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Automatic detection and scoring of the step wedge tool using image processing techniques

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ABSTRACT

Step wedge is used for quality control in radiology devices. The image of the step wedge is based on experience, visual threshold, assessment method used and resident status. This project was designed to develop a quality control program, to calculate the number of steps in the image using a computer, digital images process in the evaluation of step wedge and matlab. A number of step wedge images were taken. It was shown to a group of engineers to determine number of the steps in the image. The image was entered into the matlab program and then it was converted to gray scale, then we averaged each column and compared the column values to determine the number of steps.

المستخلص

يستخدم ال(step wedge) لمراقبة الجودة في أجهزة الأشعة. تقيم الصورة الناتجة من ال (step wedge) يعتمد على الخبرة, عتبة البصر, طريقة التقييم المستخدمة وحالة المقيم. تم تصميم هذا المشروع لتطوير برنامج مراقبة الجودة, وذلك بحساب عدد التدريجات في الصورة باستخدام الحاسوب و معالجة الصور الرقمية في تقيم صورة step wedge و برنامج matlab. تم اخذ مجموعة من صور ال (step wedge).ثم تم عرضها علي مجموعة من المهندسين وذالك لتحديد عدد التدريجات الواضح في الصورة .تم إدخال الصورة إلي برنامج matlab وتم تحويلها الي(gray scale). تمت إزالة خلفية الصورة , ثم قمنا بحساب المتوسط لكل عمود ومقارنة قيم الأعمدة لتحديد عدد التدريجات.

DEDICATION

We humbly dedicate this effort to:

Our parents for enriching our lives with wisdom, knowledge; care for others and passion to make change.

Our teachers those humble but graceful individuals that thankfully made us what we are now.

Our best friends for the support when things were up and mostly when there were down.

Finally, to everyone who stood by us; and helped by any means to bring this work to its final form.

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And of course we would like to thank and greet with all respect all doctors, teachers and staff of the department of biomedical engineering at Sudan University of Science and Technology. If it weren't for their patience and continuous tenderness we wouldn't be at this point.

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LIST OF ABBREVIATIONS

ALARA	As. Low. as reasonably. Achievable
MATLAB	Matrix laboratory
QC	Quality control
DM	Digital mammography
CHT	Circle Hough transform
LHT	Line Hough transform
MTF	Modulation transfer function
PACS	Picture archiving and communication system
HVT	Half value thickness
ROI	Region of interest
FFD	Focal film distance

CHAPTER ONE

INTRODUCTION

1.1 General Background

Dose optimization is high significance for the quality and quantity of quality-control tests on X-ray equipments. The widespread use of X-ray in the diagnosis and management of patients has led to increased radiation exposure. Although the clinical use of X-ray is governed by dose optimization and as-low-as-reasonably- achievable (ALARA) principle .

Diagnostic imaging is a multi step process by which information concerning patient anatomy and physiology is gathered and displayed with the modern technology.

Quality assurance program for diagnostic X-ray units is aimed to ensure that the image produced is consistently of high quality giving maximum diagnostic information with minimum radiation exposure to the patient and staff, at minimal cost.

Quality-control programs in diagnostic radiology aim to ensure the optimal performance of all imaging components. These programs lead to the production of images with the highest quality and the lowest possible radiation dose to patients and operators, while maintaining a high diagnostic value. The goal of quality-control programs is to help reduce costs through eliminating unproductive imaging, caused by the inefficiency of devices or materials.

Step wedge a quality control device consisting of increasing thicknesses of absorber through which a radiographs are taken to determine the amounts of radiation reaching the film .

Automation software: transforms the way test data is collected, measured and stored to mitigate risk and manage regulatory compliance. It is the premier digital solution for hospital [1].

Matrix Laboratory (MATLAB) is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation [2].

1.2 Problem Statement

The interpretation of the test depend upon the experience , visual threshold , assessment method used and state of the observer.

1.3 Objectives

1.3.1 General Aim

As for the development of radiation devices from conventional to digital, it was necessary to develop and keep pace of quality control test. to reduces test time ,increase operational efficiency and reduce human errors.

1.3.2 Specific Objectives

Design a software program to calculate the number of steps in step wedge images.

1.4 Thesis Layout

The thesis for this project consists of:

Chapter 1: Provides an introduction to the project, problem statement, the concerned objectives.

Chapter 2: Is a brief recollection of the previous works concerning some primary aspects of this project

Chapter 3: Provides a theoretical background to all the concerned topics of the project and the basics for the methodology development.

Chapter 4: Includes a detailed assembly of the various algorithms and methodologies that have been implemented for the achievement of the project objectives.

Chapter 5:Provides the final results, the respective discussions for the created systems and the evaluation of the efficacy of the results obtained.

Chapter 6: Provides the overall conclusions drawn up from the thesis and some directions that could present as useful suggestions for future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of the Most Relevant Systems and Method

In 2016, Hamza et al developed a new tool for radiographic densitometry by combining per apical films and aluminum step wedge. he reviewed 50 Kodak E-speed intraoral films. An aluminum step wedge consisting of 16 steps was constructed. Each step was 1mmx3mx10mm. The step wedge was exposed to varying exposure times, ranging from 0.05 second to 0.5 second, increasing in 0.05 second increments. Films were digitalized after processing and the MATLAB software algorithm was ran subsequently. Density of the films was measured again using a digital densitometer. In order to compare the two imaging techniques, three steps were selected. Output data from the MATLAB algorithm were compared with data obtained from the digital densitometer. The new method could detect significant differences between subsequent exposure times in step 7, while the densitometer did that in steps 7 and 12. The new method’s sensitivity in determining density changes was 5.26%, 84.1% and 93.02% in steps 2, 7, and 12 respectively[3].

In 2009, A O Hamza developed a quality control in mammographic facilities,using digital image processing, namely template matching via cross correlation, and suggests a metric for the visibility of the test objects in the images. The radiographs of the phantom are scanned with 8 bits depth resolution at 600 dpi, These images are then filtered using a Gaussian filter having a width that is optimized to the scale size of the feature. A new circle edge detector was developed since the conventional Sobel and Roberts edge detectors are omnidirectional local operators, which do not take into account the geometry of the feature. The results were compared with the template matching technique [4].

