Good afternoon.
So today's lecture is mainly dedicated to my life, my life project on computer tomography, redone transform and inverse redone transform in parallel beam and the comb beam geometry.
So you TA will explain.
And before that let me make some comments.
So this is our schedule so far.
And we have learned three lectures.
I actually physically read the overview, reconstructions and the scanner or CT systems all about like three.
So I actually is fascinating.
So let me say a little bit more.
And not only what we learned based on X3 attenuation.
So when we learn X3 attenuation, even the linear attenuation coefficient is energy dependent in the photon counting or spectral CT.
You still think X3 as a bunch of particles trying to go into a object or biological tissue.
So some particles will be scattered away of the shoulder turning into heat.
Then some rest particles or X3 photons will be detected.
So this is really point view of particle.
And I mentioned several times that the meters are really just particles in the wave.
You have a duality.
So I will mention a little bit about X3 wave nature.
This is relevant to the meeting.
I'm going to attend.
I will give a keynote in Japan and the next week.
So as a result, we have these two lectures.
So this is a white-hot lecture.
I'm a white-hot lecture.
I'm a white-hot lecture.
Those lectures will be called by me.
But as you will see, the video will play the video recorded a year ago.
And they are pretty much the same thing.
So I will still teach a nuclear physics on Friday.
And I will prepare some questions.
The other instructors will help modify.
So we will test both classes using same type of questions this time.
And the previous one, this is my own opinion.
So I could say that the students are meant to maximize contrast.
So this is the whole and better of the whole world.
So the average is 90.
It's not good to say.
So I think that the best means to go to be 50.
Then I can see the contrast.
And after all, again, still assert that you will see that the lecture's distribution will be same.
You will not subject to any disadvantage.
And this is for testing purpose.
But whenever I prepare my own side of question, I target mean 50%.
But the next one, I can say, two will be raised to other classes.
So the mean I expect will be high.
But again, these classes will be pretty much the same as I did.
So the Japanese conference, I'm going to attend.
And the world I'm going to say a little bit about wave nature of X-ray.
It's rather interesting.
So I just like explain.
So you know prism.
Prism is this object.
It's optical components.
And if you shoot a beam of white light, going through prism, you know the white light consists of all kinds of colors, all kinds of different wave lines.
Depending on wave lines, the light beam can be banned a little bit.
And that's wave lines dependent.

So higher energy light beam will purple light.
So it binds more.
And the right light binds the light.
So that's why you see rainbow.
That's the same idea.
So prism is a component.
With prism, you start appreciating light.
It's not totally particle.
It's just also some wave of diffraction phenomena.
So light can bind.
It's not just the ghost tree that we keep seeing light integral.
So then the next set up is so called very famous.
Double slid X-parameter.
So you have an opaque screen.
You have two openings.
Then each opening according to her principle, will I make spherical wave coming out? Because wave nature, so you have peak, you have value, the interferes.
So light interferes.
Then on this recording screen, you see the peak superimposed constructively.
Oh, they cancel out.
Distructively, so you have some light stripe.
So interferes pattern looks like this.
And we keep talking visible light, because we are so familiar with visible light.
You stake rods into a pond.
You may see the straight rod may look broken somehow.
This is all light, diffraction or interference phenomena shown with the double slid X-parameter.
A lot of things like this suggesting that light can be photons and can be waves.
So you need two point of view.
So actually, we are making so far.
We assume street reprovigation and particle nature.
So mechanism is a tiny way, coefficient.
So that's what we learned.
But I would like to tell you little more.
So you open your eyes to see the light in this case, X-3 waves or X-3 particles can be treated as particles.
So you go through object, so tiny way, so you have a tiny way profile.
And also, it goes some face structure.
So X-3 will be band a little bit.
It's not much.
So the face structure is not so popular, because the diffraction, the banding, is very hard to, very difficult to detect.
And also, X-3 goes through structure and subject to scattering.
You usually talk about the competent scattering.
And the coherent scattering only gives you a small angle.
Or we call it a small angle scattering.
