

***Implementation of computer method for  
Synthesizing Lung Nodules***

A major thesis submitted to Faculty of technology  
Of  
University of Delhi

Towards the partial fulfillment of the requirement  
For  
The award of the Degree

Master of Engineering in Electronics & Communication

Submitted by

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## **CERTIFICATE**

This to certify that the work entitled “***Implementation of computer method for Synthesizing Lung Nodules***” has been carried out by G.Senthilkumar under my supervision in partial fulfillment of the requirement for the degree of master of Technology in Electronics and Communication Engineering of University of Delhi, Delhi, during the session 2003-2005 at Delhi College of Engineering, Delhi.

He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this dissertation, which to my knowledge has reached the required standard. Further, it is also certified that this work has not been submitted for any other degree or diploma in any college to the best of my knowledge and belief.

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## **CERTIFICATE**

This is to certify that the thesis entitled, ***“Implementation of computer method for Synthesizing Lung Nodules”*** submitted by *G.Senthilkumar* in partial fulfillment of requirements for the award of the degree of Master of Engineering in Electronics & Communication of University of Delhi, Delhi is a bonafide record work done by him and no part there of has been presented earlier for any other degree.

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## **Abstract**

Lung Cancer is most common disease in the world. Computed tomography (CT) scanning is the best method to detect lung cancer. The aim of this project is to study how effectively the technique of image processing can be utilised in CT scan. A software application is developed by using MATLAB software to identify the real nodule and measure its various parameters. A 3D mesh of real nodules is developed by using Gaussian structure. A synthetic lung nodule is created by using certain parameters of the 3D mesh. This synthetic nodule is inserted into the CT image. The real and synthetic nodules are compared from its appearance and shape in the CT image and 3D mesh plot. It has been found that both the nodules appear to be similar. A number of synthetic nodules could be created by manipulating various parameters. The characteristics of various synthetic nodules could be stored as a database, which could be useful to the radiologist for ready references of analysing the Lung nodules.

# *Chapter 1*

## **Introduction**



## ***1.0 Introduction***

Lung cancer is the most common disease world wide and is the major cause of death from cancer, particularly amongst men. It was a rare disease until the beginning of the 20<sup>th</sup> century. Since then the occurrence of lung cancer has increased rapidly and it now accounts for an estimated 901,746 new cases each year among men and 337,115 among women. [13] This emphasizes the need for finding ways to improve the diagnosis of lung cancer so it can be caught as early as possible. Early detection is the best way of increasing survival rate for lung cancer patients. On average the five year survival rate of lung cancer patient is 47% patients whose cancer is detected early is 49%. [9]

Survival from lung cancer is dependent on the stage of the cancer. The stage is determined by the size and location of the tumor, the presence of cancer in the surrounding lymph nodes, and spread to distant sites. When lung cancer is treated in its earliest stage the cure rate approaches 70 % or greater. The size of the tumor also impacts on survival, even for tumors discovered at an early stage. The survival is worse for patients whose tumors are greater than 3 cm. than for those who have tumors less than 3 cm in size. It remains to be seen whether detection at an even smaller size (less than 3 cm.) has an even greater impact on survival.

CT screening is the best method to detect lung cancer in its earliest stage. Since the majority of lung cancers originate as a small growth, or nodule in the lung, screening CT scans are extremely sensitive in detecting nodules as small as 2 or 3 mm within the lungs. Screening CT scans are capable of

detecting lung nodules much smaller than by conventional chest X- ray. In fact in the recently published articles on CT screening, the majority of lung cancers that were found on CT scanning could not be detected on the chest X- ray that was performed simultaneously. If a nodule is found on a screening CT scan, than a decision is made to either biopsy the nodule if it appears suspicious for cancer, or to repeat a CT scan within 6 to 12 weeks to determine if the nodule has grown. Should the nodule grow, this is highly suspicious for malignancy, and a recommendation to biopsy the nodule is warranted. If on the other hand the nodule remains stable in size, and does not change, then continued observation is recommended [19]

## **1.1 Objective of the Project**

The specific Objectives of the project are,

1. Study the utilization of image processing of CT lung nodule image.
2. Implement the Computer Method for Synthetic Lung Nodule (CMSLN).
3. Identify real lung nodule for CT image and develop a 3D mesh of real lung nodule.
4. Design and develop a synthetic nodule using Gaussian structure.
5. Insert a synthetic nodule into real lung CT image to make a comparison.

## 1.2 Methodology adopted

To achieve the objectives of the project, some of the CT images of lung cancer were collected from the leading medical institute. Depending upon the various stage of the lung cancer, the lung nodules also vary from one another. So there was a need for complete study to identify a particular nodule, which helps to lead further development.

- To understand the image data acquired during diagnostic CT scan and detect lung nodules in that image.
- A software application was developed by using MATLAB software, which helped to implement the Computer Method for Synthetic Lung Nodule.
- Gaussian structure was adopted to design and develop a synthetic nodule.
- Finally, the developed synthetic nodule was inserted into the CT image to make a comparison with real lung nodule.

*Chapter 2*

**Literature Review**

## 2.0 Image

An image defined in the “real world” is considered to be a function of two real variables for example  $a(x, y)$  with  $a$  as the amplitude (eg. brightness) of the image at the real coordinate position  $(x, y)$ . An image may be considered to contain sub-images sometime referred to as regions-of-interest, ROIs, or simply regions. This concept reflects the fact that images frequently contain collections of objects each of which can be the basis for a region. In a sophisticated image processing operations to selected regions. Thus one part of an image (region) might be processed to suppress motion blur while another part might be processed to improve color rendition.

A digital image  $a[m, n]$  described in 2D discrete space is derived from an analog images  $a(x, y)$  in a 2D continuous space through a sampling processing that is frequently referred to as digitization.

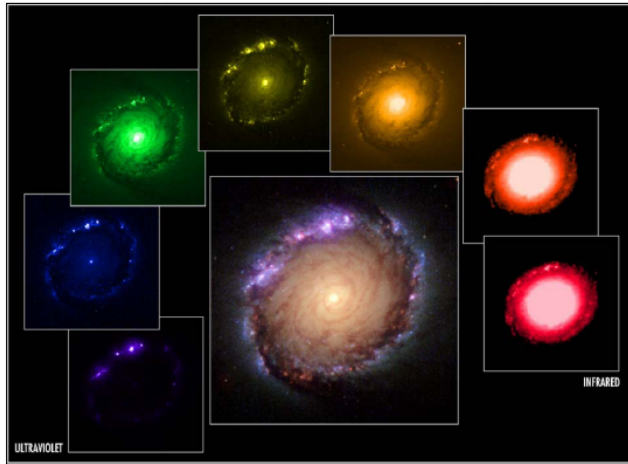


The 2D continuous image  $a(x, y)$  is divided into  $N$  rows and  $M$  columns. The intersection of row and column is termed a pixel. the value assigned to the integer.

Coordinates  $[m, n]$  with  $\{m=0,1,2,3\dots m-1\}$  and  $\{n=0,1,2,3\dots n-1\}$  is a  $[m, n]$ . In fact, in most cases  $a(x, y)$ -which we might consider to be the physical signal

that impinges on the face of a 2D sensor-is actual a function of many variables including depth ( $z$ ), color ( $\lambda$ ) and time ( $t$ ). [19]

## 2.1 Image Processing



(Fig. Shows various stage of Image Processing)

Image processing is the science of manipulating a picture. [2] It covers a broad scope of techniques that are present in numerous applications. These techniques can enhance or distort an image, highlight certain features of an image, create a new image from portions of other image, restore an image that has been degraded during or after the image acquisition, and so on.

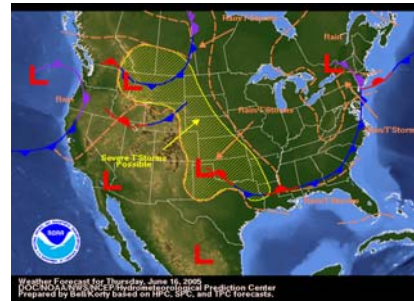
Image processing is often confused with computer graphics. Computer graphics and image processing are companion technologies. Although there are many common concepts between image processing and computer graphics, they are two separate studies. Computer graphics is the generation of synthetic images. Image processing is the manipulation of images that have already been captured or generated. Computer graphics works with 2-dimensional data. Applications in the medical diagnostic industry perform image processing on 3-dimensional data. With the emergence of certain

technologies such as volume visualization and morphing, the dividing line between computer graphics and image processing is getting more hazy.

There are four basic classifications of image processing algorithms: point, area, geometric, and frame processes. Point process modifies a pixel's value based on that pixel's original value or position. An area process modifies a pixel's value based on its original value and the values of neighboring pixels. Geometric processes change the position or arrangement of the pixels. Frame processes generate pixel values based on operations on two or more image.