In 2009, A O Hamza developed image-processing algorithms can automatically score the QC performance of DM imaging systems, by analysing a more suitably designed phantom having optimised artefacts and other structures. The collimation quality control test is designed to ensure that the radiation field matches the image receptor and the indicated light field. A suitable test image was obtained by placing coins around the periphery with their edges just touching the edge of the light field.then they develop computer program which can perform an automatic readout for the deviation between the dark portion of the film and the exterior edge of the coins. The circle Hough Transform (CHT) algorithm has been developed to locate these coins and hence the limits of the light field. The line Hough Transform (LHT) was developed and used to determine the edges of the X-ray field [5].

CHAPTER THREE

THEORETICAL BACKGROUND

3.1 X-Ray Equipment

Conventional x-ray radiography produces images of anatomy that are shadow grams based on x-ray absorption. The x-rays are produced in a region that is nearly a point source and then are directed on the anatomy to be imaged. The x rays emerging from the anatomy are detected to form a two dimensional image, where each point in the image has a brightness related to the intensity of the x-rays at that point. Image production relies on the fact that significant numbers of x-rays penetrate through the anatomy and that different parts of the anatomy absorb different amounts of x-rays. In cases where the anatomy of interest does not absorb x-rays differently from surrounding regions, contrast may be increased by introducing strong x-ray absorbers. For example, barium is often used to image the gastrointestinal tract. X-rays are electromagnetic waves (like light) having an energy in the general range of approximately 1 to several hundred kiloelectronvolts (keV). In medical x-ray imaging, the x-ray energy typically lies between 5 and 150 keV, with the energy adjusted to the anatomic thickness and the type of study being performed.

X-rays striking an object may either pass through unaffected or may undergo an interaction. These interactions usually involve either the photoelectric effect (where the x-ray is absorbed) or scattering (where the x-ray is deflected to the side with a loss of some energy). X-rays that have been scattered may undergo deflection through a small angle and still reach the image detector; in this case they reduce image contrast and thus degrade the image. This degradation can be reduced by the use of an air gap between the anatomy and the image receptor or by use of an antiscatter grid. Because of health effects, the doses in radiography are kept as low as possible. However, x-ray quantum noise becomes more apparent in the image as the dose is lowered. This noise is due to the fact that there is an unavoidable random variation in the number of x-rays reaching a point on an image detector. The quantum noise depends on the average number of x-rays striking the image detector and is a fundamental limit to radiographic image quality [6]

3.2 Production of X-Rays

3.2.1 X-Ray Tube

The standard device for production of x-rays is the rotating anode x-ray tube, as illustrated in (Fig.3.1). The x-rays are produced from electrons that have been accelerated in vacuum from the cathode to the anode. The electrons are emitted from a filament mounted within a groove in the cathode. Emission occurs when the filament is heated by passing a current through it. When the filament is hot enough, some electrons obtain a thermal energy sufficient to overcome the energy binding the electron to the metal of the filament. Once the electrons have "boiled off" from the filament, they are accelerated by a voltage difference applied from the cathode to the anode. This voltage is supplied by a generator (see below). After the electrons have been accelerated to the anode, they will be stopped in a short distance. Most of the electrons' energy is converted into heating of the anode, but a small percentage is converted to x-rays by two main methods. One method of x-ray production relies on the fact that deceleration of a charged particle results in emission of electromagnetic radiation, called bremmstrahlung radiation. These x-rays will have a wide, continuous distribution of energies, with the maximum being the total energy the electron had when reaching the anode. The number of x-rays is relatively small at higher energies and increases for lower energies [6]

A second method of x-ray production occurs when an accelerated electron strikes an atom in the anode and removes an inner electron from this atom. The vacant electron orbital will be filled by a neighboring electron, and an x-ray may be emitted whose energy matches the energy change of the electron. The result is production of large numbers of x-rays at a few discrete energies. Since the energy of these characteristic x-rays depends on the material on the surface of the anode, materials are chosen partially to produce x-rays with desired energies. For example, molybdenum is frequently used in anodes of mammography x-ray tubes because of its 20-keV characteristic x-rays. Low-energy x-rays are undesirable because they increase dose to the patient but do not contribute to the final image because they are almost totally absorbed. Therefore, the number of low-energy x-rays is usually reduced by use of a layer of absorber that preferentially absorbs them. The extent to which low energy x-rays have been removed can be quantified by the half-value layer of the x-ray beam. It is ideal to create x-rays from a point source because any increase in source size will result in blurring of the final image. Quantitatively, the effects of the blurring are described by the focal spot's contribution to the system modulation transfer function (MTF). The blurring has its main effect on edges and small objects, which correspond to the higher frequencies. The effect of this blurring depends on the geometry of the imaging and is worse for larger distances between the object and the image receptor (which corresponds to larger geometric magnifications). To avoid this blurring, the electrons must be focused to strike a small spot of the anode. The focusing is achieved by electric fields determined by the exact shape of the cathode. However, there is a limit to the size of this focal spot because the anode material will melt if too much power is deposited into too small an area. This limit is improved by use of a rotating anode, where the anode target material is rotated about a central axis and new (cooler) anode material is constantly being rotated into place at the focal spot. To further increase the power limit, the anode is made with an angle surface. This allows the heat to be deposited in a relatively large spot while the apparent spot size at the detector will be smaller by a factor of the sine of the anode angle. Unfortunately, this angle cannot be made too small because it limits the area that can be covered with x-rays. In practice, tubes are usually supplied with two (or more) focal spots of differing sizes, allowing choice of a smaller (sharper, lower-power) spot or a larger (more blurry, higher-power) spot.

The x-ray tube also limits the total number of x-rays that can be used in an exposure because the anode will melt if too much total energy is deposited in it. This limit can be increased by using a more massive anode [6]

