Introduction to Biomedical Imaging Systems
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Lecture - 02
Introduction - 01

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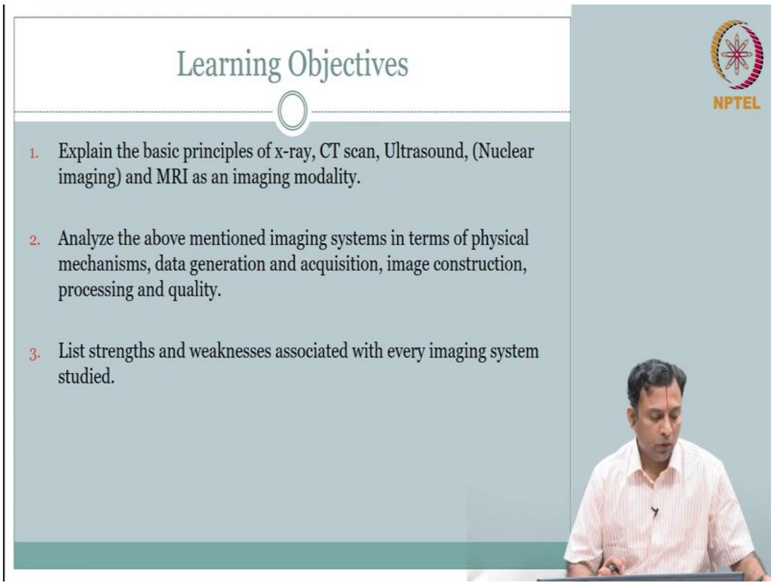

Ok. So, let us move beyond the learning objectives. So, having set the stage for the medical imaging, the course title, and the context of biomedical engineering where medical imaging fits in the big picture of biomedical engineering.

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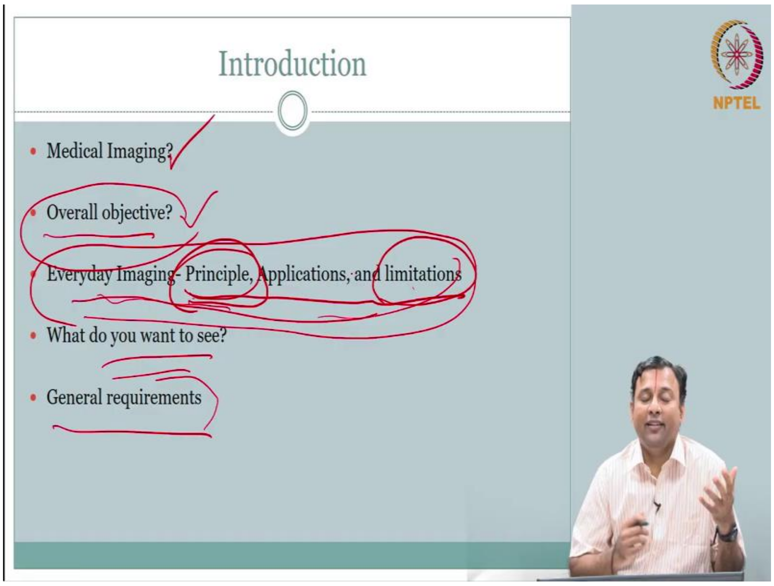

Let us move towards further introduction. I mean, here again, having set the big picture, we still need to have a bird's eye view of the medical imaging area itself before we can jump into taking each modality, for example, in detail and go through the material.

So, what we will do is quickly run through a recap of what medical imaging is. We did cover this a while ago in the context of the big picture. So, just to recall in brief, medical imaging is you saw the central picture, right, anatomy physiology. So, the idea is it is a process of extracting the parameters something to do with human physiology and anatomy and visualizing it, right. That is the key, visualizing it, seeing it, seeing that as a form of an image.

Of course, it can also be three-dimensional, it can be a movie, it can be a time lapse, but for simplicity, let us just say you are extracting some spatial distribution of these parameters that is to do with your human anatomy and physiology and visualizing it, right. That is this process.

Of course, capturing this using some ways and means some modality, like we saw an example of CT, X-ray, MRI, ultrasound and so on and so forth the different modalities. So, that is the broad idea of medical imaging. So, it is a process through which you do this, ok, fine. That is fine. I mean, it is easy to follow, I think, right.

Then, the question that pops into your mind is, well you said you know you are taking MRI or ultrasound or all the terms that we are used to the technical modality names that we are used to, right. How does; I mean is it all the same, I mean does it all fit exactly the definition or the aspect of medical imaging or only those kinds of capture medical imaging is there anything to it, right.

So, obviously, each one is different, but there should be an overall objective, right, overall objective to do this medical imaging. What could be the overall objective? So, if you are thinking about well we do medical imaging, so you are saying it is some anatomy and physiology of the human body that you are capturing.

So, one of the objectives should be naturally that the doctor is able to go through it, right, see it, see the images and make some diagnosis and you know help him cure the patient or you know give come up with a good protocol to treatment, so on and so forth. So, the idea is yes. Naturally, the output, which is the image is used for clinical purpose that is one of the objective of using medical imaging.

But is that all? Is it complete, I mean it captures the sense, but I still feel it is not capturing it to the extent that is needed that will position the context of medical imaging systems that we are going to cover, ok. So, what is missing then? Ok, think deep. Simple thing, ok, I have a bruise, I go to the doctor he says ok, today you know I cannot see you but just take a photo and send me.

