

Industrial Gamma Tomography Scans Based On Radiotracer Data Acquisition System

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Abstract: This research used radiotracer data acquisition system to get a clear image for a certain part in an object, using the cross-section principle. According to the principle, the source and the detector are rotated in different angles so as to take the information from the detector for every angle, and then this information is sent to computer for analysis and reconstruction of the final image. The readout from the detector in every angle is called projection. Multichannel analyzer is used to receive the projections from the detectors then sent to the computer using the RS-232 connector. A MAT LAB program is used to reconstruct the image from its projections.

Keywords: Colour X-Ray.

1. Introduction

X-ray imaging has applications in both medicine and industry. To produce an x-ray image in medical application, the X-rays pass from the source through the object and are detected by a film or an ionization chamber on the opposite side of that object [1]. The history of cross sectional imaging is in many ways a history of radiology in microcosm. Explorations into the theory of analog tomography began shortly after the turn of the century, and devices to actually produce tomograms were constructed in the 1930's. In the same decade work was initiated on the possible clinical applications of ultrasound and radioisotopes. This work came to fruition in the 1950's and 60's as the disciplines of ultrasonography and nuclear medicine became established as substantive contributors to clinical medicine. A major advance in diagnostic imaging occurred in the early 1970's with the introduction of computed tomography. This technology made cross sectional imaging with x rays a reality, and greatly enhanced the ability of the physician to see abnormalities in a variety of body structures, especially the brain and spinal cord. Then, the early 1980's witnessed magnetic resonance imaging, a second major advance in cross sectional imaging. Many researchers believe that the potential of this method has been explored only superficially so far, and that ultimately magnetic resonance will be acknowledged as the most important development in medical diagnosis since the discovery of x rays [7]. Cross section imaging is basically taking images of the object in different angles (every one of them calls projection) by rotating the source and the detector while the object is fixed, so the object can be in the cross of the motions of the source in different angles. The data input to the reconstruction process consists of a Set of images of the object obtained from various angles around a central axis passing through the object [4]. For many applications, image reconstruction from projections may be posed as a statistical estimation problem in which the object is estimated from noisy observed data [5].

2. Cross-Section Imaging

While X-rays cannot be focused in the same manner as light, focusing can be simulated through the relative motion of the x-ray and the recording medium [1].

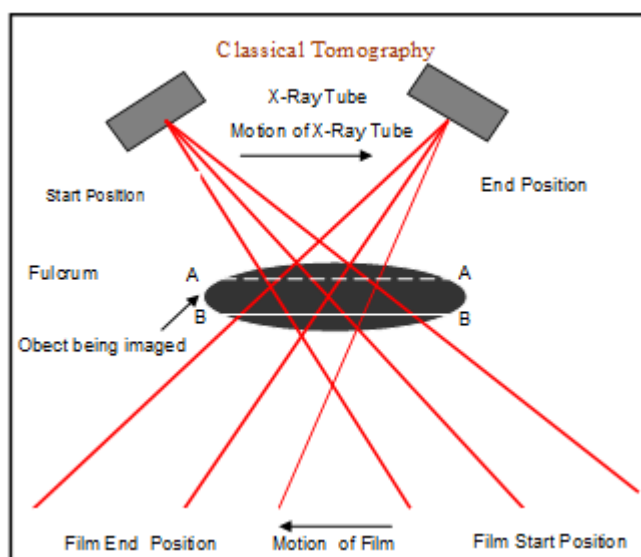


Figure 1: Classical tomography

Classical longitudinal tomography used this principle. By moving the X-ray tube and the film such that the central ray from the tube passes through a single point in the image-plane (fulcrum plane), information from the fulcrum plane (A—A) would be imaged sharply on the film, but data from other planes (B—B) would be blurred. Thus although the desired plane was imaged sharply, it was overlaid with extraneous information that often obscured the important detail in the fulcrum plane [1].

3. X-ray radiation vs. Gamma radiation

X-radiation and gamma radiation are both part of the electromagnetic radiation spectrum, which also includes

radio waves, and infrared, visible and UV light. As it known that, matter is made up of atoms; electromagnetic radiation is 'made up' of photons. The difference between the various components of electromagnetic radiation, e.g. radio waves, visible light and gamma radiation, is only their wavelength, and the shorter the wavelength, the higher the energy level. The energy associated with gamma radiation and X-radiation is high enough to break atomic and molecular bonds (that is, to ionize atoms), producing changes in matter including living cells. This high-energy end of the spectrum is referred to as 'ionizing radiation' [11].

