

RESTORATION OF NEUTRON RADIOGRAPHY IMAGES

NOREHAN BINTI MOHD NOR

UNIVERSITI TEKNOLOGI MALAYSIA

ABSTRACT

Neutron radiographic images have been used in a wide variety of industrial research and non-destructive testing applications since the early 1960s. Image in any form was never an exact representation of the object under observation because it is always corrupted by the imaging system itself. Neutron radiography image also encounters the same problem. Digital image restoration of image degraded by blurring and random noise is a solution to the problem. This research will try to restore the neutron radiography images with several restoration methods. The proposed methods are Weiner filter, regularized filter, Lucy-Richardson algorithm and blind deconvolution. All of the techniques were implemented using MATLAB programming to facilitate the demonstration of the effect of the methods. The result obtained will be analyzed and compared. It is shown that all the proposed methods can be used for restoration of neutron radiography images. The best and effective result for neutron radiography are by using Weiner filter with autocorrelation function and Lucy-Richardson (LR) algorithm with 500 iterations compared to other methods.

ABSTRAK

Imej dari radiografi neutron telah digunakan secara meluas sejak awal tahun 1960 dalam penyelidikan industri dan dalam ujian tanpa musnah. Sebarang imej yang terhasil selalunya tidak mempamerkan objek sebenar yang diperhatikan kerana kebiasaannya ia telah mengalami kerosakan akibat sistem pengimejan itu sendiri. Hal ini juga merupakan masalah yang dihadapi oleh imej yang terhasil dari kaedah radiografi neutron. Kekaburan dan juga hingar merupakan antara penyumbang kepada kerosakan imej ini. Oleh itu, untuk mengatasi masalah ini pemulihan imej perlu dilakukan. Kajian ini dilakukan bertujuan untuk mengkaji beberapa kaedah pemulihan imej yang boleh digunakan untuk imej radiografi neutron. Kaedah pemulihan yang dimaksudkan adalah penapis Wiener, *regularized filter*, *Lucy-Richardson algorithm* dan *blind deconvolution*. Kesemua kaedah ini dilaksanakan menggunakan perisian MATLAB untuk mempamerkan kesan daripada proses pemulihan imej itu. Hasil yang didapati akan dianalisis dan perbandingan antara kaedah pemulihan akan dibuat untuk mengenalpasti kaedah yang terbaik. Daripada keputusan yang didapati, kesemua kaedah pemulihan imej yang dicadangkan boleh digunakan untuk pemulihan imej radiografi neutron. Dari perbandingan yang dibuat, didapati kaedah penapis Wiener dengan fungsi autokorelasi dan kaedah Lucy-Richardson dengan ulangan sebanyak 500 kali adalah kaedah yang terbaik jika dibandingkan dengan kaedah lain kerana ia menghasilkan imej yang lebih baik.

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LIST OF SYMBOLS

A	-	Target mass number
C	-	Minimum of criterion function
D_e	-	Photographic density
E	-	Exposure of the film
E_t	-	Inelastic threshold
$f(x,y)$	-	Input image
$\hat{f}(x,y)$	-	Estimate of the original image
G	-	Slope in the linear portion of the characteristic response curve for the film
G_{offset}	-	Dark current
$g(x,y)$	-	Degraded image
H	-	Matrix
H	-	Degradation function
$H(u,v)$	-	Optical transfer function
$H^*(u,v)$	-	Complex conjugate of $H(u,v)$
$h(x,y)$	-	Spatial representation of the degradation function
I, ϕ	-	Transmitted intensity
I_o, ϕ_o	-	Incident intensity
N	-	Number of atoms per cubic centimeter
$P(u,v)$	-	Fourier transform of the function
$S_\eta(u,v)$	-	Power spectrum of the noise
$S_f(u,v)$	-	Power spectrum of the undegraded image
t	-	Thickness of specimen in the beam path
Σ_a	-	Macroscopic absorption cross section
Σ_i	-	Total macroscopic cross section

ε_1	-	Energy of the nucleus first excited state
$\eta(x,y)$	-	Noise term
σ	-	Neutron cross section of the particular material or isotope
σ	-	Standard deviation
μ_n	-	Linear attenuation coefficient for neutrons
μ_x	-	Linear attenuation coefficient for photons
*	-	convolution
∇^2	-	Laplacian operator

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CHAPTER 1

INTRODUCTION

1.1 Preview

Neutrons were discovered as independent particle in 1932 by Chadwick. The history of neutron radiography begins in 1935 when Professor Hartmut Kallman whose publication in 1948 and early joint patents with Kuhn 1937 outlined the basic principles of neutron radiography [1]. The original Kallman work was performed with a small accelerator that is equivalent to about 2-3 g of a modern radium-beryllium source. The fast neutron yield would have been about 4×10^7 neutrons per second which would yield a low intensity thermal neutron beam after moderation and collimation.

