Characterization of Construction Materials

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Lecture – 49
Image Analysis – Introduction and Image Mapping – Part 2

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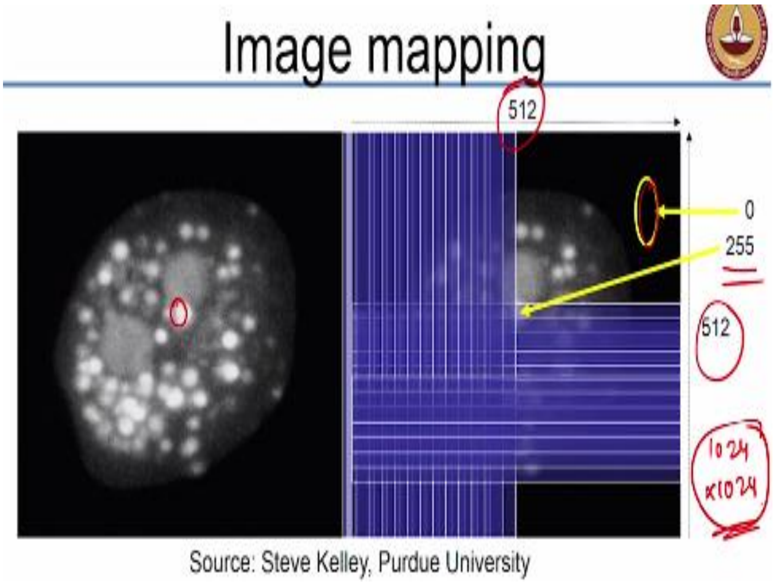

So again, this is an example of image mapping. So you have your original image on the left. It is a biological sample, for instance, and here you are overlaying that with this 512 x 512 matrix. You have a 512 x 512 pixel matrix. So that means, how many megapixels is this image? 512 * 512 = 250,000 plus. So, it is not really megapixel, but 250K pixels or 0.25 MP or million pixels. So, thousand is kilo, 1 million is mega, and 1 billion is giga. So, here it is 500 by 500, so 250,000, so 250 k pixels, so 0.25 megapixels. So, this is a very low resolution in the system. So now, what it is doing is, it is overlaying this matrix on top and looking at each point inside the matrix and giving it a gray level value. For instance, if it hits anywhere here (black region), you get a 0 count. If it hits somewhere here in this location which is very white, so you can give it the 255 value. So, you are converting each and every spot in your image to a gray level. That is what I am saying. So, if you have to operate in color, your pixel size becomes very huge and then you need to really have the right computing resources to do those kinds of operations. So converting to grayscale is much easier because you have limited number of possibilities in terms of gray levels and then you can assign this quite easily.

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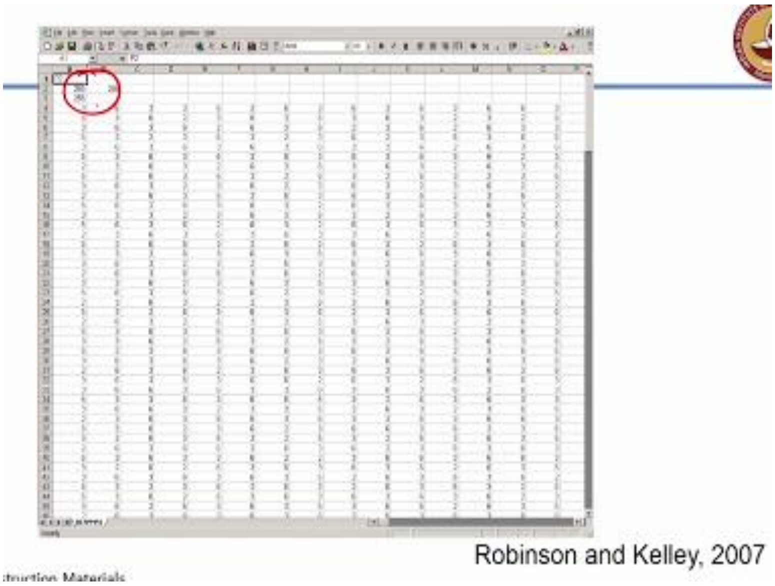

So, this is actually a 255 x 255 matrix that has been given here. This is all of course composed of very low values. So, that means mostly a dark image has been produced in this case. So this is just one sample, one part of the entire matrix.