If you just imagine a small angle scattering related to transmitted light integrals, strong signal, here is a very weak signal.
Coherent scattering is a small fraction of signal.
And this weak signal, because it is weak, we also call it a darker field contrast.
Small angle scattering components, potentially, is very important.
And if you have benign, malignant tumor, small angle scattering signal, will differ in state between them.
So this is very critical.
So now you see X-3 contrast mechanism.
Transformation or tiny way is one very popular.
In future, face contrast, small angle scattering, very important.
So look at the small animal model.
And we have a transformation.
Oldenary, actually, image.
We have a face contrast image.
So the boundaries look a little better.

And the small angle scattering contrasts and the show internal organs and other features, like first, and very clearly.
So these are future modes for X-3 imaging.
And how can you achieve multi-contrast, like a face contrast, the small angle scattering, actually imaging, I mentioned double-slate experiment.
But what we do, in the way X-3 set up, we use so-called actually grittings.
The grittings are those structures with small openings.
The aperture is around 10 microns.
This is the periodic structure.
So this is the high-tech and widely known in the field.
So these grittings actually beam or wave waves decomposed into small beam lines.
So these beam lines, you think, I made kind of actually waves.
These waves will interfere with face gritting, G1.
And what you have is some periodic structure.
Same thing as the structure of gritting G0.
So you have structure shown on the detector plate.
So if you put some object into the X-3 beam, what will happen? So you put some animal or sample, the X-3 beam will be band little bit.
And the banding or small angle scattering can be detected with half of three grittings shown here.
So this is to show you how you detect the X-3 face contrast.
So originally you have X-3 image, very regular, which introduced the structure.
So you have interference pattern here.
And with small angle scattering, you put some structure, a lot of gave, gave, you small angle scattering.
So the amplitude peak and the wave will be compromised.
So you can record a signal in terms of wave form saved, or visibility reduction.
So amplitude will be reduced.
That is due to small angle scattering.
Small angle scattering photons really just subtle around make peak loss little bit, but the wave of the wave little bit high.
So these three contrast gives us very good complementary information.
This is our library set up with three grittings here, here and in front of X-3 detectors.
And ordinary tenuous contrast you learned before.
With face contrast, you see fibers little better.
With small angle scattering, the borders in flower can be seen.
And this is our animal study.
Result, tenuous contrast, with face contrast, you see boundaries and some features, much better.
And small angle scattering, the higher invisible tenuous image can be seen.
So this is the show you all these examples.
This is the future of X-3, and the knot in Thai book yet.
And the Japanese conference, the facility, I'm going to visit, where the conference will be held.
It's so clear.
So very fancy facility.
So actually, South is a massive brighter, than what we have in library.
This is a single-trans relation facility.
Big device and the produce high brightness, X-3 beam.
And use that for a lot of fancy studies.
Face contrast is very high resolution.
So this is the summing our group and the others are working on.
So I very much look forward to interact with Japanese peers.
So this is some knowledge for you to know.
I actually imagine, as a multiple huge potential possibilities to be realized in the future.
So X-3 is not only a beam of particles, and also waves.
You can utilize wave nature.
So you ban X-3.
No photon I've lost.
If you can measure the X-3 bending, 3D signals will be low.
And you can imagine a lot of things.
So this is for your general knowledge.

I'm explaining why I'm going to scale some lecture.
But the video seems to be my lecture.
So anything you can see me email.
So this is one comment that I just know.
The second one, over spring break, they home.
So I got time to elevate the book part one, mathematical foundation.
I was able to elevate that from a draft version to second version.
I think third version going to be publishable.
Next version is logically, mathematically, right.
But we need to add more examples and figures to make it a little easier to begin.
But for you already learned part one mathematical foundation, and you review it.
That will be very good.
Otherwise, if you do not have clear idea about forward transmission and so on, and you will be confused.
When you learn say, I'm an imaging.
So this is still good time.
And if you really curious and enjoy reading a foundational mathematical staff, you'll read it through, not a lot of staff.
