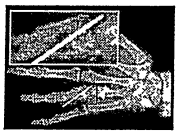
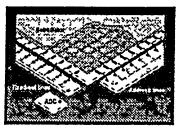
UNIVERSITY OF CRETE
FACULTY OF MEDICINE
DEPARTMENT OF MEDICAL PHYSICS

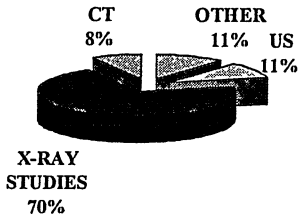
DIGITAL RADIOGRAPHY: PRINCIPLES AND DOSE MANAGEMENT

J. DAMILAKIS, Assistant Professor of Medical Physics



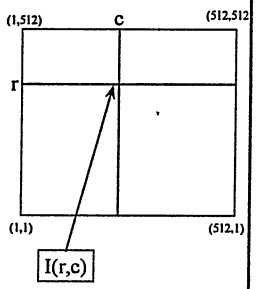


CONVENTIONAL X-RAY EXAMINATIONS: THE MAJORITY OF EXAMINATIONS CARRIED OUT IN A RADIOLOGY DEPT



PRINCIPLES OF DIGITAL IMAGING

Pixel: picture element



10 DECIMAL DIGITS

9	9	9	9
8	8	8	8
7	7	7	7
6	6	6	6
5	5	5	5
4	4	4	4
3	3	3	3
2	2	2	2
1	1	1	1
0	0	0	0

10.000 COMBINATIONS

1 9 5 6 = 1.956

1000 100 10 1

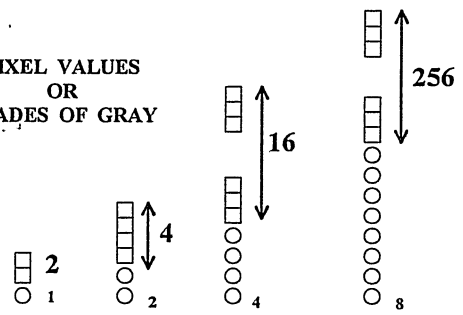
2 BINARY DIGITS

(1)	○	○	○	○	16 COMBINATIONS
(0)	○	○	○	○	

○ ○ ○ ○ = 10

8 4 2 1

PIXEL VALUES OR SHADES OF GRAY



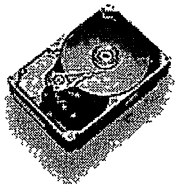
BITS

PIXEL VALUES AND SHADES OF GRAY

