A study on Improvement for distorted images of the Digital X-ray Scanner System based on Fuzzy Correction Algorithm

Jaeho Baek*, Kyungjung Kim*, Mignon Park*
*Department of Electrical and Electronic Engineering
Yonsei University
134, Sinchon, Seodaemun, Seoul, 120-749, Korea
Tel: +82-2-2123-2868, Fax: +82-2-312-2333
E-mail: jhbaek97@yeics.yonsei.ac.kr, kjkim01@yonsei.ac.kr, mignpark@yonsei.ac.kr

Abstract *- This paper proposes a fuzzy correction algorithm that can correct the distorted medical image caused by the scanning nonlinear velocity of the Digital X-ray Scanner System (DX-Scanner) using the Multichannel Ionization Chamber (MIC). In the DX-Scanner, the scanned medical image is distorted for reasons of unsuitable integration time at the nonlinear acceleration period of the AC servo motor during the inspection of patients. The proposed algorithm finds the nonlinear motor velocity modeling through fuzzy system by clustering and reconstructs the normal medical image lines by calculating the suitable moving distance with the velocity of the motor using the modeling, acceleration time and integration time. In addition, several image processing is included in the algorithm. This algorithm analyzes exact pixel lines by comparing the distance of the acceleration period with the distance of the uniform velocity period in every integration time and is able to compensate for the velocity of the acceleration period. By applying the proposed algorithm to the test pattern for checking the image resolution, the effectiveness of this algorithm is verified. The corrected image obtained from distorted image is similar to the normal and better image for a doctor's diagnosis.*

Keywords: digital X-ray radiography, distorted image, fuzzy algorithm, image correction.

1 Introduction

The beginning of a gas chamber type X-ray detector which can be applied to a digital X-ray radiography is a Multiwire Proportional Chamber developed by the Russian Nuclear Institute in 1980s. The MIC is improved better resolution than MWPC, Nowadays, the MIC whose resolution is 1.25p/mm is being produced for the medical digital X-ray radiography in Russia and China [1][4][5]. A DX-Scanner using the MIC was developed by the Advanced Digital Technology Co. (ADT), Ltd. with Yonsei University, Budker Institute of Nuclear Physics, and Korean Ministry of Commerce, Industry and Energy from October, 2003 to November, 2004. This radiography has the better advantages than film-screen X-ray radiography, but has the distortion of image by scanning velocity and vibration. It is necessary for the distorted image to compensate the presented problem through fuzzy correction algorithm.

In section 2, the fuzzy system is presented for learning motor velocity data. Section 3 introduces a configuration of the DX-Scanner with an experiment. We present the velocity specifications of AC motor and a problem by the velocity in section 4. We propose the fuzzy correction algorithm that can correct the scanning velocity every integration time through a fuzzy clustering in section 5. In section 6, experimental results that the proposed algorithm is applied to DX-Scanner are given. Conclusions are presented in section 7.

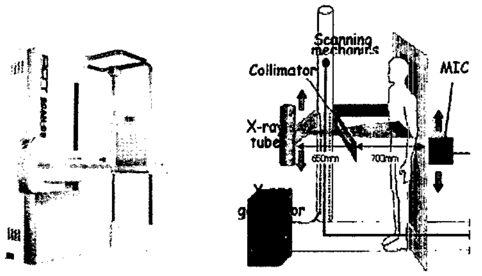
2 Fuzzy Systems

Fuzzy systems are based on the foundation of fuzzy mathematics. These are also expert's knowledge-based or rule-based systems. The knowledge base consists of the so-called fuzzy IF-THEN rules. A fuzzy IF-THEN rule is an IF-THEN statement in which some words are characterized by continuous membership functions. In general, fuzzy systems consist of a fuzzy rule base, the fuzzifier, a fuzzy inference engine and the defuzzifier.

