Medical Image Analysis
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Lecture 24
ML in Intraoperative Tissue Identification

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Hello guys, thanks for being here. I am Doctor Pravin, I am a general surgeon based out of Chennai. I am working in the team called Curium Life Technologies, we are striving towards incorporating artificial intelligence into the operating room. As, we work in collaboration with IIT Madras with the Department of Engineering Design and I thank professor G K Sir for this opportunity.

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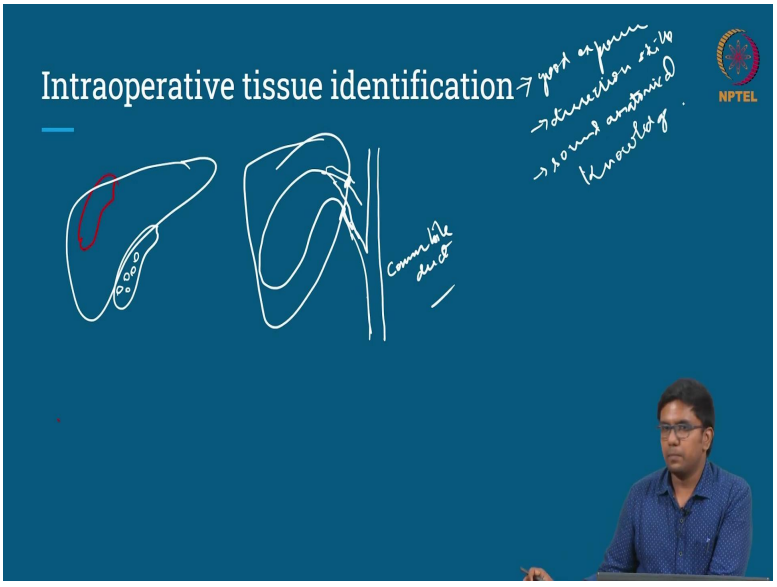

So, our aim is to minimize surgical errors and to ensure safe surgery. So, moving on to the topic, what intraoperative tissue identification is? So, the word intraoperative means that things that happened during the surgery during the course of surgery. So, during the course of surgery, it is vital for the surgeon to correctly identify the tissue only correct tissue identification can help the surgeon decide what to cut and what not to cut, what to take out and what not to take out. So, let us take the example of gallbladder surgery we know gallbladder is an organ which is pear shaped organ, pear shaped organ which is present in the under surface of the liver.

So, this is the liver we have a gallbladder and under surface of it, people tend to form stones inside the gallbladder and the only procedure that is available for the treatment is removal of the gallbladder, which is called cholecystectomy. So, this gallbladder has two connections to

it. One is the cystic duct, and another is the cystic artery. And there is something a vital structure called the bile duct, which is running alongside the gallbladder. So, if you want to remove the gallbladder, you need to clip it here, you need to disconnect this gallbladder from the cystic duct and cystic artery and remove this off, you are not go you are not supposed to go and meddle with the common bile duct, this is the common bile duct.

If at all some injury happens to the common bile duct by mistake, if it is identified during the course of surgery, it is correctable, but if it is identified only in the post-operative period, then it is a really a catastrophic event. So, we can involve artificial intelligence and machine learning for the surgeon to correctly identify whether he is going near the bile duct or not. Experienced surgeons would not have a big problem in dealing with this, but this is especially useful for beginner surgeons. So, correct interrupted to tissue identification will need good experience from the surgeon side, dissection skills of the surgeon and also sound anatomical knowledge. So, let us deal with one example.

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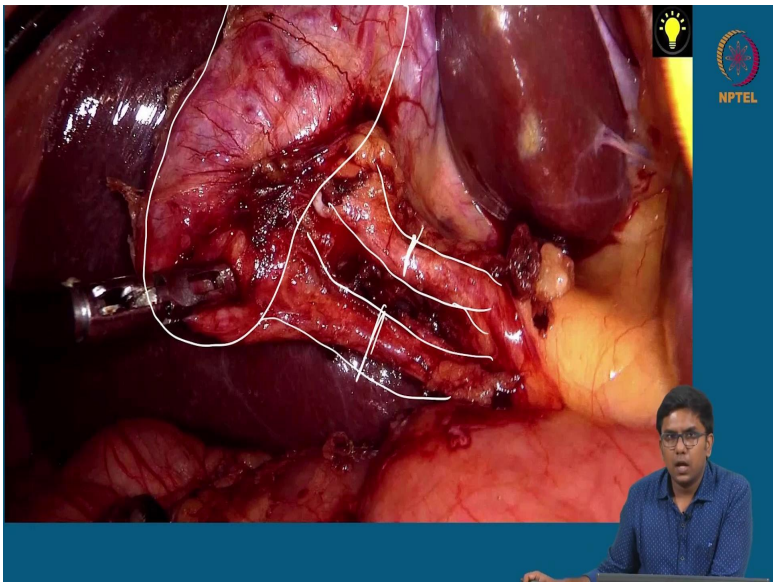

So, this is an interpretive picture of gallbladder removal surgery which we call cholecystectomy. So, this is the organ which we are going to remove it and this is where the cystic duct goes and this is where the cystic artery goes. So, in this particular surgery, the dissection has been done, quite done in a quite clean manner, we do not get to see this common bile duct anywhere else. So, the surgeon can very well cut it off here and take the organ out. Let us take another example.

