Course on Introduction to Medical Imaging and Analysis Softwares
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Module 01
Lecture 01: Introduction to Medical Image and Analysis

So welcome to the first lecture on medical image analysis. So today I am basically introduce about what we are going to do and overview over this particular subject and what makes it seriously so much of interesting. I am an associate professor Debdoot Sheet I am an assistant professor at the department of electrical engineering in IIT Kharagpur and my area is basically on medical image analysis, computational medical imaging and machine learning for medical image analysis problems

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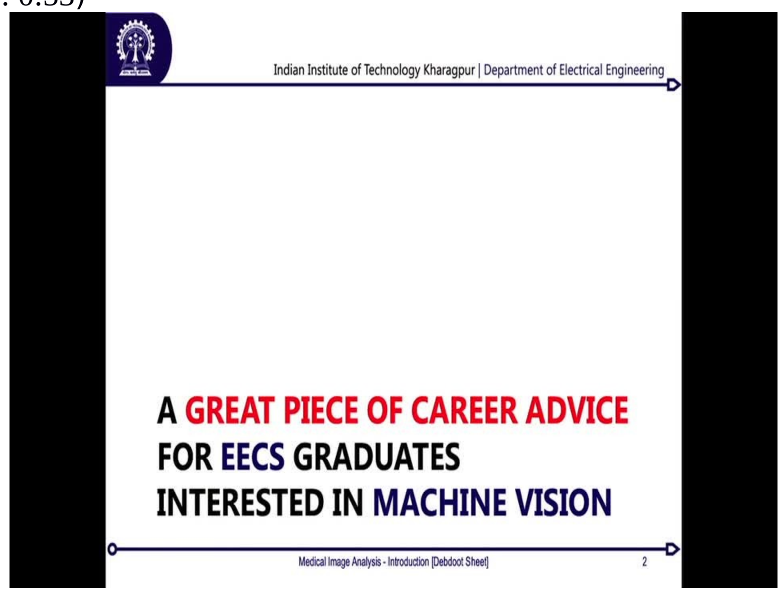

So as I said that this is a particular piece of career advice and it's a sort of I say a great piece of career advice for EECS graduates who are interested in computer vision and machine vision problems. Now the reason why I say so is actually based on lot of facts from market scenarios and how your career is going to be.

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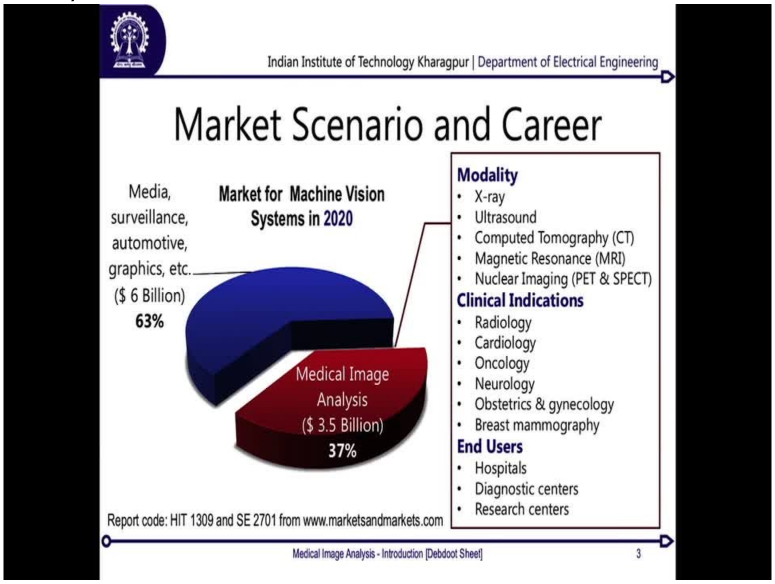

Now if you typically look into it then by the time of 2020 which is approximately a time when most of you guys are going to graduate out of yours educational careers who are taking this course now or would be sort of in your one or two years into your career over there. So around in that time this whole of machine vision market would be worth about 9.5 billion dollars.

And out of this typically three and a half billion dollars which is 37 percent of the total share would be what will be taken down by the medical image analysis itself and now if you look at particular market share it is not so small chunk in anyway and majority of this whatever is being taken down this will be across a lot of different sectors. So it will not be just focused on say hospitals or private health care centers or any particular modality which is either an x ray or ultrasound, you will actually have a quite spread across all particular modalities wherever it can go.

And this is the way how the world is progressing today that you have medical image analysis impacting possibly each and everything to do about with medicine and the major areas where it could work out in terms of modalities would be on x rays, ultrasounds, CT’s, magnetic resonance and nuclear imaging as well. On the clinical indicators which basically say about the different business verticals where medical image analysis goes into play or where actual medical use is going on over them.

So they include radiology, cardiology, oncology, obstetrics and gynecology and mammography as well. So you will be finding out that different clinical venues and different clinical avenues open up for an expertise in medical image analysis. And from there your end users are not necessarily only doctors at hospitals, they would also be including diagnostic centers which are not necessarily at hospitals they can be multispecialty clinics or tertiary diagnostic centers and a lot of research centers.

So this will include pharmaceutical industries, research labs in terms of medical imaging devices, research labs in terms of drug trials, research labs in terms of evaluating quality of health care. So all of them will be takers of medical image analysis on the longer run and that is where this all three and a half billion dollars of industries going to be catered on through.

