Digital imaging began in the mid-1960s as a by-product of space missions. Cameras in the unmanned spacecrafts provided distorted and lopsided images of the moon’s surface and a need was felt to get a clearer view. NASA (The National Aeronautics and Space Administration) then developed digital technology whereby analogue signals were converted into digital signals, which when fed into a computer, produced enhanced images that could be more meaningfully interpreted. In medicine, this technology has been used for computed tomography, ultrasound imaging and magnetic resonance imaging, which would not have been possible with conventional imaging using film-based photography.

The present discussion focuses on digital photography in medicine and will therefore be of greater interest to specialties that deal with visible pathologies such as dermatology, ophthalmology and plastic surgery amongst others. This article provides an introduction to the basic concepts of digital imaging and includes practical tips about switching to a digital photography system. Links to further information on the Web are provided for interested readers.

Why Digital?

Conventional photographic documentation most popularly using 35 mm film has served us well for years. Why then, should one consider switching over to digital technology? Digital imaging has many features that have made it popular. Consider some salient advantages:

- Combining image data with other pertinent patient information available from computerised Hospital Information Systems greatly eases archiving and recall.
- The ability to quickly transmit the images anywhere over the internal networks and the Internet.
- Archiving all this information in minimal space, and retrieving perfect originals at the touch of a few keys.
- Much lower operating costs as expenditure on procuring films, on the processing equipment, on chemicals for the development of films and on archiving space are reduced if not almost eliminated. In addition, labour requirements are curtailed too.
- Digital exams are inherently fast. Institutions with heavy patient load or turnover are able to use their resources more productively and earn high revenues while making optimal use of equipment.
- Properly designed digital imaging systems can pave the way for a broad range of future advanced applications, such as automatic analysis of images and telemedicine applications, which can permit cost-reduction and consolidation of resources.

Because of these features digital photography greatly enhances the physician’s ability to communicate with peers, patient, and the public. Dramatic reductions in cost and improvement in the quality of digital cameras have fuelled interest. With the widespread availability of computers and increasing connectivity to intranets and the internet, digital photography has become a powerful tool for physicians, surpassing the uses of conventional photography and opening new applications which would not have been possible with traditional photography on film.

Basic Concepts of Digital Imaging

Digital images are composed of pixels (picture cells). These are the basic building blocks of a digital picture. One can divide any image into a number of cells and measure the colour and intensity of each cell. A digital approximation of an image can be constructed in this way. This is called a ‘bitmapped image’. The pixel count tells us how many pixels are in a given digital image file. That count gives us an idea of the potential output size, but it doesn’t give us any information about the quality of the image. Pixel density, on the other hand, tells us something about the quality of the image. It tells us how closely the dots are all packed together, which is directly related to the amount of detail in the final image. Combining pixel count with pixel density, we can get a good idea of the overall quality and dimensions of a particular image file. As an illustration Figure 1 shows an image of 400 x 402 pixels at 72 pixels/inch and Figure 2 shows the same picture at 400 x 402 pixels at 10 pixels/inch. The output file size for both is similar although the difference in quality is clearly appreciable.

The number and density of pixels must be high enough to produce a faithful representation of the subject; the aim being to produce an image in which the human eye cannot detect...
the individual pixels. The traditional standard of image quality is the 35 mm slide, which contains silver grains packed at a very high density. This approximates to 2500 lines per inch, or 4096 $\times$ 2736 pixels per frame. Some digital imaging systems have this level of pixel density, but a lower resolution is adequate for many clinical applications. The higher cost of producing digital imaging systems which record a very high resolution and the large image files produced have limited the use of higher resolution systems, but these are now becoming more accessible.

The Digital Camera
A digital camera is essentially a conventional camera where the film has been replaced by a charge-coupled device (CCD). The CCD is a silicon chip composed of a grid of pixels that react to light as do the film grains in a conventional camera. In film-based photography chemical emulsions are changed into millions of silver grains; in digital photography, the chip transforms reflected light into voltage. The camera’s computer converts the voltages (analog) into zeroes and ones (digital) and records it onto memory in this digital format.

Red, green, and blue filters placed in front of the CCD enable the chip to digitise the colour components of an image to produce a digital colour representation. The capacity of a CCD to reproduce an image is a function of its resolution, which can be defined as the density of the light-sensitive elements or pixels, that it contains.

