CCD-based EPID and Frame Averaging Technique

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Abstract

Prototype portal imaging device (EPID) based on CCD camera, which has a 20×20 cm^2 field of view (FOV), has been developed and then tested by acquiring phantom images for 6 MV x-ray beam. While, among the captured images, each frame suffered notorious quantum noise, the frame averaging largely enhanced the image quality against quantum noise. Over 60 frames averaging, the signal-to-noise ratio (SNR) was increased by ~ 20 times and contrast was increased about 2 times in the skull-region of the acquired head-phantom image.

1. Introduction

In real-time therapeutic x-ray radiography, a video camera-based type is the most popular system among commercially available electronic portal imaging devices (EPIDs) [1]. The video camera-based EPID mainly consists of two detectors, which are an x-ray detector, converting x-ray into visible light, and a video camera, capturing the visible light with anatomical information. In order to prevent the irradiation of direct and scattered x-rays onto CCD, two detectors are optically coupled by a 45° inclined mirror and lens. In currently commercial video camera-based EPIDs, imaging tube and CCD are generally used as video cameras [1]. Since the x-ray energy in the therapeutic x-ray imaging is in order of several MeV, the image contrast and spatial resolution is inherently poor. In order to increase the image quality or to reduce quantum noise, the video camera is operated in integration mode or by frame averaging method [2-4].

In this study, we have acquired therapeutic x-ray radiographs using our prototype EPID and applied frame averaging method to increase image quality. Based on results, we will discuss the optimal operation of CCD camera when applied to EPID.

2. Materials and Methods

In order to capture the therapeutic x-ray images, we used the prototype CCD camera-based EPID system with a field of view (FOV) of 20×20 cm^2 as shown in Fig 1. It has a 135 mg/cm^2-coveage Lanex fast back screen (Eastman Kodak) attached onto a 2 mm-thick copper plate as a x-ray detector. The detector is then optically coupled to CCD camera by an aluminum-coated glass mirror, or called a first-surface mirror, with 45° inclined angle and 6 ~ 12 mm zooming c-mount lens. Samsung BW-2301ED, which is operated by the interlaced scanning mode, was used as a CCD camera.

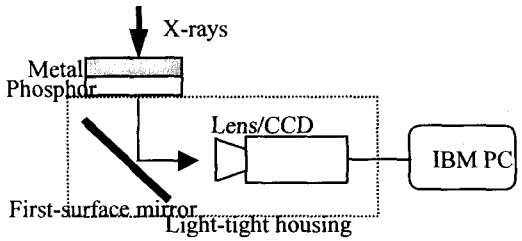

Fig. 1. Schematic diagram of prototype EPID system.

In this study, 60 frames of images are acquired in video speed of 30 frames per second. Moreover, accounting for quantum noise due to statistical fluctuations of x-rays and light quanta, each frame image is averaged after conversion into grayscale values. A signal-to-noise ratio (SNR) and image contrast were determined for small (10×10 pixels) region-of-interests (ROIs), such as skull and neck, of head-phantom images.

All experimental measurements were performed for the 6 MV x-ray beam from linear accelerator (Siemens, Mevatran KD) at 300 MU/min and 100 cm-SSD with humanoid head-phantom.

3. Results and Discussion

Figure 2 shows acquired single-frame image of a lateral humanoid head-phantom. As shown in Fig. 2, a single frame suffers notorious quantum

noise, which is due to the counting statistics of the incident x-rays, the conversion fluctuations of x-rays into light quanta in x-ray detector, signal formation fluctuations in CCD camera and so on [4]. After averaging frames, however, the quantum noise is largely reduced as shown in Fig. 3, which is 60 frames averaged image. Since, in the interlaced mode of CCD camera, a one frame is composed of 2 fields, and each field is obtained during 1/60 seconds, figure 3 gives the same effect as an acquired image integrated during 1 second in integrating scan mode.

As the number of averaged frames increases, SNR increases. At 60 frames averaged image, SNRs are increased by 10 and 17 times for the skull and neck region, respectively. In addition, between the sampled areas, the image contrast rapidly increases as number of frames averaged increases, and then starts to saturate at around 8 frames as shown in Fig. 4.

4. Conclusions

Therapeutic x-ray radiographs were acquired using the prototype video camera-based EPID with FOV of 20×20 cm^2. Although, in the interlaced mode, the captured image contains serious quantum noise from the short scanning time (1/30 seconds for one frame image), the quantum noise was reduced by frame averaging method. Moreover, the frame averaging method improved the SNR and image contrast of the single image. When more and more frames are averaged, SNR is increased but the contrast is saturated at around 8 frames.

In order to reduce the quantum noise and to improve the image quality in therapeutic x-ray imaging application, the frame averaging method is very useful technique.

References

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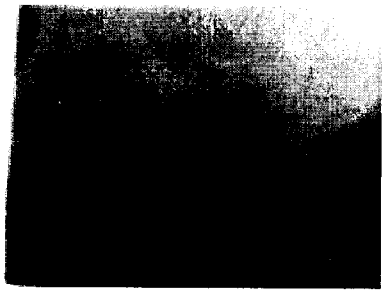

Fig. 2. A single video frame image containing serious quantum noise. (1/30 seconds)

Fig. 3. Image after averaging 60 frames, which shows quite removed quantum noise. (1 second)

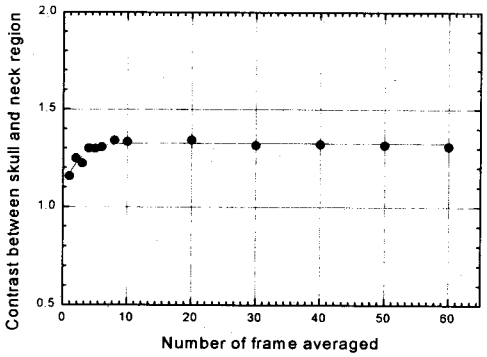

Fig. 4. Image contrast for small (10×10 pixels) region-of-interests (ROIs), between skull and neck region, of head-phantom as a function of averaged frame numbers.