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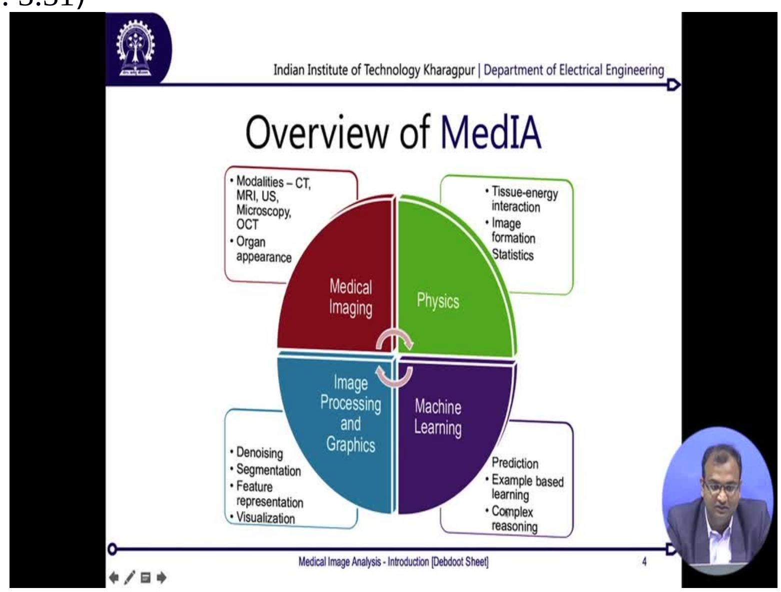

Now looking at medical image analysis, this has sort of very holistic look, so not just one single field on which you are going to work on, you have four different quadrants as I say and most of us in the community actually put it up (())(3:48). So it does include for you to learn a distinct amount of theory and the practices of medical imaging. So that is not necessarily that you would just be studying about the instrumentation or that agnostic to instrumentation you would just be studying about, how the clinical use is and how you make a clinical use out of certain modalities. But it is a holistic coverage.

So as we go down the lectures you will be introduced on to the physics and instrumentation of a particular modality and from there we would be moving on to tissue energy interactions which will make you understand as to how the physics part gets converted onto signals and from where your signal processing would be starting down from there signal processing to image formation and from image formation on to the whole of algorithms and everything you are going to start for understanding medical image analysis as a whole.

Now over here if you look into modalities you would be having CT, MR, ultrasound, microscopy, optical coherence tomography. Another critical part you will obviously be getting exposed to is about organ appearances module and what they mean to say over here is basically how different organs are going to appear in different modalities whether in a healthy state or in a disease state now a bone would appear brighter on x rays and CT's would appear darker on T1 MR and T2 MR.

Your fatty regions would appear brighter on MR and darker on x rays, your fatty regions would again appear brighter on ultrasound as well, whereas a water filled region which would appear brighter on MR will appear darker on ultrasound. Now different organs under different modalities will have different sort of ways in which they are viewed. So this is also what we need to keep in mind and you would be getting a exposed to them eventually and for you to make a very good career in medical image analysis you will also have to sort of go out the way beyond these lectures as well and read more about them and interact with more radiologists in order to understand how these appearance models keeps on changing and the more the better you know about these appearance model the better it becomes for everybody to go through the whole field of medical image analysis.

So from there the second sector is to understand physics part of it which is really important I mean why? water would appear darker in ultrasound and brighter in MR whereas fat would appear brighter in ultrasound and brighter in MR is where you need to understand tissue energy interactions together. And from there obviously the image formation and statistics of image formation together because ultrasound is specular modality, you have lot of jitter, noise uncertainty around intensities which you are going to see.

MR on the other hand will not have that much problem but will obviously be having a lower resolution, ultrasound will also be having a low resolution comparably might be a bit higher than MR at certain point of time but once we go into detail understanding of each of this physics and instrumentation you will get a much more clear understanding as to what we speak about the resolution and how the operating conditions of an instrument is what affects the total resolution of image formation and imaging going down over the.

So from there we would be moving on to image processing and graphics and now it is assumed that all of you actually have done a entry level pre course on digital image processing itself and we assume that all of you are aware of what image processing is. Now here we would be starting at a much higher level. So we start directly with denoising and feature segmentation image segmentation feature representations and from there onto a very critical factor which is called as visualization.

Now although graphics is not a prerequisite for doing this particular course, but knowledge of graphics is really important and even if you are not aware of that so what we will be doing is as we go down eventually through the courses and we get to know different software tools of how to use them for image analysis as visualization and graphics, I will be telling you about much more details about how to get them into much faster deployment mode.

So graphics is obviously another important part which will be making use when doing medical image analysis. So and last but not the least is the field which has grown in the recent times and has closed this complete loop and that is machine learning. So that would include prediction models and very simple example based learning problems and from there in the advanced weeks we would be doing stuffs on complex reasoning.

So there would be bunch of classifiers or group of classifiers, bag of classifiers, from there we will be getting into deep learning which is the buzz what coming down as of now and has taken the community by really a big way in how it is solving problems which were pertinently remaining unsolved for a longer period of time. So that is what is another significant chunk and if you look at this quadrant over here for this particular four weeks course each week we will be covering down one single quadrant over here such that we can close it down in total.

