Film digitizers vs. CCD scanners

Laser digitizers have a long history of use in medical applications such as teleradiology, image management, PACS, even computer-aided diagnosis. A new-technology CCD-based film digitizer introduced at the 1995 RSNA now provides an alternative worth considering.

The basics

Let's examine the basics: how does a digitizer convert film densities into digital values?

It is important to know that optical density (OD) is a **log** function which means that measuring higher densities with meaningful precision is **not easy**. At optical density 0,100% of the incident photons (the light going through the film) is transmitted; at 1.0 OD, only 10% make it through; at 2.0 OD, only 1% , and at 3.0 OD only 0.1%.

Laser digitizers

The advantage of using a laser as a light source is that a tremendous number of photons are produced, all the same wavelength, and the light is coherent, subject to less scatter. The point is, with such a large supply of photons, the laser film digitizer can accurately measure optical density from 0.03 to 3.6 or even 4.1 OD with 0.001 OD precision.

The transmitted photons are measured at a given location on the film (pixel) and there are typically 2 048 pixels per line, 2 500 lines on a rectangular film (8"x10" up to 14"x17"). The photons are detected by a very efficient photomultiplier tube (PMT) and the resulting output voltage is conditioned by a log amplifier. The log amplifier normalizes the extremely high number of photons (high voltage) detected at low optical densities versus the relatively low number of photons (lower voltages) detected at high optical densities. Since the source is a laser, maintaining very high signal/noise is straightforward and the result is a **scanning densitometer.**

Density precision

The laser film digitizer converts each density measurement into a pixel value which is 1000 x the optical density at that point. Optical density 2=2000, 3.2=3200, etc. To put it another way, this means that there are 1000 levels from 0 to 1 OD, 1000 levels from 1 to 2 OD, and so on.

As an example the Lumiscan 75 converts 2 048 pixels into digital density values 115 times per second which is over 235 000 12-bit measurements per second. It digitizes a 14" x 17" film in less than 25 seconds.

The end result

What does this really mean? It means that a radiologist can be confident that almost every nuance in a film will be captured by a laser film digitizer. A confident diagnosis can almost always be made with a laser-digitized film.

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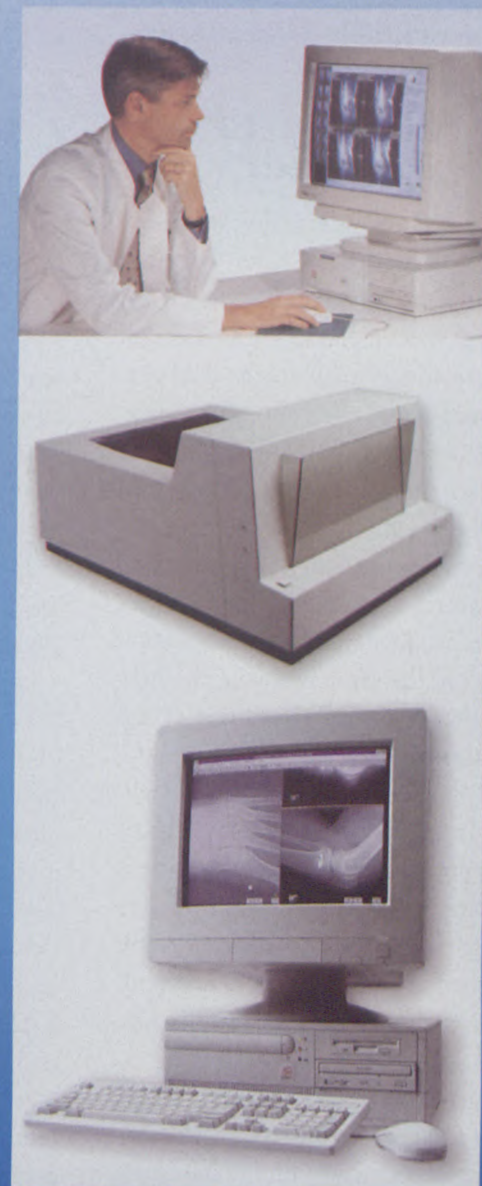
Teleradiology and PACS Systems?

