Good afternoon.
Welcome to new semester.
Can you hear me clearly?
Okay, very good. Calm down.
So today is the first lecture and we just chatted a little bit.
I know most of you from BME department
and also this course is required.
That means you really don't have a choice.
So we can explain a little bit and you'll have a good picture
and what we will learn.
So next let me just give you an outline.
So in today's lecture I basically will explain four points for you.
So what is medical imaging and why we want to learn it.
I know you have two but I will give you some additional motivation.
Hopefully you will feel studying this course is more joyful.
Also I will introduce instructors and TA.
You know there are two instructors.
My fellow instructor is teaching the same thing in the other room.
Also I will try to give you a template
and I want to collect some information about you
and not much, just one PowerPoint slice
and I will show you the format.
So I know you a little bit better so we can work together.
And last I will explain the schedule
and the major part of this course
and some books and MATLAB exercise and so on.
So first let me say what is biomedical imaging, bio-instrumentation.
These two things in this course mainly means
medical imaging, methods and systems,
certainly systems engineering and instrumentation.
And we say medical imaging or biomedical imaging
in general is really talking about something inner vision.
We all know the vision system is so important
and the civilization pretty much driven by our desire
or need to expand our capability.
And we can do certain things, we can smile things
and you can listen to your lectures or conversations
and you can see the environment.
So normally our human vision is just based on visible light
and you couldn't see through many objects
like chair, what's behind the table, behind the computer screen.
So you can only see oftentimes superficial surface pictures.
That's a lot of information already, indeed.
And we certainly want to do more, that's human nature
and we want to see through what's going on.
Particularly when you don't feel good, you feel uncomfortable,
anything wrong, so you want to see through human body.
And this will be of great importance in medical practice.
So medical imaging really the eyes for your physicians
so you know exactly you can quantify pathological
and physiological functions
and you can just make a patient feel better, even save a life.
And this is our dream and we want to have a super vision
and see through everything so we know everything.
Wouldn't that be cool?
And as you know many times the scientific fiction turned out to be true.
And the medical imaging field all started from discovery of X-rays
very early on, about more than 100 years ago.
So for the first time Ritken discovered X-rays,
the first X-ray picture believed to be a projection of his wife's hand.
And you see X-rays really help you see through opaque surface.
Then you can see bone tissue interface, tissue air interface
and the heavy metal like gold have very high contrast,
give you clear and very high signal to noise ratio.

So this is really a breakthrough achievement
and he got no real prize you know.
Nowadays the projective X-ray is widely used and has a name,
X-ray radiograph or radiography.
And you can just go to hospital and the clinic take a quick suit
and you see if your bone is okay or any fracture.
And women oftentimes have what is so called mammography,
very high resolution X-ray projective imaging,
any calcification, any small tumor.
And you can just do mammographic screening.
You detect the disease earlier, then you can cure the patient.
That's wonderful.
The projective imaging is due to X-rays penetrating power.
That's certainly great.
But when you do projective imaging,
all the structures superimposed together.
So you wouldn't have a very good soft tissue contrast.
So you have all things overlapped in one view.
And naturally you can consider what if I view the patient
from different viewing angles.
Then I do some computation.
Then I would solve for cross-section
or even volumetric dynamic pictures.
So this is what so-called X-ray computed tomography will do.
Tomography really comes from a Greek word.
It means you do slice, cut through object.
You do slice based imaging.
So you use CT and you can see what's going on inside the human body
without any overlapping and crystal clear.
Nowadays, X-ray CT resolution can be easily reached
sub-millimeter level.
So this is really magic.
And like you have a big watermelon,
you use a knife, cut it in half.
You see the cross-section.
But with X-ray computed tomography,
you do the same trick without letting you know.
It's just a scan.
And then we see clearly.
We unlock the mystery.
And then we find kidney stone or some vessel blockage.
So you can just take a right medication.
So this is just a picture of an X-ray CT scanner.
I think more than a year ago, I did an ad-tech lesson.
The title is How X-rays See Through Your Skin.
And this morning, I just checked the scenes,
many views, and 0.2 million about.
And I think a few years down the road,
the number of views would reach 1 million.
That would be cool, I think.
And I found the majority, they say, like, like.
There are a few dislikes, I know.
And a very early version, we put a wrong chemical element symbol.
So they disliked that.
But right now, the problem already fixed.
And in this lecture, I could collect
to show you about a few minutes.
But I think I leave this for you to collect.
Don't forget to say like.
It's very cool stuff.
And the X-ray imaging is the first tomographic imaging
modality.
And inspired by X-ray imaging, there
are multiple other imaging modalities