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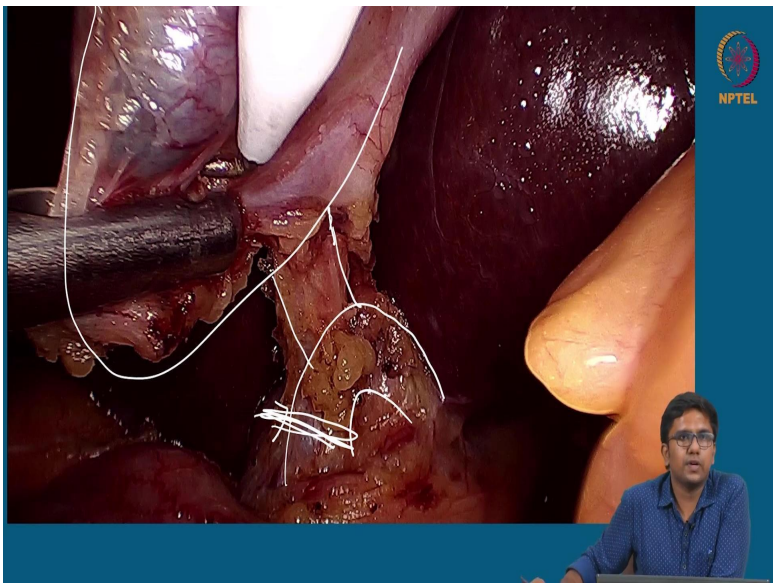

This is one another picture of the same cholecystectomy surgery, we have the gall bladder, which is over here, and the cystic duct here is very short. And the short cystic duct while operating the surgeon tends to pull the CBD here, the common bile duct here. So, we are not supposed to go near the common bile duct anywhere during the gallbladder surgery. And there are high chances that a beginner surgeon who is just starting his career in surgery can very well consider this structure to be the cystic duct go near it, clip it and cut off here. So, this is the major idea behind using artificial intelligence in intraoperative tissue identification.

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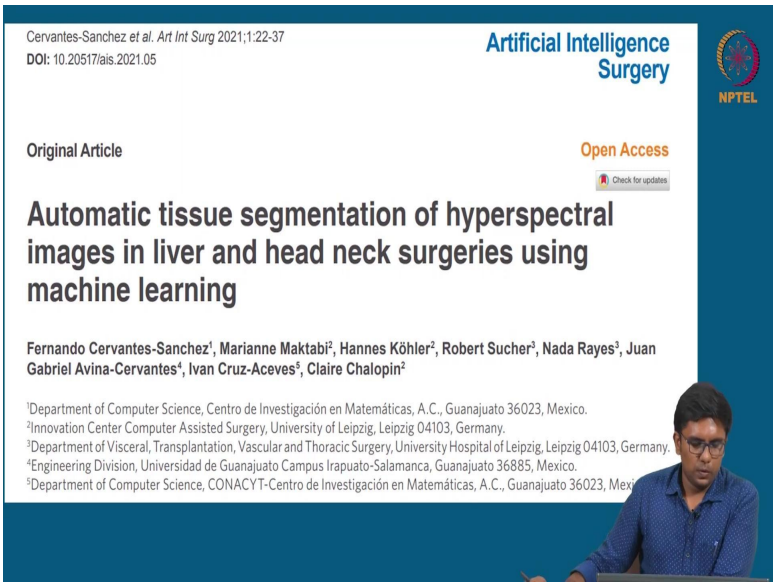

So, in this case study they have published it in the journal called Artificial intelligence surgery in the month of 2020 in the month of August in 2021, their group of surgeons and technical experts from Mexico and Germany where they have used an a novel optical

imaging technology which is called hyperspectral imaging, you guys would have been knowing about it.

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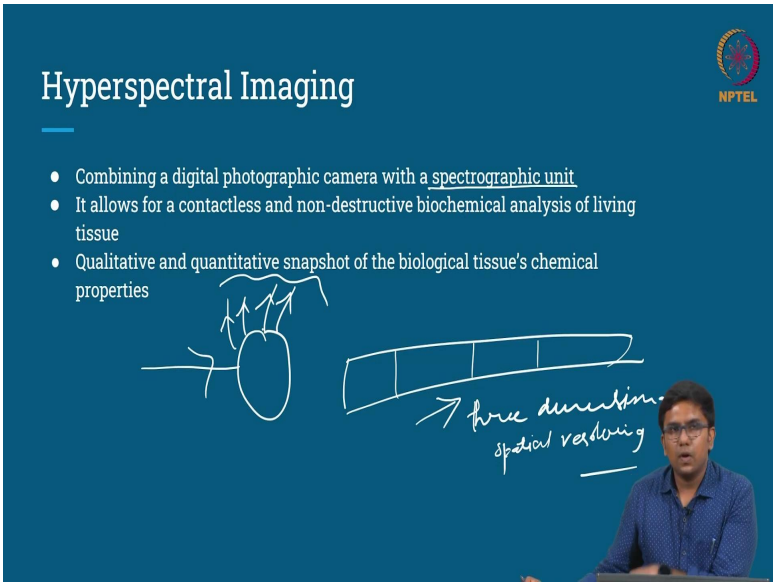

So, this is a brief intro about what hyperspectral imaging is. So, it combines the technology of a digital photographic camera with the help of along with a photo spectrometric unit that is spectrographic unit. So, we have light which is falling on an object, the object tends to reflects it and there are all the reflected signature of the light which gets off from the object tends to fall under various regions in the electromagnetic spectrum. So, this spectrographic units tends to collect all the scattered light as a signature, tends to resolve it into an entire electromagnetic spectrum, starting from the UV, IR and so on. And it tends to do a three dimensional, three dimensional spatial resolution, three dimensional spatial resolving.

