Digital Image Processing
Prof. P. K. Biswas
Department of Electronics and Electrical Communications Engineering
Indian Institute of Technology, Kharagpur
Module Number 01 Lecture Number 02
Application of Digital Image Processing

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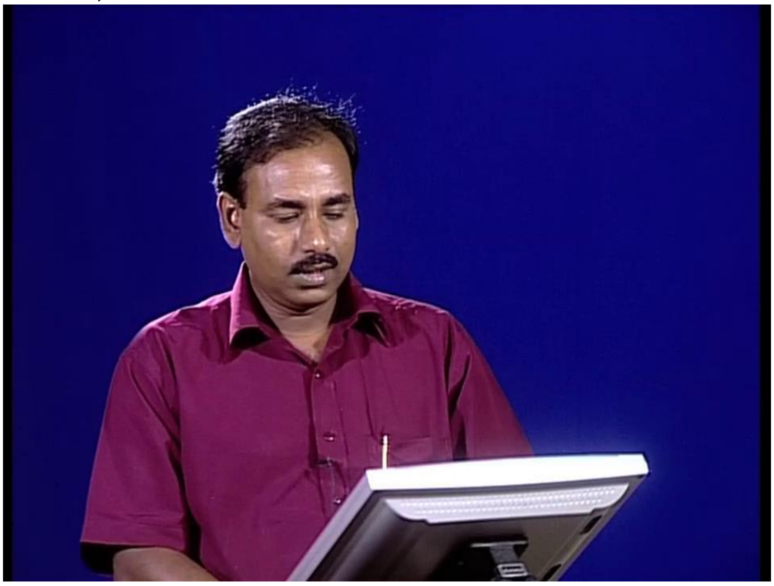

Welcome to the course on Digital Image Processing.

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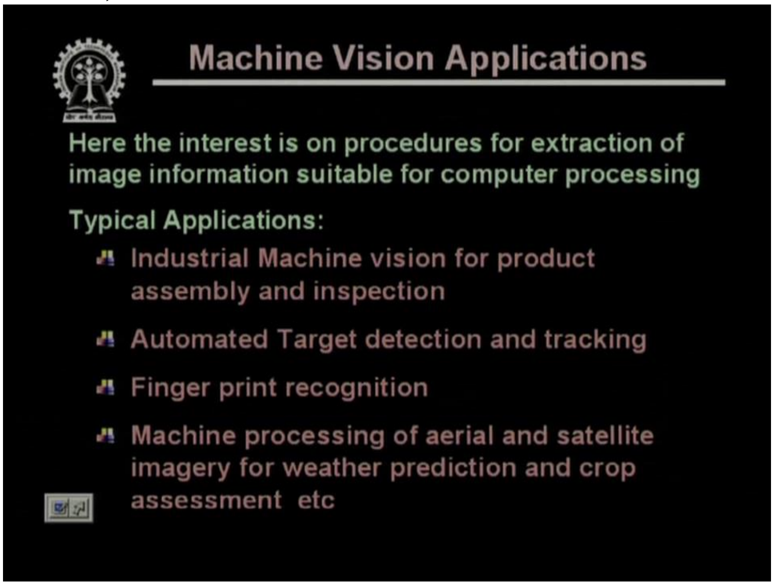

To extract some description or some features which can be used for further processing by a digital computer. And such a kind of processing can be applied in industrial machine vision, for product, assembly and inspection. It can be used for automated target detection and tracking. This can be used for fingerprint recognition. This can also be used for processing of aerial and satellite images, for weather protection, crop assessment and many other applications.

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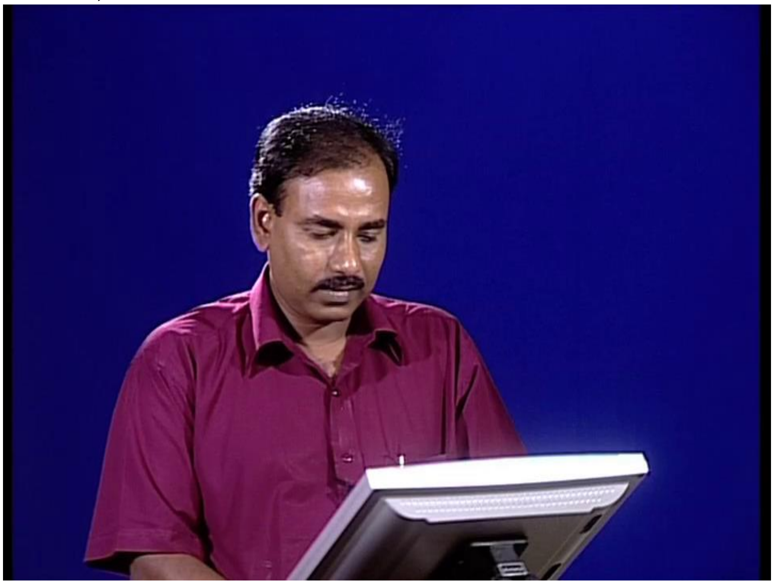

So let us look at these different applications one after another. So this shows an application of

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An automation of a bottling plant; here what the plant does is it fills up some liquid, some chemical into a bottle and after it is filled up, the bottle, the bottles are carried away by the conveyor belts and after that these are packed and finally sent to the customers. So here checking the quality of the product is very, very important

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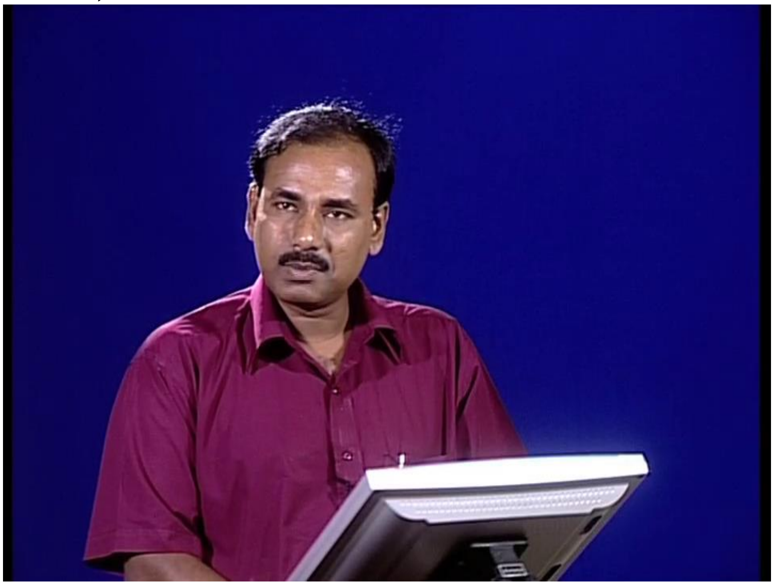

and in this particular application, the quality of the product indicates that whether the bottles are filled properly or some bottles are coming out empty or partially filled. So naturally the application will be that if we can find out that some bottles are partially filled or some bottles are empty then naturally we don't want those bottles to be delivered to the customer; because if the customer gets such bottles then the goodwill of that company would be lost. So detection of the empty bottles or partially filled bottles is very, very important and here image processing can, techniques can be used to automate this particular process. So here you find that we have shown an image, the snapshot of this bottling process where you find that

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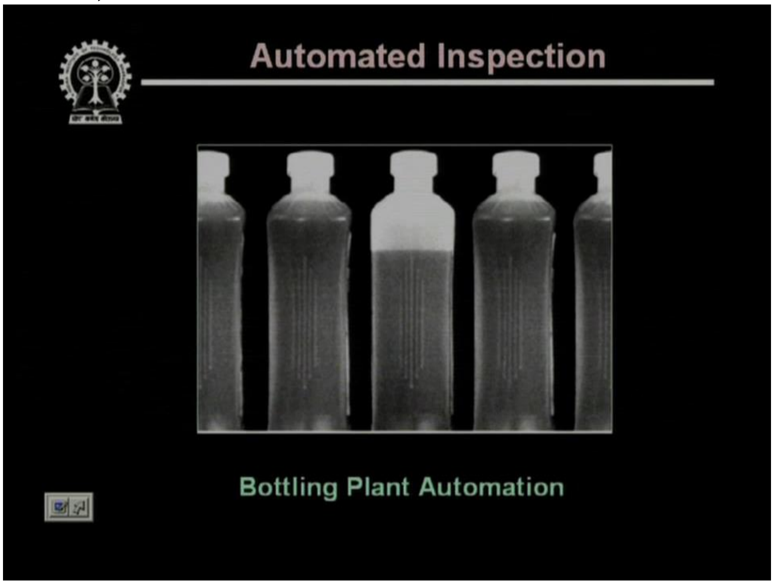

there are some bottles which are completely filled up and one bottle in the middle which is partially filled. So naturally we want to detect this particular bottle and remove it from the production line so that finally when the bottles go to the customer, no empty bottle or no partially filled bottles

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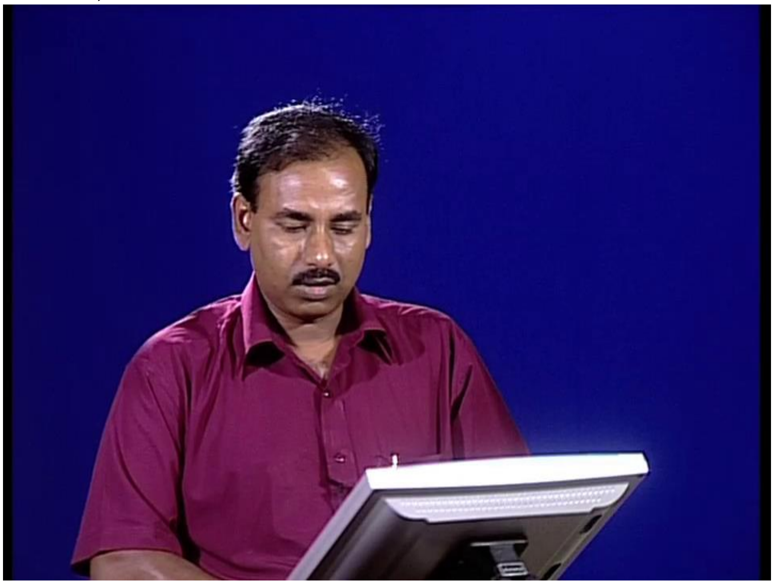

are given to the customers

Let us see another application of image processing

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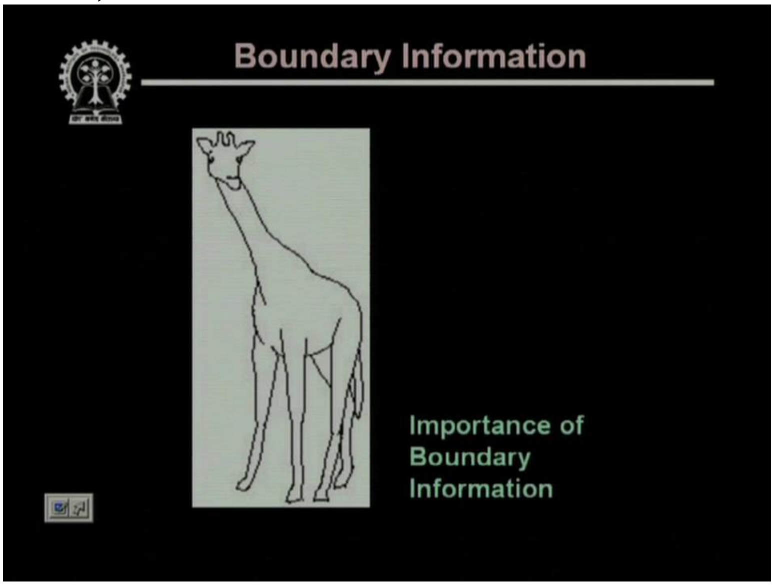

in machine vision, for machine vision purpose. Now before I go to that application, I have shown an image to highlight the importance of boundary information in image processing. So here you find we have shown the boundary image of an animal. There is no other information available in this image except the boundary contours. And you find that if I ask you can you identify this particular animal and I am sure that all of you will identify this to be a giraffe. So you find that even though we don't have any other information except the boundary

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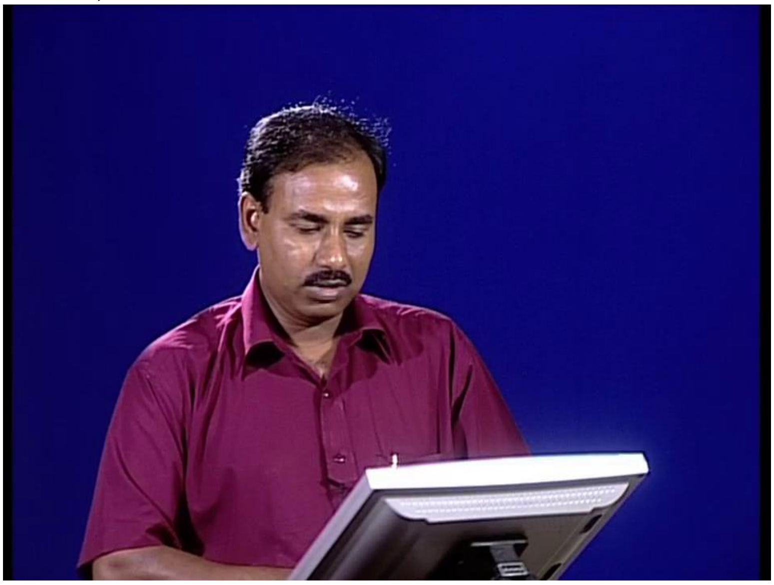

or the border of the giraffe, but still we have been able to identify this particular animal. So in many cases and most of the cases, the boundaries contain most of the information of the objects present in the scene. And using these boundary informations we can develop various applications of image processing techniques. Here is an application.

