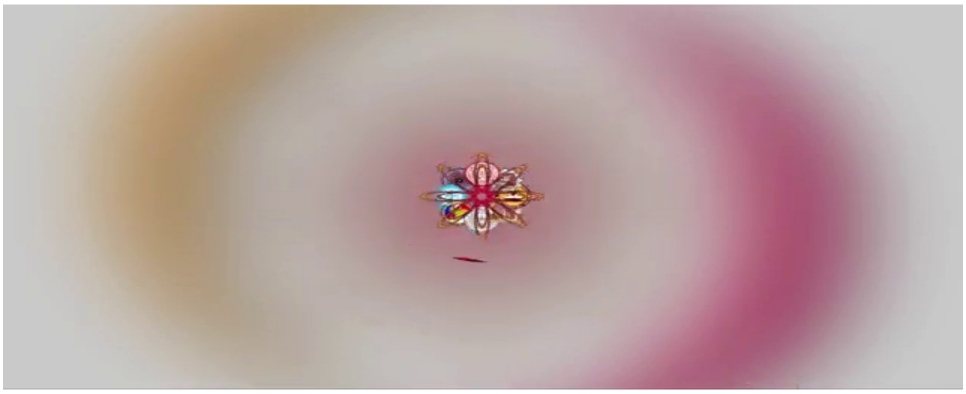
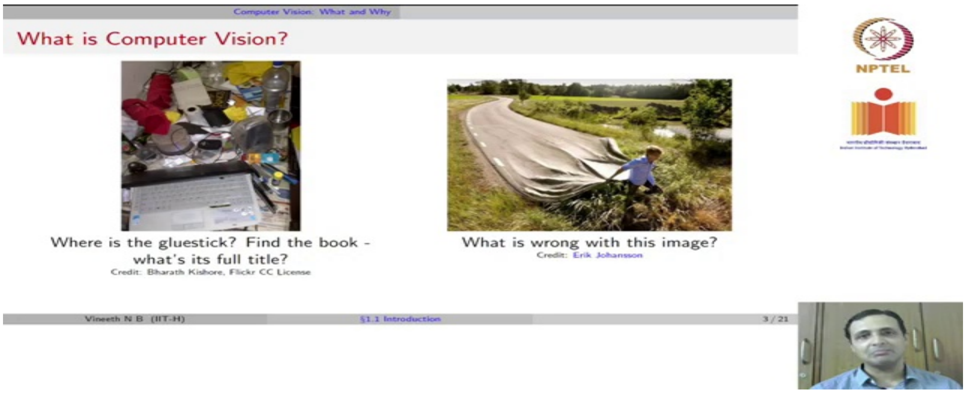


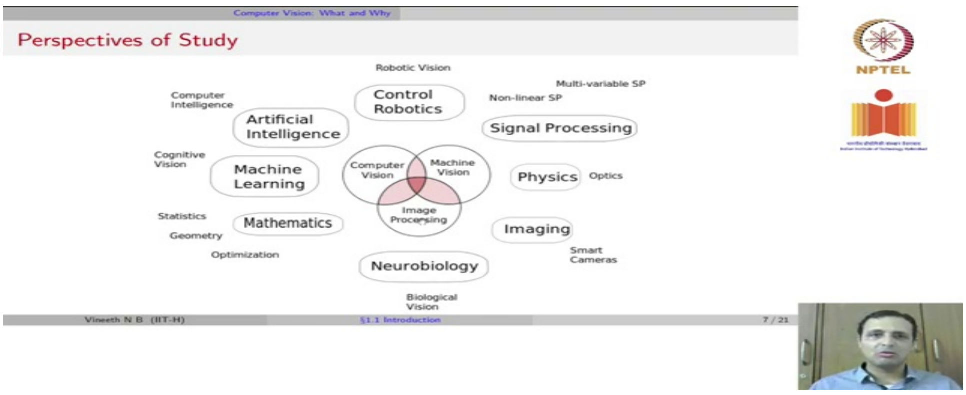
As most of you may know images are formed when a light source hits us the surface of an object and light is reflected and some of that light is reflected onto an image plane which is then captured through optics on to a sensor plane.So, that is the overall information and the factors that affect the image formation are the light source strength and direction, the surface geometry, material of the surface such as its texture as well as other nearby surfaces that, whose light could get reflected onto the surface, the sensor capture properties we will talk more about that as we go and the image representation and color space itself.



