Mine Automation and Data Analytics

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Week-5

Lecture-24

Image Processing and Analysis in Remote Sensing

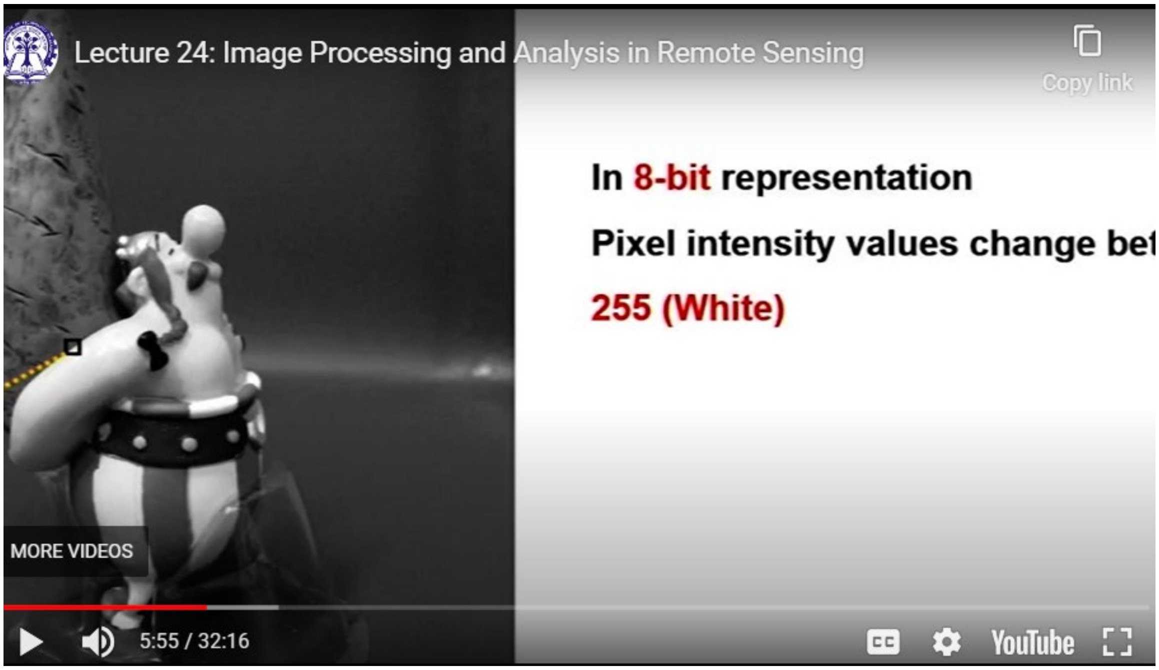
Welcome back to my course, Mine Automation and Data Analytics. Today, in this lesson, we are going to introduce a new concept that is digital image processing. You have seen in the course that in different equipment and as a sensing system camera and visual kind of data is been acquired and used in the mine site for different kind of purposes in the mine. And those images and the data are been used so it is required to understand what are the image processing that is took place with those data. So today, in this lesson, we will basically discuss the basics of digital image processing. Subsequently, we will elaborate on the remote sensing data, remote sensing image processing and so on with the case studies.

So, in this lesson, we will cover the following. What is digital image, and what is digital image processing? The state-of-the-art examples of digital image processing include image acquisition, which means image acquisition methods and the way outs. What is sampling, what is spatial resolution, what is quantization, what is gray level resolution, contrast enhancement and the histogram processing.

Digital image, so presently what are the sensing system you have seen that we are adopting and we are using. Mostly we are basically generating and we are developing and getting digital image. So digital image is nothing but a two-dimensional function that is comprises of x and y in the spatial plane and that spatial plane that value have also some intensity of the image that is basically called f. So, both these spatial coordinate and the intensity value are finite and then it is a digital image. So, if x, y and the amplitude value that is f are finite and discrete quantity, discrete quantity we call the image a digital image.

So, a digital image is composed of a finite number of elements, a finite number of elements called pixels. So, the digital image comprises of pixels. So, the lowest unit of a digital image is a pixel. So, each of which has a particular location that is the spatial value as well as the amplitude that is the intensity. This is one of the first digital images available in the domain.

Now let us see this is also a digital image. This is the image. Now you see this is the first spatial location 1, 1 row column 1, 1. This is the last pixel 2, 7, 2, 4, 2, 3, 3, 6. So this is the total number of row and column this image have.