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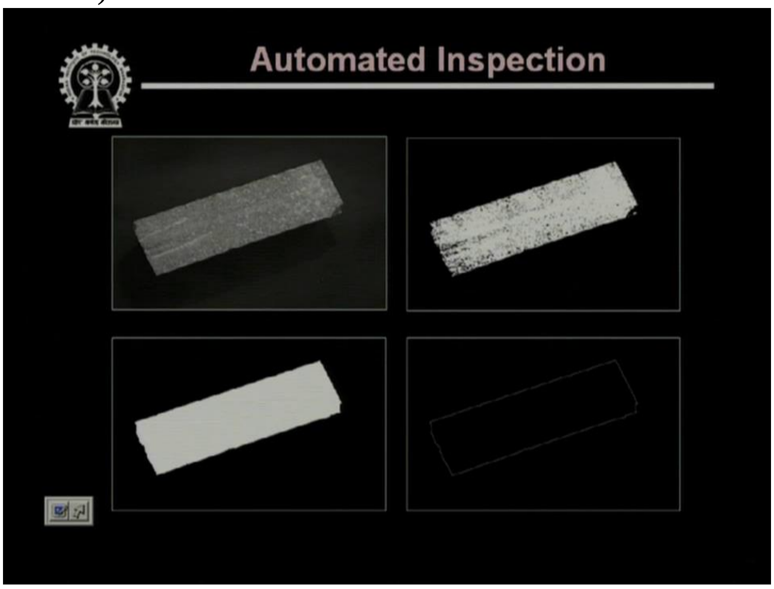

So this is again an automated inspection process and here the objects we are interested to inspect are some refractory bricks. So here we find that we have shown 4 different images. The first one is the original image which is of the refractory brick which is captured by camera. The second one is what we call, is a thresholded image or a segmented image, we will come to details of this later, where we have been able to identify that what are the regions which actually belong to this object and what are the regions which belong to the boundary. Naturally when we are interested in inspecting this particular object, we will not be interested in the background region. What we will be interested is in the region that belongs to that particular object. So this background and object separation process is very, very important in all these kind of applications. The third image that is the left one on the bottom is a field image. You will find the second image, it is not very smooth. There are a number of black patches over the white region. So the second one has filled up all those black patches and it shows that what is the profile of the object, the 2D projection of the object that we can get. And the fourth image, you will find that it shows that what is the boundary of this object. And using this boundary information we can inspect various properties of this particular object. For example, in this particular application, there can be two different types of defects.

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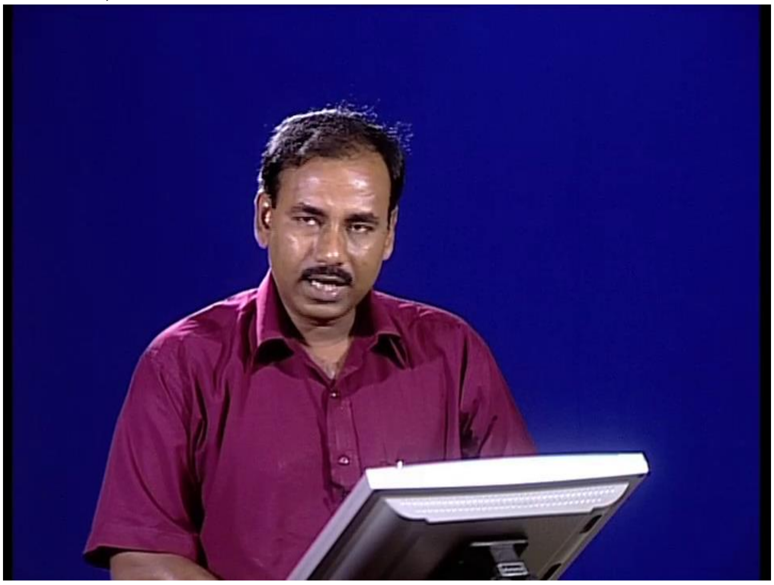

One kind of defect is the structural defect. When we say the structural defect, by structure what I mean is what is the dimension of every side of the object, what is the angle at every corner of the object. These are the structural informations of that particular object. And the other kind of inspection that we are interested to do is what is the surface characteristics of this particular object, whether the surface is uniform or the surface is non-uniform. So let us see that how these inspections can be made.

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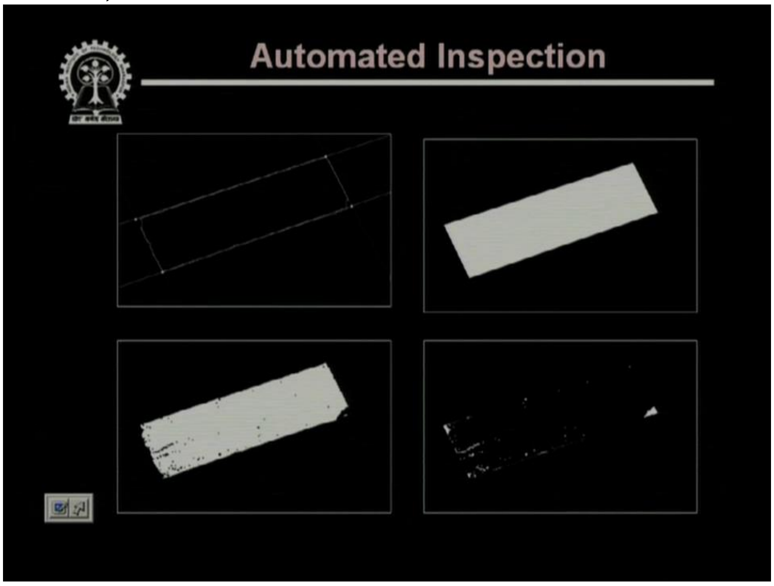

So here you find that the first image, what we have done is we have processed the boundary image in such a way that since there are 4 different boundary regions we have fitted 4 different straight lines and these 4 different straight lines; that tells you that what should be the ideal boundary of the object. And once we get these 4 different straight lines, using these 4 different straight lines we can find out what are the points of intersections of these 4 different straight lines. And using these point of intersections we know that in the ideal situation, those point of intersections are actually the locations of the corners of the object. So you find that in the first image, there are 4 white dots which indicates the corners of the object. And once we get these informations, the corners of the object, the boundary line of the object, we can find out what is the dimension of or the length of each and every side of the object. We can also find out what is the corner subtended, what is the angle subtended at every corner of the object and from this, if I compare these informations that we have obtained through image processing with the information which is already stored in the database for this particular object, we can find out whether the dimensions that we have got is within the tolerable limit or not. So if it is within the tolerable limit

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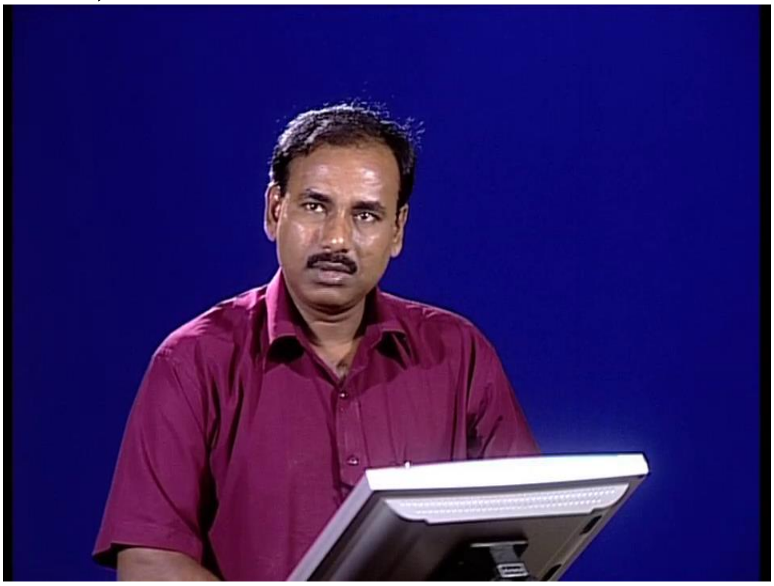

then we can accept the object. If it is not within the tolerable limit then we will not accept the object.

Now if you look at the original image once more

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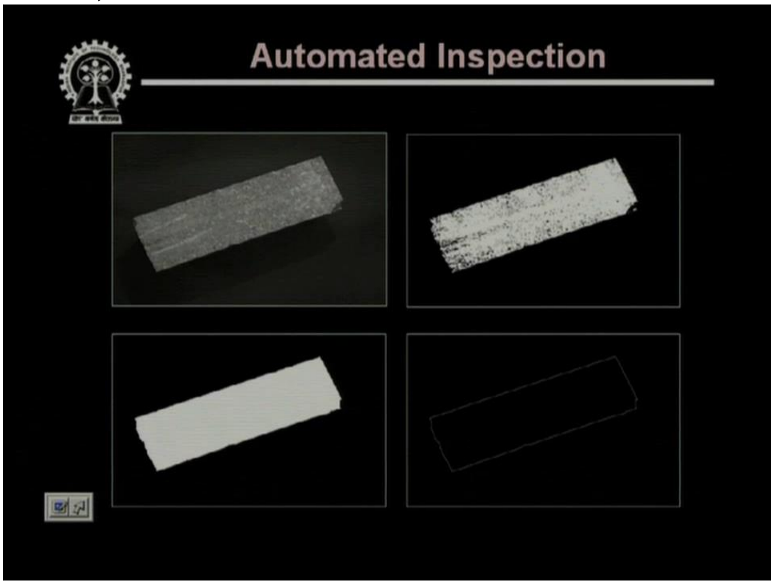

you will find that there are two different corners, the right, the corner on the right hand side and the corner on the left hand side. These corners are broken. Not only that, on the left hand side, if you look at the middle, you can identify that there is certain crack. So these are also the defects of this particular object and through this image processing technique we are interested to identify these defects. Now let us see that how these defects are being identified. So here again in the first image once we have got the ideal boundary and the ideal corners of the object, we can fill up the region bounded by these 4 different edges to get an ideal projection of the object. So the second image in this particular slide shows you that what is the ideal projection; the third image that shows you that what is the actual projection that has been obtained after image processing techniques. Now if this ideal projection, if we take the difference of this ideal projection and the actual projection then we can identify these defects. So you find that in the fourth image the two different corner bricks have been represented by white patches, also on the left hand side in the middle, you have, you can see that the crack is also identified. So these image processing techniques can be used for inspection of the industrial objects like this. And as we mentioned

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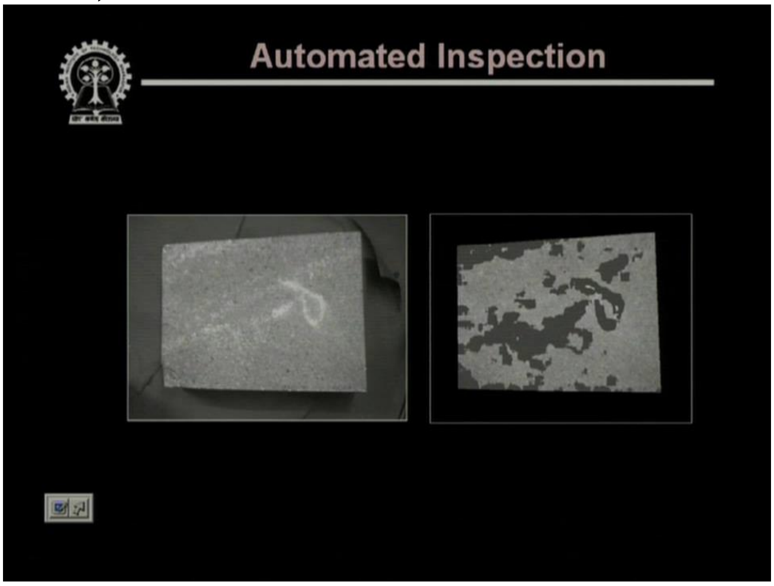

the other application or the other kind of inspection that we are interested in is the surface characteristics, whether the surface is uniform, or the surface is non-uniform.

