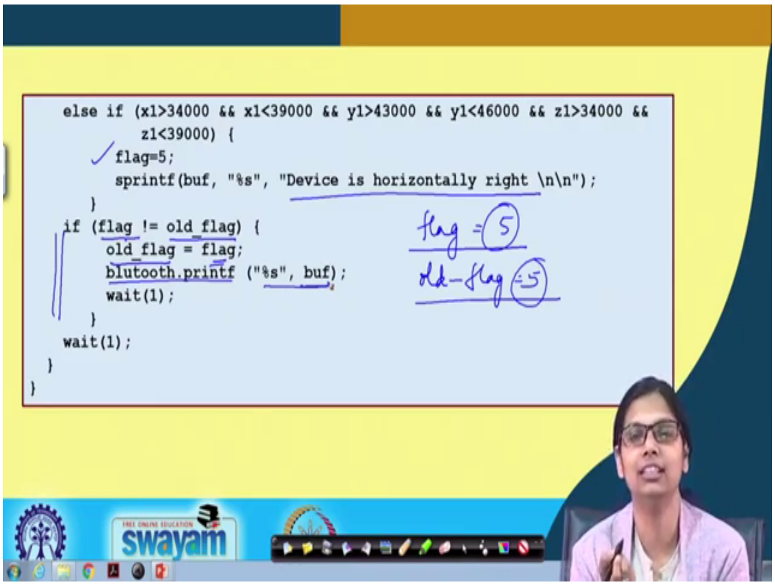

```
else if (x1>34000 && x1<39000 && y1>43000 && y1<46000 && z1>34000 &&
        z1<39000) {
    flag=5;
    sprintf(buf, "%s", "Device is horizontally right \n\n");
  }
if (flag != old_flag) {
    old_flag = flag;
    blutooth.printf ("%s", buf);
    wait(1);
  }
wait(1);
 }
}
```

And then we see that it is again horizontally right with flag 5 ok. And what we are doing in this check, we are seeing if flag initially the flag value was 0, and then it will be in any one of these conditions the flag value will change to either 1, 2, 3, 4 or 5. And old flag value was 0 initially.

So, if flag not equals to old flag, so for the first time this condition will be true, because flag value is not equal to old flag value, then what we will do? The old flag value will make a make it as flag ok. Now, what is the old flag, let us say the device was horizontally right. Then flag value will be 5.

And for the first time this old flag value was not equal to this value. So, old flag value will become 5 here, and then we print, we print the devices horizontally right. We wait for one minute, and again we check flag not equal to flag value, but no both are same. So, it will not enter here. So, whatever is displayed will remain as display, but whenever there is a change.

Let us see from horizontally right, we change it to horizontally left. In that case, what will happen is that this flag and this flag value will change. So, whenever is there is a change, then again through Bluetooth will display a text like the device is flat, etcetera, etcetera ok.

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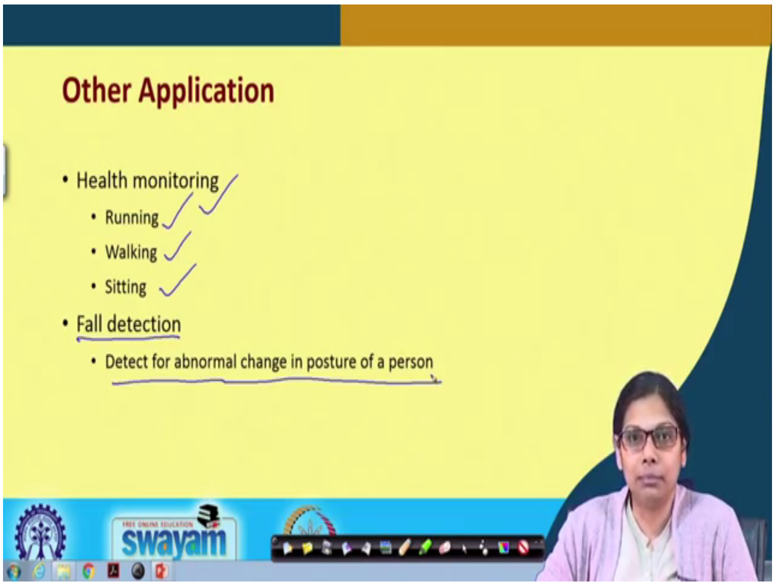

Other Application

- Health monitoring
  - Running
  - Walking
  - Sitting
- Fall detection
  - Detect for abnormal change in posture of a person

So, these are the two experiment that will be showing you the demonstration right after right after this lecture. So, there are other applications of accelerometer as well. So, one of those application I mean a burning application is in health monitoring tools or health monitoring apps that we have there in our mobile phones.

So, basically it will tell you that in a day how much time you have run or how much time you have walked, how much time you are sitting various activities basically day-to-day your activities, you can keep a track of your activities that you are doing throughout the day ok. And also there is a very vital application that is fall detection for of course elderly woman you women or men.