So, you take your camera, take a photo it is appearing blue back, right. So, yeah it is ok, it is blue back, just do some icing, rest it and it should go away. So, he is seeing and you are a human body, so he is seeing a human body and making a diagnosis. So, ok whatever he is seeing, instead of just seeing you could take a camera and do it, so that is fine, right. So, it is medical imaging. So, if you are wondering, yes it is medical imaging. So, it fits what we talked about. So, it is complete.

Well, that is complete at least it appears so, but actually, it is still not complete. Why? Why do I say it still not complete? What happens if you have a bruise, if you have a scar, if you have something a cut inside the body, what will the doctor be able to do? Well, if it is on the surface, if it is in the mouth he may ask you to open your mouth and put a light and look at it and diagnose, but what it is deep inside, right.

So, the overall objective is not just ok use the imaging process for diagnosis by looking at the parameters as a visual image, but more importantly what parameters, what anatomy physiology which is inside, right.

So, you want to the overall theme of the different medical imaging modalities is how can I see inside the body. Because of the surface yes I can see it, right I can see it, I can use a camera, but the objective of medical imaging is I want to see inside the body, right. So, that is the common theme.

So, now comes the challenge, ok. We seem to get the picture. So, do I know because MRI is new to me, CT is new to me, all those are appearing very technical, we are going to see all the equations behind the (Refer Time: 06:20) this course, so it better be complicated. So, for a for somebody who seems to be comfortable, but actually wanting to appreciate what we will see in this course is let us take an example, right.

Let us take something that you are using every day and we will answer this question as to whether can it be considered as a medical imaging system. If so, right can we because of the routine use we may be able to also appreciate all of this. So, what is it that comes to your mind? A medical imaging device that is there in everyday imaging that is used in every day imaging. In fact, that is an understatement, every you know the trend is it is like every hour, every you know every hour imaging.

So, what do I mean? What does come to your mind? I will not be surprised if first thing that comes to your mind is a mobile phone, right. Why? Because mobile phone the purpose of being able to talk to someone while you are on move that is there that functionality is there, but you see all of the advertisements for the mobile phone, it is for the camera, right.

You get camera. What does camera do? So, you are doing imaging. So, you have new terminology say you take a image of yourself it is called selfie. So, I am sure you all are familiar with that, right. So, now the question is yeah that is a everyday imaging device. We all understand there is a camera, you all are an expert, you know what is 12 megapixel, what is 8 megapixel, why should I pay more for deblurring feature you know all that.

Now, the question is now that you know all this I know you are talking about; so, there is some principle to it, ok at the outset you know what it is, right. Light is scattering off my surface, colour is nothing but the wavelength like visible light wavelength. So, each colour is of different wavelength. So, whatever is bouncing off the surface the light that is bouncing off the surface if it is captured then it gives you a picture of the coloured distribution or the whatever.

So, applications, yeah you use it to take you know that different colours in a butterfly or the early morning sun rise you have everyday applications that you do. But given that this is medical imaging do you think it is also a medical imaging device, absolutely right. The example I said you have a bruise you can take a photo, right and send it to your doctor, so that becomes medical imaging.

So, what is the limitation? Does it really I mean does it really have any challenges? So, we just convinced ourself that everyday imaging device, this is a medical imaging device nowadays, right or it can be viewed as a medical imaging system and you already can realize that it this is ticked off.

Does it solve the overall objective? Yes, the first principle overall objective it does solve, right. You send the doctor is able to diagnose. But is it complete? Is there anything more to it? Right. Well, think about it. What I want to see? Anatomy physiology of the human body, but if you take a photo you only see the skin. So, you are only talking about the skin subsystem, right.

What happens to inside the body you will not be able to take? So, now, philosophically you know your beauty is only skin deep, right because your light that you are taking photo you cannot see inside the body, it is just coming off the surface. And therefore, this a major limitation.

Of course, you might wonder and say no my you know I had a bad stomach ulcer and I was having upset stomach, so basically I have asked to go and they send some camera through, right endoscopy they send a camera through and they were able to see inside my GI track and all my stomach and they said there is this problem.

The other day I said read in a newspaper that they have this nano camera you can chew it I mean put it as a pill and it goes and it gives you images, wireless transmission of images through the path. So, how do you say it is not seeing from inside, right, I mean that is a natural question that may come to your mind if you think about it.

The point there is still principle. So, it is still, yes it is from inside the body, but then it is still only skin deep or the inner lining deep. So, if you take it through the passage esophagus it can only see the esophageal surface. It cannot see inside, right. So, brute force way is if I cut open a body, you see it, you take a camera, then the camera can be used, but then it becomes invasive, you do not want to cause harm, right.

So, the important aspect is everyday imaging is fine, camera is fine, but the overarching objective, right of medical imaging system, any medical imaging system is to be as non-invasive as possible. What do I mean by that? You want to sit outside the patient, right, you want that device to sit outside the patient and be able to see what is there inside the patient. So, you want to be able to see inside the patient sitting outside that is non-invasive.

Of course, if you take something in, right the camera and you bring it out through natural orifice it is something people call us minimally invasive. It is invasive, it is going inside the body, but it is minimally invasive, right. So, the overall objective is going to be non-invasive, sitting from outside how can I see inside the body.