But you are rather basic, and you can just quickly read linear system definition.
You'll review it.
It's very easy.
What's a linear system? Just have the superposition principle.
Just a line.
So your database type is a lot.
What's a convolution? The convolution is naturally introduced for safety environment linear system.
The convolution definition.
So you have the double integral.
You remember the flip, you translate it, you do point-wise multiplication.
Then you do integral.
Why you have this definition? Because for safety environment linear system, that's a way to compute output.
If you know input, if you know impulse, response function, you may need to review little bit.
What's the impulse function? Delta function.
So those things are rather easy.
If you have a rough idea, you review, maybe 10 minutes, or 10 minutes, or 10 minutes, or two chapters.
Then this Fourier series, Fourier transform, are statistically treated.
So you review, you see how mathematically you have Fourier series, you have Fourier transform.
So all the remarks are for additional comments.
You may or may not read.
That's okay.
But these two write boxes, you better understand.
Later you will learn.
I'm R.I.
case-based.
So we need Fourier analysis all the time.
We just learned filter the bad projects in Fourier slices theorem.
So these are very important.
So these two boxes review it.
So the mathematical steps treatment, a stream line, and I was, I could have this worse, at the beginning of the semester.
But you know, this is take time.
We just have many, many things altogether.
So this is the god time, Supreme Breaker results.
And the sampling theorem is a application of Fourier analysis.
So read data section and a few pages.
Then this create Fourier transform was introduced naturally.
So these things are key.
And the network you read and not that critically depends on Fourier analysis.

But you still need to know the general idea.
Newer network, artificial neural network, is a modern feature of data processing, signal processing.
And the topographic reconstruction.
Image quality, assessment, general knowledge, when you have image, how you see image is better or not.
In the remark section, I put some information.
It's very hard to read.
Unless you're very motivated and you read for one hour, you will feel really good.
But it's not required.
So this part I think is good.
As a reference, in the future you got anything confused.
You can review back.
So this is the second notes or second comment.
Last one, Pia told me, once you said PLC wants to know the answer to the first examination.
And we do not want to disclose the question because in the future, to a certain degree, I will reuse the problem.
But I can still give you some comments.
Pretty much the question is, some are straightforward, some are little tricky.
So if you check the book or you check PowerPoint, those things can be easily figured out.
Like the first page, I purposely make a blurry.
This is a reminder.
These things are fundamentally basic, fundamental stuff, basic knowledge.
Some are tricky.
For example, question six.
It says, convolution of two non-negative functions must be negative.
And this is not tricky one.
So this must be true.
The second question, yes or no question, function cannot remain the same after it's convolution, it's any function.
This is a little tricky.
And some things you think convolution is a operation.
We have messed up a function little bit.
But if you read the book carefully, we keep saying delta function.
Delta function can always something, and it will be the same thing.
This is slightly tricky.
So this statement is cannot, but actually with delta function, you could, and the answer is false.
The third one, convolution of two identical functions, will always change the shape of the function.
This is generally the case.
You can follow two rectangular functions after convolution.
The shape becomes triangular function, right? But remember, if you have Gaussian, come off with Gaussian, the shape is changed.
But the result is a little bit widen for Gaussian function.
For delta function, delta, come off with delta, it's still delta, nothing changes.
So this correct answer, little tricky, but not that tricky.
The answer is false.
Last one, convolution concept applies only in one dimensional case.
And we say this can be extended to dimensional.
Remember, you have two dimensional Fourier transform.
I say the blurry, blurry, it's due to 2D convolution.
If the system is saved, it's basically an invariant linear system.
So since like this, I wouldn't consider the questions challenging, but little tricky.
If you pay attention, you will get them all right.
But the question was designed to tie the different, so I hope, indeed, some students might solve.
So this is page 1.
So page 2, this is just 2D Fourier transform.

So original image, you have false background.
If you just take a low part image, we'll look a little blurry, because all high frequency components were removed.
Here is the other hand, in this spectrum, you zero out low frequency components.
So high frequency components, calories bound to ij.