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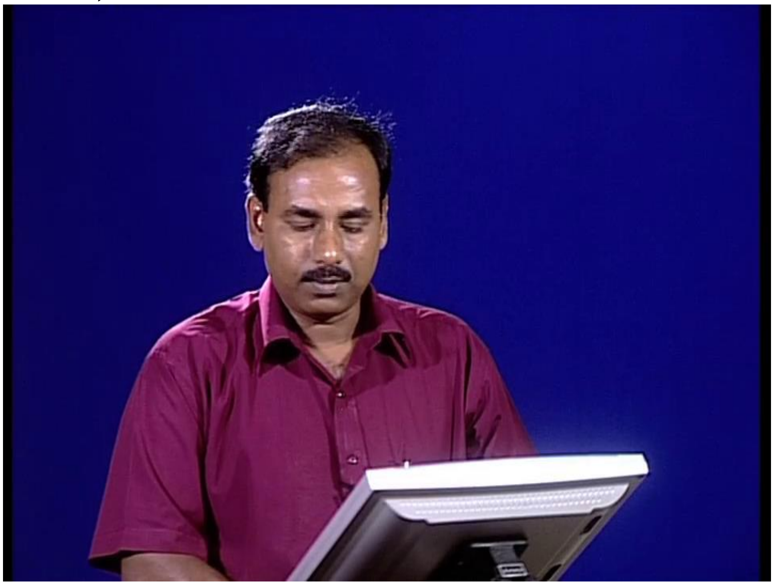

So when we want to find out or study the surface characteristics, the type of processing techniques which will be used is called texture processing. And this one shows that

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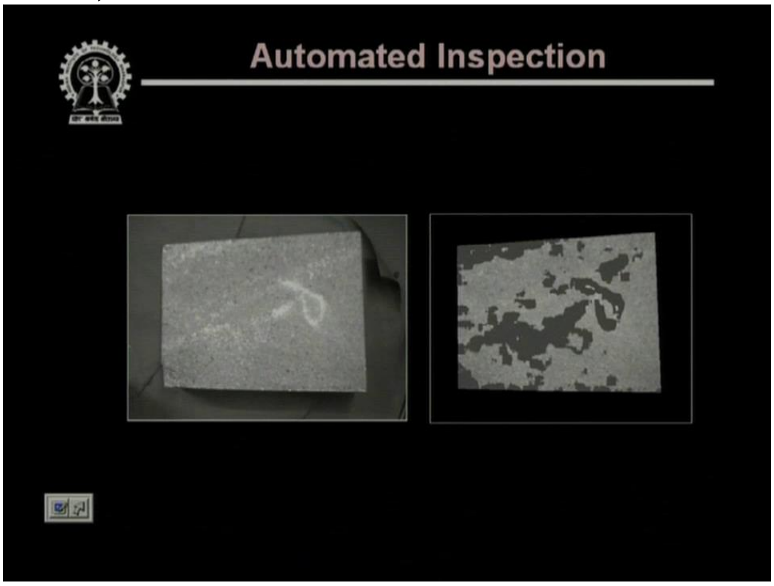

for the surface of the object it is not really uniform, rather it contains 2 different textures and in the right image those 2 textures are indicated by 2 different gray shades.

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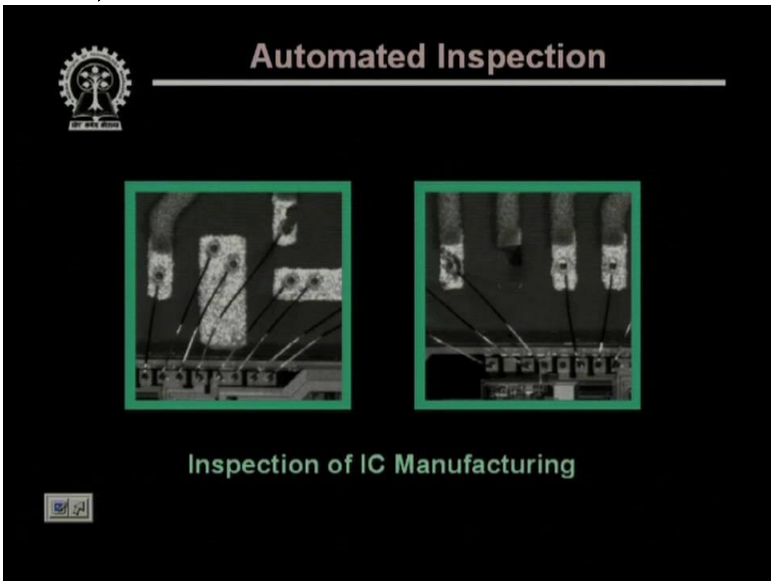

It shows the application of image processing techniques for automated inspection in other applications.

For example, the inspection of Integrated Circuits during the manufacturing phase. Here you find that in the first image, there is a broken bond where as in the second image some bond is missing which should have been there. So naturally these are the defects which are to be identified because otherwise, if this IC is made, then the IC will not function properly.

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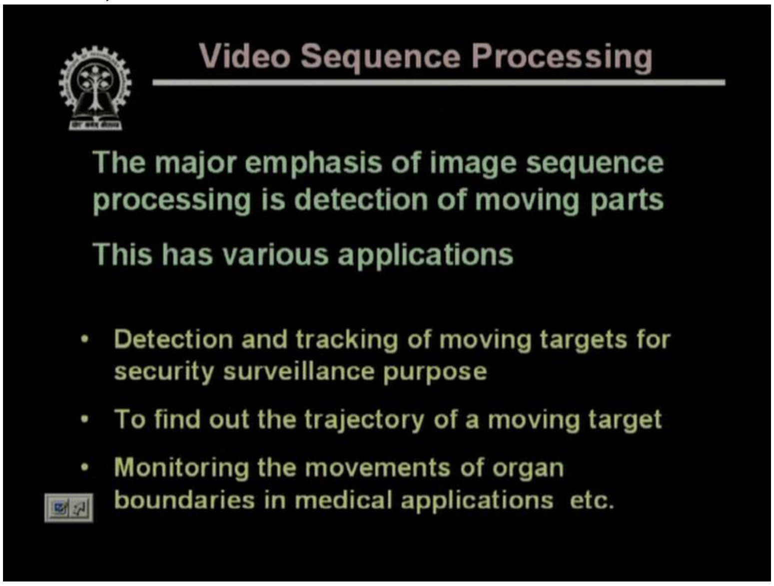

So those are the applications which are used for machine-vision applications, for automating some operations and in most of the cases, it is used for automating the inspection process or automating the assembly process.

Now we have another kind of applications by processing the sequence of images which are known as video sequence. The video sequence is nothing but the different image frames which are displayed one after another. So naturally when the image frames are displayed one after another then if there is any movement in the image that movement is clearly detected. So the major emphasis in image processing, image sequence processing is to detect the moving parts. This has various applications. For example, detection and tracking of moving targets and major application is in security surveillance. The other application can be to find the trajectory of a moving target. Also monitoring the movement of organ boundaries in medical applications is very, very important

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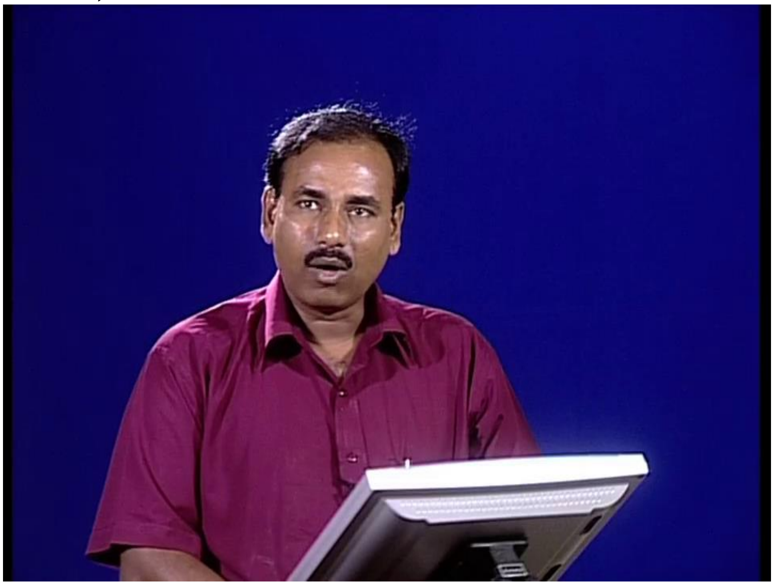

and all these operations can be done by processing video sequences.

So let us take one such example.

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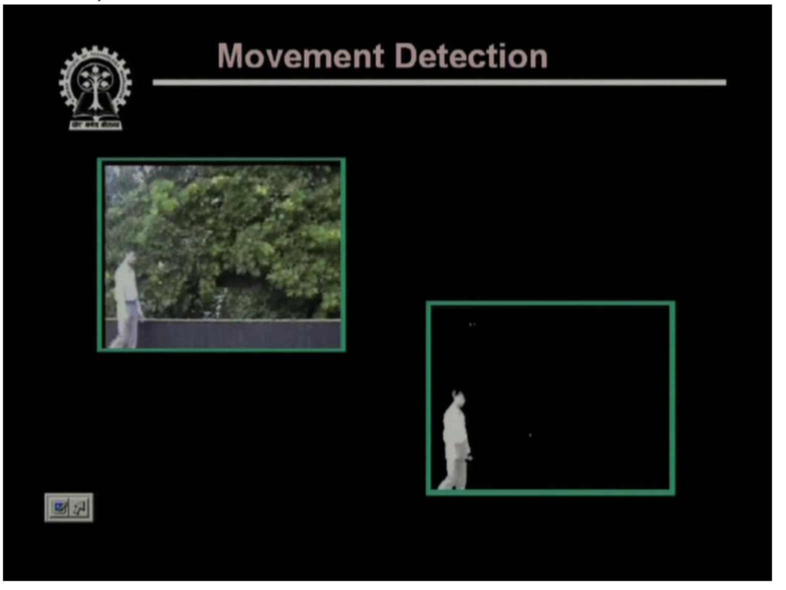

Here you find that in the first image some person is moving against a green background. So let us see this.

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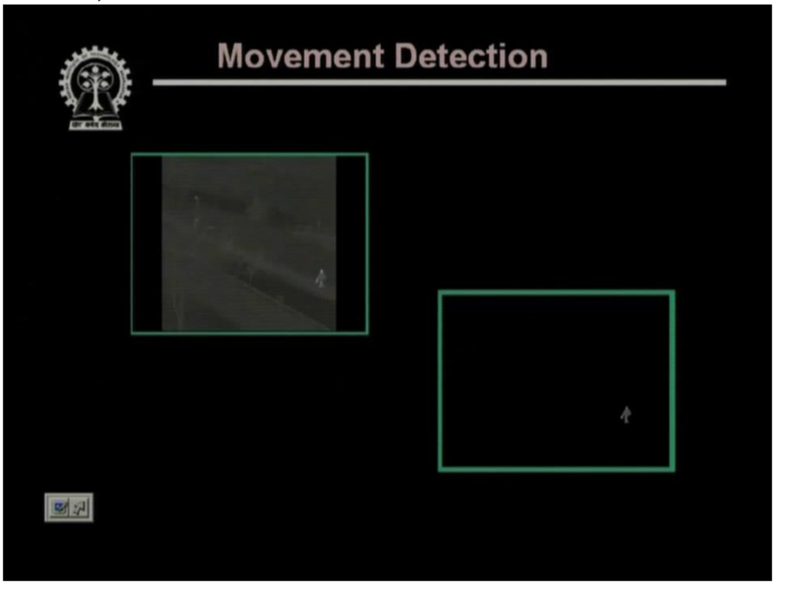

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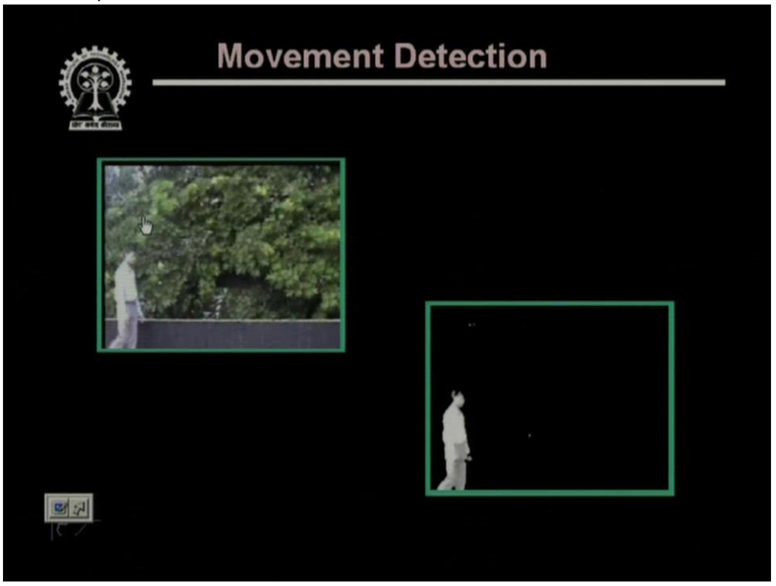

So here we find that a person is moving against a background.