4 BITS PER PIXEL

DIGITAL RADIOGRAPHY

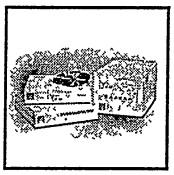
STORAGE AND RETRIEVAL



HARD
DISK
40 GB +

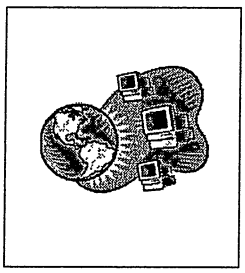
CD 680 MB

DVD 4.7 GB

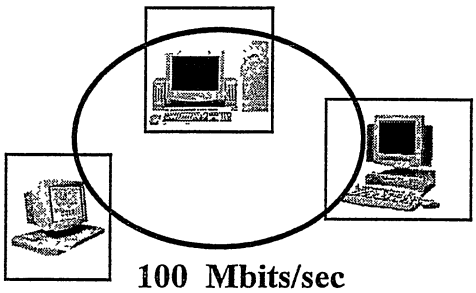


DIGITAL RADIOGRAPHY

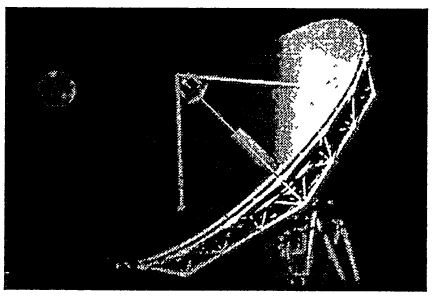
TRANSPORT



FIBER OPTIC CABLE

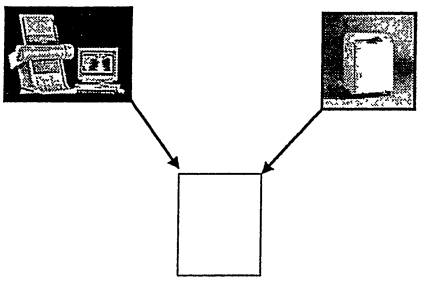


100 Mbits/sec

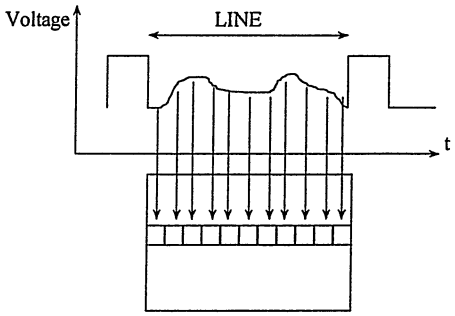


ANALOGUE IMAGE CAPTURE

FILM CR



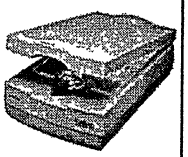
DIGITIZING AN ANALOGUE SIGNAL



DIGITIZATION OF A MAMMOGRAPH

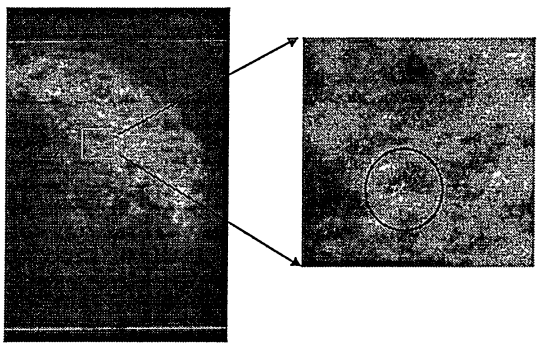
- **8000- element linear array CCD scanner 304 mm x 430 mm field scan size (Microtec, ScanMaker 9600XL)**

dpi	100	200	300	800	1200
Pixel size (μm)	250	130	85	40	20

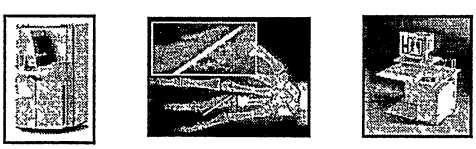


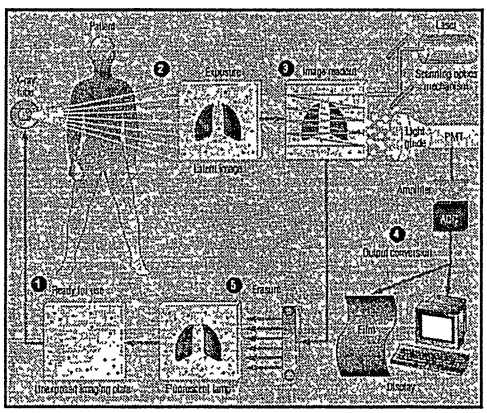
- **Pixel depth: 8 and 12 bits per pixel**