Digital Camera Selection
Increasing specifications in more affordable packages mean that you should not consider a camera which specifies a resolution of less than 2 million pixels. Above this, buy the highest resolution you can afford, 3 and 4 megapixels cameras are now commonplace and there are some models which offer 6 million pixels, rivalling the 35-mm film in resolution. Beware of statements such as ‘effective pixels’. This may refer to software-enhanced resolution rather than the true resolution, making direct comparisons invalid.

Compact cameras are cheaper and easy to use because everything is built into one small package, often with a built-in flash and zoom lens. They offer a reasonable level of flexibility and control and may be adequate for most needs. When looking at specifications, be sure to differentiate ‘optical zoom’ from ‘digital zoom’ capabilities. ‘Optical zoom’ is the same as the zoom range mentioned in film cameras. Because the size of the CCD is usually smaller than 35-mm film the figures are not directly comparable, but most manufacturers will quote a ‘35 mm equivalent zoom range’ making comparisons more valid. If you work at multiple locations, size will be an important consideration as you will be more likely to carry a smaller camera with you everywhere.

In contrast to compact cameras, SLR (Single Lens Reflex) cameras have view-through lenses, which are often interchangeable, an external flash, and the ability to focus and to adjust exposure manually when needed. However, digital SLR cameras tend to be more expensive than digital compact models. SLR units also tend to be larger and bulkier than compact cameras, although SLR cameras are becoming lighter and more compact with each successive generation. The ability to change lenses and external flash allows the use of dedicated macro lenses with an external ring flash for “shadowless” macro-photographs, which are very useful for many medical applications.

Digital cameras are constantly evolving and thus recom-
mendations for particular models are not included here. Ex-
haustive reviews of all consumer models are available on the
Web. It is useful to browse through these when choosing a
camera. Useful collections of reviews are provided at Digital
Photography Review (http://www.dpreview.com), The Imaging
Resource (http://www.imaging-resource.com) and Steve’s
Digicams (http://www.steves-digicams.com).

The flexibility of the modern prosumer digital cameras
means that specialised images can often be acquired by sim-
ply placing a digital camera against the eyepiece of an optical
instrument such as a microscope. Some experimentation is
required, but as the results are immediately viewable, this is
not a problem. Figure 3 is an example of an image of the eye
acquired by holding a digital camera up to the eyepiece of a
slit lamp (a binocular microscope used for eye examination).

The Computer
You will need access to a reasonably fast computer with plenty
of storage. While specifications are rapidly evolving, as a mini-
umum, one would specify a Pentium 4 or an equivalent proc-
essor above 2 GHz and 256 MB RAM. Computers with slower
processors will be able to handle the tasks, but can sometimes
be painstakingly time-consuming. If you already have a com-
puter which you want to use, consider increasing its RAM
(physical memory) as this can often be done at a relatively
lower cost. A large hard disk is useful, e.g. twenty photographs
a day using 1 MB each would need 100 MB a week, and thus
5 GB a year for image storage alone. Add in all the software
involved and you will find that a hard disk below 20 GB is not
a practical proposition. Removable media like CD-R or DVD-
R are useful for archiving, but it preferable to have the last
couple of years’ images on your computer hard disk, so that
you do not have to retrieve and load the right disk for your
current patients! Whilst most consumer cameras will be sup-
plied with cables and software to transfer images from the cam-
era to your computer, it is often easier to use a card reader
attached to the computer. This enables the memory card of
the camera to be removed and inserted into the card reader.
The computer can then access the images as it treats the
memory card as an additional drive in your computer.

Software
Several types of software are used for image transfer, editing,
storage and retrieval. The first type of software transfers im-
ages from the camera to the PC. This software, typically, is
packaged with the camera and is used to transfer images over
serial, small computer systems interface (SCSI), universal se-
rial bus (USB) or FireWire cable. With the advent of PC-based
removable memory card readers, this software may never be
used, as the card reader provides direct transfer of images
from the memory card to the PC.

The second type of software consists of image enhance-
ment or manipulation software, which converts images into
other file formats for use in documents and slides or adds text,
lines or graphics. The most commonly used program of this
type is Adobe PhotoShop, a professional image-editing tool.
A basic version may be packaged with some cameras as Adobe
PhotoShop LE (Limited Edition) or may be purchased sepa-
rately.

Image database software is the most important software
component of all since it stores patient images and other rel-
vent information (e.g. demographics, physical findings, treat-
ment plans, operative data) in an organized fashion for future
retrieval.