Except for the fact that medical imaging and physics we will be doing together and we would be giving image processing and graphics one week and machine learning one week and one another week is where I do this binder of all of them together and give you certain examples of very real life scenarios where they get into use. We take a one challenging problem, we solve it in the class and see how different people have done it and how we are going to evaluate the performances.

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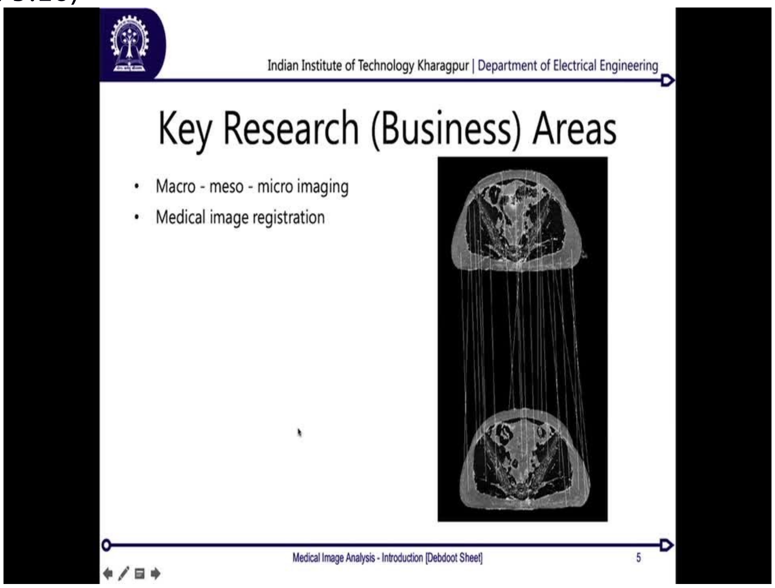

So from there, let us look into what are the key areas for research and business as far as medical image analysis is concerned. So the first is you need to understand about different modalities of imagining. So they range from macro imaging which is where the whole body gets imaged together, the resolution is obviously much lower, but the penetration depth is much higher. So you can have the complete body image but the resolution at which you can image which is a size of the pixel of the voxel or two neighboring points which you can distinguish on that image is much further apart.

So voxels will be of the size of few centimeters over there. From there we come on to mesoscopic range imaging in which we get this new modalities called as optoacoustic imaging modalities. So what they basically do is they have a resolution which is close to microscopy which is in micron ranges, but they obviously have a depth of penetration which is in the order of a few centimeters which is very much closer to the micro imaging mode.

But the down side is obviously they have a much limited field of view in order to achieve this one. So there is a tradeoff over there. And to micro imaging which is when you have resolution at the level of microns and that is when you are going to use modalities like optical coherence, tomography or histopathology for digital pathology application is where you get them. So in this particular course we are going to study applications, imaging physics, instrumentation across all of them so that we can give you a complete flavor of all different sectors or at least most of the different sectors where medical image analysis is being used today.

Although, just a small course with 20 lectures is really not so sufficient to do a justice to the complete field which is doing at a rate much faster we can imagine with at least four papers coming each day at this current year. So one classical area for medical image analysis is medical image registration and this is about say patient goes for a scan of a CT scan today, a patient goes for a CT scan after six months but at a different location at a different center with a different CT machine.

The resolutions are different, the patient has obviously might have a body change as such, might have loss some weight, become thinner and stuff. Now the doctor wants to actually relate between what happened six months ago and what happens today for different points. But then the images are going to look very different and they are bit warped around each other, they need to have some sort of an alignment between what happen what location was present on that image six months ago to a location present on the image today.

And this is the whole field which is called as registration where you are going to register point to point and say that six months ago this point looked this and this is a major area in which medical image analysis has been working and has been an active research and has been an active research for the last 30 years or more than that.

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From there the another interesting area is actually organ localization and this is where on whole complete images you need to find out organs itself. And this these are where algorithms actually make a way of making it much more easier for a life of a clinician rather than wasting a lot of time for them to search out over volume spaces. And as you know that although we are imaging in 3d but say your computer screens or x ray films on which they are looking at they are inherently 2d, they cannot see a 3d.

So they are basically looking down into a frame of such 2d images coming down, a train of such 2d frames with them. And over them mentally they try to correlate and visualize how an appearance would be in the 3d spacs itself. Now would not it be wonderful to actually have algorithms which can find out in the 3d and segment them out and localize out different organs coming down over them.

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Now from there another interesting area is on organ segmentations. So once your localization has been over, then you can segment out so that you can get the volume information, the surface information and if you have say live imaging going on as in on a CT angiography or an MR angiography where you have very fast scanning going on such that you can see organs in motion itself. So now you can actually look at how is the organ expanding and contracting whether all expansions and contractions are isotropic or non-isotropic.

So this is another critical one which would critical area which has to work on for organ segmentations as well.

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So from there recent area which has been on really looked out throughout the community is on visualization using augmented reality for visualization. So this is where in a classroom a doctor is trying to teach students about how different kinds of fractures can be there on a bone and then try to find out like what would the bone look like without a fracture. And imagine that you are able to do it looking as if you are looking at actual (skel) skeleton and trying to do it.

