Introduction to Biomedical Imaging Systems

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Lecture - 01
Course Overview

Welcome to this course. This is on biomedical imaging system at the introduction level, so titled as Introduction to Biomedical Imaging Systems. Myself, Arun Kumar Thittai; I will be handling this course. And this is essentially tailored towards biomedical engineering students if you are in a curriculum.

Typically it is a seventh semester, eight-semester course, or for post-graduate students, this will be your first-year regular core course. So, of course, this is also open to other students from different backgrounds, and no real prerequisite is assumed beyond basic introductory, you know, linear algebra and physics and which is typically taught in the first year.

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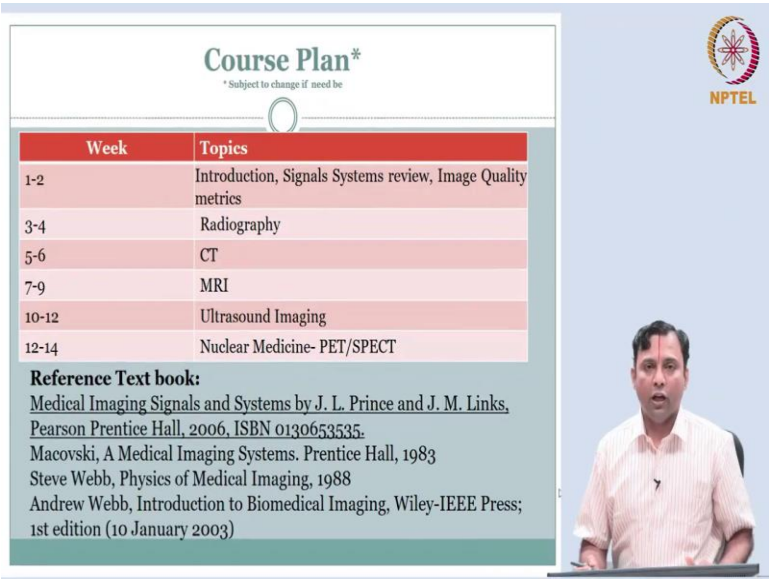

This is the rough course plan that we will do. So, what you see here is planned for it is typically 12 to 14 weeks. Given the format, we will try to cover for 12 weeks, and we will try to cover different modalities in a specific manner. For example, you see the reference books here. As you will notice, this is kind of taught well with or traditionally thought as an imaging physics course.

So, you see some of the classic textbooks like Macovski which are basically a physics of medical imaging. So, recently we have lot more engineering students start to take this in biomedical engineering program in the last maybe a decade or a couple of decades. So, there is going to be some physics, but also engineering aspects to it, and so the title of the course is also appropriately named as imaging systems.

So, what we will try to do is cover all this. Each of them is self-contained, each modality is self-contained, it is organized such that you could, in fact, start with an introduction, do the basic and then jump to a modality of your choice maybe that is the one that you are going to work that is the one that you got the job for you know.

So, you could actually, without losing the generality you could jump to a particular modality and start to cover that from the physics and the engineering perspective. And these are the reference textbooks. Like I say, it is a reference because several topics are good in a certain textbook, so from the material will be taken from one takes others from others.

So, we will what we will try to do is I will try to keep a format that is consistent with the first textbook here. This is in view of the fact that this textbook is also available in India as an Eastern Economy Edition. So, you could afford the textbook, and so it is available. And so that is the kernel that is the theme that will start to use, but we will take certain portions from the other textbooks as well, ok.