So, you see when old people generally have to stay back in their house alone most of the time. Even if there are people to look after them, but might there might be certain situations, where we find them all alone ok. And under such condition, if nobody is around them and there is some serious issue like they fall down in bathroom or in house only. Then how do their near ones will come to know, how will that be informed to their kids their children are there relatives anybody.

So, this fault detection application can be very nicely done using this accelerometer, but we need to keep into various I mean false positive conditions all the conditions you have to check, it should not generate some false alarm ok. So, this using accelerometer detecting for abnormal change in posture of a person is one of the very vital application that can be considered you can take up as a project work maybe ok. So, we have come to the end of this lecture. Now, we will be showing you the demonstration.

So, in the final week, we have been working with one of the device that is accelerometer ok. And what it what it does etcetera, I have already explained. Now, what I wanted to do is that the coordinates that we received from this accelerometer, I want to send it to my mobile phone let us see ok. We can do that, how do we do this communication. So, we need to have some communication through which my mobile phone, and this microcontroller along with which is connected with the accelerometer should communicate.

So, in this process we need a Bluetooth module, we all know the purpose of Bluetooth how it works. Now, the thing is that we will be connecting a popular Bluetooth module that is HC-06, where we will be sending some data from the microcontroller to my PR device that is my mobile phone ok. So, why we are requiring this, because later what we will do is that will connect accelerometer, and will transmit the x, y, z coordinate through Bluetooth to through Bluetooth to the mobile device ok.

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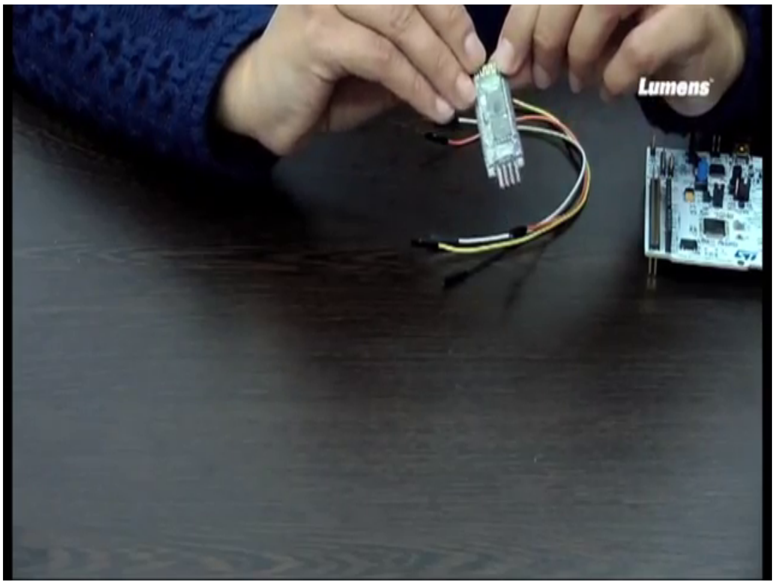

So, let us see the connection that we can do we have to do for this Bluetooth with STM board ok. This is the Bluetooth module that is HC-06, you can see it has got four pins ok, so the four pins goes like this. It has got an RX, it has got a TX, it has got a ground, and it has got a BCC ok. So, this is basically the BCC, then ground, then this is TX, and then it is RX, BCC, ground, DX, RX ok.

So, this I will be connecting with the ground BCC, and TX, RX pin of this STM microcontroller with which we were working. First we will just connect these two, and we will send a data from this microcontroller to my device ok. So, for doing this also you need one more thing that you have to install a Bluetooth terminal, I am coming to that little later.

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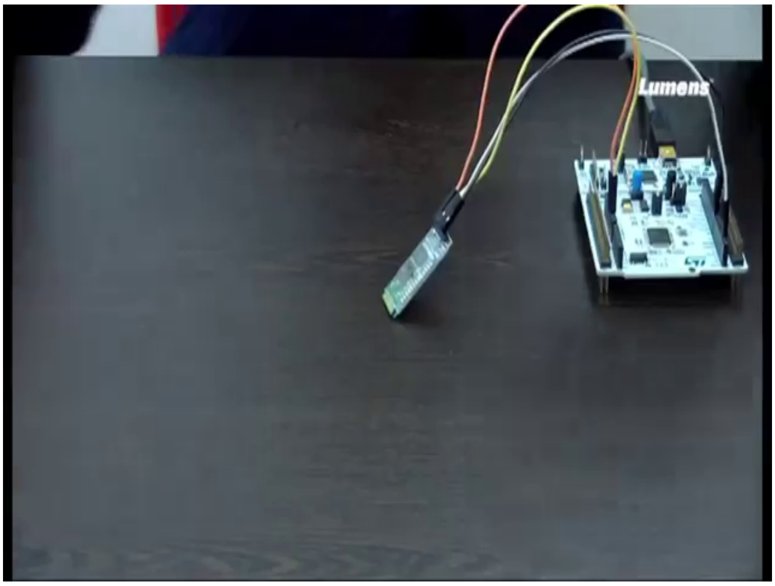

First let me show the connection here that we have to do. So, as I said this is BCC, which is connected to this one this is ground, which is connect since ground which is connected to the ground port of this STM board. And then we have TX and RX. The TX is connected to port two D 2. And the RX is connected to D 8 ok. So, this is all about the connection. So, what I did, the four pins of this Bluetooth module is connected with the four pins of this STM module. Basically, if you think what we are doing will be transmitting something from here, and it will be received by this our expand of this Bluetooth right.