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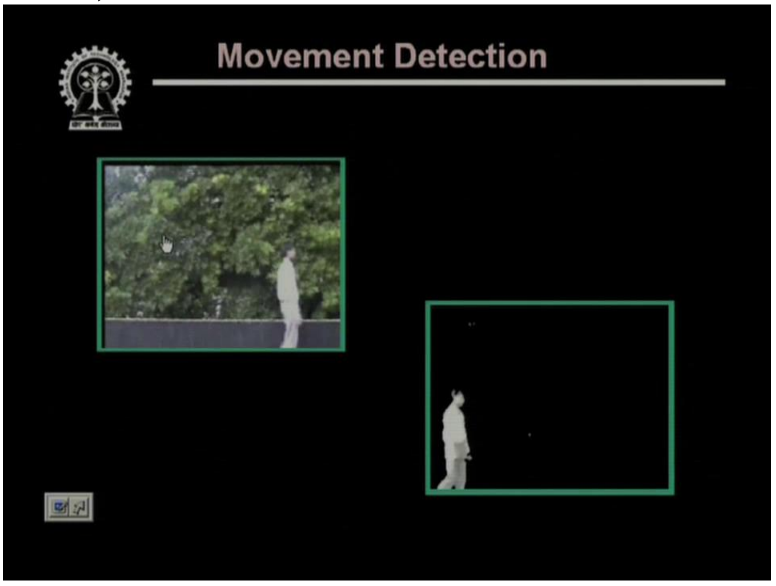

So through image processing techniques we can identify this movement. In the second processed sequence you will find

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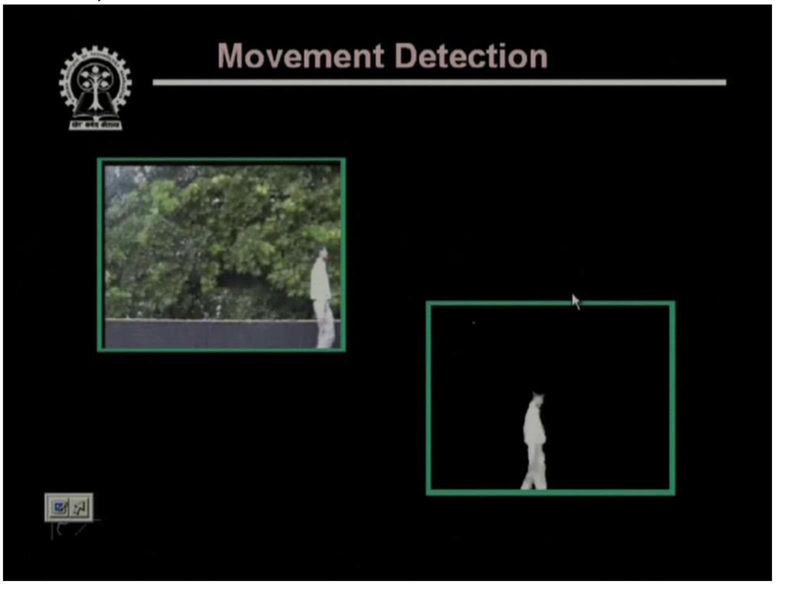

that the person is moving which is clearly shown

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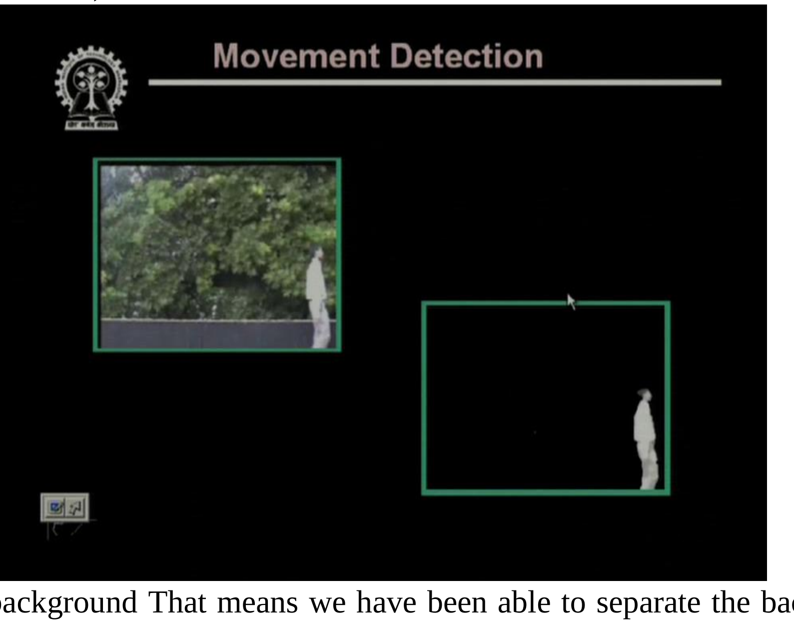

against a black background That means we have been able to separate the background from the moving object.

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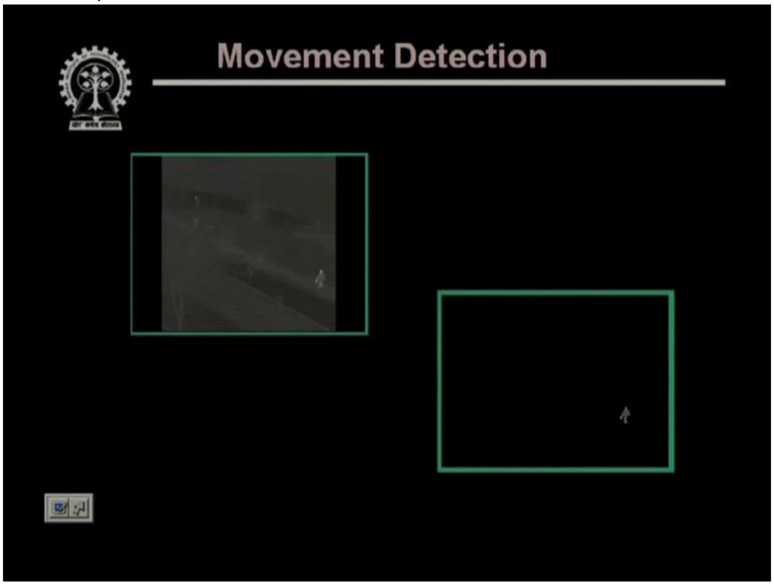

Now this particular application which has been shown, here the image was taken or the video sequence was taken on broad daylight. But in many applications, for example, particularly for security applications, the images are to be taken

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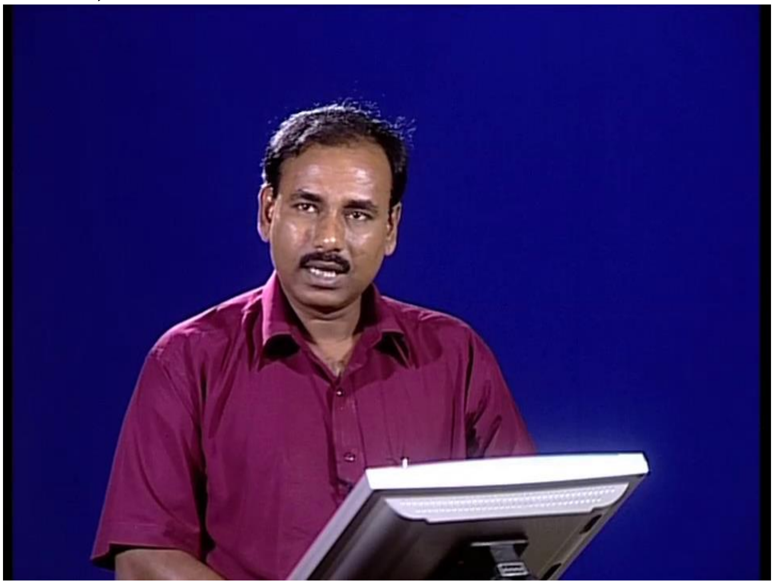

during the night also when there is no sunlight. Then what kind of image processing techniques can be used for such

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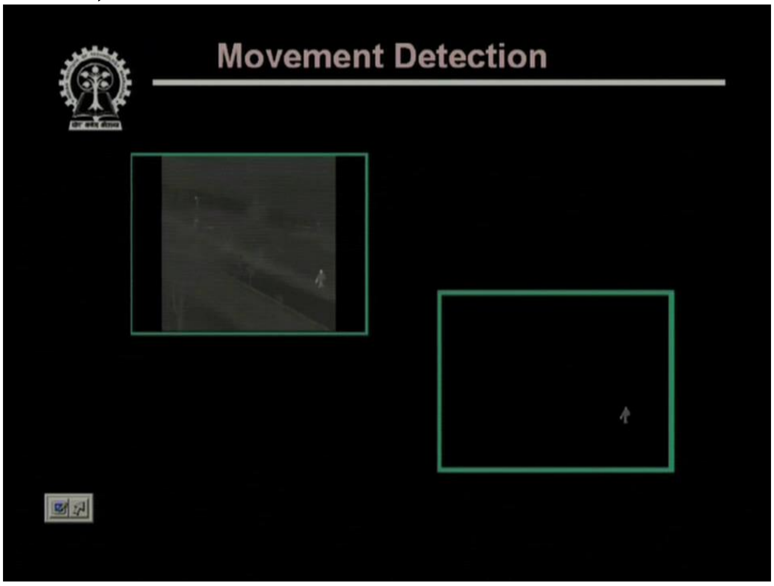

surveillance applications? So here you find that we have shown an image which is or a sequence

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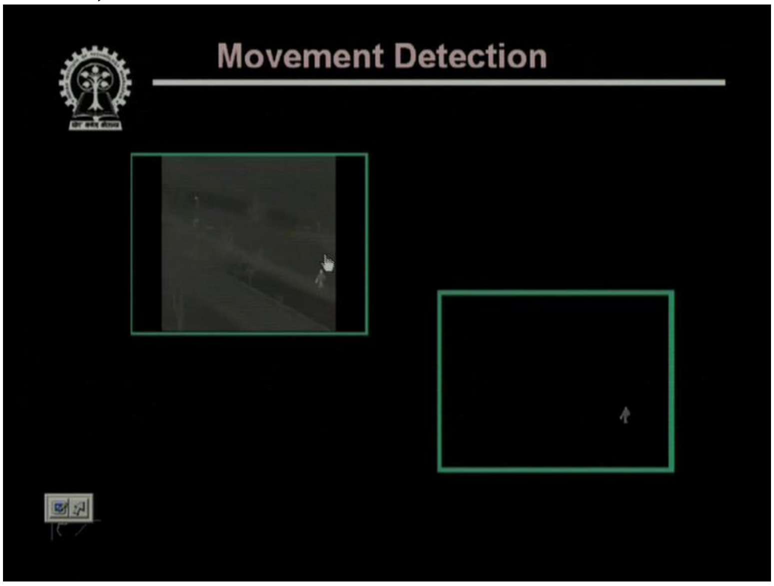

which is taken during the night and the kind of imaging that you have to take is not the ordinary optical imaging but here we have to go for infrared imaging or thermal imaging. So this particular sequence is a thermal sequence. So again here you find that a person is moving against a still background. So if you just concentrate in this region you will find that the person is moving. And again through image processing techniques, we have identified

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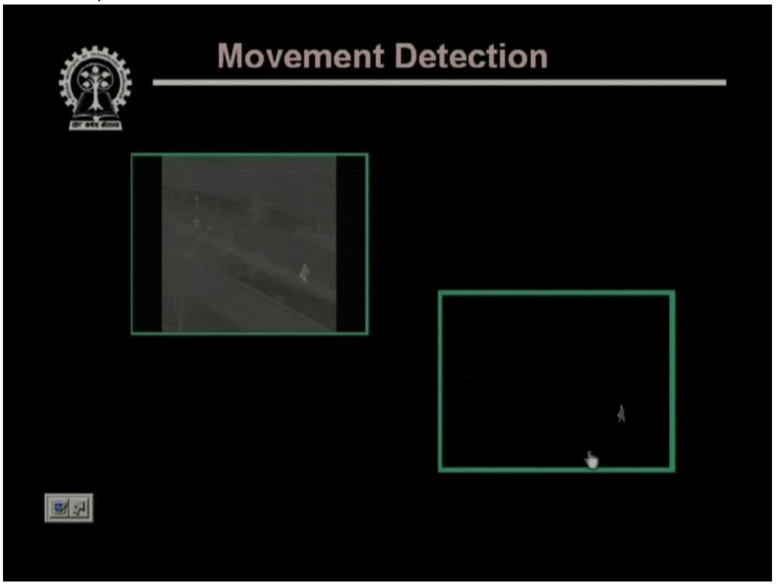

just this moving person against the still background So here you find that the person is moving and the background is completely black. So these kinds of image processing techniques can also be used for video sequence processing. Now let us take a look at another application of this image processing technique.

