Advanced IOT Applications
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Lecture - 02
Outdoor localization without GPS – I

We will try and do a concise demonstration of what we stated about localization without GPS. I will make one assumption that, take an example of a vehicle which is entering either a thick tree cover or a tunnel or some position you will find many spots like that where there is no GPS. However, there was a last GPS point somehow which got recorded.

It is not a bad assumption because as you move you will find that suddenly you will lose GPS and then and suddenly you will get it back. So, the last GPS point was available to you.

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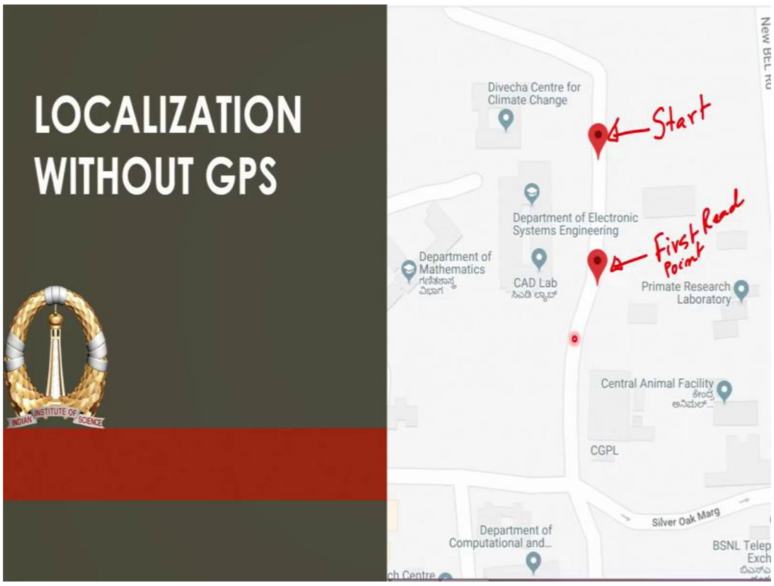

So, let me turn your attention to this slide deck here. So, this is what we want to do. There is a starting point which is essentially the point where the last GPS coordinate was available. And the vehicle has started to move the second point is where the first read occurred, consider the vehicle moving towards the direction of the second point from the starting point, as shown in the above figure.

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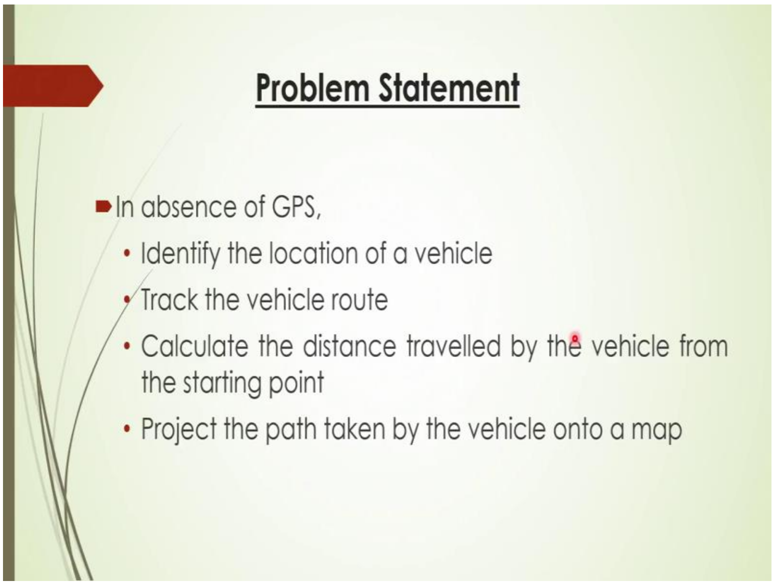

Now, let us see. What you want to do? In the absence of GPS, you want to identify the location of the vehicle. You want to track the vehicle route this is another important thing. You want to calculate the distance travelled by the vehicle from the starting point and you want to project the path taken by the vehicle onto a map. If you are able to if you have a static map with you and you are able to project the path taken by the vehicle on such a map, your job is done. You essentially know in real time where the vehicle is at a given instant in time. So, I hope this problem statement is clear to you and these are what these are the things activities that you want to do when you do not have GPS.