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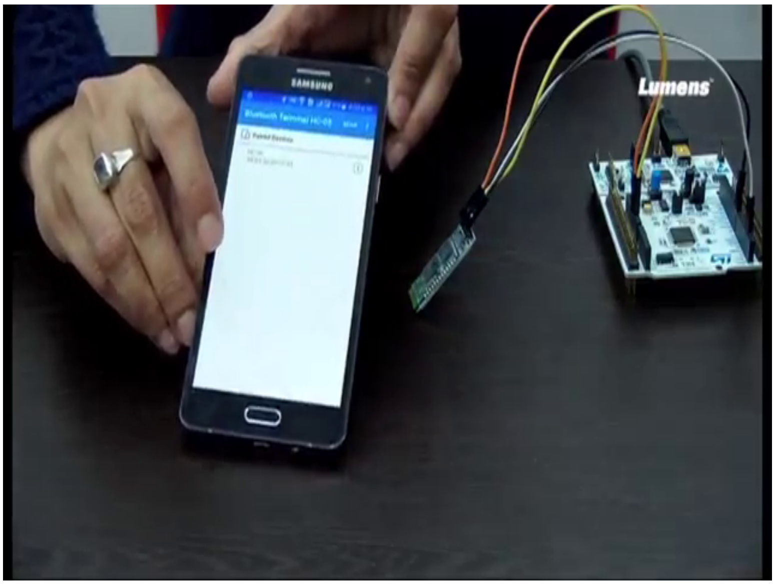

As I said, now once you have this Bluetooth module connected, you also need a Bluetooth terminal ok. So, I have already installed a Bluetooth terminal, this is the Bluetooth terminal that I have already installed.

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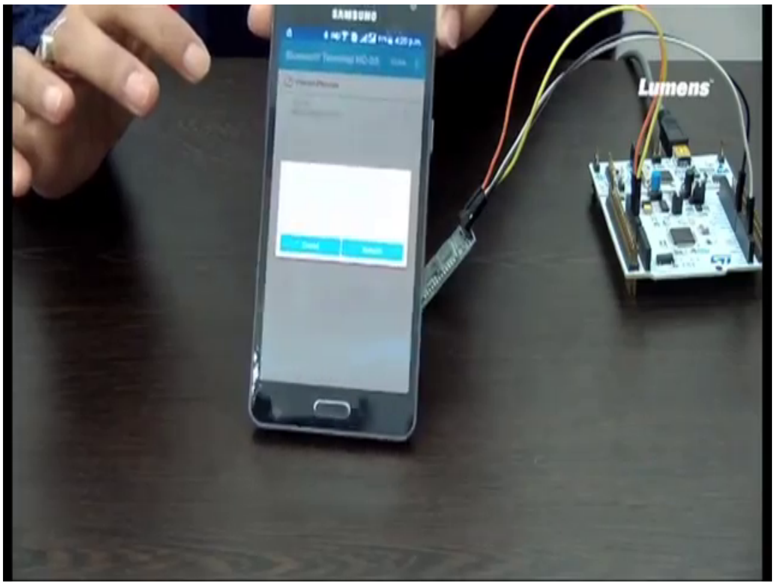

So, here you can scan, and then it will scan and it will actually display, what all devices are nearby. And if you see that let me connect to we powered this ok, there is one more point let me first tell, and then I will talk about this part of the connection. You see when I connect this LED is blinking, basically this is blinking this is blinking, this meaning that it is ready for connection ok, it can connect to any other nearby devices, you can see it is blinking ok.

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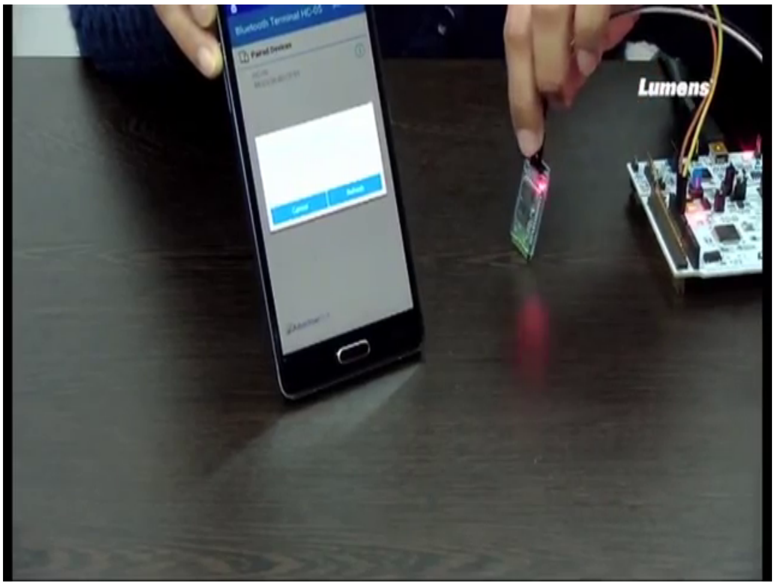

