Good afternoon.
Today we are going to explain the system and hardware aspect of computed tomography.
As you see the title is CT scanner.
We will have next lecture on MATLAB TA session.
So we will explain some filtered bag projection and so on.
So you will have opportunity to review
the MATLAB command and functions so you do filtered bag projection.
Then you will have spring break.
I think maybe next week is spring break.
So I think that's why not so many students today.
Last semester same thing.
This lecture some students already prepared spring break.
So let's see the outline of today's lecture.
So first we talk about projection data truncation.
Then we talk about scanning mode and we will go on to image artifacts.
And finally we will mention X-ray radiation dose which is harmful to patients.
As we explained in the previous lecture, so when you collect X-ray projection data
so from the unimpeding perspective you want to get image result layer by layer
so from the outer most shell so gradually peel the onion.
So you would need all the X-ray measurement given any lines through the region of interest
you would want to have the line integral associated with the ray.
So this is in 2D situation.
So still keep in mind the unimpeding idea.
So we say we need at least a point on X-ray source trajectory on any lines through the object support.
This is just another way to say we have a measurement for any line through the cross section.
So we need to have all kinds of data.
And in the 3D case you still have a point X-ray source
so instead of using a linear detector ray you would use a planar detector ray use a two dimensional detector ray.
So we have a cone beam geometry from a point source
so you shoot all the X-rays from a cone
so you have a cone beam of X-rays
and X-rays supposed to be sufficient to cover whole object
in other words the object is fully contained in the cone beam.
So this is something similar in the 2D case.
Once you have all the rays shown here
you can always re-sort or re-organize or re-bin the X-rays into parallel beam geometry.
And in the parallel beam geometry you can do Fourier transformation based imaging.
So you have a Fourier slice theorem
so you use the one dimensional Fourier transform
to recover Fourier spectrum in 2D space.
So each time for each projection you get one profile recovered.
You keep changing the view angle
so you get the radial line sweep nicely over the whole Fourier domain.
Likewise in 3D situation we need an extended version of Fourier slice theorem
so you really need a Fourier transform.
Fourier transform as we learned is the foundation of classic CT theory
which requires complete coverage of a whole cross section or entire object.
So you have projection data you can use Fourier slice theorem in 2D or in 3D
then you perform inverse Fourier transform in 2D or in 3D.
So this is a classic scheme called central dogma.
So whole cross section or entire object must be completely covered by X-ray beam.
So any beam shape you can always re-bin into parallel beam geometry.
And the result of the data can be inversely transformed back
to the original image domain.
That's the way you perform image reconstruction

as we learned filtered back projection is nothing
but just inverse Fourier transform in polar coordinate system.
So this part pretty much explained.
So if you follow me you should know the essential idea I'm talking about.
So in my opinion what's the difference between classic CT theory and modern CT theory?
It's about the data truncation.
So if the data is not complete
so in the Fourier slice theorem it says you have a full projection profile
to perform one dimensional Fourier transform.
What if the data is not complete?
You miss a portion of data.
Then you cannot perform Fourier transformation anymore.
So in that case you will have data truncation problem.
I think to a good degree modern CT theory is developed
to address data truncation problem.
So before I explain what kind of data truncation we have
let me first show you four generations of CT scaling geometry.
Usually we call it generations or modes.
So basically that's a way how you collect x-ray projection data systematically.
The easy way, the first generation
you have a single point x-ray source
you have a point detector.
So each time you just measure one line.
One line integral.
So you just translate this setup.
So along one direction you have one parallel beam projection.
Then the whole thing is just translated
just rotated by a small angle.
Then you move to next viewing angular position
to get another parallel beam projection.
And this is a function of viewing angle theta.
So this is the first generation.
The second generation you want to improve data acquisition
efficiency instead of one line integral a time.
So you really use a small detector array.
So each time you collect multiple line integrals
you should have a narrow fan beam.
You translate this narrow fan beam
to get more data.
So you cover the cross section completely.
So when you do one translation
that is equivalent to you collect multiple parallel beam projection.
So you do this translation once
how many parallel beam projections have you acquired?
So the answer is you count how many detected shells you have.
So you have five detected shells
and you collect five parallel beam projections.
Then you rotate the whole setup by a small angle.
Then do the translation again.
So you keep doing this.
Then when you become a little richer
So you say I can improve data acquisition efficiency even more.
So instead of just say five or six small number of detector arrays
you can afford say hundreds or even thousands of detector elements.
So you have a wide detector array along a straight line or along an arc.
So this is a full fan beam imaging geometry.
Then you rotate cells in the detector assembly continuously
and you can collect the data.
And this is something good
to satisfy the data acquisition data sufficiency condition.
So if you perform full circle scanning
then you see okay no problem.
And any line going through patient that cross section