Important questions which need to be addressed when considering these are:

- Is it DICOM 3.0 Compliant?
- Am I locked in to one supplier?
- What can the system grow into?
- Am I locked into one support Company?



With Windows NT being specified as the standard throughout the world, you need a system that can grow with your practise without being limited by any of the above considerations.

IMED are distributors of Teleradiology, PACS, Laser and CCD Scanners, of which RadWorks and Lumisys have been declared the GOLD STANDARD for the industry. Point to point 2K Teleradiology systems including scanner and PC's from low R100 000's.

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The various models of laser film digitizers are designed to provide the end-user with the best system for specific applications.

New CCD digitizer

Now let's consider a "new-technology" CCD digitizer. "New" because some innovative technology is incorporated into a basic CCD design which results in a lower cost digitizer with **acceptable** clinical performance - certainly much better than typical CCD scanners, for some easy to understand reasons.

First, a proprietary solid-state illuminator is used rather than a light bulb to produce more photons which are also of the same wavelength. Advantages: It doesn't burn out every six months, there's less scatter, and more photons means higher signal/noise (more accurate density measurements) at higher optical densities.

Second, high quality optics are used to focus the transmitted light onto the CCD chip. A more efficient lens means more photons (higher signal/noise) and less optical noise.

Third, an aerospace quality CCD chip is used to maximize signal/noise. The particular chip utilized has been selected for its low noise characteristics and to further reduce noise (crosstalk), the detector elements are averaged so that 2 048 pixels are collected over 14".

Density resolution

Because of all this attention to noise reduction, the output can be normalised by a log amplifier, just as it is in the laser film digitizer. This means once again that very precise density measurements are produced over the dynamic range of the system:

- 1000 levels from 0 to 1 OD,
- 1000 levels from 1 to 2 OD,
- 1000 levels from 2 to 3 OD,
- 200 levels from 3 to 3.2 OD.

Typical CCD scanner

Now let's look at a typical CCD scanner. It should be recognized that all those available on the market share essentially the same performance characteristics because the laws of physics are equally applicable.

A common claim is that spatial resolution is much better. This is because all CCD chips (detectors) have a large number of elements (4000, 6000, even 8000), so in theory a line of film can be digitized into a like number of pixels. In fact, two inherent characteristics of CCD chips are electronic (dark current) noise and "crosstalk" (photons which should be detected by one element are detected by two or more elements). So most CCD scanners are practically limited to 1000-2000 pixels per line (by averaging) to circumvent these problems. This is usually regarded as acceptable since most radiologists do not want to deal with larger image files anyway.

The more relevant issue surrounds claims of optical density range. Note that all manufacturers say they measure optical densities up to 3.0 or 3.2 or 3.5, but are unwilling to specify with what **precision** density is measured over that range.

A CCD element is designed to produce voltage when it detects light (photons). This voltage level is digitized and the resulting digital value is supposed to be related to the density of the film at a given point.

At optical density 0, maximum light passes through the film, so maximum voltage is produced by the CCD element. This is typically **calibrated** to be 10 volts. At optical density 1, only 10% of the light transmitted at optical density 0 will be detected (optical density is a log function). This means the voltage output density 1 is 1.0 volt.

If the CCD output is being digitized into 12 bits or 4 096 density levels, then the number of density levels between optical density 0 and optical density 1 is 3 686. This is calculated knowing that the full range of the CCD output is 10 volts = 4 096 density levels and 9 volts = 3 686 density levels (90% of 4 096).

This gets more interesting now. From optical density 1 (1 volt) to optical density 2 (0.1 volt), the output of the CCD element is 0.9 volts which equals 369 density levels (9% of 4 096).