Now, this is my device, this is my mobile device, which I will be scanning first ok. So, it is we are scanning this, and you just notice one thing that the LED is blinking led is continuously blinking in this Bluetooth module ok. No device found, it says just a second ok.

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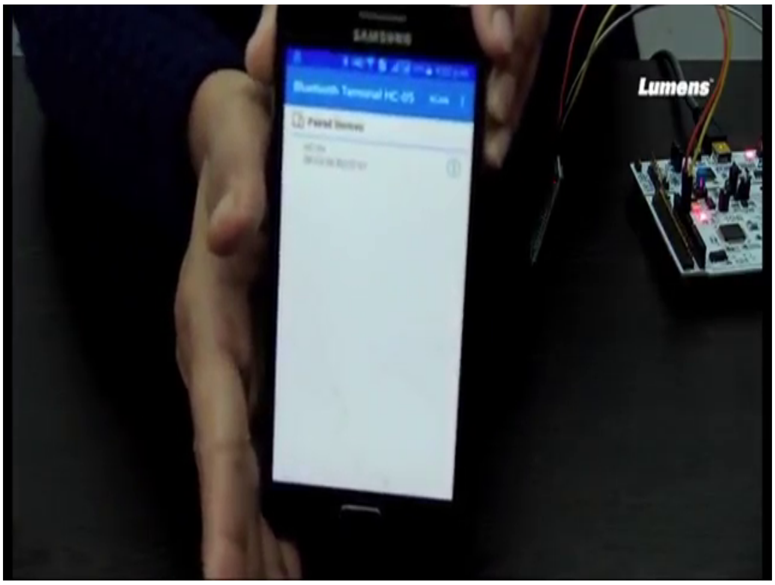

Now, it is showing that there are some devices ok, and as I have already connected previously. So, you can see that the pair device, it is showing up here is this one. This one is the pair device here, so I will just HC-06.

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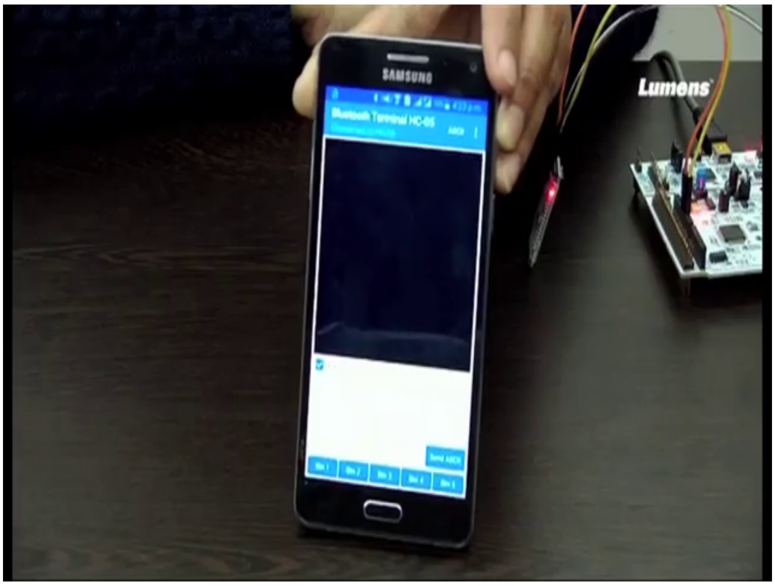

I will just click on that and you can see a terminal is coming ok. Now, see what has happened. Once the connection is established with this mobile, the LED has stopped blinking ok. Now, I will show you once more by switching off the connection, let us say I switch off the connection. And you can see that the LED has started to blink again, so it is ready for connection. And when I again connect, it has stopped that means it has connected. Now, I will send two messages from this particular, I will send through Bluetooth from this microcontroller to from this microcontroller to this mobile ok, let us see what message it ok.