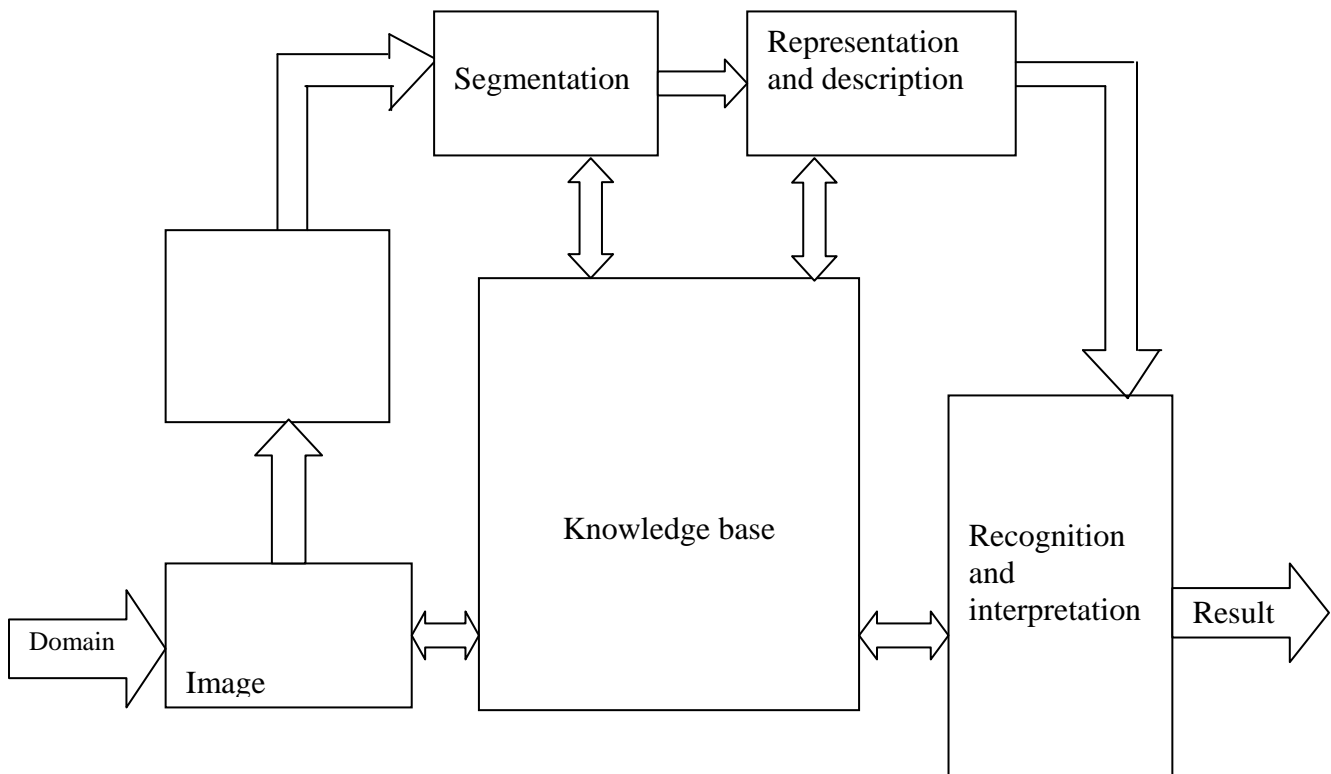


(Fig. Shows Frame Processing)



(Fig. Shows Geometric processing)

## 2.2 Fundamental steps in image processing



*Figure (a) Fundamental steps in image processing*

### **2.2.1 Image acquisition**

The first step in the process is image acquisition, that is to acquire a image. To do so requires an imaging sensor and the capability to digitize the signal produced by the sensor.

The sensor could be a monochrome or color TV camera that produces an entire image of the problem domain every 1/30 sec. The imaging sensor could also be a line-scan camera that produces a signal image line at a time. In this case the object motion past the produces a signal image line at a time .in this case, the object's motion past the line scanner produces a two-dimensional image. If the output of the camera or other imaging sensor is not already in digital from an analog-to –digital converter digitizes it. The nature of sensor and the image it produces are determined by the application. In terms of our example mail reading applications really greatly on line scan camera.[8]

### **2.2.2 Preprocessing**

After a digital image has been obtained the next step deals with preprocessing that image. The key function of preprocessing is to improve the image in way that increases the chances for success of the other processes. In this example, preprocessing typically deals with techniques for enhancing contract, removing noise and isolation regions whose textures indicate a likelihood of alphanumeric information.



### **2.2.3 Segmentation**

The next stage is segmentation. Broadly defined, segmentation partitions an input image into its constituent part or objects. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. On the one hand a rugged segmentation procedures bring the processes a long way towards successful solution of an imaging problem. [8]On the other hand weak or erratic segmentation algorithm almost always guarantee eventual failure. In terms of characters and words from the background.

The output of the segmentation stage usually is raw pixel data, constituting either the boundary of region or all the point in the region itself. In either case converting the data to a form suitable for computer processing is necessary. The first decision that must be made is whether the data should be represented as a boundary or as a complete region. Boundary representation is appropriate when the focus is on external shape characteristic such as is on internal properties, such as texture or skeletal shape. In some application however these representation coexist. This situation occurs in character recognition applications, which often require algorithm based on boundary shape as well as skeletons and other internal properties.

Choosing a representation is only part of the solution for transforming raw data in to a form suitable for sub sequent computer processing. A method must also be specified for describing the data so that features of interest are high lighted. Description also called feature selection, deals with extracting

features that result in some quantitative information of interest or features that are basic for differentiating one class of object from another. In terms of character recognition descriptor such as lakes and bay are powerful features that help differentiate one part of the alphabet from another.

#### **2.2.4 Recognition and Interpretation**

The last stage in figure (a) involves recognition and interpretation. Recognition is the process that assigns a label to an object based on the information provide by its descriptors. Interpretation involves assigning meaning to an ensemble of recognized objects. In terms of our example identifying a character as say a c requires associating the descriptors for that character with the label c. interpretation attempts to assign meaning to a set of labeled entities. For example, a string of five numbers-can be interpreted to be a zip code. So far we have said nothing about the need for prior knowledge or about the interaction between the knowledge base and the processing modules in figure (a)

Knowledge about a problem domain is code into an image processing system in the from of knowledge database. This knowledge may be as simple as detailing regions of an image where the information of information of interest is know to be located, thus limiting the search that has to be conducted in seeking that information. The knowledge base also can be quit complex, such as an inter related list of all major possible defects in a martial inspection problem or an image database containing high-resolution satellite image of a region in connection with change detection application. in additional to

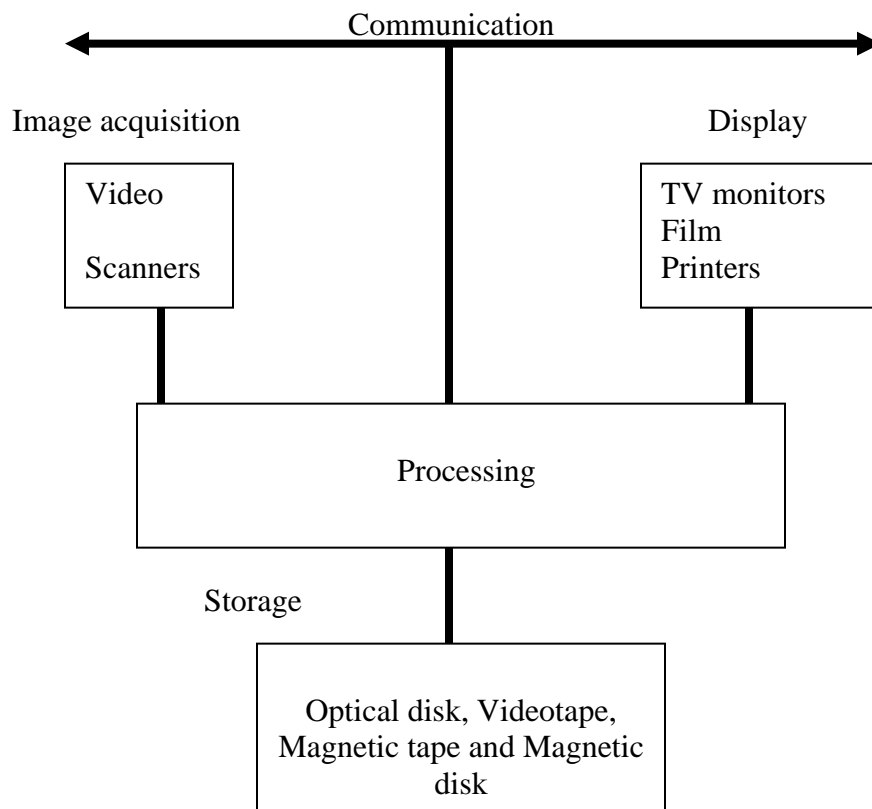
guiding the operation of each processing module, the knowledge base also controls the interaction between modules .This distinction is made in figure (a) by use of double headed arrows between processing modules and the knowledge base as opposed to the single headed arrow linking the processing modules. This depiction indicates that communication between processing modules generally is based on prior knowledge of what a result should be. . This knowledge guides not only the operation of each module, but it also aids in feedback operations between modules through the knowledge base. For instance, a string of numbers in the correct location but consisting of only four characters might lead the interaction module to suspect that two characters are joined. A feedback request through the knowledge base to the segmentation stage for another look is an example of knowledge utilization in performing image processing tasks.