using, say, gamma rays and radio frequency signals,
visible light, infrared light.
And all we perform indirect measurement kind of scenes,
lamped together, superimposed together,
overlapped, then you use physical models
and computerized the technique to unravel the mystery
to reconstruct the cross-sectional image.
So we have a very wide EM spectrum.
And here, you have gamma rays.
And the visible light, infrared light, and microwave,
and all these things.
And each typical spectrum corresponds
to different imaging modalities.
And here, we have an X-ray CT.
And I mentioned a little bit minutes ago.
Then we have a nuclear imaging, optical imaging, MRI.
So all things together.
And the link to genetic profiling.
And you can know a lot about the human body and the disease.
So this is a very cool thing.
And I worked mainly in X-ray imaging area
and also a little bit optical imaging.
And recently, we started working on MRI
and a little bit of nuclear imaging.
So we feel each imaging mode has strengths and weaknesses.
We should link them together.
So let me say a little bit more about tomographic imaging.
We would say tomography is not like an ordinary picture.
You take it.
Then that's what you get.
But for tomography, you have a measurement.
And the measurement is not like an ordinary picture.
And the measurement is not directly what you really want to have.
You want to have a cross-sectional image.
Actually, measurement gives you overlapped projected view.
But you can have many views.
And you need to do certain trick to invert the process
to reconstruct cross-sectional image.
So we say tomography is for inversion.
So inverting the physical model underlying
the particular imaging modality.
And normally, inversion is harder than forward process.
And the last century, pretty much people do modeling.
And the forward gives you all the knowns.
Then you can predict what will happen.
So you have an object.
You have a force to push it forward.
Given the mass, given the force, you know how the object will move.
This is a forward process.
And the inverse problems are very important.
So you know the outcome.
You try to infer what's the reason.
And like function, give x.
And you can compute the value of function as f of x.
So this is a forward problem.
Then give you f of x and a certain knowledge
about the function of the system.
We ask, what is the variable x?
That's the inverse problem.
And normally, the inverse problem is harder.
But it's feasible.
Like the egg, you can boil the egg.
We do that almost every week or even daily.
But once the egg is boiled, how can you unboil it?

And this can be done.
So this is not easy.
So it becomes a popular science article.
How do you do the inversion so that you get the raw egg again?
This is cool.
You can read it if you don't know about this.
And another example, like the iPhone camera
or any optical camera.
And then we take a picture.
The camera may be good, may be not so good.
If not so good, we say the real picture
got blurred a little bit.
So you have this blurring involved.
You have this blurred image.
And then later, I will teach you to model this process
as a convolution process.
You know, this convolution is pretty much like multiplication.
Convolution in spatial or time domain
is equivalent to multiplication in Fourier domain.
So once you have this multiplication,
this is a forward process.
You take a picture, it's a forward process.
You get a blurred image.
What is inverse problem?
Inverse problem is as follows.
You have this blurred image, and you
know the system will tend to blur things out
according to this so-called point spread function.
I will explain later.
OK.
So given this blurred output and the knowledge
about the system, how can you go back to recover clear image?
That is inverse problem.
That's harder, but more interesting.
In your primary and high school, you
learned basic mathematical operations.
And in your calculator, you see plus and minus
and multiplication division.
And when you learn more, and you are in university,
you learn more, and these basic operations
will take more advanced form.
That is summation.
You add the things together, and you
could add many, many things together, infinitely many.
And each element is so small, but so many added together.
You get a definite number.
So this is advanced form of addition.
OK?
Integral.
So you make a program here.
And the subtraction, and I would say it's just my own view.
It's just the subtraction.
You do it in a fancy way.
You just try to find a small differential
and compare it to the increment in the variable domain.
Then what you get, you get first-order derivative.
That's certainly very important.
And then you do more.
And then you have a better perspective
in your university education.
Then what will be the advanced form of multiplication
division?
I would say the multiplication.
Now you will learn linear system and the convolution.