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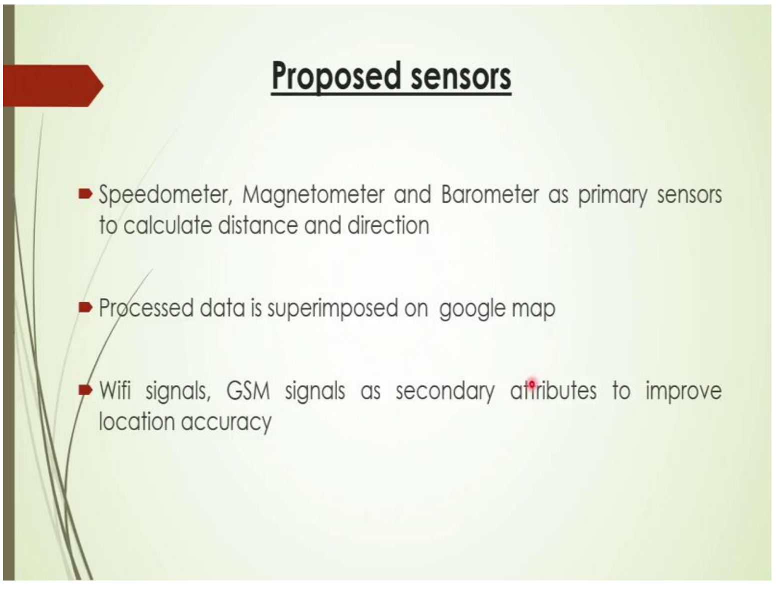

Now, what are those sensors that you want to use in order to get to that? It will be great if you get access to the speedometer of the vehicle in fact not just a speedometer, but also the odometer, the one that gives you the distance directly from a vehicle. We can handle them separately when we do the automotive part. Actually, if you go back and look at the automotive systems, there is the on board diagnostics connector available in all vehicles manufactured after 1996. This is called OBD 2. The OBD 2 will give you for sure one of the Electronic Control Units (ECU) will give you the speed, from that speed you should be able to directly know how much linear distance you have travelled. In fact, that will as we were discussing maybe you do not want speed, but you are interested in directly reading the odometer which is a direct indication of how much distance the vehicle has moved because speed will involve integration and integration errors and all that.

So, what would be the best thing is to directly read the odometer. So, assume that you do not have a speedometer, but you need an equivalent of speedometer to be in place. Let us see how we do that suppose you did not have access to a speedometer, because saying OBD 2 is all good if it is a four wheeler. What will you do if you are on a two-wheeler, there is nothing equivalent of an OBD 2 for a two wheeler. So, it is still good to construct from basic principles a simple speedometer.

And for that we will try and use a Hall sensor and a magnet. The Hall sensor will be connected to the frame and then there will be a magnet connected to the rim. And each time the magnet crosses the Hall sensor a pulse is generated and when you start counting pulses you know how many rotations and based on that you know how much distance. The very simple speedometer very reliable system. Off course, you can have pulse you can you can be missing pulses if you do not mount it properly, anyway we will come to that. So, those issues can come.

So, we will construct that very simple speedometer. And from there we will use magnetometer for all the turnings and barometer if you are climbing any hill or anything which is over 10-15 feet, so that there can be change in the pressure and that pressure indication can again come back onto the map and somehow you will be able to combine everything. But for the moment, we will not worry about barometer. We will again take this up as a separate module. We will just concentrate on speedometer and magnetometer as primary sensors to calculate the distance and direction.

Now this is important, what happens you do not process the data, I will show you something, which will be then be superimposed on the Google map. Now, as the vehicle is going under a thick tree cover or somewhere if there is let us say a wayside GSM signal coming or if there is a free Wi-Fi somewhere, you may want to argument those signal also to improve your location accuracy. So, you must think out of the box try and see how can I argument and improve the accuracy by simply taking those free Wi-Fi signals which are available on the way side or GSM signals coming from the nearest tower, they will basically use them as secondary attributes and improve the location accuracy. So, this is what you should try and attempt to do yourself if you are planning to build a localization system without GPS.

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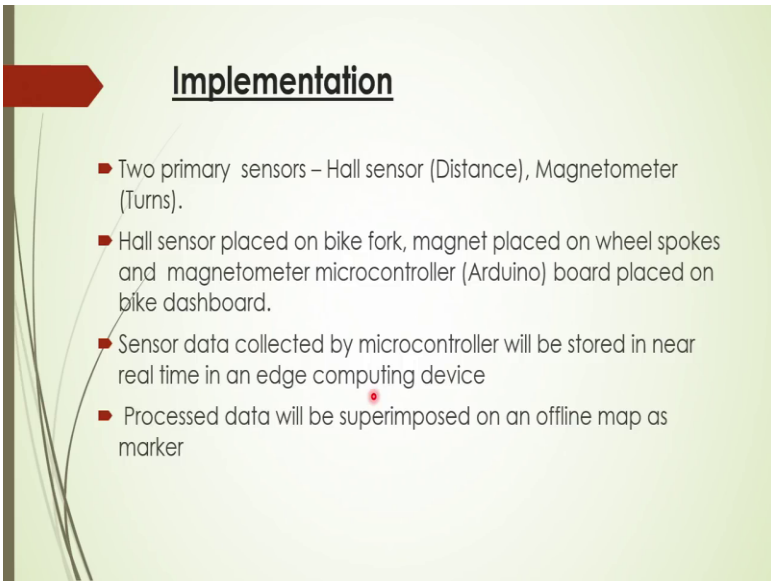