The optimal fuzzy logic system is constructed as

$$f(\bar{x}) = \frac{\sum_{l=1}^{N} y^l \exp\left(-\frac{\left|\bar{x}-\bar{x}^l\right|^2}{\sigma^2}\right)}{\sum_{l=1}^{N} \exp\left(-\frac{\left|\bar{x}-\bar{x}^l\right|^2}{\sigma^2}\right)} \quad (1)$$

The fuzzy logic system composes centroid defuzzifier, singleton fuzzifier, product inference engine and Gaussian membership function. We are given N input-output pairs $(\bar{x}^l, \bar{y}^l)$, $l = 1,2,\cdots,N$. We present to construct a fuzzy



(a) (b)

Figure 1. (a) DX Scanner (b) Configuration of DX Scanner

system $f(\bar{x})$. A fuzzy logic system can match all the N pairs to any given accuracy. For any given $\xi > 0$, we require that $\left|f(\bar{x}^l) - y^l\right| < \xi$ for all $l = 1,2,\cdots,N$.

The optimal fuzzy logic system (1) uses one rule for one input-output pair in the training set, thus it is no longer a practical system if the number of input-output pairs in the training set is large. For these large-sample problems, various clustering techniques can be used to group the samples so that a group can be represented by only one rule in the fuzzy logic system.

From a general conceptual point of view, clustering means partitioning of a collection of data into disjoint subsets or clusters, with the data in a cluster having some properties that distinguish them from the data in the other clusters. For our problem, we first group the input-output pairs into clusters according to the distribution of the input points, and then use one rule for one cluster.

The nearest neighborhood clustering algorithm is one of the simplest clustering algorithms [7]. In this algorithm, we start from putting the first data as the center of the first cluster. Then, if the distances of a data to the cluster whose center is the closet to this data ; otherwise, set this data as a new cluster center.

3 Digital X-ray Scanner System

The DX-Scanner and the configuration of the system in this thesis is shown in Figure 1. The basic elements of the system are used an X-ray tube, a High Frequency Generator (HFG) which supplies electric high power with the tube, a collimator with 0.6mm slit which produces flat fan-shaped X-ray beam and is located at 650mm from the focus of tube and at 700mm from the detector, a detector which is designed by MIC, a high velocity data processor which processes signals from a detector, electronics and system control part, based on graphic user interface, which controls X-ray exposure does, X-ray exposure time and scanning velocity, and 500W AC servo motor. The tube, the collimator, and the detector synchronously move in vertical direction.

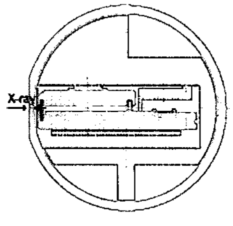


Figure. 2 General layout of MIC

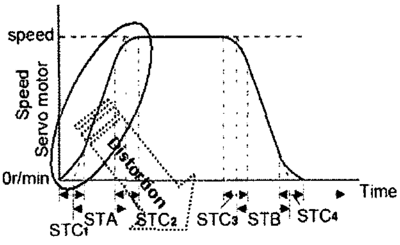
The X-ray tube produced by Toshiba and the HFG produced by SEDECAL are applied to the DX-Scanner. The distance between the X-ray tube and the detector is fixed on 1,350mm to reduce the distortion of horizontal image, to minimize the decrease of sharpnesss by a size of tube's focus, and to procure a person space for feeling at ease.

The MIC shown as Figure 2 is a flat capacitor with uniform anode and a cathode consisting of the 2048 strips. The strips with a length of 40mm and a width 100μm have a pitch 200μm. To avoid a parallax, all strips are directed to X-ray focal spot, which should be situated at the distance 1300mm from beginning of strips. The distance between anode and cathode is 2mm. The gap of a collimator installed at entrance window of the detector is 0.35mm. The detector is filled with Kr at pressure 40atm. X-ray quantum pass through collimator gap and cause gas ionization between the electrodes. The value of the ionization charge is proportional to the energy deposit in the detector. This charge under influence of an electric field moves to electrodes of the chamber and induce the signal on the strips. At the end of integration time, the collected charges read out sequentially with multiplexer, amplified and digitized with ADC. Each multiplexer connects 256 strips with one ADC. After that, data are transmitted to the external electronic block for additional processing. After processing, the digital data are transmitted via ethernet connection to PC.

System control part is a computer program developed and upgraded to be convenient for a user who works with it. This is the most important part of the DX-Scanner, because it makes the scanner watching states of the system and operating each part synchronously. The system control program is able to set up X-ray exposure dose and time for a patient's form, scanning velocity and is designed to start scanning pushing the button.