### **2.2.5 Elements of image processing**

The element of general-purpose system capable of performing the image processing operation discussed in section above figure (a)

This type of system generally performs image:

- (1) Acquisition
- (2) Storage
- (3) Processing
- (4) Communication
- (5) Display



### 2.2.5.1 Image acquisition

Two elements are required to acquire images. The first is physical device that is sensitive to a band in the electromagnetic energy spectrum (such as the x-ray, ultraviolet, visible or infrared band) and that produces an electrical signal output proportional to the level of energy sensed. The second called as digitizer is a device for converting the electrical output of the physical sensing device into digital form. [12]

As an example consider the basics of x-ray imaging systems. The output of an x-ray source is directed at an object and a medium sensitive to x ray is placed on the other side of the object. The medium thus acquires an image of materials (such as bones and tissue) having various degrees of x-ray

absorption. The medium itself can be film, television camera combined with a converter of x-ray to photons or discrete detectors whose outputs are combined to reconstruct a image.

## **Cameras**



Most consumer video cameras and all digital cameras use essentially the same type of solid-state chip for acquisition. Some professional video cameras use an older tube-technology that has advantages in terms of resolution, dynamic range and a logarithmic response to light intensity, but has problems of scan distortion, corner darkening (vignetting) and defocusing, and long term stability that can be overcome but only at significant cost (inexpensive tube-type surveillance cameras are not suitable for serious imaging work).

## **Scanners**


If you are using a flatbed scanner, then depending on the interface control, you can vary pixel per inch settings, adjust color balance and brightness, etc. Photoshop saves the pixel per inch setting of scanned images with the image. The image will be displayed normally (that is, with every image pixel shown on the screen) in Photoshop, but if the image is saved in a disk file and later opened in a word processor or some other program, the program may display it in its original dimensions, compressing the detail.

When flatbed scanners are used to acquire images from printed books and magazines, the half-tone pattern in the printing can interact with the spacing of the sensors in the scanner to produce moire patterns. But it is usually a good practice to acquire the image at the highest optical resolution the scanner can provide (not using interpolated resolution), and then reducing the image to the desired resolution and size later in Photoshop. Scanners do not generally average the brightness over the pixel size when used at less than their maximum resolution, but simply sample the brightness by reading at some location within the pixel area; this gives rise to aliasing and moire effects. [7]

**Overhead  
scanners**



Flatbed scanners have a light sensor (generally a CCD) and a light source, both mounted on a moving arm, sweep past the stationary document on a glass platen. Automatic document handlers (ADH) are available on some models, and can increase throughput and lessen operator fatigue for sets of uniform documents in reasonably good condition. A specialized variant of the flatbed scanner is the overhead book scanner, in which the scanner's light source, sensor array and optics are moved to an overhead arm assembly under which a bound volume can be placed face up for scanning.

<p><b>Drum Scanners</b></p> 	<p>Drum scanners produce the highest resolution; highest quality scans of any scanner type, but at a price. Besides their expense, drum scanners are slow, not suitable for brittle documents and require a high level of operator skill. Thus they are typically found in service bureaus that cater to the color pre-press market.</p>
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The various choices of available imaging devices are not enumerated fully or reviewed here. [17] Some of the issues to be taken into account when choosing a camera or scanner are:

- Actual resolution of the images. There is no benefit to acquiring images with these "extra" pixels, which simply require more time for processing and more space for storage.
- Brightness range and whether the acquired image has pixel values that are linear or logarithmic with brightness. For example, covering a range of optical density up to 3.0 or greater is impossible with an 8-bit scanner. Photoshop can open images with 16-bit depth but cannot process or analyze them until they have been reduced to 8 bits (however this reduction need not be linear).
- Sensitivity, especially for low light images such as fluorescence microscopy, and dynamic range, especially for applications such as astronomy where there are simultaneously very bright and very dim features.

- For color acquisition, color fidelity and whether the acquired image corresponds to the actual color temperature of the illumination. True color measurement typically requires standards and highly stable light sources and other electronics.
- Whether the raw image data are transferred to the computer, or whether any compression is introduced (many consumer-level digital cameras use JPEG compression to reduce file size, and this is very bad for subsequent measurement of brightness, color, dimension, etc.).
- Speed of acquisition, whether the rate at which images are grabbed (e.g. 30 frames a second for conventional US television) is adequate or needed to capture changing scenes, to select fields of view and to focus the image. For digital cameras, it is desirable that the camera incorporates a shutter to control the exposure to the entire chip. Some cameras take quite a long time to collect the image.
- File size, which for large format color images can occupy many megabytes of storage.
- Sensitivity to vibration, electromagnetic fields, or other workplace environmental factors. For cameras this can include image distortion due to fields. For scanners a three-pass system may not be able to register the images if there is vibration.
- Noise in the image due to thermal noise in the semiconductor detector, amplifier or digitizer noise, etc., and whether it can be reduced by appropriate shielding of wires, cooling, etc.



- Cost (including the cost of whatever interface may have to be added to the computer).

## **Processing**



Processing of image involves procedures that are usually expressed in algorithm form. Thus with the exception of image acquisition and display most image processing functions can be implemented in software.

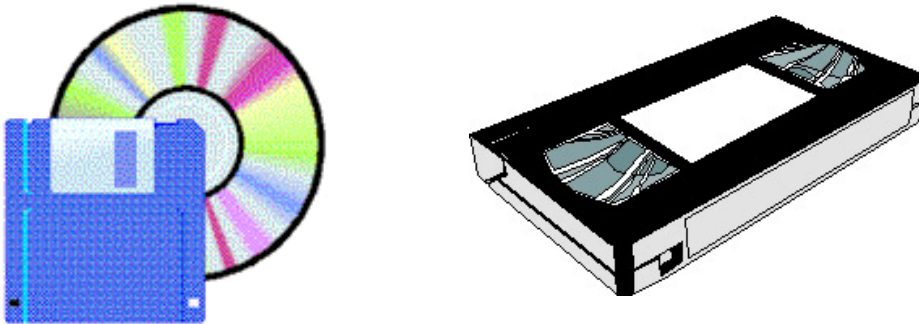
Image processing is characterized by specific solutions. Hence techniques that work well in one area can be totally inadequate in another. All that the availability of powerful hardware and basic software does is to provide a starting point much farther along than a decade ago. The actual solution of a specific problem generally still requires significant research and development.

## **Communication**

Communication in image processing primarily involves local communication between image processing systems and remote communication from one point to another typically in connection with the transmission of image data. Hardware and software for local communication are readily available for most computers. Most books on computer networks clearly explain standard communication protocols.

Communication across vast distances present a more serious challenge if the intent is to communication image data rather than abstracted result. As should be evident by now, images contain a significant amount of data.

## **Storage**



An 8-bit image of size 1024&1024 pixels requires one million bytes of storage. Thus providing adequate storage is usually a challenge in the design of image processing systems. Digital storage for image processing applications fall a into there principal categories.

- (1) Short term storage for use during processing
- (2) On-line storage for relatively fast recall
- (3) Archival storage

Characterized by infrequent access. Storage is measured in bytes (eight bits), Kbytes procedures that are usually expresses 4d in algorithm from. Thus with the exception of image acquisition and display most image processing function can be implemented in software.

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## **Display**



Monochrome and color TV monitors are the principal display devices used in modern image processing systems. Monitor is driven by the output of a hardware image display module in the back plane of the host computer or as part of the hardware associated with an image processor.

## **2.3 Related work**

The number of images available to radiologists is growing rapidly. For example, [14] High Resolution CT (HRCT) imaging protocols of the lungs on single detector scanners typically generate up to 40 images per study, while multi-slice protocols may generate 300-600 high-resolution axial images. Although most lung diseases produce recognizable alteration in the lung

anatomy that can be captured by thin-slice CT scans, it is often difficult and time consuming to analyse images accurately and efficiently by hand. Efficient methods for visualization and image interpretation are required to assist radiologists in focusing their attention on diagnostically interesting events. Such a system should be able to indicate the existence and location of potential abnormalities and to provide measurements and visualization of the size and distribution of abnormalities in order to facilitate diagnosis. His research covers the approach of modeling and visualizing human lung anatomy. The model provides assistance in segmentation and detection of anatomical lung features and patterns of pathology in HRCT lung scans. To facilitate image segmentation and labelling, the model includes both a symbolic representation of the anatomy and a representation in the form of a 3D atlas had been experienced.