So, now, comes another difficult philosophical question to answer. So, what do you want to see? Right. I just said sitting from outside you want to see inside the body, and the vivid example that you know camera you can you know send a camera, tiny camera through the esophagus you can see inside the body and we have repeatedly been saying this visualizing seeing because the doctor in the end looks at the image sees the image and makes the diagnosis. So, the question is what do you want to see.

So, recall, if you are going to do camera we talked about the principle, what is it capturing? It is capturing in some sense the property of the tissue of how it reflects what wavelength back, right, that is what it is captured. So, if it is you know if this is a grey pen, that means the light that is bouncing off is at a wavelength that gives you can see the say you see it as a grey colour.

So, the point is that is the principle. So, that is the property that is captured when you are taking the camera. So, that begs the question, so what do you want to see. Well, it depends on you know it depends on the modality, right, it depends on what that property has influence or what that property catches of the underlying pathology, right.

So, the question is a tricky question. I hope you would be able to appreciate the answer to it at the end of this course. So, what do you want to see? One way to think about it is I want to see any parameter that can provide, I want to visualize any, the parameter itself could have some units, right, but I want to visualize it as a image.

So, how do I visualize some parameter, the distribution of that parameter as an image, right, that is what I mean by what do you want to see. You want to see some parameters. What is that parameter? What does it what is the attribute of that parameter? What is the units of that parameter? What is it correlated with underlying physiology or the anatomy? What aspect? I think that is the tricky question that we will get a picture as we go along, ok.

That is fine. So, that is the whole idea that that field has different sub-modalities and each one by its own rights is a field by itself. But then there is going to be overall, because we have an overall objective there should be some general requirements. Irrespective of the modality all of them will have some basic requirements, and they have to satisfy certain requirements. What could be that?

So, before I just list that and make it feel like we know this I would like essentially for you to take this extra 2 seconds, 3 seconds, 10seconds to run through, ask you question, ask yourself this question, ok. He is talking about different modalities we go into the detail and we know the overall objective, right, we know the overall objective.

So, what would I, what would be the general requirements for a imaging system? Right. So, we talked about one example imaging system that you are very familiar with, with all the aspects of principle application, limitation. So, now in this contest can you think about what could be the general requirement? Ok.

I can see some of you already flashed in your mind, you know what he talked about seeing from outside to inside. So, first the requirement is it should be as non-invasive as possible, completely non-invasive is best, maybe sometimes it is minimally invasive, but you cannot really cause harm, you cannot really you know cut open to see inside that is, ok. So, that is straightforward from what we discussed so far.

Then, is there anything else from a technical point of view that flashes your mind? Requirement should be ok, it does not matter what parameter it captures, in the end the doctor is going to make a diagnosis that is going, this, it is going to help him make some diagnosis.

So, it is not about just you know visualizing some parameters as an image, it should be of some reasonable quality, so that the doctor can make diagnosis, reliable diagnosis, right. So, then there is some minimum image quality that you would expect it to pass, ok. Very good.

Is there anything else? Or there are several other aspects to it, but one another important thing is does it give me new information, right, does it give me new information, new insights which is able to help the doctor make diagnosis, ok. So, the idea is it has to provide some from a technical perspective, right. It has to give some additional insights compared to what the doctors having available already, ok. So, these are some general requirements from a technical perspective.

Apart from that no the generic ones, it has to be accessible, right, what is the point having a super imaging medical imaging system that can do wonders. But it is super expensive and people cannot afford and it is only in one state of the arts centre you know that that is ok.

From a scientific endeavor we may feel proud about such a device, but from a practice point of view you know. So, the requirement should be maybe it is affordable, maybe it is easy to access, maybe it is able to you know from an infrastructure point of view. It is not really it should be maintainable, right; so on and so forth, right.

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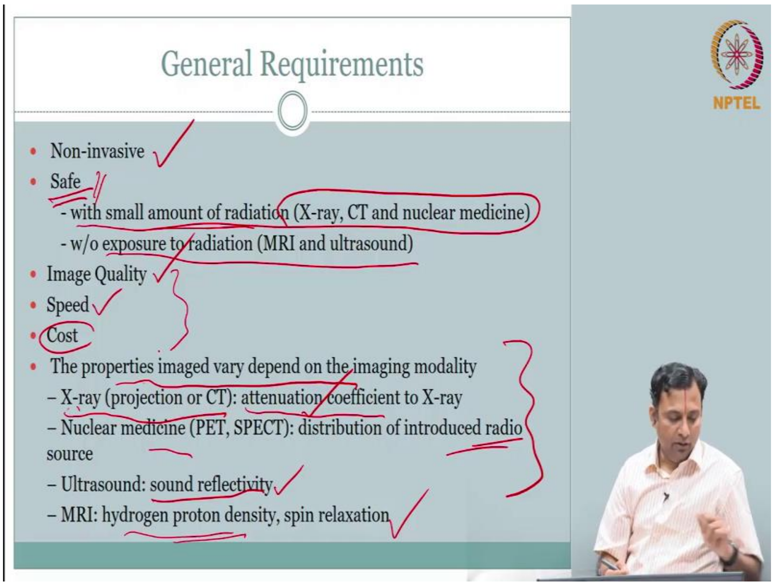

So, non-invasive; important aspect safety I do not want to look into and say look you get very good parametric into medical imaging, I can see what is there inside the body. However, you know what in the process of doing that I am causing more harm, right.