So you look at the image, you look at this very much like a contour.
So this is a high frequency filtering result.
And the question, 11, is fundamentally important.
And I spend a lot of time explaining convolution, the convolution theorem.
And it's a very cool thing.
You have two time domain or special domain functions.
I find the gizzing about one dimensional case.
You do convolution, you do Fourier analysis.
And if you do Fourier transform individually upon I find the g you multiply them together.
And that's the same.
As you forward transform the convolution result.
So this is what we learned several lectures dedicated to data.
And this is what we ask you to put.
So if you learn the convolution theorem, you know that you'll be able to produce.
Some students say convolution, this is the i times g.
That's multiplication.
It's not a convolution.
So if you think a convolution is just a simple multiplication, then I have an impression.
You didn't start it very carefully.
So this is the sense, like the fundamental idea you should review.
And the last page, and this is just a big picture about this criticalization sampling in special domain, the Fourier domain, and related to the two chapters that I use right box, ask you to review.
You follow this logic link, fundamentally important for engineers.
So if you still have confusion, then you just review.
Make sure.
Whether or not we will test again.
We are not going to test the Fourier transform again.
But good for you to know, as RPI engineering, biomedical engineering student.
So you can review the text book.
And this, this circuit analysis, and I copied the question from the internet.
So if you feel confused in any way, I think the analysis is straightforward.
If you understand KCL and KVL, you click this link, you can see how you solve the problem.
Newer network, or basic definition.
So I wouldn't consider the examination is too challenging.
And if you follow the basic steps, they did homework, paid attention to PPT and lecture, you shouldn't do too bad.
And the homework, I wouldn't say too much, but I would like to use your ideas.
This is what we did before, and got a new, some new report, low-end CTC system.
But what is so average, you want to do sub-mata, your masterpiece.
Just let you know, my part, and the rice that I gave to KCL and the CBOX playing Mac Live, and the RIDAM program, interesting example.
Okay.
By the way, today's office has changed from 2.30 to 3.30 because I have a faculty meeting, I have to go.
This is your study.
Thank you.
Alright.
Lights rehearsal.
Hello? Is that okay? Okay.
So today I'm going to be talking to you guys about how to use MATLAB to demonstrate some of the CT principles that you have been learning in the class.
And so this image right here, this small movie is from a website that's down here below that was showing the one of the new technologies that GE has developed that they called Revolution CT.

And you can get these very high resolution images of the skull and some of the veins and arteries and capillaries inside the skull.
And they have some other pretty cool images like this on this website if you wanted to look at some real world applications and how people are continuing to develop them for very high resolution stuff so that you can see more details inside the body for clinical use.
And so this is just a reminder if you wanted to follow along with the code that I put up on LMS.
And so if you want to follow along with the code you have to make sure that you have MATLAB as well as the signal processing and image processing tool boxes.
And if you haven't already then you can just download the zip file from LMS and then put all the files into MATLAB folder and then you should be able to run them as we go along in the class or at home if you want to do it separately at home.
And so I'm just going to give a general theory of CT which most of it is just a review from class.
And so the general theory of CT is that there's x-ray projections that take in multiple views and then tenuation due to the different properties of tissue.
For instance bone versus muscle they have different attenuations.
And so then you solve an inverse problem which is using the radon transform to get the tomographic information where CT stands for a computed tomography.
So for instance you have the x-ray image here which is just a 2D projection and then you take multiple projections like these two different views of this girl here.
And then you take the inverse, do the inverse problem or the radon transform and then you can get something like this which is a very high resolution detailed image of the human with the bones as well as some other features that are highlighted in different colors here.
So this would be a 3D imaging case but for this class we just have 2D imaging cases in terms of the radon transform.
And so for the resolution of CT reconstruction the number of the rays that you use or the x-rays in this picture here affects the radial component of spatial resolution and then the number of views or the number of angles that you take this theta value affects the circumferential component of resolution.
So the circumferential is labeled here on this just cartoon CT slice and then the radon resolution is this sort of this type of resolution here.