Now you do not have any classical means of doing it on 3d other than trying to have an augmented reality come into it. And this is where the community is taking it long way and we would come down to a certain examples where we would be showing you how visualization improves the way which this delivery is happening in the field.

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Now from there to virtual anatomy, and this is basically the field where you say you have a complete MR scan or a CT scan of your body done. And now your whole anatomy which is every organ every single tissue every single bone is digitized over there, segmented, digitized in a digital model. So your body is equivalent to a cad model which you can carry along with them. So now if a doctor wants to find out internal injuries or certain legions or certain diseases within your body they do not need to scan through every single x ray reports over there which is much more tedious but actually can look into your whole body.

And imagine this to be something like this on cad models as engineers you would have always laid down different transparency levels when you are looking into them and then you can see down different objects coming in and out. Now the same way if a doctor can do it with your body would not that be wonderful for the diagnosis part over there? So we will be touching down upon virtual anatomy and how we create those as well.

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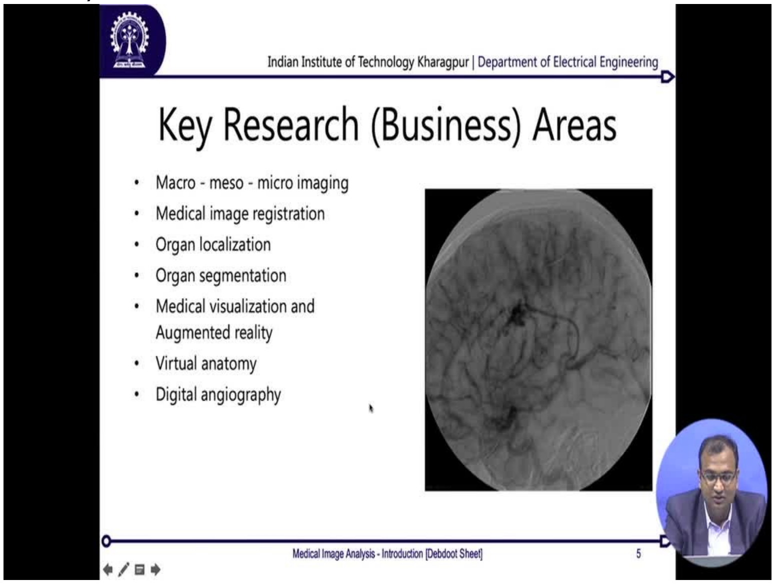

From there another very critical application is obviously digital angiography or what also called as digital subtraction angiography. And this is where is a technique in order to find out where there is a deposition of blood or regularity in flow of blood. It has immense applications from cardiology to neurology which are two major takers over there and has been on an active area of research for than more than 30 years as of now.

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From there we come into another interesting area which is about despeckling and that is very much related to speckle imaging modalities like ultrasonic or optical coherence tomography where you have lot of speckles coming down which lead to tediousness in the way in which images need to be interpreted and it cannot just be a denoising because that would get rid of edges and very salient behaviors. And there are very specific ways of how to solve them out.

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So from there we enter into 3d optical microscopy and this more the medical image analysis it has immense applications in life sciences till now and is finding definitely immense applications over here as well. So this is a 3d model of a neuron image under florescence for different layers over there which were segmented and again resynthesized by alignment so that you can look into the complete 3d model and view how a neuron looks like and how they different processes are going down on over there. So this aids a lot of scientific discovery and something which is upcoming on the field called as precision medicine.

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So from there, a very critical one is digital pathology which is extending a pathology which is extending a pathology scapability via digital means. So a pathologist no more needs to be at the center where the slide comes down. So say there is a collection center which is thousand kilometers off from where the actual pathologist is located. Now transporting a physical slide for thousand kilometers would take more than at least a day's time within current infrastructures which is available throughout the world, most of the places in the world.

So instead of that a thousand kilometers over a digital communication mean would basically be a few seconds of delay or even lesser than that. So it is easier to communicate images than to actually physically communicate the slide and that is where digital pathology is finding a big niche area of business and where medical image analysis is impacting it in a significant way.

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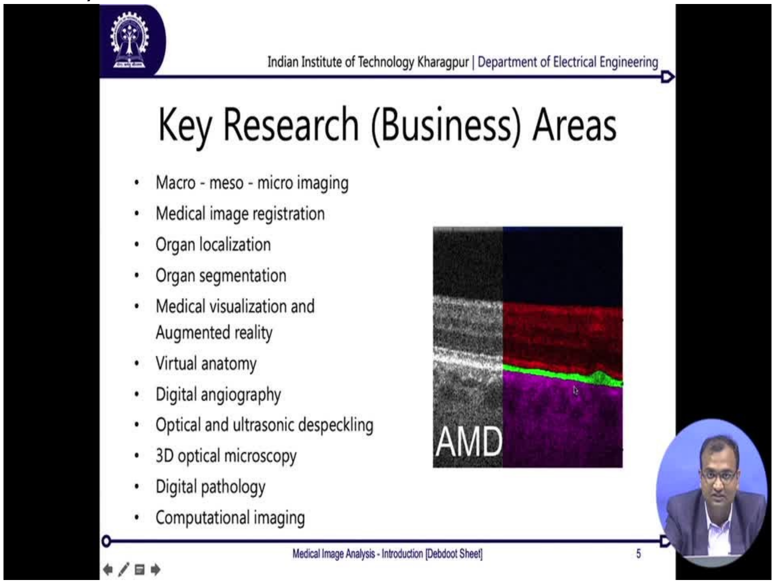

From there to computational imaging which is about synthesizing virtual equivalents of astrologies and different organ types or different pathology types by looking at simple images and simple signals from imaging modalities. We will be coming down into much more details and interesting over here. So what you see is basically different layers of a retina for a from a patient for age related macular degeneration and very specifically this thin layer over here is called as Retinal Pigment Epithelium, RPE and if you look at this particular image it is really hard to distinguish because it is in a band of white zones whereas this is a much thinner layer.