The main catch behind this, this is totally noninvasive radiation free and it is a very user friendly technology. So, this allows for a contactless and non-destructive biochemical analysis of living tissue. Living tissue each living tissue will have its own spectral properties which is being utilized here. So, for example, a blood vessel, let us take the example of the liver, the gallbladder in the liver surgery, the liver, the spectral property of the liver is due to the thing called blood which is flowing in it and the spectral property of the common bile duct and the gallbladder is due to the bile, which is a substance which is inside it.

So, each tissue in the human body will have different spectral property which is being utilized in this technology. So, they do qualitative and quantitative snapshots of the biological tissues chemical properties. So, let us see this.

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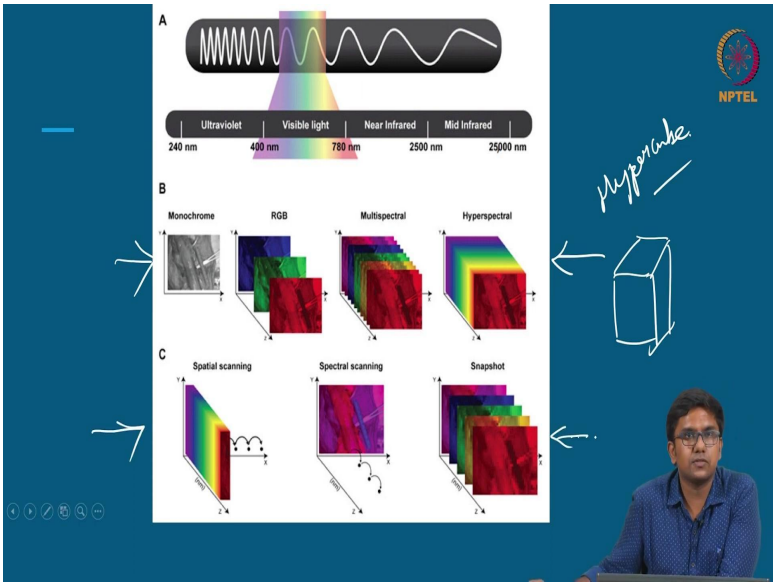

So, this is the total electromagnetic spectrum we have UV, visible light infrared and mid infrared spectrum. And the one once which are mentioned here shows the dataset which they have derived with the help of different image capturing technologies, which is monochrome, trichrome, RGB, multispectral and hyperspectral. And the one data set which we have get from the hyperspectral imaging is what is called a hypercube. This is called the hyper cube. So, the series here in C, we have describe how these hyperspectral imaging devices collect data actually.

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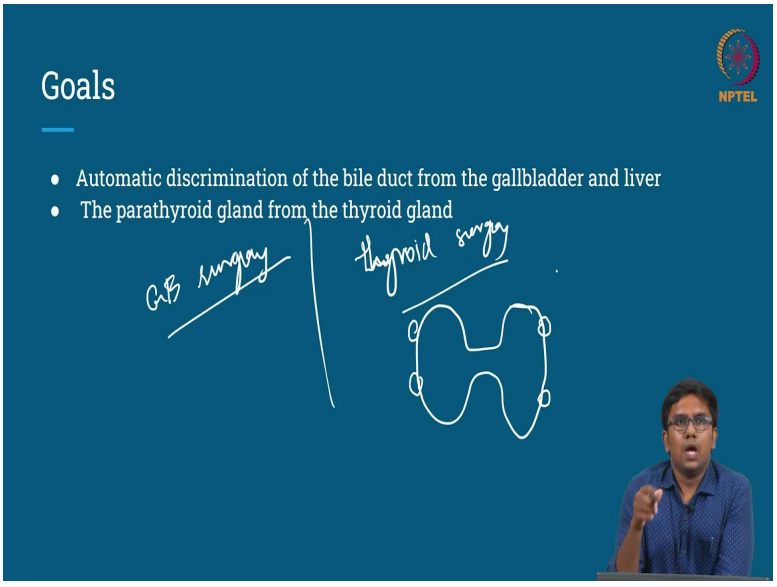

So, the goal of this study is they have taken two medical conditions that is one is gallbladder surgery and the next one is liver surgery, I mean, thyroid surgery. So, gallbladder surgery, we

have just spoken on it. Thyroid surgery, thyroid gland is something which is present in front of your neck. So, during the thyroid surgery, there is something called the parathyroid glands. So, this is the thyroid gland which is present in front of your neck. There is something called the parathyroid glands which is present on the back of the thyroid glands and the surgeon is not supposed to remove the parathyroid glands during surgery.

So, if the surgeon tends to remove the parathyroid gland along with the thyroid gland during surgery, then the patient is doomed to develop abnormalities in the levels of calcium. There will be low blood calcium levels in his post-operative period for which he needs to be supplemented with perinatal or oral calcium supplements.