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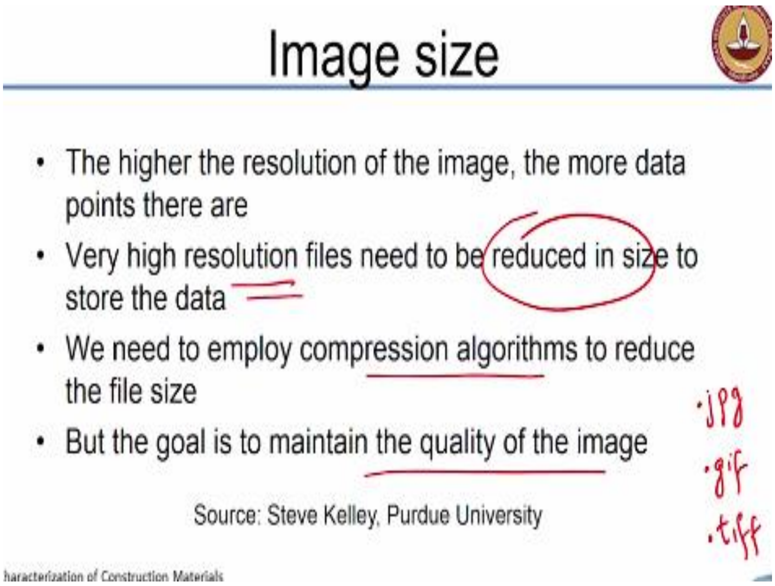

So, the higher the resolution of the image, the more data points there are. So, supposing I take the same thing and have 1000 x 1000 or 1024 x 1024, I am breaking it down into much smaller areas which are representing one pixel. The area is still the same, but I have more pixels. So, now what is happening is my resolution has improved because I put in more pixels for the same area. It is not magnification, remember, it is just resolution. We are improving resolution because we have more pixels for the same area.

But this now means that my operations with this image will take more time because now my matrix is 1000 x 1000 or 1 MP. I have reached 1 megapixel in this case because the previous case is 250,000. This is 1 million. So it is basically your computing power now required to analyze the same image goes up by 4. Now this way, you can actually enhance images with very high resolution also, but the problem is if you want to store these high resolution files, you need to reduce the file in size. To reduce the file in size, we apply compression algorithms. So can you give me an example of a compression algorithm? What is the most popular type of image that you are familiar with? What is the image extension? .jpg or .jpeg. We call it a jpeg image or sometimes you have .gif or .tiff. So, each one of these is nothing but compression algorithms that take the image, and compress the data that is required to store the information in the pixels. So, the greater the resolution, the more number of data points you need to actually store, but then the file size becomes too cumbersome. So, to reduce that, if you have operated in Adobe Photoshop and you tried to save anything as a JPEG image, you will know that it asks you what level of storage you want, image quality that you want. Dots per inch is for printing. 1 to 12 is the image quality that you can save the JPEG in. So when it is 1, that means you are trying to compress it too much. When it is 12, you are not compressing it significantly.

But then the point of compression is to still maintain the quality of image. The image quality should not be lost because you cannot really do operations and measurements on an image that is of poor quality. So, you need to compress the image well enough to store it properly and handle it, but it should not become so small that is not easy to operate on. So sometimes when you put images in your Word document or you put in your PowerPoint presentations and you save your document or presentation, the file size becomes huge. So very often, you can go to individual pictures and compress the picture. That means it is applying the compression algorithm within the word processing or presentation software to compress the picture. So there you can compress it to different levels. If you have seen in Word, it gives you options. How much do you want to compress? Email format, etc. So there it gives you the DPI options, whether you want to print it or you want to send it as an email attachment. So, how much do you want to compress is a choice that is given to you, but then for a report, it is okay, but if you have to do an analysis, you cannot really compress it too much.