Microcalcification lesion < 1 mm



COMPUTED RADIOGRAPHY





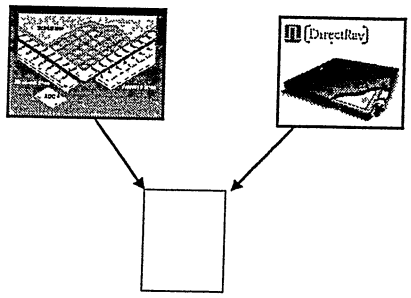
CR: DOSE REDUCTION

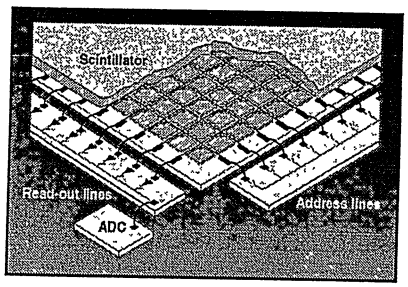
USING CR, PATIENT DOSE CAN BE REDUCED SIGNIFICANTLY (UP TO 50%) IN COMPARISON WITH CONVENTIONAL RADIOGRAPHY
H. Sandmayr et al, European Radiology 1997

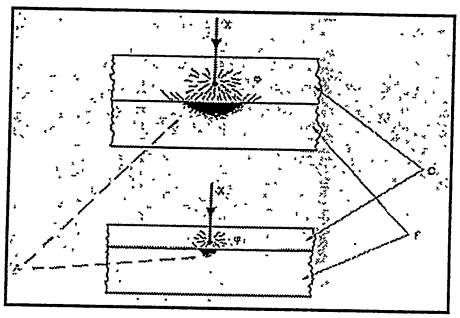
DIRECT IMAGE CAPTURE

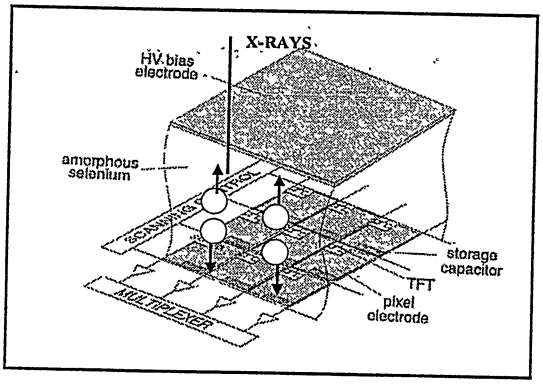
AMORPHOUS SILICON

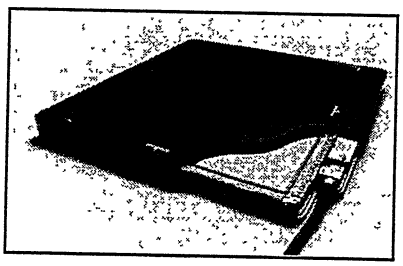
AMORPHOUS SELENIUM

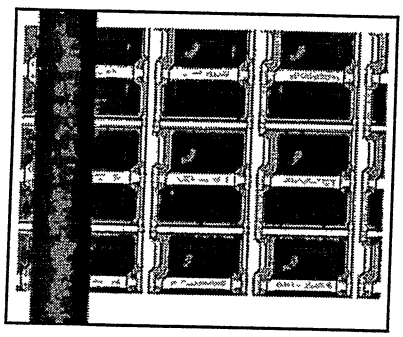






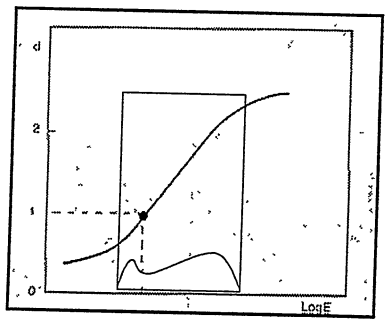


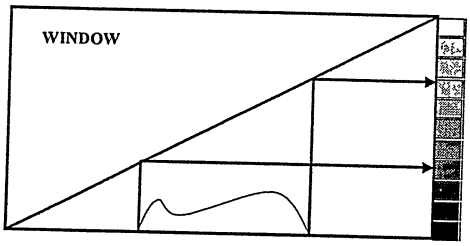




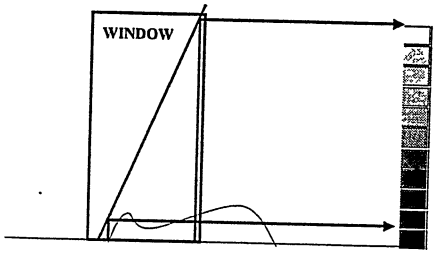
FLAT PANEL DETECTORS: DOSE REDUCTION

FLAT PANEL DETECTORS CAN REDUCE DOSE TO THE PATIENT UP TO 75%
M. Strotzer et al, AJR 1998

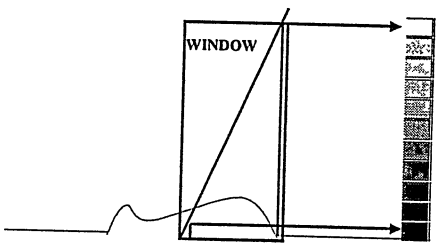




CAPTURED IMAGE



CAPTURED IMAGE



CAPTURED IMAGE

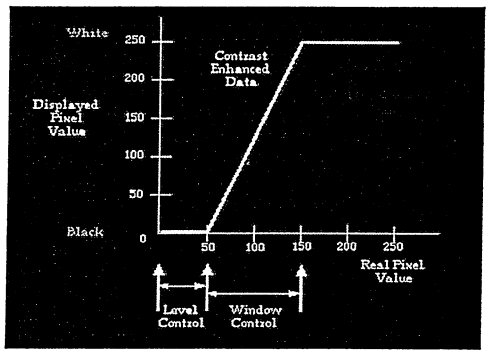
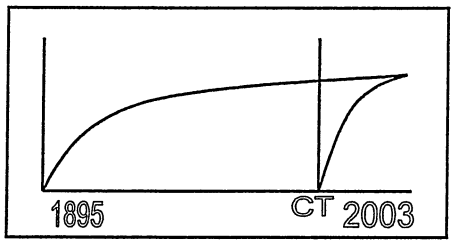
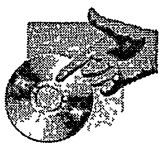


IMAGE QUALITY



BEFORE .....  REMEMBER :







BEFORE .....  REMEMBER :





ICRP digital draft 20 April 2003 32/221/03

ICRP TG 46
"Dose Management in Digital Radiology"

Members:
E. Vano (Chairman), R. Loose, B. Geiger, B Archer, K. Faulkner
Corresponding members: M. Rosenstein, J.M. Fernandez, H P. Busch, M. Wucherer, B. Bergh, R. Gagne.

CHAPTER 1: Introduction

Key points:

1. One of the most significant changes occurring in medical imaging is the transition from analogue based film to digital image format. A pixel matrix representation of an image is introduced by digital radiography and fluoroscopy. Each pixel is used to store a specific numerical value related to an individual grey level in the image.