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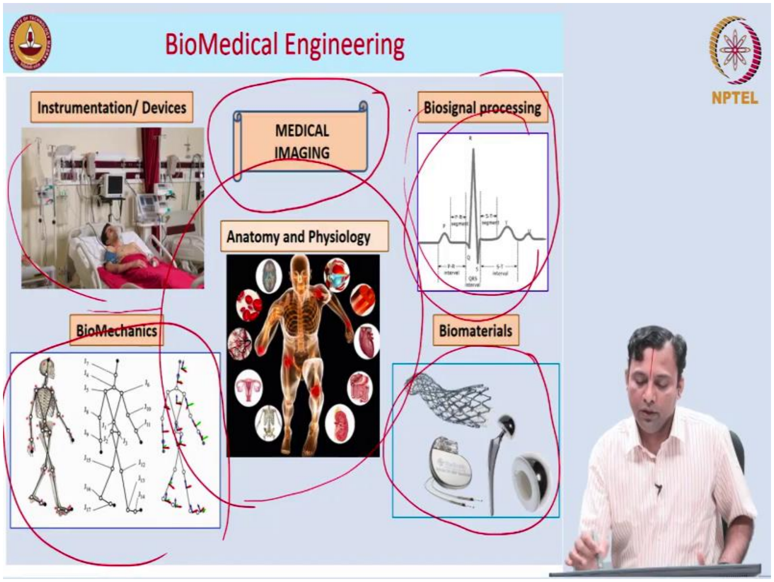

So, moving on, before we actually jump into the subject itself, let us just take a big picture view of where this topic or where this subject is going to be listed right. And you will see that we have electrical engineering, civil, mechanical, computer science, and you will not see biomedical engineering.

So, this is not listed as a vertical, but this is one of those subjects which fall in the multidisciplinary or interdisciplinary programs. And in some engineering colleges, you know globally if you look at it some fall you know that these biomedical engineering itself falls under a vertical of complex systems engineering ok. So, there are several ways to look at it.

But essentially, this is the theme. All of it is going to deal with something to do with anatomy or physiology. Our idea is to get some information from anatomy or physiology, so that is what the whole biomedical engineering is dealing with.

Given this broad theme, since there is no core program globally in the last two-three decades, each country, each you know, continent depending on their availability, each school, have kind of taken a stronghold, and we could broadly classify them with different verticals.

For example, from what you see here, you see a lot of devices right. This is a hospital, and you have a lot of instruments. So, those could be taught as one particular subdivision right, or here you see a signal right this is a typical ECG example that you see. So, this is a signal. So, you also see some implants right which has so these are to do with material properties. And one of the earliest understandings is to do with you know skeletal motion, so your biomechanics.

So, what I try to list here is the branches if you want to see the clusters of work that has grouped world wise depending on the availability or access or the expertise to a certain aspect of biomedical engineering can be grouped as you know biomechanics, instruments devices, biomaterials, of course, I have only signal here which is called biosignal processing, and deliberately I left it there because I did not talk about this one another big vertical.

So, as you can imagine already typically, this is covered in an electrical engineering course. So, students from electrical engineering backgrounds may have a lot of you know prerequisites or base core material taught in their electrical engineering program curriculum. This comes from mechanical engineering background mechanics will be taught. So, biomechanics typically students from mechanical background find it a lot more interesting and you know field connected to.

You have biomaterials, right. Likewise, biosignal processing. I just deliberately left signal processing, but you would also now be very familiar with image processing. So, biosignal and image processing, so most of these groups mostly come from electrical engineering school.

So, as you can see, why I highlighted medical imaging separately is oh this is a mix of all different backgrounds. So, this is actually, in some sense, interdisciplinary within the multidisciplinary biomedical engineering program. So, we will just focus one more slide on the big picture. So, what is medical imaging?

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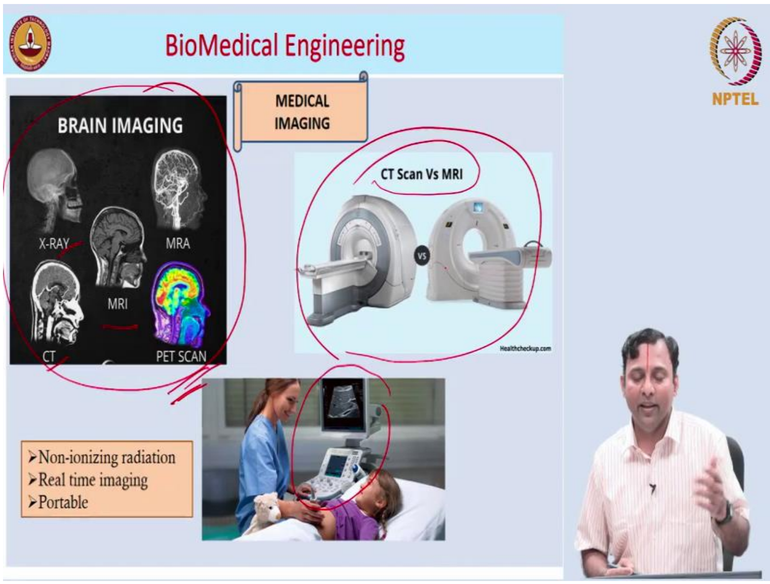