So how we are using computational techniques in order to do it is about computational imaging as a whole.

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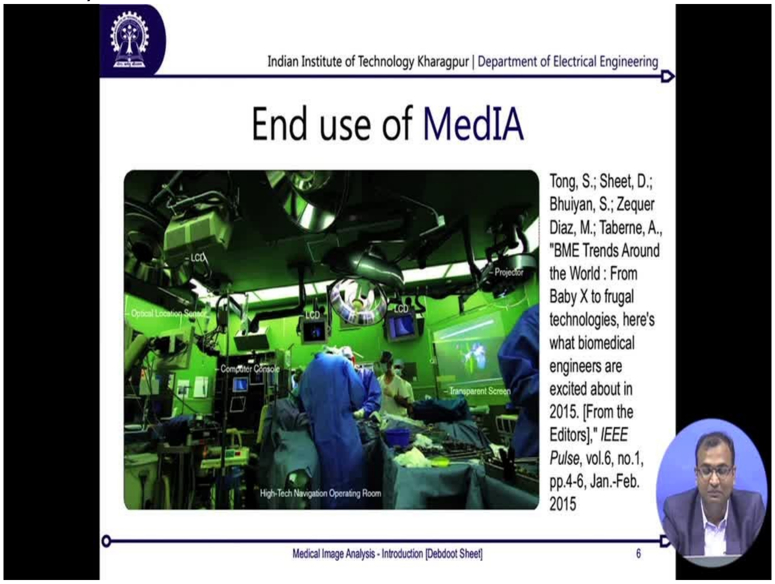

Now at the end of it you have lot of fancy algorithms, but the question does come as to where are you going to use them. And the main use is actually in operating rooms of the future and when I say future it is not so far away future as such because in 2015 we had done a small cover article for I cube E pulse on which this is the view from one of the hospitals in Japan where they are already using medical image analysis during treatment planning and during the surgical process going down in operating room.

So the way this has changed is the decision process what surgeons need to take, what physicians would be taking down for diagnosing people has been revolutionized in a very significant way and that is how medical image analysis is going to impact significantly of how our wellbeing and our treatment is on the future. So it is basically a field which is going to impact you possible the most because humans are the biggest benefactors who will be for medical image analysis in the future.

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Now let us come down to a break even of what we are going to study. So week one I would be touching down upon introduction and few of these imaging modalities and how tissue and edgy interaction happens organ appearance in each of them. Two week two we would be doing a bit of advanced topics on image processings including textures some of you might have done some courses on textures for image processing as well.

But there would be bit more of regular texture descriptors which we use in prospective of medical image analysis. From there we would be entering into region growing, random walks, active contours models for segmentations and evaluation and validation. And on the third week following that I would be entering into machine learning techniques starting with decision trees, random forest and neural networks and from there going on to how deep learning is being used for medical image analysis.

From there till week four we would be touching upon five very specific case application area scenarios in which we do retinal vessels segmentation, then CT lung CT vessel segmentation. So although both of them are vessel segmentation problems, but here it is on retinas and the images are RGB full color images whereas, in the second case it is on the lung which is a different organ and it is on CT which is grey scale image. So the way of modalities and everything is different, although the organs are maybe similar type of structures which we are looking at.

So can we have similar kind of operators which we use? Can we have some sort of understanding from one field to the other field? or has one field help in collaboratively developing what the other field is doing? This is what we are going to learn and really enrich ourselves on week 4. From there I will be entering into brain MR lesion segmentation from a very promising challenge in the recent years.

From there we enter into tissue characterization which is where we study about the initials about virtual histologies and computational imaging. And from there I would be entering into histrology segmentation which is a very promising area as prospective of digital pathology and to come up in the future days as well.

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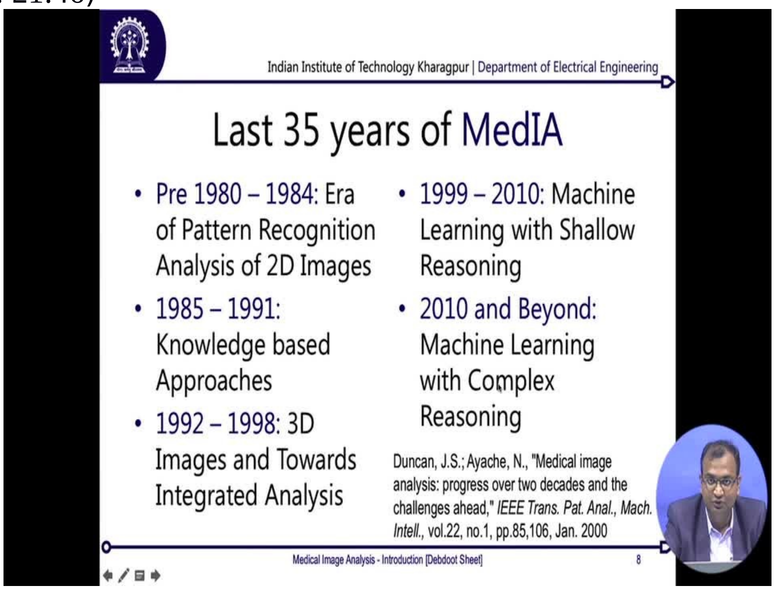