2. Unlike film, digital imaging has a wide contrast dynamic range. It offers the ability to balance image quality and dose. It allows post processing, and different presentations on monitors. Additional benefits of digital imaging include computer archiving and network communication.

3. In conventional radiography, a large radiation exposure results in a "black" film, while a small exposure produces a "white" film. In digital radiology the brightness of an image can be made independent of the dose by post processing (e.g. window/level). An overexposure which may not bet noticed by the radiologist or radiographer, can also produce images of good quality.

4. The diagnostic information provided by modern digital detectors can be equal to or even superior to conventional film-screen systems if equivalent dose parameters are used.

5. Today there are two main technical approaches for digital radiography systems: phosphor storage plates for use in cassettes in conventional X ray systems and flat panel detectors (direct digital registration of image information at the detector) requiring dedicated imaging systems.

6. Digital fluoroscopy systems are usually based on the use of image intensifiers (II). The output of the II is projected onto a video-camera or CCD-chip converting the signal into a digital image. Some newer systems use a dynamic flat panel detector instead of the II and video-camera.

7. Digital radiology imaging is still more expensive than film based radiology. However, the additional cost may be justified by considering the excellent image quality achievable with lower doses for many imaging tasks, the improved workflow, the potential for teleradiology and expert consultation, the reduction of archive space and shorter patient examination times with greater comfort.

