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A Linear Scanning Digital Radiographic System for Chest Imaging[1]

Kwang Suk Park and Byoung Goo Min

Department of Biomedical Engineering, College of medicine, Seoul National University, Seoul 110, Korea

=Abstract=A linear scanning digital radiographic system was developed using photodiode array as a detector. Images are collected using this linear photodiode array sensor of 1024 pixels after X-ray photons are converted to light photons by the image intensifying screen. Sensitive area of each photodiode cell of a linear array sensor is 0.63 mm by 1.3 mm. This linear array sensor scans with 0.65 mm increments along the scanning axis using a DC servo motor to form 1024 lines of image within 0.7 sec of scanning time.

A fore-slit, located between the X-ray tube and the patient, converts an area beam to a fan beam and reduces the patient exposure and scattering effect. Also, this fore-slit scans syncronously with the detector assembly. Detected electrical signals are integrated to enhance the efficiency of X-ray exposure and multiplexed to four serial streams representing detected values of linear array. Then, it is calibrated to compensate for X-ray fluctuation, uneven sensitivity and bias of each pixel. Collected images are A/D converted with 12 bit resolution, transferred to the computer and displayed on a high resolution monitor.

Images can be processed by the image processing algorithms and all parts of the system are controlled by the computer. And, images are effectively compressed for storage and transmission via the local area network in the department of radiology and to clinical wards.

Key words: ***Digital radiography, Linear scanning, Photodiode array***

INTRODUCTION

The degradation of a radiographic image by scattered radiation is the well known problem of conventional radiographic systems. Even though scattered radiation is reduced greatly using grids, the remaining scatter is still large. The degradation of image quality due to this scatter is theoretically analysed and measured in a quantitative manner (Wagner 1980). Barnes, Sorenson and Niklason have suggested a more empirical method tc estimate the scattering effects(Barnes 1976; Sorenson 1976, 1982; Niklason 1981). The slit apparatus they used was successful in significantly reudcing the scattered radiation compared with grids.

In order to circumvent the dynamic range limitation of the film, electrical sensors are widely being considered as a replacement for the film as an image detector. There are several types of electronic detectors which have their own advantages and disadvantapes. Solid state electric detectors, image intensifying tubes and selenium imaging plates are among those used to yield clinically useful images. A number of digital radiographic imaging systems are being developed that are intended to eliminate scattered radiation and yield improvements in radiological images using slits and electrical detectors.

Sashin *et al.* have used high resolution photodiode arrays and lens assemblies for the development of a digital radiographic system(Sashin 1979, 1982). It requires optical lens assemblies which limit the efficient use of X-ray exposure and has poor resolution in the scanning axis because of 100:1 pixel ratio. Tesic *et al.* have developed the experimental digital chest unit using solid state linear arrays (Tesic 1983, 1984). It provides some

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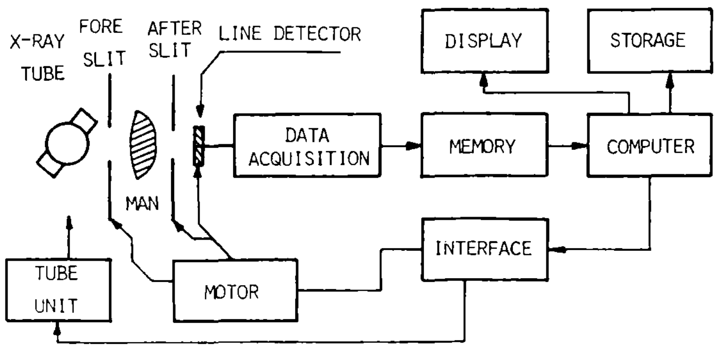

Fig. 1. Block dagram of linear scanning digital radiographic system.

clinically acceptible images and suggests the efficiency of the digital radiographic system. But it takes 4.9 sec of scanning time and large X-ray tube loding. To reduce the acqusition time with the elimination of scattered radiation, Rudin *et al.* have suggested mechanically rotating wheels with the acquisition time of 0.1 sec (Rudin 1981). But it takes pre-operation time to accelerate huge rotaing wheels and consumes large quantities of power.

In this paper, we present a digital radiographic system developed using slits and photodiode array sensor which collects a image within 0.7 sec by simple linear scanning.

MATERIALS AND METHODS

The overall block diagram of the linear scanning digital radiographic system is illustrated in Fig. 1.

An X-ray beam generated in the X-ray tube is converted to a fan beam by fore-slit located between the X-ray tube and the patient. A fore-slit limits the beam to expose the narrowly selected linear area to reduce scattered radiation and patient exposure. Transmitted radiations through the patient are composed of primary radiation and scattered radiation, and scattered radiation is blocked by after-slit which is located between the patient and the detector.