The above mentioned comparison shows that, the only difference between Gamma-ray and X-ray is the energy level. Accordingly, both types may have interchangeable usage, this justify the assumption presented by this paper.

4. Methodology

In this research, a stepper motor is used to rotate the source and the detector while the image plane remains fix.

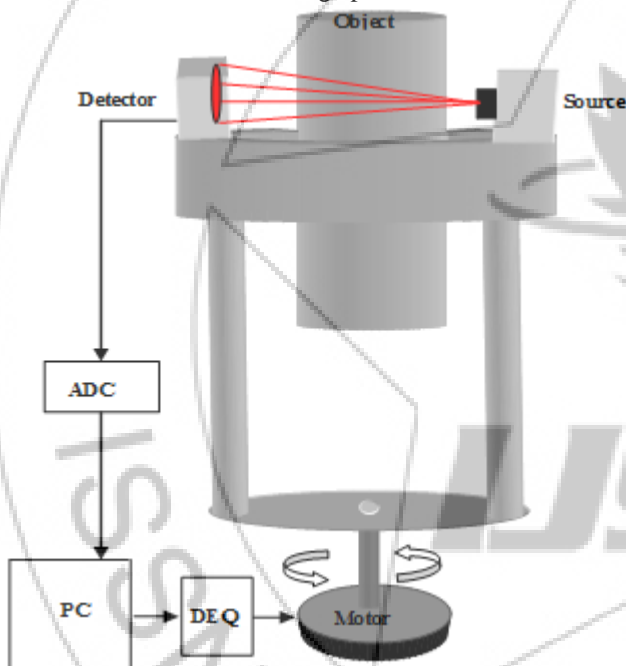


Figure 2: system tomography

The stepper motor is controlled by a computer program (LAB VIEW), the computer is also used to gather the projections and reconstruct the images using MATLAB.

A serial communication is used to link the detector and the computer (MATLAB program), and a national instrument device to provide the communication between the computer (LABVIEW) and the motor.

4.1 Stepper Motor

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses.

The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied [8]. A stepper motor unipolar type - 5 degree every step – 5volt is used.

4.2 Lab view

LABVIEW is a programming language developed by National Instruments, and designed to facilitate communication between different types of hardware, such as personal computers, function generators, A/D converters, et cetera. It has a graphical way of depicting pieces of code, instead of being text-based [9].

LABVIEW is used to write a piece of program to control the motor movement; this program is used in sending pulses in a certain order to move the motor in the desired way (Stops every 60 degree for 5 seconds to get the projection). The pulses are passed to the motor from the computer through a national instrument device; this device receives the digital pulses from the program and transforms it to electrical pulses (5 volts) in order to move the motor.

4.3 Analog to digital converter (ADC)

Analogue-to-Digital Converters (ADCs) transform an analogue voltage to a binary number (a series of 1's and 0's), and then eventually to a digital number (base 10) for a reading on a meter, a monitor, or a chart. The number of binary digits (bits) that represents the digital number determines the ADC resolution. However, the digital number is only an approximation of the true value of the analogue voltage at a particular instant because the voltage can only be represented (digitally) in discrete steps. How closely the digital number approximates the analogue value also depends on the ADC resolution [10].

4.4 Multichannel analyzer

A multichannel analyser is used to process the data from the detector so as to convert it to a digital data that can be saved as a text file and to provide a serial communication between the detector and the computer through rs-2003 connector and method.

Multichannel analyzer is succession of single channel analyses whose windows are all the same width and are arranged sequentially .in order to increase energy [2]. In actual (MCA) the single channel analyzers are replaced by a single device called an analog to digital converter device [2]. The (ADC) measures the height of each pulse as it's comes in and determines to witch (SCA) the pulse corresponds [2].

4.5 Ludlum Model 4612 IAEA Counter

The Ludlum Model 4612 IAEA Counter is a twelve detector SCA (single channel analyzer) with PC control of all necessary operating parameters. Up to twelve detectors may be connected to the Counter each with independent high voltage, threshold or sensitivity, and window settings [3].