That is more advanced form of multiplication.
And the division is an inverse problem.
So you go back.
Tomographic imaging is an inverse problem.
And the inversion is much harder.
It's challenging.
So we say this lecture is not easy.
And you cannot just remember things.
Then you get a good grade.
You really need to know quantitatively what's going on.
It's not easy.
And it's more challenging.
But I hope that will be also more rewarding.
OK?
Biomedical engineering area is highly interdisciplinary.
And the multi-modality imaging, as I mentioned,
involves X-ray, optical, ultrasound.
Ultrasound involves mechanical vibration.
So you need to know a lot of stuff.
Needless to say, you need to know mathematics, chemistry,
physics, all things.
So it's very cool.
So I have this icon.
So you see the relevant to medical imaging.
So you need to really think broadly and try
to observe the knowledge and see how all these fancy things,
good stuff, put together, you can see through human body
and help people in a tremendous way.
So that's very cool.
So by now, I hope you have a very wonderful idea
of what is this lecture and what we will cover.
Biomedical imaging instrumentation,
we focus on these modern technologies.
It's very cool.
And it's very cool.
And why I need to learn these very cool things,
I would say at least two reasons.
And I put a career requirement second.
First, we say medical imaging gives you
a lot of critical health-related knowledge.
And you need the knowledge.
And yourself, like myself, in the last year,
I think maybe two years ago, I got the kidney stone problem.
I was sent to hospital, inject contrast agents.
They do CT scan.
They see, OK, you got a kidney stone.
How large, where it is.
So you know medical imaging knowledge.
And you will feel comfortable in the future.
And sooner or later, you will do a hospital visit.
And you will be scanned.
You know what's going on.
So that is very important.
And sooner or later, you will have your own family.
And your family members, those you love, may have a problem.
And with imaging modality, how do you interpret the results?
Now you become student in this class.
So you'll have a real opportunity
to have a deep insight into the medical imaging knowledge.
So this is really a good thing.
And even you do not perform imaging research.
And even you do not plan to be an imaging PhD student.
So this is just the first point.
The second point is really career-wise.

And we are in, as most of you indicated,
you are in biomedical engineering department.
We are a highly interdisciplinary department.
And this is BME in perspective.
And originally, we have civil mechanical engineering.
And as time went by, chemical, material, nuclear, aerospace,
and electrical computer engineering department
came to play.
And later, only fairly recently, the biomedical engineering
department becomes a newest engineering department
in school of engineering.
Our BME is one of the oldest in the nation.
And we have two parts of research concentrations.
And one is imaging.
So what I'm teaching, and I also do a lot of research here.
And the other is so-called term, tissue engineering,
regenerative medicine.
And certainly, there are other things.
Priorities in our BME department here.
And as a BME student, whether or not
you take medical imaging or biomedical imaging
as your concentration.
And this is your required course.
So to satisfy your career academic requirement
as you said, you have no choice.
Since you have no choice, so you really should learn it well.
And also, for those of you who do the imaging concentration
and you learn the medical imaging course really well,
that will be very helpful for your future job search.
And I would say BME is a great profession.
And there are a lot of news articles
talking about why BME is so good for you guys
to learn at this particular time.
And the job market grows well.
And the graduate got a good pay.
So a lot of data shown here, this block.
And you can Google for yourself.
And also, we say medical imaging has a huge market.
That means a lot of companies.
And especially recently, the Asia market
getting bigger and bigger.
A lot of R&D money put into medical imaging business.
So you see the Europe portion.
And the Asia portion in the future
will be even more prominent.
So this is very cool.
In imaging modality research, and the CT and MRI
are more important in this survey.
And actually, nuclear imaging is also very important.
It has a big share.
You see the data.
So every year, the money goes higher a little bit.
And I read a very interesting article.
And you can click this link.
Later on, I will upload my slides into your Blackboard system.
So you can find the information.
And you just click the link.
Then you will see the article.
This is a very interesting article.
Basically, the authors ask a lot of physicians
about their opinion in the past century
on what would be the most important technical innovation
just overall, anything.
iPhone, computer, anything.