So, this is of interest because safety is a key thing you will see as we go into the details just because I am an engineer and I know how to get very good image quality, I cannot, I have to pay attention to whether safety is compromised or not, patient safety not the device safety alone, ok.

So, in that sense these are all routinely used, right, X-ray, X-ray, CT, nuclear medicine are routinely used. So, there is a safety issue with radiation, right, ionizing radiation we will go into the details. But the idea being it is a cost versus benefit ratio. It is practiced at a level that is as low as possible, so that you can get the information, the benefit of getting this information far out ways the small risk that you run when you do radiation.

Of course, there are other modalities where there is no problem. There is no what is known detrimental biological effect like your MRI and ultrasound, right. So, safety is a concern when you when you have the imaging system one of the requirement is it has to be as safe as possible. Then image quality, of course, speed, speed in the sense that how soon can the doctor get that information from the patient, right.

So, you can from the basic intro slides you already saw that in ultrasound probably the doctor can see it life, right. They can see the body inside as it is being scanned or it can be like other modalities like MR or CT where the patient is there they finish the scanning after that the computer processes it and give. So, you want it to be as quick as possible that is ones. Cost, I touched upon that.

Of course, I did not kind of loud think this before the slide was shown because then it will become too complicated. So, now, we said ok you get new property, I said you get new information and I left it at that.

So, the idea that we what we will cover here is eventually, right, what you are going to be imaging using the different modality. What is the parameter that you are going to capture? The different modalities are capturing different properties of the body tissue, right; how it is distributed inside the body using some principle some signal, right.

So, in case of X-ray essentially it is a attenuation coefficient to X-ray. So, you have your tissue, how does the tissue attenuate, how much does it attenuate the X-rays when it passes through that is going to be the parameter that you are going to look at. In case of nuclear medicine, right, it is a radio activity.

So, it is you introduce a radio activity, right some substance and that is going to give out signal, right. It is going to decay. So, you are going to measure the decay and say, ok lot of activity, lot of decay is happening at a particular location. Likewise, sound, sound essentially looks at I send sound into the body and it gets reflected back, right.

You are very familiar with echo’s. You know there are several places where they say this is you stand in this mountain and you shout your name and you listen back your sound will come back you that you hear the echo. Similar thing happens here, only thing it is not mountain you send sound inside the body and it gets reflected it gets bounds back and the echo’s come back and based on the echo’s you are saying where all the mountains are, where all the interfaces are, ok. So, that is what you are trying to capture.

In magnetic resonance imaging, there are several parameters you can you can go after. Most commonly for biomedical human body you are talking about hydrogen because we are all water bodies, right. We have lot of H 2 Os, so there are lot of hydrogen’s, so hydrogen proton and spin relaxation property.

So, do not worry if you are not still able to latch on to the details here. Just to say that each one just the look of it you can see one is capturing the coefficient of attenuation, the other is talking about some radio activity, some other modality is talking about reflection and here it is talking about some spin properties and density. So, each one is capturing different aspects that is all you need to recognize at this time.

So, the general requirements is you might be wanting the imaging system to capture give new information as much as possible. If I can get the same information from existing modality unless you have other benefits, they may not be able to the doctors may not even prefer they you know there is no gap, ok. Very good.

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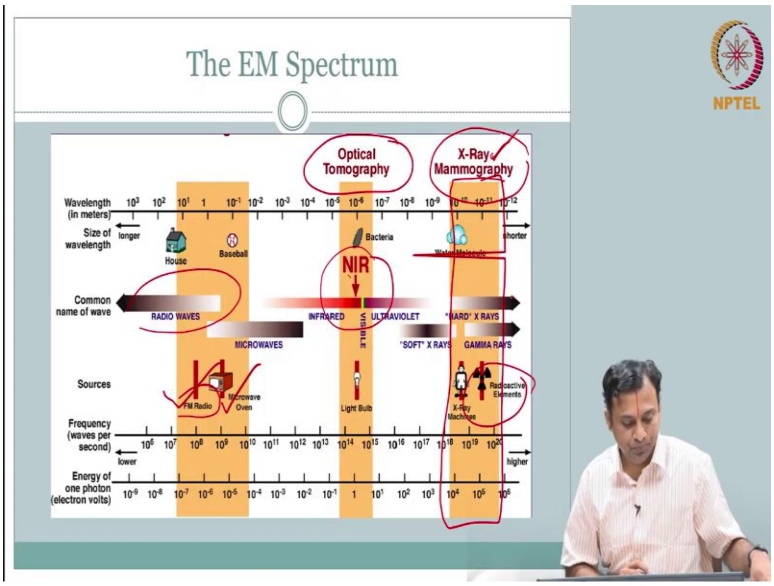

So, let us move on. So, this is to do with the general requirements. What we will do now is just quickly you know march forward and say we started about different signals, right, we talked about I just did, you have some attenuation, you have some radioactivity, you have X-rays, right spin, of course, sound reflectivity.

So, let us see. So, all of these are some physical signals, right. There should be some physical parameters units quantities. So, let us see what are the two at least big signal domain that will be explained exploited. One is your electromagnetic spectrum that you see. So, I am sure you can quickly recognize, of course, it is labeled here.