The Counter is configured with a host board and up to 12 slave boards. The host board collects the counts from each slave board and communicates with the computer. The host board has an RS-232 connector for communicating with a computer or other device capable of serial communication, a power connector, and a reset button. The reset button performs the same function as cycling the power. The slave boards are responsible of powering the detector and sending the count data to the host board [3]. After power-up the Counter will begin sending a 50 byte data message every 50 milliseconds. This message contains the count data for each channel and the status of each channel. The message is terminated with a carriage return and line feed character. The count data is the number of counts received in the previous 50 milliseconds. The count for each channel is stored in 3 bytes [3]. To convert the bytes into the count, multiply each byte as follows:

$$(\text{Byte 1} * 65536) + (\text{Byte 2} * 256) + \text{Byte 3}$$

The data is collected from the sensors in the x-ray detectors in every angle. Data is then sent to the computer using the rs-232 connection. Every angle enters the multichannel analyzer in a different channel; the multichannel analyzer sends them to the pc one by one based on the active channel.

4.6 RS-232

The rs-232 is to link between the multichannel analyser and the computer .and it is transforms the data in a serial fashion to the computer.

5. Image reconstruction

5.1 Taking projections

As shown in figure (1), By moving the gamma-ray tube and the film such that the central ray from the tube passes through a single point in the image-plane (fulcrum plane), information from the fulcrum plane (A—A) would be imaged sharply on the film, but data from other planes (B—B) would be blurred. Thus although the desired plane was imaged sharply, it was overlaid with extraneous information that often obscured the important detail in the fulcrum plane [1].

This image appearance is simulated in MATLAB, as a result of the movement of the gamma-ray tube, the projection in any angle affected by the projections of all the previous angles.

A fan-beam function in MATLAB was used to simulate the projections taking from a sample image in different angles (the more the angles the more accurate the reconstructed image of the object).

The fan-beam function computes *projections* of an image matrix along specified directions. A projection of a two-dimensional function $f(x,y)$ is a set of line integrals. The fan-beam function computes the line integrals along paths that radiate from a single source, forming a fan shape. To represent an image, the fan-beam function takes multiple

projections of the image from different angles by rotating the source around the center of the image. As arguments an image and the distance between the vertex of the fan-beam projections and the center of rotation (the center pixel in the image) is specified. The fan-beam function determines the number of beams, based on the size of the image and the settings of fan-beam parameters (Fan Sensor Geometry, Fan Sensor Spacing and Fan Rotation Increment) [6].

The algorithm depends on the Radon transform, interpolated to the fan-beam geometry. The results vary depending on the parameters used [6]. In general, the Radon transform of $(f(x, y))$ is the line integral of (f) parallel to the y' -axis:

$$R_{\theta}(x') = \int_{-\infty}^{\infty} [f(x', y') \cos \theta - y' \sin \theta, x' \sin \theta + y' \cos \theta] dy'$$

Where:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$F = \text{fan beam}(I, D)$ computes the fan-beam data (sonogram) F from the image I . A sonogram is a special x-ray procedure that is done with contrast media (x-ray dye) to visualize any abnormal opening (sinus) in the body [6].

D is the distance in pixels from the fan-beam vertex to the center of rotation. The center of rotation is the center pixel of the image calculated as follows [6]:

$$\text{sqrt}(\text{size}(I, 1)^2 + \text{size}(I, 2)^2)$$

The fan-beam function calculate the projection at every angle, and to simulate the blurriness accords as a result of the movement of the gamma-ray tube, every projection was added to the projection of the previous angles.

5.2 Reconstruct the image

By knowing the size of the film that receives the projections, the data received from the serial board can be organized in MATLAB in a matrix form (x, y) , the columns contain the projections every projection in a different column. The number of the columns is the number of the angles (and the number of the projections) and the size of every column (the number of the rows) is the size of the film. IFANBEAM function is used to reconstruct an image from fan-beam projection data. The projection data, the angles and the distance between the vertex of the fan-beam projections and the center of rotation when the projection data was created are specified. The ifanbeam function converts the fan-beam projection data to parallel-beam projection data with the fan2para function, and then calls the iradon function to perform the image reconstruction [6]. iradon uses the filtered back projection algorithm to compute the inverse Radon transform. This algorithm forms an approximation of the image I based on the projections in the columns of R . A more accurate result can be obtained by using more projections in the reconstruction. The filtered back projection algorithm filters the projections in R and then reconstructs the image using the filtered projections [6].

