VALIDATION OF GAMMA CAMERA DESIGN BY USING GATE

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I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering (Computer Engineering) with Honours.

Signature : …….

Supervisor's Name : DR. WIRA HIDAYAT BIN MOHD SAAD

Date : …….

This thesis is dedicated to my beloved family...

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ABSTRACT

This project present the result of the simulation of gamma camera brand Toshiba model GCA-7100A by using GATE software. The aim for this project is to design the gamma camera simulation with the variation of radioactivity and the distance between collimator and point source. The material used for the collimator is tungsten instead of lead and other heavy materials. As for back compartment, the material used is pyrex slab. The materials are chose based on the materials used for the real gamma camera. For the nuclear radioactivity, Technetium-99m is used as it is proven to be good medical radioisotope. The result obtained shows that as the distance between collimator and point source increases, the result image become blurrer. The project continues with the analysis of the FWHM from the obtained result. It is found that the image become blur due to the increment of the size of the FWHM. The best distance is 10cm from point source to the collimator. This project also analyze the relationship between the radioactivity and the photon counts, as the radioactivity increases, the photon counts also increase.

ABSTRAK

Projek ini memaparkan keputusan simulasi kamera gamma jenama Toshiba model GCA-7100A dengan menggunakan perisian GATE. Tujuan projek ini adalah untuk mereka bentuk simulasi kamera gamma dengan perubahan nilai radioaktif dan jarak antara collimator dan titik sumber. Bahan yang digunakan untuk mencipta collimator ialah tungsten bukan plumbum atau bahan-bahan berat yang lain. Bagi petak belakang, bahan yang digunakan adalah papak Pyrex. Bahan-bahan ini dipilih berdasarkan bahan yang digunakan untuk kamera gamma yang sebenar. Untuk radioactiviti nuklear, technetium-99m digunakan kerana sudah terbukti ia merupakan radioisotop perubatan yang baik. Keputusan yang diperolehi menunjukkan bahawa jarak di antara collimator dan titik sumber bertambah, imej hasilnya menjadi semakin kabur. Projek ini diteruskan dengan menganalisis FWHM dari keputusan yang diperolehi. Ia didapati bahawa imej menjadi kabur disebabkan oleh kenaikan saiz FWHM. Jarak yang terbaik ialah 10cm dari titik sumber dengan collimator. Projek ini juga menganalisis hubungan antara radioaktif dan tuduhan foton, sekiranya berlaku peningkatan radioactiviti, kiraan foton juga meningkat.

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LIST OF ABBREVIATIONS

GATE	Geant4 Application for Topography Emission
MRI	Magnetic Resonance Imaging
SPECT	Single-photon Emission Computerized Tomography
PET	Positron Emission Tomography
MCNP5	Monte Carlo N-Particles 5
PMT	Photomultiplier Tube
NAI	Sodium Iodide
FWHM	Full Wave Half Maximum

LIST OF SYMBOLS

KeV	Energy in Kilo
.Sin	Sinogram file
^{99m}Tc	Technetium-99
Bq	Becquerel

CHAPTER 1

INTRODUCTION

This chapter elucidate the introduction of the study. It is divided into six section which are background, problem statement, aim and objectives, scope and limitation, thesis contribution and organization of the thesis.

1.1 Background

1.1.1 Validation Process

Validation is a process by which a procedure is evaluated to determine its efficiency and reliability. The data from the process design throughout the production is collected and evaluated, which established scientific evidence that a product or process is capable of consistently delivering quality results. The effective validation process contributes significantly to assuring product quality.

Validation process involves a series of activities taking place over the lifecycle of the products and process. There are two important stages of the validation process which are design validation and qualification validation. In the design validation stage, the design of the products is defined based on knowledge gained from the development and scale up activities. In the second stage which is qualification validation, the design is evaluated to determine if the products is capable of reproduce the approximately same results.

Validity is the most important consideration in developing and evaluating selection procedures. In order to provide a scientific basis for the proposed score interpretations, validation requires the gathering of evidence. However, the most important purpose of the validation process are quality, safety and effectiveness of the products.

To support the proposed uses, sufficient validity evidence that is already exists is an important consideration in a lot of validation efforts. Validation effort is design by taking the relevance and availability of existing evidence and the potential information value of new evidence into consideration. All validity conclusions are conclude from the results in the validation process.

1.1.2 Modalities for Nuclear Imaging Technique

There are several imaging techniques that have been developed by the researcher to detect the presence of abnormal cells in human body.