You know what comes out?
And MRI and CT scanning, the tomographic imaging technique
combined really becomes the number one.
So the most important innovation by a considerable margin
is MRI and CT.
So the capability sees through human body is so important.
We are recognized.
And how they work, so we will learn.
So you know this.
And you have knowledge for your future job interview.
And the companies are many in the medical imaging business.
And GE, say hi.
This is my first name, GE.
The difference is lowercase e.
And General Electric, they have a capital one.
So you don't have a conflict.
So they founded a little later than RPI.
So they're a little younger, but still a very old company.
And we are the oldest technological university
in the country in the English speaking world, actually.
So you see a little bit of history.
We are doing great.
And the GE also doing great.
And the GE Global Research Center
is the branch of the GE, performing
long-term R&D research.
And they have a great reputation in the world,
as evidenced by two Nobel Prize winners
and many other great things.
We would say the GE Global Research Center
in Nazca, Europe, is 20 minutes down the road.
So we collaborate on multiple projects together.
So this is a really great opportunity
for our imaging student.
A student may want to be a professor,
may want to run their own business,
or go to some top companies.
I would say in the biomedical imaging area,
that's your number one industrial choice.
And many would agree.
It's the Global Research Center, GE,
is in Troy, in Nazca, Europe.
So this is a great opportunity for imaging student.
We can interact with the company,
with the Global Research Center, then later on.
And then you can get hired.
And you have advantages relative to other students.
It could be a big thing if you are an imaging major.
So third point, let me introduce a little bit
about the instructors, so we know each other.
And also, I will request some information
from you, maybe after the lecture,
you spend 10 minutes, 15 minutes,
you prepare a slide sent to me.
So first, let me introduce our fellow instructor,
Hashem Mohammed.
And you can read his impressive background.
And he got a PhD.
He did postdoctoral fellow training
and worked as a scientist.
And he did a lot of great things, as you can read,
and published a good number of papers, and so on.
And he teaches in parallel to this lecture.
So this is my peer.

I teach medical imaging in this special setting.
So the university is recording these primary requests.
They think this is good.
And oftentimes, I would attend an academic conference.
And in the future, I think if we have the lecture recorded,
students can watch.
So this is better than some just casual recording.
I tried, but not very good quality.
So this time, we really use the professional service.
And if you're interested, you can just
click on my website to learn more.
And I already said I'm an imaging researcher.
I have been working on X-ray and optical imaging.
We have a biomedical imaging center in Seabase.
In Seabase, you know the Center for Biotechnology
and Interdisciplinary Studies.
And Professor Xavier Intes is an international authority
in optical molecular tomography.
And he used to teach this lecture as well.
But this particular semester, he did something else.
And I'm more focused on X-ray imaging.
So we collaborate, try to advance optical and X-ray
imaging technologies.
And we target innovative and influential ideas
by all the class partners.
Like we collaborate with GE Global Research Center,
with Yale, and MGH, and Stanford, and other places.
And you know this biotech and interdisciplinary study
building, and it's called the Seabase building.
And right now, the building was there for over 10 years.
And we have a lot of good numbers and summarizing achievement
obtained in the Seabase building.
This is one of the most beautiful buildings
on the RPI campus, you know.
So I have my own laboratory in the basement.
So if you go into this door and just go here,
you will see the X-ray imaging lab.
Some of you, if you're interested, I can show you.
And then my office is somewhere here.
Let me show you an internal view.
You know the Seabase building is L-shaped, OK?
So I tend to think this sorter axis is X.
This is a Y. Longitude is Z.
And then my office is at the origin of the system.
So very easy to remember.
You enter the Seabase, and then you can find me
during the office hour, OK?
And UTA is Matthew Gatchin, and he is my PhD student.
So this slide summarizes his background,
and I will show you his office hour later on.
OK?
And he is very interested in brain imaging
and is doing some fantastic work.
And he also likes to play with these kind of fancy things.
So some of you may know him.
OK?
He likes a mushroom and so on.
So I hope you put your information on one slide
and put your RIN number here.
It's just that I put I and 0, 1, 2, just J.
Just randomly put it there.
By the way, remember, I and J in MATLAB both represent square root
minus 1.
So it's just an imaginary number unit, both of them.

So you just put your things and tell me
a little bit about your background.
So this will help me adapt my teaching material.
And normally, I just finalize my slides
right before the lecture.
And each time, I change a little bit.
I have been teaching this for about four years.
OK?
So you can send to me today or tomorrow.
So I hope to have a collection.
And by the way, put your photo here.
You see, Matthew put a photo here.
You also put your photo here.
I try to remember your face and the name,
but I'm not very good at that.
And also, my eyesight isn't very good.
So sometimes you run into me, and I ignore you,
so don't take personally.
OK?
So last part, and I will explain to you
how we are going to learn together.
So this is quite important.
So let me explain to you.
We have a tentative schedule.
And basically here, but we may change a little bit
and see.
But I'm fairly sure we will follow this precisely.
So this is the first lecture.
OK?
This is the first lecture.
The second lecture, and my teaching assistant
will explain to you a little bit about MATLAB.
And I will say a little more.
And you need to do some homework today about MATLAB.
And I will come to that in minutes.
And actually, Friday, I will be giving a seminar
in New York City, Columbia University.
I'm not here anyway, so this is a good match.
OK.
Then we talk about the first part of the course.
The first part, really, this light blue part,
I would call it a foundation.
And then the dark green part, I call it modality,
or modalities, multiple modalities.
And why we need a foundation.
And then my earlier experience indicates
that most of you are not trained in linear system
and Fourier analysis.
And we have a very diversified background here.
Some students, they say, have a strong applied math
or physics or electrical engineering.
They know systems and Fourier analysis quite well.
And the other students, you have a strong emphasis
on biology, chemistry, material.
And you don't know much.
And I said earlier, medical imaging is very challenging.
And you cannot just sit here and listen to my conversation.
You know everything.
This is simply not possible.
And you need to spend time.
So I will do my best to prepare you
so you have a good foundation on which you can build your knowledge.
You understand each and every imaging modality very well.
And again, the order of the teaching is the latest I made.