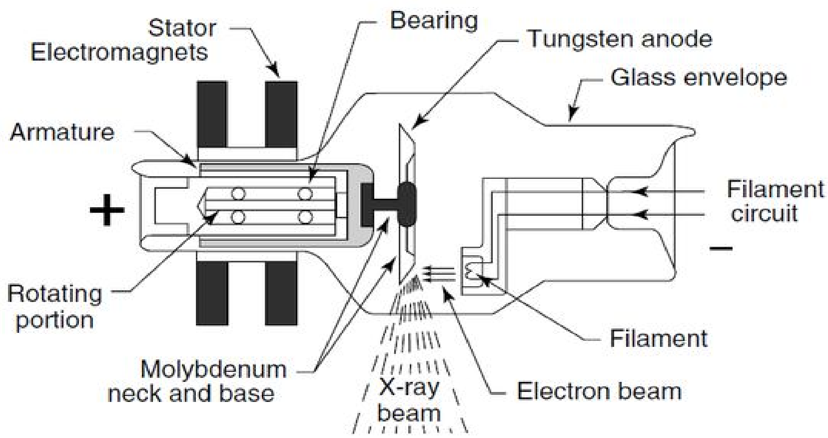

Fig.3.1 x-ray tube

3.3 Generator

The voltages and currents in an x-ray tube are supplied by an x-ray generator. This controls the cathode anode voltage, which partially defines the number of x-rays made because the number of x-rays produced increases with voltage. The voltage is also chosen to produce x-rays with desired energies: Higher voltages makes x-rays that generally are more penetrating but give a lower contrast image. The generator also determines the number of x-rays created by controlling the amount of current flowing from the cathode to anode and by controlling the length of time these current flows. These points out the two major parameters that describe an x-ray exposure: the peak kilovolts (peak kilovolts from the anode to the cathode during the exposure) and the milliampere-seconds (the product of the current in milliamperes and the exposure time in seconds). The peak kilovolts and milliampere-seconds for an exposure may be set manually by an operator based on estimates of the anatomy. Some generators use manual entry of kilovolts and milliamperes but determine the exposure time automatically. This involves sampling the radiation either before or after the image sensor and is referred to as phototiming. The anode-cathode voltage (often 15 to 150 kV) can be produced by a transformer that converts 120 or 220 V ac to higher voltages. This output is then rectified and filtered. Use of three-phase transformers gives voltages that are nearly constant versus those from single-phase transformers, thus avoiding low kilovoltages that produce undesired low-energy x-rays. In a variation of this method, the transformer output can be controlled at a constant voltage by electron tubes. This gives practically constant voltages and, further, allows the voltage to be turned on and off so quickly that millisecond exposure times can be achieved. In a third approach, an ac input can be rectified and filtered to produce a nearly dc voltage, which is then sent to a solid-state inverter that can turn on and off thousands of times a second. This higher-frequency ac voltage can be converted more easily to a high voltage by a transformer. Equipment operating on this principle is referred to as midfrequency or high-frequency generators [6]

3.3.1OPERATING CONSOLE

The operating console, the part of the x-ray machine most familiar to the x-ray technologist. is the apparatus which allows the technologist to control the x-ray tube current and voltage so that the useful x-ray beam is of proper intensity and penetrability for producing a good quality radiograph [7].

The Operating Console usually provides switches to control:

Line compensation, KVp, mA, Exposure time, mAs (milliampers-second), Exposure Switch On newer equipment that incorporates phototiming, separate controls for mAs may be present.

All the electric circuits connecting the meters and controls located on the operating console are at low voltage so that the possibility of hazardous shock is minimized. Fig3.2 shows a circuit diagram of an X-ray machine [7].

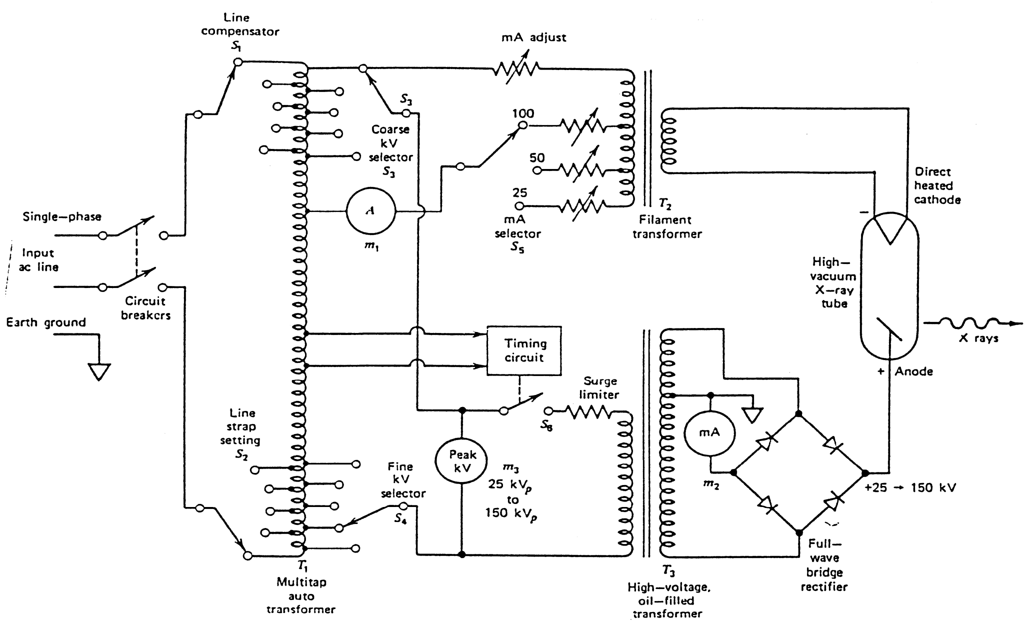

Fig.3.2 Circuit diagram of an X-ray machine.

3.4 Image Detection: Digital Systems

In both radiography and fluoroscopy, there are advantages to the use of digital images. This allows image processing for better displayed images, use of lower doses in some cases, and opens the possibility for digital storage with a PACS system or remote image viewing via teleradiology. Additionally, some digital systems provide better image quality because of fewer processing steps, lack of distortion, or improved uniformity.

A common method of digitizing medical x-ray images uses the voltage output from an image-intensifier/ TV system. This voltage can be digitized by an analog-to-digital converter at rates fast enough to be used with fluoroscopy as well as radiography.

Another technology for obtaining digital radiographs involves use of photostimulable phosphors. Here the x-rays strike an enclosed sheet of phosphor that stores the x-ray energy. This phorphor can then be taken to a read-out unit, where the phosphor surface is scanned by a small light beam of proper wavelength. As a point on the surface is read, the stored energy is emitted as visible light, which is then detected, amplified, and digitized. Such systems have the advantage that they can be used with existing systems designed for screen-film detection because the phosphor sheet package is the same size as that for screen films.

A new method for digital detection involves use of active-matrix thin-film-transistor technology, in which an array of small sensors is grown in hydrogenated amorphous silicon. Each sensor element includes an electrode for storing charge that is proportional to its x-ray signal. Each electrode is coupled to a transistor that either isolates it during acquisition or couples it to digitization circuitry during readout.

