SLANTING EDGE METHOD FOR MODULATION TRANSFER FUNCTION COMPUTATION OF X-RAY SYSTEM

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To my beloved mother and father

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My wife and son

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In the name of Creator of the Universe (Allah)
Most Merciful and Most Gracious

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ABSTRACT

The edge method is commonly used to determine the modulation transfer function (MTF) of a straight edge image in radiography systems. Measurement of MTF by using slanting edge method is an important way to evaluate the quality of a slanted edge image, as it is difficult to acquire a straight image. Slanted edge image offers more data by reprojection of the data to the slanted line, and gives more points in the edge spread function (ESF). Straight and slanted edge images data were used to measure the ESF, the line spread function (LSF) and the presampled MTF using MATLAB R2011a program. Edge images were taken from a $0.05\,mm$ thick lead foil in a conventional radiographic screen-film system, and a $0.48\,mm$, $1.2\,mm$ thick aluminium test objects with a $1.08\,mm$ thick lead in a Fuji computed radiography (FCR) system. Edge images of lead test devices provide higher MTFs than that of aluminiums. The MTF values of slanted edge images were compared to those obtained by straight edge images for spatial frequency range about $0 - 7\,cycles/mm$. The MTF results of lead test devices for conventional and computed radiographic systems are similar, although the computed system has better MTF for spatial frequencies between 0 and $2\,cycles/mm$ with a very low fluctuation due to the extremely small noise. However, for $2 - 7\,cycles/mm$ the conventional system has better and higher MTFs for both straight and slanted images. In the conventional radiographic system, the experimental MTF results are accepted by the method with the mean MTF difference of 0.006 for the straight ($0\,degree$) and the slanted with ($2\,degrees$) of edge images for spatial frequencies between 0 and $7\,cycles/mm$. On the other hand, the mean MTF difference for the straight ($0\,degree$) and slanted ($1\,and\,2\,degrees$) resultant MTFs in the computed radiographic system are 0.003 and 0.004 respectively. The best MTF result was obtained from the slanted edge image ($2\,degrees$) in the FCR system.

ABSTRAK

Kaedah sisi biasanya digunakan untuk menentukan fungsi pemindahan modulasi (MTF) imej sisi lurus dalam sistem radiografi. Pengukuran MTF dengan menggunakan kaedah sisi condong adalah satu cara lain yang penting untuk menilai kualiti imej, kerana kesukaran memperoleh imej sisi yang lurus. Imej sisi condong menawarkan lebih banyak data dengan unjuran data ke garisan condong, sekaligus memberi lebih banyak titik dalam fungsi taburan sisi (ESF). Imej sisi lurus dan condong telah digunakan untuk mengukur ESF, fungsi taburan garis (LSF) dan MTF prasampel menggunakan perisian MATLAB R2011a. Imej sisi telah diambil dari kerajang plumbum setebal $0.05\,mm$ dalam sistem radiografi skrin filem konvensional dan aluminium setebal $0.48\,mm$, $1.2\,mm$ serta plumbun setebal $1.08\,mm$ dalam sistem radiografi dikomputasi (FCR). MTF imej sisi peranti ujian plumbum lebih tinggi daripada yang aluminium. Nilai MTF imej sisi condong dibandingkan dengan yang diperoleh daripada imej sisi lurus untuk julat frekuensi ruang kira-kira $0 - 7\,kitaran/mm$. Keputusan MTF peranti ujian plumbum bagi sistem konvensional dan sistem radiografi dikomputasi adalah serupa, walaupun sistem radiografi dikomputasi mempunyai MTF lebih tunggi untuk frekuensi ruang di antara 0 dan $2\,kitaran/mm$ dengan turun naik kecil disebabkan oleh hingar yang kecil. Walau bagaimanapun, bagi $2 - 7\,kitaran/mm$ sistem konvensional mempunyai MTF lebih tinggi bagi kedua-dua imej lurus dan condong. Dalam sistem radiografi konvensional, didapati min perbezaan MTF sebesar 0.006 untuk imej sisi lurus ($0\,darjah$) dan sisi condong ($2\,darjah$) untuk frekuensi ruang di antara 0 dan $7\,kitaran/mm$. Sebaliknya, dalam sistem radiografi dikomputasi min perbezaan MTF untuk imej sisi lurus ($0\,darjah$) dan sisi condong ($1\,dan\,2\,darjah$) adalah masing-masing 0.003 dan 0.004. Hasil MTF terbaik telah diperoleh daripada imej sisi condong ($2\,darjah$) dalam sistem FCR.