And so the number of rays that you use and the number of views that you use affects what your reconstruction will look like of your tissue sample.
And so the radon transform that Dr.
Wong has mentioned in the class and explained in detail is just a representation of the x-ray projection data in the form of what's called a sinogram.
And so this indicates the characteristics of a sample.
So for instance if an object is closer to the field of view of the camera then it produces a higher amplitude.
So for instance this is the equation for performing the radon transform and then this is the picture from a previous slide where it describes the rays and the views and the angle the angles that you use to get the different projections and then this is a sinogram, example sinogram of like this sample for instance the small yellow ball here the small yellow circle would have a higher amplitude when it's closer to this yellow which is like the detector at different angles and so you have this sort of wavy sort of wavy white area which is the higher amplitude area.
And so then you have the forward radon transform and then you also have the inverse for a radon transform to reconstruct your data and so this relies upon the four-year slice theorem and so in just short summary the 1D for your transform or Ft of the radon transform projection profile acquired a specific angle is equivalent to the value of the 2D for your transform along the line at the angle phi and then you put together the radon transform profiles at all acquisitions to get the full two-dimensional for your transform and then you can inverse you can do the inverse for your transform 2D for your transform to reconstruct the image and so this is a description of just having one line here and so one line is at the angle that's data here or phi and the example in the text here and so you have one projection on one line and then you change the angle and you have a projection along the next line and then the next line and

the next line and so as you combine them at a certain number of angles then you get you can use the inverse 2D for your transform to get back your image and then this is known as back projection and so it's the standard method of reconstructing CT slices and so the synogram is used to back project each view and then all of the views are combined to get the whole image and so this is just a very simple cartoon example where there's this oval with two small ovals inside the red ones and then this would be something like the synogram at this one view this top down I guess a view and then there's the two high amplitude areas with the small the two large circle and the big small circle and then you can back project to get the reconstruction at this one view and then in this second image it's the left to right I guess view where you have the two different two different higher amplitude areas for the small and the big circle and then you back project it to get this sort of image and then this is just for two views but if you combine them then you can get these two squares here and since it's only two views it just ends up being two squares but if you have multiple views then you can interpolate out the two circles within the larger circle to get back your original your original sample or image and then in addition filter back projection sometimes is required because the unfiltered back projection from just a regular synogram can sometimes reduce a blurry if your synogram is not very high resolution or if it's just kind of blurry due to the attenuation or something like that and so sometimes you need to filter the the synogram in order to get a very good a better back projected image and so this is some examples of the of a synogram which is not very I mean the white area is pretty clear but then the difference between the white area and the background area is not so distinct and so when you get the back projected image is just sort of this blurry white gray circle but then if you filter the synogram then you can see that the edges are very defined compared to the unfiltered synogram and then the reconstructed image for this case would be you can see that there is an oval and a white circle inside which could be like a tumor or something like that and so there are multiple filters that you can use these are just three examples that I think we're also given in the class where this is what the three filters look like that you would apply to the synogram and so this I found this pretty cool it's the filtered back projection in progress and so the first one is just the original synogram and then this is going through the different views and then you can see what's going on to do the back projection so you get this the phantom or the sample image original phantom sample image back and so it's going through all the different views and so how can we use MATLAB to demonstrate these CT principles and so MATLAB has two different distinct functions for parallel beam and fan beam CT simulations and so in the next few examples that I have for you guys there's these three different samples that we're going to use and so one is just this small square and then another one is this larger gray circle with a small circle in there in the edge which could represent something like a tumor and then this last one is one that's already installed in MATLAB or it's already included in MATLAB it's called the Shepp Logan phantom which is a very common phantom that people use in in the field to sort of validate the techniques so if one group uses this phantom to demonstrate their back projection technique then other groups also understand that okay since they use this phantom I understand what's going on here so that they can compare like their own versus that group's results and so it's used as sort of a standard in the field and so parallel beam CT the parallel beam CT function is just called radon for