

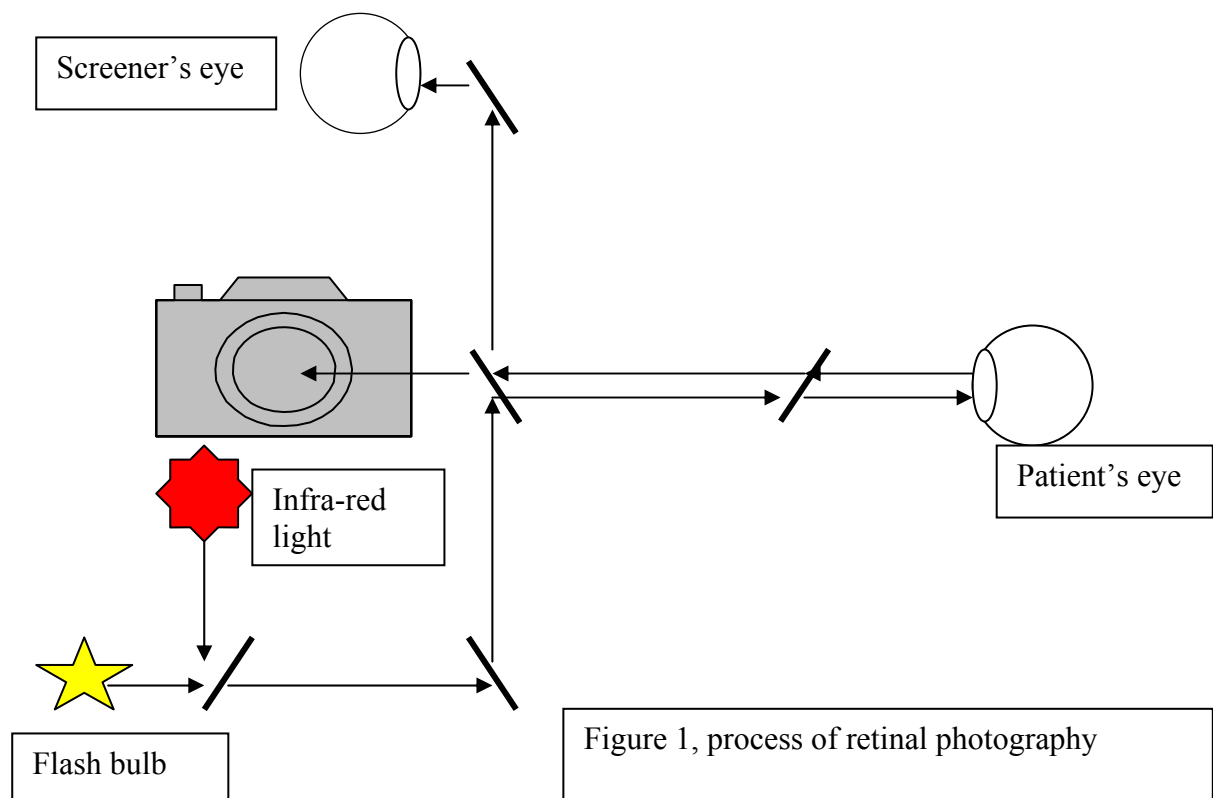
How Does a Digital Retinal camera Obtain an Image and Convert it into a 500kb file for storage onto a server.

Digital retinal cameras are now being used in a variety of conditions to obtain images of the retina to detect diseases such as; glaucoma, diabetic retinopathy, vascular occlusions, inflammatory disorders and age related macular degeneration. It is useful to have these digital images as a hard copy that can simply be stored and re-visited. However images of a large number of images take up a lot of computer space, which hospitals cannot accommodate, and take a long time to transmit; to get around this the images can be compressed using JPEGs.

The Fundus Camera, taking the photograph

A fundus camera is a low power biomicroscope with a digital camera attached at the back; allowing the retina to be photographed. There are two types of fundus camera mydriatic and non-mydriatic. Non-mydriatic fundus cameras work without the need to administer drops for dilatation of the eye; as long as the patient's pupils are $\geq 4\text{mm}$. With a mydriatic camera dilatation drops must be administered before an image may be taken.

Mydriatic cameras work using a tungsten halogen lamp as a viewing lamp which is projected onto a mirror. The mirror reflects the light up into a series of lenses which focus the light. Light is reflected onto a mirror with a central aperture, and through the anterior chamber of the eye. The resulting retinal image leaves the eye through the central aperture of the previously described mirror back to the single lens reflex camera system (see figure 1). An electronic flash source is utilised to take the photographs.