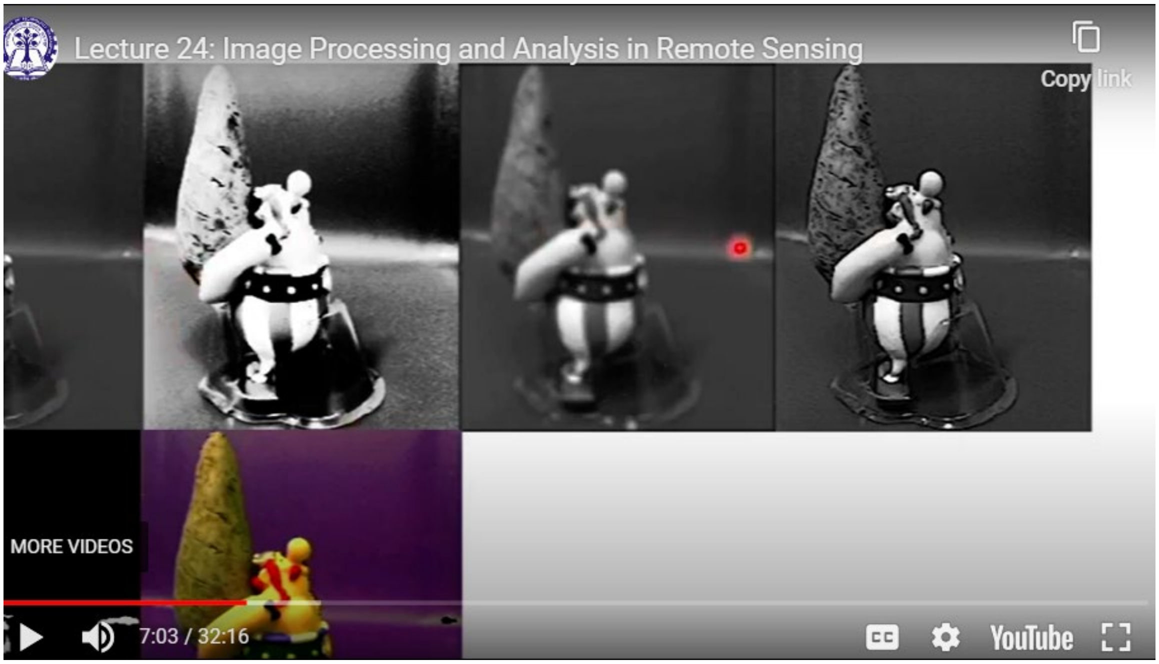
So now, on the first pixel, what is the pixel intensity? It is around 103. The last it is 88. So here a big area is selected, a little bit big area that comprises of number of pixels. Here, only single pixel value, here number of pixels are there. So, in those pixels the row and column value it is basically the brightness value, the intensity.

So, these image is a comprises of these many number of pixels. So, 2427 into 2336 this is multiplied the total value is the number of pixels. So, these number of pixels have each pixel have intensity. So, these many data this particular image has. So digital image is a good repository of the data.

So, this is basically a 2D matrix function row and column. So, in 8-bit representation, so pixel intensity value changes between 0 to 255. So, 8 to the power eight is basically 256. So, we are starting from 0. So, it is 0 to 255.

So, the whitest part brightness value is 255. The darkest part brightness value is 0. Digital image. So, digitization implies that a digital image is an approximation of the real scene. So, this is basically the digitization of a particular point.

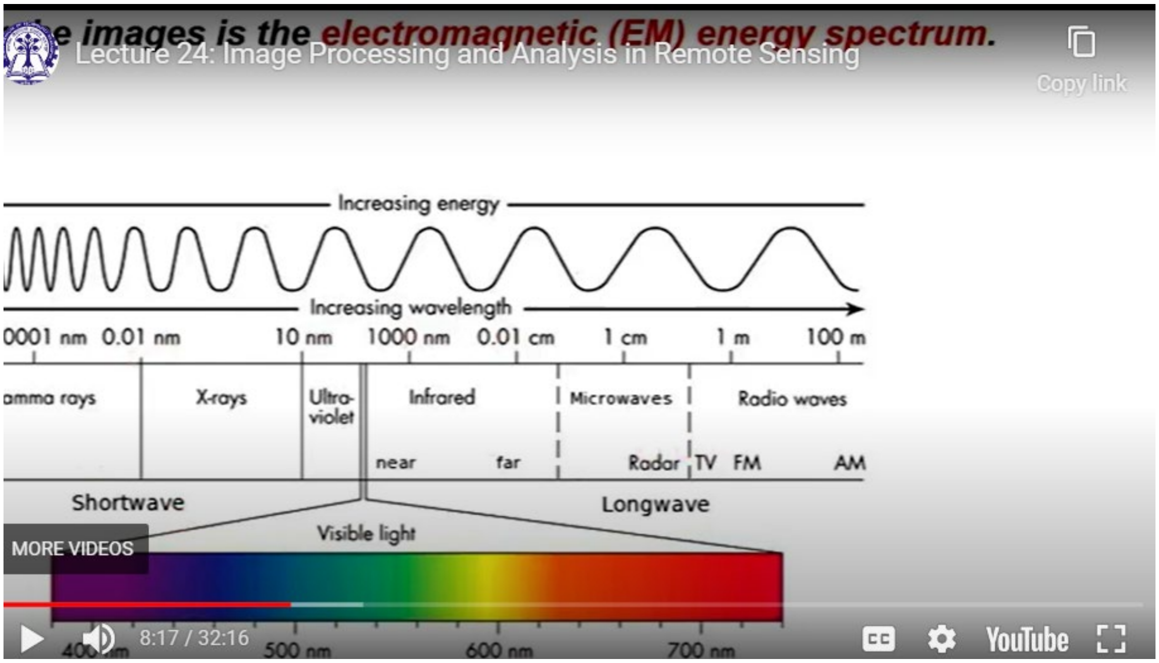
So let us see one point of this particular image. So, this is the magnified one of the one-pixel value that is comprises on one pixel. Digital image processing. So, the same image has gone through a several level of processing. The same image representation is different.