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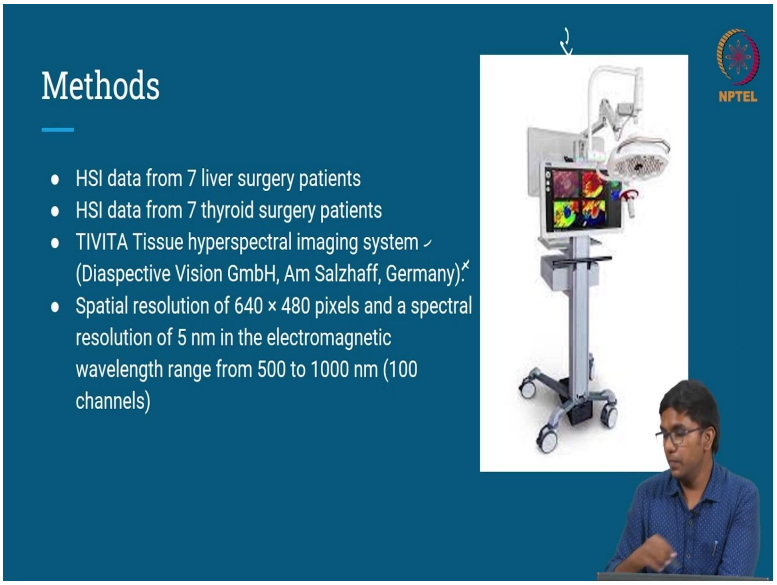

So, this is how they do it. They collect hyperspectral imaging data from 7 liver surgery patients, I mean, they mean to say it has gallbladder surgery patients and hyperspectral imaging data from 7 thyroid surgery patients and they use the tissue hyperspectral imaging system from German brand for a collection of hyperspectral data. And this system which is shown in this image gives a spatial resolution of about 640×480 pixels and spectral resolution of about 5 nanometers and electromagnetic wavelengths ranging from 500 to 1000 nanometers.

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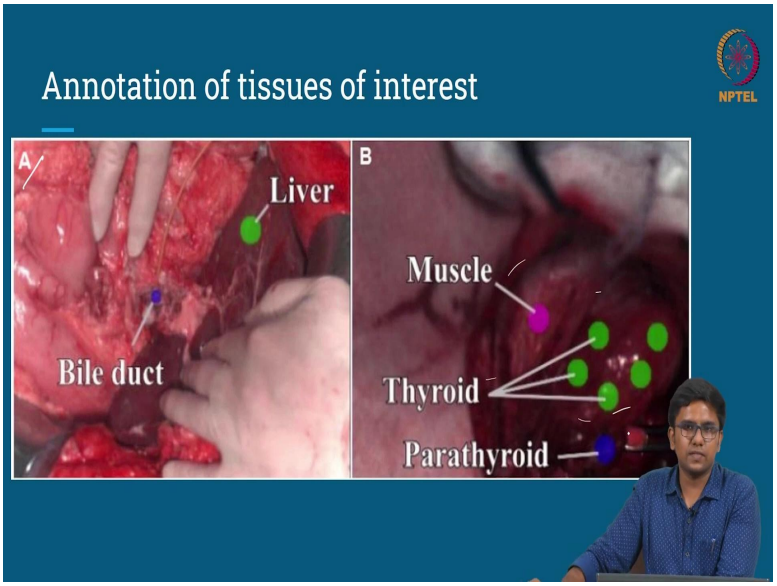

So, what they do? The data which is collected the hyperspectral image, this is what is shown here, the one on the left that is the picture A they show where the liver and the bile duct is. Surgeons are involved here and annotation of this data they are not doing a semantic segmentation or complete manual annotation of the entire thing, but they just allow it to label. So, this part is liver and one over here is also the liver and this is where the bile duct place. So, this is for the thyroid surgery, this is the entire thyroid gland which is shown and muscles in the neck are shown over here and this is where the parathyroid gland lies. So, they have not done complete annotations of it because it is extensively laborious task.

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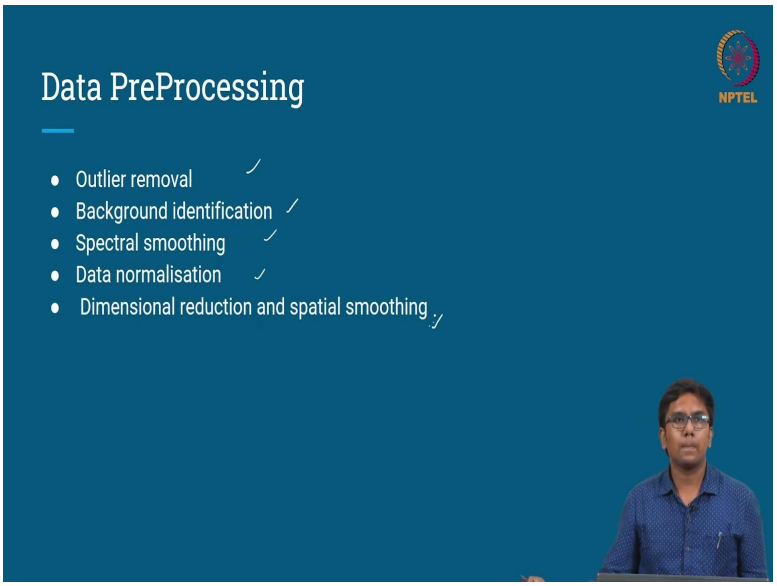

So, this is how they preprocess the data they remove outlier first, they develop a system for foreground identification of structures which are presented in the foreground and they ignore the background things and spectral smoothing is done data normalization is done and dimension reduction and spatial smoothing is also done. Let us see each one of them.