the radon transform and so the beams or the simulated beams which are one pixel apart from the source and the the beams are from the source are projected parallel to the detector and so if this is the source and this is the detector the beams are projected parallel to the source and the detector and the sample and this is from the math works help page if you wanted to get some more detailed information about that and then the parallel beams and detector are rotated around the center of the image at a certain angle theta here and so if you imagine that these are all sort of like connected like this then you just rotate everything at a rotation angle theta which is also an input to the function and so this is from the math lab help page as well like how do you use this radon function and so you have just the radon and then these are the two outputs the R is just the like intensity value that you get or an amplitude value and then the XP is this the detector locations if that's in information that you want to get out of your simulation and then the eye is your input image and then the theta is the maximum rotation angle that you want to use and so this would be how you would run this function and so the example the first example that I uploaded as the code in math lab is just called this x1 underscore parallel so if you wanted to if you downloaded that and wanted to run it on your own you can do that now or at home and you can change this p type which is in line 5 to 1 2 or 3 for the three different sample types the square the circle with the small circle or the shep logon phantom and so if you run this code which I will run the code as I when I in a second you can see that as the red arrow is changing the information is also added to the signagram where the image domain is just the for this case is just the white square and then this is the signagram information and so this is for the square and so you can see that as this arrow is changing is just changing the different angles looking at the different angles from the original angle and then you can see that information is added to the signagram here and then this is what your final signagram would look like for the rotation angles that I input here and if you change the different types in this line here then you can see what the signagram looks like for something like this this phantom where there's a small white circle within a gray circle and so you can see that it's very obviously different and the small white circle also adds some information to the signagram this sort of wave here since the since it's getting or since the detector in the source are getting closer to or farther away from this small white circle then the attenuation values are changing and so for for the third one this is what I would look like this phantom is more complex there's a lot more small areas within it which would represent different like tumors or different structures and so you can see that the signagram is also a lot more complex there's more information here and so this would be more similar to what you would encounter in like a real brain CT for instance and it wouldn't be as simple as just like a black on a white small white square on a black background oops and so these are just some small examples that we can try with the codes and so what do what happens when we change the theta step the theta step value which is just the amount if it goes like 1 2 3 4 5 where if it goes 1 5 10 15 to the different to the maximum angle from what if we change that value from 1 to 5 and then what's happening here and so this is what the signagram would look like for the square small white square phantom and you can see that as we collect fewer angles because there's a larger step this is from 0 to 180 so it goes 0 5 10 15 instead of 1 2 3 4 5 then you have fewer angular views and you can see that this lower resolution it's more there's just it looks more like blocky compared to the previous one so that means there would be lower resolution and then if you have your if you try to reconstruct from this signagram it would also be lower resolution and so we can try that here if I change the theta step here to 5 then you can see that the resolution is a lot lower it's just more streaky I guess more blocky in that sense the lower resolution and so in order to get a high resolution signagram you want to have a pretty low theta step and so then what happens if you change the maximum theta value I had 180 before to 45 and then what's happening here and so when you do change this value before it was 0 to 180 now it's 0 to 45 and as you can probably imagine it basically truncates truncates the signagram because you only scan a part of the part of the sample and so if you only scan a part of the sample then you wouldn't be able to get your full reconstructed image back when you do the when you do the reconstruction and so if I change this back to 1 then change this to 45 for instance then you can see that it only stops the arrow

only stops right here so you only scan from this small region here and so you only have a part of the signagram and so you only get not a not a very good reconstruction because you would only had information from this small area here and then in addition to the forward radon transform which is just the radon function then you also can perform this parallel beam back projection with the i radon which is just inverse radon transform function and so this is a back projection for parallel beam signagrams only and then you can also do filter back projection which is implemented in the code already and so this is how the function looks and so i is just your reconstructed image your output and then i radon is the number the name of the function itself r is your signagram input and then theta is the rotation angles that you want to look through and then there's this also interpolation method and this filter