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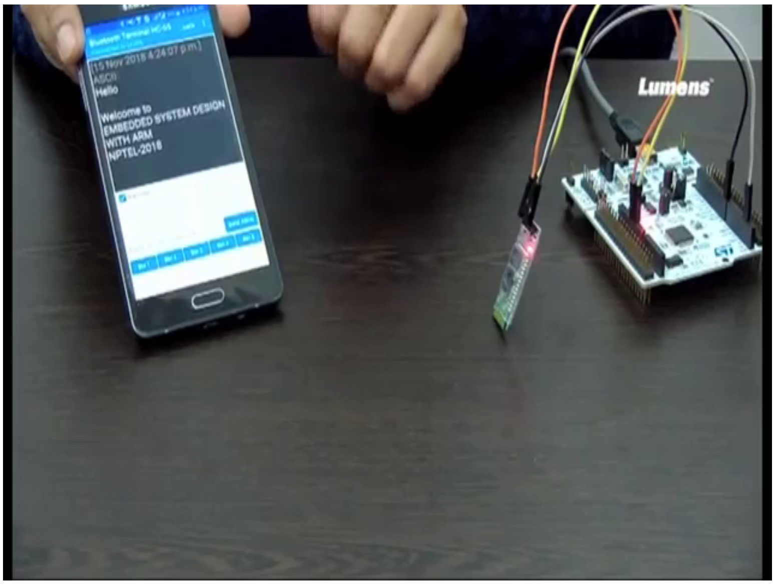

So, you can see hello came followed by welcome to embedded system design with arm NPTEL-2018 ok. So, this is just a sample data that we are sending you can send anything ok. So, this is how you can actually connect a Bluetooth module with any other device, and then you can send the data through your microcontroller and through this communicating device to any other mobile device or so. So, here I just sent these to the terrorist's hello and welcome to embedded system design with arm.

So, this is the simple connection that I have shown that how you will be connecting a Bluetooth module with your mobile. Now, what we will be doing, we will be integrating this part of this Bluetooth module along with accelerometer ok. And will see that we will be taking up one more experiment on a seller meter, which will show something using this mobile.

Today, I will show you another experiment, where I will integrate accelerometer along with the Bluetooth connection that I have already shown. And then will analyze the orientation of any object ok. So, what I will be doing, the accelerometer will be getting the x, y, z coordinates. And through Bluetooth no that is a accelerometer will be receiving the x, y, z coordinates.

Then the microcontroller will do the needful, it will analyze it that whether the coordinate received signifies that the device is flat or the device is vertically up or it is vertically down or it is horizontally left or it is horizontally right ok. This is the first set, I have already discussed that I will be showing with accelerometer. And then I will be showing another experiment, where it will not send the message repeatedly, rather it will only send, when there is a when there is a you know changing orientation of the program ok.

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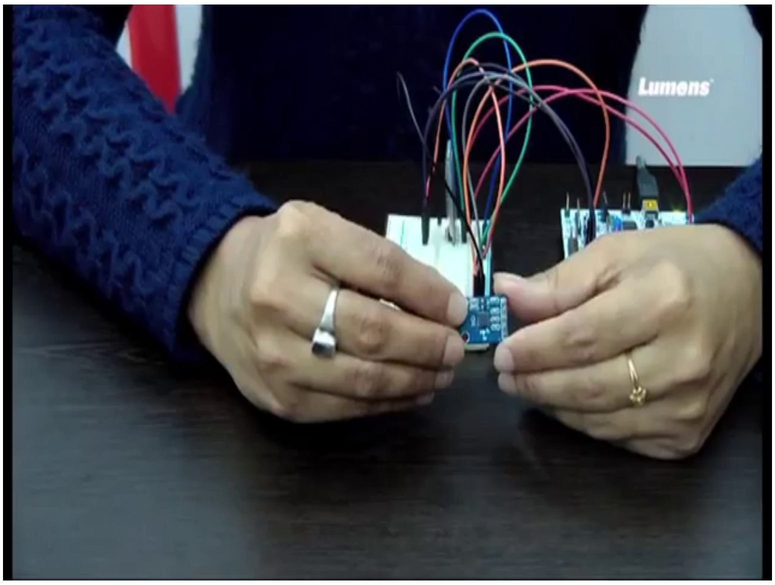

So, you see that this is the accelerometer ok, it has got 5 pins ok. So, these pins are BCC, x, y, z and ground. So, one is BCC, then x, y, z, and then ground ok.

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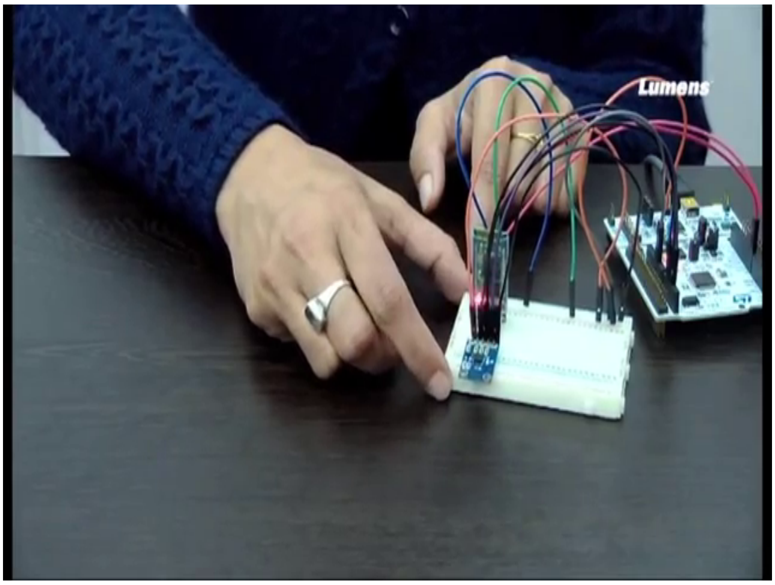