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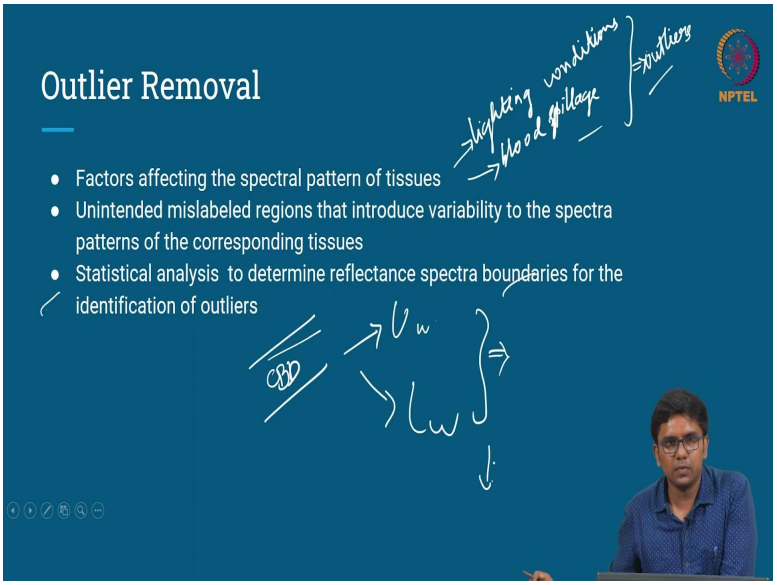

So, this is outlier removal. So, there are many factors that affect the spectral pattern of tissues. One such factor is lighting conditions in the war, I need to say here is the operating room. Some surgeons can operate with a very bright light on and some surgeons used to operate with a mid-brightness range. So, the spectral pattern of tissue can really change with the lighting conditions inside the operating room. And it also depends upon the presence of blood in the tissues. During surgery, there is a chance that blood gets pulled around in the field, surgical field and the presence of blood around the target area can also affect the spectral pattern of tissues.

There can even be unintended mislabeled regions that introduce variability to the spectral patterns of the corresponding tissues. So, what they have done to remove this, I mean these are characteristics outliers, all these things are considered as outliers. So, they have done something called statistical analysis to determine the reflectance spectra boundaries for the identification of outliers. What I mean to say here is that they have HSI data for let us see for the common bile duct which is one of the target tissues which they use HSI here for they have determined some upper wavelength for common bile duct and the lower wavelength for common bile duct.

And, only those reflectance images which they capture that belongs to this wavelength range will be considered for processing and those that light beyond these two are considered as outliers and they are removed.

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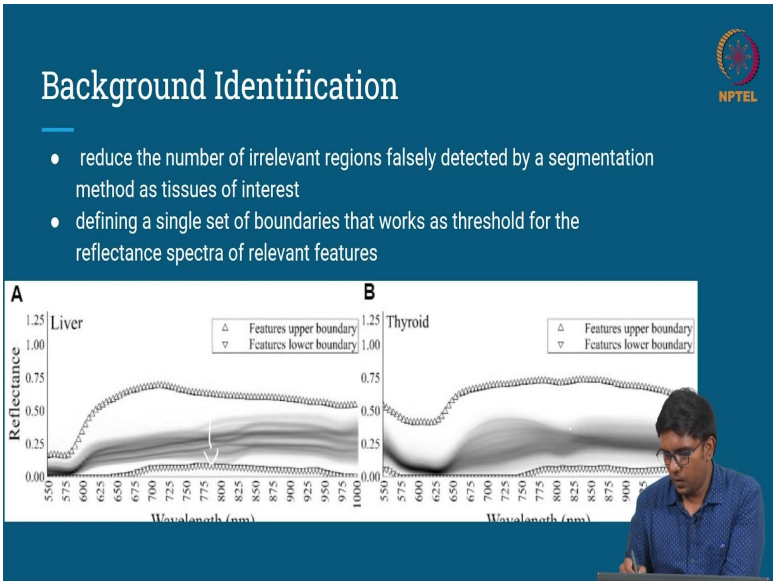

They use a similar thing for background identification. So, within the surgical field that can be the instruments, the hands of the surgeon which get inside that. So, to reduce the number of irrelevant region they call these as irrelevant regions. So, to reduce the number of irrelevant regions falsely detected by a segmentation method along with the tissues of interest. For this they also define the set of boundaries that works as a threshold for the reflecting spectra of the relevant features. This image shows that for example, to identify the liver, they have an upper boundary, reflective spectra for the upper boundary for the reflectance spectra on the lower boundary and only those in between these are considered for processing the data. Similar thing is carried out further thyroid surgery also.

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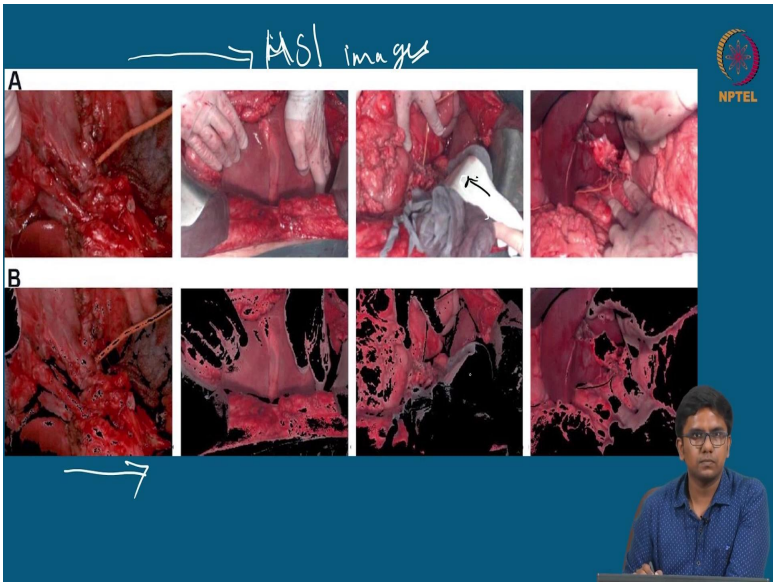