input is the filter to be used for the filtered back projection and these two are optional you can just do i radon r theta if you don't want to do if you want to do unfiltered back projection that's also okay too it's also valid in MATLAB to not have these two last inputs and so if you wanted to run this x2 parallel back one and so that's the function that performs the parallel beam back projection and so this line 32 implements the normal back projection without the filter and then line 35 implements the filtered back projection and i included the hamming filter as just an example but there are also multiple other filters that are included in this function that you can use or you can even create your own filter and put it in there in as one of the inputs if you wanted to try those ones out for yourself and so this is what the image looks like for just the just the regular white square and so you can see that the back projected image there are these two you can see there's sort of a cross here because this is an unfiltered back projection but then when you have the filtered back projection there's you can see more clearly the white square and not so much of the other background stuff and so if you change the filter type it also would change what your filtered back projection image looks like here and so if we wanted to run this code here so this is what it would look like this is just the two images from the from the previous slide and this is what the sineagram looks like which we saw in the first example but then if you change to the the last phantom here then you can see that there's some more artifacts in this one then in this one for when I use this specific hamming filter but I can change that filter to see what the results look like for the different filter types and sometimes depending on what your sineagram looks like you might want to use different filter types according to like what you want to look at for instance more edges or if it's too blurry you can use different filters for your different applications that you're looking at and so now we just briefly look at what happens if you change the maximum theta in line 23 or the step which is similar to in the previous example so what happens if you change those two values and so the default values that I had were 180 and 1 but if you have 180 and step 5 then you can see that there's even more artifacts here in the just the white square image you can see these sort of diagonal streaks in the regular back projected image but some of these are removed you can see the edges a little bit more clearly in the filtered back project image and then if you change the maximum theta to 90 with the step of 1 then you can see that it's not really as clear that it's a square it's a little bit more rounded at the edges and there's also some more artifacts in the background here this sort of cross and so when you change the step value the reconstructions are slightly less defined just because you have more discrete steps but then if you change the maximum theta angle then the reconstructions have lower resolution because there's less angles here that you use and so the next type of CT that MATLAB can simulate is called the fan beam CT which Dr. Wang also mentioned in the class and so this is the function is just called fan beam and so the source beams are projected in a fan shape from a beam vertex and so this is sort of a picture of what it would look like this is also from the MATLAB help page for this fan beam function so you can look at that for more details as well and so this this person or sample would be the this would be where the sample is and then the source is here and then it projects in a sort of diagonal or a fan shape beam and then the detectors on the other side of the sample and so this picture in this picture here the D value is the distance between the fan beam vertex which is like the source vertex position and the sample center of rotation so for this small square it would just be the diagonal but if it was a human for instance it would just be the center the center region of the sample and then the source and detector again are rotated at an angle theta so the source and detector move move together at an angle theta for the fan rotation angle in this picture here and so this fan beam function it calculates the projection data for a specified fan beam geometry and for this function the rotation angle is fixed at 0 to 360 so you can't say you only want 0 to 180 or 0 to 45 for instance this function it's fixed for 0 to 360 and so this is the this is the entire function definition but you don't have to use all of these inputs and outputs and so this f1 is just the fan beam output and then the sensor position and the fan rotation angles are also some outputs that you use but are not required and then you use the fan beam function and then P and D are the input image and the distance between the source vertex and the object center and then this fan sensor spacing and D sensor 1 this fan sensor spacing is just a specific property like name you have to say that you're putting in this D sensor 1 value as the fan sensor spacing property name and this these last two are optional here and then there's also this they all matlab can also perform a fan beam filter back projection with this i fan beam function here and so this it actually converts the fan beam data to parallel beam projections and then it uses the filter back projection algorithm that was in the few slides ago to perform the inverse rate on transform and so this is the function definition for the i fan beam and so i fan 1 is your output your reconstructed image and then i fan beam and then f1 is your signogram that you get as the fan beam output and then D is the distance to the object and then again this fan sensor spacing and the D sensor 1 it gives the property the property of the D sensor 1 to this fan sensor