

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

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COMPUTATION OF X-RAY SYSTEM

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To my beloved mother and father
&
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 aluminium. 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 plumbum 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 $0 - 7\text{ kitaran/mm}$. Keputusan MTF peranti ujian plumbum bagi sistem konvensional dan sistem radiografi dikomputasi adalah serupa, walaupun sistem radiografi dikomputasi mempunyai MTF lebih tinggi untuk frekuensi ruang di antara 0 dan 2 kitaran/mm dengan turun naik kecil disebabkan oleh hingar yang kecil. Walau bagaimanapun, bagi $2 - 7\text{ kitaran/mm}$ 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 ($1\text{ dan }2\text{ darjah}$) adalah masing-masing 0.003 dan 0.004 . Hasil MTF terbaik telah diperoleh daripada imej sisi condong (2 darjah) dalam sistem FCR.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF SYMBOLS	xvi
	LIST OF ABBREVIATIONS	xviii
	LIST OF APPENDICES	xix
1	INTRODUCTION	1
	1.1 Background of Study	1
	1.2 Statement of Problems	3
	1.3 The Purpose of this Research	3
	1.4 Research Objectives	4
	1.5 Significance of Study	4
	1.6 Scope of Research	5

2	LITERATURE REVIEW	6
	2.1 Edge Image Acquisition	6
	2.2 Slanting Edge Method	8
	2.3 The concept of Resolution	12
	2.4 Modulation Transfer Function (MTF)	13
	2.5 The ESF and the LSF	16
3	RESEACH METHODOLOGY	19
	3.1 Introduction	19
	3.2 Edge Image Production	19
	3.3 Angle of Measurement	26
	3.4 ESF and LSF Computation	28
	3.5 MTF Computation	32
4	RESULTS AND DISCUSSION	34
	4.1 Determination of MTF	34
	4.1.1 Image 1 (0 degree)	35
	4.1.2 Image 1 (5 degrees)	36
	4.1.3 Combination of MTFs for Edge Image 1	39
	4.1.4 Image 2 (0 degree)	40
	4.1.5 Image 2 (7 degree)	42
	4.1.6 Combination of MTFs for Edge Image 2	43
	4.1.7 Image 3 (0 degree)	45
	4.1.8 Image 3 (6 degree)	47
	4.1.9 Combination of MTFs for Edge Image 3	48
	4.1.10 Image 4 (0 degree)	49
	4.1.11 Image 4 (5 degree)	51
	4.1.12 Combination of MTFs for Edge Image 4	53
	4.2 Discussion	55
	4.3 Comparison of MTFs	58

5	CONCLUSIONS AND PROPOSED FUTURE WORK	60
	5.1 Conclusions	60
	5.2 Future Work	61
	REFERENCES	62
	Appendices A - C	65 - 86

LIST OF TABLES

TABLE NO.	TITLE	PAGE
4.1	Comparison of the MTF values for a straight (0 degree) and slanted (2 and 5 degrees) of edge images from a 0.05 mm thick lead in the conventional radiography system	58
4.2	Comparison of the MTF values for a straight (0 degree) and slanted (1, 2 and 5 degrees) of edge images from a 1.08 mm thick lead in the computed radiography FCR system	59

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	The edge test device and its holder (Samei <i>et. al.</i> , 1998)	6
2.2	The schematic of the three-step alignment procedure for the edge device (Samei <i>et. al.</i> , 1998)	7
2.3	Orientation of edge relative to pixel matrix (schematically, edge angle exaggerated) (Buhr <i>et. al.</i> , 2003)	11
2.4	The modulation (M) of image intensity is defined as $M = (I_{max} - I_{min}) / (I_{max} + I_{min})$ (Bourne, 2010)	14
2.5	A typical MTF for a film-screen detector (Prince and Links, 2006)	15
2.6	The edge and line spread functions can be used to determine a direction-specific MTF	17
2.7	The Line spread function (LSF), and edge spread function (ESF) are shown isometrically (top) and in profile (bottom) (Bushberg <i>et al.</i> , 2002)	18
3.1	Flow chart of Edge algorithm steps	20
3.2	The experimental set up for the measurement and the arrangement of the screen-film (cassette), bar pattern test object, lead step, and lead mask on the rig (Hassan <i>et al.</i> , 2002)	21

3.3	The chest X-ray machine for the measurement and the arrangement of the imaging plate (IP cassette type CC), an edge test device which is placed close to the detector (photo was taken from UTM health centre).	22
3.4	The light beam diaphragm of a chest X-ray tube and the beam cone covers 3 cm away from each side of an edge test device (photo was taken from UTM health centre).	23
3.5	Edge images for a 0.05 mm thick lead taken from the conventional radiography system	24
3.6	Edge images for an 0.48 mm thick aluminum taken from the computed radiography FCR system	24
3.7	Edge images for an 1.2 mm thick aluminum taken from the computed radiography FCR system	25
3.8	Edge images for a 1.08 mm thick lead taken from the computed radiography FCR system	25
3.9	Edge detections	26
3.10	Angle determination by Radon transforms	27
3.11	Estimated edge angle which is about 2 degrees for one of the slanted edge image	28
3.12	Re-projection and binning of the two-dimensional edge image data into a one-dimensional trace perpendicular to the edge (Samei <i>et al.</i> , 1998)	29
3.13	Mapped and Sorted the Edge Spread Function (ESF) for a slanted edge image	30
3.14	Binned and smoothed the edge spread function (ESF) for a slanted edge image	32
3.15	Smoothed the line spread function (LSF) for a slanted edge image	33