For example, you see optical tomography, so that that tells you that it uses optical optics and it is in the near infrared range, near infrared range, ok. You already see X-ray mammography; that means, you are already looking at this is a modality that you know X-ray mammography; that means, the waves here, the X-rays here belong, it has certain wavelength, right frequency, so energy, you can look at it any perspective, right.

So, in this region if you have electromagnetic waves that are used to explore interact the human body and your human the tissue inside, how does it interact with this particular wave if we can capture that and if that changes from a normal state to a pathological state then that image will reflected. So, that is what this is going to exploit of this range in the electromagnetic spectrum.

You can actually look at it, even though only two I have explicitly outlined, you can pretty much see that almost last majority of the rage is actually used by a biomedical imaging. When I say, you are looking at these are some items that are not biomedical, I mean microwave oven what is to do with micro biomedical imaging, not so there are you know a certain restricted applications, right given the constraint. There are microwaves are also used for human, for interacting with tissues.

So, mostly on the therapeutic they have shown microwave hyperthermia. You can also have microwave imaging, right. So, you have them. It is again radio waves, ok. I understand radio waves. So, FM radio I understand. What does it do with biomedical medical imaging? So, RF frequencies, right we talk about magnetic resonance, lot of instrumentation will be involve playing with RF frequencies, ok, ok. So, all of the modalities that we cover, we will cover in this almost all is covered here.

What is conspicuously missing from whatever we have covered so far? Well, all of these are electromagnetic you talked about X-ray, I see X-ray; you talked about MRI, I see something to do MRI. You talked about PET that is radioactive decay again it is going to be in this range here, you have radioactive elements, right. So, all of them are here. What is conspicuously missing? We are talking about ultrasound, this is the key. Ultrasound does not fit here it is not an electromagnetic wave, it is a pressure wave, right.

So, in some sense I mean just my insight is I have noticed most of the electrical engineering departments people work with electromagnetic because you know in electrical engineering in second year or third year you have electromagnetic waves. So, you get started and you get lashed onto it, but ultrasound imaging I see several people. If you are from mechanical engineering you are introduced to waves, wave propagation, so it is a mechanical pressure wave.

And so, suddenly the mechanical engineers become excited its pressure means we know we can handle it. So, in some sense of electromagnetic spectrum covers everything, but your ultrasound imaging that signal is not found here, ok. Never mind, all of them have the same requirement, same underlying overall objective and overall contribution impact, their own unique impact to the field of medical imaging.

So, irrespective of your background whether you feel comfortable with pressure waves or with electromagnets does not matter. The understanding of the science and how do you engineer it with the overall objective in mind, how do we look at it, right that is what is the theme. I hope you will benefit by starting to think in the direction at the end of this course, ok.

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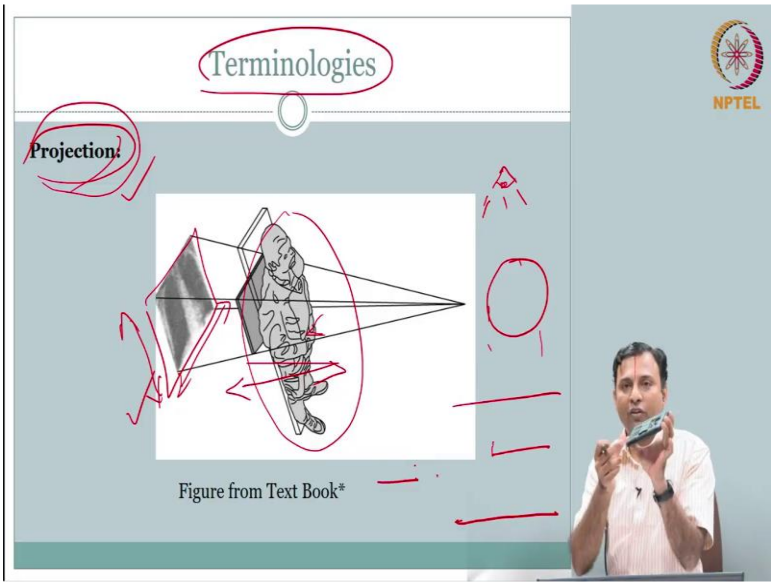

So, much for electromagnetic spectrum. So, before we jump in, right, take one modality at a time, it still few items left most importantly has to do with terminologies. What do I mean by terminology? So, far I have been very conscious not to use any technical language because that may throw you off I mean. So, we have tried to give a feel retain everyday language and try to have a connection with what is what this course is going to help you with, right.

So, now, we will start to introduce few basic terms because we have to proceed further, at the least we should have common understanding of what we are going to use. So, first thing is projection. So, this is a vivid description, right. What do you see? If you have been to any chest X-ray which I am sure most of you would have been by now, right because at most work places most students you have to do TB checking.

So, they do chest X-ray when you join. So, I am sure most of you would have had the experience and gone for a chest X-ray. So, that is fine if you recognize this as a chest X-ray process that you see here that is fine. But what is projection? Right. Can you can you appreciate what is projection?