spacing between the different sensor pixels and so again these two are optional for this function here and so if you wanted to run this third example this x3 underscore fan beam that I uploaded on elements and the D value in line 25 is slightly larger than half of the diagonal distance of the image this is just a convention that was used in in this function and then the D sensor is equal to 1 in line 26 and so this is what the fan beam signogram looks like for the small square sample and then when you do the reconstruction this is what it looks like it's pretty good you can see that very well that this is a small white square but then you can also i'm not sure if you can see it very well here um not really on the slide on the screen but there are some small dots around the corners here which you might be able to see easier on the powerpoint on your own computer but um there are some small dots here so it's not a perfect reconstruction so if we run this code here okay it's not a more clear here or maybe not but there are some artifacts here you can see it more clearly if you run the code on your own computer I guess but it doesn't come out very well on the screen here but then if you look at this for the oops for the different phantom types for the more complex phantom type then um this is what your signogram looks like which we saw in the previous um in the previous examples but this is for the fan beam and you can see that this is 0 to 360 as a rotation angle and then this is what the reconstruction looks like and so you can kind of see it a little bit more here but there are some artifacts that look sort of like a diagonal lines um around the edges here but the um information inside the um white outline is still pretty clear and so what happens if you change the sensor spacing from one to five or from one to zero point five but you don't change the d value and so if you have the d sensor as the zero point five this is the one which is just the default value if you change it to zero point five the resolution slightly increases but then if you change it to five you can see that the resolution decreases very drastically it's uh very blurry it kind of doesn't really look like a square it looks more like a few like a rounded square um but you can see that the resolution is related to the sensor spacing that's one of the um one of the properties that can change how your resolution is in your reconstructed image and so high spacing uh such as this d sensor equals to five means the lower resolution here and so we can see for um for like this phantom for instance um yeah this you say if you change the uh d sensor in this line 26 here to five then you can see how drastically the sonogram decreases in resolution as well as the um fbp reconstruction where um this was the original image but this is the reconstruction but then if you change it to zero point five then it looks a lot better um it looks pretty much like the original image with some artifacts but you can remove those um you could remove those artifacts with post processing or you can change some of the other um properties to increase the resolution further and so then what happens if you increase the d value um in line 28 which is just the line for the uh function definition but then you set the d sensor equal to one and so the d value is the distance between the uh vertex of the fan beam source and your middle plane of your sample and so if you increase or decrease that distance what would happen and so the default is approximately one ninety one here which is just calculated from the um sides of the square and then if you increase it to 300 the resolution uh decreases and then if you increase it to 500 it decreases even further where you can see that there's a lot more artifacts in the background here as well and so if you have a higher source to object uh distance it also gives you a lower reconstruction resolution and so if we wanted to see that in um for this phantom if I change this one back to one but if I change this to 500 then you can see again that the resolution is a highly decreased and also why this is supposed to be sort of an oval it's there's some um edges that are showing up here so the resolution is pretty low um for this case and so this sort of simulation it can also help you to um design your sensors or your detectors and so you can use this sort of simulation and say oh well I need a distance that's lower than 500 or something like that um uh to help you guide how you're making your actual um your actual CT system design or something like that and so um that's all I have for you for this MATLAB section but um this is just a reminder that you have a homework that's due um tonight at alone 59 where you do um where this is posted on LMS but I just reposted it again here where you'd use the radon and the iridon functions for um in the lips and then you also have a second homework that's due on Friday from the green textbook there are a few problems that are here and then also um there's this optional project to make another sort of art ex poster type thing or a design for a portable CT scanner um or CT scanner for novel application and you can look at these two papers that um I think were published by Dr.

Wong's group um for some examples or inspiration but um this would be an optional project for design um and then this is due on Friday um on this Friday um this part is optional the designing the art ex project but then the um problems from the green book are required um and so these are all this is due on Friday and then um that's all that I have unless you have any questions for Dr. Wong for homework or for slides um and I already post all of these on LMS so you can look back uh at the slides if you want to go over it yourself um for fun or for learning um but that's all that I have unless anyone has any questions then I guess that we're all set for to do