At about the same time the investigation done by Kallman and Kuhn, similar studies were being conducted by Peter, also in Germany [1]. Peter had the advantage of a much more intense neutron source, namely an accelerator, whose output was roughly equivalent to a 10 kg radium-beryllium neutron source. The exposure time to obtain neutron radiograph by Peter are faster which is in the order of 1-3 minutes compared with days in previous work

Because of the Second World War, further development of neutron radiography did not occur until the mid-1950s when nuclear reactors were developed as prolific sources of neutrons [2]. Indeed, Peter had to wait until 1946 to publish his results and Kallmann and Kuhn until 1948. The next major development programme in neutron radiography was mounted at the Argonne National Laboratory under the control of Berger [1]. In 1966 work on neutron radiography commenced at the UK Atomic Energy Authority's Dounreay Experimental Reactor Establishment, and in 1969 work was also recommenced at the Atomic Energy Authority Research Establishment at Harwell. Since that date many laboratories all over the world have become actively interested in neutron radiography.

The first neutron radiographs produced were not in a high quality, but it gives valuable information about neutron sources and image detection methods. This is because the early research work on neutron radiography was concentrated on developing the techniques and delineating the useful application areas of the technique while laboring under the disadvantage of very low output neutron sources. Subsequent improvements in technology have made neutron radiography a useful tool for inspecting materials and devices containing elements such as hydrogen, beryllium, lithium, and boron. It was especially useful for inspecting electronic and explosive devices having nonmetallic materials contained in a metal jacket.

Neutron radiography, like conventional X-ray radiography, uses a form of penetrating radiation to nondestructively assess the physical integrity of selected materials and structures. The radiographic image is essentially a two-dimensional shadow display or picture of the intensity distribution of thermal neutrons that have passed through a material object. Although both types of radiography are similar in many ways, attenuation characteristics of the two types of energy are not only different but are sometimes opposite in nature. The total neutron cross section is the criterion for utilizing neutron radiography, whereas density and atomic number are the parameters of concern when testing with X-rays. Consequently, one method cannot replace the other in fact they complement each other [3]. Neutron radiography complements conventional X-ray radiography and gamma radiography

by having the capability of detecting flaws and material conditions in structures and devices that cannot be effectively assessed with other methods.

The unique capability of neutrons is due to the fact that they do not interact with orbiting electrons in the atoms of materials being tested. This property allows them to travel rather freely through materials until there are in direct collisions with atomic nuclei. The nuclei of some nonmetallic materials attenuate neutrons more than those of dense materials such as iron. This allows imaging of low density ordnance devices encased in high density metallic materials. Other unique capabilities of neutron radiography are to assess the flow of lubricant and fuel in aircraft and automobile engines during test operations and also radiographed the burning propellant inside the steel rifle barrels or rocket motors.

Neutron radiography does have some disadvantages. These include the fact that practical neutron sources and shielding materials are large and heavy, and adequate sources are expensive. Relatively long exposure times are required for the smaller, low-yield neutron sources. More complex film exposure procedures are required for neutron radiography than for X-ray radiography, and low-level radioactivity of cassettes and transfer screens causes some issue for personnel safety [3].

1.2 Background of Research

Images made with neutrons have been widely used in industrial research and non-destructive testing applications since the early 1960s [4]. General applications for neutron radiography include inspections of nuclear materials, explosive devices, turbine blades, electronic packages and miscellaneous assemblies including aerospace structure (metallic honeycomb and composite components), valves and other assemblies. Industrial applications generally involve the detection of a particular material in an assembly containing two or more materials. Examples include detection of residual ceramic core in an investment-cast turbine blade, corrosion in a metallic assembly, water in honeycomb, explosive in a metallic assembly or a rubber 'O ring' in a valve. Nuclear applications depend on the capability of neutron radiography to yield good, low background radiographs of highly radioactive material, to penetrate fairly heavy assemblies and to discriminate between isotopes [5].