This is a colour kind of representation. This is a black and white represent. Most of these are black and white representations. This is a kind of line representation. This is again a specified kind of color representation, change color orientation.

So, depending upon the necessity probably we all of us know some amount of image processing we have seen in the studio. Anyone visiting in a studio, we are capturing a passport image and the studio person doing some kind of manipulation on the image. That is nothing but a digital image processing. On the digital image, he or she doing some amount of work, doing some amount of applying some amount of transformation and developing a new image and that is delivering to the customer. So that is also comprises of basic level of image processing.

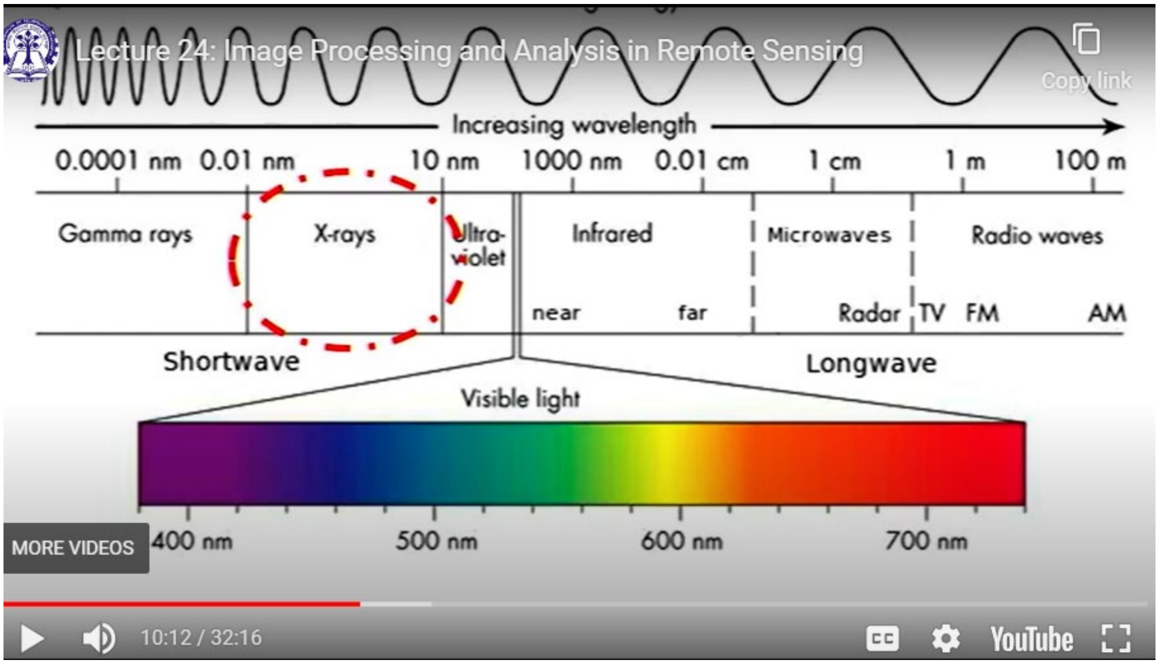
Sources of digital image. So, the primary source of the digital image is the electromagnetic energy spectrum, EM spectrum. So, this is basically the total bandwidth of the electromagnetic spectrum starting from the gamma-ray to the radio wave. So, we have abundant sources of digital images in this world now. So, I will briefly show you the image captured using different spectrum and how it looks like.



And there are different implication of that and based on that analysis recently you probably have seen that using those image the astronomer and the physicist has basically captured the first black hole pictures. Gamma-ray. So, this is gamma ray is basically from 0.001 nanometer to 0.01 means 0.01 nanometer to 0.01 means 0.0001 nanometer to 0.01 nanometer band.

So, this is the gamma-ray. So, gamma ray is used to capture the data of the space about the stars, about the galaxies. So, this is the first image is from the Chernokov telescope. This is fitted with the gamma-ray imaging system. This is gamma ray imaging of the medical nuclear medicine of the body particularly for some dedicated reason this particular picture been captured. Here, our intention is to show what kind of image it would be.

So, gamma ray imaging of a star burst galaxy about 12 million light years away. So that kind of phenomena is been captured. This is basically, this particular image is a final product after several levels of image processing. It is captured from the gamma-ray spectrum imaging system.