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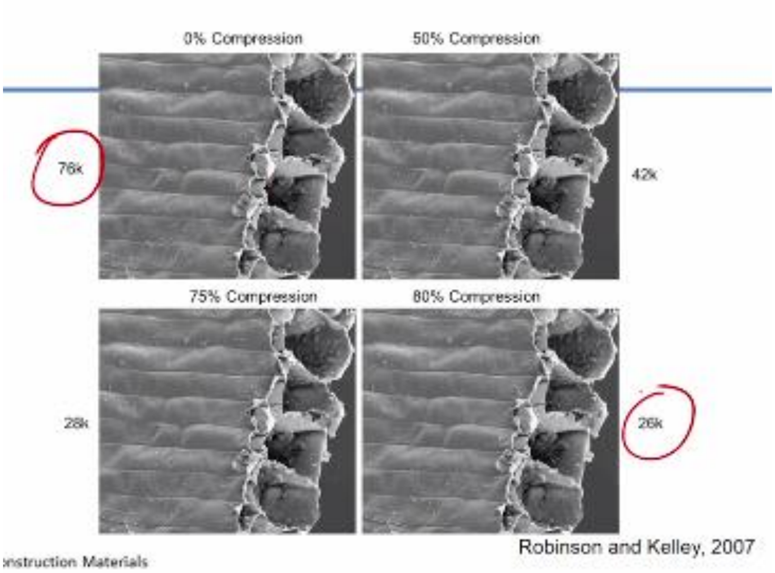

So again, this is just an example of a biological image which has been compressed. So this is 0% compression, where you have a 76k image, but it has been compressed all the way down to about 26k, but even at this level, you think that the image clarity is not really gone, it is still keeping the clarity intact and that is the power of these image compression algorithms. They have been created to maintain the quality of the image. So that is why a lot of the effort that goes in to actually maintain this quality reflects in the right type of image that you are saving. Now, of course, there are multiple types of image formats that are available. JPEG is a thing of the past. Now everybody talk about PNG, SVG, and so on. If you look at most internet based images, they are stored in much different formats.

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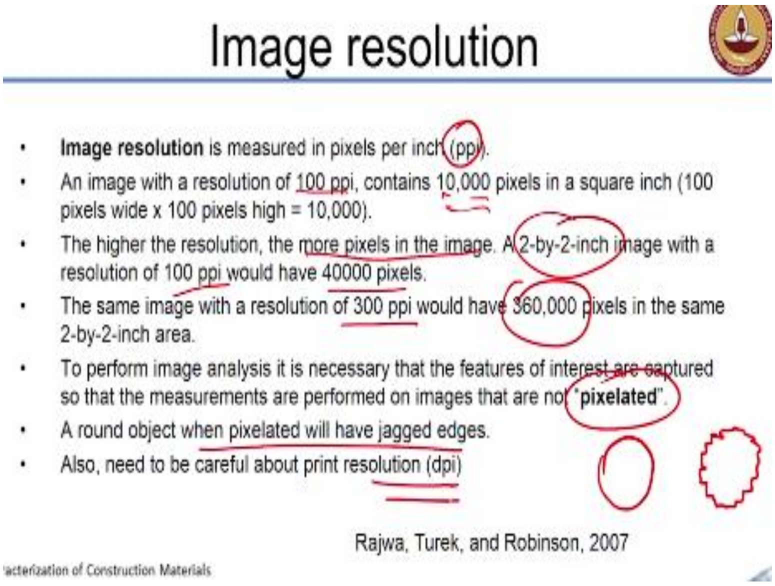

So image resolution is nothing but what is measured in pixels per inch, ppi. When you print, you talk about dots per inch because it is coming as a printout on your paper. There you talk about dots per inch. The old dot matrix printers were having a very low resolution of printing, but today the laser printers have a very high dot per inch resolution. So, they are able to print more and more dots in a smaller area, which is why your printed image becomes much clearer.