you will have somewhere actually measurement.
So line integral will be acquired.
So this is third generation geometry still very popular.
Modern CT scanners pretty much in this geometry
but this one dimensional detector array is expanded
into say multi-row or cone beam.
We will come to that later.
The fourth generation really we make the detector array full ring
so you do not need to rotate detector anymore.
You just keep rotating actual cells.
This is the fourth generation geometry.
And after that we have something called oh what's the problem?
What's the problem?
Computer comes back.
Then we have electron beam CT.
So this is something like extra tube.
So electron beam is illustrated here.
Then we have a big extra tube.
This is a whole setup.
This whole thing can be considered as extra tube.
So electron beam is steered towards constant target
in a multiple metallic arc.
So each arc will generate x-ray shooting upward.
And the electron beam can be electromagnetic steered
going this way.
So this is not mechanical rotation.
Remember the third generation geometry
we do mechanical rotation.
This is electromagnetic steering.
The imaging speed is very fast.
So I say the driving force behind the development
or evolution of scanning generation
is to have higher and higher data acquisition efficiency.
So you collect the same amount of data
within shorter and shorter period.
This is to improve temporal resolution.
And then the most challenging CT application task
is cardiac imaging.
So your heart beats very fast, maybe 60 beats per minute,
maybe 100, depends on.
So we do tomographic reconstruction.
The theory assumes the object, the structures are stationary.
But actually you keep moving around.
I mean your heart is in motion.
So you need to reduce data acquisition time.
So this electron beam scanner was designed
for cardiac CT imaging.
And the problem with this e-beam scanner
is the cost.
And also image noise is high.
And the fourth generation geometry,
when you shoot x-ray in this direction,
so scattered signal will be captured by other detectors.
So there are some cost and scattering problems.
So the third generation geometry remains in practice.
So that is more popular.
The electron beam CT scanner, also out of date.
And how we define CT scanning modes
or how many generations we save for CT scanning,
that depends on.
If you check different textbooks,
they have different versions.
But usually first three generations seems no question.
One is the first generation, the second, the third.

But the later generations kind of depend on.
This is a matter of opinion.
So scanning mode, we see the diamond here.
So try to remember.
First generation parallel beam, narrow fan beam,
third generation wide fan angle, and rotation.
So this is third generation fan beam rotating detectors.
The fourth generation and this fifth generation.
The next one, you call it sixth or seventh generation.
It's helical scanning.
So helical scanning is an out-of-box idea.
So usually you do imaging.
So if you only have one dimensional detector ray,
so what we explain to you, you do rotation.
So you do half circle or full circle rotation.
You collect enough data for you to reconstruct cross-section
using, say, filtered back projection
or iterative reconstruction algorithm.
So after you get one cross-section image,
then you translate the patient a little bit.
Then you do next cross-section.
So this is step and suiting mode.
So you do one cross-section, you move to next.
So you need to accelerate the table.
De-accelerate the table.
Do one circle scanning.
Do it again and again.
This is time-consuming because the anatomical structures
and the pathological features generally are in 3D.
So you cannot let the patient hold the breast too long.
So you do one slice after another.
The throughput is not good.
Motion artifacts is an issue.
So spiral scanning is a great idea.
You just ask the patient to stay still, hold the breast.
Then table translation and the actual source
and the detector rotation and the data acquisition
are continuously, simultaneously performed.
So if you just view the actual source
from a patient perspective, the actual source
will trace a helical trajectory.
That's why we call it a helical imaging.
And here you see the data truncation.
The second generation is too small.
So data is transversely truncated.
When you use a comb beam scanning,
when you use a helical scanning,
the data is longitudinally truncated
because you use a helical trajectory
within any transverse plane.
You do not have a complete data set
for 2D image reconstruction.
So this is a spiral, single-slice CT.
It's further illustrated.
You see the imaging geometry.
So you have a nice helical around the patient.
So how do you make the trick
so you can still perform image reconstruction?
Because with helical scanning and so on here,
if you want to reconstruct this xy cross-section,
ideally you should have scanning geometry
within xy plane, but actually you use
this green helical scanning geometry.
So only at this location you have in-plane x-rays