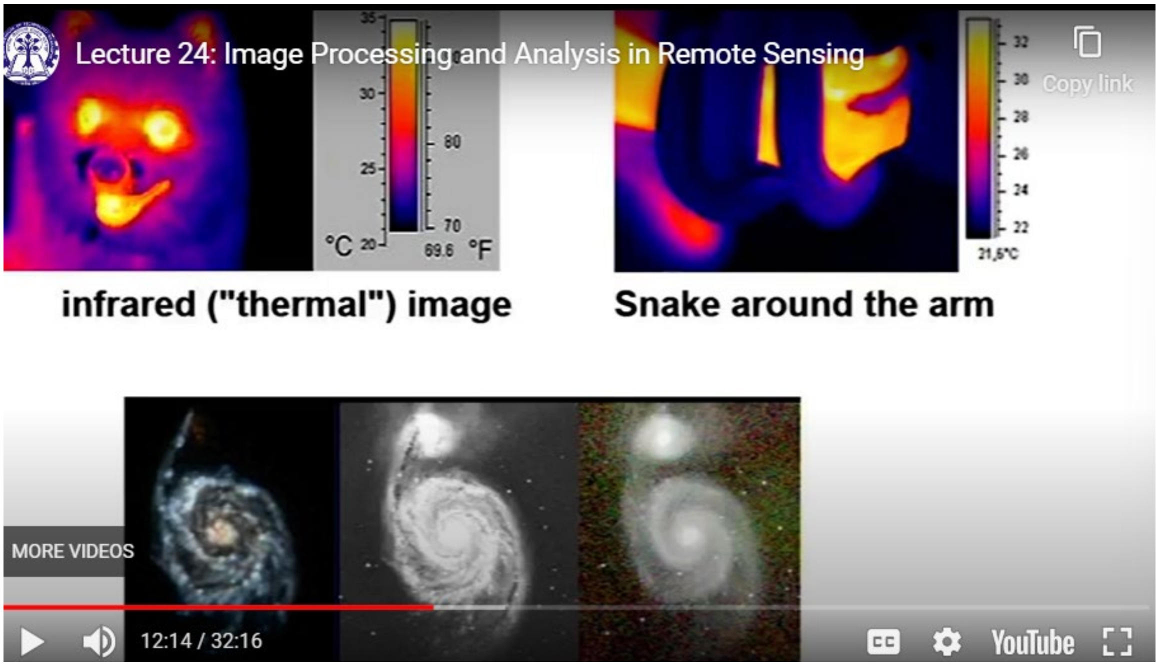


X-ray. So, this is from 0.01 nanometer to 10 nanometer bandwidths of the electromagnetic spectrum wavelength. So, this is a kind of data is captured for different X-ray imaging for the human bodies, different parts. And also, there are some observatory that basically capture the X-ray imaging of the different part of the space. So, this is from the D. Chandra X-ray Observatory the different data about the galaxy about the space.

Ultraviolet. This is basically from 10 nanometer to 1000 nanometer less than 1000 nanometer. I think it is 10 nanometer to 400 nanometer. So, this is a kind of image, and the A image is basically of a normal corn, and this is of a smooth corn. This is the Cygnus duve of the space. Different image been captured using this imaging technique.

Visible light. This is from 400 nanometer to 700 nanometer wavelength. And these are the visual image of a real-world scenario. Infrared. In mine site in different occasions we need infrared imaging to map the heat temperature in the mine as well as on the strata so that we can basically pinpoint, we can identify the source of spontaneous heating on a pile, on a overburden, on a coal spoil or like that.

So, these are the infrared imaging. This is basically thermal imaging. So, this is basically the 2, 3 image we have shown. Infrared of a cat and dog. This is a snake is around the arm, how the temperature is contour is there. This is of the different measures with the ultraviolet ray and near infrared of these basically the galaxy.

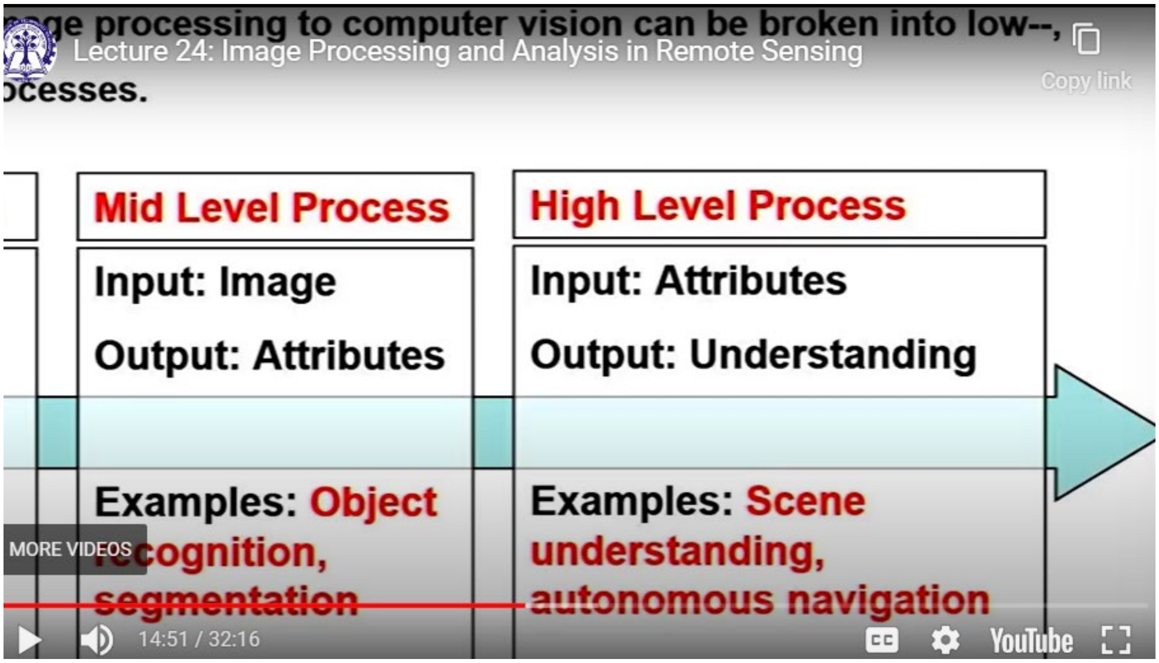


Microwave. It is from in a centimeter level wavelength. So, this is basically used basically for the agricultural purpose as also monitor the depth level, subsidence monitoring. Synthetic aperture error is one of the applications.