But here image resolution on the screen is measured in terms of how many pixels you have in an inch. So, image resolution of 100 ppi means you have 100 * 100 that is 10,000 pixels in a square inch. Similarly, higher the resolution, more are the pixels in the image. So 2 x 2 inch image with the resolution of 100 ppi means you have 40,000 pixels. Again, if you increase the resolution from 100 to 300 ppi, the same 2 by 2 inch image will have 360,000 pixels in the same area. So you are basically increasing the size. To perform your image analysis, you need to have very clear-cut features observed in your image so that you can perform the measurements and your image should not be pixelated. That is something you have learned before - what is a pixelated image? You must have discussed with your friends when you take a picture sometimes and displayed on the screen, you sometimes make this comment it is pixelated. What do you mean by pixelated? The choice of your resolution is not good enough to show the features clearly, sometimes a pixelated picture like I will show you in the next picture.

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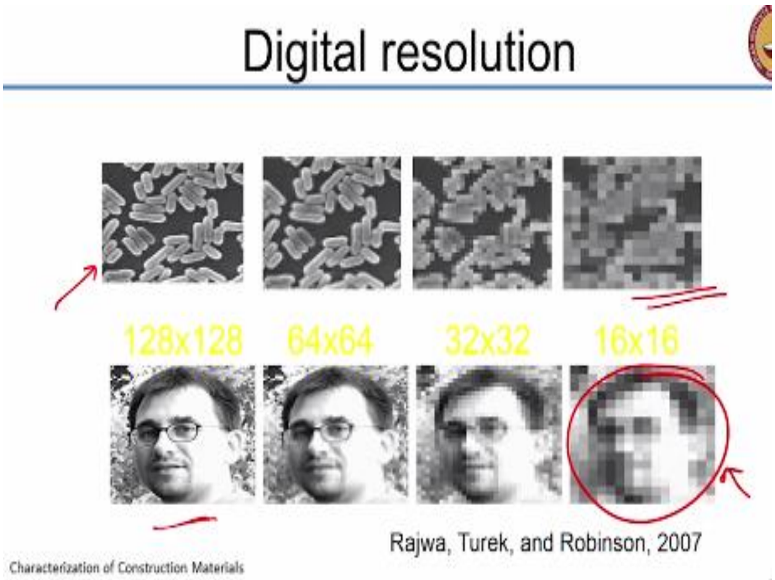

This is a pixelated image (right image). You have chosen very less amount of pixels that is not able to show the degree of clarity that is expected in this image, in an attempt to reduce the size, your image is now pixelated. Look at this here, you cannot obviously make out anything from this, at least here, there is semblance of a human face. In this image, there is absolutely nothing that you can make out (top-right), but here, even in a 128 x 128 pixel matrix, you can still make out these are some biological cells that are being observed in the microscope.

So, a round object when pixelated will have jagged edges. So if you have a round object like this, it might look like this otherwise (jagged). That is what a round object will look like if you have low resolution (refer drawing in slide), less number of pixels defining the same object. Again, as I said earlier, you need to be careful about print resolution also, because images have to be printed on a 2-dimensional paper, in which case we have to choose the right level of print resolution to convey the quality of the image carefully on the paper. A pixel is always a square, i.e., picture element is always a square, so you are choosing less number of squares to represent the same area. That is basically your pixelated image.