And the other instructor still using the conventional way,
whether I try a new way and try to emphasize more
about the linear system and the Fourier analysis.
And those two things are critically needed.
And if you do not understand these things crystal clear,
very well, later on, you will have trouble.
I don't want you to run into trouble.
And you should really spend time to learn these things with me
and understand why you can perform Fourier analysis.
And you have the e to the power i theta.
And it says it can be some really elegant form.
Watch that.
And you have just a serial expansion
and why you can define that way.
You need to have a clear understanding.
Linear system superficially is very easy.
You have two things input to the system.
The result will be some of individual response
to the two input separately, something like that.
But there are some tricky things behind the linear system concept.
And for safety environment system,
you have the concept called convolution.
And the convolution oftentimes will confuse you.
So you need to spend time to know the convolution,
know the Fourier analysis.
Later on, the time you spend in the foundation part
will be well paid off.
Because you do the CT imaging, do MRI imaging,
the Fourier transform will come back again and again.
So you do need this part, then the modulated imaging here.
And then we have three examinations.
After we finish the foundation, we do examination one.
Then we finish the nuclear imaging and the CT imaging.
You do two.
The MRI can be grouped next, I think.
Then you have the examination three.
So these three examinations will be closed book,
in classroom.
And your final grade will be combination
of your homework, attendance, and your performance
in three examinations.
You know the teaching hour and the office.
Then the office hour for TA is listed here,
and his email also listed.
I believe in this semester, on two occasions,
I think this convolution and I think probably this one,
MRI imaging, the first MRI imaging.
This I will give a talk in California.
At the end of March, I will give a talk in Europe.
So I will pre-record my lecture.
In the classroom.
And then my TA will play maybe two days ago, one day ago,
I will do record.
So pretty much like I'm here.
And then my office hour, easy to remember.
And then whenever I finish my formal teaching,
like today, I need some rest and I have my lunch.
Then just an hour later, the same day,
3 to 4 o'clock will be my office hour.
And if you want to talk to me, find the origin of the system.
Remember, you can see me in my office.
And one thing you need to know.
And Friday from 4 o'clock to 5 o'clock
is our regular laboratory meeting time.

So that being said, Friday, you could come a little earlier.
But the last 10 minutes, maybe you better not come.
Maybe I could leave the office.
And maybe 3 to 4.
Then you couldn't see me.
You can always reach me via email.
Say when I'm out of town, my office hour, I'm not there.
You couldn't reach me.
But you send me email.
I have a reputation.
I process all the email same day.
So a student send me email.
So it will tell me you want to reach me.
So within one day or sooner, you will get my response.
Also, my student, your TA, Matthew,
is a brilliant student.
And he will help you.
And he is also very responsive.
So I started the foundation part here.
Really focus on linear system convolution
and the four-way transform.
I want to explain this clearly.
And the network is a special type of system.
Things link together.
As an electrical engineer, I learned a lot of network.
Resistor, capacitor, inductor linked together.
You can do a lot of good things.
A recent development of the machine learning,
I think artificial neurons can do fantastic things
and outperform humans.
I show some discussion about future
of artificial intelligence.
Very cool.
So we have all these things.
A problem used to be in this part,
we do not have a good textbook.
For the green part, imaging modality,
you have the textbook.
That's very good.
You read it.
You may not need your instructor.
You'll get pretty much knowledge.
But for this part, four-way transform linear system,
many, many books.
And the books may be too much.
And also the notation, like what's
the mathematical definition of four-way transform
and the different books, different web pages.
It gives you different definitions.
Quite confusing.
It would be preferable.
If we have a single textbook, so you can flip through.
And not a problem for green part,
but it used to be a problem for the light blue part.
And very recently, I found a good book
in Stanford University.
There is a double E course called double E 261.
The title is four-way transform and its application.
And I sent an email to the instructor two days ago.
He hasn't replied yet.
And I checked the website this morning.
And I found the course website as well.
So you can see the course.
You can download the book.