Radio wave. Radio imaging is also used. Basically, it is very robust, and it is above 1 meter level wavelength of the spectrum. So, radio wave is basically, this is an MRI image, magnetic resonance along with the radio wave spectrum. This captured the structure in a human brain specifically for some medical purposes. Digital image based on the electromagnetic spectrum. So, these are the wide spectrum of the image we are captured using different electromagnetic spectrum, gamma rays, X-ray and the, optical image, infrared and radio wave about the galaxies and only the first middle one is the optical one, visible light.

There are some other imaging techniques other than the electromagnetic spectrum. It is ultrasound imaging many times used for the medical purposes. Level of image processing. So now let us focus on the image processing. So, it is basically depending upon the requirement, there are several levels of processing is required on the image.

So it is from the low level, mid level to high level image processing based on the context, based on the necessity, based on the requirement. So, these are basically three categories. Low level process means initial input is image, output is also image. We are basically doing some amount of work on it, basically removing noise. We are doing some surfing and basically in the studio when we are captured the digital image, passport image, we are basically doing this kind of low-level processing.

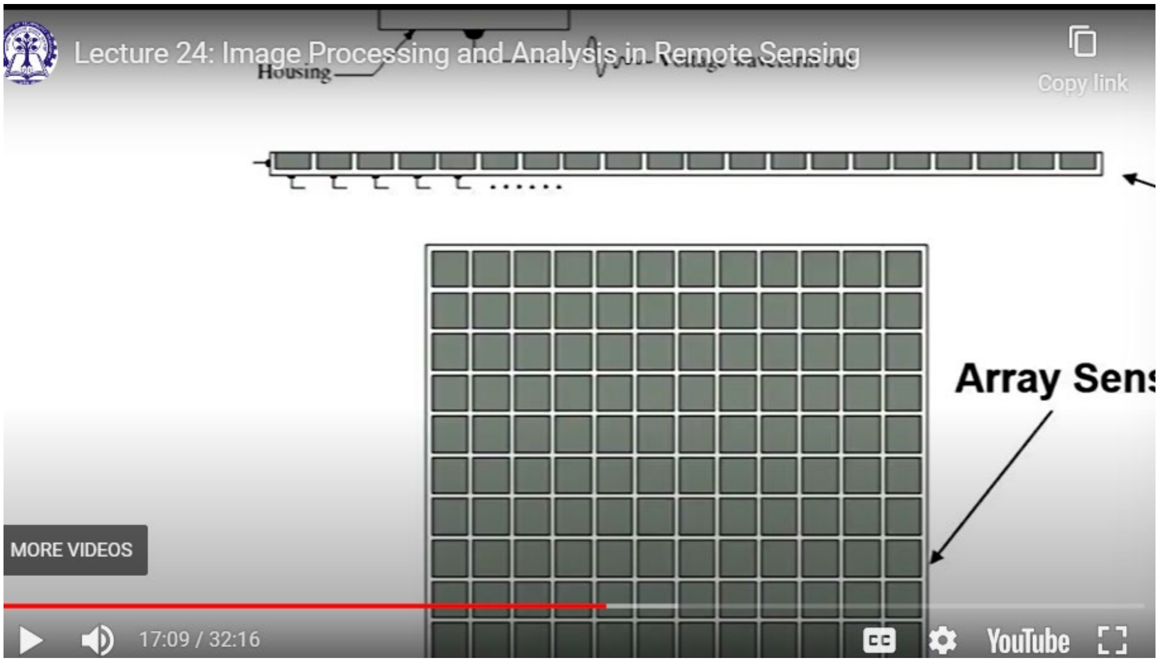


So that is also image processing, but it is a low-level processing to brighten your face, to showcase it very clearly, to smoothen it, to surfen it compared to the other attributes. So that is basically low-level process. The second one is the mid-level process. Input is the image and the output is attribute, some amount of characteristics, some amount of other data. Here object recognition of the segmentation of the image and the high-level processing is basically input is attributes.

The attributes we are getting from the mid level processing, the output is unknown, developing some understanding or rebuilding some kind of situations, scene understanding, autonomous navigation. So, in autonomous systems we mostly rely on these high-level image processing. That is why we are basically focusing on that. Now, let us focus on how these images are acquired. So, the image is generated by the combination of illumination sources and the reflection or absorption of the energy from the source by the element of the scene being imaged.

So, imaging sensors are used to transform the illumination energy into digital images. So, this is basically the energy. Here basically come, there is a filter, then there is a sensing material and this sensing material is with power source and there it is inside a camera or maybe like that. Then that generates a voltage wave plate, waveform output. So from that intensity, spatial, all these are in shape, and data is acquired.

