Advanced IOT Applications
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Lecture - 01
Overview of Localization using IOT sensors

Let us take this first topic of localization and try and see what are all the things that we should cover in this course, see when you talk about IOT applications and if you talk about localization as a horizontal across, all applications that we are building, in an IOT you can look at different type of sensors.

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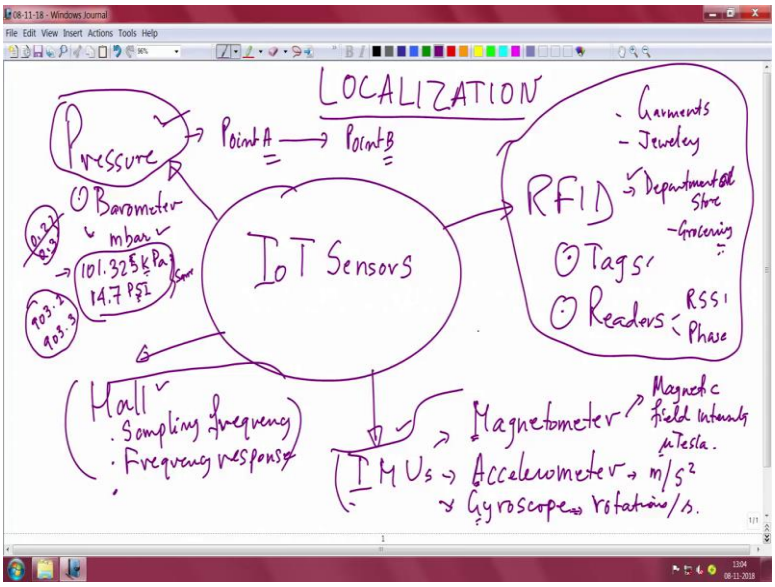

Let me draw your attention to what I have written on this board on this screen here IOT sensors in this course particularly with respect to this course we will look at RFID, we will look at IMU, we will look at hall sensors and we will look at pressure sensors. These are the main sensors that we are going to work with for localization. It appears strange to you perhaps that nowhere GPS is shown and that is the key, you are not really looking at anything with respect to localization with GPS system because GPS has it is own problems it has its own advantages and so on.

So, we may have to use an indirect way of measuring distances and from distances try to arrive at localization of these sensors. So, now if you look at RFID and look at what are these applications that will require RFID. Let me start putting some of the applications in

forward to you take a large warehouse, when you say warehouse it could be a warehouse where there are garments, there can be garments, there can be jewellery, or it could be a departmental store where we go and buy groceries.

So, all these essentially have lot of items and keeping inventory of these items is a tedious task, today each of these items have a barcode and they are barcoded and placed in a particular rack and each time a customer picks an item, the item is put into a basket and brought in front of the point of sale system there the barcode is read the amount is deducted and then there is a billing which we are all familiar with. This is fine as far as barcodes are concerned, supposing you want to have inventory, this bar code is not going to help you at all. It is only for billing it is only meant to know the item and so on and so forth.

It cannot tell you where and how many of these numbers are available, which means anything with respect to inventorying them is not going to work. So, for that what people have done is they said this is a dumb way of doing barcode is good, but it is dumb, let us now try and replace it with something much more useful something more interactive. So, they replaced gradually they started replacing the barcodes with RFID tags.

These are all passive, the costs are not down to earth, but costs are fall the time you can buy a RFID inlay for less than 15 rupees or so, if you go and look at the previous course you will know about readers, interrogation and all that, you can do all of that. So, this inventory business can be solved, you can do inventory and you can get to know the numbers for example, you are looking at pickles or you are looking at papad, you are looking at amount of rice bags that are there or the lentils that are there or something like that you want to know what is the quantity available.

So, each tag let us say if reads a tag you will know that the tag corresponds to some amount of weight and some amount of quantity and so on so, that is solved. So, is it going to be enough? Well the answer is no, you are not only interested in the inventorying the items in a departmental store you also are interested in knowing where the item is available, because when you enter a pharmaceutical shop the man who is managing it exactly knows where paracetamol is available and so on. It is purely based on human’s memory of placement of an item and he can quickly pick it up, sometimes he or she also gets confusion where that item is.