Ok, try to think with me, tell to yourself I see a 3-dimensional, I would not say object, let us say it is a human, right. So, I have a human being who is three-dimensional, right. He is he has all the 3, height, width, and front to back, ok. So, he has three dimension. But when you capture the chest of interest for some diagnosis, what is the chest X-ray capturing? Right. Here it is three dimension here the image, right you have seen X-ray film it is a two dimensional, there is no third dimension, there is no thickness to it.

So, you have collapsed the depth. So, this is the width, this is the height, so you have two dimension, the third dimension which is the front to back is collapsed is collapsed to the plane of paper, right. So, you have to say it more correctly; that means, you have a three dimensional object, you have made a projection of that on a 2D plane by reducing the third dimension. So, projection when we did here a 3D became 2D.

So, for example, let us say just to appreciate the language and the challenges that we may encounter, right. So, here is a this is a poor object to begin with. Let us see if I can use a mouse, right. So, this is a 3-dimensional object, right. It has a weird shape. But what happens if I keep it like this? Right. You are going to see only the projection. So, what is the shape of the projection? Right.

I am trying to keep it as straight as possible, so if you if you really do not see any shadows of it or you are not at an angle what you would see is the depth of the mouse will be gone, you will only see the rectangle, right. You do not know that the rectangle, if I do it like this you will see a mountain and a flat base, but if I put like this you will see only a rectangle, you will not see whether it is a mountain or is it a cuboid, you will not know that, right.

So, one of the disadvantages of projection is, one of the disadvantages of the projection is one-dimension is lost, whether you need it or not, well you will I mean it has information, right. I will not be able to tell the shape of this correctly if I do not know the third dimension, I will say it is a rectangle mouse, but it is not.

So, I need access to different dimensions if possible. But at some level it is ok. So, a chest X-ray is still usable, but it has its limitation. So, projection is something that you are going to deal with very much, right, you need to know. So, just the thought process I would like for you to take, right.

This course is fantastic course in the sense that you can use toys that is available in your home, right and try to appreciate what you will get. If a camera is looking and the image is formed you can try it yourself as well to understand the geometry.

So, you can play at home, take some weird objects, look at you know different angles and try to draw the projection, right. So, that will tell you, that will make you comfortable as to how the projection is good, but then it does not really reveal the complexity of the 3D object, ok. But we will have to start somewhere. So, that is something that you need to start to train yourself, ok. So, that is for projection.

Of course, it goes without saying I have taken a 3D and collapse it to 2D. What happens if I have at this circular disc? Right. They have a circular disc, what is the projection? So, I am going to see from here. I am see from there this is going to be circular disc, circular disc has no thickness, so it is a 2D, right.

So, what will it appear? Well, you going to see only a line, right. So, this object if you take this is light, it has it has some thickness, but let us say it is very much smaller than the thickness of this mouse. So, I will say this is a 2D object, it is not a 3D object it is a 2D object.

So, then what happens? If I look through this 2D object, right, if I look at this direction, so it has only two dimensions this one and this one, the thickness is no thickness, ok. If I have like this what is the projection? It is a line, right, it is a line. If I project it like this, what is the projection? It is again a line, but then that line is going to be shorter, right. Length that is two-dimensions when you project become one dimension less, right, clear, ok.

So, now, I took a simple case of rectangle, so that I can see it projects to a line of different. So, you take some weird objects in your home in fact, do not have to imagine have a light source, keep the object, you see the shadow and you know then fly your imagination, ok, good. So, that is terminology first important thing is projection because you will use this very much.

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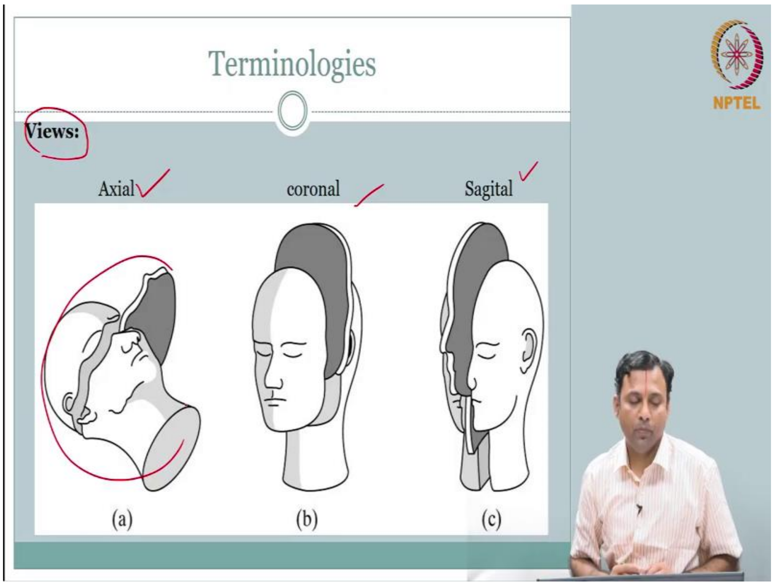

Then is views, right. So, again this is the challenge you can already appreciate, when I did the projection also I was very careful, I said if you look at it this way it is one thing, if you look at it this way it is another projection. So, the projections change depending on where you are viewing.

So, if I keep the object same then and if I say this is 0 degree, I am looking at it this direction, right in the direction where you are looking at the screen then you are seeing the height of the phone. But if I go 90 degrees, right if I go 90 degrees, so instead of that I did this. So, if I view 90 degrees then it becomes the width. So, depending on the view angle I can have different projections.