So, I will be connecting this with I will be connecting this with the breadboard, where I have already made the connection. So, you can see this I have connected with BCC, this I have connected with ground, and this is x, y, z. So, I will just put this down here. And Bluetooth connection, we have already seen. And you can see that the Bluetooth this red light is blinking, the LED is continuously blinking meaning that it is ready for connection, but the device has not connected yet ok.

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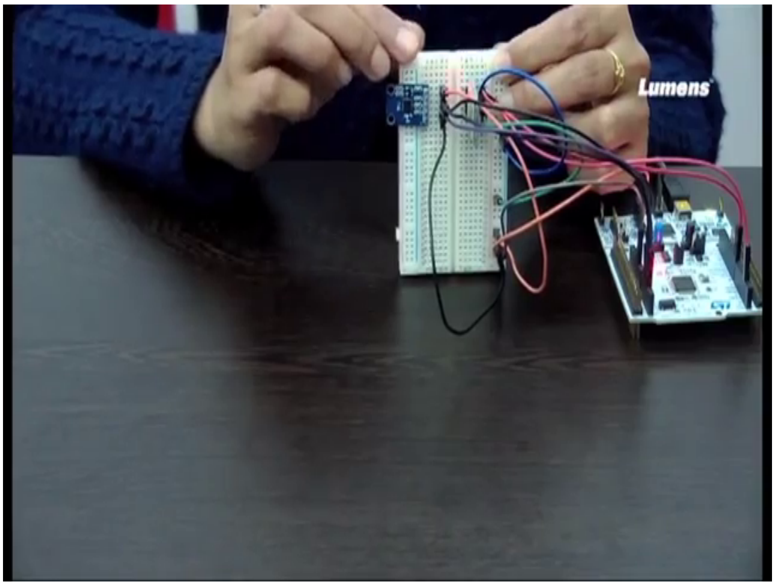

Now, the way we have made the program, when we place the device in this fashion meaning it is flat, when well put it in this fashion. So, this one is basically the up one, it will say that it is vertically up.

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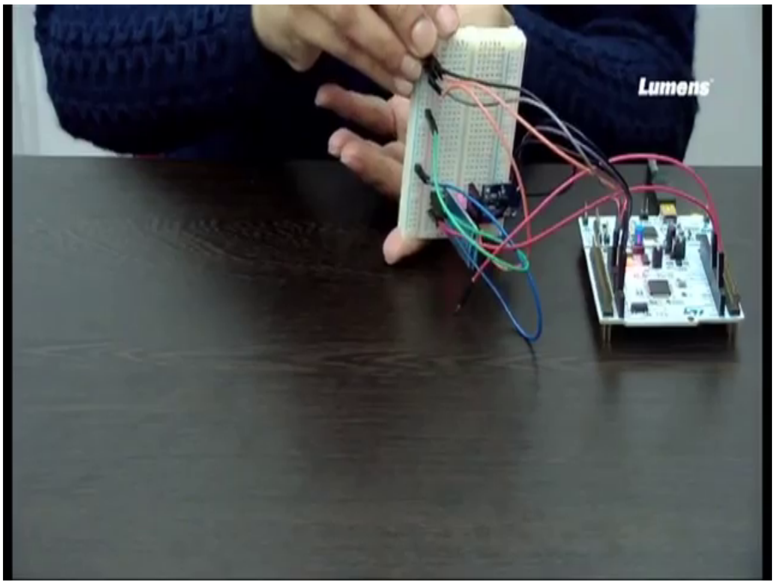

If you make it like this, it should say vertically down ok.

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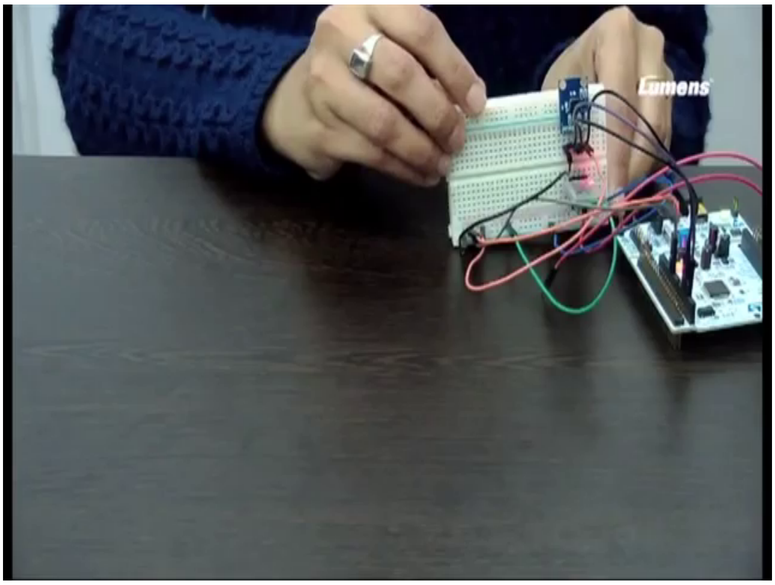

And then if you turn left, it will say horizontally left.