1.1.2.1.1 Magnetic Resonance Imaging

Magnetic Resonance Imaging or MRI is one of the medical imaging that uses magnetism, radio waves and a computer to produce images of body structures. The MRI scanner is a tube surround by a giant circular magnet. The patient is placed on the movable bed and insert into the magnet. A strong magnetic field that create by the magnet inside MRI aligns the protons of hydrogen atoms, which are then exposed to a beam of radio waves.this will make the MRI produce a signal. The signal information is processed by a computer, and an image is produced. However, it is low in specificity, which leads to the false-positive detection. Figure 1 is shows an image of MRI scanner.

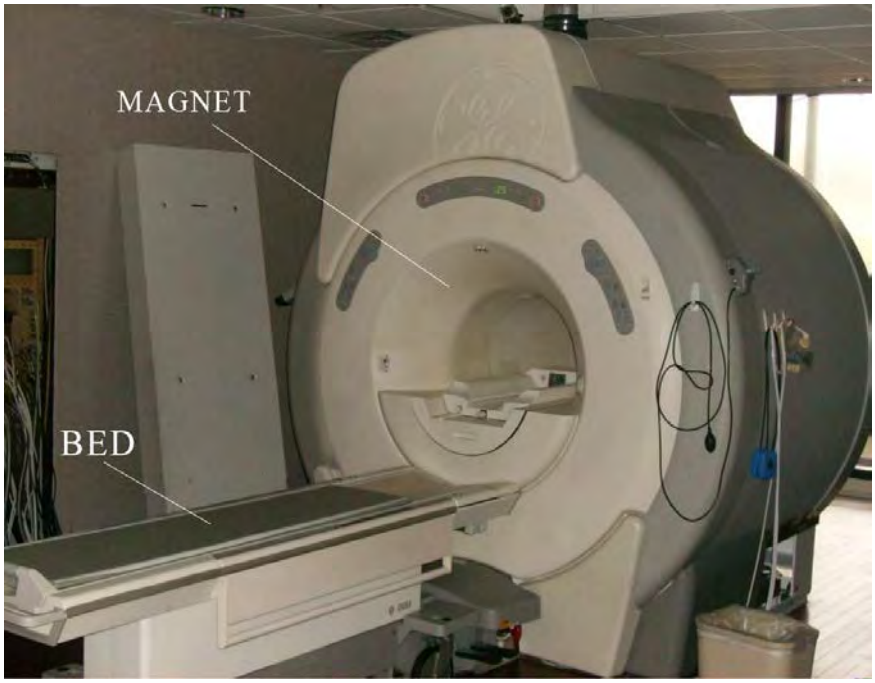

Figure 1.1 : Magnetic Resonance Imaging machine

1.1.2.1.2 Nuclear Imaging

Nuclear imaging is the best option for detecting the malignant growth in the body. This is because the mechanism of the nuclear imaging is a functional type imaging. The examples of nuclear imaging are gamma camera, single photons emission computed tomography (SPECT) and positron emission tomography (PET) scanner.

SPECT scanner consists of several fundamental components which are detectors, energy resolution, and collimator. There are several types of detector include scintillation cameras, solid-state, pixilated scintillation crystals, and semiconductor detectors. The image quality of the SPECT imaging is depends on the energy. The energy need to be adjusted to be use with technetium. The collimator is the most important component of the SPECT system for determining the image quality. The width and depth of the collimator septa control the resolution and sensitivity.

PET scanner is one of the types of nuclear imaging, there are two aspects that make it difference from SPECT which are radio-tracer required and the method of photo

detection and mapping. PET using positron emitter such as Flourin-18 to emit the coincident photons whiles the SPECT using single photon emitter such as Technetium-99. SPECT have several limitations compare to PET. The limitations are SPECT have low sensitivity, and low resolution but SPECT is widely use because SPECT is cheaper than PET and half-life of the radionuclides used with SPECT is longer than PET.

Gamma camera is planar imaging type scanner. Unlike SPECT or PET, the image captured by gamma camera is in 2D image form. However, the only difference between gamma camera and SPECT is the head of SPECT camera has the ability to rotate 360 degrees around the sources and capture photon from different angle to form a 3D image, while the head of gamma camera static at one place.

1.1.3 Simulation Program

A simulation program is use to simulate particles such as photon and gamma rays. The most common program that been use to simulate particles are Monte Carlo N-Particles 5 (MCNP5). The MCNP5 is paid software which is distributed only to researchers and it is not easy for someone to obtain the program. There is one open source software that have been developed by the European Organization of Nuclear Research (CERN) which known as GEANT4[1]. GEANT4 capable of simulate almost all type of particles and its abilities is on par with MCNP5. The only difference between GEANT4 and MCNP5 is its user interface. MCNP5 has its own user interface meanwhile the user interface for GEANT4 need to be built from the command prompt.