So, this is one such example. So, the series under A shows the HSI images and one in this B shows how the preprocessing is done to remove the background data, I mean the background images, the surgeon's hands are over here and these are removed here and we have the instrument here, we have the instrument here and that is being removed here at this place.

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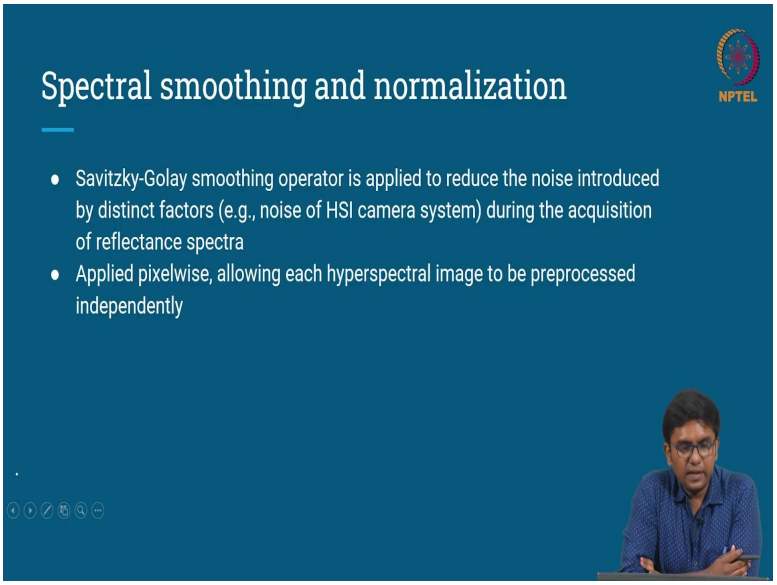

The next step in the data preprocessing is spectral smoothing, I think you people be knowing better than me. So, they use something called the Savitzky-Golay smoothing operator to reduce the noise which is introduced by distinct factors during the acquisition of reflectance spectra.

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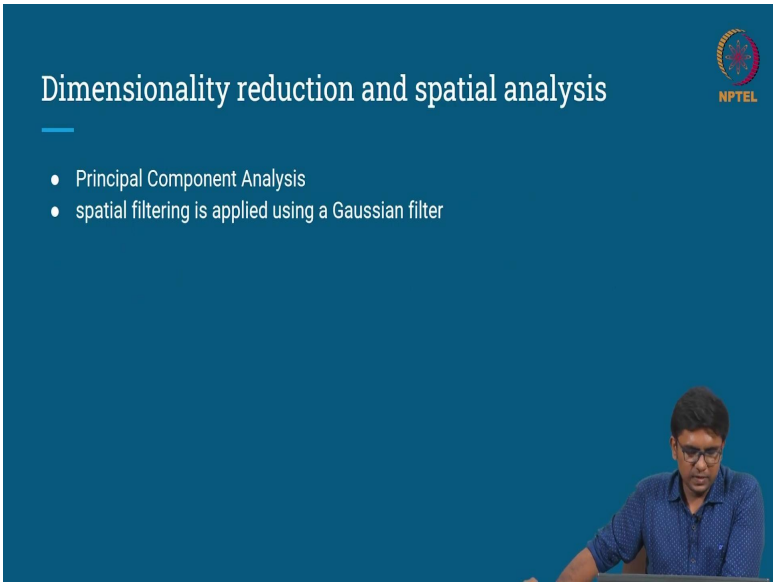

And the final thing they use is the principal component analysis to for reduction in dimensions and spatial analysis.

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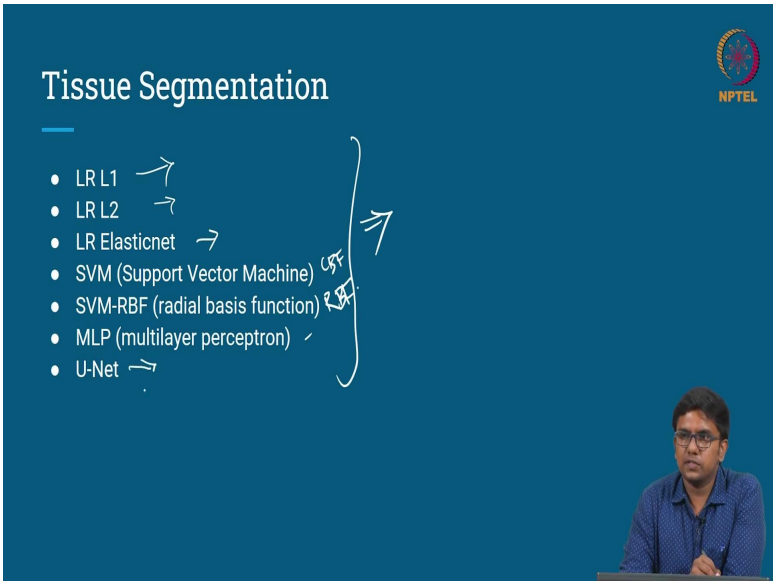

So, for tissue segmentation, they have used 7 algorithms to check 1, 2, 3 based on the logistic regression, LR L1, LR L2 and LR Elasticnet and to the support vector machine, which has linear basis function and radial basis function also. On the multi-layer perceptron and finally, the usual convolutional network which is called the U-Net.