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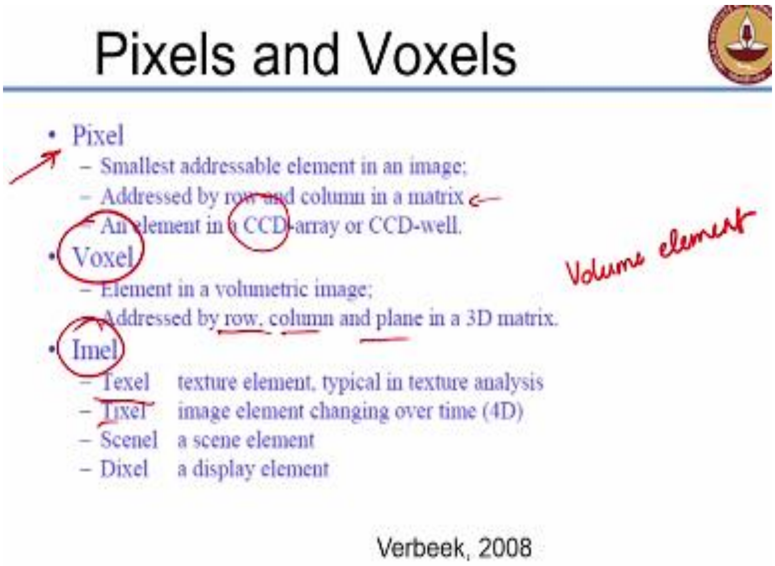

Now, a pixel is a picture element, which is the smallest addressable element in an image. As I said, it is addressed by a row and column in a matrix and it is nothing but an element in the array, which is present in your charge coupled device - CCD.

Now, if you are looking at a volumetric image or a 3-dimensional image, you cannot call it a pixel anymore, it is called a voxel or volume element. So here, what you need to have is attributes that are defining 3 dimensions. You have a row, column, and plane in a 3-dimensional matrix.

Now if you want to complicate things further, you have what is known as Imel. Now, do not ask me what an Imel is, I think it is an image element, but I could make out voxel, but I am not very sure what imel. Anyway, imel is essentially to look at specific features of your object. For example, an imel could be a texel, which is a texture element, if you are doing a texture analysis of your object. It could be a tixel, which is a time-dependent image element which changes. Scenel is a scene element and dixel is a display element. So, again, these are terminologies that are not so commonly used in typical image analysis, but then, for people who are looking at stereographic imaging who want to understand the 3-dimensional time-dependent behaviour of materials of objects as they change and using microscopy to image such things, they have to be familiar with how these also get operated upon.

But for now, our discussion primarily will be with 2-dimensional images, and we will deal ourselves with pixels. You can get voxels also. For example, if you are doing something like an X-ray tomography analysis. X-ray tomography is when you are actually doing a 3-dimensional representation of your object by taking slices of the object with X-rays and these X-rays are then put together and you get a 3-dimensional image of the entire specimen. There, each and every element in this 3-dimensional space will be called a volume element or a voxel.

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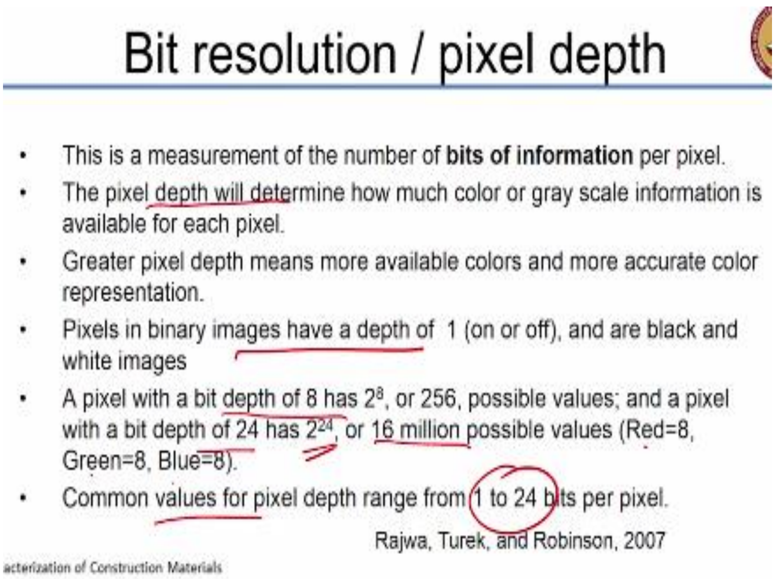