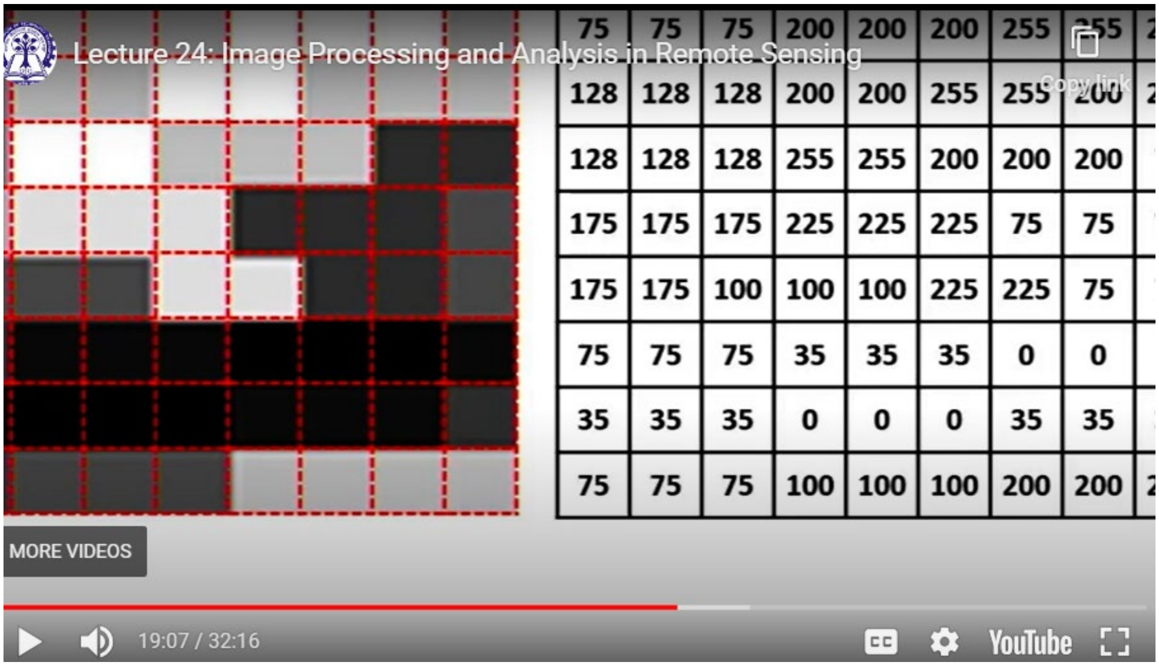
So, this is a single sensor. So, types of image sensors. So, the last slide we have seen, this is a single sensor. Now you see the line of sensors, a line on a line that is a line sensor. Then sensor arrayed in array, it is basically array sensor. That is in a modern camera we use this kind of array sensors.



So, in digital image processing, we principally do the sampling related to the coordinate value, spatial context (x, y) and also the quantisation related to the intensity value. So, quantisation is basically on the bit level, how much amount of intensity if it is an 8-bit image, the range is 0 to 255, and we can increase upon based on the capacity. So, let us see a continuous image. So, this is a continuous image. So, a continuous image consistently have some kind of brightness value, but you can see the brightness value change or the intensity change from this graph.

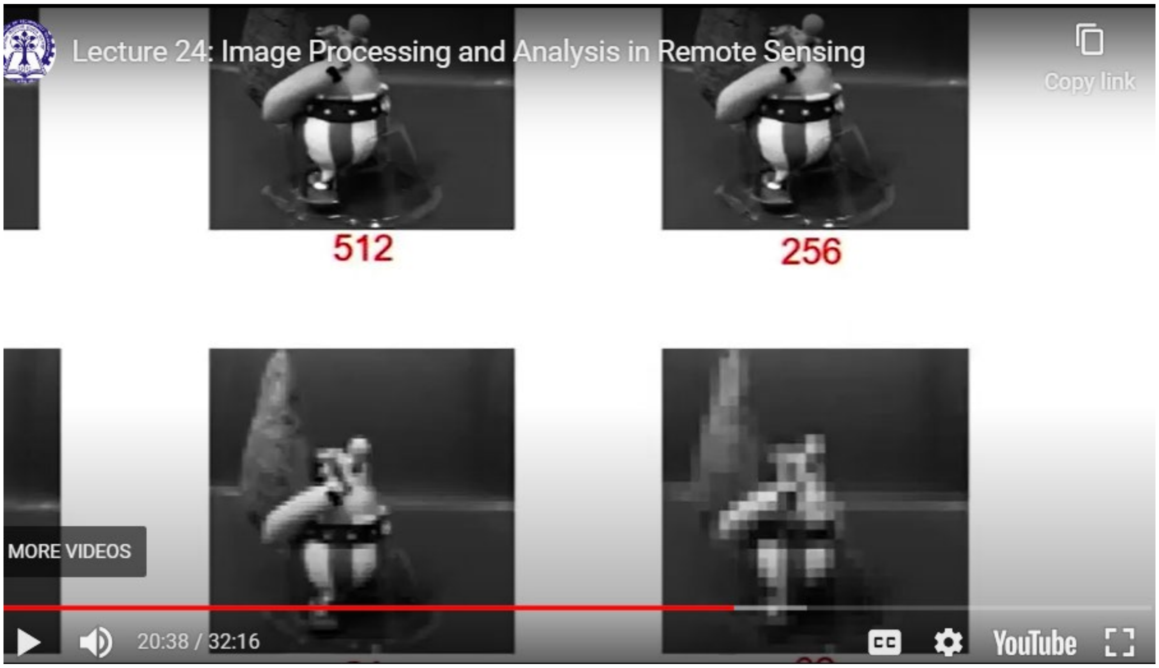
So, a line has been drawn on this image from A to B. Now inside, you see the change of illumination or intensity, and you can see. So that is basically shows that in different pixels, different point, it has stored different intensity and based on that you can basically understand the surface features of that particular object. This is also same. So, this is a continuous image from that, how it basically saved on a sensor's arrays and this is basically result of the sampling and quantization. So, bit by bit, pixel by bit, it is shown in this particular image.