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LIST OF SYMBOLS

α	-	Tilt angle
Δs	-	Sub-pixel bin width
$\Delta \mathrm{x}$	-	Slight shift of the sampling positions between the lines
$e(x)$	-	Edge Spread Function
f	-	Spatial frequency
$f_{Nyquist}$	-	Nyquist frequency
$\mathrm{I_{amp}}$	-	Sinusoidal amplitude intensity
$\mathrm{I_{bg}}$	-	Background intensity
$\mathrm{I_{max}}$	-	Maximum signal intensity
$\mathrm{I_{min}}$	-	Minimum signal intensity
i	-	Row number
j	-	Column number
$l(x)$	-	Line Spread Function
M	-	Modulation
$\mathrm{M_{in}}(f)$	-	Input signal modulation
$\mathrm{M_{out}}(f)$	-	Output signal modulation

N_{ave}	-	Average line numbers resulted in a one pixel
p	-	Pixel dimension
pp	-	Pixel pitch
$S(i, j)$	-	Distance from the edge
θ	-	Re-projection angle

LIST OF ABBREVIATIONS

DQE	-	Detective Quantum Efficiency
ESF	-	Edge Spread Function
FCR	-	Fuji Computed Radiography
FFD	-	Focus-to-film distance
FFT	-	Fast Fourier transform
IP	-	Imaging plate
LSF	-	Line Spread Function
MTF	-	Modulation Transfer Function
ROI	-	Region-of-interest

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Spatial resolution is a property that determines the quality of an image which is acquired by X-ray imaging system. The quality of an image in the field of medical imaging is very important for medical diagnosis purposes. However, the image quality is usually affected by a few factors, especially the spatial resolution. A high level of image quality translates into a more accurate diagnosis. The evaluation of resolution properties for an X-ray imaging system is commonly done by the modulation transfer function (MTF) (Morishita *et al.*, 1995). This is the most important factor for the characterization of image quality and to explain the nature of the measurement signal transfer of an imaging system.

The capability of a system to transfer the modulations in the input signal is measured by the MTF. The MTF describes as a ratio between the information recorded and the total amount of information available (Curry *et al.*, 1990). The MTF may be able to compare the imaging qualities of competing systems as a more accurate way to help the radiologist to choose the best suitable system for clinical needs (Permal, 2008).

The effect of a medical imaging system with certain input functions is the qualitative and quantitative study to understand about the characteristics and physical behavior of that system. There are several ways to study the system by a test input function. The input functions characterize the behavior of the system. A ‘physical’ test function and the output signal of an experiment can be analyzed to determine the transform characteristic through the system (Macovski, 1983). The MTF of an X-ray imaging system is determined by measuring the line spread function (LSF) (Samei *et al*., 1998). The LSF is the response of the imaging system to a test device with an exact narrow slit. Therefore, a method for measuring the MTF which is carried out with slit method is a method that has been widely studied in the past (Morishita *et al.*, 1995).

In this study rather than the LSF, the edge spread function (ESF) will be used to measure the MTF, which is more capable, and suitable in many applications (Boone and Seibert, 1994). The ESF can be measured by a sharp edge of a test device image. In this study investigation of image is the slanted edge image of the above method. Hence, instead of sampled MTF, a method for measuring the pre-sampled MTF will be used. The local smoothing of the ESF and the LSF will be used to reduce the noise.