So again, bit resolution or pixel depth is given here. It's a measurement of number of bits of information per pixel. Please remember, if you have a single bit in a binary image, you only have either black or white okay. So, pixel depth basically determines how much color or grayscale information is available for each pixel. Greater depth means more available colors and more accurate color representation. So, again, this will depend obviously on the capability of your monitor also. You cannot represent each image with the same level of clarity on different types of monitors, like your cathode ray tube monitors, your LCD screens and your LED screens, which are 3 generations of televisions that you have seen, will not have the same representation of colors. So today, the LED screens that come have a much brighter and much wider variation in colors that are possible, that can be represented on the screen. But we need to imagine that the energy it takes to actually project that level of image and that level of clarity with so many different types of colors obviously is much greater.

So pixel with a bit depth of 8 has 2^8 or 256 possible values. So that is what is defining your grayscale images, which have 256 values from 0 to 255. But a pixel with a depth of 24 has 2^{24} = 16 million values. Now imagine, you have 16 million possible combinations of red, green, and blue that define several different types of colors that can be depicted at a single time in an image. But if you have to use those images for your processing, it would be almost impossible. It can be done, but the computing power you need would be tremendous. Generally common values of pixel depth are from 1 to 24. So, the sharpest TFT or LED screens will have this level of resolution possible, 2^{24} especially when the broadcast is in high definition, you can actually get this extent of color information.

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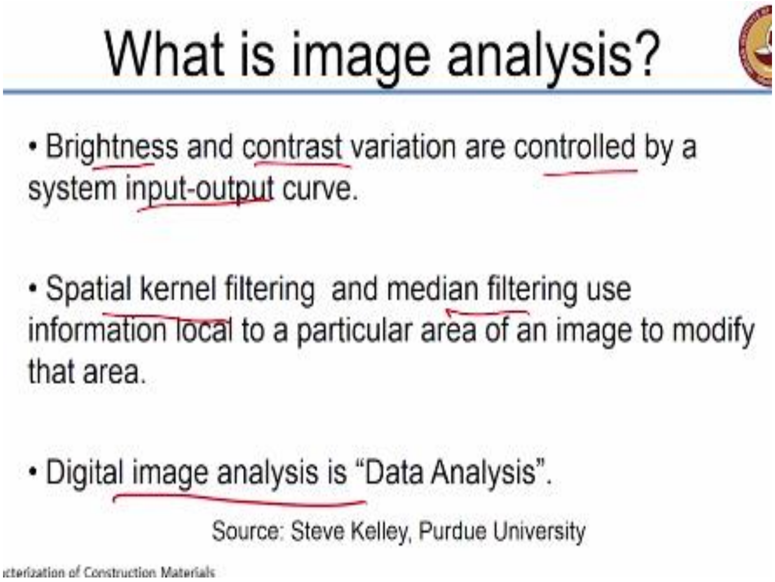

So again, the various common processes that we typically do are to control the brightness and contrast in the image. That is what we always keep doing in images because before we even start looking at the image, we want the image to have the right level of brightness and contrast. Now this is something which is controlled by a system input-output curve.

To do more complex operations on the image, for example sharpening or smoothing, you do what is known as spatial kernel filtering and median filtering. This is nothing but matrix operations that can help you enhance or suppress certain qualities of the image. Now what do you mean by suppress quality of the image. You might have sometimes taken pictures of yourself where the tip of your nose may appear very bright because of the flash. Now, obviously for a good quality image to be stored on your personal collection or for a print, you want to reduce the brightness in your tip because of the flash and that can be done by suppressing certain features. So not always do you want the images to look sharp, sometimes you want to smooth images also. Sharp means also you have clearer features, but you also get more noise when it is sharp. Smooth means your features are numbed down to some extent, but the noise also gets canceled out to a large extent, and that is called smoothening.