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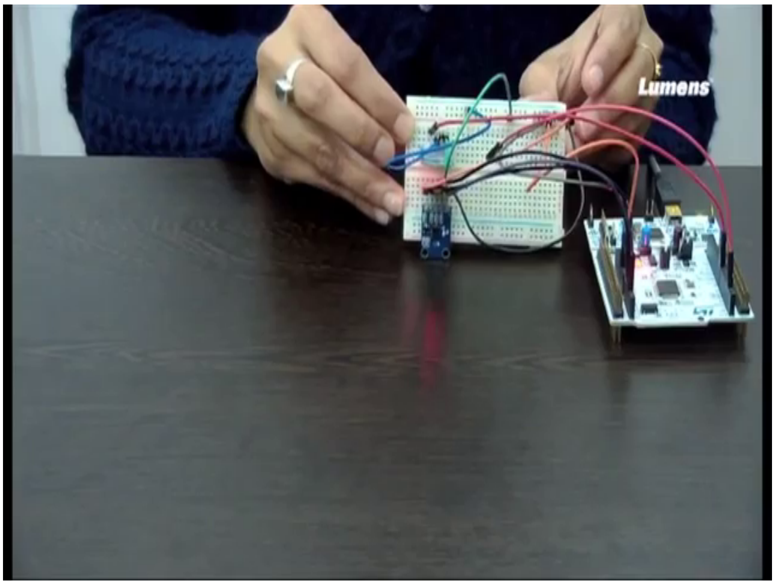

And when you do this, it will be horizontally right ok.

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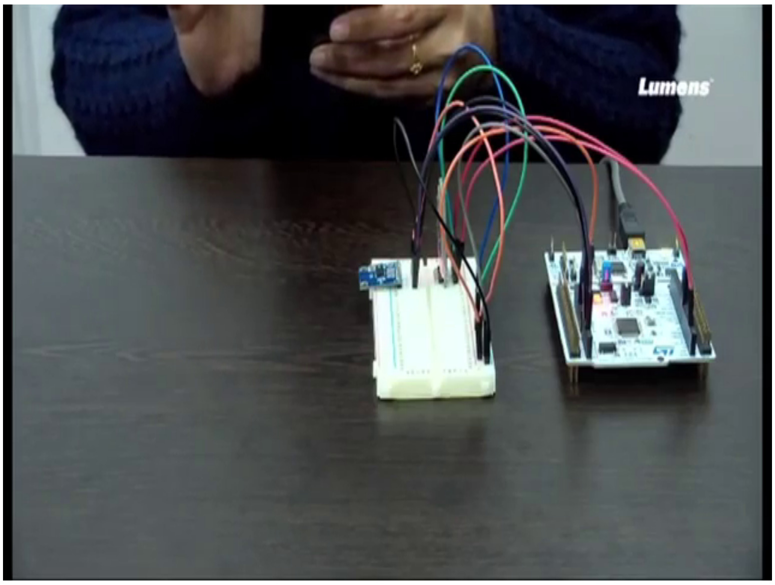

So, let me first do the needful ok. So, this is the connection with Bluetooth, we have already seen. And this is just the connection, I have made with this accelerometer. And this will be my horizontally, this is vertically up this position should be ok, and this is flat. So, I just kept it in flat position. And I said there are two set of codes that we have put for one code it will continuously send that what is the orientation of this particular device, this let us say this is my device.

And in the next program whenever the orientation changes, then only it will actually send the data through this Bluetooth module ok. So, let me first let me first connect to the Bluetooth module the same way. So, it is still blinking you can see that, and now I will do the connection. And you can see that it is now stable.

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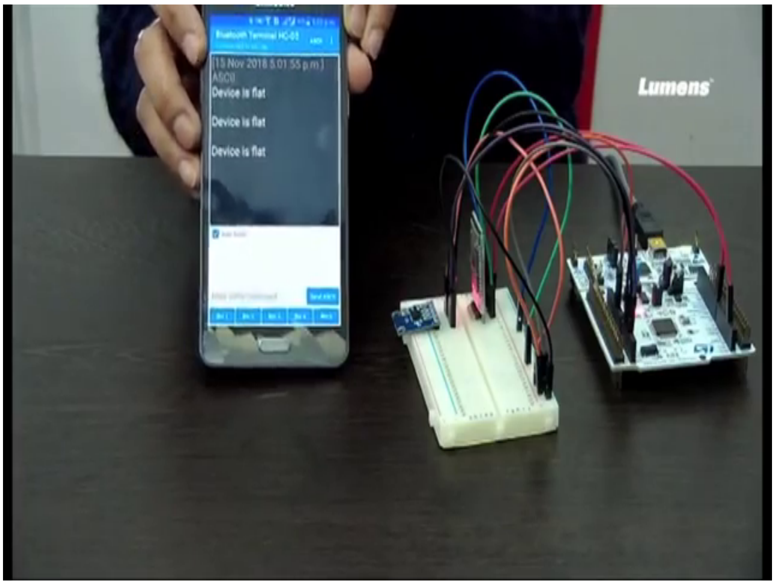

```
[15 Nov 2018 5:01:55 p.m.]
ASCII
Device is flat

Device is flat

Device is flat
```