In this work, the MTF will be obtained by a slanted edge image and the result will be compared to those obtained by a straight edge image. This study will try to find a method in order to indicate the smallest difference between the MTF values of a straight and slanted edge images, especially between the straight ($0\, degree$) and slanted ($2\, degrees$) for radiographic screen-film system and digital radiographic system. The angles of the edge images will be determined by a simulated technique using MATLAB R2011a program. This method calculates the ESF using slanted edge images through the differentiated process to obtain the LSF. Finally, the pre-sampled MTF is deduced by Fourier transformation of the LSF, similarly by using MATLAB program.

1.2 Statement of Problems

Typically, the edge method is used to derive the MTF of a straight edge image. The edge method needs the edge to be aligned perpendicularly to the x-axis. However, if the edge is slanted and then to measure the MTF of that image is a question to be investigated, whenever the edge test device for slanting edge method cannot be placed with the X-ray beam source in a straight line. The difference in the mean MTF for the slanted edge image against the straight edge image will also be analyzed. A simple and effective method needs to be deviced to measure the MTF of the edge images. Computer software MATLAB will be used to solve the MTF measurement of an edge image, so that quality of the images produced can be determined and analyzed.

1.3 The Purpose of this Research

The main aim of this work is to measure the MTF of a slanted edge images for a conventional radiographic system with a screen-film Lanex Regular/T Mat G and a computed radiographic system with a Fuji film imaging plate (IP) Cassette type CC . Better MTF provides better resolution, which is a factor to produce higher image quality.

1.4 Research Objectives

1) To determine the MTF of the slanting edge method for the spatial frequencies.

2) To understand the edge image generation process to obtain the presampled MTF by using MATLAB program.

3) To compare MTF values of slanted edge image with those obtained by straight edge image.

4) To evaluate X-ray imaging system by computing the MTF of edge images for different test devices.

1.5 Significance of Study

The importance of this work is to determine the quality of an image in radiography for diagnostic purposes when the image is the slanted edge image. This work will give information about the MTF from slanted edge image to identify the nature of film-screen and the imaging plate (detector) with high quality for image resolution. In addition, the method is important to determine better X-ray imaging system which is capable to transfer the modulations in the input signal.

1.6 Scope of Research

In this study, four straight edge images will be used to measure the ESF, for each image there are slanted edge images which will be processed to compute the MTF for two X-ray imaging systems. Edge images will be taken from different edge test devices. A conventional radiographic screen-film system with a $0.05\,mm$ thick lead foil and a radiographic screen-film namely Lanex Regular/ T Mat G will be used to record the attenuated X-ray distributions, or more commonly, to obtain edge images from an X-ray source $80\,\mathrm{kVp}$, $1.6\,\mathrm{mAs}$ with $16\,mm$ aluminium filtration. However, in a Fuji computed radiography (FCR) system a $0.48\,mm$, $1.2\,mm$ thick of aluminium test objects and a $1.08\,mm$ lead thick with a Fujifilm IP Cassette type CC will be used to acquire edge images. The X-ray beam will be generated by $50\,\mathrm{kVp}$ tube potential with $6\,\mathrm{mAs}$ and $1.2\,mm$ aluminium filtration in the digital radiographic system.

MATLAB programs will be used to compute the presampled MTF by calculating the Fourier transform of the LSF, while the LSF will be obtained through the differentiation of the ESF of the system. Finally, the presampled MTF which will be obtained from the four slanted edge images will be compared with those obtained from the straight edge images.

REFERENCES

Baert, A. L., Brady, L. W., Heilmann, H. P., Hricak, H., Knauth, M., Molls, M., Nieder, C. and Reiser, M. F. (2010). *Digital Mammography*. Medical Radiology. Diagnostic Imaging and Radiation Oncology ISSN 0942-5373. Springer-Verlag: Berlin

Boone, J. and Seibert, J. (1994). An analytical edge spread function model for computer fitting and subsequent calculation of the LSF and MTF. Medical Physics. **21**: 1541-1545.

Bourne, R. (2010). *Fundamentals of Digital Imaging in Medicine*. (1st Edition) Springer-Verlage: London.