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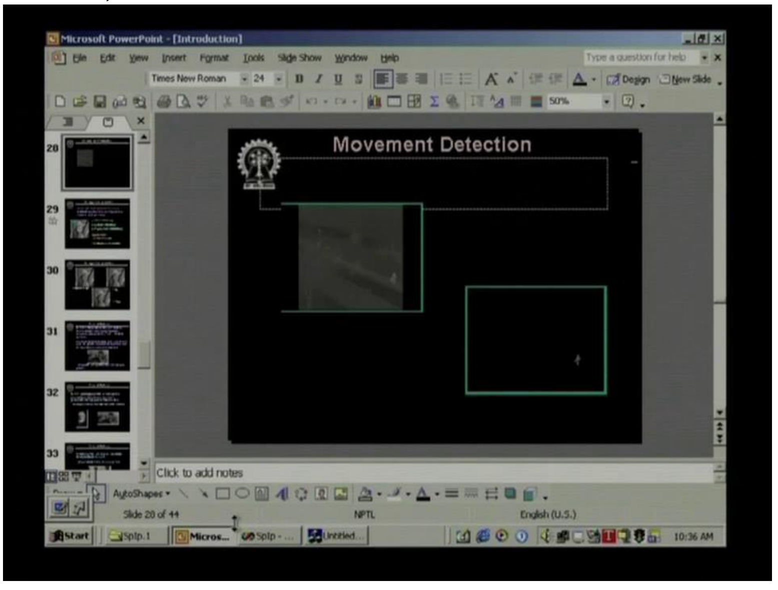

Let us look at this.

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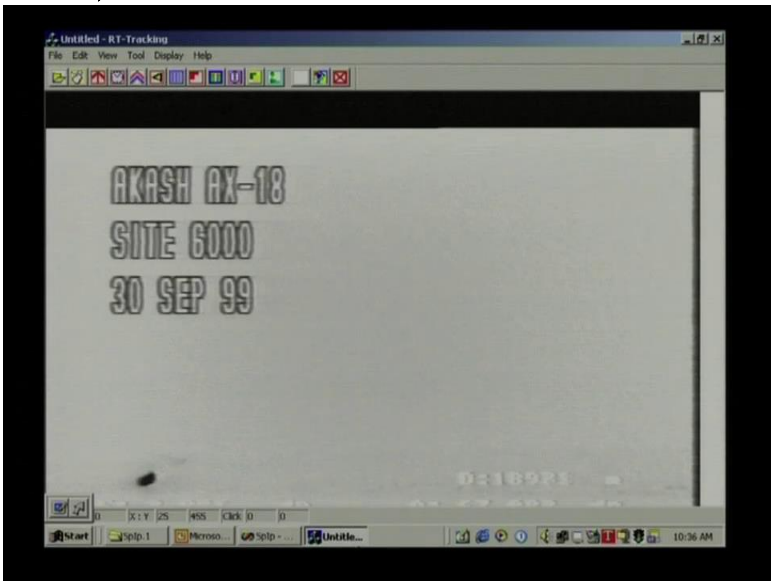

Here we have a moving target, say like this. And our interest is

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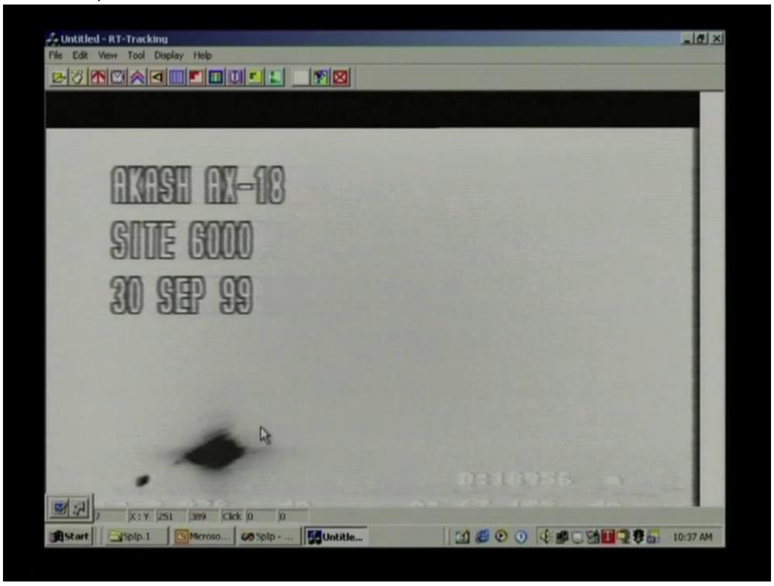

to track this particular target That is, we want to find out what is the trajectory that this particular moving object is following. So what we will do is we will just highlight the particular point that we want to track. So I make a window like this

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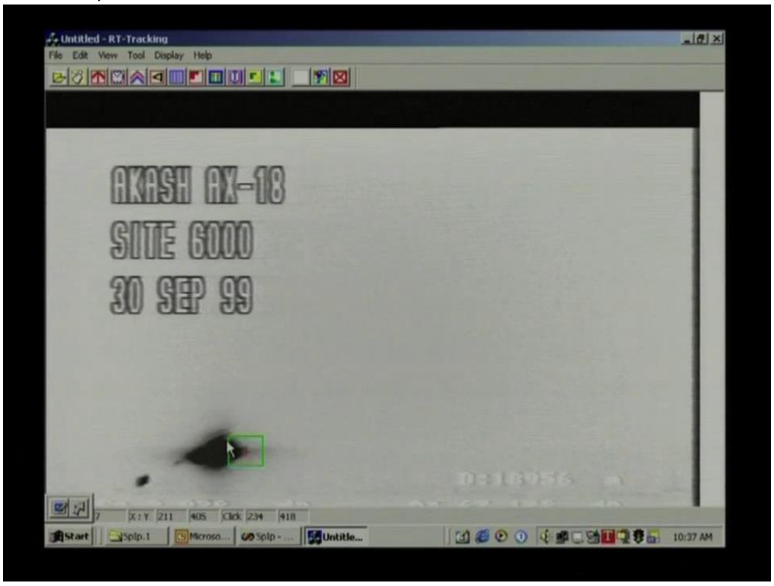

with the window covers the region that I want to track. And after making that window, I want to make a template of the object region within this window. So after making the template, I go for tracking this particular object. So you will find, again in this particular application, the object is being tracked in this video sequence. Just look at this.

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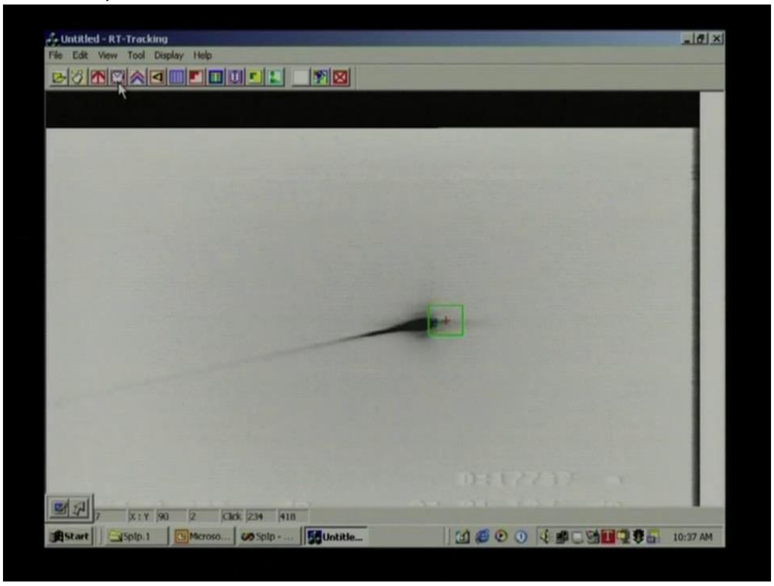

So you will find that over the sequences the object is changing its shape.

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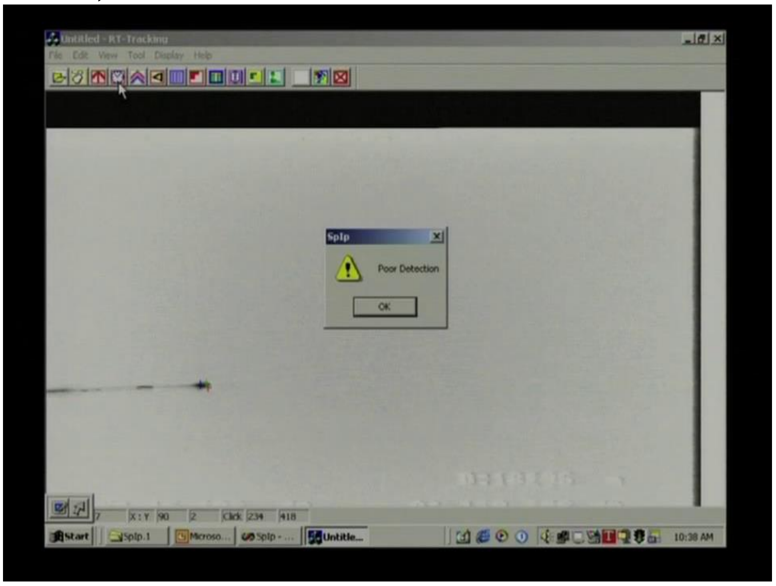

But even after changed shape, we have been able to track this particular object. But when the object cannot be matched any further, the shape has changed so much

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that the object cannot be matched any further, it indicates poor detection. So what is the application of this kind of image processing techniques? Here the application is, if I track this moving object using a single camera, then with the help of a single camera, I can find out what is the azimuth and elevation of that particular object with respect to certain reference coordinate system. If I track the object with 2 different cameras and find out the azimuth and elevation with the help of 2 different cameras then I can identify that what is the x, y, z coordinate of that object with respect to that 3D coordinate system. And by locating those locations in different frames I can find out that over the time which path the object is following and I can determine that what is the trajectory that the moving object follows. So these are the different applications of video sequence processing.

So we have mentioned that we have a third application which is compression

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and in compression what we want is, we want to process the image to reduce the space required to store that image or if want to transmit the image we should be able to transmit the image over a low bandwidth channel. Now let us look at this image and let us look at the region, the blue circular region. You will find that in this particular region, the intensity of the image is more or less uniform. That is, if I know that the intensity of the image at a particular point, I can predict what is the intensity of its neighboring point. So if that prediction is possible then it can be argued that why do have to store all those image points? Rather I store one point and the way it can be predicted, its neighborhood can be predicted, we just mention that prediction mechanism. Then the same information can be stored in a much lower space. You will find this second region. Here again in most of the regions you will find that intensity is more or less uniform except certain regions like eye, like the hat boundary, like the hair and things like that. So these are the kind of things which are known as redundancy.