There are two common methods for introducing the charge signal on each electrode. In one method, a layer of x-ray absorber (typically selenium) is deposited on the array of sensors; when this layer is biased and x-rays are absorbed there, their energy is converted to electron-hole pairs and the resulting charge is collected on the electrode. In the second method, each electrode is part of the photodiode that makes electron-hole pairs when exposed to light; the light is produced from x-rays by a layer of scintillator (such as CsI) that is deposited on the array. Use of a digital system provides several advantages in fluoroscopy. The digital image can be processed in real time with edge enhancement, smoothing, or application of a median filter. Also, frame-to-frame averaging can be used to decrease image noise, at the expense of blurring the image of moving objects. Further, digital fluoroscopy with TV system allows the TV tube to be scanned in formats that are optimized for read-out; the image can still be shown in a different format that is optimized for display. Another advantage is that the displayed image is not allowed to go blank when x-ray exposure is ended, but a repeated display of the last image is shown. This last-image-hold significantly reduces doses in those cases where the radiologist needs to see an image for evaluation, but does not necessarily need a continuously updated image. The processing of some digital systems also allows the use of pulsed fluoroscopy, where the x-rays are produced in a short, intense burst instead of continuously. In this method the pulses of x-rays are made either by biasing the x-ray tube filament or by quickly turning on and off the anode-cathode voltage.

This has the advantage of making sharper images of objects that are moving. Often one x-ray pulse is produced for every display frame, but there is also the ability to obtain dose reduction by leaving the x-rays off for some frames. With such a reduced exposure rate, doses can be reduced by a factor of two or four by only making x-rays every second or fourth frame. For those frames with no x-ray pulse, the system repeats a display of the last frame with x-rays [8]

3.5 Penetrating power

The penetrating power of X-radiation increases with the energy (hardness). The relationship of energy and penetrating power is complex as a result of the various mechanisms that cause radiation absorption. When monochromatic (homogeneous - single wave length) radiation with an intensity Io passes through matter, the relative intensity reduction ΔI/Io is proportional to the thickness Δt. The total linear absorption coefficient (μ) consisting of the three components is defined by the following formula:

$$\frac{\Delta I}{I_0} = \mu \cdot \Delta t$$

Expressed differently

$$I = I_0 \cdot e^{-\mu t}$$

In which:

Io = intensity at material entry   t = thickness

I = intensity at material exit   e = logarithm: 2.718

μ = total absorption coefficient

Figure.3.3 shows the resulting radiation intensity (logarithmic) as a function of increased material thickness

When radiation is **heterogeneous** the graphs are not straight, see (figure .3.3).

The slope of the curves becomes gradually shallower (because of selective absorption of the softer radiation) until it reaches [8].

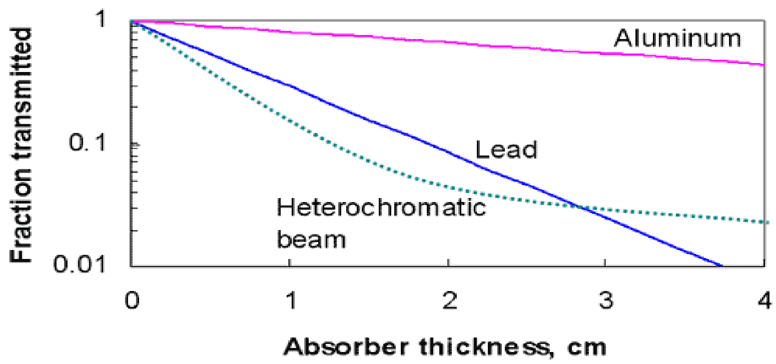

Fig.3.3 Intensity of radiation as function of increasing Thickness

3.6 Half-value thickness

A convenient practical notion (number) of the linear absorption coefficient is the introduction of the half-value thickness (HVT). It quantifies the penetrating power of radiation for a particular type of material and is defined as the thickness of a particular material necessary to reduce the intensity of a monochromatic beam of radiation by half, as shown in figure .3.4. This HVT-value depends on the hardness of radiation [8]

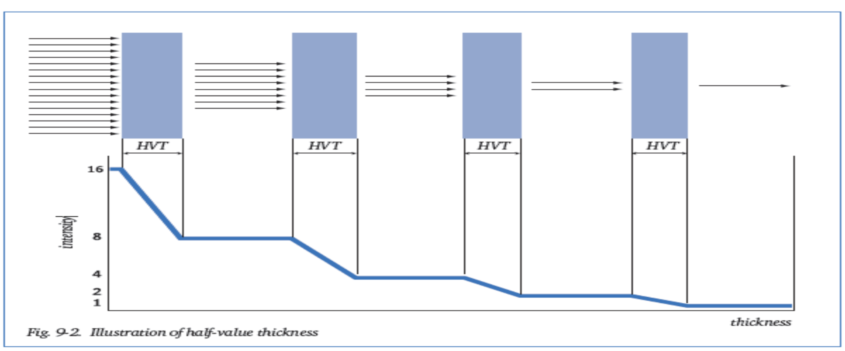

figure .3.4 illustration of half –value thickness

3.7 Quality assurance

'Quality assurance' is all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given requirements for quality (ISO 9000:1994). As such it is wide ranging, covering all relevant procedures, activities and actions, and hence all groups of staff involved in the process under consideration [7].

3.8 Quality-control

'Quality control' is the regulatory process through which the actual quality performance is measured, compared with existing standards, and the actions necessary to keep or regain conformance with the standards. Quality control is one part of overall quality assurance. It is concerned with operational techniques and activities used:

To check that quality requirements are met,To adjust and correct performance if the requirements are found not to have been met [7].

QC is a part of the QA program which refers only to individual checks on each of the technical aspects of the examination, in other words QC deals with techniques used in monitoring and maintenance of the technical elements of the systems that affect the quality of the image. Therefore QC is the part of QA program that deals with instrumentation and equipment

Diagnostic imaging is a multi step process by which information concerning patient anatomy and physiology is gathered and displayed with the modern technology.

There are different sources of variability in both human and equipments factors that produce sub-quality images if not properly controlled. This can result in repeat exposures that increase both patient dose and department cost and decrease the accuracy of image diagnosis. This in turn can result in customer satisfaction that ultimately costs the healthcare providers lost business.

The purpose of a quality management program is to control or minimize these variables (equipment, image receptor, processing, viewing conditions, and competency of the technologist, support staff, and the observer or interpreter) as much as possible.