And this is quite a good book, fit my taste,
explaining these things using all the consistent notations.
And also his lecture video recorded.
You click, you can see.
But be aware that you don't need that much knowledge.
The double E course, there's a whole semester.
And the book, 400 pages.
You don't need that much.
So the best way to utilize this single book is free.
And I asked for permission.
He didn't reply.
But I read they see Stanford engineer everywhere.
That means we could use it.
I think it's a public thing, everywhere, including here,
including your dome, everywhere.
We got permission here.
So the best thing is that you just follow my explanation
very carefully.
If anything you feel confused, you want to review,
you can find relevant pages.
Maybe among the 400 pages, you need to read less than 100 pages.
And not that hard.
You flip through.
And some good point, the way to tease the material,
his way is outstanding.
Stanford is outstanding, for sure.
But I will not use his way.
And I think my way has some unique merit.
Just say he put a linear system later.
I put a linear system first.
And at some point, some angles may not be same.
And you can compare.
You see a good person really from my own understanding.
So not necessarily to follow a good example.
But this is a very good reference.
And you can find a single reference.
And you can also search Google.
You can discuss.
But I would recommend this for this lecture.
Let's try the new ways to see how you feel.
For the dark green part, you use the green book.
The green book in the university book store, you can buy one.
It's good.
You read.
And not very thick, but well written.
Little bit out of date, but foundation things never change.
The fundamental principle.
I will mention some new stuff.
In the imaging modality, you will see from X-ray imaging,
you will start with actually physics.
How you collect the data.
The data modeled as a line integral.
So it's actually penetrating through the object.
And what do you measure mathematically
under certain something?
Mathematically equivalent to line integral.
This is an integral transform called a read-on transform.
So you have an object.
And you do read-on transform.
From one direction, all these line integrals
add it up to make a one-dimensional profile.
This projection orientation can be changed.
So underlying image, f of x, y, can be converted
to a different two-dimensional image, p of t theta.

T is a coordinate along your detector direction.
Theta is the orientation of the projection.
So the two-dimensional function, f of x, y,
is converted into a different two-dimensional function,
p of theta t.
So given imaging geometry, you know the coordinate system.
You have a detector placed there.
So you know these t coordinates.
You know the theta angles.
And given an underlying image, you
can predict what kind of data you will have.
Basically, you just do line integral
along this x-ray path.
Any pixel numbers you add it together,
you have a total sum.
So this is a forward process.
And you implement the forward process
using physical measurement.
The magic x-ray just can do the trick.
Then the tomographic imaging process is opposite to that.
It's an inverse process, as I mentioned.
So given a data set, p of t theta,
and you've got all these kind of projections,
the question is, what's the underlying image?
Then we need to just do some computational processing.
Then we can go from p of t theta back to f of x, y.
So this can be done, mathematically done.
And the trick is that, one of the tricks
is that you perform a one-dimensional forward
transformation.
You get a one-dimensional profile.
And this happens to be the profile in the projection
domain.
You have the profile along this orientation.
And in the forward domain, this forward domain,
two-dimensional forward domain, is a 2D forward spectrum
of this 2D image.
So you build a link.
You get it from data measurement.
You get a projection profile.
But this is only one radial line information.
And it's not a two-dimensional forward transformation.
Fortunately, the angle this radial line makes, theta,
is the same as the projection orientation theta.
So if you keep rotating the projection data acquisition
system, you rotate it.
The theta keeps changing.
Then the radial line in the frequency domain
will sweep over whole Fourier domain.
You have all the information in Fourier domain.
The Fourier transformation is invertible.
You perform inverse Fourier transform.
You get an image back.
So this is just a preview.
And later, you will learn what's a Fourier transform, why
it can be inverted, and why you say this 1D Fourier
transform will give you 1D profile in 2D Fourier space.
And you don't know yet.
But this is just a preview.
So you have a little bit warmer up here.
Actually imaging, I explained quite a bit.
And the next imaging model I want to say
is about positron emission tomography.
Actually imaging, you do tomographic reconstruction.