So, if you are talking about hundreds and thousands of items in a pharmacy in a departmental store or in a jewellery shop or in a garment warehouse it is almost impossible if you do not get to know where an item is. You may need this kind of localization of where a garment is, not necessary from a shopkeeper's perspective. You may also want to know from a customer's shopping experience perspective, you might have seen this in malls that are coming up now as you enter a mall and you have your Bluetooth on.

There are what are known as good beacon technologies which are available right, there is apple I beacons which is the very popular way you put low transmit power beacons on let us say a particular garment rack and that rack is telling you it is an attractive offer which is available and as you move closer and closer it will tell you where that rack is. So, it is also if you have a nice application on your mobile phone it can direct you to that particular-garment rack which is giving you a good offer to buy. So, it is also from that perspective you need localization.

So, let us not look at that because that is a very standard thing you can use Apple, i-beacon and there is an equivalent android beacon technology which is available, and you build an application on your android phone. As you move into the departmental store it will direct you to different locations within the departmental store and you will be able to pick an item.

But now let us look at the problem for the shop owner, let us look at it just not the inventory purpose, but also from localization of these of these garments, also look at this way when customers come during a festival season several of this customers pick this garments try them on and maybe sometimes in trial room sometimes just look at it and you know move to the next track and leave it there.

So, they are misplaced, and you need to put it back in it is respective location, sometimes garments can also be mistakenly or otherwise can also be removed from the shop without billing right. So, you may also want to detect those situations. So, all these things essentially mean that unless you localize correctly the solution is not complete not just about tagging items, not from a point of sale items, not just limiting yourself inventorying them, but also localizing them. All of it should happen over hundreds,

thousands and millions of items which are there inside these large departmental stores or you know huge shopping malls essentially.

So, RFID has been a technology in which people have sort of been using and tags as I have said have no power. So, let us look it passive RFID tags and readers. Now what is the core algorithm that one should use in order to localize, that is the focus of this course. Here we can look at 2 things, one is we can look at what is available from the tag to the reader, now before we get into that detail you have to come up with an idea of what is the scenario under which you want to localize, scenario can be the following.

If you go into any departmental store there are corridors in which you have items on either side and then there are there is place for the human to move to look around on either side to pick what he or she wants. So, there is a nice guiding path which is available to you and this is something that you may want to exploit as and when you want to do localization that is one part. The second part is it is almost humanly impossible for humans to do all these kind of activities, sometimes in some applications human are a must in some applications it may perhaps be just enough that you make an automatic process where you switch on a robot just before you put down the shutters of your shop.

And then let the robo go into all these little paths that have been created for humans to move and then it sort of localizes all the tags. It inventories and localizes all the tags and by the time you open the shutter in the morning you have a nice email or perhaps some way of visualising it and telling you where items are and what are the items that have to be adjusted, removed, replaced, put back so on and so forth. So, once you get the localization information you can use it in different ways.

So, the scenario that we can consider, and we should be considering is can we put up a robotic platform which will do localization of all the tags and it will be able to tell you where a tag is located. It should tell you the xy location of the tag, let us assume z is fixed because that will be a little harder, but let us just keep it at xy which is already very good we will tell you where the tag is. So, you need algorithms for xy location of the tags.

What are the signatures available for doing this? One is you can use simple ranging which essentially means you can use receive signal strength, the received signal strength

can be sort of somehow related to the distance between the tag and the reader that is situated. So, somehow you should be able to infer that, but that is hard. So, because RSSI is not a very reliable way of measuring distances between tags and readers, this simply because environment keeps changing and reflections are there inside these kinds of indoor environments.

And therefore, what you read as an RSSI value today at this instant may not be easily repeatable soon after. So, that is RSSI is perhaps is not a good way, you find some other way, if you take any signal one of the things attributes of any signal is the phase. So, phase is a good way to measure, the distance between the tag and the reader. So, let us see how phase-based approaches can be applied and algorithms on top of them for processing the tag reads for example, you may want to do clustering, clustering algorithms are applied on a bunch of xy location, to arrive at the correct xy location of a tag.