So with that let us look io what has happened for the last 35 years in medical image analysis now? This is based on a review from Duncan and Ayache in tami in 2000 January. Now this was a somewhere around from 1980's till the year 2000 from 2000 to 2016 when we are recording this one and you are looking at it. So this is where you can just add on to them and you will be getting down what the beyond scene is.

Now this era up to 1984 was basically when pattern recognition and analysis was carried on 2d images and from 85 to 91 is when knowledge based approaches started coming down for the first time. So you have stuff like rule based analysis and rule based influencing which came down for the first time at that point of time. From there in 92 onwards what happened is that a lot of 3d imaging started coming into play and a lot contribution was basically the way in which storage technology was doing down was revolutionized, we could store much larger amount of data.

Processes where becoming faster the silicon fab process was really going great. So we could actually with this faster processes we could process larger chunks data in much smaller time or within a human time period. So maybe a whole volume of a human body CT could now be processed in so as of today you can process it in a couple of minutes, so at that point of time it was basically 24 hours.

So expected that the patient is not going to die, so now you have the enough of computing power in order to do a 3d processing as well. And that is how these algorithms were developing, so from 1999 to 2010 was the era of a Shallow Reasoning with machine learning and that is when again you have lot of compute power and your Pentium processors from there to core i family of processors from Intel coming down which really helped in this whole development.

And from 2010 and beyond what happened was real booming in the field of how neural networks where doing and how deep learning was coming up over there and that is when complex reasoning started to getting up. So a lot of approaches which happened and lot of development in this phase did play a lot of (())(23:55) but then again all of this knowledge which was being learnt in this phase was just phased out in one single day because of this complex reasoning and hierarchical learning which came around this period.

So eventually when we go to those lectures I will come to them, but then only one word of caution is that if you can solve it in a simpler way, please do not go to this complex way. That is a word of caution which I generally exercise and request everybody because the computational overhead for training and testing is much higher with these complex methods. So until the problem is really something which is worth solving in a complex way generally try to solve to in a much simpler way. And the simpler model is always the better one as per (())(24:35) which most of us know about.

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Now let us look in to what challenges are there in 2017 for medical image analysis and if you look gradually through them so one of this famous one is the CAMELYON2017 challenge which is automated detection and classification of breast cancer metastasis. Now this is upcoming for ISBI which is one of the major conferences. We have it listed down the line as well.

The next one is about prostate lesions segmentation, then you have the very famous multiple sclerosis segmentation from brain MR we will be solving it as one of our exercise problems later on in the last week. And you have some interesting problems called as M2CAI and this is where you look into interventional videos which is about surgeries being performed and using this videos of surgeries being performed and pre-operative data which is pre-operative MRs or CT scans can you come down to a much better form of doing a surgery.

So this is when computers for the first time are interacting along with clinicians during the surgical procedures and helping them improve the way they are doing a surgery. From there to you actually have some places see on kaggle was this ultrasound nerve segmentation challenge where you could actually win about a 100k dollars as well. So definitely you know that you can also make money by image analysis at some point of time.

So you definitely follow it up on kaggle . You have many more challenges as well coming up on kaggle for which are related to medical image analysis.

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Now one of the main sources where you can get an idea about what these are as to go on this particular website which is called as grand challenges dot org. And over here so the day when we are recording this lecture we just had to off the challenges for 2017 coming down. But down the list if you look on so you would be having many more challenges. So all the earlier challenges from 2016, 15, 13 are listed over there and you can the whole data is available online and you can download and use it free of cost, you do not have licensing issues for most of them.

So this data is what plays a significant role in evaluating performances of your methods, and if you are looking for data sets this is one of the places where you should definitely visit and try to use. Now I mean assuming obviously since you are sitting down for medIA class you are definitely a career aspirant for medical image analysis.

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And the first thing which I would say is find a research challenge which is most important and grand challenges in biomedical image analysis this particular website is the place where you can find out one research problem in order to…

You will get plenty of other research problems on MICCAI which is the annual conference of the MICCAI society and this is a place which is this is the top most conference as far as medical image analysis is concerned. another top line conference is obviously at ISBI so definitely find out certain problems and more papers and areas to work on at ISBI. You have another top line conference which is SPIE medical imaging which is happening which happens every year in the month of February itself so keep an eye on them as well.