They proposed a new recognition method of lung nodules from X-ray CT images using 3D Markov random field (MRF) models. [6] Pathological shadow candidates are detected by a mathematical morphology filter, and volume of interest (VOI) areas, which include the shadow candidates are extracted. The probabilities of the hypotheses that the VOI areas come from nodules (which are candidates of cancers) and blood vessels are calculated using nodule and blood vessel models evaluating the relations between these object models by 3D MRF models.

Medical images generally provide a “snapshot” of a portion of the patient’s anatomy at a particular moment in time. [5] A second image, taken at a later

time, may show obvious differences. Such changes may occur for at least four reasons. First, some image acquisition techniques are dynamic, resulting in a sequence of related images each of which differs from the others. Second, changes between images may result from changes in the image acquisition process, as may occur if the two studies are of different modalities or employ different parameter settings. Third, organs may shift or deform between images as a result of change in the patient's position, respiratory motion, or an external force such as intraoperative retraction. Finally, changes in image objects over time may occur because the patient's anatomy has itself changed, as may happen with progression or regression of pathology, or as may occur with operative resection of tissue.

This author discusses a means of defining tubular objects from 3D image data and of registering such images with other 2- or 3D images that contain at least a subset of the same tubes. Such registration can provide a means of understanding, interpreting, and analyzing a variety of changes that may occur in images taken over time. An advantage of the approach is that blood vessels exist throughout the human body. The methods outlined here are therefore immediately applicable to a wide variety of disease processes, to a large range of image modalities, and to almost any anatomical region.

The author proposed a recognition method of lung nodules based on experimentally selected feature values (such as contrast, circularities, etc.) of pathological candidate regions detected by our Quoit filter. [22] In this paper, we propose a new recognition method of lung nodule using each CT value

itself in ROI (region of interest) area as a feature value. In the clustering stage, first, the pathological candidate regions are classified into some clusters using Principal Component (PC) theories. A set of CT values in each ROI is regarded as a feature vector, and then Eigen vectors and Eigen values are calculated for each cluster by applying Principal Component Analysis (PCA). The Eigen vectors corresponding to the 10 largest Eigen values are utilized as base vectors for subspaces of the clusters in the feature space. In the discrimination stage, correlations are measured between the testing feature vector and the subspace, which is spanned by the Eigen Images. If the correlation with the abnormal subspace is large, the pathological candidate region is determined to be abnormal. Otherwise, it is determined to be normal. By applying our new method, good results have been acquired.

First, to detect cancer shadows, he proposed an image filter called Quoit filter, which is a type of mathematical morphology filter. This filter can automatically detect abnormal shadows with the sensitivity over 95%[22], but it detects many false positives, which are mainly related to blood vessel shadows. In order to reduce such false positives, we developed a discrimination method of cancer shadows based on feature values obtained from pathological candidate regions detected. In this method, they experimentally choose about 15 types of the feature values such as average CT values, modified circularity, and X ray attenuation. However, it could not be guaranteed that they were the optimal combination for recognizing the pathological candidate regions. They also explained a new recognition method

using each CT value itself in a ROI area as a feature value. By applying PCA to these CT values, essential information can be extracted from CT images, and the accuracy of our CAD system is increased drastically.

Author focuses on characterizing the internal intensity structure of pulmonary nodules in thin-section CT images for classification between benign and malignant nodules. [21] This approach makes use of shape index, curvedness, and CT density to represent locally each voxel constructing the three-dimensional (3D) pulmonary nodule image. From the distribution of shape index, curvedness, and CT density over the 3D pulmonary nodule image a set of histogram features, and 3D texture features is computed to classify benign and malignant nodules. Linear discriminant analysis is used for classification and a receiver operating characteristic (ROC) analysis is used to evaluate classification accuracy. The potential usefulness of the curvature-based features in the computer-aided differential diagnosis is demonstrated by using ROC curves as the performance measure.

Nodule segmentation of the 3D pulmonary nodule image consists of three steps as given bellow

- 1) Extraction of lung area
- 2) selection of region of interest (ROI) including the nodule region
- 3) nodule segmentation based on a geometric approach.

This lung area extraction step plays an essential role when part of a nodule in the peripheral lung area touches the chest wall. The ROI including the nodule

was selected interactively. A pulmonary nodule was segmented from the selected ROI image by the geometric approach proposed by Caselle. The geometric approach was based on deforming 3D surfaces, represented by level-sets, toward the nodule boundary to be extracted in the 3D chest image. The deformation process of the used 3D deformable surface mode can automatically stop when the deforming surfaces reach the object boundary to be detected. In their application they controlled a stopping condition to exclude vessels and bronchi which contact the pulmonary nodule.

## **2.4 Applications in Image Processing**

### **Science and space:**



In earlier years image processing was solely by scientists. These scientists were members of the space study community and the department of defense. The space program brought us many image processing techniques. These



techniques have a huge factor in our successful exploration of the solar system.

Over the years NASA has had plenty of images to process. The ranger spacecraft provided hundreds of images of the lunar surface. The surveyor 7 spacecraft returned 21038-television image of its landing site on the moon. The mariner 4, launched in 1964, returned 22 digital images of mars. The Viking missions started in 1975 and they provided over 100000 images of mars. The voyager mission, in 1977, launched two spacecraft that returned a wide range of imagery of outer planet: Saturn, Uranus, Neptune, and Jupiter. These different space probes transmitted images of space back to earth as serial data streams .The data transmission were often interrupted by static and solar flares and the images were corrupted. Reconstruction and filtering techniques removed the noise and restored lost portions of the images. Some of these methods had never before been used and now are used in many fields including electron microscopy, seismography, and medical diagnostics.

**Movies:**



Although Hollywood has always experimented with using computers to generate special effects and touch-up frames the use of computers in

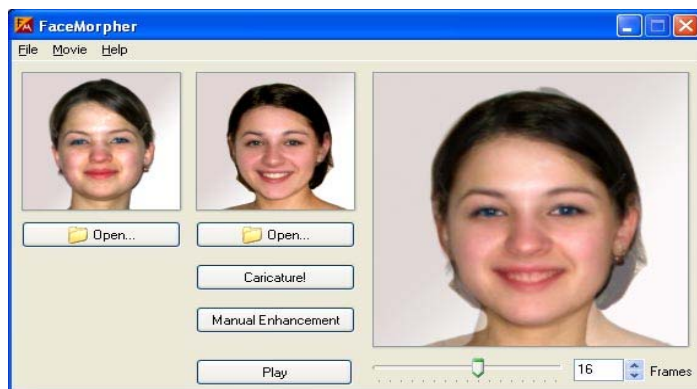
filmmaking has dramatically increased in last few years. Computers transmute one image into another remove unwanted objects from a frame and create new frames by compositing parts of other frames.

### **Image composition:**

Image composition was also used in the movie *forrest Gump*. The protagonist was added to various historical film segments many including U.S presidents. Image compositing was also used in this movie to create large crowds by replicating small groups of people over and over.

Movies are often shot and later digitally cleaned up to make them more presentable ugly power lines, facial wrinkles, or unwanted onlookers can be removed from the frames. In the movie terminator 2, the “good” terminator rides a motorcycle off an embankment falling more than twenty feet. During filming the Davidson was suspended by wires to insure a safe landing later a computer removed the wire rig.

### **Morphing:**



One of the newer image processing techniques used by Hollywood is morphing. The first use of morphing in a movie was in *Willow*. Willow, the

protagonist, uses his magic wand with which he is not a turtle, then into a tiger, and finally to turn into a sorceress. The processing for the film was done by industrial light and magic (ILM).

Morphing has found its way in to television commercials and music videos. Pacific Data Image (PDI) used morphing to transform a 1990 Plymouth Voyager van into the 1991 model. In an Exxon commercial, PDI transforms a moving car into a running tiger. In Michael Jackson music video, *Black or White* a series of dancers' faces are transformed into each other. Jackson himself is also morphed as he turns into and out of a black panther during the video.

### **Image warping:**

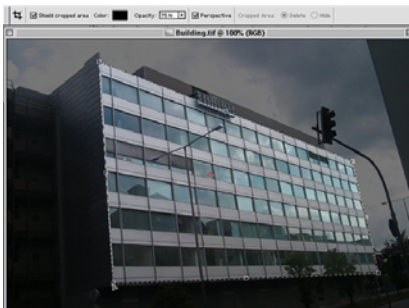


Image warping is not always used for bizarre transformations. It can be used to alter live action to make an actor taller or shorter, thinner or fatter. It can reduce the size of a noise or alter other physical features.