3.9 The quality levels

3.9 .1 Expected quality

this is the level of quality of the product or services that is expected by the customers and may be influenced by outside factors such as word of mouth from friends and relatives.

3.9 .2 Perceived quality

this the customer’s perception of the product or services. It is based on the customer's perception of the product or services and is highly subjective and more difficult to measure quantitatively. For patients undergoing diagnostic imaging, their experience (such as how long they had to wait) during the procedures greatly influences their perception of quality.

3.9 .3 Actual quality

this is the level of quality uses statistical data and considers all factors that can influence the final outcome. It can also compare the quality of the product or services with that of a competitor

3.10 QC levels

3.10.1 Noninvasive and simple

can be performed by any technologist and include tests such as the wire mesh test for screen contact.

3.10.2 Noninvasive and complex

performed by a technologist who has been specifically trained in QC procedures. Because more sophisticated equipment is used.

3.10.3 Invasive and complex

performed by engineer or physicist since it involve some disassembly of the equipment.

The quality of the image on the film can be assessed by three factors, namely :

Contrast, Sharpness and Graininess

As an example, consider a specimen having a series of grooves of different depths machined in the surface. The density difference between the image of a groove and the background density on the radiograph is called the image contrast. A certain minimum image contrast is required for the groove to become discernible. With increased contrast:

the image of a groove becomes more easily visible

the image of shallower grooves will gradually also become discernible

Assuming the grooves have sharp-machined edges, the images of the grooves could still be either sharp or blurred; this is the second factor: image blurring, called image unsharpness.

At the limits of image detection it can be shown that contrast and unsharpness are interrelated and detectability depends on both factors.

As an image on a photographic film is made up of grains of silver, it has a grainy appearance, dependent on the size and distribution of these silver particles. This granular appearance of the image, called film graininess, can also mask fine details in the image. Similarly, in all other image forming systems these three factors are fundamental parameters.

In electronic image formation, e.g. digital radiography or scanning systems with CCTV and screens, the factors contrast, sharpness and noise are a measure for the image quality; pixel size and noise being the (electronic) equivalent of graininess .

The three factors: contrast, sharpness and graininess or noise are the fundamental parameters that determine the radiographic image quality. Much of the technique in making a satisfactory radiograph is related to them and they have an effect on the detect ability of defects in a specimen.

The ability of a radiograph to show detail in the image is called “radiographic sensitivity”. If very small defects can be shown, the radiographic image is said to have a high (good) sensitivity. Usually this sensitivity is measured with artificial “defects” such as wires or drilled holes. These image quality indicators (IQIs))

3.11 Quality-control test

3.11 .1 Categories of QC Tests

Safety ,Mechanical accuracy ,Imaging Performance and Display System

3.11 .2 Types of QC tests

3.11 .2.1 Acceptance testing

is performed on new equipment that has undergone major repair to demonstrate that it is performed within the manufactures' specifications and criteria. The results obtained during acceptance testing are also used to establish the baseline performance of the equipment that is used as a reference point in future QC testing [7].

3.11 .2.2 Routine performance evaluations

are specific tests performed on the equipment in use after a certain time has elapsed. These evaluations can verify that equipment is performing within previously accepted standards and can be used to diagnose any changes in performance before becoming radiographically apparent [7].

3.11 .2.3 Error correction tests

evaluate equipment that is malfunctioning or not performing at specification and are also used to verify the correct causes of the malfunction so that the proper repair can be made

3.12 Quality control of conventional x-ray

The main objective of quality control is to achieve a high quality image either on film or Imaging Devise at possibly low radiation dose to patient and personnel .

3.12 .1Test Types

Acceptance test, Monitoring test, Annual Test and After repair or tube replacement

3.12.2 Parameters to be checked in Radiography (performance testing)

Beam Alignment and Collimator Accuracy, Constancy of Radiation output and, linearity of mR/mAs versus kV2 (Small & Large focus), Assessment of Total Beam Filtration (HVL), Assessment of Focal Spot size (Line Pain Ph) Accuracy and constancy of Exposure Timer, Measuring of Scattered Radiation (using Water Phantom), Leakage Radiation from X-Ray tube [7].

3.12.3 step wedge test

Triangular aluminum tools placed over a radiographic film during exposure to determine the penetrating ability of an x-ray beam. Show in (figure .3.5).

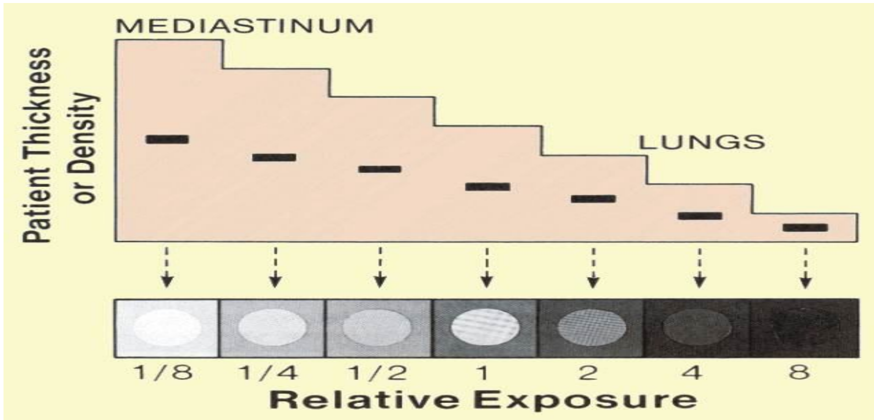

figure .3.5 thickness and relative exposure

A step-wedge is a test tools made from aluminum ,it's used to confirm that a generator has been correctly tested at the time of manufacture and installation

Step Wedges can be used to determine, mAs linearity, Contrast vs. kVp.They can also be used for Darkroom fog testing, Film comparison, Screen comparison and Technique chart development.

3.13 Digital images

To create a digital image, we need to convert the continuous sensed data into digital form. This involves two processes: sampling and quantization. An image may be continuous with respect to the x- and y-coordinates, and also in amplitude. to convert it to digital form, we have to sample the function in both coordinates and in amplitude [9] .

Digital images are discretely sampled on a rectangular grid The image values are stored digitally. A certain number of bits is set aside for each cell (each pixel). Since each bit can hold two values (one and zero), a n-bit pixel can hold 2^n discrete intensity levels. Color photos are commonly stored with 24 bits per pixel, with 8 bits each for the three fundamental colors, red, green, and blue. For each color, 256 intensity levels are possible. Most magnetic resonance and ultrasound images are also stored with 8 bits depth, whereas computed tomography normally provides 12 bits, the pixel size determines the absolute limit for the spatial resolution, and the bit depth determines the contrast limit [10] .