you measure that you have line integrals
as we explained to you.
Then immediately the x-ray source moves out of plane.
So you have x-rays above the plane.
You have x-rays below the plane.
And to perform image reconstruction
for the xy plane, for example,
any line through this cross-section,
you should have x-ray line integral measured.
Particularly this ray A, you need the value,
the line integral value measured along ray A.
But in reality, you have a ray above this ray A,
you have a ray below the ray A.
You couldn't measure line integral along the ray A.
So that's the problem.
What do we do?
So engineers say this is an easy problem.
And use helical scanning, we got benefit.
It's just continuous table motion.
No acceleration, no de-acceleration.
And the patient lying on the table,
say, how do you brush?
Just the table going through.
Then the patient asks, what to do next?
And the technician or staff member
just tell him or her that you're done.
So it's very quick.
So for the speed, for the temporal resolution,
the advantages, and you have to do this trick.
You perform linear interpolation.
Upper ray, lower ray, then you got two numbers.
And the number in between, you think,
this is a linear, linearly changing process.
So you perform linear interpolation.
And you can synthesize in-plane data set,
then you use filtered bioprojection.
So that was the first try, indeed.
And the second method, a little bit better.
You perform helical scanning.
You do have an upper ray and a lower ray.
Instead of using nearest rays of same orientation,
you could say, before you reach all the way to this position,
and you got this position, you shoot an opposite ray.
So with the opposite ray closes to ray A,
the interval or the distance between measured
and to be estimated line integral,
the distances become little, the range become little less.
So the narrower the range, the more accuracy is expected.
And so the half scan interpolation
would give you better longitudinal resolution.
Longitudinal image resolution along z direction,
normally is not as good as what you expected
for in-plane resolution.
So in early years, Sbarro City was introduced,
and radiologists enjoyed temporal resolution.
Then they see motion blurring along z direction,
because the interpolation process is involved.
Because the patient is continuously pushed
into the CT scanner, so you have motion blurring
along the motion direction or the z direction.
Just like you take a photograph,
and if you're running, so you see motion blurring.
And they say, no free lunch.
You have better temporal resolution.

At the cost of compromised longitudinal image resolution
or longitudinal blurring, because the patient is in motion
when you do data acquisition.
So this is the time when I just graduated.
So I found a job with St.
Louis Washington University
Medical School.
So that time, helical CT was introduced.
And we did some analysis about helical CT scanning mode.
See, for conventional step and the shooting mode,
you have multiple circular scanning geometry.
And for each scanning circle, you can reconstruct one CT slice.
So this is what we explained in the previous lecture.
You do so multiple times.
But with helical CT, instead of you do single circular scanning,
you do one continuous helical scanning.
And for each helical turn, you perform data interpolation.
So you can synthesize data site.
You can perform, say, imagery construction here or here.
Because this helical scanning is continuous.
So while you are going to center your central slice,
it becomes arbitrary.
So you have libraries to select many longitudinal locations.
Then you computationally synthesize many planar data sites.
And you can reconstruct many, many images.
This is called retrospective reconstruction.
So this is interesting.
So this observation is interesting.
Why is that?
Say, you do long tumor detection.
There is a chance that the tumor just
stays between two slices.
So with conventional scan, this is top slice, bottom slice.
And then the tumor stays just between.
Then you have a partial volume averaging artifacts.
So for each slice, you couldn't see the tumor very clearly.
We really want to see small tumors.
If the tumor only half into a given slice,
you couldn't see very clearly.
And then you have image noise.
So that's not very clear.
But with spiral CT, I mentioned that the longitudinal position
can be arbitrarily selected.
Then you have a real opportunity.
You just do the reconstruction densely enough.
One of the slides will happen to contain the tumor.
So you have very good contrast resolution.
And then we make this journal paper.
So we published in medical physics.
And then we performed linear system modeling for analysis.
And the knowledge I told you in the first part of the lecture.
So our key conclusion, a theoretical conclusion,
is that for given X-ray dose, you send a given number
of total X photons.
You will shoot either in conventional mode
or helical mode, given X-ray dose.
Helical CT would allow substantially better longitudinal
resolution than conventional stepping and shooting.
Due to the inherent retrospective reconstruction
capability.
So we wrote several papers.
We specifically suggest that for given one helical turn,
how many slices, roughly three to four slices,
you need to densely reconstruct.