Buhr, E., Gunther-Kohfahl S. and Neitzel, U. (2003). Accuracy of a simple method for deriving the presampled modulation transfer function of a digital radiographic system from an edge image. Medical Physics. **30** : 2323-2331.

Bushberg, J. T., Seibert, J. A., Leidholdt, JR. E. M., and Boone J. M. (2002). *The Essential Physics of medical Imaging*. (2nd ed.) Lippincott Williams & Wilkins: New York.

Bracewell, R. N., (1995). *Two-dimensional imaging*. Englewood Cliffs, N.J., Prentice Hall. 505-537.

Canny, J. (1986). "A computational approach to edge detection." IEEE transactions on pattern analysis and machine intelligence.- **PAMI-8**(6): 679-698.

Cunningham, I. and Fenster, A. (1987). Amethod for modulation transfer function determination from edge profiles with correction for finite-element differentiation. Medical Physics. **14**: 533-537.

Curry, T. S., Dowdey, J. E., Murry, R. C., (1990). *Christensen's Physics of Diagnostic radiology*. (4th ed.) United States of America: Philadelphia, Lea & Febiger. 201 – 218.

Donovan, M., Zhang, D. and Liu, H. (2009). Step by step analysis toward optimal MTF algorithm using an edge test device. Journal of X-Ray Science and Technology. **17**: 1-15.

FujiFilm corporation, (2005). Fuji Computed Radiography FCR CAPSULA XL Image Reader (CR-IR 356), IP cassette type CC. JAPAN: 26-30, Nishiazabu 2-Chome, Minato-KU, TOKYO 106-8620.

Hassan, W. M. S. W. (2008). *Measurement of modulation transfer function of diagnostic x-ray screen-film systems in a hospital setting*. (1st. ed.) Research monograph (Universiti Teknologi Malaysia. Research Management Centre).

Hassan, W. M. S. W., Munajat, Y. and Sahibuddin, S. (2002). Physical image quality evaluation of medical radiographs. *Jurnal Fizik Malaysia*. **23**: 201-206.

Hendee, W. R. and Ritenour, R. E. (2002). Medical Imaging Physics. (4th. ed.) Wiley-Liss: New York.

Macovski, A. (1983). *Medical Imaging Systems*. Prentice Hall Inc: Upper Saddle River.

Morishita, J., Doi, K., Bollen, R., Bunch, P. C., Hoeschen, D., Sirand-rey, G. and Sukenobu, Y. (1995). Comparison of two methods for accurate measurement of modulation transfer functions of screen-film systems. Medical Physics. **22**: 193-200.

Nickoloff, E. L. and Riley, R. (1985). A simplified approach for modulation transfer function determinations in computed tomography. Medical Physics. **12**: 437.

Permal, R., (2008). *Calculation of Modulation Transfer Function of Screen-Film Systems Using MATLAB 7.04*. (1st. ed.) Research monograph (Universiti Teknologi Malaysia. Research Management Centre).

Pitman, G. P. (2009). Determination of the Contrast and Modulation Transfer Functions for High Resolution Imaging of Individual Atoms. Department of Physics. University of Toronto: Toronto, Ontario.

Prince, J. L. and Links, M. J. (2006). *Medical Imaging Signals and Systems*. Pearson Prentice Hall: USA.

Rossmann, K. (1964). Measurement of the Modulation Transfer Function of radiographic systems containing fluorescent screens. *Phys, Med. Biol*. **9(4)**: 551-557.

Salleh, K. A. M., Hassan, W. M. S. W. and Hamzah, Ab. R., (2010). Resolution and noise properties of CMOS and CR digital radiography systems. Jurnal Teknologi. **9**: 103-115.

Samei, E., Flynn, M. and Reimann, D. (1998). A method for measuring the presampled MTF of digital radiographic systems using an edge test device. Medical Physics. **25**: 102-113.

Yin, F., Giger, M. and Doi, K. (1990). Measurement of the presampling modulation transfer function of film digitizers using a curve fitting technique. Medical Physics. **17**: 962-966.