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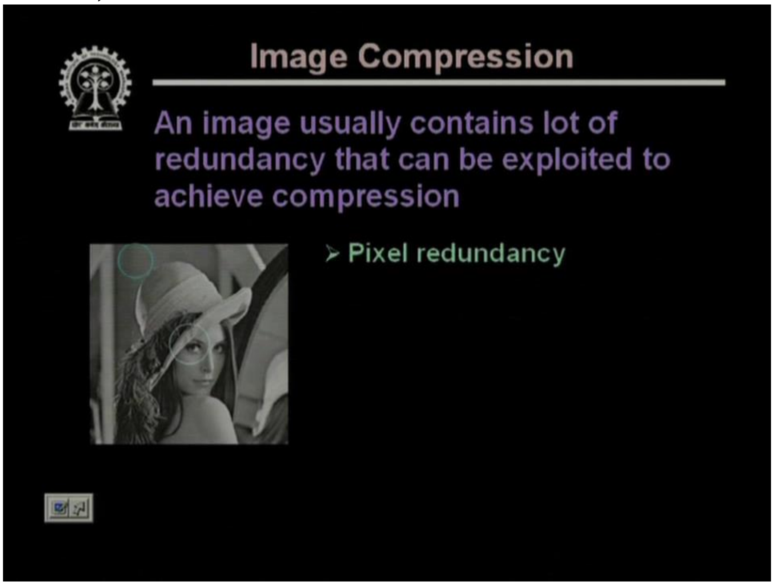

So whenever we talk about an image, the image usually shows 3 kinds of redundancies. The first kind of redundancy is called a pixel redundancy which is just shown here.

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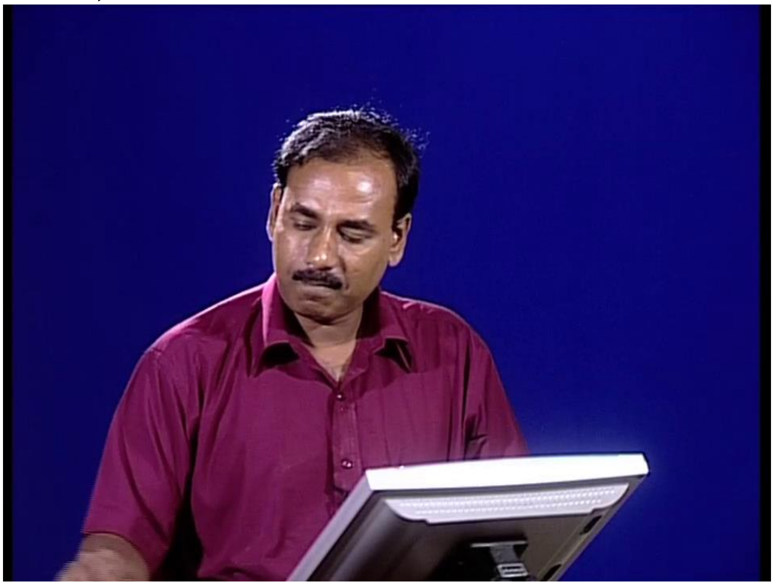

The second kind of redundancy is called a coding redundancy and the third kind of redundancy is called a psychovisual redundancy. So these are

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the 3 kind of redundancies which are present in an image So whenever we talk of an image

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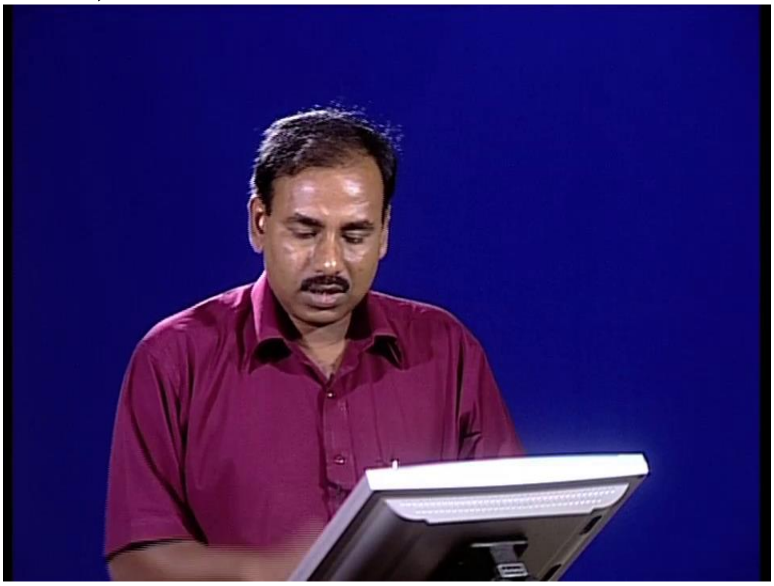

the image contains two types of entities, the first one is the information content of the image and the second one is the redundancy and these are the three different kinds of redundancies.

So what is done for image compression purposes, you process the image and try to remove the redundancy present in the image, retain only the information present in the image. So if we retain only the information, then obviously the same information can be stored using a much lower space. The applications of this are reduced storage as I have already mentioned

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if I want to store this image on a hard disk, or if I want to store a video sequence on a hard disk,

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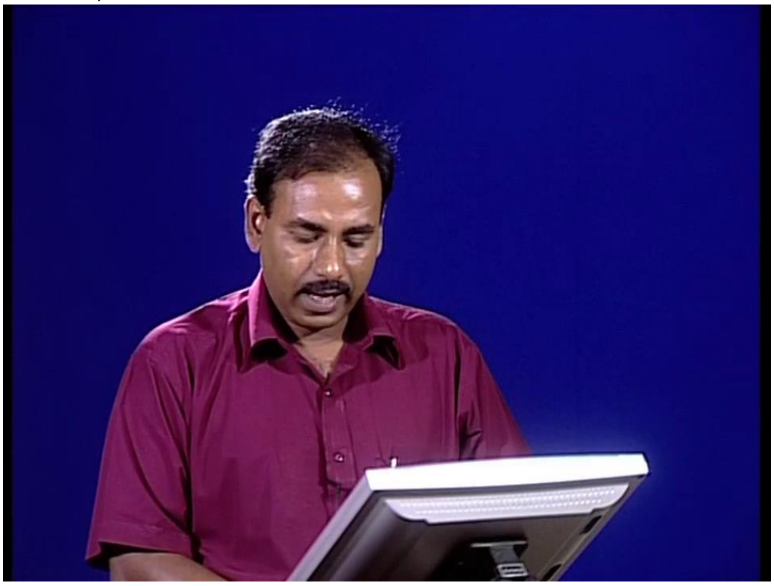

then the same image or the same digital video can be stored in a much lower space.

The second application is reduction in bandwidth.

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That is if I want to transmit this image over a communication channel or if I want to transmit the video

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over a communication channel then the same image or the same video will take much lower bandwidth of the communication channel. Now given all these applications, this again shows that

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what we get after completion. So here we find that we have the first image which is the original image, the second one shows the same image but here it is compressed 55 times. So you find, if I compare the first image and second image, I find the visual quality of the two images are almost same, at least visually we cannot make much of difference. Whereas if you look at the third image which is compressed 156 times, now if you compare third image with the original image you will find that in the third image there are a number of blocked regions or blocking, these are called blocking artifacts which are clearly visible when you compare it with the original image. The reason is, as we said that the image contains information as well as redundancy. So if I remove the redundancy, maintain only the information then the reconstructed image does not look much different from the original image. But there is another kind of compression techniques which are called lossy compression.

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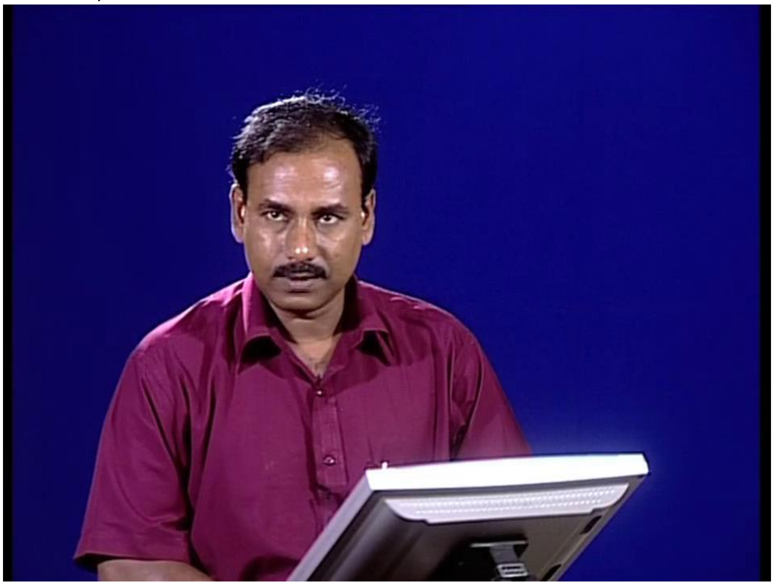

In case of lossy compression, what we remove is not only the redundancy but we also remove some of the informations so that after removing those informations the quality of the reconstructed image is still acceptable. Now in such cases, because you are removing some of the information which is present in the image so naturally the quality of the reconstructed image will not be as the original image. So naturally there will be some loss or some distortion and this is taken care by what is called rate distortion theorem.

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Now if I just compare the space requirement of these 3 images, if the original image is of size, say 256 by 256 bytes Ok that is 64 kilo bytes, the second image which is compressed 55 times, the second image will take slightly above something around say 10 kilo bytes, Ok. So you find that the difference. The original image takes 64 kilo bytes but the second one takes something around 10 kilo bytes where as the third one will take something around 500 bytes or even less than 500 bytes. So you will find that how much reduction in the space requirement we can achieve by using these image compression techniques.

So given these various applications

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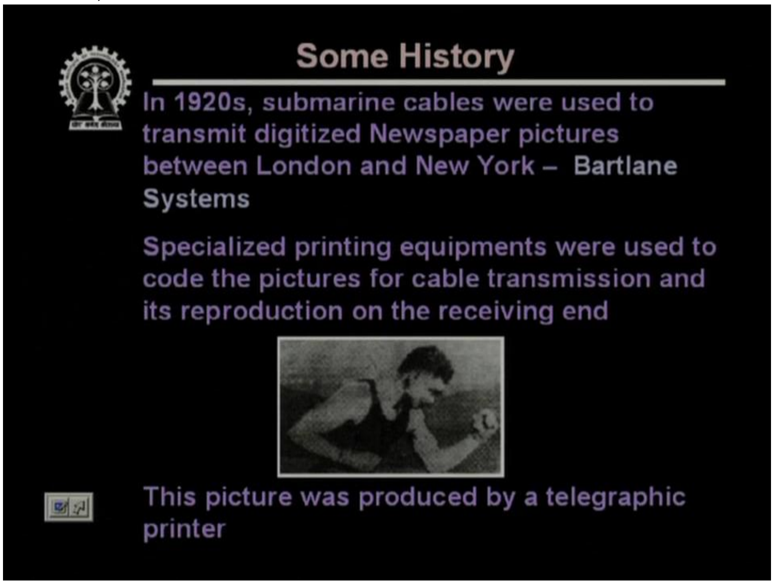

now let us look at some history of image processing. Though the application of image processing has become

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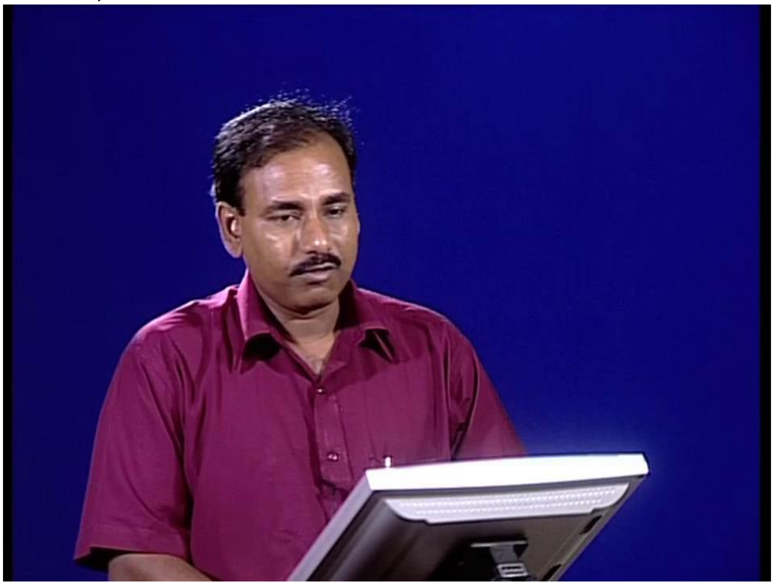

very, very popular for last 1 or 2 decades but the concept of image processing is not that young. In fact as early in 1920s image processing techniques were being used. And during those days, the image processing techniques or the digital images were used to transmit the newspapers pictures between London and New York. And these digital pictures are carried by submarine cables; the system which was known as Bartlane Systems. Now when you transmit these digital images via a submarine cable then obviously on the transmitting side I have to have a facility for digitization of the image, similarly on the receiving side, I have to have a facility for reproduction of the image. So in those days, on the receiving side