Now, this is basically a matrix. So, the image we have seen, so different array is there. So that array is basically saved the brightness value. Here you can see, this is the image.



The black is basically 0. This is white, it is 255. So, in between the brightness values, you can see the change. This is near to the white spectrum or white value. So, it is around 200 like that. This is basically near to the black or black; it is 0 like that. So, this basically, finally, a digital image is nothing but a data with spatial location and the intensity.

So, we can do some amount of processing using some mathematical model, and we can see a change new image and. also from that, we can go to the next level to understand about the object quality about the object characteristics based on the requirement. For example, in our case, time to time we may require object detections whether it is a lorry, whether it is a truck, whether it is a shovel from the image acquired. So based on providing some kind of inputs or logic, we can easily identify using the object detection. Yes, it is a lorry, it is a truck, it is other vehicles like that of the image acquired in the mine site. Now sampling, a different level of sampling, it has been shown based on the purpose and also on the same size and different size we have already seen.



And here is the quantization of the bit level. The lowest bit is the one bit and here is the 8 bit you can see as the bit size increase, the image quality is also enhanced. Image enhancement, so it is basically done by two ways. One is the spatial domain method, so it manipulates the pixel of a given image for the enhancement and second is the frequency domain method manipulates the Fourier transform of a given image for enhancement. So, this is basically the input image, we are doing transform and enhance the quality. Now we are applying some transformation function and transformation function may be of any type and based on that finally an output is basically a new image G(x, y).

So, it is basically from original image you are getting a new image through a new image and then you are getting a new image. Basically, from the original image, you are getting a new image through a transformation function. So, this is one way is near neighborhood mask, this is the middle value of the x, maybe this particular value is miss. So, we can basically reconstruct this image or fill this particular pixel with the value from the nearby pixels. Image enhancement in spatial domain, point processing, this is processing is done at the point level, point by point wherever it is required.

So, enhancement at any point in an image depends only on the gray level at that point. Mask processing or filtering where the value of the mask coefficient determines the nature of the process. Contrast stretching is basically the difference in visual properties, marking, making an object or image distinguishable from other object and the background. Resizing, zooming, creating new pixel location, assigning gray level value to these locations and it can be done by interpolation. So, there are three standard interpolation we followed and many peoples are used nearest neighbor interpolation, bilinear interpolation and bicubic interpolation.

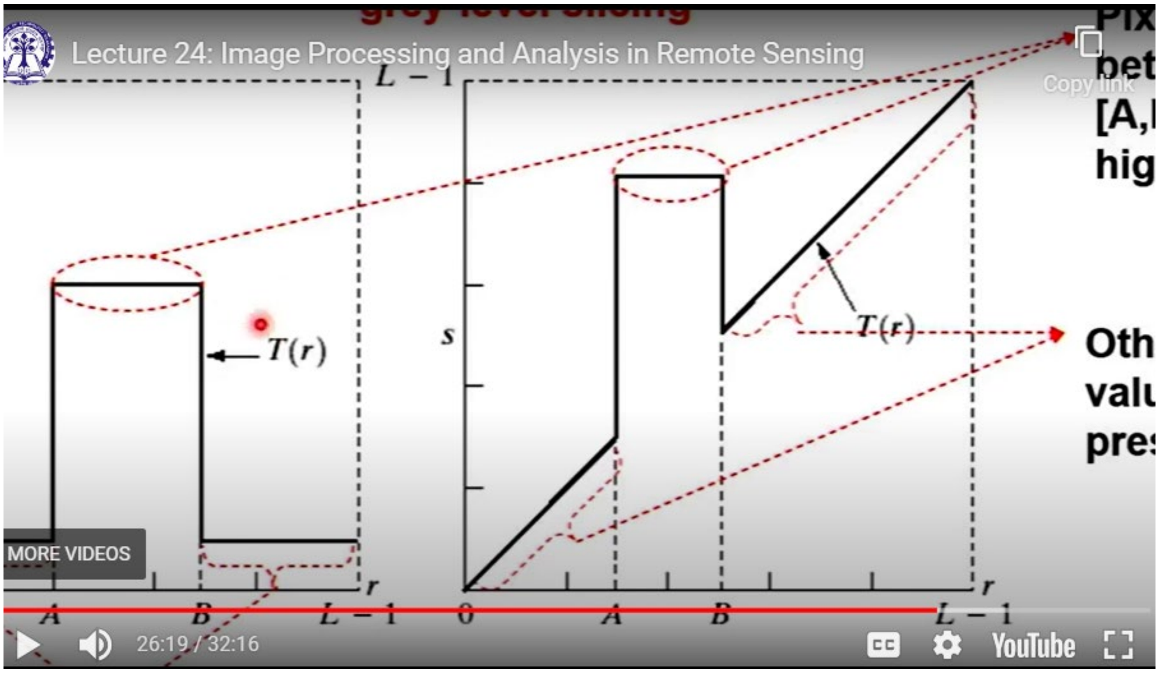
So, these are basically the output of different interpolation technique applied on the image and when it is been upgraded to the next level from 128 to 1024, how it is basically performed and from 64 to 1024 how it looks like. Contrast enhancement, contrast stretching. So, it improves the contrast in an image by stretching the range of intensity value to span a desired range of value. So maybe the spectrum is 8-bit, so the intensity value should lie from 0 to 256. So, it has been observed that it is not occupied the total locations, total space.

