DIGITAL IMAGE PROCESSING IN X-RAY IMAGING

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ABSTRACT:

In this paper, an application of digital image processing and analysis technique has been discussed, which can be useful in healthcare domain to predict some major diseases for human being. This contribution discusses a selection of today's techniques and future concepts for digital x-ray imaging in medicine. This application is an image processing system, which works on the basis of a new unified radiography/fluoroscopy solid-state detector concept. Advantages of digital imaging include the possibility to archive and transmit images in digital information systems as well as to digitally process pictures before display, include the possibility to archive and transmit images in digital information systems as well as to digitally process pictures before display, we examine the real time acquisition of dynamic x-ray images (x-ray fluoroscopy). Here, particular attention is paid to the implications of introducing charge-coupled device cameras. We then present a new unified radiography/fluoroscopy solid-state detector concept. As digital image quality is predominantly determined by the relation of signal and noise, aspects of signal transfer, noise, and noise-related quality measures like detective quantum efficiency feature prominently in our discussions. Finally, we describe a digital image processing algorithm for the reduction of noise in images acquired with low x-ray dose.

Keywords: Image acquisition, Image enhancement, Image sharpening, Image restoration

[1] INTRODUCTION

In this paper, we discuss selected current topics of digital image acquisition and processing in medicine, focusing on x-ray projection imaging [1]. If you just look at this name - digital image processing; you find that there are 3 terms. First one is processing, then image, then digital. So, a digital image processing means processing of images which are digital in nature by a digital computer. Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image. Here, we find that digital image processing techniques is motivated by 2 major applications. The first application is improvement of pictorial information for human perception. So, this means that whatever image you get, we want to enhance the quality of the image so that the image will have a better look and it will be much better when you look at the image [2]. A key feature of digital imaging is the inherent separation of image acquisition and display. Also, digital images can be stored and transmitted
via picture archiving and communication systems (PACS),' and be presented on different output
deVICES, like film printers or cathode ray tube (CRT) monitors (softcopy viewing) as shown in
FIGURE 1

The separation of image acquisition and display in a digital system is illustrated by
comparing analog and digital acquisition of single high resolution projection images (x-ray
radiography). The principle of the imaging setup is sketched in Figure 2. X radiation passes
through the patient before exposing a detector [1]. Widely used for image detection are analog
screen/film combinations as shown in Fig. 1, which consist of a film sheet sandwiched between
thin phosphor intensifying screens.

The phosphor screens convert the incoming x radiation into visible light blackening the
film, which, after developing, is examined by viewing on a light box.

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**Figure 1.** Principle of conventional x-ray image detection by a screen/film combination. The light-sensitive
film is sandwiched between two phosphor intensifying screens which convert the incoming x-radiation into
visible light.

Well-established digital alternatives include storage phosphor systems (SPS), 2–4 also
known as computed radiography (CR) systems, and a selenium detector based digital chest
radiography system [(DCS) [5, 6].
In CR systems, the image receptor is a photostimulable phosphor plate, which absorbs and stores a significant portion of the incoming x-ray energy by trapping electrons and holes in elevated energy states. The stored energy pattern can be read out by scanning the plate with a laser beam. The emitted luminescence is detected by a photomultiplier and subsequently digitized. Common plate sizes are 35X35 cm$^2$ sampled by a 1760X 1760 matrix, 24x30 sampled by a 7576X1976 matrix, and for high resolutions 18x24 cm$^2$ sampled by a 1770x2370 matrix. The resulting Nyquist frequencies are between 2.5 and 5 lp/mm. An example CR image is given in Figure 3. The detector of a DCS consists of an amorphous selenium layer evaporated onto a cylindrical aluminum drum. Exposure of the drum to x radiation generates an electrostatic charge image, which is read out by electrometer sensors. Maximum size of the sampled image matrix is 2166x2448 pixels, with a Nyquist frequency of 2.7 lp/mm.[3]
In analog as well as in digital systems, the acquired radiographs are degraded by non ideal system properties. These include limitations of contrast and resolution, and are described for instance by the modulation transfer function (MTF). Other undesired effects are spatially varying detector sensitivity and unwanted offsets. Additional degradations can be introduced by accidental over- or underexposure. Unlike screen/film systems, however, digital systems enable the compensation of such known degradations by suitable processing like gain and offset correction and MTF restoration [2]. Furthermore, the problem of over- or underexposures is virtually eliminated by the wide latitude of the SPS and DCS image receptors (about four orders of magnitude) and the possibility to digitally adjust the displayed intensity range. Finally, methods like "unsharp masking" and "harmonization" can be employed to enhance with respect to diagnostically less important information, and to optimize image presentation on the selected output device. Figure 2.1 shows the result of applying such enhancement techniques to the radiograph in Figure 3[4]

In the next section we review x-ray image quality measures needed later in the paper. We then consider digital real time dynamic x-ray imaging, known as x-ray fluoroscopy. Here, we pay particular attention to differences in noise behavior of electronic camera tubes and solid-state charge-coupled device (CCD) cameras. This is followed by a discussion of a new flat solid state x-ray sensor for both digital x-ray fluoroscopy and high resolution radiography. Finally, in, we describe a recently developed quantum noise reduction filter [5].