There are several clustering algorithms which people talk about the talk about k means clustering, they talk about db scan and all that. So, we look at db scan because it is a very popular way of applying a clustering algorithm for these bunch of xy location. So, you read you do some processing like clustering and so on with some very good probability you arrive at this is where the location of the tag is, this is as far as RFID is concerned.

Now let us turn our attention to IMUs, here one would be interested in looking at IMU I mean the Inertial Measurement Units which are commonly available on most mobile phones, you have magnetometer, you have accelerometer and you have gyroscope. Gyroscopes give you rotations per second, accelerometer gives you in metres per second square and magnetometer gives you magnetic field intensity in micro tesla. Essentially the magnetometer value in micro tesla is an indicator of how much in angle you are away from the earth's magnetic North.

So, it will give you a number so, that way you must use this tesla and convert it back into angle. And that there is a standard way to do it let us I will give you some pointers which will allow you to look at those equations which are essentially used to the little formula that are used, which will allow you to convert the magnetic field intensity measured in micro tesla into the angle away from the earth's magnetic North. So, where can you apply this? Think of situations where you want to use IMUs in indoor location of human.

So, as you know most humans carry mobile phones and you are interested in reaching a particular office or a particular location inside a commercial building you are interested and you have the map of the building, is multi floor you are the map of the building and you are interested in getting guided to that particular location inside the building, now as you know building will have multiple floors and each floor may actually look identical. So, you may have to solve the problem of, on which floor you are and then you must say if I am on the right floor, how do I reach that particular office or lab or it is a cafeteria, of that particular floor and so on.

You may want to use IMUs for that kind of localization applications and use these sensors which I mentioned to you like accelerometer, gyro and magnetometer available in phones. So, here the scenario is the one in this course is we are going to look at mobile phone as an IOT device, we will build small applications which will allow us to localize on a map tell you quite accurately, where you are on a particular floor of a building. It is a hard problem again because these IOT sensors that we are looking at are quite noisy, you know applying certain filters on these sensors is an important requirement and we will have to see what are the minimal things that you may have to do so that you get the right kind of data point with which you can use for the purpose of localization.

So, that's what we will try and cover in the IMU part of the localization. I already mentioned to you that floor detection is a very important requirement, in the indoor localization using IMUs, unless you know on which floor you are reaching that cafeteria or lab, or any other point is not going to be easy.

Therefore, you may have to use a sensor like a pressure sensor, essentially pressure sensor is a barometer, will measured in terms of milli bar. 101.325 kPa (kilo Pascals) is the pressure at sea level which can be equivalently represented as 14.7 PSI.

In mobile phones it will also give you in millibar and floor to floor if you change in a mobile phone you will see that the value changes from 0.2 to 0.3. So, that is the change in the millibar, suppose you are reading 903.1 millibar in one floor you will essentially read 903.3 maximum in the above floor.

See why there is a change, is also because of the amount of the height that you climb sometimes floor to floor is 10 feet, sometimes floor to floor is 8 feet and so on and so forth. That height difference can give you little bit change in value, but quite accurately

the value which change by 0.2 or 0.3 which is a good indicator that if you start from ground floor and as you move up to the fourth floor or fifth floor for every floor you will get this difference. So, it will become a significant number as you move up in terms of number of floors that you cross.

So, quite accurately you will be able to estimate on which floor you are if use pressure sensors, particularly the barometer which is part of most IOT devices like mobile phones. Finally, let us look at hall sensor, supposing you are in a situation where you are traversing a tunnel, you are in a vehicle or car or a two-wheeler and there is no way by which you can get access to GPS signals. But you have offline maps with you, which you can easily get from Google maps. But for people who are interested in building their own maps there are open street maps which you can download and build your own applications, because Google maps and other maps which you see on your phones if you are using it for commercial purposes you have to pay for it. Essentially, for personal use I think there is no problem in using these maps and its quiet freely available now. So, suppose you have the map with you, there is no GPS information is available to you. So, you may have to an essentially count the wheel rotations.