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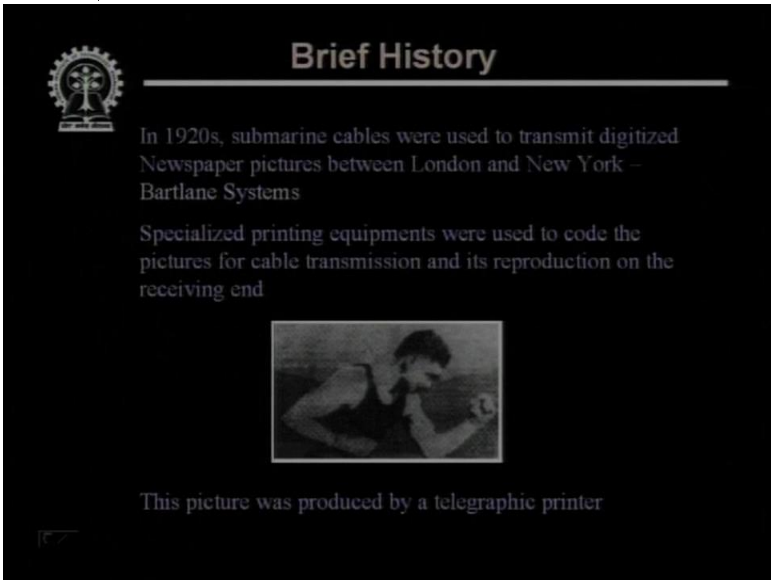

the pictures are being reproduced by the telegraphic printers and here find a particular picture which was reproduced by a telegraphic printer.

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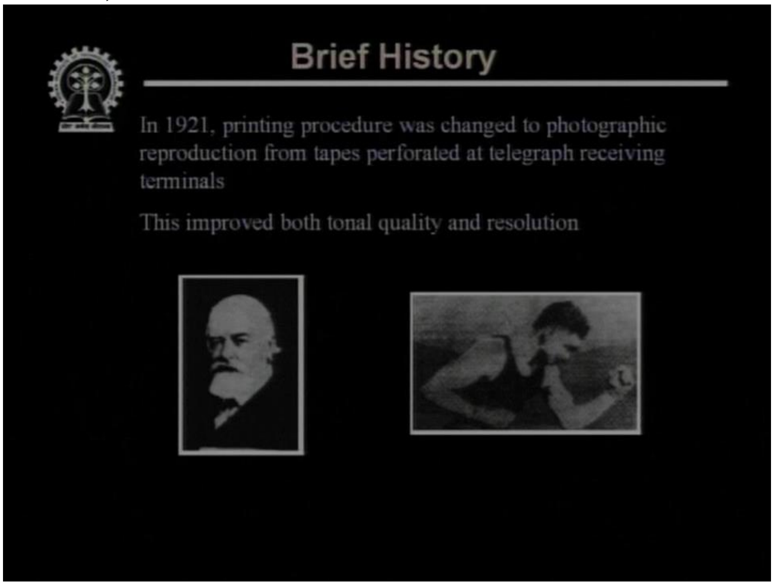

Now next in 1921, there was improvement in the printing procedure. In the earlier days, images were reproduced by telegraphic printers. In 1921 what was introduced was the photographic process of picture reproduction. And in this case, on the receiver, instead of using the telegraphic printer, the digital images or the codes of the digital images were perforated on a tape and photographic printing was carried on using those tapes. So here you find that there are 2 images, the second image is obviously the image that we have shown in the earlier slide. The first image is the image which has been produced using this photographic printing process. So here you find that the improvement both in terms of tonal quality as well as in terms of resolution is quite evident. So if you have compared the first image and the second image, the first image appears much better than the second image.

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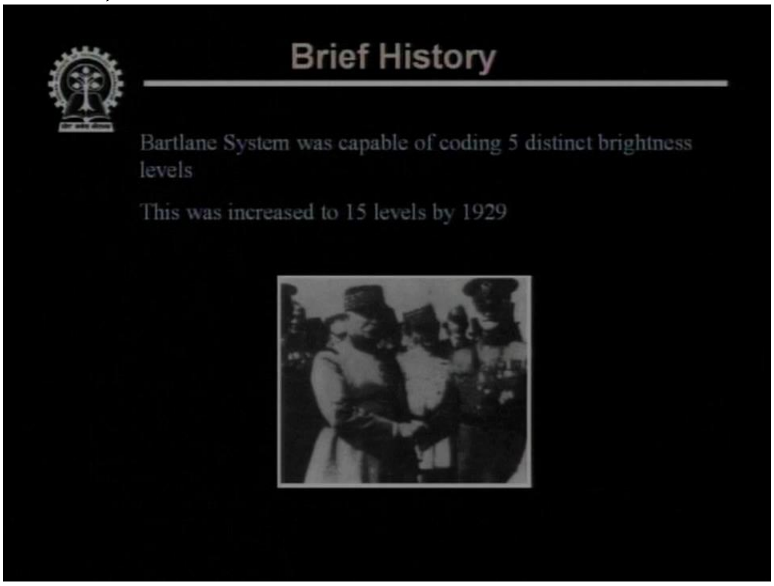

Now the Bartlane System that I said which was being used during 1920s that was capable of coding 5 distinct brightness levels. This was increased to 15 levels by 1929, so here you find an image with 15 different intensity levels and here the quality of this image is better than the quality of the image which was produced by the Bartlane system. Now since 1929

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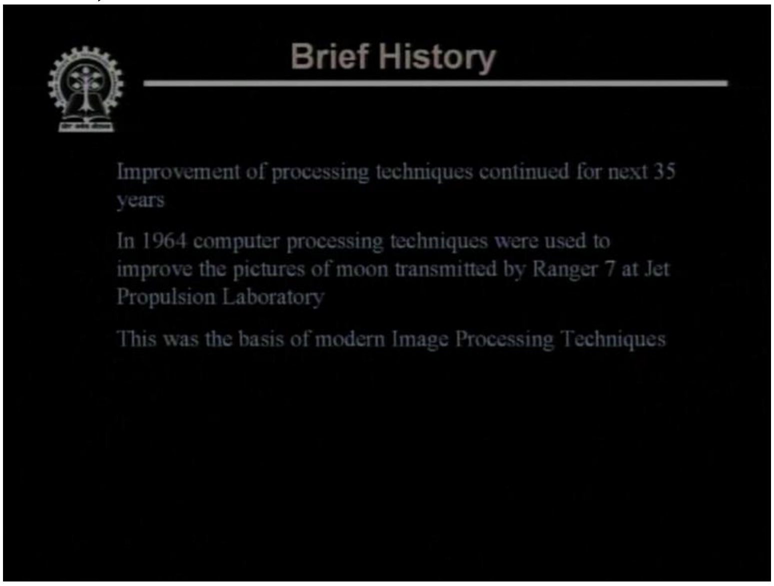

for next 35 years, the researchers have paid their attention to improve the image quality or to improve the reproduction quality.

And in 1964, these image processing techniques were being used by, in, at Jet propulsion laboratory to improve the pictures of moon which have been transmitted by Ranger 7.And we can say this is the time from where

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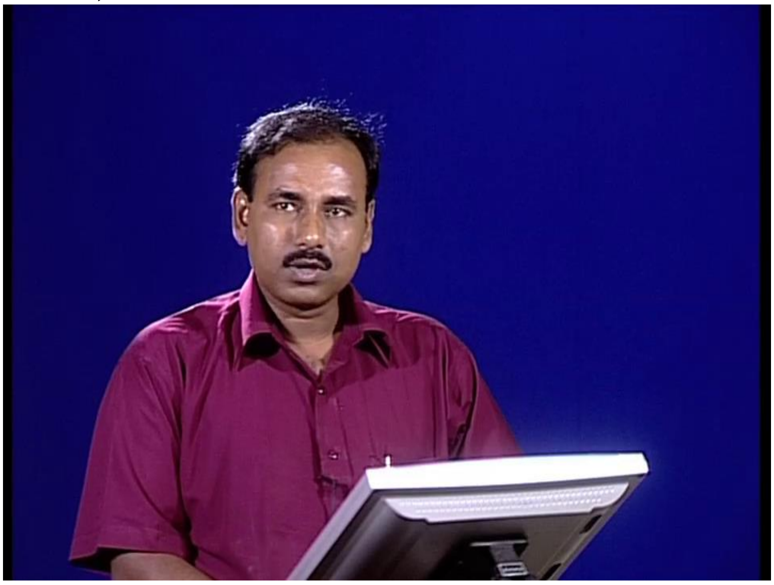

the image processing techniques or the digital image processing techniques has got a boost. And this is considered to be the basis of modern image processing techniques. Now given the applications as well as

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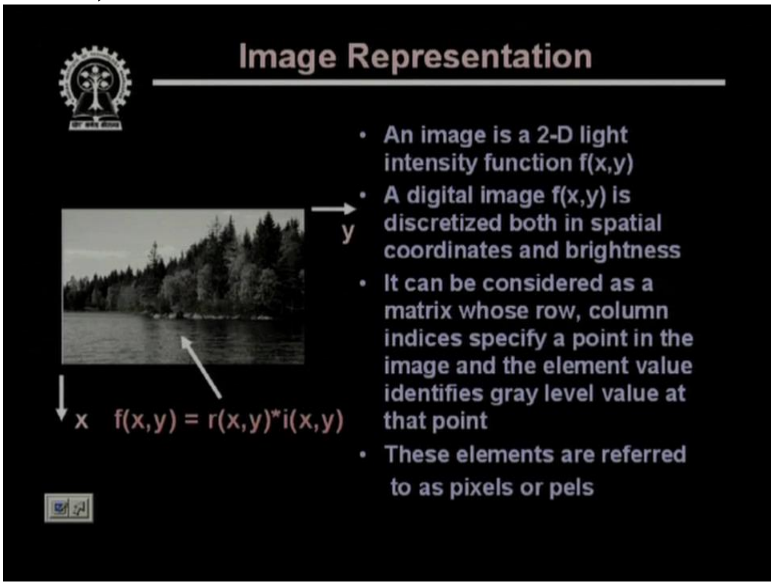

and the history of image processing techniques, now let us see that how an image is to be represented in a digital computer. This representation is very, very important because unless we are able to represent the image in a digital computer, obviously we cannot process the image. So here you find that we have shown an image and at a particular point "x, y" in the image conventionally the x coordinate is taken vertically downwards and the y axis is taken horizontally towards right. And if I look at this image this image is nothing but a two dimensional intensity function Ok which is represented by f "x, y". Now if at any particular point "x, y" we find out the intensity value which is represented by f "x, y" this f "x, y" is nothing but a product of two terms. So here you find that this f "x, y" is represented by the product of two terms one term is r "x, y" and other term is i "x, y". This r "x, y" is the reflectivity of the surface of the corresponding image point Ok. After all how do we get an image or how do we, how can we see an object? You find that there must be some light source. If I take an image in the daylight this light source is usually the sun, so the light from the light source falls on the object surface. It gets reflected, reaches our eye and then only we can see that particular object. So here you will find that this r "x, y" that represents that reflectivity of the point on the object surface which is used from where the light gets reflected and falls on the image intent. And this i "x, y", it represents the intensity of the incident light. So if I take the product of the reflectivity and the intensity, these two terms are responsible for giving an intensity at a particular point in the image. Now if we look at this, you find if this is an analog image then how many points we can have on this image? Obviously there are, there is information at every possible point both in the x direction and the y direction. That means there are infinite number of points in this particular image. And at every point the intensity value is also continuous between some minimum and some maximum and theoretically the minimum value can be 0 and the maximum value can be infinite. So can we represent or can we store such an image in a digital computer where I have infinite number of points and I have infinite possible intensity values? Obviously not! So what we have to do is, we have to go for some processing of this image

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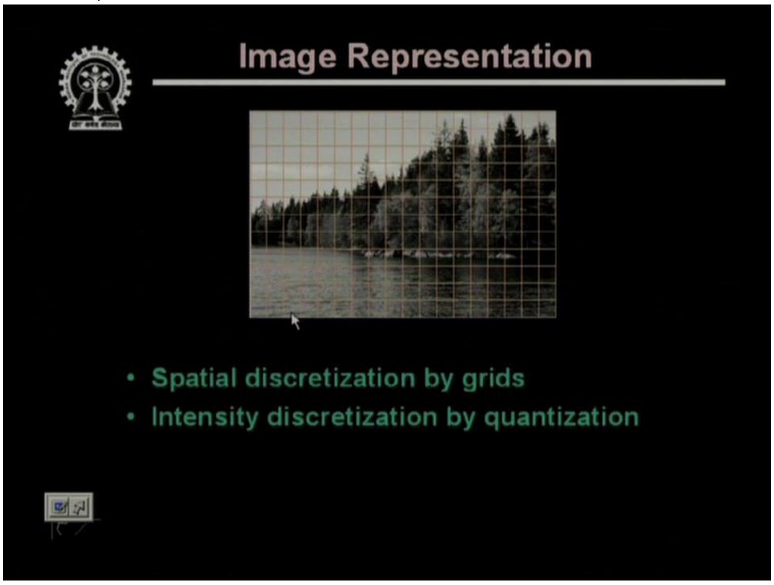

and what we do is, instead of storing all the intensity values of all possible points in the image we try to take samples of the image on a regular grid. So here the grid is superimposed on this particular image and what we do is we take samples, image samples at various grid points, Ok. So the first level that we need for representation of an image in a digital computer is spatial discretization by grids. And once we get these sample values, at every point the value of that particular sample is again continuous. So it can assume any of the infinite possible values, which again cannot be represented in a digital computer. So after sampling the second operation that we have to do is discretization of the intensity values of different samples, the process which is called quantization.