3.14 Digital images processing

The field of digital image processing refers to processing digital images by means of a digital computer, Interest in digital image processing methods stems from two principal application areas: improvement of pictorial information for human interpretation and processing of image data for storage, transmission, and representation for autonomous machine perception [9].

3.15 Digital image formation

In conventional (film) radiography, the human eye is used to examine a physical record of the radiographic image, which has recorded the intensity of X-rays incident on the film as varying degrees of opacity (shades of grey between black and white). In digital imaging the intensity of X-rays is first measured point by point and then individually digitised and converted into many (e.g. 12 bit = 4096 levels) discrete grey values including their corresponding coordinates. This recording process is known as mapping; a map consists of many (millions) discrete measuring points with their individual grey levels. Finally, these grey levels and their coordinates are displayed to form a coherent image on a video screen, or printed, as a collection of picture elements ("pixels") for examination by the human eye.

Because of the 1-to-1 correspondence between each final image pixel and the discrete measurement area (sensor size), the areas on a digital detector are also commonly referred to as pixels. For digital radiography using panel, flat bed or line array detectors this process of digitization with assigned grey levels is done at once, at the detector itself. In case of

imaging plates the digitization and grey level assignment is done in the so-called "reader", see section 16.4. The mapping process allows data to be measured and stored from a much wider dynamic range than the eye can normally perceive. After an image has

been stored, different maps can later be applied to show different thickness ranges, without affecting the original measurements. These maps can be linear or non-linear: for example, a logarithmic map is sometimes used to more closely mimic the response of conventional films [8].

3.16 Gray scale

The grayscale transformation function maps the intensity range into itself, grayscale transformation can increase or decrease the intensity range. They are often used to recover valuable visual information from images that are overexposed, underexposed, or have very small dynamic range. They can also be used when the intensity range is too large to be displayed on a certain medium such as a terminal, printer, or film. Grayscale transformation algorithms are often a part of visualization software [11].

3.17 MATLAB

The basic data structure in MATLAB is the array, an ordered set of real or complex elements. This object is naturally suited to the representation of images, real-valued, ordered sets of color or intensity data. (MATLAB does not support complex-valued images.) MATLAB stores most images as two-dimensional arrays (i.e., matrices), in which each element of the matrix corresponds to a single pixel in the displayed image. (Pixel is derived from picture element and usually denotes a single dot on a computer display.) For example, an image composed of 200 rows and 300 columns of different colored dots would be stored in MATLAB as a 200-by-300 matrix. This convention makes working with images in MATLAB similar to working with any other type of matrix data, and makes the full power of MATLAB available for image processing applications [12].

CHAPTER FOUR

MATERIAL AND METHOD

4.1 Materials

4.1.1 step wedge

step wedge is an aluminum device that, when exposed to x-rays, displays a range of exposure intensities on a radiograph. These exposure "steps" are analyzed to evaluate the performance of the x.ray machine and the processing system.

Figure.4.1 step wedge.

description of the step wedge

11 Steps

Step wedge: 2.50 x5.50 x1.299 in.

Each step: 0.5 in surface; 3mm rise.

Weight: 1.10 lb (0.50kg).

4.1.2 X-ray Generators and detectors

description of the X-ray Generators

perlove , Nanjing perlove medical equipment max tube voltage 150 kv.

Figure 4.2 **X-ray Generators and detectors**

4.2 Method

4.2.1 System Overview

As a beginning the step wedge images was exposed to x.ray then entered to the MATLAB. Second, convert background to black and extract the region of interest in order to calculate the number of steps, calculate the mean of matrix rows, compare between pixels value and display the number of steps.

This project was divided into four Main phases: Step wedge test, segmentation, ROI extraction and statistic operation.

4.2.2 System implementation stages

4.2.2.1 Phase one: Step wedge test

The same mAs should produce the same exposure each time, This will be true if the mA and Timer are accurately calibrated. The kVp must be the same.

Tools needed, Aluminum Step wedge , Lead Blockers and Cassette.

Procedure Focal- film distance (FFD) 40 inch, Place cassette on table, Step wedge is place on cassette, Collimation set to size of step wedge, Lead blockers cover the area around exposure, Set a baseline technique and initiate first exposure, Cover exposed section of film and prepare for second exposure, Change control setting and the put back to original setting, Make exposure, Continue process with changes in power level or mA setting, Focal Spot settings and time settings,Make sure that the exposed areas of the cassette are covered by the lead blockers, Process the film.

4.2.2.2 Phase two: segmentation

Segmentation of an image entails the division or separation of the image into regions of similar attribute. In order to reduce operation, computational time and avoid impacting the effectiveness of step wedge region must be extracted.

With consideration to characteristics of the step wedge image gray level's histogram as shown in the fig. 4.3 a threshold value was selected depending on the two peaks of film and step wedge values. Then the borders of the generated binary image were cleared by suppressing structures lighter than their surroundings located at the borders. The area opening method used to remove small object from binary image. A set of background pixels that cannot be reached by filling in the background from the edge of the image were filled using “imfill“ command in MATLAB. The process of overlapping binary image and original image was the last stage in segmentation phase.

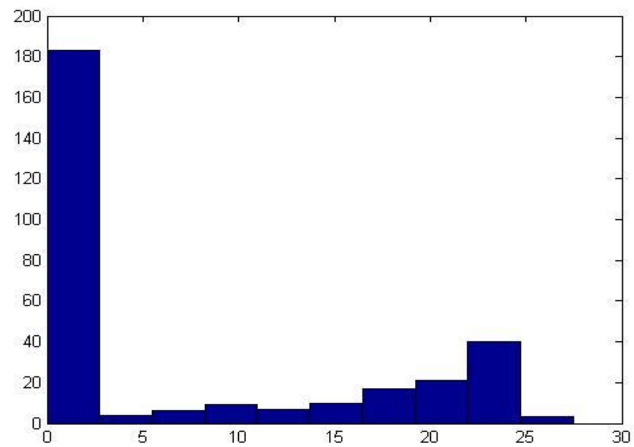

Fig.4.3 histogram of the step wedge image in gray level values.