Image warping was first used to straighten distorted pictures returned from satellites and various space missions. The distortions were introduced by lens aberrations or because the subject matter was spherical rather than a flat plane. Image warping via geometric transforms was used to invert these

distortions and allow a more accurate determination of scale and spatial relationships.

### **The paperless office**



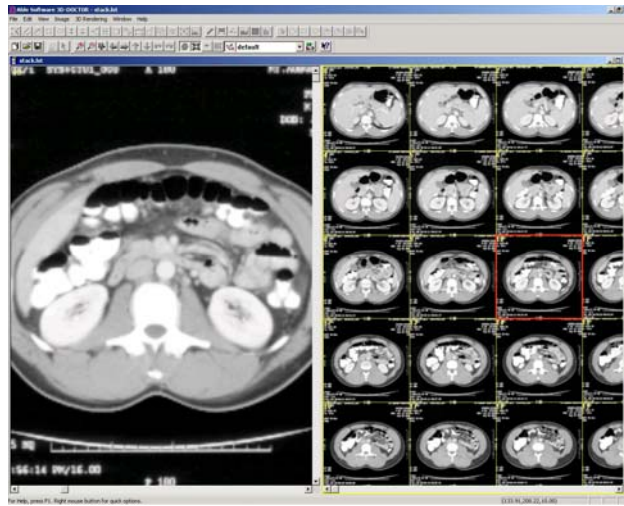
A current trend is the paperless office. In the ideal situation all documents are stored digitally and retrieved to a CRT or some other display this is done with document image processing (DIP). Estimates claim that American businesses produce 1 trillion page of paper documents a year in this environmental age finding way to conserve paper is very important.

DIP system can preserve document as ASCII text. This allows documents to be searched for specific occurrences of text. To do this the black mark on a white document must be converted to text. This is accomplished with optical character recognition (OCR). OCR is not classified as image processing but as a similar science, image analysis.

Many businesses that must keep track of thousands of documents are using DIP. Banks are using DIP to archive processed checks, loan applications and account statement. Governments are storing property deeds and titles; voter

registration forms; birth, marriage, and death certificates. Hospitals are using DIP to keep track of thousands of medical images, insurance forms, record of procedures and personnel and patients' record.

## 2.5 Medical image processing



Medical industry has long been a user of image processing there are various well-known imaging technologies used including X-ray and ultrasound. [2] Computed Topography or Computer Aided Tomography (CT and CAT), wasn't widely used until the 1980s. Doctors use CT scanners to diagnose skeletal sites such as the spine, head and pelvis. Magnetic resonance imaging (MRI) offers views of soft tissues, such as the spinal cord and heart. Positron emission tomography (PET) shows measurements of the body's chemical and physical processes. Magnetic source imaging (MSI) monitors the tiny electrical signal in the brain during thinking and motor functions.

All these images when stored in a computer can be enhanced and manipulated so that a doctor can focus on the area of interest. Much of this medical imagery can be sampled in three dimensions. This allows doctors to rotate and translate portions of the image on the screen for study. These animated reconstructions of medical data are invaluable to doctors and surgeons.

Another advantage to digitized medical imagery is the ability for doctors to diagnose patients across long distances. The image data can be transferred in minutes to a doctor at a remote location. Patients can be diagnosed without leaving their local hospital.

Image processing systems are being used to determine the effectiveness of chemotherapy treatment on patients with liver tumors. A system developed by researchers at the City Polytechnic of Hong Kong detects and computes the penetration and distribution of chemotherapeutic drugs throughout a liver tumor. It builds a 3-dimensional model of the tumor showing just where the drug has reached, providing doctors critical feedback regarding the success of the drugs. It may also be used to establish the effectiveness of chemotherapy in treating cancer of other organs.

A system designed by Quantec Image Processing Limited (Liverpool, England) can detect scoliosis, a spinal deformity that afflicts 1 in 200 children. The system works by first projecting light in a pattern of horizontal lines onto the computer. The software then creates a 3-dimensional reconstruction of the surface for analysis. Medical personnel can then view the back from any angle. There are two big advantages of this system over common X-rays. The first is that it uses halogen light so the side effects of radiation are not present. The

second advantage is cost of an X-ray is well over 50 while the scan is around 50 cents.

Medical imaging technology is not limited to the study of human's scanners are allowing paleontologists to study dinosaur fossils. Glen daleo, a CT saner differentiate between a fossil and the rock in which it is embedded. This technique for image acquisition combined with image processing software from cemax Inc allows paleontologist and curator of the museum of the Rockies (Boseman, MT) uses this imaging technology to study dinosaur fossils. This new technology allows paleontologist to see the parts of a fossils. This new technology allows paleontologist to see the parts of a fossil was to obtain this information without destroying the fossil in the process. Now scientists can study fossilized dinosaur eggs of which fewer than 200 have been found.

Image of various kinds are increasingly important to medical diagnostic processes [22] and difficult problems are encountered in selecting the most appropriate imaging modalities acquiring optical quality images and processing images to obtain the highest quality information.

*Chapter 3*

**Computed  
Tomography (CT)  
Scan**



### 3.0 History of CT Scan

Computed Tomography (CT) imaging is also known as "CAT scanning" (Computed Axial Tomography). Tomography is from the Greek word "tomos" meaning "slice" or "section" and graphia meaning "describing". [18]

CT was invented in 1972 by British engineer Godfrey Hounsfield of EMI Laboratories, England, and independently by South African born physicist Allan Cormack of Tufts University, Massachusetts. Hounsfield was later awarded the Nobel Peace Prize and honored with Knighthood in England for his contributions to medicine and science.



The first clinical CT scanners were installed between 1974 and 1976. The original systems were dedicated to head imaging only, but "whole body" systems with larger patient openings became available in 1976. CT became widely available by about 1980. There are now about 6,000 CT scanners installed in the U.S. and about 30,000 installed worldwide.

The first CT scanner developed by Hounsfield in his lab at EMI took several hours to acquire the raw data for a single scan or "slice" and took days to reconstruct a single image from this raw data. The latest multi-slice CT

systems can collect up to 4 slices of data in about 350 ms and reconstruct a 512 x 512-matrix image from millions of data points in less than a second. An entire chest (forty 8 mm slices) can be scanned in five to ten seconds using the most advanced multi-slice CT system.

During its 25-year history, CT has made great improvements in speed, patient comfort, and resolution. As CT scan times have gotten faster, more anatomy can be scanned in less time. Faster scanning helps to eliminate artifacts from patient motion such as breathing or peristalsis. CT exams are now quicker and more patient friendly than ever before. Tremendous research and development has been made to provide excellent image quality for diagnostic confidence at the lowest possible x-ray dose.

### **3.1 CT Scan: How does works**

Computed Tomography is based on the x-ray principal: as x-rays pass through the body they are absorbed or attenuated (weakened) at differing levels creating a matrix or profile of x-ray beams of different strength. This x-ray profile is registered on film, thus creating an image. In the case of CT, the film is replaced by a banana shaped detector which measures the x-ray profile.



*Outside view of modern CT system showing the patient table and CT scanning patient aperture*

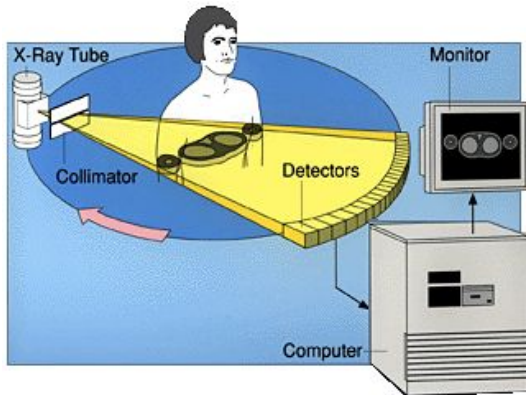


*Inside view of modern CT*

*system, the x-ray tube is on the top at the 1 o'clock position and the arc-shaped CT detector is on the bottom at the 7 o'clock position. The frame holding the x-ray tube and detector rotate around the patient as the data is gathered.*

A CT scanner looks like a big, square doughnut. The patient aperture (opening) is 60 cm to 70 cm (24" to 28") in diameter. [18] Inside the covers of the CT scanner is a rotating frame which has an x-ray tube mounted on one side and the banana shaped detector mounted on the opposite side. A fan beam of x-ray is created as the rotating frame spins the x-ray tube and detector around the patient (see figure below). Each time the x-ray tube and detector make a 360° rotation, an image or "slice" has been acquired. This "slice" is collimated (focused) to a thickness between 1 mm and 10 mm using lead shutters in front of the x-ray tube and x-ray detector.