So we show in this paper, in that way,
and the helical CT would not only give you
better temporal resolution.
It will actually give you better longitudinal resolution.
So no loss.
That's something important for introduction
of helical scanning mode.
Otherwise, they say, you do helical scanning,
I gain temporal resolution.
I lose longitudinal resolution.
But we say, if you do reconstruction right,
you do overlapping reconstruction,
you can have better longitudinal resolution
and better temporal resolution.
So this is a piece of work we did earlier.
So helical spiral CT started with single slice,
with linear detector ray.
And I said that you could use, you see,
this two-dimensional ray.
Then you have a cone beam helical spiral CT.
So for cone beam spiral CT, the data truncation,
shown here, actually solves it.
And then you have a, if you have any plane cutting
through the patient, so the actual beam
will form a fan beam here.
So this fan beam is longitudinally truncated
because the patient is a long object.
And given the detector size,
you cannot have all the data,
the entire actually cone beam
cover the patient completely.
And you may only interested in heart or inner ear,
so you cannot cover patient
with really huge cone beam.
So your data become naturally truncated.
So that's why we say data truncation
is important for helical scanning.
And this is the paper I wrote early 90s,
General Cone Beam Reconstruction Algorithm.
So we say for cone beam helical scanning,
and the beam is in divergent geometry,
you cannot simply perform linear interpretation.
So mathematics is more complicated.
And this paper happened to be the first paper
for helical cone beam scanning.
And this paper got a good number of citations.
And nowadays the multi-slice
cone beam helical scanning is widely used.
And the number of CT scans
every year worldwide is between
100 and 200 million
multi-slice cone beam CT scans.
So this is a very high number.
And the paper I wrote,
I mentioned the helical cone beam paper,
we didn't file any patent,
but that turned out to be the biggest mistake.
So if we file an IP,
that will be tremendously valuable.
And helical scanning involves multiple technologies,
like sleep ring, I will mention later,
X results, and also reconstruction algorithm.
The software scanning model is important.
Just take an extreme case,

say each helical scanning we think is not that valuable,
just give me one cent.
If you get a million scans each year,
just for one scan,
so each year you will get one million dollars.
So this is probably the biggest mistake
we really should file IP.
Anyway, so we wrote the first paper,
just to show your peers and minds,
the prototype of this process is
the algorithm we developed.
Anyway, so the longitudinal data truncation
from a single slice,
single slice you do helical turn,
you have a parallel beam, adjacent race,
you can perform interpolation.
But when you have a wider angle cone beam,
you need a more advanced algorithm.
So the first paper I wrote on cone beam helical scanning
is a proximate algorithm,
then it took our whole field
about a decade,
over a decade, and then we come up
with this so-called
exact helical cone beam algorithm.
So it looks like it is still in
filtered back projection format.
The author, Dr.
Katowice,
is a mathematician, so the paper is very dense to read.
But anyway, you know the filtered back projection algorithm
can be worked out.
And the paper, usually engineering students
couldn't follow completely.
Just to let you know,
there is an exact algorithm, so modern CT theory
can deal with longitudinally truncated data.
And earlier I also mentioned
data truncation,
the second generation geometry
is transverse data truncation.
Helical CT is the problem
of longitudinal data truncation.
Symmetric to that problem,
we have transverse data truncation problem.
This is even more interesting.
So what do we mean by transverse data truncation?
Think this green base is your cross section.
The blue one is the region of interest.
I may not be interested in your whole cross section.
I only want to see, say,
your heart is the region of interest.
I only want to see in the ear structure,
I want to put a cochlear implant.
So the region of interest, ROI,
is small.
So we could
shoot a narrow fan beam
through the ROI only.
Then you do rotation like you do third generation
fan beam geometry.
So in this case,
the projection profile shown here
is transversely truncated.