You have anatomical structural features reconstructed.
And the positron emission tomography
is, on the other hand, about the function of a human body.
And the way you do tomographic imaging
is to introduce radioactive tissues.
The radioactive chemicals will participate
in your physiological activity.
Like a tumor take a lot of sugar.
If you couple the sugar molecule with radio tracer,
so the tumor take a lot of sugar.
And the same way, take a lot of radio tracer.
Radio tracer keep emitting gamma ray photons.
Gamma ray and the X-ray spectrum pretty much overlap
and can penetrate the human body.
So whenever you receive, so you use a collimator,
you see gamma ray photons coming this way.
That means some radio tracer along this line.
You can formate it into line integral as well.
So the Fourier analysis is useful for positron emission tomography.
And the positron emission is some interesting physical,
chemical process.
And when the event happens, and the two power of gamma ray
photons are generated, they propagate from the same location
towards the opposite direction.
So each time you capture two gamma ray photons,
then you say an event must be along this line of response.
So this is called a PET imaging.
And the sister mode in nuclear imaging
called a single photon emission CT or SPECT.
And this way, the radio tracer keep emitting gamma ray photons
randomly.
And then nothing paired.
This is that you have a radio tracer source randomly
emitting gamma ray photons.
And you get a gamma ray photons, you know something happened
along this way.
You do not expect a paired gamma ray photons.
So you do not detect that way.
And we will learn in detail later.
And the third one is magnetic resonant imaging.
And then we utilize radio frequency signals.
So we subject a patient into a strong magnetic field.
Then we use radio frequency signals
to manipulate the hydrogens.
Then we can get a radio frequency signal.
So this is sensitive to water content
in the local magnetic field environment.
So you can get a lot of information.
And like the chemical shift, like a brain activity,
so that is very cool.
And the MRI CT nuclear imaging has three most important imaging
modalities.
And in addition to these three big things,
we have two other very important modalities
we will also cover.
Right now, it's 15 minutes.
And normally, 15 minutes, I give you 10 minutes rest.
But this is an introductory course.
Let me just finish a few more slides.
That's all for today.
So next two imaging modalities are not as powerful.
I wouldn't say that.
They're not as popular as the first three,
but still very powerful, useful.

And it's cost-effective ultrasound imaging,
I said, based on mechanical vibration.
And you use a transducer based on piezoelectric material.
You vibrate the crystal.
Send the wave into human body.
The wave will meet some structures that will reflect
the back or transmitted through the human body.
You collect the signal.
You can make this kind of image.
And then no risk and cost-effective high speed.
We see the future engineer here.
So this is an ultrasound device.
It's cost-effective.
And the optical imaging is also very important.
Utilize the visible infrared light.
And you see molecular cellular interaction with light.
And some unique information or signature will be extracted.
And this is a piece of work we did about 10 years ago.
And basically, we used so-called luminescence probe.
And to tag proteins or gene expressions.
And then after the tagging process,
so any particular protein will emit luminescence light.
This is pretty much like what you see in the summer night.
You see the firefly.
You see the luminescence light come out.
So anywhere you see the bioluminescence light come out,
you think there are some certain protein expressions
beneath the surface.
And this is a passive imaging mode.
So you have the animal in a dark room.
You just walk around.
You see certain light emission patterns shown here.
So you can do the modeling.
So you have animal.
You do tomographic scanning.
You have tomographic image volume.
And then you can use optical scanning
to do optical characterization.
So you know the major organs and the structures here
and what are their optical properties.
So you have a shape model, optical model put together.
So this is the knowledge you know about the object.
With all this detailed knowledge,
so any light source put inside the body,
you can predict what will be the external signal.
So this is a forward process.
And as I said, tomographic imaging
is about inward process.
So this part, the forward process,
is not that interesting.
The interesting question is, given the surface measurement,
what is the bioluminescence source distribution
inside the body?
And we can perform tomographic image reconstruction.
So this is a system we build.
We put animal here.
And the light is weak, so we put multiple mirrors
to collect all the light.
And then we have the full external views.
And then we can perform, we call it
bioluminescence tomography.
So I made it a name, bioluminescence tomography.
It has been often used in the literature.
And we are able to recover light source distribution.

