Biomedical Ultrasound Fundamentals of Imaging and Micromachined Transducers

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Lecture - 01

Welcome to Biomedical Fundamentals of Imaging and Micromachine Transducers. I'm Karla Mercado-Shekhar, a faculty member in the Department of Biological Sciences and Engineering at the Indian Institute of Technology, Gandhinagar.

Hello, I'm Himanshu Shekhar, from the Department of Electrical Engineering, also at IIT Gandhinagar. We will be co-teaching this course along with our colleague, Professor Hardik Pandya, from the Department of Electrical Systems Engineering at the Indian Institute of Science, Bengaluru.

Now, let's start with the question: What is imaging? Imaging refers to the process of creating a visual representation of the form or structure of a target object. Every day, we use phones and cameras to capture images. In fact, we possess an incredible natural imaging system—our eyes. Our visual system relies on optical components like the lens, and sensors in the retina, specifically the rods and cones, to create images. Behind the scenes, there's complex biological signal processing happening in the brain, which allows us to perceive vision.

Interestingly, both our eyes and cameras use visible light to form images. But what about medical imaging? Medical imaging refers to the technologies that allow us to see inside the human body for diagnosis, treatment guidance, and monitoring. Before medical imaging was developed, autopsies were the primary way to understand the inner workings of the body. However, relying solely on postmortem studies can sometimes be misleading.

Yes, absolutely, Karla! For instance, did you know the literal meaning of the word "artery"?

No, what does it mean?

The word artery comes from the Greek word arteria, which literally means "windpipe."

That's surprising! Arteries contain blood, not air. Why are they called windpipes?

Well, back in the day, when people performed autopsies, they found that arteries were empty. So, they mistakenly believed that arteries carried air, not blood!

Oh, so with medical imaging, we can actually see inside the body in real time without needing to cut it open! That's right. But how do medical imaging modalities work? Essentially, we use different techniques to visualize various physical properties of the body. For instance, in x-ray imaging and computed tomography (CT), we visualize attenuation, while in magnetic resonance imaging (MRI), we observe proton spins. Similarly, in ultrasound, we can detect scatter—such as how ultrasound waves scatter within tissues.

Exactly. By sending energy into the body and receiving the resulting signals, we can create a distribution of these physical parameters. Here are some of the main machines used for imaging: x-rays, CT scans, MRI machines, and ultrasound devices.

Let's focus on ultrasound imaging. Ultrasound refers to sound waves with frequencies higher than the human ear can hear—above 20 kilohertz. In clinical applications, the frequencies used for imaging are much higher, ranging from 2 to 15 megahertz. Ultrasound is known for being safe, relatively affordable, and portable compared to other imaging techniques.

One of the most common uses of ultrasound in the clinic is fetal imaging. For example, here on the left, you can see an ultrasound image of a fetus in the mother's womb at around four months of gestation.

So, what will you learn in this ultrasound course? We will cover the physics behind ultrasound, the instruments used, signal generation, and how ultrasound images are constructed. We'll also explore different clinical applications. Additionally, you'll learn about the development and characterization of ultrasound transducers and various microfabrication techniques used to create them, which will be taught by our colleague, Professor Hardik Pandya.

By the end of this course, you'll have a solid foundation in ultrasound imaging, ready to explore this interdisciplinary field further—whether you pursue it in academia or the industry. We look forward to having you in the course, and happy learning!