Now, what we have is for the demo, we have two primary sensors. I mention to you Hall sensor for distance measurement magnetometer for any turning on the roads. And it is purely two-dimensional at the moment. We are not looking at any height related information. And this is a very important assumption to make at the moment it is just purely two-dimensional. See the idea also is that this is not going to solve you know removal of GPS you cannot be saying I will throw away GPS. In situations where you do not have GPS for short durations for very constrained environments, for certain very specific requirements, you may want to rely on this kind of techniques that is why we are doing this IoT course related to localization. It is not that it is going to replace high technologies it is that is not going to work. But this is a simple technology which can work over points where GPS does not work, so that is how we started everything.

So, let us see a Hall sensor placed on the bike fork. So, we actually use the two-wheeler, so that this OBD 2 problem can be avoided, because we do not have access to the OBD 2. A Magnet is placed on the wheel spokes. And there is a magnetometer which is part of the hardware controller, it is essentially an Arduino board placed on the bikes dashboard somewhere you have some place and then you install it there. Sensor data is basically collected by the microcontroller will be stored in real time in an edge computing device. And then the process data will be superimposed on an offline map as a marker, so that is the key thing here.

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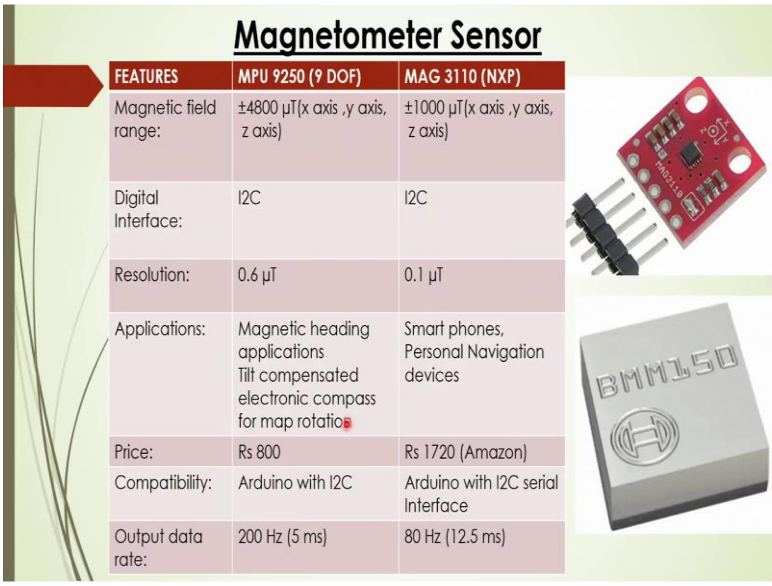

Let us see what the possibilities are for to choose a magnetometer sensor. We call the first session of this design for IoT course which we did the previous module. Whenever you talk about design, you talk about design choices. There are several choices that you have to make which one will you choose here you have two magnetometer sensors you have MPU 9250 is a 9 degree of freedom magnetometer and there is a MAG 3110 from NXP.

So, then and if you look at the interfaces, the resolution and all that, it appears that there both may be suitable. The MPU is cheaper actually it is 800 rupees as compared to 1720 which is from the MAG system. And compatibility is there with Arduino both though have compatibility this is much higher output data rate as compared to a lower data rate which is from MAG and so on. So, essentially you will have to do some sort of comparison before you arrive at any specific magnetometer for your applications. Essentially this MAG is integrated into smartphones personal navigation devices and all that and this MPU 9250 is for magnetic heading applications tilt compensation, an electronic compass for map rotation and all that. So, you can see that we looked at both of them and we try to see which one will be the most suitable one.