4.2.2.3 Phase three: Region of interest

Region of interest was extracted using clear black function that can first detect empty rows and empty columns by compare between image consequent from segmentation process and zero matrix has the same size. second it will delete empty rows and columns that are detected.

4.2.2.4 Phase Four: statistic operation

To calculate the number of the step wedge from the severed image , we calculated the mean value for all the rows pixels in the image matrix by using the command (mean) , that would produce image matrix contains one row with mean value so we can compare each pixel with the previous pixel ,if the difference is large than the threshold the program will consider that as the step number one and move to the next pixel and compared and so on. Program will display the result after the last compare in command window.

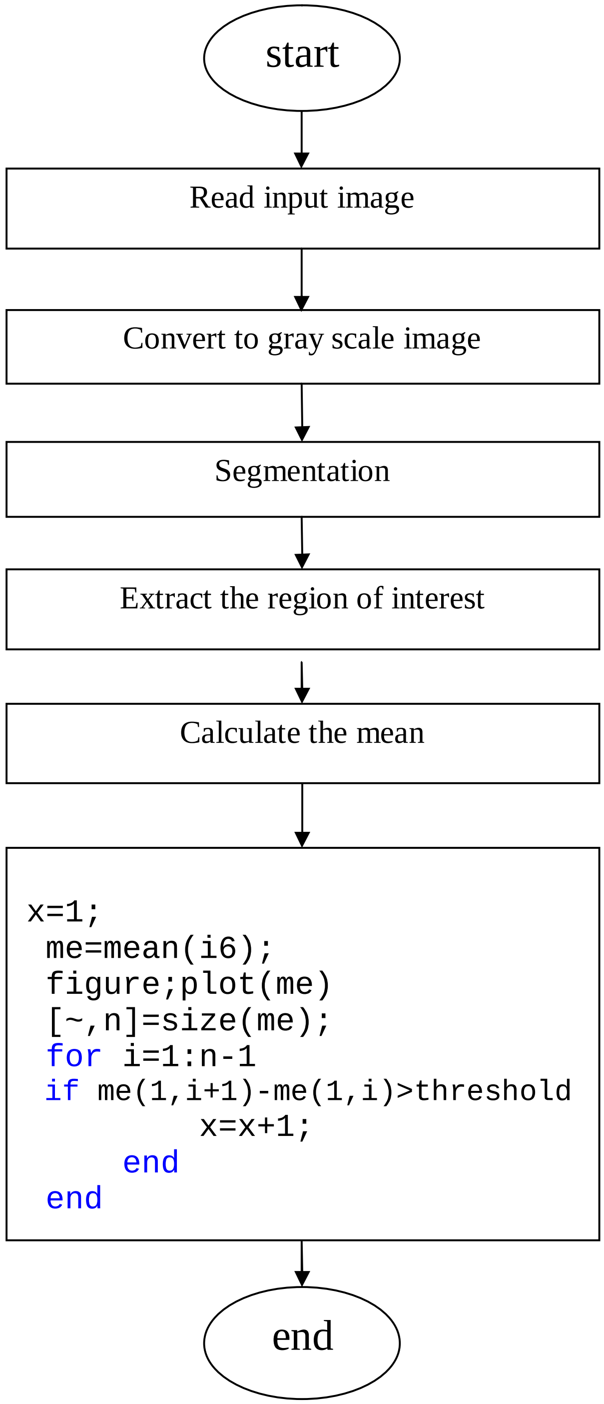

Figure 4.4 Flow chart of the system

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Result of image convert

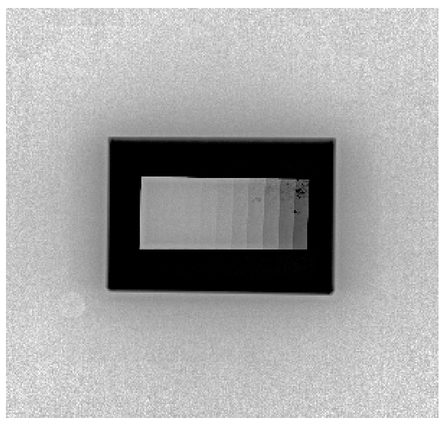

Figure.5.1 a. step wedge image

the visible number of the step wedge is depending on the amount of the kv and mAs.

5.2 Result of segmentation

The resulted images after following the segmentation process are shown in figures below:

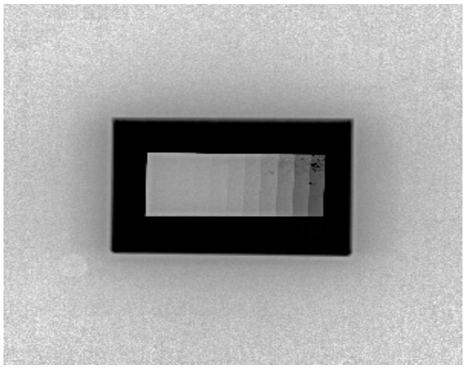

Figure.5.2 Original image after applying

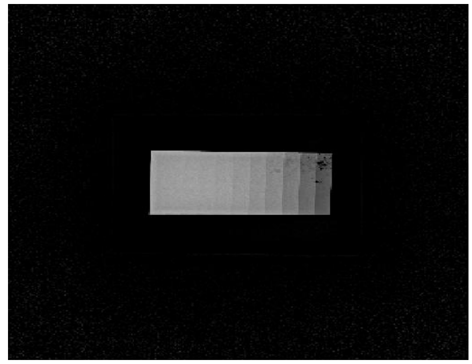

Figure.5.3 border cleaning

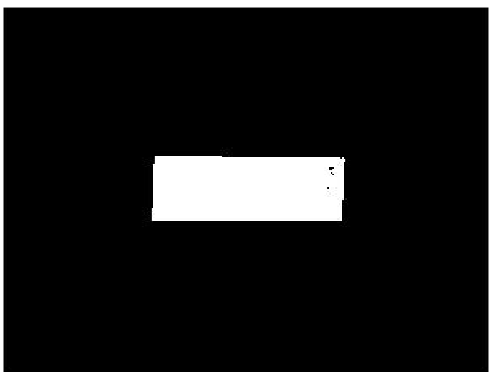

Figure.5.4 area opening

Figure.5.5 filling operation

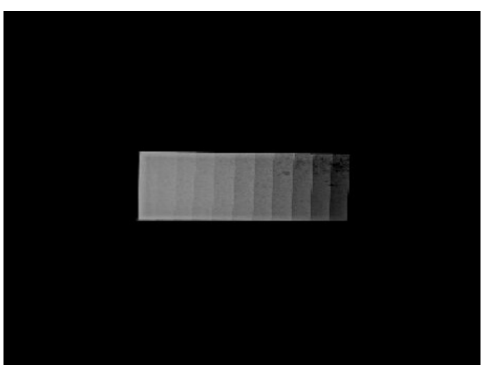

Figure.5.6 over lapping image with original image

5.3 Result of ROI extraction

After segmentation process we need to remove the background of the image so it would not interference with the calculation process as shown in (figure.5.7).