So, not always do you want to have only sharp images and obviously not always you want to have only smooth images. And because of this power that you have of image analysis techniques, you can make things appear as they are not, or you can make actual features disappear and that is the power of image analysis. That is why, you need to use it with a great level of care to show the object that supports or disproves your theory, whatever theory you are trying to prove at the macro level, the image interpretation has to be aided by the image analysis to either prove or disprove that theory. But it should not be used to muddle the minds of the viewer or minds of the reader to such an extent that they forget about what is being talked about in the macro scale because you are doing all these gimmicks at the micro scale. In many cases, a lot of gimmicks are resorted to by many researchers, we need to be clear that we do not fall for the trap and go for the more valuable information. So, digital image analysis is akin to data analysis, we are actually doing basically data analysis.

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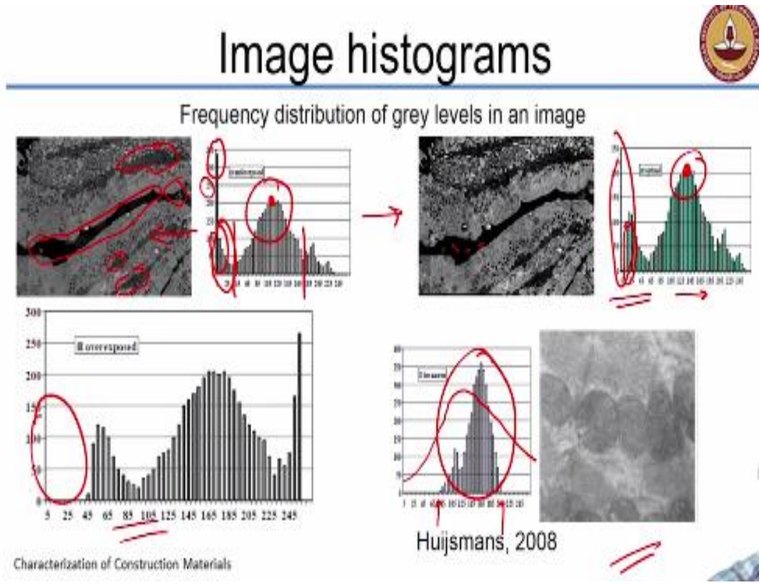

So, each gray level image can be broken down into the frequency distribution of the number of times a particular gray level value appears in that image. That is nothing but a histogram. You have drawn histograms before in school and college. So here, what you are simply doing is representing each pixel’s value, which is from 0 to 255 in a histogram. So, if the white value 255 appears in that image 150 times, the histogram should represent 150 for the 255 points.

So, here for example is the image on the left and histogram on the right. So, you see the frequency distribution of how many times the particular spot appears. So here you can see a large black region is present in the middle and there are also certain other black regions which are present elsewhere. So obviously, that will have gray level that is close to 0. So you do have a very high number of points where the gray level is close to 0. You also have several points where the gray level is not necessary 0, but not too far away from 0, and then you move to this particular region, which seems to have a peak of a certain number of gray levels. So you have a distribution of gray. You do not really have specific peaks like this, your histogram does not look like this (with sharp peaks). That means you do not have 0 and 255 and exactly one gray level in between. You have multiple gray levels and therein lies the challenge of actually separating out the kind of phases that you want to look at.

Again, this is the same image which is being represented (on the right), but there seems to be some better clarity in this image. What do you think has happened to the left side image on the right? So, here a lot of the black has been eliminated. So what has been essentially done is that your points have been shifted to the right. You see here and what we are doing is adding some gray level to each spot. So, adding a fixed value to each spot. So for example here, the peak was close to 110 or so, here our peak is shifted to about 125. So, more or less what we have done in this case is added a single gray level to each point, for example a point was having a gray level of 0, I have added 15 to it and made it 15.