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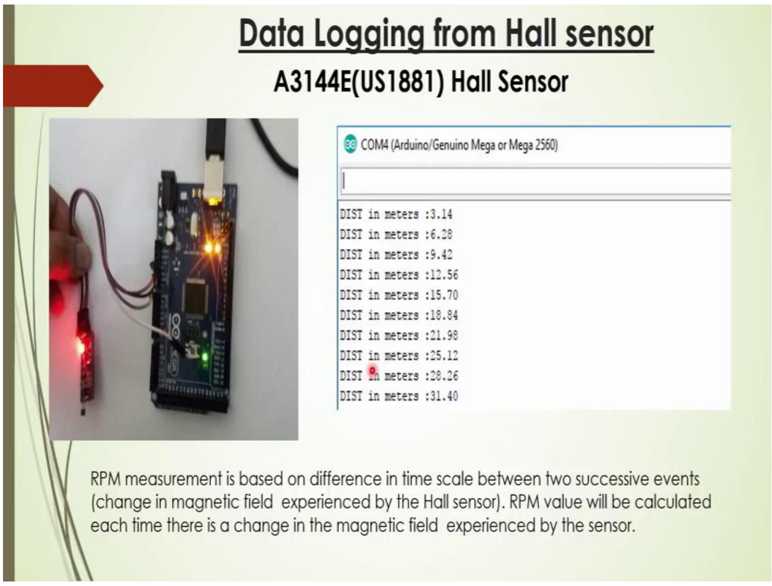

Now, data logging from the Hall sensor as you can see this is the Hall sensor that we have used A3144E is the Hall sensor. And it is directly giving you the distance in meters as the pulse as the pulses keep coming, you will see that it is showing you the distance 3.14, 6.28, 9.42. Units of 3.14 is essentially getting repeated and it is coming out very nicely. So, RPM measurement is based on a difference in time scale between the two successive events, change in magnetic field experienced by the Hall sensor. The RPM value will be calculated each time there is a change in the magnetic field experience by the sensor quite straight forward and then you will see that you are actually able to convert those pulses periodic pulses that you are getting into distance in meters.

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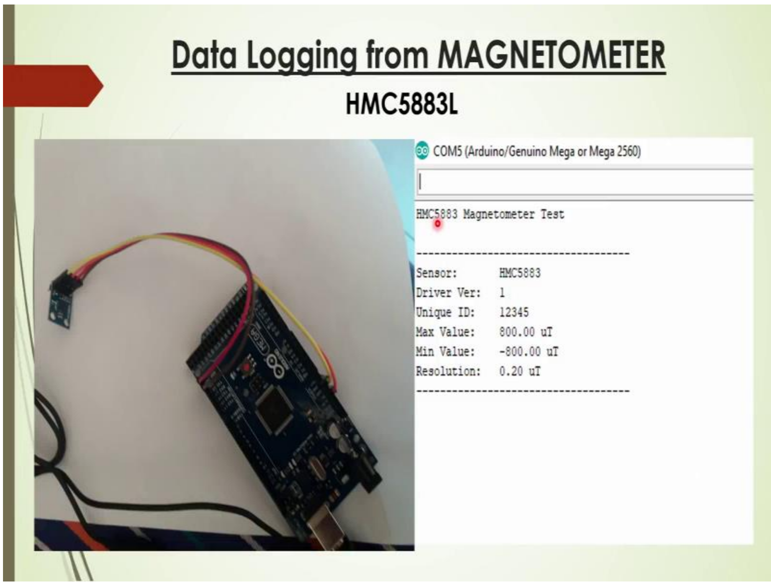

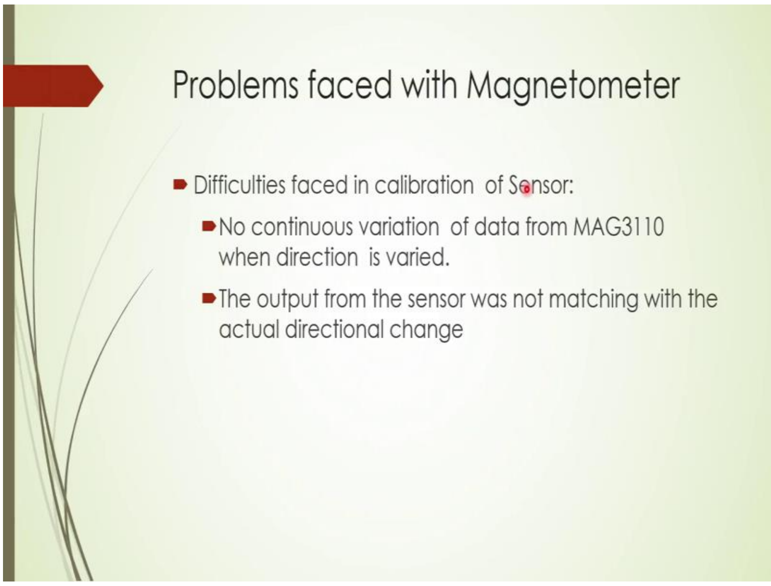

So, I mention to you that design choices have to be made. And we found that the design choice essentially means that you have to choose a right sensor for the right activity. And ~~you~~ I have just put this slide to tell you that the MAG 3110 was actually not so suitable for this application, because there was no continuous variation of the data coming from the MAG magnetometer. The output also from the sensor was not matching with the actual directional distance. So, we had some troubles with the magnetometer, you may end up facing such issues. So, it is important for you to essentially ensure that you take care of those issues by selecting the right magnetometer for your applications.