As the x-ray tube and detector make this 360° rotation, the detector takes numerous snapshots (called profiles) of the attenuated x-ray beam. Typically, in one 360° lap, about 1,000 profiles are sampled. Each profile is subdivided spatially (divided into partitions) by the detectors and fed into about 700 individual channels. Each profile is then backwards reconstructed (or "back projected") by a dedicated computer into a two-dimensional image of the "slice" that was scanned.



*Diagram showing relationship of x-ray tube, patient, detector, and image reconstruction computer and display monitor*

Multiple computers are used to control the entire CT system. The main computer that orchestrates the operation of the entire system is called the "host computer." There is also a dedicated computer that reconstructs the "raw CT data" into an image. A workstation with a mouse, keyboard and other dedicated controls allows the technologist to control and monitor the exam. The CT gantry and table have multiple microprocessors that control the rotation of the gantry, movement of the table (up/down and in/out), tilting of the gantry for angled images, and other functions such as turning the x-ray beam on an off.[18]

CT scan usually taken 30 to 90 minutes, but because of delay that can occur you should allow at least hour for the test. Drink lot of liquid and urinate frequently for 24 hours following the scan to help flush the contrast material out of our body.

During CT scan, patient will feel no discomfort from the X-ray. However the table where patient lie on may feel hard and the room may be chilly because air-conditioning is used to keep the X-ray equipment at a constant

temperature. He/she may become uncomfortable from lying in one position for a long time. Some people feel discomfort or anxiety (claustrophobia) when placed inside the CT scanner. If this keeps him/her from lying still in the scanner, a medication may be given to help relax him/her.

If contrast material is injected into patient's arm, he/she may feel warm and flushed and get a metallic taste in his/her mouth. In rare cases the IV contrast material may cause nausea, vomiting, or a headache.

### **3.2 Professionals who perform CT Scan**

Like all medical imaging examinations, computed tomography (CT) imaging requires a team effort. The computed tomography patient care team is headed by a radiologist. Other team members include CT technologists and often a nurse who specializes in administering injections. Each of these professionals has an important set of responsibilities, described below.

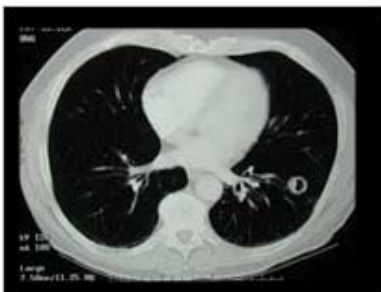


*The technologist seated at the CT control console and the radiologist discuss the patient's study*

The Radiologist is a physician with specialist training (residency or fellowship training) who may be board-certified. [18]After obtaining his or her medical doctorate (MD) or doctor of osteopathy (DO) degree, these physicians have additional special radiological training making them eligible for examination by the American Board of Radiology. This training includes special instruction in the safe use of x-ray radiation and the use and interpretation of CT images. The radiologist interprets the CT images and sends a report to the referring physician. The radiologist may also administer or oversee the contrast injection. The radiologist will perform any CT guided biopsy procedure or other intervention.

The CT Technologist is specially trained to operate the sophisticated CT systems. Typically, CT technologists have had two or more years of training in x-ray and computed tomography and are certified by the American Registry of Radiologic Technologists (ARRT). The CT technologist performs the patient examination under the supervision of the radiologist. The CT technologist may also administer the contrast injection required for some CT examinations.

### **3.3 CT Applications and Clinical Benefits of CT Imaging**



*High resolution axial CT image of the chest showing the vessels of the heart (center of image) and pneumonia in the both lungs.*

Unlike other medical imaging techniques, such as conventional x-ray imaging (radiography), CT enables direct imaging and differentiation of soft tissue structures, such as liver, lung tissue, and fat. CT is especially useful in searching for large space occupying lesions, tumors and metastasis and can not only reveal their presence, but also the size, spatial location and extent of a tumor.

CT imaging of the head and brain can detect tumors, show blood clots and blood vessel defects, show enlarged ventricles (caused by a build up of cerebrospinal fluid) and image other abnormalities such as those of the nerves or muscles of the eye.

Due to the short scan times of 500 milliseconds to a few seconds, CT can be used for all anatomic regions, including those susceptible to patient motion and breathing. For example, in the thorax CT can be used for visualization of nodular structures, infiltrations of fluid, fibrosis (for example from asbestos fibers), and effusions (filling of an air space with fluid).

CT has been the basis for interventional work like CT guided biopsy and minimally invasive therapy. CT images are also used as basis for planning radiotherapy cancer treatment. CT is also often used to follow the course of cancer treatment to determine how the tumor is responding to treatment.

CT imaging provides both good soft tissue resolution (contrast) as well as high spatial resolution. This enables the use of CT in orthopedic medicine and imaging of bony structures including prolapses (protrusion) of vertebral discs,

imaging of complex joints like the shoulder or hip as a functional unit and fractures, especially those affecting the spine. The image post processing capabilities of CT - like multiplanar reconstructions and 3-dimensional display (3D) - further enhance the value of CT imaging for surgeons. For instance, 3-D CT is an invaluable tool for surgical reconstruction following facial trauma.



*Axial CT image of the lumbar spine showing a slight prolapse of the disk impinging on the spinal cord.*

CT is becoming the method of choice for imaging trauma patients. CT exams are fast and simple and enable a quick overview of possibly life-threatening pathology and rapidly enables a dedicated surgical treatment.

### **3.4 Risks in CT Scan**

- The risk of a CT scan causing a problem is small. There is a slight risk of developing an allergic reaction to the iodine contrast material. The reaction can be mild (itching, rash) or severe (difficulty breathing or sudden shock).
- Death resulting from an allergic reaction is rare. Most reactions can be controlled using medication. Be sure to tell your health professional if you have allergies of any kind, such as hay fever, iodine allergy eczema, hives, or food allergies.



- The contrast material used during CT scanning can cause water loss or damage to the kidneys that may lead to kidney failure. This is a concern if you are dehydrated or have poor kidney function. If you have a history of kidney problems, blood tests (creatinine, blood urea nitrogen) may be done before the CT scan to check that your kidneys are functioning properly. For more information, see the medical tests creatinine and creatinine clearance and blood urea nitrogen.
- If contrast material is used you may be at risk for kidney problems if you have diabetes, especially if you take metformin (Glucophage). You will need to stop taking metformin for a period of time before the test and resume taking it as directed by your doctor or the radiologist.
- There is always a slight risk of damage from being exposed to any radiation, including the low levels of X-rays used for CT scan. However, the risk of damage from the X-rays is usually very low compared with potential benefits of the test.

*Chapter 4*

**Image Processing  
for  
Lung Nodules**

## **4.0 Nodules**

A nodule is usually a small round shadow seen on chest x-ray anywhere in the lung. A 2 to 3 mm nodule is very small. The smaller the nodules the less likely it is to be cancer. You should get your previous chest x-ray so they can be compared with the most recent. If this nodule was on previous chest x-ray taken or more years ago and is unchanged, no further testing is needed.

Nodules are due to infections, inflammation, or tumor. It's possible for pneumonia to cause a nodule directly from the infection itself or indirectly by the infection causing inflammation. A granuloma is a nodule of inflammation that can occur in any part of the body.

### ***4.1 Lung Nodules***

A nodule is defined as a relatively round lesion that is less than three centimeters in diameter. A lung nodule is located within the lung itself, not in the airways. Nodules may range from a few millimeters up to 4cm. [18] A patient with a lung nodule usually experiences no symptoms; the nodule is most often detected on a chest x-ray. More than half of solitary or single nodules within the chest are benign, or non-cancerous, usually due to a previous infection. However, all solitary chest nodules are considered potentially malignant until proven otherwise, and for this a needle biopsy may be required.

A biopsy involves removing a small piece of tissue for examination by a physician. A needle biopsy, sometimes called a needle aspiration, is the easiest way that tissue can be safely removed from the body. The procedure, which is

most often performed by a radiologist or interventional radiologist, involves a needle that is inserted through the skin. The needle biopsy may use a syringe or an automated needle to obtain the tissue sample.

## **4.2 Limitations of Needle Biopsy of Lung Nodules**

In a small number of cases, the tissue obtained during a biopsy may not be adequate for diagnosis. [18]

Needle biopsy is not cost-effective for small lesions one to two millimeters in diameter. The needle is too difficult to position into the nodule and the nodule is too small to provide enough tissue for an accurate diagnosis.

For patients with certain conditions associated with emphysema, lung cysts, blood coagulation disorder of any type, insufficient blood oxygenation, pulmonary hypertension, and certain heart failure conditions, a needle biopsy may not be recommended. In these situations, your physician and the physician performing the biopsy will work together to help decide the best course of treatment. Alternatives to lung biopsy usually include continued follow-up with imaging and surgical removal of the abnormality.