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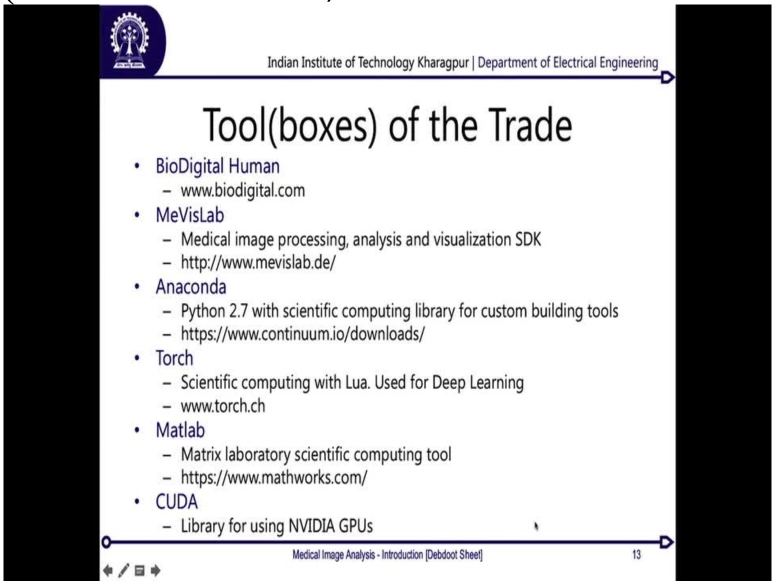

So now that you know your problems, the next comes as to what tools do you use for it and that is where we come into the tool boxes of the trade as I say. Now first point is you need to understand a lot of anatomy, without that it becomes really hard. The best way of doing it is to go on BioDigital human is reading through medical textbooks on anatomy is something of the past, as engineers we are not used to reading too much of bulkier text. The best way is to actually go through a puzzle solving game on BioDigital human, so you can change down you can look at a skeleton system so say you want to look at the skeleton system and the nervous system together, so you just have 2 clicks over there and a CAD model kind of superposes one on top of other you can choose.

So, you learn down anatomy in a much better way and would possible be saying that why we did not have this when we were doing biology somewhere in middle school and high school. the main tool we use for most of our algorithms as far as basic image processing and visualizations is concerned is called as MeVisLab. This is a open source, free to use for for research and development purposes, so you have a commercial license though, but for education purposes that is free. So do make use of MeVisLab.

We would be making them for we will be using them for few of our tutorials as well which we will be covering. Next is most of algorithms we write down is preferred to be on python so that they can be inter device compatible and you can use these python scripts again within your

MeVisLab as well, you can define your own algorithm within MeVisLab and push it within the pipeline. So MeVisLab is something which look similar to Simulink in matlab where you have boxes and you can drag and drop boxes and connect between them and solve the problem, so MeVisLab is a similar one.

Python so keep in mind we use python 2.7 for doing it and the reason is that all the image related libraries are available on 2.7 and it is much more standardized. From there for our deep learning applications we would be using torch which is a scientific computing environment based on Luas. So in the successive lectures where each of them come we have much more detail about how to use them.

And obviously Matlab is sort of an indispensible tool as much as most of us are concerned from for trying out basic hands but definitely not a very preferred tool from the final development and deployment prospective as such. And CUDA which becomes indispensible at the age when for high throughput computing you would obviously be needing GPU's from NVIDIA.

So this is another library which is very important and as we go into deep learning and when we do our torch experiments we would be doing more details about how to use them as well.

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So where to read is you can prefer to very specialist literatures which include the major journals, the first journal is obviously medical image analysis the same name as for the topic. From there you can move on to transactions on medical imaging, on computational imaging, then journal or biomedical and health informatics which was earlier known as IEEE transactions on information technology and biomedicine.

the recently launched SPIE journal of medical imaging is another treasure trove and a very established journal on the field is computerized medical imaging and graphics which is real big treasure trove for finding out age old and to track the progress of this particular field over a long period of time. So for general reading obviously I suggest that you read through other topics on biomedical engineering and image processing as such and definitely have a look through a journals on computer vision graphics because a lot of times we do share across multiple communities into ways of how things work.

So certain algorithms and how they work for computer vision have a lot of times inspired the way medical image analysis has solved a certain problem for one area which was not solved in computer vision as such and has been vice versa as well. So I we definitely suggest that you do a cross disciplinary reading as well.

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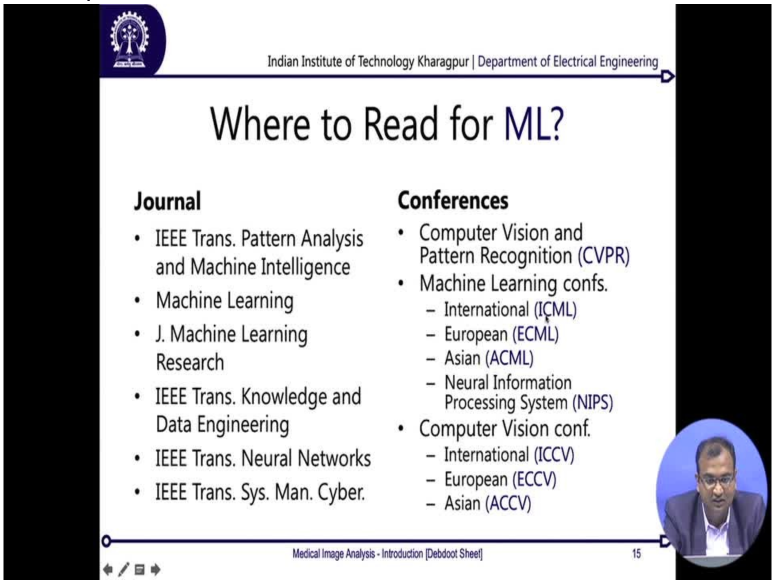

From there you would need to understand about machine learning because that is the very significant as far as medical image analysis is state of art today. So for journals you can read it from pattern analysis and machine intelligence from machine learning from machine learning research TKD transaction on neural systems and TSMC.