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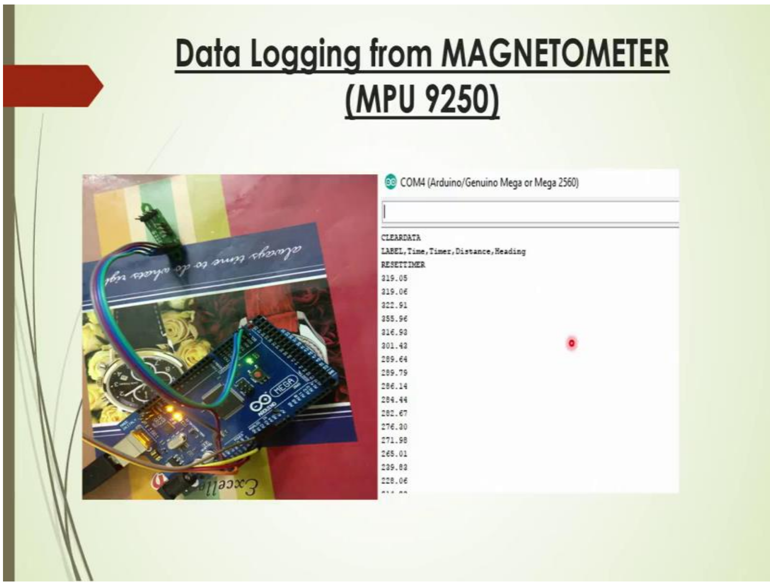

Now, the magnetometer we finally settle down was the MPU 9250. Please note that it is much cheaper than the other magnetometer, but somehow this seems to be doing the actual job and then we are able to log the data. And essentially showing you how the direction is changing. In above shown figure, you will see some fluctuation in this numbers here 319, 301, 289 and all that. I agree that there is some change even if the vehicle is going straight, they seem to be some change in the value of the micro tesla readings coming from the magnetometer.

And this can pose a serious problem for you because you may not be even be sure whether the vehicle is moving straight or whether it is tilting to some direction because you will see 271 to 309. If you look at the above figure look at this 228 to 319 is quite a difference in micro tesla values. In reality you may not even have move too much, you may not have change direction too much, but this kind of fluctuation you have to somehow be able to handle which essentially means and bring us to a very important point that you must process the data. So, this is the key take away from this slide.

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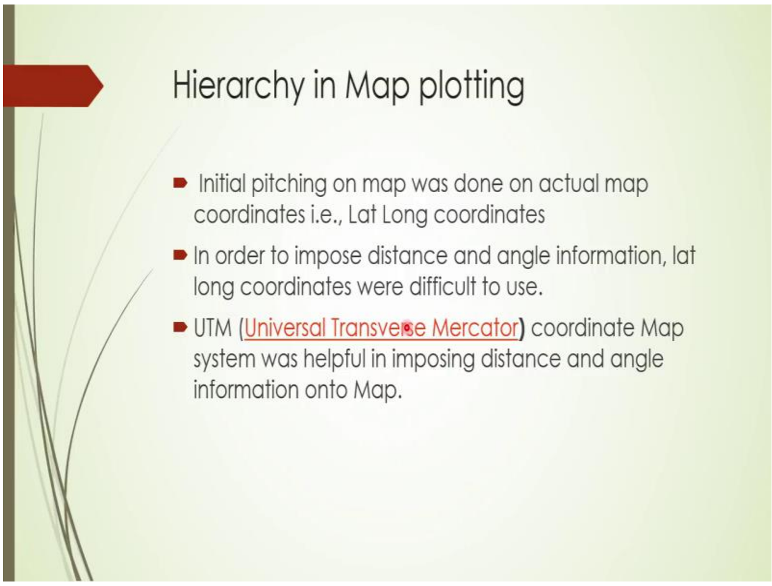

Now, what is the next important activity essentially you have to map whatever is available to you in terms of the distances on some sort of a map which is a very standard thing like a Google map or something like that? So, essentially what we have to do is as I mentioned recall that we started with the last GPS coordinate available to us. So, you actually know the lat long there. From that what you do is, hold that latitude and longitude, you actually know the physical location from where you started.