4 Velocity Specification of AC Servo Motor and Distorted Image

AC Servo Motor is robust in construction and has lower inertia. However, in general, they are nonlinear and highly coupled machines, and their torque-velocity characteristics are not ideal [2]. AC Servo Motor uses



(a)

(b)

Figure 3. (a) Velocity characteristics of HC-SFS52B (b) The distorted image cause of (a)

Mistubisi's HC-SFS52B. This motor has been developed specifically for use with the compact MR-J2S60A packaged.

In the DX-Scanner, the most important parameters are *STA* (s-pattern Acceleration time constant), *STB* (s-Pattern Deceleration time constant), *STC* (s-pattern Acceleration/Deceleration time constant). This motor velocity-time characteristics has s-pattern during accelerating period and nonlinear pattern at STC period shown in Figure 3 (a) [8].

The relation between motor velocity and integration time detected from the MIC is very important variables when detecting linear X-ray. If these two variables are not correct, the detected image occurs in the distortion. We can know that X-ray image data is stretched and distorted by this nonlinear velocity increment shown in Figure 3 (b). The X-ray exposure, the detector's operation, the scanning velocity are so synchronously worked by starting to detect the signal of the system ready and exposure button that we can acquire the normal data. Because a measured image of a patient has error by the problem, a doctor may make a wrong diagnosis. If X-ray is exposed after fixed velocity, it is necessary to treat the image with another of image processing methods cause by the medical image included unessential noisy pixels. Therefore, the image does not fit to standard X-ray dimensions and specifications.

5 Fuzzy Correction Algorithm

When the radiography moves, the scanning velocity has exponentially increased by the desired velocity though the detector measures the image line every integration time which is sampled every 0.02cm. Therefore, several lines of the detected image during acceleration time are not correct and the whole image is exponentially distorted in previous section.

We propose the correction algorithm based on fuzzy system Eq.(1) by clustering of Ref. [7] using motor velocity data, **STEP 1** to **STEP 8**, that can correct the distorted medical image caused by the scanning velocity of the DX-Scanner. For fuzzy clustering, input-output pairs are ;

$$[x(t-\alpha); x(t)] \tag{2}$$

where $x(t-\alpha)$ is last motor velocity data and $x(t)$ is present motor velocity data.

In addition, we also use the histogram equalization using a special feature of human's eyes that is more sensitive for contrast than intensity of image.

STEP 1. Vertical line number is computed through STC_1, STC_2, STA and integration time.
STEP 2. Receive data of scanning velocity and store that to located memory from main controller of the system.
STEP 3. Make fuzzy velocity system through presented fuzzy system.
STEP 4. Compensate error with means of error between observed real data and value of fuzzy velocity system.

$$S(t) = v_k(t) + \varepsilon \tag{3}$$

where $v_k(t)$ is fuzzy velocity logic system, and ε is means of error.
STEP 5. Scanning distance is computed every integration time during acceleration using Eq. (3).
STEP 6. If scanning distance is as large as 0.02cm or larger than 0.02cm, the line pixels are restored to new memoy.
STEP 7. Equalize histogram of restored image and stretch the histogram using the histogram equalization and stretching algorithm [3].
STEP 8. Recall the whole image on the preview.

PART I is the fuzzy learning process with motor data from **STEP 3** to **STEP 5** and PART II is multithreaded the correction process from **STEP 6** to **STEP 8** with PART II.

6 Experimental Results

The fuzzy correction algorithm is applied to the DX-Scanner. The scanning velocity of motor are 7cm/s and

14cm/s. Integration time are 2.5ms at 7cm/s and 1.25ms at 14cm/s.