So, let us assume that you have to count the wheel rotations, which will tell you what is the linear distance that you are covering. So, one can use hall sensors, when we talk about wheel rotation we will essentially put the hall sensor on the frame and we will put a magnet on the rim of the vehicle and every time the magnet crosses the hall sensor there is a certain amount of voltage induced in the hall sensor and that will tell you that one rotation is completed, hall sensor with magnet essentially to arrive at how much distance you have covered. Now that will not be enough by just counting the distance be taking turns will be going taking a left or right turn and so on.

So, you will need assistance of other sensors like magnetometer sensors have to be used combined with the hall sensor which will tell you something about the location of an automobile inside a tunnel. So, let us see if we can arrive at how to use these hall sensor and magnetometer sensor in combination to see how you track or localizer vehicle outdoor, but without any information about the GPS. There is another thing I want to tell you about this pressure information; pressure information is not just about floor detection, but also there are other applications for use of pressure sensors.

One of the things is let us say you are going from point A to point B.

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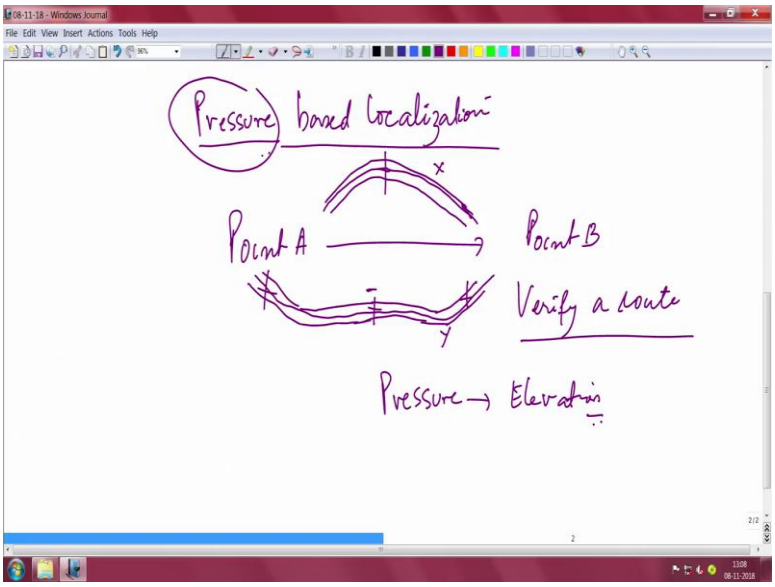

Let us say in pressure based localization, suppose you are moving from point A to point B, let us say there are at least 2 routes, which are route X and route Y (as shown in the above figure) now it is quite easy for you to also apply pressure information; Consider that you are asked to take a particular route, let us say you are asked to take route Y and not route X . Here it is quite easy if use pressure-based localization because you know that pressure if you take point in route Y never exceeds a certain threshold.

Whereas if you take X you will see that there is a difference, you can also verify for instance, if you use the simple pressure sensors and you can convert pressure to elevation. If you know pressure you can convert it into elevation and vice versa you know where the elevation was low Comparatively. With the elevation profile and then arrive at whether the vehicle that was asked to take route Y actually chose route Y or not. This information can be stored locally inside the sensor node and at point B it can simply be read off and then you just quickly plot with a few sensor values.

And then you know whether it has crossed the threshold and simple threshold is enough to arrive at whether the route chosen was right or wrong. You just do not ha have to do threshold you can actually plot the whole route and the sensors value will tell you pressure profile for the particular route travelled, using which we will try and see to reconstruct the route in coming lectures.

In summary this course is not so much about GPS and all that, but it is about how IOT applications can be built with these IOT sensors, can actually assist aid in solving very large problems of localization of sensor nodes. Let us now move on to see a few demonstrations of these applications we will get into the details and then we will then build other applications in terms of trying to complete this module.