Figure 3: Photograph of the anterior segment of the eye
showing a cataract acquired by an Olympus C40Z camera held
up against the eyepiece of a slit lamp. The camera was
focussed to infinity and the flash was turned off.

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The camera stores the images on ‘memory cards’. These can
be thought of as removable disks (similar to floppy disks, but
much smaller physically with a much larger capacity). Remem-
ber that there are competing formats of memory cards, which
are not interchangeable. So you must have the correct reader
on your computer, although card readers that can read multi-
ple formats are now available. You will most likely have to
acquire some large capacity memory cards as high quality
digital images create large files, which even with compression
are usually in the region of 1MB. Fortunately, large capacity
SD cards up to 128 or 256 MB are readily available enabling hun-
dreds of photos to be taken on one card. Some cameras can
use ‘micro-drives’ that are miniaturised hard drives, sporting
capacities of 340 MB or 1GB.
A wide variety of software choices are available, ranging from basic consumer image databases to medical-specific databases to customized applications tailored specifically to individual types of practices.

PACS (Picture Archiving and Communication System) is an image-based information system for the acquisition, storage, communication, archiving, display and manipulation of medical images via network. PACS provides information to multiple users at the same time regardless of their location. The DICOM (Digital Imaging and Communications in Medicine) standard was originally developed for the standardisation of radiological images but has now been adopted by most medical specialities. Essentially, if a piece of equipment is DICOM compliant, most other modern imaging and archiving systems will be able to interact with it.

**Using Digital Imaging in an Analogue World**

Although digital images are becoming increasingly acceptable for most medical uses, it is still necessary to produce hard copies of images, whether for insurance, documentation or to meet publication requirements of peer-reviewed journals. Hard copies of reasonable quality can be generated rapidly and easily on a colour laser or inkjet printer. Dye sublimation and some high-end inkjet printers can deliver a true photographic print of an image. The cost and speed make it impractical for most physicians to own them solely for the purpose of generating this type of prints on an occasional basis. Furthermore, these photograph-like images do not always resemble real photographs sufficiently to be a good substitute for glossy photographic prints. Commercial services can provide these services and online print services are also available for this purpose.

When moving to digital imaging, the problem of converting the existing slides and photographs into the digital format has to be resolved. This can be achieved by using a scanner or getting this done through a commercial service. The resolution of the scanner is the most important issue to be considered while acquiring a scanner for this purpose. One should always go for the highest possible resolution affordable; here it is the optical resolution that one is interested in. Brochures and salesmen may mention very high resolution, which on closer questioning turns out to be ‘interpolated’; this means that the software is increasing the resolution. The golden rule in all imaging is that the quality of the original source is paramount, thus the native optical resolution is more important than the software-enhanced interpolated resolution. Flatbed scanners are now *de rigueur*. Handheld scanners are only useful for scanning text and low quality small images. If you need to convert old 35-mm slides, always retype text, scanned text slides do not reproduce well. For pictures it is best to use a slide scanner; this uses very high resolutions compared to a flatbed scanner. The ‘slide-adaptor’ available on most flatbed scanners is generally not good for this task due to relatively lower resolution, although some of the highest specification flatbed scanners will be able to do a reasonable job of scanning slides. If you do not have access to a slide scanner, it is best to get prints made from your original slides and then to scan the prints, this will give a much better picture quality.

**Summary**
- Digital imaging is now an essential part of medical practice
- Current digital systems can match conventional film-based photographs
- Digital imaging systems can deliver additional benefits which film-based systems cannot
- The convenience, instant results and easy archiving make digital photography ‘the way to go’

**Online Resources**


The DICOM website at http://medical.nema.org/ has further details. Also look at http://www.xray.hmc.psu.edu/physresources/dicom/index.html. For detailed information on PACS look at http://www.irpacs.com/pacsbasics1.htm and follow the various links.


**References**

8. Chan L, Reilly KM. Integration of digital imaging into emergency medi...

This is second article in the series of 'Medical Photography'. Next article focuses on 'Digital Photography in Anatomical Pathology'.

**Announcement**

**PP Surya Kumari** prize is awarded by Indian Pharmacological Society every year for the best research paper published in any journal on “diabetes mellitus, other endocrinal and metabolic disorders” in the last five years. The prize is open to Indian scientists working in Indian laboratories. The award is presented to the winner at the annual conference of IPS. Those who wish to compete for the prize for the year 2004 may submit five reprints/copies of the paper (published in 1999-2003) to the Chief Editor, Indian Journal of Pharmacology at the following address on or before 31st March, 2004.

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