We demonstrate the restored procedures in section 5 using two examples which is applied to motor acceleration

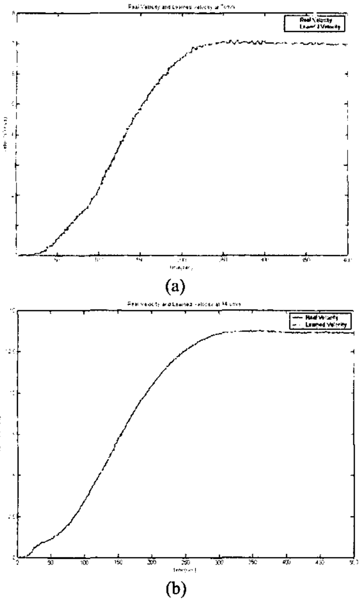


Figure 4. Real Velocity and Learned Velocity (a) At 7cm/s (b) At 14cm/s

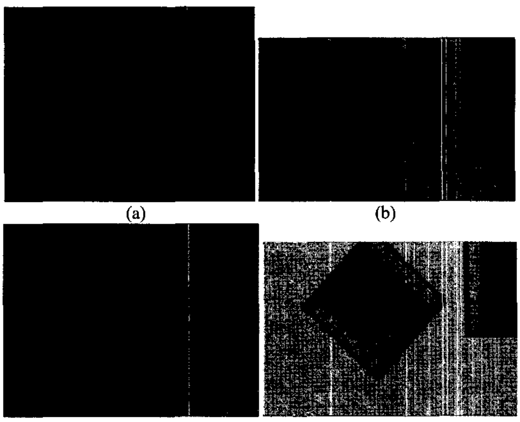


Figure 5. (a) The distorted image (b) The corrected image at 14cm/s, (c) the distorted image (d) the corrected image at 7cm/s

time such as 250ms by setting STC_1 , STC_2 , STA parameters in the system. The image is the vertical image pixel resolution pattern and horizontal image pixel resolution pattern.

We can see that the learned velocity follows the real motor data at 7cm/s and 14cm/s in Figure 4. Figure 5 (a) and (c) are the originally distorted images by nonlinear velocity. Figure 5 (b) and (d) show the corrected images after processing the correction algorithm. It can be seen that the resulting images are normal and much better.

7 Conclusions

In this research, we have described the DX-Scanner using the MIC. The problem having the motor in this system is presented. We have known that the distorted image is generated by the problem.

A fuzzy correction algorithm has been proposed to correct the distortion in shape of the acquired image : the column X-ray images are distorted in shape due to the nonlinear velocity of scanning motor. To correct such distortion, we have employed the fuzzy system using motor velocity data for the nonlinear scanning velocity. The distorted column image has been corrected sequentially in 8 steps. We have acquired far better than an original image through the algorithm.

Acknowledgement

Authors would like to thank ADT members for supporting this research. This work has been partially supported by ADT and Korean Ministry of Commerce, Industry and Energy.

References

[1] S E Baru, A G Khabakhpashev, L I Shekhtman, "A low-dose X-ray imaging device", Eur. J Phys. 19(1998) 475-483.

[2] P. C. Sen, Principles of Electric Machines and Power Electronics, Wiley, 1997.

[3] Dongjung Kang, Jongeun Ha, Digital Image Processing using Visual C++, SciTech, 2005.

[4] E.A. Babichev, S.E. Baru, V.R. Groshev, A.G. Khabakhpashev, V.A. Neustroev, P.A. Papushev, V.V.Porosev, G.A. Savinov, L.I. Shekhtman, Yu.G.Ukraintsev, Yu.B. Yurchenko, "Comparison of Xe and Kr filled ionization chambers for application in digital scanning radiography", Nuclear Instruments and Methods in Physics Research A 525(2004) 352-355.

[5] E.A. Babichev, S.E. Baru, V.R. Groshev, A.G. Khabakhpashev, V.V. Leonov, V.A. Neustroev, V.V Porosev, G.A. Savinov, L.I. Shekhtman, "The new effective detector for digital scanning radiography", Nuclear Instruments and Methods in Physics Research A 513(2003) 57-60.

[6] Jaeho Baek, Kyungjung Kim, Soyeon Kim, Mignon Park, "Restoration Algorithm for the distorted image of the Digital X-ray Scanner System using the Multichannel Ionization Chamber", ITC-CSCC 2005 Conference, 2005.

[7] Li-Xin Wang, "Training of Fuzzy Logic System Using Nearest Neighborhood Clustering", Fuzzy Systems, Second IEEE International Conference, 1993.

[8] Mitsubishi Electric. General-Purpose Interface MR-J2S-* A Servo Amplifier Instruction Manual, 2000.