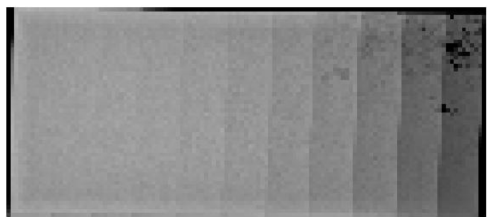

Figure.5.7 extract image

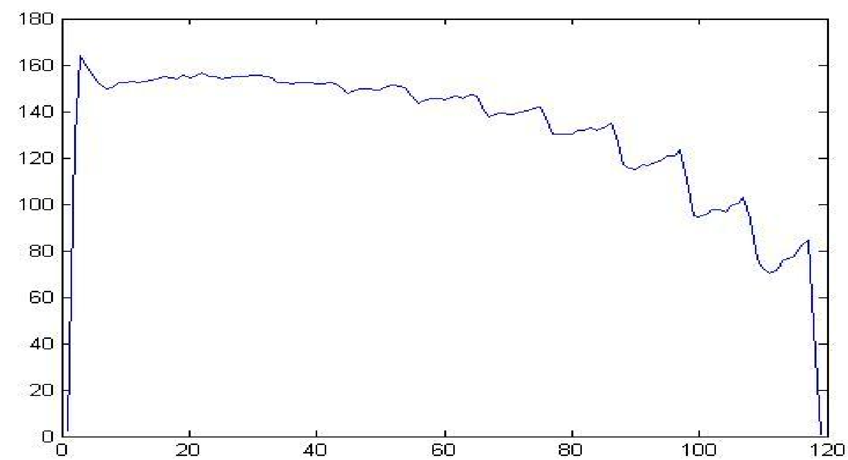

Figure.5.8 Figure showing the gradation of pixel value.

Table 5.1 show the compare between observers read and software read

Image read	by observers	by software
Image 1	7	6
Image 2	11	11
Image 3	8	8
Image 4	8	9
Image 5	8	9
Image 6	9	9
Image 7	6	6
Image 8	8	9
Image 9	8	8
Image 10	9	9

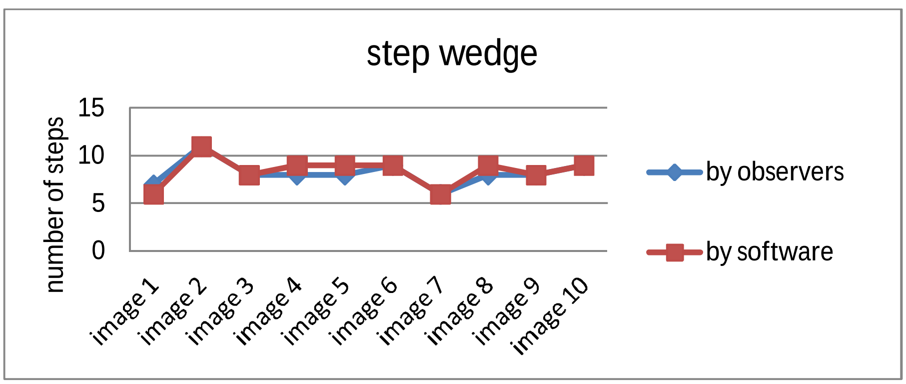

Figure.5.9 compare between observers read and software read

CHAPTER SIX

CONCLUSION RECOMMENDATION

6.1 Conclusion

The x-ray image contrast is determined by an expert evaluating step wedge images visually. The dependence on human factors results in a variability of of scoring result. In this work a method has been developed to a analyze the step wedge images by means of automatic image processing technique .the methods used had to locate the test objects automatically and suggest a measure for their visibility.

A set of a algorithms were develop to a achieve the proposed automatic system for steps detection in step wedge images .firstly, images was obtained and entered to matlab. Second images converted to gray scale then images was segmented and steps region was extracted, thus image was ready for steps detection . it was observed that each step should have same pixels value , so the different between pixels value indicate the number of steps in images.

6.2 Recommendations

Step wedge must made from pure aluminum and it must be well manufacture. The beam alignment and collimator QC test should perform before step wedge test.

The radiation must be soft radiation . A future work on this program could include more statistical tools to achieve better result.

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APPENDICES

Appendix

Program code

```
x=uigetfile('.bmp','step.bmp');
%reading step wedge image
 i=imread(x);

 i1=rgb2gray(i);
%convert the image to gray scale image
figure;imshow(i1 )

%%%%%%%%segmentation%%%%%%%
i2=imclearborder(i1);
%clear image border
i3 = bwareaopen(i2, 10);
% remove small object

i4 = Extractstepwedge(i3, 1);
%Extract only the two largest blobs.
figure;imshow(i4 )

i5 = imfill(i4, 'holes');
%Fill holes.
figure;imshow(i5 )

%%%%%%%%%ROI extraction%%%%%%%
i6 = clearBlack(i1,i5);
%remove the black background from the image
[x,y]=size(msk);
tst1=zeros(x,y);
% detect empty rows
```

```
r1=[];
m=1;
for j=1:x
    if msk(j,:)==tst1(j,:)
        r1(m)=j;
        m=m+1;
    end
end
% detect empty columns
r2=[];
m=1;
for j=1:y
    if msk(:,j)==tst1(:,j)
        r2(m)=j;
        m=m+1;
    end
end
% Deleting
out = img;
out(:,r2)=[];
out(r1,:)=[];
end


 figure;imshow(i6 )
%%%%%%%% calculate the mean%%%%%%%
x=1;
me=mean(i6);
%find the average value to each columns pixel

figure;plot(me)

%%%%%%calculate the number of the steps%%%%%
[~,n]=size(me);
for i=1:n-1
if me(1,i+1)-me(1,i)>2.5

     x=x+1;
end
end
```