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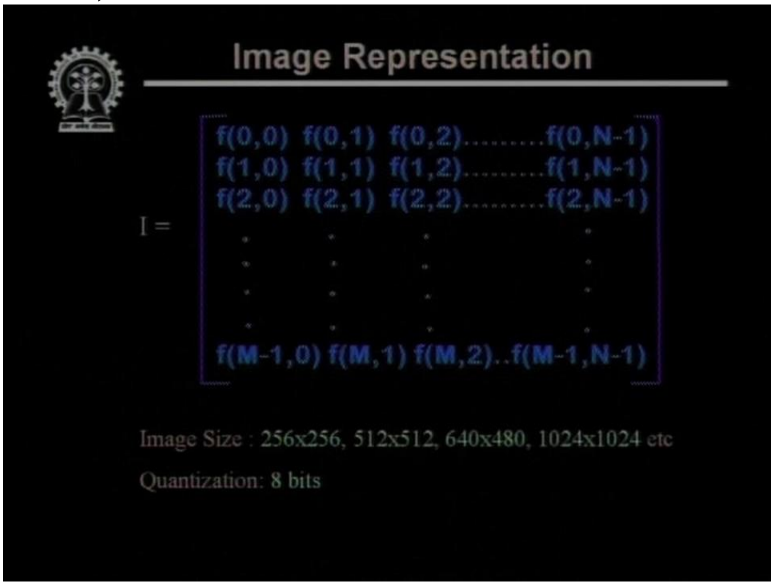

So effectively what we need is an image is to be represented by a matrix like this, Ok. So this is a matrix of finite dimension. It has n number of, m number of rows and n number of columns. Typically for image processing applications, the image size which is used is either 256 by 256 elements, 512 by 512 elements, 1 K by 1 K elements and so on. Each of these elements in this matrix representation is called a pixel or a pel. Now, quantization of these matrix elements, now you find that each of these locations represents a particular grid location where I have to, I have stored a particular sample value. Each of these sample values are quantized and typically for image processing applications, the quantization is done using 8 bits for black and white image and using 24 bits for color image. Because in case of color, there are 3 color planes red, green and blue. For each of the planes, if I use 8 bits for quantization, then it gives us 24 bits which is used for representation of digital color image.

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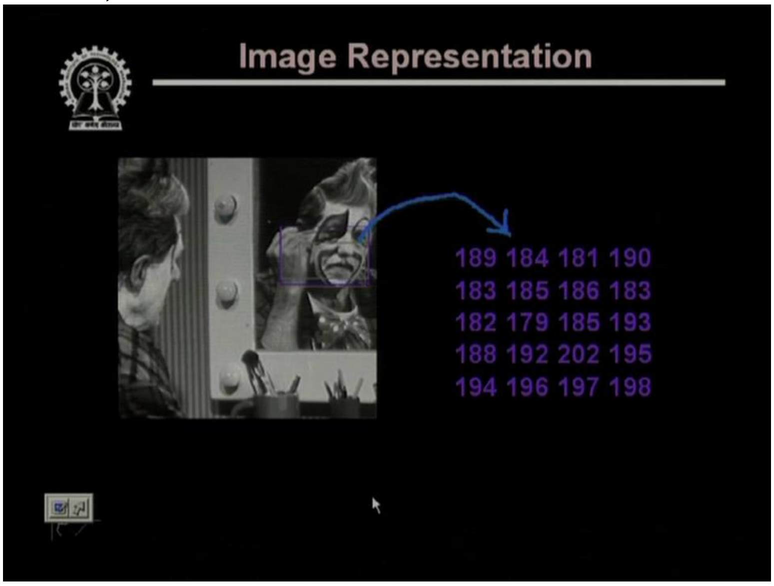

So here you will find that we just show an example that given this image if I take a small rectangular area somewhere here, then intensity values of that rectangular area is given by a matrix like this.

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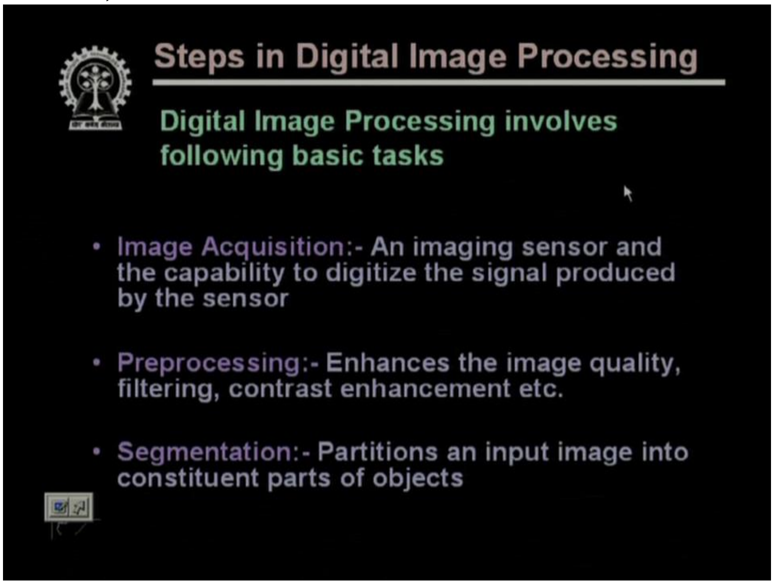

Now let us see what are the steps in digital image processing techniques. Obviously the first step is image acquisition. The next step after acquisition is we have to do some kind of processing which are known as preprocessing which takes care of removing the noise or enhancement of the contrast and so on. The third operation is segmentation that is partitioning an input image into constituent parts of objects. This segmentation is also responsible for extracting the object points from the boundary points.

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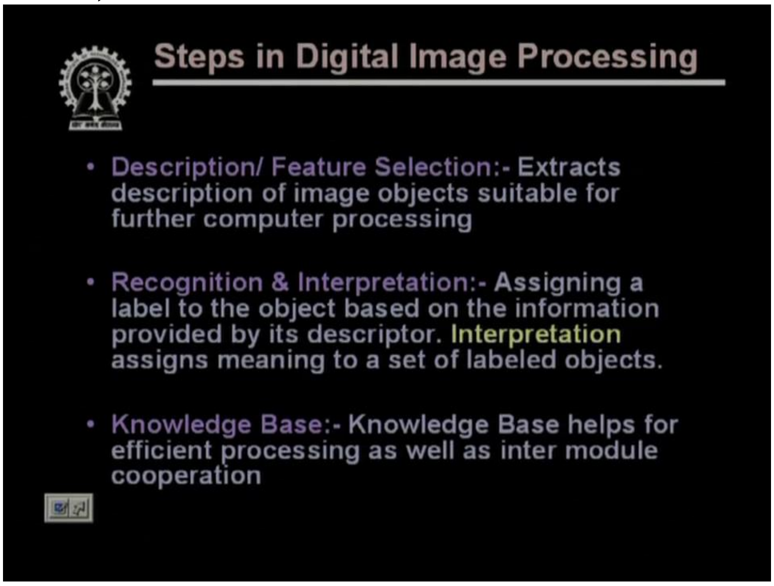

After segmentation, the next step is to extract some description of image objects which are suitable for further computer processing. So these steps

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are mainly used for machine vision applications Then we have to go for recognition. So once we get description of the objects, from those descriptions we have to interpret or recognize what the object is. And the last step is

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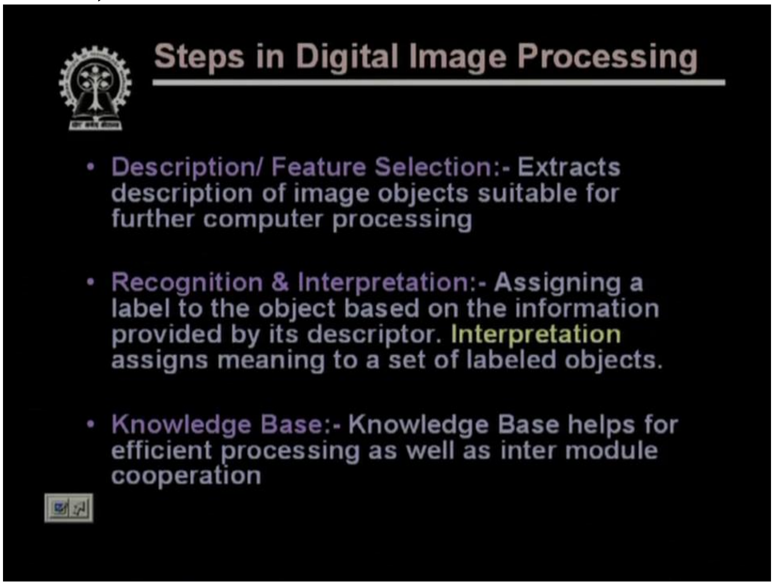

the knowledge base, what the knowledge base helps for efficient processing as well as inter-module cooperation of all the previous processing steps.

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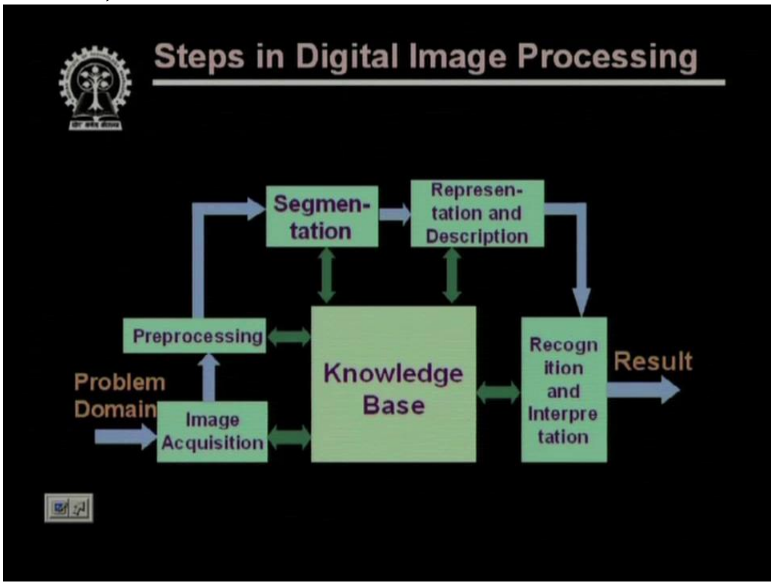

So here we have shown all those different steps with the help of a diagram where the first step is image acquisition, the second step is preprocessing, then go for segmentation, then go for representation and description and finally for recognition and interpretation and you get the image understanding result. And at the core of the system we have shown a knowledge base and here you find that the knowledge base has a link with all these different modules, so the different modules can help of the, can take help of the knowledge base for efficient processing as well as for communicating or exchanging the information from one module to another module. So these are the different steps

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which are involved in digital image processing techniques and in our subsequent lectures we will elaborate these digital, on these different processing steps one after another. Thank you.