So, what happens if I have 45 degree? Right. This is width, sorry this is width, this is height, what if I had it at an angle? What is a projection? This will still be a line projection, but the length of the line is going to be you have to calculate, right.

It is going to change because you are at an angle, ok. So, that means, it becomes important that we have some common language, terminology to talk about what do we mean by view angle. Most commonly used view angles for medical imaging is axial, coronal or sagittal.

So, axial means it goes through head to toe, right. When you lie down, so that is another thing just because we are all used to if you say MRI, CT, you go into the scanner you go into the bed, so you are lying down. So, axial means you go from head to toe cutting through, right like this, like this. Coronal is front to back. Sagittal is sideways, right cutting from one side to the other. So, you go from vertical like this. So, that is the view. You look from the side that is sagittal. You look from the front it is your coronal, you cut through it is called axial views, clear, ok.

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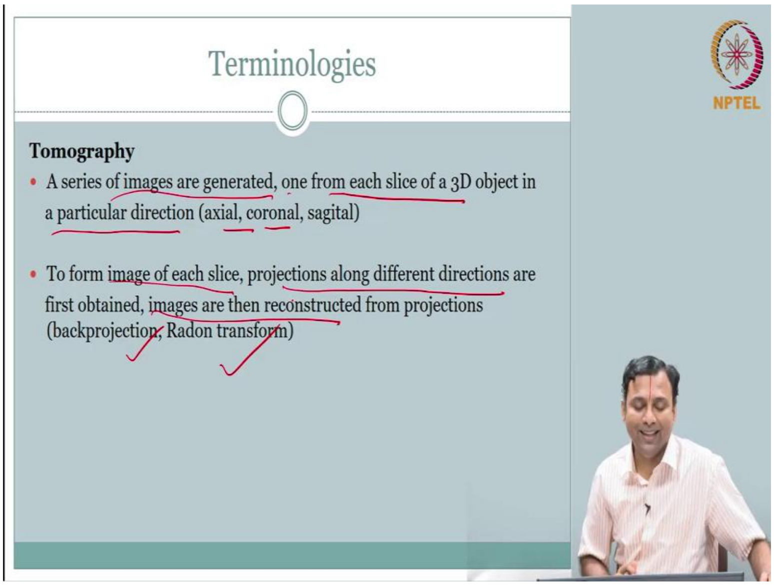

What is tomography? So, you can clearly see now, suddenly we have gathered place and we are you know getting into some details. So, we said computed tomography, so now, he is talking about tomography. So, we need to know what is tomography before we go and say its X-ray tomography or positron emission tomography. So, we need to get to that.

So, what is tomography? Tomo, right tomo is cut, slice, graphy is graph making a picture graph, right. So, a series of images, so in our case we had a 3D object, when we saw from different views, we had different projections, different slice, right. So, you have a series of images are generated, one from each slice of the 3D object in a particular direction, direction is your view, right, your axial, coronal or sagittal. So, essentially these are just slices, right.

So, what I want is the cut section view that is I want the 3D part of it. So, if I took this object, right and I projected I saw only the rectangle. But then if I do perpendicular or another view I would see this or if I do another I would see this. So, can I use all the slices from different orientations, not just perpendicular any angle, any view angle, those are your, right; can I use all that, so that I can actually get the 3D object, right.

So, can I form the 3D object from a series of 2D slice? Right. So, that is what we mean by tomography. So, to form an image of each slice projections along different directions are first obtained, images are then reconstructed from projections. So, there are several techniques to do that. So, you can get different projections how do I get to the object from the projections that is, that you will use what we call as reconstruction, ok.

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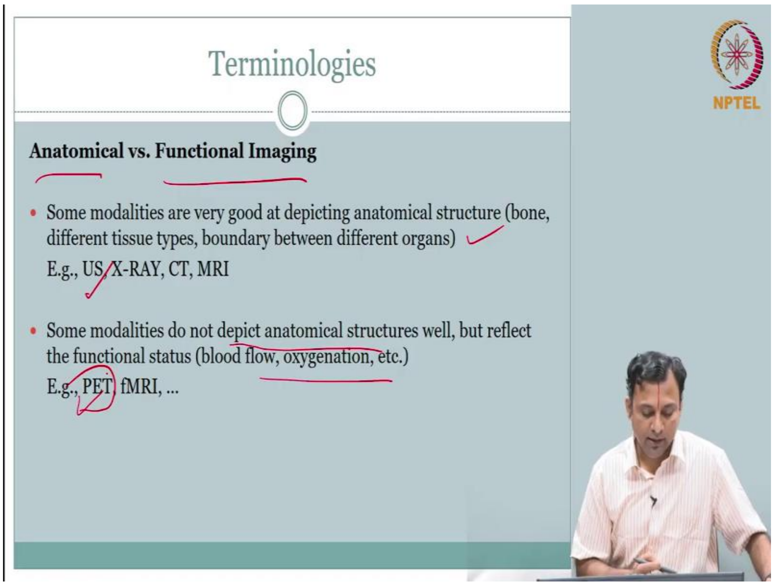

So, this is a nice place, we will probably take this concept and we will end this module. So, last terminology is ok you are talking about parameters, we talked about views, we talked about you know all CT, X-ray, MRI and we did say anatomical or physiological in the beginning as well. So, one another way to classify the medical imaging system and the medical images is whether is it anatomical or functional imaging.