So, the moment we talk about medical imaging, what comes to our mind? We are all very familiar, we have encountered this. Immediately, we will say, ‘Oh, I know my father was go asked to go for an echocardiography’ right. ‘I was asked to go for an abdomen scan’, ‘my brother went for a chest X-ray’.

So, we kind of use it, but you notice all this language carefully, there is no hierarchy. Some are saying that they went for a head scan, abdomen scan, in some places you say they went for an MRI, someplace you say they went for chest X-ray or Angio. So, you really look at it, you are either talking about a modality or you are talking about the application where the problem is the organ that is being investigated.

So, there is no big when you use it the way you would have probably formed your opinion about a topic it is still scattered right. So, the objective is actually there is a very nice beautiful organization you know built upon these topics. So, for example, if you say brain imaging if you want to characterize all this based on the application right. Then you see immediately within that if it is just going to be brain imaging you could end up taking the brain image using a different modality.

Some of them are listed here, say you would have been familiar with MRI right, X-ray, this is PET scan which is basically Positron Emission Tomography right. We will cover that. Then you have your CT, which is Computed Tomography. So, you could immediately organize when you talk about imaging, you could talk take a standpoint from a clinical perspective.

So, in this course, you will find umpteen textbooks in medical imaging from a clinical perspective, ok. Because they want to know what is normal, what is abnormal, and then go further diagnoses. So, that is one way of grouping the topic. Another way is, this is fine. Our interest is not on the clinical application; we are not going to diagnose use these images to do any diagnosis.

Our objective is if I see this image do I know where this image is coming from? When we say, we know how where the image is coming from, it has to come from instrumentation. So, again you would have been very familiar with CT scan or MRI. So, you can see the instrument is also very complicated. And typically, you use one of these instruments to acquire these images and acquire data and reconstruct these images.

And in a typical biomedical instrumentation course right, we really do not cover instrumentation for imaging systems because this is a whole breed by itself. So, in this course, right when we talk about biomedical imaging systems, we are going to talk about some of these modalities and how these images are coming using the instrumentation of the corresponding modality right, some can be as complex.

And you also have few others probably some of you may be able to recognize this you would have been you know going to a doctor you will say I know that that is your ultrasonography machine. So, it has its own advantages right non-ionizing real-time, so unlike CT or MRI where you are asked to lie inside the patient bed, and you basically have to sleep, and when they do the imaging, and they give you a slide a disc of images after you come out or share it with your doctor.

Whereas during Ultrasound you could actually lie down, and you could see your own image. I mean by you not that you will understand anything, but at least it is real-time. And it can be moved around, ok. So, this is the broad contours of medical imaging. So, you have different aspects why I said of different background people can be interested, they can come through and attend some of these modules is because of this reason.