1.2 Problem Statement

Gamma camera is not popular among doctors compare to MRI scanner, SPECT scanner and so on. In Malaysia, the availability of gamma camera is very limited due to its expensive price and the demand is low. Other than that, the development of nuclear technology in Malaysia is very slow compare to other countries such as USA, France, and so on.

Because of the limitation of gamma camera and nuclear technology in Malaysia. It is not possible to do the research on the real gamma camera. Besides that, two important aspects that need consideration are the safety and awareness because the gamma camera is related to nuclear particles which is gamma rays.

The simulation program is the best option in order to validate the gamma camera. Moreover, the parameters of gamma camera model such as thickness of collimator, distance between source and the camera can be change easily by using simulation program as the parameter of the real gamma camera is fixed.

There are three types of software that been known can simulate the gamma camera which are MCNP5, GEANT4, and GATE. However, due to expensive price and the gamma camera for this model had been simulated before by using MCNP5 software, the only option are to use the open source software whether GEANT4 or GATE software. GATE is an abbreviation for GEANT4 Application for Topography Emission which has the GEANT4 framework embedded into it. The GATE software is used because it is focusing on the nuclear imaging compare to GEANT4 software.

1.3 Aim And Objective Of Research

The aim of this project is to design the gamma camera brand Toshiba model GCA-7100A simulation using GATE and analyses and validate the results. In order to achieve that, the objectives have been set for this research. The objectives are:

- To build the particle simulator environment system using GATE package.
- To design the gamma camera brand Toshiba model GCA-7100A simulation by using GATE particle simulation.
- To analyses and validate the result of the simulation.

1.4 Scope And Limitation

This research is conducted in GATE simulation environment. The gamma camera simulation is designed by using GATE programming code based on gamma camera brand Toshiba model GCA-7100A. There are several reasons this gamma camera model has been used as a benchmark. The reasons are this model is a common planar gamma camera that is widely used in medical field. It is also use a normal collimator which is a multihole collimator. Moreover, it has been simulated in MCNP5 environment in the previous study make it easier to be validate.

The collimator used in this study is a multihole collimator. This type of collimator is a most common use collimator in gamma camera. This study focuses on the different distance between the point source and the collimator. Other important scope is the point source, the point source acts as a source that contain gamma rays. The point source emits gamma rays from specific distances from the collimator. Other than that, the number of radioactivity of the point source will be varied in order to get more accurate result.

1.5 Thesis Contribution

The most important contribution of this thesis is the simulation of the gamma camera brand Toshiba model GCA-7100A that has been developed by using open-source simulator software and this shows that an open-source software can be reliable as the paid software such as MCNP5. This thesis presents the analysis and result from the simulation, starting from the result of different distance between point source and collimator and the different number of radioactivity of point source. The simulation can be used as a reference in the next study.

1.6 Organization Of The Thesis

This thesis is organized based on the Universiti Teknikal Malaysia Melaka thesis format. This thesis is divided into five different chapters including this chapter.

Chapter two presents about the literature review on the previous study related to this thesis. Various method and approach to the research is reviewed and studied.

Chapter three explains the methodology of the research. It is divided into three section which are general methodology, simulation methodology and result analysis methodology.

Chapter four discuss about the findings and output results of the research. It is contain two sections. All the research will be conclude and recommendation for future work and research will be explain in chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter presents the literature review of the previous research related to the thesis. Basically this chapter will be focusing on the gamma camera and the simulation software, starting with the discussion about the components of the gamma camera and its function. The discussion continues with overview on GATE software and its application, which is also include the basic physics of GATE simulation program.

2.2 Basic Operation Of Gamma Camera

Gamma camera is developed by Hal Anger in years 1957. The original name of the gamma camera is scintillation camera. Gamma camera is a medical equipment that has the capability of detecting gamma radiation. Gamma radiation can be describe as a product of radioactive atoms and it is the most energetic form of electromagnetic radiation, but with a very short wavelength of less than one-tenth of a nanometer. Gamma rays interact with material by colliding with the electrons in the shells of atom. They can penetrate through materials or through people and can travel from one to hundreds of meters in air depending on its initial energy.

Gamma camera is used in medical imaging study to show the abnormalities in human body. Example of these abnormalities is cancer cells and congenital abnormalities. However, person that needs to be scan by the gamma camera must ingest or inhales a tracer material that emits gamma radiation. This tracer can also be inject into the human body and it can be introduced to specific part of the body