Truncated both sides, you cannot use
Fourier slice theorem anymore.
So how can you deal with this transverse data
truncation problem? This is very
challenging.
And the mathematicians proved
in this case, you cannot solve
the problem uniquely.
In other words,
you have a measurement and you can just
make many structures.
All of these different
structures will give you same data.
So you do not know which one is true.
So this is called interior problem, no unique
solution.
And several years ago,
my group revisited the problem
and we solved the problem.
So that's something
we feel very good about it.
The mathematical conclusion, say, interior problem,
no unique solution, is not wrong
actually.
But if we introduce some
prior knowledge, like say,
within this ROI, we have a sub region
over which the X-ray linear
coefficient is known.
So if you have
this assumption, and we theoretically
proved the interior problem
can be solved in theoretically
executive fashion.
So the small
sub region, like this orange
region here, could be air in your airway,
blood density, blood in your aorta.
So you have some structure you know.
So with that as a reference base,
and we can reconstruct
image over ROI from truncated
data.
And I call it interior
tomography.
And the reviewers
liked our work, but they also
asked some questions.
And one of my
students tested the blood density
for white, black, Asian,
or African people.
Women, men,
all have the same blood density.
So we used that as a reference marker.
When you do cardiac imaging, you do not
need to shoot X-ray everywhere, just focus
on your heart.
So this will
save radiation dose.
I will mention
radiation dose is not good in the last part of
this lecture.
Then reviewer say,

When you do CT scanning, often times
you read a green textbook, they mention X-ray
contrast agent.
So you introduce iodine
into blood stream, so the blood vessel
can be seen clearly.
So your blood
density is constant.
But when we do CT
cardiac CT scanning, often times
we introduce contrast medium.
So you cannot rely on known
blood density, CT number, for cardiac CT
scanning.
So this is a good question.
It took our group about two years,
three years, and then we figured out another
solution.
We said, now let's assume
the reason of interest that we do not
have known sub-region.
So like blood
density, we do not use it.
So we assume
the reason of interest is piecewise
polynomial.
So it's just some reason
you can cut into finitely many
sub-regions.
We do not need to know
the boundary, but we just know
you can decompose the ROI
into a number of reasons.
And each
reason can be well modeled as
constant or quadratic function,
multi-variable, or generally
multi-variable polynomials.
And with
this assumption, pretty much like what we
learned, band-limitedness.
The signal is
band-limited.
Then you can use
sampling theorem to do the trick.
Now we introduce this sparsity-based
model.
We say just the number of
sub-regions.
Each region is fairly
smooth.
Then again we show this problem
can be solved.
So just show you
this example.
And with
CIP chest scan, you could
reconstruct the whole chest with all the
data.
Or you just use truncated data.
So actually it's only through this circular
reason of interest that we can still perform
a very good reconstruction.
This is real

data scanned on Siemens' scanner.
So
we know this interior tomography is not
just mathematical curiosity.
It really
gives you good
reconstruction results.
So let me just say something about
CT versus interior tomography.
So we say that
classic theory, what we learned, what I
explained in the textbook,
you need to collect all the data.
So there's a sufficient condition,
fan beam, cone beam.
So any
through the object, cross-section
or entire object, should be measured.
That means
the data should really completely cover
the object.
But for interior tomography, we only
need partial data.
So the data
only goes through the region of interest.
So with filtered back projection, you can
reconstruct the whole cross-section.
But with
interior tomography, you only reconstruct
a relatively smaller region of
interest.
So analogy is that
classic reconstruction is a global
reconstruction is like a wholesale.
And the interior tomography is very precise.
So any place you're interested, you should actually
you can reconstruct the image.
It's retail.
And that opens the door to new opportunities.
So look at this diagram.
So you shoot
x-rays only through this region
of interest, this right region of interest.
So in single-gram domain, you only have this portion.
There are data outside.
The outside
data would be useful for unimpeding, as I
explained before.
So if you interpret
unimpeding on the surface
value, you would think you do need external
data.
So you can peel the onion layer by layer.
But interior tomography is a magic.
You only need this right region
interior data.
And you can go back, but you cannot
reconstruct outside region of interest
for the internal region.
And we can perform
very good image reconstruction.
So this gives us more flexibility.
We can be more precise.
So this represents