Primary radiation passed through a after-slit is converted to light by an image intensifying screen (enhanced version of 3M-12) and converted light photons are collected by the linear electric detector. This linear electric detector coupled with an image intensifying screen is composed of 1024 pixels of photodiode cell and each cell has a sensitive area of 0.6 mm by 1.3 mm.

A fore-slit, a after-slit and a linear detector scan linearly using the driving servo motor system to form 1024 lines of image during 0.7 sec of scanning time.

Table 1. Specifications of developed linear scanning digital radiographic system

Field size: 63 cm by 60 cm
Image size: 1024 by 1024 pixels
Detector: Photodiode array(S994-19, HAMAMATSU, JAPAN)
Resolution: 0.8 line pairs/mm
Pixel size: 0.5 mm by 1.3 mm
Focal spot size: 0.7 mm by 1.4 mm
A/D converter: 12 bits
Display levels: 256 levels (8 bits)
Scanning time: 0.7 sec
Zooming factor: x4, x16
Parallelism: 4
Image magnification factor; 1.06-1.40
Source to detector distance: 112 cm
Fore slit width: 2 mm
After slit width: 1.3 mm

Detected electrical signals are integrated to enhance the efficiency of X-ray exposure and multiplexed to four serial streams of signals respensenting detected values of linear photodiode array. These integrated streams of detected signals are calibrated by hardware circuits to compensate for X-ray ripple, uneven sensitivity and bias of each pixel. A/D conversion is performed with 12 bit resolution and converted data are collected by a buffer memory for high speed data acquisition.

Then, collected data are transmitted to display memory in the main computer through a parallel interface port. Images are displayed with 1024 by 1024 resoultion and focusing on the region of interest may be performed with magnification factor 4 or 16. Images can be further processed for image enhancement, image analysis, restoration, and dual energy subtraction using developed image processing algorithms. And images may be compressed using compression algorithms for storage and transmission via the local area network in the department of radiology and to the clinical wards.

A servo motor system drives the linear detector and slits by the command signal from the main computer. The main computer also controls the X-ray tube exposure, data acquisition unit and driving servo system. Details of the developed system are given in Table 1.

RESULTS

Images of the normal adult obtained by the linear scanning digital radiographic system are de-