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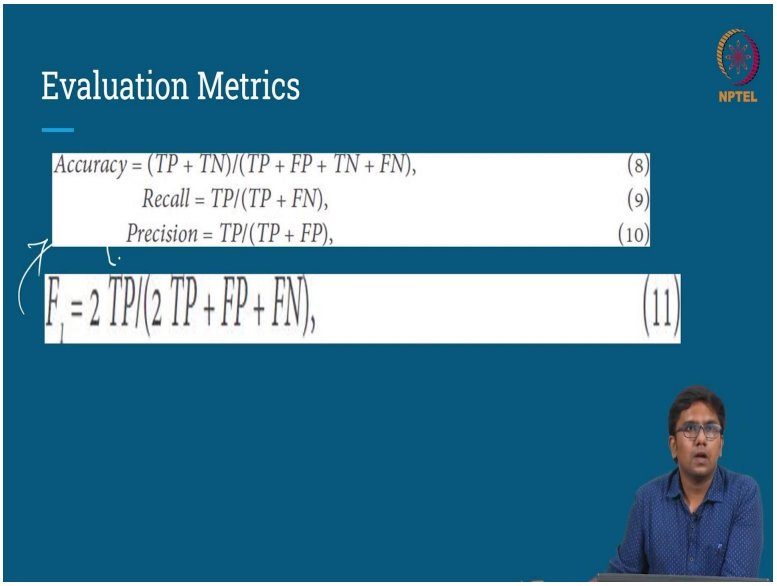

So, they evaluate the functions of those algorithms which help of 3 metrics I mean 4 metrics which is accuracy, recall, precision and F_1. We know that F_1 is something an average of the recall and precision.

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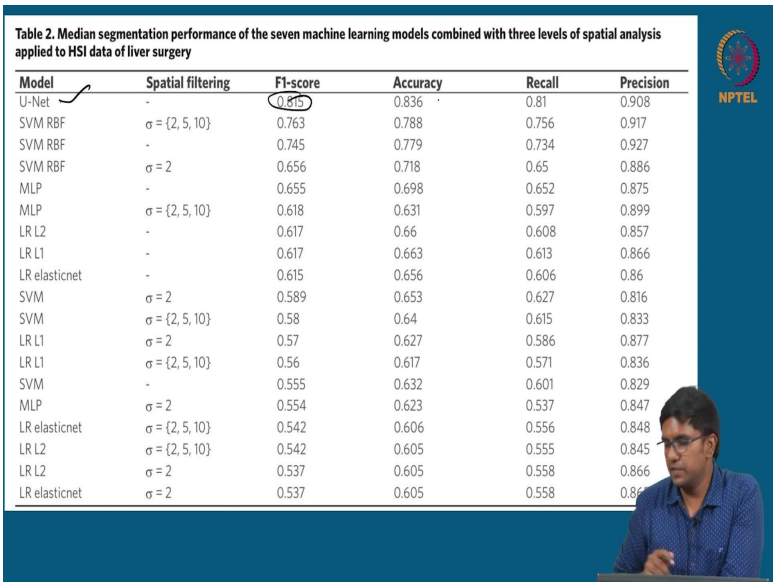

So, this is how they describe your results. So, this is the result of various models which they have trained for identifying gallbladder report, portal vein and bile duct in the case of liver surgery and the fine unit to be having highest F_1 score and performing much better than all other six algorithms which were described.

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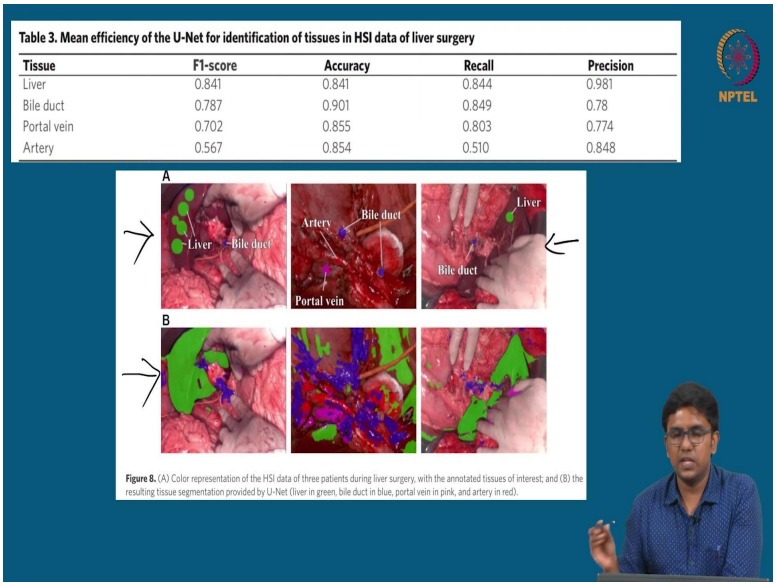

And this is one such image. So, one in the series A shows that the hyperspectral imaging data and one of the series B shows the tissues are getting segmented using U-Net.