6. Measurement Results

The following figure 3 shows the projections data calculated and the reconstructed image, using three different rotation angles. All projections were calculated using fanbeam arc geometry, and 0.25 degree for the angular spacing of the beams, the distance between the center of rotation and vertex of the projections is constant at 250 pixels and the projections were calculated around the center pixel at three different angle increments (rotation angles). a is the test image, b is a plot of the projection data calculated at 1 degree increment angle and the reconstructed image, c is a plot of the projections data calculated at 6 degree increment angle and the reconstructed image, d is a plot of the projections data calculated at 10 degree increment angle and the reconstructed image.

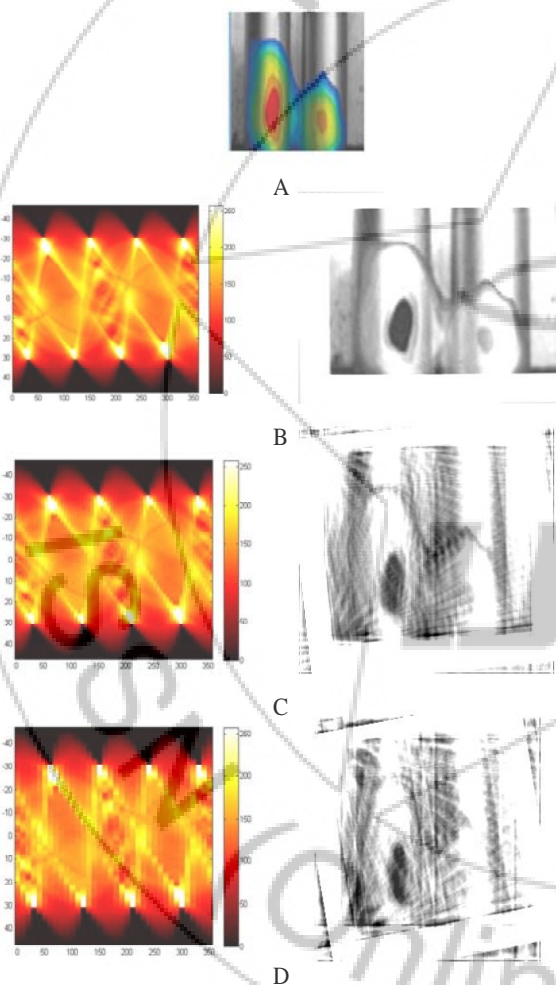


Figure 3:

7. Conclusion

This research resolves the problem of receiving the data from the detector in more than direction in one column since reordering the data in MATLAB is an easy process; Also MATLAB program provides a simple way to reconstruct the projections. As it has been mentioned this research solves two of the biggest problems can face us in gamma tomography method and cross sectional imaging. Manly the computer is used to control the motor and to process and

reconstruct the image (object) projection. Next step should be focused on improving the reconstruction method to provide better reconstructed image with less angles and less gamma beams.

References

- [1] Ct-image reconstruction", Terry Peters Roberts Research Institute - London Canada
- [2] Multichannel analyzer (MCA) (EG&G ORTEC ADCAM).
- [3] Ludlum Model 4612 IAEA (12 Channel Counter)Ludlum Measurements
- [4] David B. Kay, John W. Keyes Jr, William Simon, "Dionuclide Tomographic Image Reconstruction usnig Fourier Transform Techniques", University of Rochester, Rochester, New York
- [5] Anand Rangarajan , and Gene Gindi, "Joint-MAP Bayesian Tomographic Reconstruction with a Gamma-Mixture Prior Ing-Tsung Hsiao" , Matlab help.
- [6] Cross Sectional Medical Imaging(A History), Wiiiiam R. Hendee, Ph.D. Science and Technology Group American Medical Association, Chicago, IL 60610
- [7] Industrial Circuits Application Note (Stepper Motor Basics) www.solarbotics.net/library/pdflib/pdf/motor
- [8] LABVIEW Course , Leiden University
- [9] analog to digital conversion, Measurement computing
- [10] Kishor Mehta, " X-ray radiation vs. Gamma radiation" Ph.D., U of MD, Atomic Energy of Canada (Ret.), I.A.E.A. (Ret.).
- [11] Industrial Process Gamma Tomography International atomic energy agency 2008 (Industrial Applications and Chemistry Section International Atomic Energy Agency

Author Profile



Maha Abdelaziz received the B.S. degrees in Electrical and Electronics Engineering from Omdurman Islamic University in 2011, respectively. During 2011-2013, she stayed at Atomic Energy Commission of Sudan, Instrumentation Center working as a cooperating Electronics Engineer and a researcher assistant. Between March and May of 2014 she worked in Omdurman Islamic university as a cooperating teacher assistant.



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