So, in some sense, anatomically, you can think about structural imaging. So, the structure is there it is not changing with time, right. So, if I am standing still and you want to take a photograph, that is fine.

If you want, but then if you if you are trying to take my heart, it is going to be challenged, but it is still structure if I want to know the shape and size of my heart then anatomical function would do, but then you have to capture it fast enough that you can get the structure, ok, but that is not.

So, what is functional imaging? Functional means it is capturing some activity, right. So, in whatever you know already let us get the easy ones out. So, some modalities are very good in depicting anatomical structure, so some things that we covered already you can imagine. So, we did for chest X-ray. If you break a bone you go for an X-ray, right they do only structural imaging these, there are defect, is there a crack in your bone. So, that is good enough.

So, that is something that you can imagine you know now X-ray is routinely used. Of course, you can do that for ultrasound, right. Most common people see is when a pregnant lady they goes to the doctor they want to keep the fetus imaging and see if the baby is starting to grow, right based on that they have protocols. So, they want to see the structure, is the hand coming out, right is the femur, is their bones developing, so is the spine coming. So, they all that is a structure, right.

So, you can use ultrasound, X-ray, CT, MRI any of these is commonly used for structural imaging. Some modalities, right, if everything if one modality can do everything you do not have so many, you do not need so many modalities.

But each one has its own advantage and disadvantage that is the thing that I said you should probably start to appreciate. So, it happens that certain things were very poor in anatomical imaging, they do not know where the structure is, but they know what the activities happening therein, right.

For example, we are talking about of course blood is flowing inside the blood vessel, I may not be able to see the bone tissue, but then I may not even be able to see the wall of the vessel, but I can see what is the oxygen contain concentration in the blood, right, partial pressure of the blood. If I can see that then that is functional, right.

Of course, if you couple 2-3 different modalities then you see the structure and function, right. So, functional imaging has its own advantage. Not all of them can do, right, not each, I mean not one modality can do everything. So, here if you notice PET positron emission tomography, radioactivity like I said, right.

So, there you can use that to visualize where metabolism is active, ok. So, you may not actually see for example, a stomach, but you know there is lot of activity you are ingesting and you might see lot of activity. You might see, you may not see the structure of a kidney for example, or a bladder, but you may it is the radio activity that you had probably it is coming trying to come out of the body and you will see the activity there, right.

So, you will not see the structure well defined, but then you will see the activity how much it is consuming, right. So, that is, so PET is usually very adept at doing that this is functional MRI. So, MRI a can also be used for functional imaging called as functional MRI, ok.

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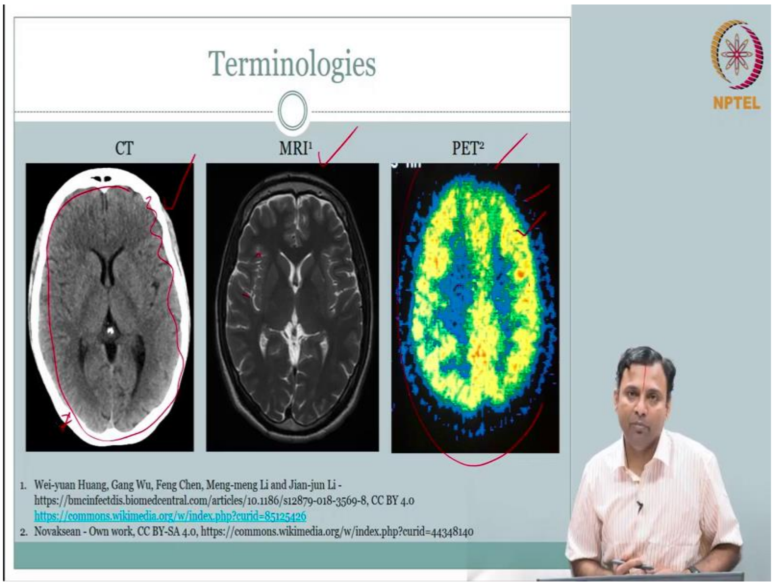

So, here is the advantage of this course. Anything that we talk if you see there is no substitution to the understanding. So, what do you see here? From what we covered you should be able to recall, ok, this looks like some axial slice and axial slice through the brain, ok that much is good, but then each one is looking different, one is in colour, here I see a very well this one, but I do not see much of details. Here I see all the details also very well, right.

So, now you understand each modality is different. This is if you guessed it, yes it is CT, this is MRI, this is PET. So, this is your functional imaging. So, what this is depicting? Each colour is depicting the activity, glucose uptake. So, you can clearly see certain activities, certain part of the tissue is active, it is consuming the glucose whereas, certain others are having low activity. You do not even see the skull, right.

Here you see the skull vary you can measure the thickness of the skull; here I cannot do that, right. So, each one whereas, here I can actually tell the activity. So, this is what they use commonly, right, which part of the brain is active when you are thinking about something, when you want to move your hand all PET imaging is helpful, right. Of course, MRI is also useful there, but PET I think is a very vivid in that in that sense, ok.

I think we will stop right here, this module. We will start back continuing from where we left here, in going through each of the modality, giving an introduction to each of the modality, right. The historic context of how each modality developed that will be the next session.

Thank you.