Then what you do, you convert that latitude and longitude into some form of two-dimensional coordinate system which is called the UTM, which is shown in above figure, it is called the Universal Transverse Mercator coordinate map. This is basically a map which is a conformal projection which uses two-dimensional Cartesian coordinate system and to give locations on the surface of the earth.

So, if you want more information, please look up the Wikipedia page. It will tell you that it is a nice way to sort of convert it into two-dimensional form. And essentially like the traditional method of latitude and longitude, it is a horizontal position representation that is it is used to identify locations on the earth independently of vertical position, so that is why it is the actually it is a two-dimensional system. However, it differs from that method in several respects, but we will not get into the detail of that.

So, you are somehow using this UTM coordinate map system which was helpful in imposing distance and angle information on to the map. So, please look up UTM which will help you to take whatever readings you are getting and pin it back onto the maps. This is very important, because in real time you getting the distances. When you get distances in real time you have to put it back onto the map, so that you are following the map accurately.

So, you take the initial lat latitude and longitude given by the GPS system? You will have the two-dimensional values with you. You are collecting distance and you are collecting the direction you take, add it back to the initial value that you got. Then you get the new distance and the new direction. And then put it back onto the map that way you iterate between the map and the values that you are getting from your system and that is how you will be able to sort of track the system.

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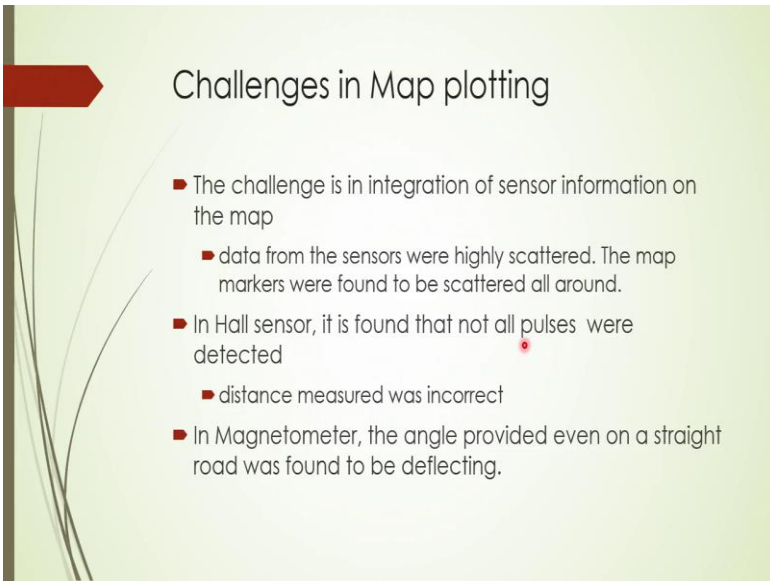

So, there are challenges though it is not without that with just it will work straightaway. The challenge is in integration of the sensor information on the map as I mentioned it is easy for me to say these things, but it going to be difficult for you to when you actually do it and you have to do it so that you get some experience on it. Essentially the data from the sensors was highly scattered, the map markers were found to be scattered all round. So, you will have some difficulty there.

The Hall sensor is also not going to give you know all pulses. So, you will at times have problem of loss of pulses which means that distance error you will start getting because you lose one pulse, you will lose some metres and the distance measured will be incorrect. Also magnetometer I showed you that was fluctuating you may actually be on a straight line, but the micro tesla values were fluctuating quite a bit. So, the magnetometer the angle provided even on a straight road was found to be deflecting. So, all these issues will come.

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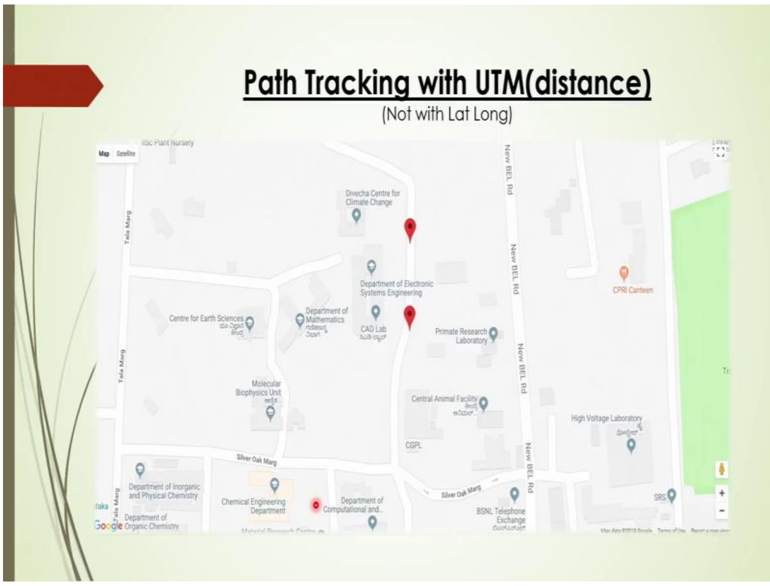

But nevertheless you will see some very interesting things. It is not so bad. You should not get put off for the fact that we have all these problems, you will see some interesting results. This is path tracking with UTM distance; there is no lat long. So, you can see that we have converted the lat long information from the first slide into UTM distance. Again you get back these two points that we had initially put (as shown in above figure). So, it is already very good. It is putting back in the two-dimensional Cartesian coordinate system.