So these five imaging modalities are the key stuff
in this course.
You still remember the five imaging modalities.
X-ray, projective scan.
So CT is number one.
Nuclear tomography.
Tite spectra number two.
And MRI number three.
And ultrasound and optical.
So five guys.
This is about imaging from indirectly measured data
to cross-sectional images.
And once you have an image, you can certainly
perform image analysis.
So that is in the domain image processing.
And you can segment image.
You can classify.
You enhance.
You can deblur.
So all these things are important.
And some imaging textbook contain image visualization.
And I read an article yesterday.
Filippo introduced augmented reality
for medical imaging guided surgery.
So you wear fancy glasses.
So this is cool.
But this is not the main content of this BB course,
bio-instrumentation, bio-imaging.
So we focus on tomographic imaging.
Image analysis, we may just wave our hands, but you know it.
So again, it's a big picture.
See, for human body, you have phenotype.
You have genotype.
And biomedical imaging really about the phenotype.
Phenotype, bioinformatics, genetic profiling
really give you a lot of information of genotype.
And you need to link both sides together.
This is a big picture.
But we mainly focus on imaging side.
And I said, next lecture, I will be out of town.
And anyway, this is good timing.
You need to use next lecture to prepare you
with MATLAB knowledge.
And the Fourier transform, linear system, and so on,
we want to learn together actively.
And not just a lesson, just read.
You do.
Then you see how convolution Fourier transform
will be working for you.
And you see, oh, this is the way.
So you have that moment.
You will learn better.
So the MATLAB is a universal environment, widely used.
And the RPI supports this.
And you need to get this.
Then you can download from web.
And the RPI has the IT support.
Opposite to the library, you should download.
If any problem, you can, easy way,
just opposite to the library, you have a computer desk.
Instead of maybe most of you, I believe you already have it.
Then you can download from MATLAB website.
This is free.
I downloaded it.

You read the first chapter.
It flips through and very straightforward.
And I was recommended to use the so-called on-ramp.
This is just a stocking video.
It's two hours.
The next lecture could be just like this.
We do the same thing as on-ramp, two hours interactive lecture.
And I tried myself.
I think this is really good.
I would rather use the next lecture,
let TA to say a little bit to enhance your knowledge,
not let him or myself go through two hours typical MATLAB video
or interaction with you.
It's very good.
So on-ramp is your homework.
And I will send all of your email to make this on paper,
so very clear.
So your homework, you do this.
Any problem, you can get help from TA,
and you will see him next lecture.
So you go through.
You have a book.
You have a two-hour interactive lecture.
And this is my progress report.
You see I did this.
Any data?
Yeah, January 14.
And I go through stuff.
I know this, but I just try to go through myself.
It's very good.
And the last question, talking about some spectral analysis
from remote stars.
So it's very cool.
You go through in a very straightforward.
You need to get prepared to use MATLAB, not too fancy things,
just basic things that you have a tool to do your homework,
some of the homework.
It's very good.
So you have minds on, hands on, so everything works for you.
And this is about the MATLAB.
That's the point.
I mentioned right now the huge wave about machine learning,
artificial intelligence, robotics, all cool things.
In that data survey, I found medical imaging is a hot area.
You see a number of papers keep growing.
But machine learning is really catching up,
and even hotter than medical imaging.
And I would say combination of medical imaging
and deep learning, machine learning,
will mean a lot of things.
So I wrote an article titled Perspective on Deep Imaging.
If you are curious, you can do a search about my view
of future medical imaging, how we are going to do the inversion.
So I mentioned this to you.
And this is conventional classroom teaching.
If any of you are really motivated, want to do more,
you could select, it's not required, just an option.
You can say, I want to learn the imaging course,
while I select a project, like machine learning to imaging.
I have a lot of ideas.
So if you work that way, we could just say the research project
will be 70% of your score.
30% will be your other things.
So you'll have a decent opportunity,

but you need to make a decent offer.
Normally, students do not have time,
but just in case some of you want to be really involved,
and the office and the door is open.
Some students work with me, even some high school students
work with me in research.
Result, some of them even get a journal paper published.
This will be a boost to your career, but you need to spend time.
You need to get well prepared.
You feel this course seems easy to you.
You want to be challenged.
The option is there.
I think the future in medical imaging, or in medical field
in general, is really great.
We can use artificial intelligence
and replace radiologists.
In the future, even surgeons, right now they are paid too high.
It was a robotic surgeon who can do the job
and wondering what we can do eventually.
Machines will do a lot of things for us.
This is a scientific fiction movie called Elysium.
Any of you watched this one?
Have you watched this one?
This is cool.
This is a future machine.
Everything together can do fantastic things.
It can treat any disease.
Replace, regrow your organ, and regenerate your organ.
And it can reverse aging process.
So this is very cool.
Very cool related to medical, in general,
medical imaging in particular.
This is a future scanner.
So I hope you feel motivated to learn well.
So much for today.
Thank you.