deeper theoretical understanding.
All the green data is irrelevant
to exact reconstruction over ROI.
So this is not known before our work.
So with this interior
tomography, we can do many things.
And I have
multiple presentations.
We say interior
tomography takes less amount of data.
Less is more in many sense.
Less means deeper
understanding.
We can handle larger objects.
And we can use less reading dose.
And here, we say it can be faster.
Why can it be faster? All the scanning
geometry from first generation, second
generation, until helical scanning, all mean
to scan faster and faster.
A cone beam is better than a fan beam because
you can do data acquisition in parallel.
But with interior tomography, so here
you can achieve higher level parallelism.
So you have multiple X-ray cells and
smaller detector array.
And in limiting case,
you can have something like this.
So many X-ray focus spot.
And here we
would need the concept so-called carbon nanotube
code emission based
X-ray cells.
So you can really make
modern technology can make distributed
X-ray cells.
And the small detector element
is distributed around something like fourth
generation geometry.
Once you do this,
at any time instant, you can
collect multiple
X-ray projections.
But each projection
is truncated projection.
So dealing with
data truncation problem, then you can reconstruct
small reasonable interest.
And this
will represent
fastest tomographic
imaging speed.
You cannot outperform
this design.
Because
say the data acquisition time
is determined by speed of X-ray photons.
That is speed of the light.
And you cannot
go faster than speed of the light.
So we filed IP at Virginia Tech.
And I will mention this interior tomography
potential for cardiac imaging later.
And now let me explain to you CT

scanner architecture.
So we know
you need line integrals.
You put
together, you use filtered bioprojection
Fourier transform based
reconstruction.
Or you just
use the interior tomography to do
ROI based reconstruction.
And how you really collect the data,
you need to build a hardware system.
We call it
CT scanner.
So this is a donut-shape
structure called Gantre.
Gantre is the framework.
You put everything
together.
So if you open it up, you will
see a lot of hardware components.
You have X-ray cells and you have
some collimator or ball type.
Just define the shape and just remove
certain low energy photons.
Here we will remove some low energy
photons because you don't remove it.
Low energy photons would not penetrate the patient
anyway.
That will only contribute
to reducing dose to patient.
So you will detect
attenuated X-ray signals
after
the patient.
And you need collimator to
reject scattered signals so you can
have, we will define the line integral
measured.
And this scanner is a
magical thing.
You just look at things like
this and you translate the patient into the
Gantre, you get a number of CT images.
So internal
structure will be clearly
resolved.
And let me show you this typical
diagram.
So you have X-ray tube here,
very heavy.
So in our lab we have one
donated by GE, very heavy one.
And you have high
voltage supply to support this X-ray
tube.
And you also need some cooling
system.
When you scan patient
and you spend a lot of energy, the
tube becomes hot.
You need just
do water cooling, air cooling,
so you need some cooling system.

This is the whole Gantre.
You have a patient
table, patient is here, and you have a
detector ray.
In front of the detector you
need to have collimator here.
And the
traditional CT scan you have the
source detector and the
accessories staff mounted
on a Gantre.
Then you rotate
say half circle, one circle, then you
rotate back, go back and forth, so you do not
keep doing this way, because the cable is linked
to those components.
It will keep rotation
to multiple
circles and
the wires will be messed up.
But for helical scanning
then you have this slip ring
system.
The slip ring system allows you
to do continuous helical scanning
without a cable problem.
So you
really waste slip rings and no cable.
So the power is
delivered to the source through a slip ring.
Just a ring with some
well-designed contact.
You can keep rotation
and through the contact the data can be
transmitted out, the power can be sent in.
This is just something with very small
little fractions.
So the slip ring is a
critical technology for
the data through slip ring will be
sent to computer and local drive.
So this is just an idea shown here.
So when you design
CT scanner, I say you try to
have faster and faster
CT imaging speed.
The critical
application is really cardiac imaging.
Cardiac
imaging represents the holy grail of CT
imaging.
So I show you different
architecture, multiple generations.
Then what will come next?
So what will be CT architecture, particularly
for cardiac CT?
We have been working with GE Global Research Center
and then my collaborator Bruno
Dieman and we at RPI work together
try to find best architecture,
best scanner design for
dedicated cardiac CT scanner.
So this paper was highlighted last year.
So if you're interested, you can click, you can