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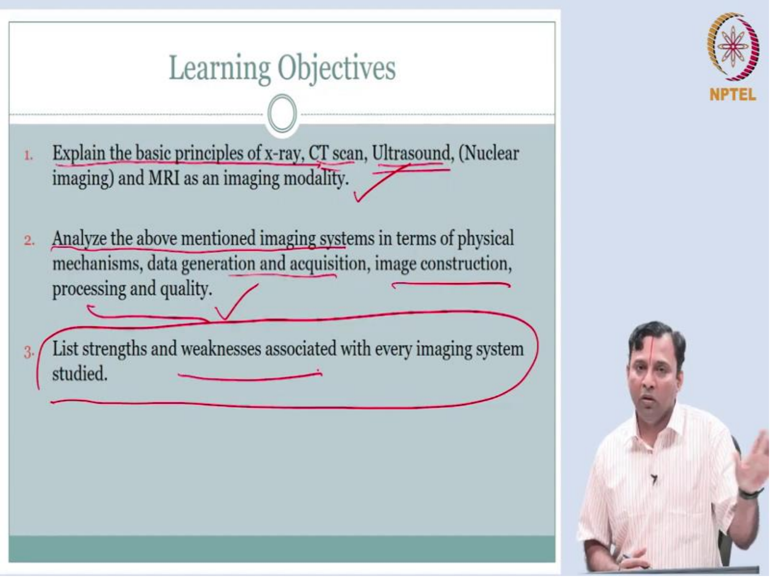

So, what we will attempt to do in this course is this is the learning objectives. What I mean is you end up taking this, you listen through the videos, you, in fact, go through one of the modules, one of the imaging modalities, you should be able to at least explain the basic principles. Of course, if you take one of the modules at least that particular module, you should be able to explain what it is.

When I say explain now is the trick we are not doing clinical diagnosis, that means, we should be able to explain when I see a green pixel, or yellow pixel, or gray pixel, or a black pixel, do I know what it means? Do I know what it represents of the body? Do I know how we got the pixel there. Why is the value so much right? So, that is the aspect that I would expect.

To some extent, we should be able to analyze the system. When I say analyze, it is not analyzing the image, it is analyzing the system. What do we mean by analyzing the system? Is the image showing poor quality? Right, is there a dropout, or is it because the patient himself biologically does not have the signal there, or is it because the instrument probe is gone, or is it because of software, right, any of that.

So, you should be able to analyze the output. And you know, understand the system and system settings that give rise to an image. This is very important, I say because we most applications people I find some of our students tell is they get image processing job right. So, they go do some MRI brain image processing.

But the challenge is when the doctor is asking why am I getting this image artifact since yesterday? It is not because the patient is different suddenly, it is because one of the subsystems – there is some miscalibration, there could be some element that is gone so on.

So, this engineer who is going to help them should actually have the ability to understand which subsystem could possibly cause the error. So that they can then call the company and have them come and change a component you know, it could be as simple as that or maybe this is had its life you change the whole system.

So, that is something that I typically encounter from our students then they go for a job and they ask ‘Oh, I applied this filter, I get this image’, but the doctor saying there is some problem you know. So, I think that is important. Most of this is a key thing. This is the challenge, for each modality you should know what is the weakness and also its advantages.

This is important because this is when as a student when you take this course, typically what happens is you look at the industry, you look at your seniors you ask them, and they say you know what now for example, what I encountered when I was the student ‘Oh you know you are working in Ultrasound you know MRI is the next breadwinner’. Because when I was a graduate student Nobel Prize, two Nobel Prize were given for MRI.

So, they said, you know MRI is going to eat up everything there is no scope for Ultrasound. But you know, in reality, the more you start to understand and more you can reason out, you will understand that each modality has its strength and weakness. So, you should be able to clearly articulate understand that, so that it is not only good to you because you will become comfortable in making your choice, but also to the person you are advising right.

So, a doctor could be there, he will say you know what they released the latest scanner last month, and they are saying this gives superb image quality. As an engineer on board, you should be able to say, well, these are the specification here. These are probably cosmetic it is just marketing language the there is no fundamental change in the quality. So, this is a price that we can afford, this is an investment that we can make; or no, no this is just something that we could do it in house as well on our existing scanner.

So, unless you are clear about this and you are able to work in a team and explain to the doctor right, that is a skill set that is really needed. And therefore, one of the objectives of this course, the way it is tailored and the way I will try to give examples and homework problems and assignments is keeping in view this aspect of engineering. Because there are several classic textbooks on imaging physics, it is an old subject.

But when you try to apply that knowledge to the current technology with the end-user in perspective, I think that is a gap that that needs to be addressed, which this course will strive to address. So, we will actually stop here and then start with Modality Specific Introduction in the ongoing lectures.

Thank you.