So, what is this basically in terms of your typical image operation? Enhancing. So here, please remember, there is contrast and there is brightness. What do you understand by contrast, the difference between black and white. If you increase the contrast that means I have increased the distance between black and white. If I increase the brightness, all I am simply doing is putting more light on the image. So I am raising the gray level. So whatever was completely black earlier now is having a gray level of about 15 or so, 10 to 15. So this just the same image shifted. The scale is different here, frequency is still 200, but there is an increase in the gray level of each point by about 10 to 15.

Now, the same image is overexposed in this case, overexposed means what? Too much brightness, what will happen in that case is you are cutting off a very large region of gray levels. So, that means you are not getting the same information that you want to get.

This is again one more picture (bottom right picture) with more subtle gray levels, you do not really have a completely black or a completely white feature in this image. But you look at the distribution of the histogram, it is confined to somewhere at 80 to about 205 or 210. So it is in a narrow region and your total image looks completely uniform almost. You are not able to clearly distinguish these circular features well enough.

What you would have to do is in this case increase the contrast. When you increase the contrast, you increase the distance between the lowest gray level and the highest gray level, so you will probably make it spread out when you increase the contrast; you increase the distance between the lowest and the highest gray levels.

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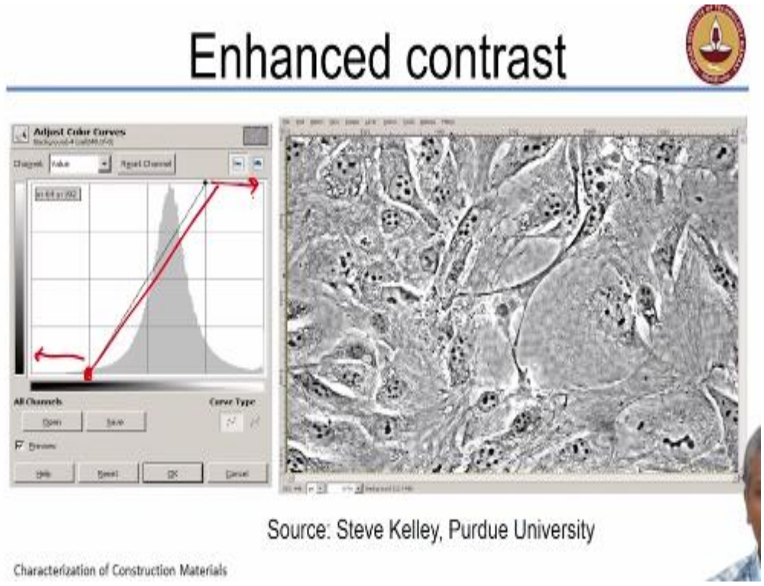

Again, just to give you an example, this is the original image for example for a biological sample and that is your histogram. When you increase the brightness, all you are simply doing is enhancing. So this line here (on the left graph) basically is representing the gray levels. So all you are doing is taking that line simply up, and you can see that the image is losing some of its characteristics.

But in the same image, if you increase contrast, you are increasing the distance between the whitest and the blackest spots. So all you are doing is increasing the slope of this line. So in the first case, the slope was not too steep. Second case, the slope is the same, but you are simply raising the gray levels of each and every point. In the third case, you are changing the slope to enhance the dark and the white. In other words, what we are doing here is that all the objects which have a gray level below this (point marked in left graph) have been turned to black and all the objects that have a gray level above this have been turned to white. So, we are increasing the sharpness or increasing the rate of drop from black to white or white to black. So that is why the contrast is basically increasing. We will stop with this for this lecture and continue on the next lecture with some examples as to how these processes can be applied to common images that we view in cementitious materials and see how well we can translate that into actual data about the phase contents which are present in the material and so on.