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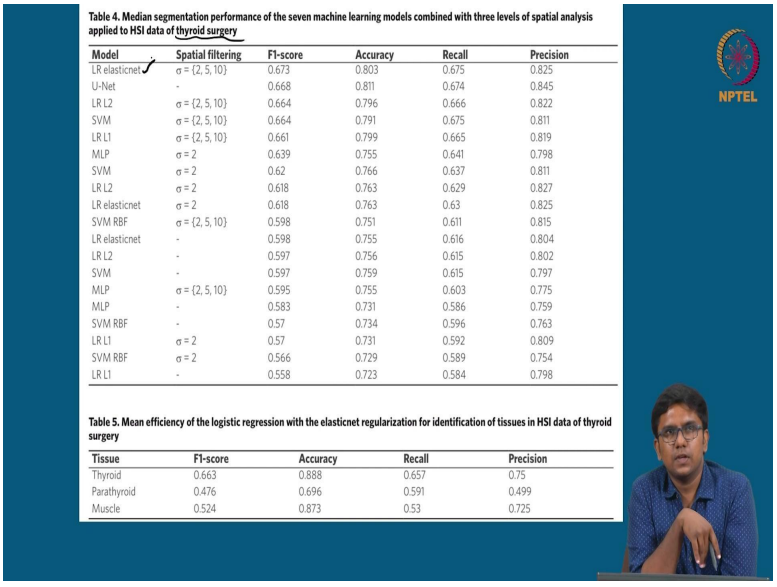

And, this is for the thyroid surgery and for thyroid surgery data they find that LR Elasticnet algorithm scores much higher over all other algorithms.

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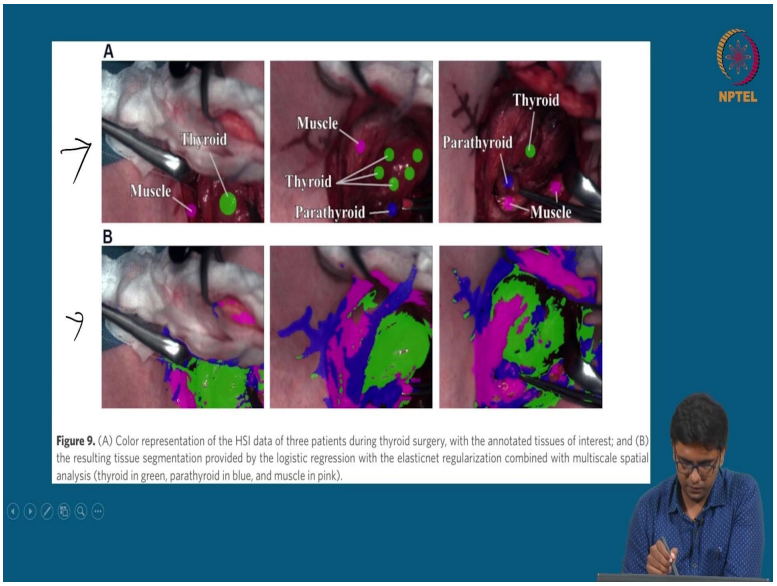

So, this is the HSI series for the thyroid surgery A and this is how the tissue segmentation occurs. So, the parathyroid, the thyroid gland is see over here in green and the parathyroid regions where the parathyroid will be there is given in the group.

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So, I think we are coming to the end of the session. So, this is just to give an intro that there is one novel optical imaging system which can even be used in intraoperative assistance. HSI is being used to identify tumours in post-operative specimens. I mean after the surgery we have the post-operative specimen in that specimen whether the tumour is present or not for that HSI is being used and you people will be knowing HSI is also used in forensic medicine and many other fields of science, but it is a potential field that is HSI can also come into play in

intraoperative assistance. Are they using it sir but they have not published it, it seems, but they are using the similar technology for identification of perfusion.

During bubble surgeries we have a disease they have a similar technology but even where I am using it. During this is the intestine actually, in given the we have the blood supply to the center stage, we have a deceased thing which is happening here. To remove this, we need to cut it off. We putting a cut point wrapper what happens is we have two ends, which needs to be attached to each other. This is the blood supply to the bubble. So, this is one end, this is the other end. So, when we stitch both ends together, the blood supply of the ends need to be perfect in order to get for this to be successful. If the blood supply is not perfect, then this we call it an anastomosis. This is bound to leak in a postoperative period.

So, intraoperatively they check the perfusion of the ends using HSI they have an extra attachment to the camera headset. So, whenever we remove the deceased bubble out deceased intestine out this they activate this mode in the camera, this camera will tell that the answer well perfused or not, the ends of the intestine are well perfused or not.

Student: So, if it is not perfused we will cut till that end where it is perfused Sir.

Professor: We can revise this actually we if we find that this end is not does not have a good blood supply. We can even revise this end, we can chop it off here.

Student: Because where it is joined that has to be…

Professor: One if fit us a good blood supply it will survive these are the vessels.

Student:

Professor: There are surgeons doing micro vascular anastomosis or even we have an operating microscope.

Student: operating microscope, so using that…

Professor: Using that we have an operative and they say HSI are very good role in this. At present, we have the ICG technology which is there with the end sign in green we give the dye, do a fluorescent imaging intraoperatively and just check whether the answer perfused or not. If the answer well perfused then we go ahead with the surgery. If it is not perfused then we need to revise things.