From optical density 2 (0.1 volt) to optical density 3 (0.01), the output is 0.09 volt or 37 density levels.

From optical density 3 to optical density 4, only 4 density levels are possible, which is meaningless. In other words,

- 3 686 levels from 0-1 OD,
- 369 levels from 1-2 OD,
- 37 levels from 2-3 OD,
- 4 levels from 3-4 OD.

In fact, it is generally accepted that typical CCD scanners are limited to a useful optical density range of 0 to 2.3, maybe 2.5. Camcorders use CCD detectors to record images on video tape. When the light level is

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very low, the image becomes fuzzy, contrast is poor, and colour quality is significantly degraded. The same phenomena occur when scanning a dark film with a typical CCD scanner - there just aren't enough photons to provide useful information.

Diagnostic quality

Radiologists based many of their diagnoses on very small changes in optical densities which they see on film and which they should **want** to see on digitized images.

How to compare

A very simple but telling test is to digitize a calibrated step wedge with densities ranging as high as you feel appropriate to your particular application (for diagnostic teleradiology, 0-3.6 is a good range; 0-3.2 is fine for convenience teleradiology; 0-4.1 is required for mammography films). If you place a strip of scotch tape perpendicular to the density bars, you will created a density differential of about 0.03 OD.

The idea is to demonstrate performance using **known** input: (a) what is the dynamic range of the system (when do the density bars begin to be difficult to differentiate), and (b) what is the density precision of the system (at what density level can you no longer see the tape). It should be noted that comparisons of digitized clinical images are not very meaningful because the density range and the density differentials are **not** known.

You will find that the Lumiscan 20 will differentiate the bars up to 3.2 OD and the tape is visible at the 3.2 OD level, although the data is noisy as would be expected. Most other CCD scanners will not exceed 2.4 to 2.5 OD, which is almost an order of magnitude lower performance than the Lumiscan 20 (remember OD is a log function).

The Lumiscan 75 will differentiate the bars up to 3.6 OD and you can see the tape - without much noise - as expected. And the Lumiscan 85 performs well up to 4.1 OD, again per specification.

The final analysis

In the final analysis, much of the decision is economics. If patient volume/critical need justifies a laser film digitizer, then it is absolutely the best choice of all. The primary reason for buying a CCD-based scanner is because **price is more important than quality** as in low volume, convenience teleradiology, etc.

This information was supplied by Imed.

COMPANY NEWS

ELSCINT

The Elscint SeleCT SP wins CT Spiral KwaZulu Natal tender

The KwaZulu Natal Department of Health and Welfare has announced Elscint, South Africa, as the successful tenderer for the supply of CT spiral scanners and teleradiology to the KwaZulu Natal province. It is the largest single CT order of its kind in South Africa. The SeleCT SP CT scanners will be situated in rural and urban sites servicing the +8 million population of the province. Hospitals recommended for installation include: Ngwelazana Hospital, Madadeni Hospital, R.K.Khan Hospital, Ladysmith Hospital, Greys Hospital and Port Shepstone Hospital.

In addition, these sites will all be linked to Wentworth Hospital, Durban, for diagnosis referral. The OmniPro system is to be used as the basis for teleradiology using Telkom Diginet routers with 64kBaud/s transfer rates.

The tender was won on a performance and cost basis with competition from all major CT manufacturers in South Africa. Evaluation and adjudication was unique in that all suppliers were invited to an open adjudication of the tender submissions and were provided opportunities to question competition on various aspects of their systems.

According to Elscint the SeleCT SP is unique in its class, in that it utilizes the premium technology of the Elscint CT Spiral family of systems. This spiral scanner with its short geometry, low voltage slip rings and solid state detectors has the highest efficiency in respect of dose utilization. This translates into excellent image quality and significant operating cost savings to the users. Furthermore, it is capable of large patient

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