With a non-mydratric camera rather than a visible halogen viewing lamp, the viewing lamp is derived from an infra-red source. The infra-red illuminating source passes through a series of mirrors into the patient's eye; this image may be viewed on a screen and focussed to get a clear, crisp image of the retina. When an electronic flash is pressed the digital photograph is taken and the resulting image shown on a monitor. Using particular programs the contrast, lightness and colour of the image may be manipulated.

The fundus camera, obtaining the image

The main operating component in a digital camera is the CCD (Charge-coupled device). A CCD has millions of light-sensitive elements, each representing an individual part of the picture, known as a pixel. When light hits the CCD it triggers an electrical charge; the strength of the electrical charge determines the colour of the pixel, black is shown where no charge is triggered and white is where a full charge is triggered. The CCD then converts these charges from analogue format into digital format very quickly and the retinal image can be viewed on a monitor.

Cameras used for digital retinal screening may either be three chip or single chip devices. Three chip devices separate the incoming light into three; one copy is passed through a red filter, one through a green filter and one through a blue filter before being directed onto the CCD. Single chip devices simply pass all the light onto the CCD chip which has tiny colour filters placed over it so that they are all sensitive to green, red and blue light. The colour filters have twice as many green filters than blue or red as the human eye is most sensitive to changes in green light. The image shown on the monitor is created by estimating the values for the two missing colours. Both of these filtering devices are used however the single chip device has a higher resolution.

Compression of images

Compression of the digital images is very important when thinking about a clinical situation, due to the need for quality control and reduction in storage. It is also important to be able to send images over a network quickly for secondary, tertiary and arbitration grading. The images after compression need to be of a certain quality for people to be able to grade images with confidence that they are looking at the true picture, and not that the image has been obscured due to pixilation.

When considering what is the best method for compression spatial resolution and intensity resolution are very important. Spatial resolution is the determination of how many pixels make up an image. This therefore determines, in the case of a retinal camera, how many pixels make up a particular region of retina. The more pixels per region the clearer the image is, therefore the more likely it will be that a screener will detect any abnormalities. Intensity resolution is also an issue; this is the number of shades of grey that a pixel can represent. When compression occurs it is very important that the colour image is not impeded by a too limiting intensity resolution, otherwise again a screener may find it harder to distinguish abnormalities.

Some graphic file formats such as TIFF (Tagged Image file Formats) use Loss-less compression. In this case the image stored is identical to the image taken, however it is reduced in size. When reviewing this from a retinal screening point of

view it is important to have the image on a large monitor, so that abnormalities may be distinguished by the naked eye. JPEGs are a more suitable method of compression where retinal screening is involved.

JPEG (Joint Photographic Experts Group) is the method of compression most suitable to a retinal screening programme. JPEGs use a piece of mathematics called discrete Cosine transformation to turn the square of all the data into a set of curves, some small and some large, that go together to make up the image. This is a type of 'lossy' compression; indicating that some of the data is lost when compression occurs. The human eye is more sensitive to moving objects and edges rather than gradual transitions; and to red and green light and rather than blue light. Therefore by utilising the inadequacies of the human eye slight changes to colours, particularly blues can be made that will go unnoticed, and therefore are unimportant. JPEGs work by reducing the number of blue shades available and merging very similar shades into one. This saves storage space, as fewer colours means less space is required to hold it. By using this method it also preserves the height and the width of the image, so that that a full monitor sized view of the image is clear and available for the screener. An example of this is an image which may be 6 mega pixels (18MB) when full colour (256 levels) is used. Therefore when this image is stored as bitmap onto the hard drive 18MB takes up a lot of space and so not many images may be stored.



Figure 2, Left shows a Bitmap image, Right shows the same image stored as a JPEG.

However as a JPEG the same image may only take up 600kB; and the difference may not be noticeable to the eye. From the images above the difference in storage size for the image on the right is 9.3MB and the image on the left is only 470KB; without any differences to the gradability.

One useful parameter of JPEGs is that the amount of data which is discarded is controllable, dependent upon the image. It is therefore important that it is only compressed once, so that images are not reduced and reduced in size. A bad compression however would be very detrimental to a retinal screening scheme, as pictures appear blurred and therefore would be ungradable (see below).



Figure 3, Image showing JPEG that has been too compressed.

When digital images are stored on a server, they are stored as a series of numbers. This therefore means that when the images are replicated they are replicated directly from these digits; allowing no deterioration in quality to occur. This is an important consideration in terms of retinal screening as graders computers will be attached to a main server which can access a network containing a patient database with past retinal images, for comparison, and other important patient information.

In conclusion, digital retinal imaging uses a digital camera based on the use of mirrors and lenses to focus the light reflected from a patient's retina through a variety of colour filters and onto a CCD, which detects the intensity of light. The image produced is then compressed to reserve space and transmission time using a JPEG method; which reduces the storage space by the individual number of colours used, particularly blues. The images may then be accessed by graders linked to a computer network with relative ease and clarity.