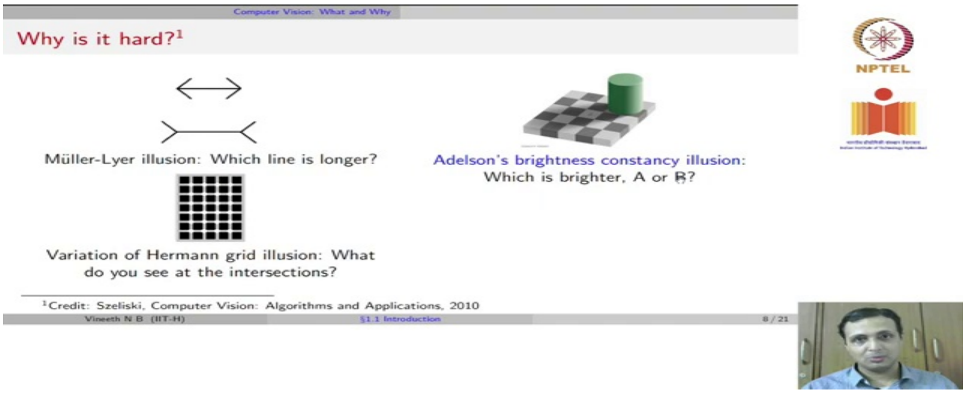
Starting with how light gets reflected off a surface the more typical morals of reflection state that when light hits a surface there are 3 simple reactions possible, there are more than 3 but 3 simple reactions to start with.Firstly, some light is absorbed and that depends on a factor called albedo rho and typically when you have a surface with low albedo more light gets absorbed.Some light is reflected diffusively.So, an example of a surface where this happens is a mirror where we all know that the reflected light follows the same angle as the incident light.Generally, in the real world most surfaces have both specular and diffuse components and the intensity that you receive at the output depends also on the illumination angle because when you have oblique angle, lesser light comes through.And in addition to absorption, diffuse reflection and specular reflection, there are other actions possible like there is transparency, where light could pass through the surface, there is refraction such as a prism where light could get refracted there is also sub surface scattering, where multiple layers of the surface could result in certain levels of scattering.And finally, there are also phenomena such as fluorescence, where the output wavelength could be different from the input wavelength or other phenomena such as phosphorescence.

So from a view point of colour itself we all know that visible light is 1 portion of the vast electromagnetic spectrum, so visible light is one small portion of the vast electromagnetic spectrum, so we know that infrared falls on one side, ultraviolet falls on the other side and there are many other forms of light across the electromagnetic spectrum.So, coloured light which arrives at a sensor typically involves two factors, colour of the light source and colour of the surface itself.So, an important development in sensing of colour in cameras is what is known as the Bayer Grid or the Bayer Filter.The Bayer Grid talks about the arrangement of colour filters in a camera sensor.So, not every sensing element in a camera captures all three components of light you may be aware that typically we represent light as RGB at least coloured light as RGB; Red Green and Blue.We will talk a little bit more about other ways of representing coloured light a little later, but this is the typical way of representing coloured light and not every sensing element on the camera captures all three colours instead a person called Bayer proposed this method in a grid manner where you have 50 percent green sensors, 25 percent red sensors and 25 percent blue sensors which is inspired by human visual receptors.And this is how these sensors are checkered, so in a real camera device you would have a sensor array and there is a set of sensors that captures only red light, there is set of sensors that captures the green light, there is set of sensors that captures the blue light and to obtain the full colour image demosaicing algorithms are used where surrounding pixels are used to contribute the value of the exact colour at a given pixel.

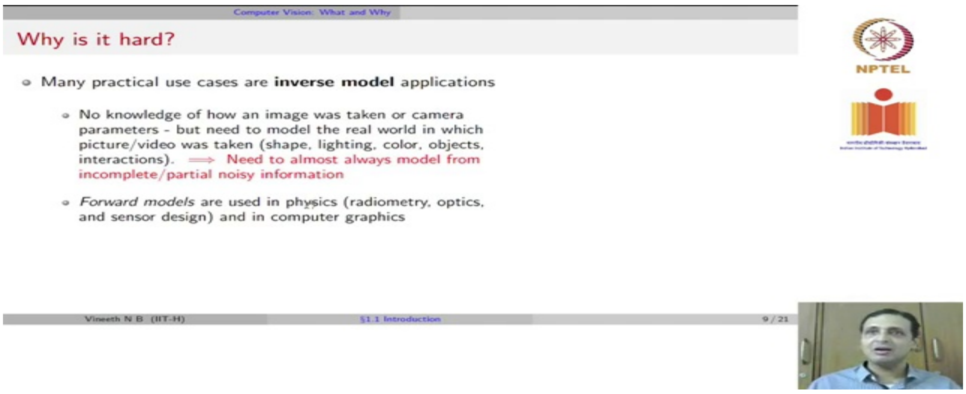
Then the image is obtained in an analog or digital form which represents the raw image that you get, the typically cameras do not stop there, you then use demosaicing algorithms which we just talked about, we could, you could sharpen the image if you like or any other important image processing algorithms.Some white balancing, some other digital signal processing methods to improve the quality of the image and finally you compress the image into a suitable format to store the image.So, first thing is the camera sensor itself so you all must have heard of CCD and CMOS.