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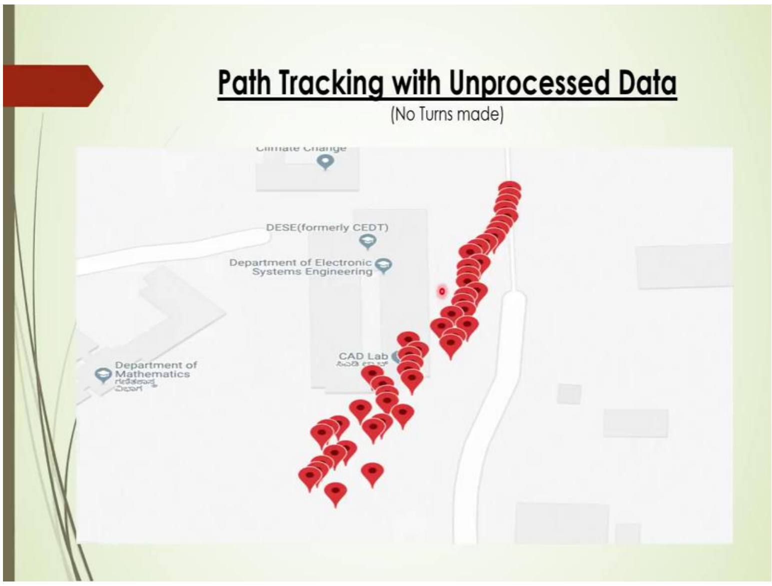

But, if you do not process the date you can see that if you do not process the data, what actually happens is, you start from here and instead of going straight (as shown in below figure), you start drifting away (as shown in above figure).

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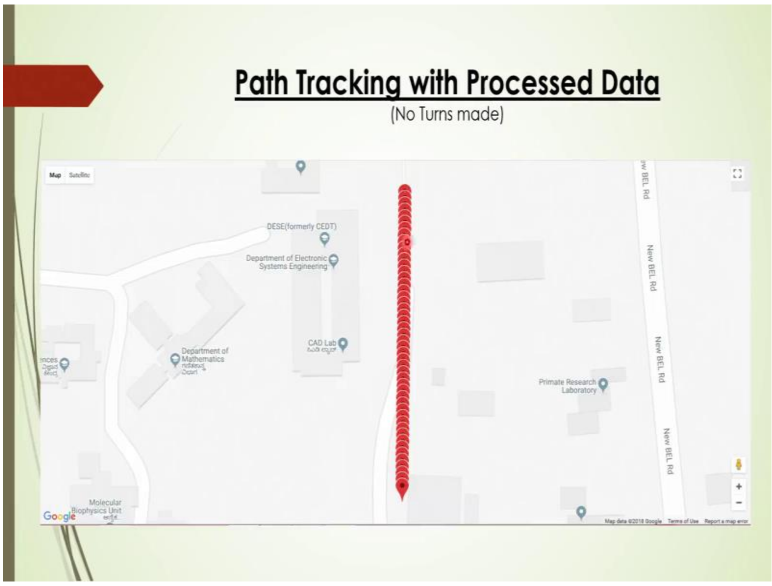

So, if you process the data, you will actually go straight no problem.

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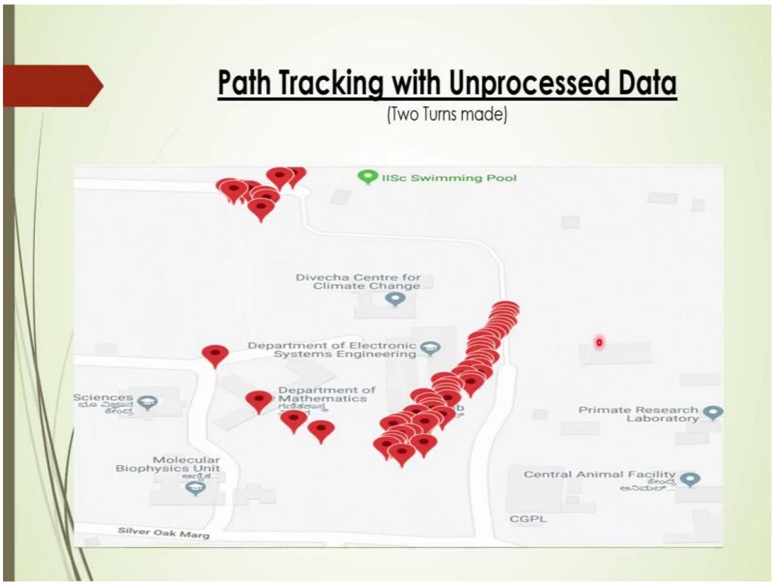