### **4.3 Synthetic Lung Nodules**

A synthetic nodule is like a real but it will simulate through Gaussian structure. The analysis of a real lung nodule, which leads to the Gaussian structure being used for creating synthetic nodules. The size and shape characteristics of real lung nodules are incorporated into the nodules synthesis technique. A synthetic nodule is then created, analyzed and compared to the real lung nodule. Finally, the applicability and benefits of our simulation technique to lung nodule segmentation technique development are offered.

In this project MATLAB is used to create 3D mesh of real lung nodule and simulate the synthetic 3D mesh for further analysis.

### **4.4 Gaussian structure**

The Gaussian smoothing operator is a 2-D convolution operator that is used to 'blur' images and remove detail and noise. In this sense it is similar to the mean filter, but it uses a different kernel that represents the shape of a Gaussian ('bell-shaped') hump. This kernel has some special properties which are detailed below. [1]

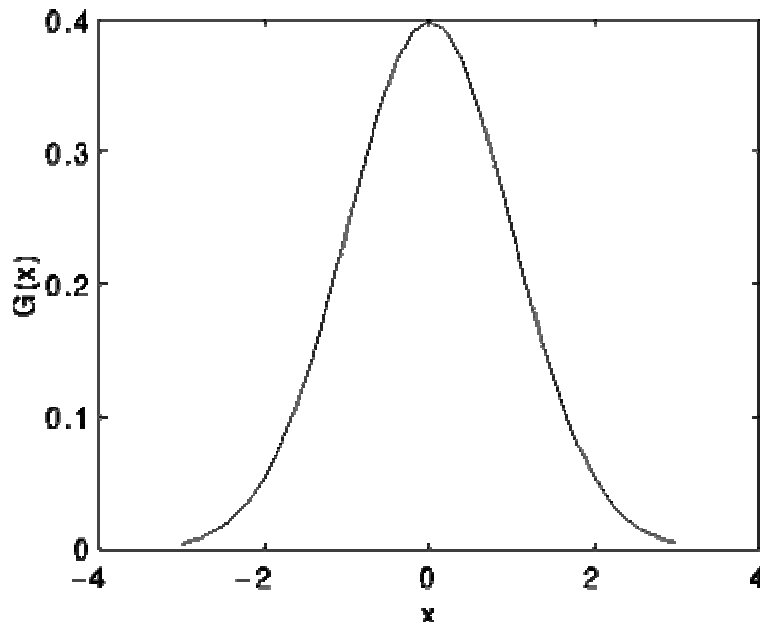
#### **How It Works**

The Gaussian distribution in 1-D has the form:

$$G(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2}{2\sigma^2}}$$

Where  $\sigma$  is the standard deviation of the distribution.[3]We have also assumed that the distribution has a mean of zero (*i.e.* it is centered about the line  $x=0$ ).

The distribution is illustrated in Figure 1.

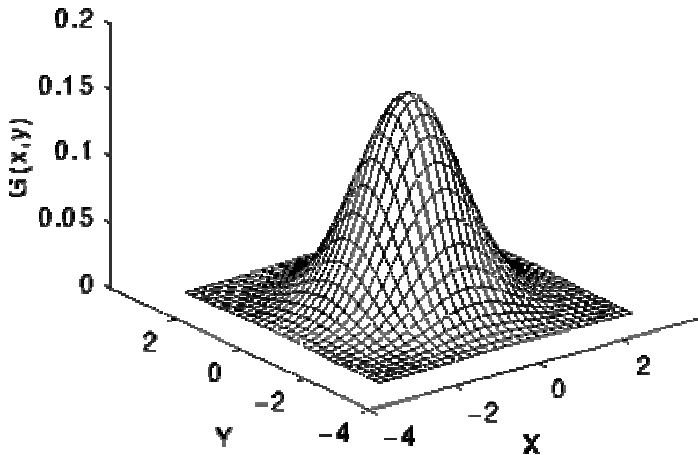


**Figure 1** 1-D Gaussian distribution with mean 0 and  $\sigma=1$

In 2-D, an isotropic (*i.e.* circularly symmetric) Gaussian has the form:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

This distribution is shown in Figure 2.



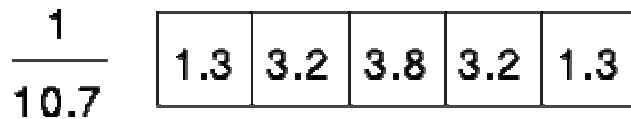
**Figure 2** 2-D Gaussian distribution with mean (0,0) and  $\sigma=1$

[4]The idea of Gaussian smoothing is to use this 2-D distribution as a 'point-spread' function, and this is achieved by convolution. Since the image is stored as a collection of discrete pixels we need to produce a discrete approximation to the Gaussian function before we can perform the convolution. In theory, the Gaussian distribution is non-zero everywhere, which would require an infinitely large convolution mask, but in practice it is effectively zero more than about three standard deviations from the mean, and so we can truncate the mask at this point. Figure 3 shows a suitable integer valued convolution mask that approximates a Gaussian with a  $\sigma$  of 1.4.

	2	4	5	4	2
	4	9	12	9	4
$\frac{1}{115}$	5	12	15	12	5
	4	9	12	9	4
	2	4	5	4	2

**Figure 3** Discrete approximation to Gaussian function with  $\sigma=1.4$

Once a suitable mask has been calculated, [10] then the Gaussian smoothing can be performed using standard convolution methods. The convolution can in fact be performed fairly quickly since the equation for the 2-D isotropic Gaussian shown above is separable into  $x$  and  $y$  components. Thus the 2-D convolution can be performed by first convolving with a 1-D Gaussian in the  $x$  direction, and then convolving with another 1-D Gaussian in the  $y$  direction. (The Gaussian is in fact the *only* completely circularly symmetric operator, which can be decomposed in such a way.) Figure 4 shows the 1-D  $x$  component mask that would be used to produce the full mask shown in Figure 3. The  $y$  component is exactly the same but is oriented vertically.



**Figure 4** One of the pair of 1-D convolution masks used to calculate the full mask shown in Figure 3 more quickly.

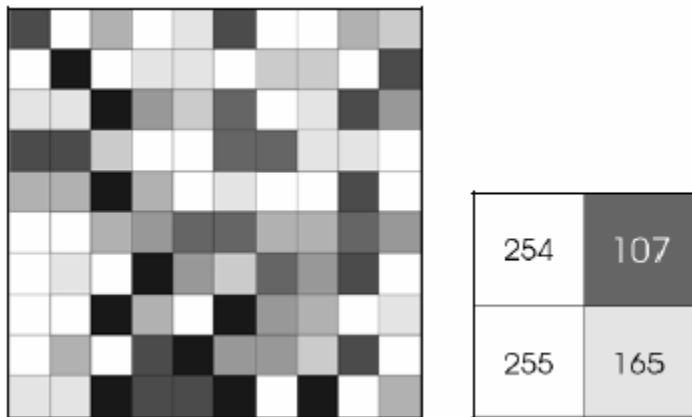
A further way to compute a Gaussian smoothing with a large standard deviation is to convolve an image several times with a smaller Gaussian. While this is computationally complex, it can have applicability if the processing is carried out using a hardware pipeline.

The Gaussian filter not only has utility in engineering applications. [11] It is also attracting attention from computational biologists because it has been attributed with some amount of biological plausibility, *e.g.* some cells in the visual pathways of the brain often have an approximately Gaussian response.



## 4.5 Gray Scale

In a (8-bit) gray scale image each picture element has an assigned intensity that ranges from 0 to 255. A gray scale image is what people normally call a black and white image, but the name emphasizes that such an image will also include many shades of gray. [20]



**Figure 2: Each pixel has a value from 0 (black) to 255 (white). The possible range of the pixel values depend on the colour depth of the image, here 8 bit = 256 tones or grayscales.**

A normal grayscale image has 8 bit colour depth = 256 grayscales. A “true colour” image has 24 bit colour depth =  $8 \times 8 \times 8$  bits =  $256 \times 256 \times 256$  colours = ~16 million colours.



**Figure 3: A true-colour image assembled from three grayscale images coloured red, green and blue. Such an image may contain up to 16 million different colours.**

Some grayscale images have more grayscales, for instance 16 bit = 65536 grayscales. In principle three grayscale images can be combined to form an image with 281,474,976,710,656 grayscales.

There are two general groups of 'images': vector graphics (or line art) and bitmaps (pixel-based or 'images'). Some of the most common file formats are:

GIF — an 8-bit (256 colour), non-destructively compressed bitmap format.

Mostly used for web. Has several sub-standards one of which is the animated GIF.

JPEG — a very efficient (i.e. much information per byte) destructively compressed 24 bit (16 million colours) bitmap format. Widely used, especially for web and Internet (bandwidth-limited).

TIFF — the standard 24 bit publication bitmap format. Compresses non-destructively with, for instance, Lempel-Ziv-Welch (LZW) compression.