CHAPTER 2: Digital systems fundamentals and their advantages.

Key points:

1. It is a characteristic for any digital radiography device, that the x-ray detection stage, the final storage and the means for displaying the image (e.g. a workstation with adequate viewing software connected to a monitor providing diagnostic quality) are physically separate components.

2. For the field of medical image communication, the DICOM standard has been established. But dne to the rapid development of new technologies and methods, the compatibility and connectivity of systems from different vendors is still a great challenge.

3. Storage Phosphor Systems use a storage phosphor plate to record as latent information the image from the x-ray exposure. They are cassette based, so that existing x-ray equipment can be used without modifications. But therefore exposure parameters cannot automatically be stored together with the image data.

4. The newest developments are the "flat-panel" detectors. X-ray detection and image read-out is performed in one step. Common is the integrated assembly consisting of an x-ray converter and the read-out electronics. X-ray equipment with "flat-panel" detectors is able to store exposure parameters together with the image data.

5. One of the advantages to digitise the image information is the application of image processing to improve visualisation. As a consequence of these processing capabilities, there is no longer a strict correlation between the brightness (or blackening) of the image and the exposure.

6. A function available in all the work stations is "windowing" and allows specifying only a subset range of the full range of pixel values for display. All image information outside the window range is no longer visible. Window centre and width are typically transferred as part of the DICOM header of an image. A wrong window setting may also be interpreted as under- or overexposure by mistake.

7. A poorly performing image display device can compromise the quality of the acquired data. The user should have complete information with respect to a minimum set of requirements for the image display device either by physical specification of important display parameters and/or by reference to specific models of image display devices.

CHAPTER 3: Dose and image quality in digital radiology

Key points:

1. With digital radiology, higher dose per image usually means better image quality .... Thus, it exist the risk to use higher dose than necessary.

2. With digital fluoroscopy systems it is very easy to obtain (and delete) images .... Thus, it exist the risk to obtain more images than necessary and to irradiate in excess the patients.

3. Not all the clinical tasks require the same level of image quality. Quality criteria should be established for the different clinical tasks to avoid excessive doses without a clear additional benefit in the diagnosis in respect of a lower dose examination..

4. It is convenient to re-evaluate the local diagnostic reference levels when digital techniques are implanted to optimise the image system and to have a baseline to compare with future patient dose assessment.

5. A basic training in digital radiology is necessary for radiologists, medical physicists and radiographers involved in the use of the new techniques.

6. Loss of image quality could be caused by the level of compression and post processing. These aspects are dependent on the modality and should be investigated for the different kind of modalities and clinical tasks..

CHAPTER 4: Chapter 4 Regulatory Aspects and Quality Management

Key points:

1. *Within the next several decades, many medical facilities will be film less, relying more and more on the display and analysis of digital images. This paradigm shift will involve new regulations and invoke new challenges for practitioners and radiology employees in the area of quality management.*
2. *Before a digital radiology system can be employed for clinical use, it must be evaluated by the authorised expert. The tests conducted are designed to assess the overall imaging capability of the system and to optimise the radiation dose to the patient required to achieve an acceptable clinical image.*
3. *After initial evaluation, an ongoing, comprehensive QC programme is required for digital radiology systems to ensure that acceptable image quality is maintained, radiation doses to patients remain as low as practicable, and that problems with the system are corrected in an effective and timely manner.*
4. *The relatively effortless techniques required to produce images with digital radiographic and fluoroscopic systems increase the tendency of practitioners to over-document radiological studies. Thus, justification of radiation exposures and optimisation of the radiographic techniques and protocols must be a critical part of the digital quality assurance programme.*
5. *The use of diagnostic reference levels in digital radiography is an important component of quality management and essential for the avoidance of unnecessarily high patient doses.*
6. *Digital imaging systems should provide security protocols to protect the privacy and confidentiality of all patient data.*