And as far as conferences are concerned definitely go through the major top of the line conferences which includes CVPR to say at least and for machine learning definitely (())(32:23) ICML, ECML, ACML and for general computer vision would be ICCV, ECCV and ACCV. So have a look through these ones which are definitely a big treasure trove.

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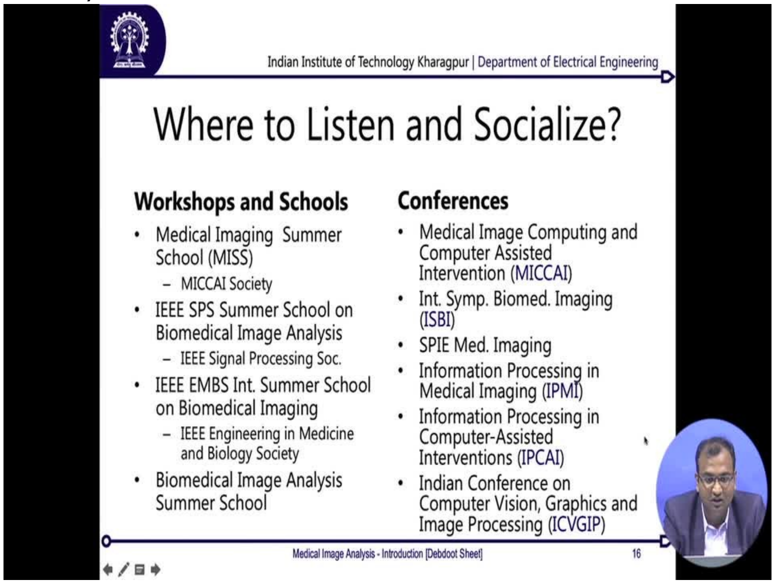

Now as far as medical image analysis is concerned, we have very specific workshops and schools going on annually and globally which include the MISS from MICCAI society, there are from signal processing society of IEEE, there is from EMBS as well. So you can participate and look out for regular interactions so they are generally week long schools where you have much more holistic coverage, much more depth coverage and have a small interaction workshops as well.

You can get a much detail understanding about the field and it is generally prestigious to attend these ones with scholarship provided by most of them for attendees as well. So for conferences you would be having an eye on MICCAI, ISBI, IPMI and IPCAI. And definitely our Indian conference on computer vision graphics and image processing has a very special session called as med image which is on medical imaging and hosted on one of the day.

So this is what happens every two years and we recently completed in 2016 December. So you can have a look for the papers published out over there as well and for the next one to come up in 2018, be prepared for them to really go and visit and for the next future ones as well.

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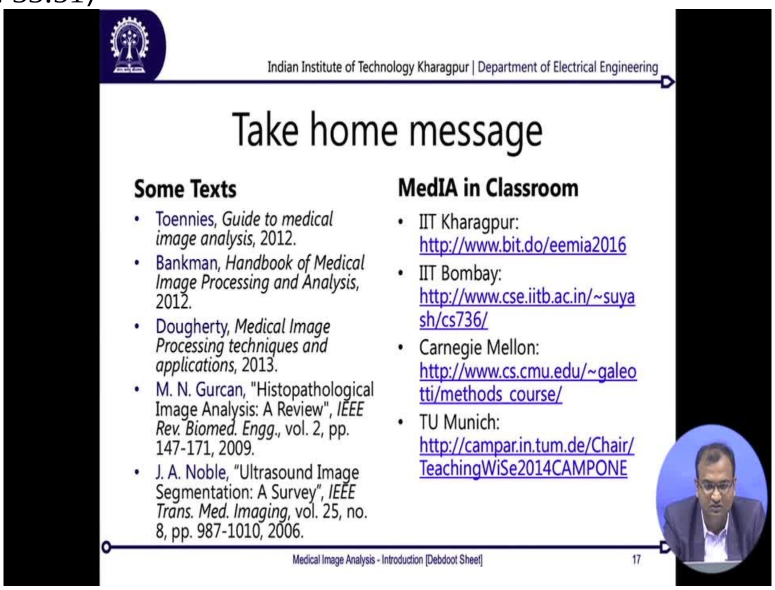

So from there we are actually at the end of this particular introduction lectures. So as a take home message I have a list of few books which will be very useful for you to study form and if you papers which can act as initial indicators of it. Beyond that we do teach medical image analysis in class room at few of the universities across the world and in India.

These are a few just the few of the pointers to particular places which teach it , obviously this is not the exhaustive list of it, but is just a mere pointer. So I believe this would keep you excited to continue on with the next of the lectures and as we go on eventually we would be starting first with the imaging modalities and their physics and keep on moving down the line. So with that stay excited and thank you.