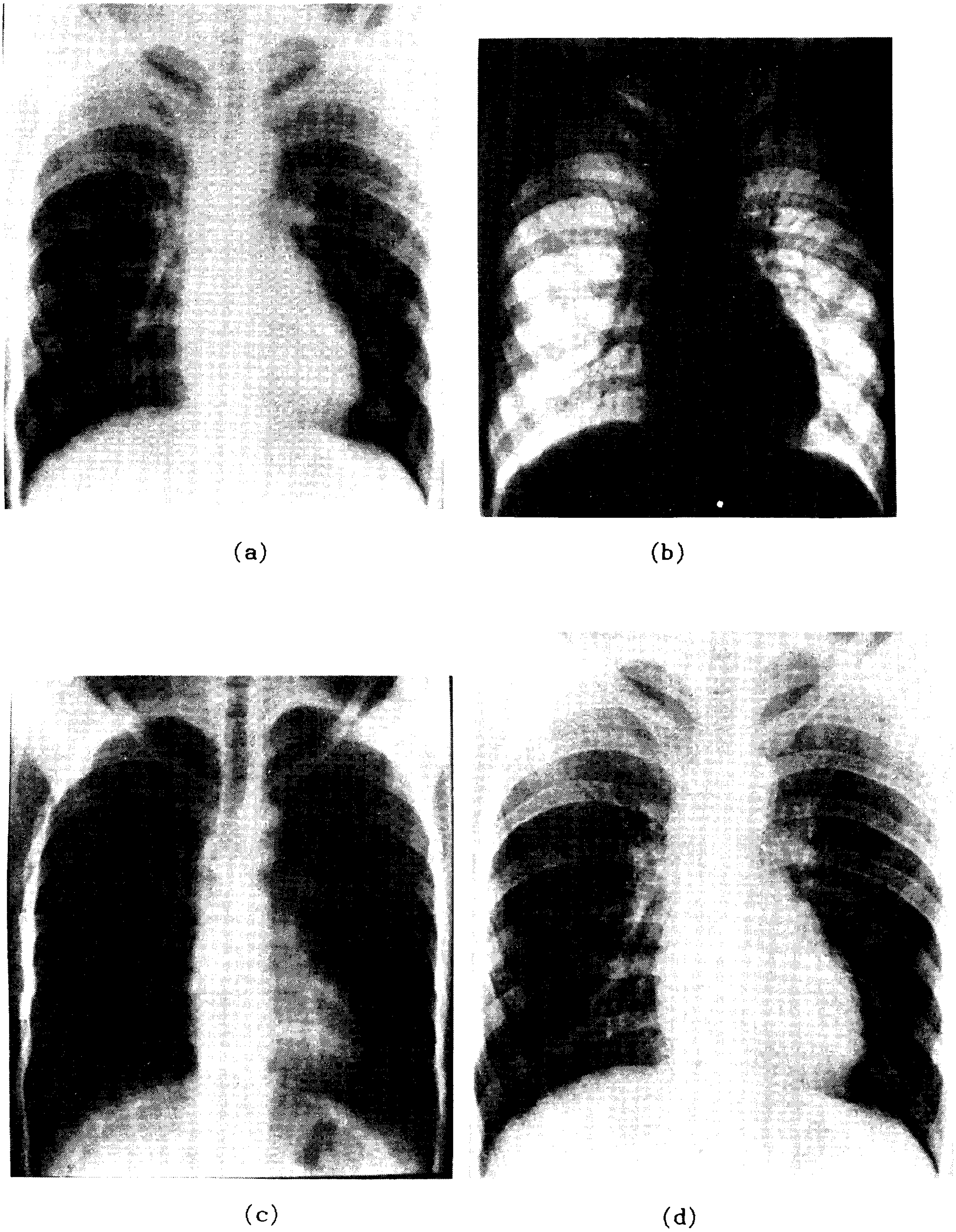

Fig. 2. Images obtained with the linear scanning digital radiography system. An original image without any processing (a), a contrast inversed image (b), a histogram equalized image (c), an unsharp maksed image (d).

monstrated in Fig. 2. Tube voltage was set at 80 KVp and tube current was set at 50 mA. An originally obtained image without any processing (a), shows details of anatomy with increased contrast. A contrast inversed image (b), by simple look-up table manipulation offers increased detectability for the low contrast region compared with the non-inversed original image. Fig. 2. (c) shows a contrast enhanced image by histogram equalization method so that the image pixel values are uniformly distributed over the entire range and offer statistically optimal contrast for the image. An unsharp masked image (d) maskes unsharp components of the image so that the sharp feature of the image can be emphasized and is suitable for the detection of edges and abnormalities.

Image data can be compressed to 1/20 of the original data using a cosine transform, and this data can be transmitted through the local area network.

DISCUSSION

The developed system has several advantages compared with the other types of digital radiographic systems. It needs no lens assemblies which limits the efficient use of X-ray exposure, and uses linear scanning mechanism which offers short acqusition time and simple mechanical structure instead of rotational motion. And parallel processing structure reduces the image acqusition time to 0.7 sec.

Image obtained with the developed system have great dynamic range, so minute contrast difference can be detected by several contrast enhancement methods. This greatly improved image contrast is due to the elimination of scattered radiation and the use of a electronic detector. However spatial resolution is still inferior to the conventional radiography of 3-4 lps/mm. Fooley *et al.* have investigated the effect of pixel size in the diagnosis of pulmonary lung nodules, and found that even though true positives are increased with the increase of spatial resolution, there is no great difference among them when pixel size is 0.2 ×0.2 mm, 0.4×0.4 mm or 0.6 × 0.6 mm (Fooley, 1981).

Image acquisition time is short compared with other types of digital radiography systems (Tesic 1983). But it is still long compared with the conventional radiography. Even the motion of patient, during the image acquisition time such as pumping motion of heart may distort the shapes in image, image bluring hasn't occurred because the image of each line is obtained withing 1/250 sec. Relatively long acquisition time also increases tube loading, but patient exposure is small compared with the conventional radiography because only a very small part of the body is exposed each time during image acquisition.

One of the factors that degrade the system performance is the mismatch of sensitive wavelength between the image intensifying screen and the photodiode array sensor. The wavelength of light emitted from image intensifying screen is 550 nm and peak sensitive wavelength of photodiode array is 880 nm. At 550 nm it produces only 60% of its maximum output current. This mismatch is due to the manufacturing technology of the screen and solid state device and may be enhanced by further researches on phosphors and solid state materials.

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=국문초록=

흉부 촬영을 위한 선형 구동 디지탈 X-선 장치

서울대학교 의과대학 의공학교실

박광석 · 민병구

광다이오드 배열소자를 선형으로 구동하여 X-선 영상을 촬영하는 디지탈 X-선 촬영장치를 개발 하였다. 영상은 영상 증폭 스크린에 의하여 X-선이 빛으로 변환된 다음 1024개의 셀로 구성된 광다이오드 배열소자에 의해 검출된다.

광다이오드 셀의 수광 면적은 0.6 mm × 1.3 mm이다. 전위슬릿을 X-선 발생기와 환자 사이에 설치하여, 산란효과를 제거하고 환자에 대한 X-선의 노출양을 줄였다. 전위슬릿은 광다이오드 검출기와 동기되어 구동 모터에 의하여 선형으로 구동된다. 검출된 영상은 12비트의 디지탈 신호로 변환되어 컴퓨터에 입력된다.

컴퓨터는 입력된 영상의 표시, 처리 및 저장 및 전송을 위한 데이타 압축알고리즘을 수행하고, 촬영장치의 모든 부분을 제어하는 신호를 발생한다.