4.1	The smoothed ESF of a straight edge image of 0.05 mm thick lead for the radiographic screen-film system.	35
4.2	The smoothed LSF of a straight edge image of 0.05 mm thick lead for the radiographic screen-film system	35
4.3	The MTF of a straight edge image of 0.05 mm thick lead for the radiographic screen-film system	36
4.4	The Smoothed ESF of a slanted edge image (5 degrees) of 0.05 mm thick lead for the radiographic screen-film system	36
4.5	The Smoothed LSF of a slanted edge image (5 degrees) of 0.05 mm thick lead for the radiographic screen-film system	37
4.6	The MTF of a slanted edge image (5 degrees) of 0.05 mm thick lead for the radiographic screen-film system	37
4.7	The MTF of a slanted edge image (2 degrees) of 0.05 mm thick lead for the radiographic screen-film system	38
4.8	MTF results of edge images (0 degree, 2 degrees and 5 degrees) of a 0.05 mm thick lead for the radiographic screen-film system	39
4.9	The Smoothed ESF of a straight edge image of 0.48 mm thick aluminium for the computed radiography FCR system	40
4.10	The Smoothed LSF of a straight edge image of 0.48 mm thick aluminium for the computed radiography FCR system	41
4.11	The MTF of a straight edge image of 0.48 mm thick aluminium for the computed radiography FCR system	41
4.12	The Smoothed ESF of a slanted edge image (7 degrees) of 0.48 mm thick aluminium for the computed radiography FCR system	42
4.13	The Smoothed LSF of a slanted edge image (7 degrees) of 0.48 mm thick aluminium for the computed radiography FCR system	42

4.14	The MTF of a slanted edge image (7 degrees) of 0.48 mm thick aluminium for the computed radiography FCR system	43
4.15	MTF results of edge images (0 degree and 7 degrees) of an 0.48 mm thick aluminium for the computed radiography FCR system	43
4.16	The fourth-order polynomial MTF results of edge images (0 degree and 7 degrees) of an 0.48 mm thick aluminium for the computed radiography FCR system	44
4.17	The Smoothed ESF of a straight edge image of 1.2 mm thick aluminium for the computed radiography FCR system	45
4.18	The Smoothed LSF of a straight edge image of 1.2 mm thick aluminium for the computed radiography FCR system	46
4.19	The MTF of a straight edge image of 1.2 mm thick aluminium for the computed radiography FCR system	46
4.20	The Smoothed ESF of a slanted edge image (6 degrees) of 1.2 mm thick aluminium for the computed radiography FCR system	47
4.21	The Smoothed LSF of a slanted edge image (6 degrees) of 1.2 mm thick aluminium for the computed radiography FCR system	47
4.22	The MTF of a slanted edge image (6 degrees) of 1.2 mm thick aluminium for the computed radiography FCR system	48
4.23	MTF results of both edge images (0 degree and 6 degrees) of an 1.2 mm thick aluminium for the computed radiography FCR system	48
4.24	The Smoothed ESF of a straight edge image of 1.08 mm thick lead for the computed radiography FCR system	49
4.25	The Smoothed LSF of a straight edge image of 1.08 mm thick lead for the computed radiography FCR system	50

4.26	The MTF of a straight edge image of 1.08 mm thick lead for the computed radiography FCR system	50
4.27	The Smoothed ESF of a slanted edge image (5 degrees) of 1.08 mm thick lead for the computed radiography FCR system	51
4.28	The Smoothed LSF of a slanted edge image (5 degrees) of 1.08 mm thick lead for the computed radiography FCR system	51
4.29	The MTF of a slanted edge image (5 degrees) of 1.08 mm thick lead for the computed radiography FCR system	52
4.30	The MTF of a slanted edge image (2 degrees) of 1.08 mm thick lead for the computed radiography FCR system	52
4.31	The MTF of a slanted edge image (1 degrees) of 1.08 mm thick lead for the computed radiography FCR system	53
4.32	MTF results of edge images (0 degree, 1 degree, 2 degrees and 5 degrees) of a 1.08 mm thick lead for the computed radiography FCR system	53
4.33	MTF results of edge images (0 degree, 1 degree, 2 degrees and 5 degrees) of a 1.08 mm thick lead for the computed radiography FCR system for spatial frequencies from 0 to 3 cycles/mm with the MTF ranges between 0.6 and 1.05	55

LIST OF SYMBOLS

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

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Numerical comparison of MTF values	65
B	MATLAB M-codes for angle determinations	72
C	MATLAB M-codes for computing the ESF, LSF and the MTF	76

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 devised 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 kVp, 1.6 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 kVp tube potential with 6 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.

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