find easily and all kinds of combination.
We think how to build
CT scanner, just like architecture,
how you design your room.
So we design scanner, the same thing.
But what is best architecture,
so this is what we are trying
to write a grant proposal
to meet June deadline and this one
is not covered in the review.
This is something I really want to do
in collaboration with my GE collaborator.
There's something we say, we have conventional
cardiac CT scanner.
So right now they use
third generation geometry, but with
cone beam helical scanning mode, you can call it
improved third generation
or just helical cone beam generation.
So you have this already.
Scanning
speed is very fast.
Each second
you can rotate three to four turns.
And the acceleration involved
is, I think, order of magnitude
higher than what you have when you launch
space shuttle.
So this is high
technology, a lot of high technology in it.
And the current best temporal resolution
and the spatial resolution for cardiac CT
is
500
mu m,
so micron, 500 microns.
But for cardiac imaging and doctors
or cardiac surgeons, and I have a neighbor
who is a cardiac surgeon, he says
if we can have 100 micron resolution,
that will solve a lot of clinical problems.
And we want to improve
cardiac CT resolution.
So
one way is just in the conventional
framework, but you need the higher
resolution, the higher
imaging speed is required, because you want to
freeze the motion to very
much freeze the motion to small
scale comparable to
the spatial resolution you want.
But if you rotate
too fast, the X-ray tube does not
have enough time to emit enough photons.
So there is a limit.
Then here is
out-of-box solution using our
interior tomography.
So we build this stationary
ring.
So then
the data acquisition time for conventional
rotation-based scanner, the

one second thousand view, we can use
one second for all the view.
So you just boost the flux
by orders of magnitude.
This is
just a stationary design.
You imagine
the cardiac patient lying on the
table.
You scan, you see the image immediately.
Then you feel some reason, you feel
you want more information, higher resolution.
You translate the patient out.
Then you match
this magic ring into your tomography
over there.
This stationary has
a well-defined reason of interest.
You can translate the ring up and down
or left to right.
So you make sure
this small reason of interest is in
registration to the reason you result with
conventional cardiac CT.
So this way I think
should be an out-of-box solution.
It's a way to go.
That's just my opinion.
So let's just have eight minutes
rest, then we continue.
How many of you have read the green
textbook CT chapter?
How many of you already read the CT
part?
You can see the book
is well written, but many new things
not in the book.
So please follow my lecture.
You will get more knowledge.
Thank you.
Thank you.
Thank you.
Thank you.
Thank you.
I want to ask a question.
Is this the first one?
The second one is decreasing current.
You think it's a current patch, but it's not.
This is decreasing voltage.
Should we add
the first row?
The first row,
R101.
Do you know beer is low?
Add it up.
What's the difference between this and this?
This is also added up.
Last time I asked, he said it's normalized.
Zoom in, I can't see clearly.
I can't find the book.
It's all beer is low.
It's all calculated directly.
There's no trouble.
This is 1.6.

Relative intensity.
It's separated.
S1, S2, S3.
You calculate all three.
Relative means who is higher, who is lower.
Normalize, find the highest value.
The highest value is S1.
The highest value is S1.
How much is the highest value?
You calculate it.
There's always a highest value among these three.
You take the highest value and divide it.
The highest value becomes S1.
The rest is 0.5, 0.3.
Relative.
Can you understand these two lessons?
Yes.
I need to see a few more.
After listening to the last three, I can understand.
I can't understand directly.
You have to look at it again.
Have you read the chapter in advance?
Sometimes.
Take a look at it first.
This is a basic idea.
Like this.
This is hard to understand.
Sometimes it's okay.
If you hear half of it, you can't follow it.
You have to review it.
This is difficult.
You need to have an idea.
Thank you.