So, it is been concentrated to particular zone. So, we can stretch basically the spectrum, the frequency so that it can take all these of intensity from 0 to 256 or at least more so that image quality may be enhanced. So, this is basically converting an image from a lower level to the higher level or brightening, so from the dark level to the lighter level. So, it can be done using different kind of functions. Here it is been shown from black and white transformation. So, it is here some basic gray level transform function used for the contrast enhancement, l is equal to 2k, k is the number of bits used to represent its pixels.

Here, it is image negative, r is the input, and s is basically the output range, the output image. So here, basically now here also applying some amount of transformation. So based on the transformation you can see the original image, how it looks like when it is been transferred to the other sector using this negative image. Logarithmic transform, r is the input, and again, s is the output. We are applying some level of transformation and based on that basically, we are basically getting newer information from the image. Logarithmic transform, s is equal to crv, r is basically the original input, and s is the output.

We are again applying some level of transformation and here, when the gamma value is 0.5, 0.3 and 0.7, how the image basically looks like after applying the logarithmic transformation on that same image.

So, this is basically showing the result of different gamma values. Here the piecewise linear transform, here on the different levels we are applying the transformation at different pixel level at different point and part of it basically enhance part of it kept preserved like that. So here it is, piecewise linear transform. So in this particular figure from the A to B zone we are basically heighten the basically the pixel value and basically now original one this, now A, B portion is this and these other pixel values are darkened. So now we are also basically heighten that to a level and we are basically making a gradient.



So, this is a gray-level slicing. This is a piecewise linear transformation bit plane slicing of an 8-bit fractal image. This is piecewise linear transformation bit plane slicing. Now, we will see the histogram processing. So, the image is comprises of a spectral location and the intensity. So based on the intensity that intensity histogram will be very much helpful to understand about the image and image quality and applying some kind of statistical tools we can basically enhance the image quality.

So, this histogram is basically the discrete function $h(r_k)$ is equal to n_k where r_k is basically the kth gray level of the range of 0 to L minus one that is 0 to 255 for example in 8-bit image and n_k is the number of pixel having the gray level r_k. So, number of pixel the frequency is basically plot. So, the normalised histogram is basically $P(r_k)$ is equal to nk divided by n for k is equal to 0 to 255 for 8-bit and the $P(r_k)$ is can be considered to give an estimate of the probability of occurrence of the ray level of r_k. So here is basically the histogram plot, the frequency plot of the image.

So, it is basically a dark image. So, most of the brightness value is on the darker side. So that is now a bright image, most of the intensity value on the higher side. So, this is the difference after applying some kind of transformation how it looks like in these four basic gray level characteristics, one gray dark, bright then the low contrast and the high contrast image. This low contrast image has used only is part of the total spectrum of the available bit and high contrast image use the full width of the bit length and by that it basically showing a better-quality image that may be time to time whenever required we may have to do this kind of transformation.

So, let us discuss a few questions. The question is what are the types of images you know or rather the question I want to ask that what are the image are possible, what are the type of image possible. So, A is binary, B black and white, C grayscale, D color and E all of these. What is the right answer? Right answer is all of these are basically the different types of image, binary, black and white, grayscale and color. The right answer is E, all of these.

The second question, fill the blacks. So I have put a sentence a color image has dash, dash and dash pixels. What is the right answer? For a color image, color image has red, green and blue pixels.

Question number three, the size of each pixel in a binary image is, question is the size of each pixel in a binary image is A 1-bit, B 2-bit, C 4-bit, D 8-bit and E 16-bit. The right answer is 1-bit. So, a binary image of a single pixel comprises of 1-bit only.

Now, one information you must note for the futures because this data might be required time to time for you. Storage requirement for all the images type. We have already discussed some of the image type, color, gray, black and white and so on and so forth. So, the binary, it is the 1-bit per pixel, black and white, 8-bit per pixel and the grayscale is 8-bit per pixel and the color is 24-bit per pixel which basically it has red, green and the blue channels together.

So, 888 is basically the 24-bits. So, I think that will give you a clear picture about the storage requirement in this kind of situation.

So, these are the references.

So let me conclude in few sentences what we have covered in this particular lecture. We have covered the basics of digital image and different image acquisition techniques and a low level, medium level and high-level image processing what is and a very preliminary level of image processing, particularly the contrast enhancement image enhancement we have covered.

Thank you.