In neutron radiography, there are several components tend to degrade the image, limiting the resolution of neutron radiography. The image degraded sources in neutron radiography are geometric unsharpness associated with lack of collimation in the beam, statistical fluctuation associated with low neutron beam intensities or gamma ray background, scattering degradation caused by scattering of neutrons which deflects the beam, motion unsharpness due to object motion during the exposure, and limitations in the imaging and processing systems, such as converter-film unsharpness and electrical noise [6].

In neutron radiography, corrupted images often pose problem for analysis and detection of the object being observed. To overcome this problem, restoration process was used to reduce the blurring and noise effects on the image. Restoration was one of the areas in image processing techniques that have emerged as an important multi-disciplinary field with applications in widely variety of area [7].

1.3 Scope of the Research

The restoration of digital images degraded by blurring and random noise is of interest in many fields such as radar imaging, bio-medicine, industrial radiography, seismology and consumer photography. This research was limited to the neutron radiography images. The image from the neutron radiography will be restored using Wiener filter, regularized filter, Lucy-Richardson algorithm and blind deconvolution. All of this technique was implemented using MATLAB software version 7.0.0.19920 (R14) to facilitate demonstration of the result from the proposed restoration methods.

1.4 Objective

The objectives of the research are as follow:

- 1) To study the restoration techniques using MATLAB so it can improve the quality of neutron radiography image.
- 2) To analyze the effect of digital image restoration techniques to the neutron radiography images.
- 3) Comparison of restored neutron radiography image produced by different restoration methods.

1.5 Literature Review

The restoration of digital images degraded by blurring and random noise was become interest in many field such as aerial and radar imaging, biomedicine, industrial radiography, seismology, and consumer photography [7]. There are many restoration methods for image processing but in this study it's limited to Wiener filter, Lucy-Richardson filter, blind deconvolution and regularized filter.

Restoration of image using Wiener filter give impact to image processing field. In 1989 Guan and Ward [8] publish a paper on restoring blurred images by the Wiener filter. In this paper, the restoration of images distorted by systems with noisy point spread functions and additive detection noise is considered. Computation was carried out in the frequency domain using the fast Fourier transform (FFT) and circulant matrix approximation. Experimental results in this study show that the modified Wiener filter outperforms its linear counterpart (based on neglecting the impulse-response noise). The modified Wiener filter also gives better restoration results than a Backus-Gilbert technique.

Restoration using regularized method is also of interest to researcher in image processing field. Mesarovic *et al.* [9] in their paper on regularized constrained total least squares (RCTLS) image restoration found that this technique reduces significantly ringing artifacts around edges. Additionally, the problem of restoring an image distorted by a linear space-invariant point-spread function that is not exactly known is formulated as the solution of a perturbed set of linear equations. The RCTLS method is used to solve this set of equations.

Blind deconvolution technique was another restoration method in the image processing field. The objective of the blind image restoration is to reconstruct the original image from a degraded observation without the knowledge of either the true image or the degradation process. A detailed description of the blind deconvolution

methods can be found in journal article by Kundur and Hatzinakos [10]. In this paper, they present a novel blind deconvolution technique for the restoration of linearly degraded images without explicit knowledge of either the original image or the point spread function. The technique applies to situations in which the scene consists of a finite support object against a uniformly black, gray, or white background. According to them, this occurs in certain types of astronomical imaging, medical imaging, and one-dimensional (1-D) gamma ray spectra processing, among others. In this study, they prove that convexity of the cost function, establish sufficient conditions to guarantee a unique solution, and examine the performance of the technique in the presence of noise. The new approach was experimentally shown to be more reliable and to have faster convergence than existing nonparametric finite support blind deconvolution methods. For situations in which the exact object support is unknown, they propose a novel support finding algorithm.

Jin Wei [11] in his study found an effective image restoration method for neutron radiography image. This study applies a combination of two methods which is dual-tree complex wavelet transform (DT-CWT) to suppress noise and Lucy-Richardson (L-R) algorithm to deconvolution. Results obtain in this study is compared with the result of original L-R algorithm (without denoising step) in order to illustrate the effectiveness of the proposed scheme. The result shows that the combination of these two methods gives nearly perfect reconstruction.

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