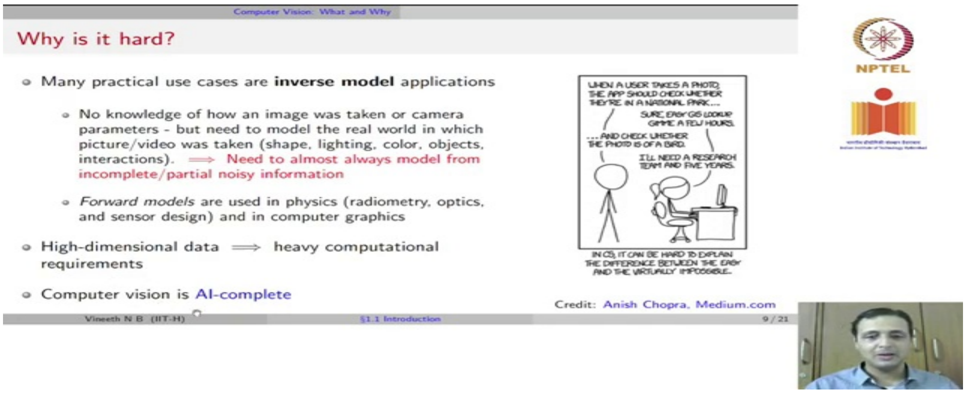
So, the other factors that you need to understand when you talk about image formation is the concept of sampling and Aliasing, we will talk about this in more details bit later but a brief review now is Shannon Sampling Theorem states that if the maximum frequency of your data on your image is f_max you should at least sample at twice that frequency.



Why so, we will see a bit later but for the moment that frequency that you captured it is also called the Nyquist frequency and if you have frequencies about the Nyquist frequency in your image then the phenomenon called Aliasing happens.So, why is this bad and what impact can it have on image formation? This can often create issues when you up sample or down sample an image.Other colour spaces that are used in practice are XYZ, YUV, Lab, YCbCr, HSV so on and so forth.There is actually an organization call the CIE which establishes standards for colour spaces because this is an important, this is actually important for the printing and scanning industry, I think this is extremely important people working in that space.So, that is the reason there are standards establish for these kinds of spaces, we would not get into more details here once again if you are interested please go through these links below to know more about colour spaces what do you mean by additive, subtractive, so on and so forth, please look at these links.Finally, the last stage in image formation is image compression, because you have to store the image that you captured, so typically you convert the signal into a form called YCbCr where Y is luminance CbCr talks about chrome what is known as colour factor or the chrominance and the reason for this is that you typically try to compress luminance with a higher fidelity than chrominance.



Because of the way humans or the human visual system perceives light, luminance is a bit more important than chrominance, so you ensure that luminance is actually compressed with a higher fidelity which means your reconstruction is better for luminance than for chrominance, so that is one reason why YCbCr is used as a popular colour space before storage, once again if you do not understand YCbCr, go back to the previous slide look at all of these links to understand YCbCr is one of the colour space representations that are available in practice.And as I just mentioned so the most common compression technique that used to store an image is called the Discreate Cosine Transform which is popularly used in standard such as MPEG and JPEG Discreate Cosine Transform is actually a variant of Discrete Fourier Transform and it is a you can call it as a reasonable approximation of an eigen decomposition of image patches.So, we would not get into in for the time now, videos this is how images are compressed using method call DCT, videos also use what is known as block level motion compensation, so you also divide images into frames and set of frames into block and then you store certain frames based on concepts from motion compensation, this is typically used in the MPEG standard which uses, which divides all frames into what are known as i frames, p frames and b frames and then uses strategies to decide how each frame should be coded, that is how videos are compressed.



PSNR is defined as 10 log to the base 10 i_max square by MSE, where i_max is the maximum intensity and MSE is simply talks about the mean squared error between the original image and the compressed image, how much is the mean squared error pixel wise between these two images.And the numerator talks about the maximum intensity that you can have in an image, so this is typically called as PSNR which is used to measure the quality of image compression, there are other kinds of matrix which are based on human perception but this is the most popular statistical metric that is used.That is about this lecture on image formation so if you need to read more please read chapter 2 of Szeliski s book, please also read the links provided on some of the slides specially one of those topics interest you or you are left with some questions please read those links.If you want to know in a more detail form about how images are captured including the geometric aspects of it and the photometric aspect of it please read chapters 1 to 5 of Forsyth and Ponce.