So, if you look the above figure this is path tracking with unprocessed data this is another example, but this is with two terms. The original path is it should go straight; it should take a turn. This is the one turn and then another turn, this is what you should happen (as shown in below figure), but you can see that (as shown in above figure) this markers are throne all over the place inside the IISc campus.

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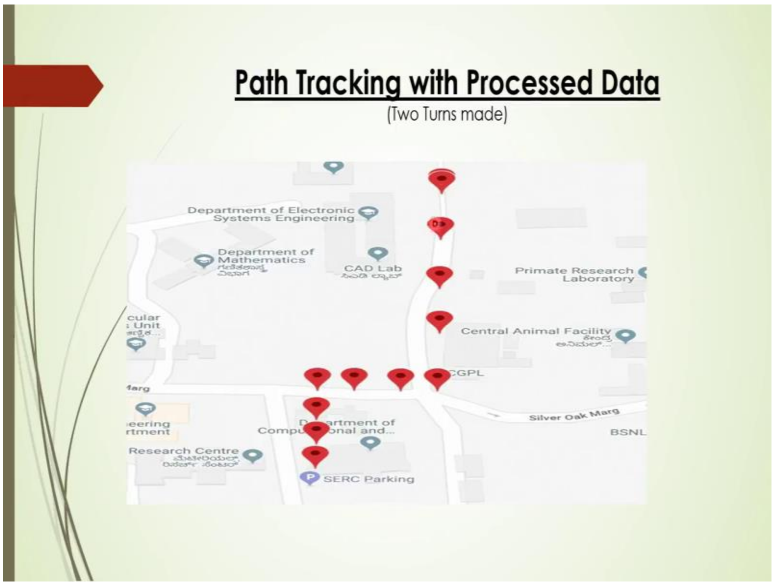

But, if you process nicely you get one turn and you will get almost another turn (as shown in above figure), all though it did not turn accurately at that point it turn alright.

So, you can see that this kind of path tracking with process data is definitely a very good possibility.

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In the demonstration the microcontroller is powered, through this USB and it is connected to laptop. And to Arduino port, we have interfaced with magnetometer.

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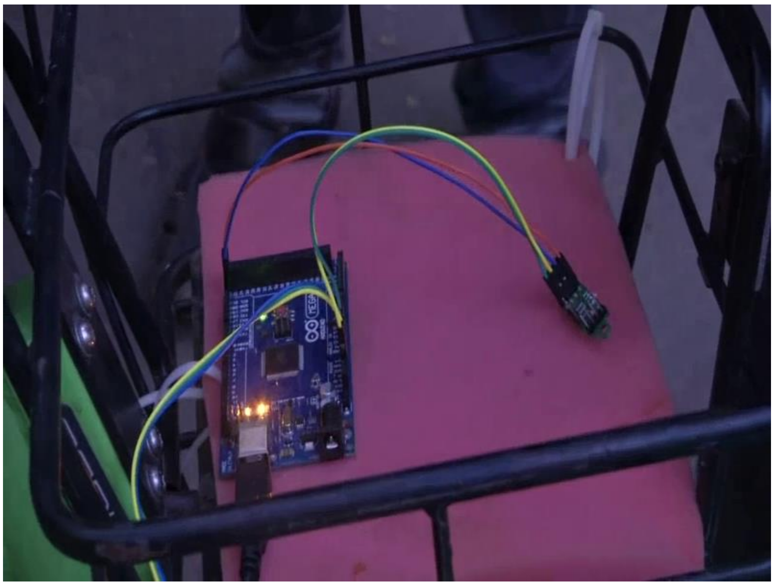

Now, this magnetometer essentially will give you the turns and the direction change and all of that. Now for wheel counting, rotations, you use Hall sensor.

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And Hall sensor is fixed on the frame. So, every time this magnet comes close to the Hall sensor board, there is a pulse which is counted. And you know you process the data from ~~the~~ both from the direction as well as from the wheel pulses coming from the Hall sensor. And put it on top of the map, after suitable data processing, then you should be able to localize the two-wheeler on a given path.

Thank you.