And now see what message is getting displayed, the device is flat, so it is lying flat ok. Now, I will make this device vertically up, so it is vertically up now ok. Now, I will make this device vertically down, so maybe just a second. So, now I have made, now this is showing that the devices vertically down ok. And the device is flat now, every two second it is sending this. Now, again I have made it vertically up, which is displayed in this terminal. And then I will make horizontally left ok, I have done to the left side. And now I will make it horizontally right, so you can see that it is now horizontally right.

So, these are the few orientation, which we have made with respect to x, y, z axis. We have already seen that what value will receive on x, y, z axis. And depending on how we have put the accelerometer here, we have made the code accordingly. So, the way you put the accelerometer, it depends largely upon how you are actually putting their accelerometer, and then receiving data, and then how your device is put up ok.

So, these are the few things, we have to take into consideration when we do this ok. Now, I will again disconnect, so I will disconnect. And you can see that it has started to blink again, this LED has is blinking again ok. Now, I again dumped another code, where only it will change, if the orientation of this particular device changes ok, it will not change or it will not send the device to this mobile through Bluetooth, if the position does not change. If the position changes, then only it will sent ok, let me first connect, it is still blinking. So, now it is not blinking; so, the Bluetooth connection as we made with this device ok.

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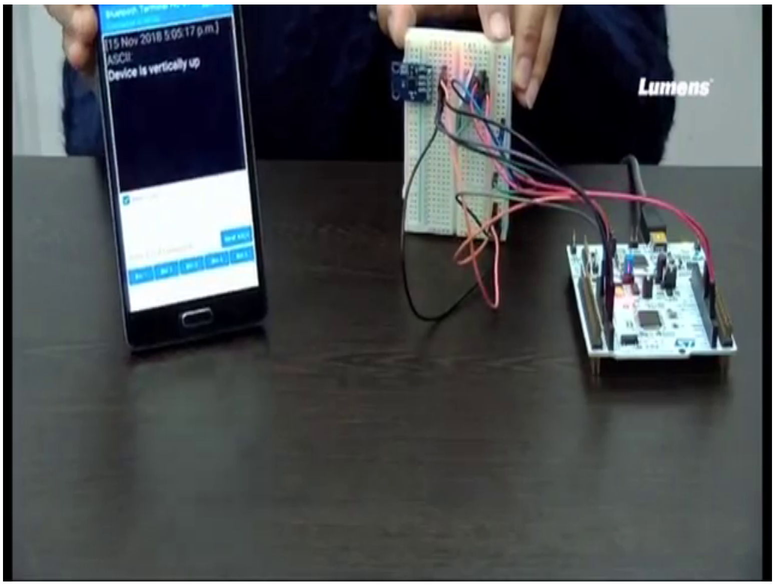

[15 Nov 2018 5:05:17 p.m.]
ASCII:
Device is vertically up

Now, I am not changing the device. Now, let us say I have changed devices vertically out. Now, if you recall in the previous experiment, it was continuously displaying that it is vertically up in 2 seconds, but now I am not displaying that ok. I am only displaying, when there is a change. Now, you see message has been sent that the device is flat.

So, whenever there is a change in orientation or change in position of this device that is the orientation, then only there is a message coming up otherwise no. So, continuously we are not sending something, we are only sending something whenever there is a change in this particular device orientation its up. Now, it is horizontally right, now it is up. And after let us say few second, I will just put it down, so device is flat. And it will not send any message unless an otherwise there is a change in the position of this device ok.

The code for the same was already discussed, I have just shown the demonstration. There are various application of this accelerometer, I have already discussed previously like you can even track the number of steps a person is walking in a day ok. So, we have already seen that when we move the accelerometer in various position, in various ways, the x, y, z value changes ok and when we are sitting or we are moving in a very slow position, how the value changes.

So, you can actually take all these things into consideration while tracking like for tracking the activity basically, the activity human activity. So, you can track human activity using this accelerometer in our mobile phones as accelerometer is there. And there are many other application very good application like fall detection for elderly woman, elderly person basically that can also be done using this accelerometer. And there are a couple of things people have already done using this accelerometer. So, you can also try out doing some other examples other experiments.

Thank you.