[2] X-RAY IMAGE DETECTION

An x-ray tube generates x-radiation by accelerating electrons in an electric field towards a tungsten anode. On hitting the anode, about 1% of the electrons generate x-ray quanta, which leave the tube through an x-ray transparent window. The x-ray beam consists of a discrete number of x-ray quanta of varying energy, with the maximum energy being limited by the applied tube voltage. Typical values for the tube voltage range between 60 and 150 kV. The energy distribution of the x-ray quanta determines the beam quality. A thin aluminum plate about 3 mm thick, which absorbs low-energy x-ray quanta unable to pass through the patient, is integrated directly into tube window[1]. These Digital x-ray imaging quanta would only add to the absorbed patient dose without contributing to the imaging process. In the following, the thus reduced range of energies is approximated by a single, average energy, i.e., we assume mono energetic x radiation. For tube voltages of 150 and 60 keV, these average energies are about 63 and 38 kV, respectively [3]

Owing to the discrete nature of x radiation only a limited, potentially small number of x-ray quanta contributes to the imaging process at each pixel. For instance, in x-ray fluoroscopy the typical x-ray dose for an image is about 10 nGy at a beam quality of 60 keV. This results in a quantum flow $q_0$ of roughly $q_0=300$ quanta/mm$^2$. X-ray quantum noise is caused by random fluctuations of the quantum flow, which obey a Poisson distribution. Therefore, the standard deviation $\sigma$ of quantum noise is proportional to $(q_0)^{1/2}$[5].
Figure: 4 Enhanced version of Figure 3. First, middle and high spatial frequencies were amplified relative to very low ones in order to make such details better visible (harmonization). In a second stage, the image was given a sharper appearance by additional amplification of high spatial frequencies by unsharp masking. A Portion of size 700x1846 pixels from a radiograph of a foot (dorso-plantar) acquired by a CR system.

[3] DIGITAL X-RAY FLUOROSCOPY

X-ray fluoroscopy is a real time dynamic x-ray imaging modality which allows a physician to monitor on-line clinical procedures like catheterization or injection of contrast agents.
DIGITAL IMAGE PROCESSING IN X-RAY IMAGING

Figure: 5  E Sketch of fluoroscopy system [1 : movable C arm, 2 : x-ray tube, 3 : x-ray beam, 4 : patient, 5 : operating table, 6 : detection front end, 7 : video signal fed to processing unit and monitor (not shown) enhanced version

An x-ray fluoroscopy system is sketched in Figure 5, a movable C-shaped arm bearing the x-ray tube and the image detection "front end" is mounted close to the operating table. The position of the C arm can be adjusted arbitrarily during the clinical procedure. The detected dynamic images are displayed on a CRT monitor placed near the operating table, hence providing the physician with immediate visual feedback [4].

[4] FLUOROSCOPY IMAGE DETECTION

Today's detection front ends consist of an x-ray image intensifier (XRII) coupled by a tandem lens to a TV camera, which is followed by an A/D converter. The XRII is a vacuum tube containing an entrance screen attached directly to a photocathode, an electron optics, and a phosphor screen output window. Images are detected by a fluorescent caesium iodide (CsI) layer on the entrance screen, which converts the incoming x-ray quanta into visible photons, which in turn reach the photocathode. The CsI screen is a layer approximately 400µm thick and evaporated onto an aluminum substrate. The absorption of these creensis about 60%-70%. In addition, CsI is grown in a needle-like structure such that the individual needles act as optical guides for the generated light photons. This prevents undesired lateral propagation within the CsI layer, and thus ensures a relatively good screen MTF[3].
CONCLUSION

This article described selected topics of medical x-ray image acquisition and processing by digital techniques, some of which are already well established, while others are presently emerging. By first comparing digital radiography systems to analog ones, it was shown that a key advantage of digital imaging lies in the inherent separation of image acquisition and display media, which enables one to digitally restore and enhance acquired images before they are displayed. It turned out that the amount of restoration and enhancement which can be applied is fundamentally limited by noise.

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REFERENCES