PS — Postscript, a standard vector format. Has numerous sub-standards and can be difficult to transport across platforms and operating systems.

PSD — a dedicated Photoshop format that keeps all the information in an image including all the layers.

## **4.6 Filtering**

There are many other 2D image filters available. Some of them are more complex, some others are simpler. [16]Factor represents the "high end" image

filter. It performs a complex combination of linear and non linear processing of image data. As a result of this processing, you get images that are sharper than originals and much less noisy than originals. That is a very difficult job that few of other image filters can do.

In order to get sharpening combined with noise suppression, an image filter must use non linear processing of the image data. Such processing must be tuned individually for each image. Unlike many other filters Facor filter does not need tuning of its parameters for every new image. You specify what kind of processing you like in a configuration file and then you can filter millions of different images with this configuration. Unique Facor's adaptive algorithm tunes Facor for every image.

Finally, non linear processing of image data often causes distortions. They appear as either absence of some details in processed images or appearance of structures that were not present in original images (artifacts). Unlike other filters, Facor preserves all details and does not add any artifacts.

That is why Facor is suitable for the most demanding applications, including processing of medical diagnostic images.

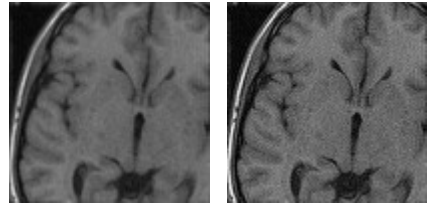
## **Applications**

Facor is a very flexible image filter. It can be tuned to give the best results for almost all types of images. Its major application today is processing of the medical diagnostic images, mainly MR images.

## Linear filters

Linear filters change images by suppressing some spatial frequencies and (or) emphasizing other frequencies in an image. An emphasis of high frequencies makes images sharper. On the contrary, suppression of high frequencies reduces a noise. The problem of linear filters is that they are unable to suppress noise and make an image sharper simultaneously. Therefore the contrast of details remains the same. Here are the examples:

MR image of a head



MR image of a wrist

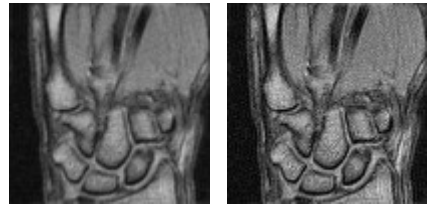


Photo image



*Chapter 5*

*Computer method  
for  
Synthetic Lung  
Nodules (CMSLN)*

## 5.0 MATLAB

*MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation. [15] Using MATLAB, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and Fortran*

### Overview and Key Features

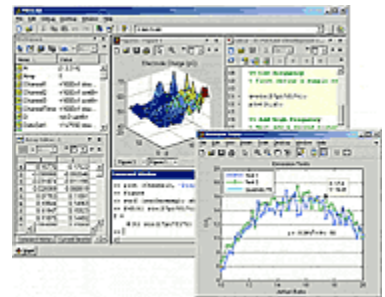
Importing and Exporting Images

Pre- and Post-Processing Images

Analyzing Images

Visualizing Images

Spatial Transformations and Image Registration

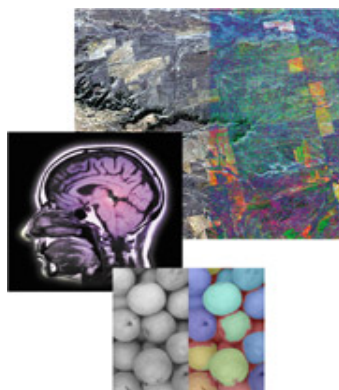


MATLAB provides a comprehensive set of reference-standard algorithms and graphical tools for image processing, analysis, visualization, and algorithm development. We can restore noisy or degraded images, enhance images for improved intelligibility, extract features, analyze shapes and textures, and register two images. We can inspect the algorithms, modify the source code, and create own custom functions.

The Image Processing supports engineers and scientists in areas such as biometrics, remote sensing, surveillance, gene expression, microscopy, semiconductor testing, image sensor design, color science, and materials

science. It also facilitates the learning and teaching of image processing techniques.

- Image enhancement, including linear and nonlinear filtering, filter design, deblurring, and automatic contrast enhancement
- Image analysis, including texture analysis, line detection, morphology, edge detection, segmentation, region-of-interest (ROI) processing, and feature measurement
- Color image processing, including color space conversions and device-independent ICC profile import and export
- Spatial transformations and image registration, including a graphical tool for control-point selection
- Image transforms, including FFT, DCT, Radon, and fan-beam projection
- DICOM import and export
- Interactive image display and modular tools for building image GUIs
- Support for multidimensional image processing



The Image Processing Toolbox includes algorithms for decorrelation stretching (top), color image processing (center), and watershed-based segmentation (bottom).

## 5.1 Processing in CMSLN

### 5.1.1 A Method for Synthesizing Lung Nodules

CT images of real lung nodule cases formed the basis for the lung nodule insertion technique. The following figure 1.a shows a CT images with a nodule. [9]

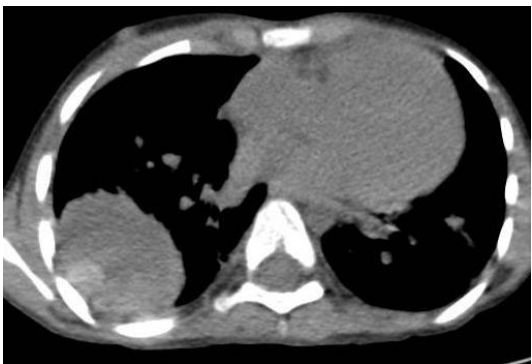


Figure 1.a: CT image with nodules

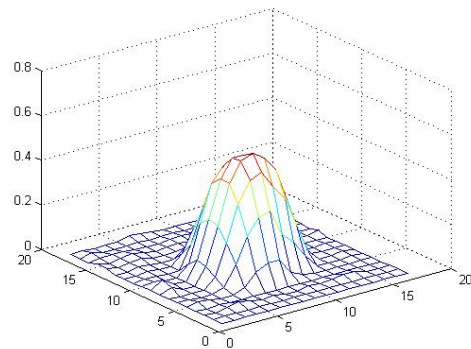


Figure 1.b: 3D mesh for real nodule

In Figure 1.b shows the nodule resembles a sharp bell shaped structure. Based on this observation a Gaussian shape was used for the synthetic nodule structure. This shape has been used as a structural base in other experiments involving synthetic nodules. The magnitude and standard deviation of the Gaussian are all parameters that can be manipulated. The following formulas are used to create the Gaussian that forms the basis for the synthetic nodule.

(a)

This result is then sampled to create an  $M \times N$  matrix,  $G[m,n]$  centred on the origin. The sample period is equal to 1 as the sampling period. The Gaussian is a symmetric 2D intensity

$$G(x,y) = e^{-\frac{(x^2+y^2)}{2\sigma^2}}$$



image. The next step in the creation of the synthetic lung nodule addresses this issue. A random, asymmetric matrix is added to the Gaussian to provide it with an authentic look [4].

$$R[m,n] = \text{random}_{m,n}$$

$\text{random}_{m,n} \in [-a,a]$ , distributed uniformly

$$F[m,n] = \alpha \times G[m,n] + \beta \times R[m,n]$$

(b)

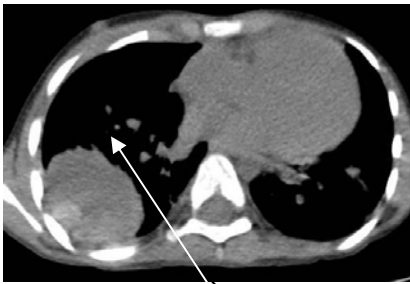
In (b)  $\alpha$  and  $\beta$  are scaling terms. The final steps id to take the modified Gaussian,  $F[m,n]$ , and insert it into a real CT image. [9]This is done using a Graphical User Interface (GUI) that reads in the DICOM image data. To blend the nodule smoothly into the image any values of the nodule that are less than those of the image at the insertion coordinates are replaced with the original image value. The parameters that determine the appearance of the nodule are accessible in the GUI. These parameters are the peak intensity and standard deviation of the base Gaussian, the dimensions M and N of the sampling matrix and the interval of the random matrix. The process of inserting the nodule involves adjusting the parameters until the inserted nodule appears as desired by the user.

### **5.1.2 Experimental try-out and discussions**

A CT image of a patient, who has lung cancer, was collected from a leading medical institute for this experiment. A software application was developed

using MATLAB to analyse the lung nodules. This application has following features:

1. Identify the real nodules in the CT image. The following figure2 shows the real nodule present in the CT image.



Real nodule

Figure 2: Real nodule present in the CT image

2. The figure 3.a and 3.b shows a 3D mesh and surface of real lung nodule.

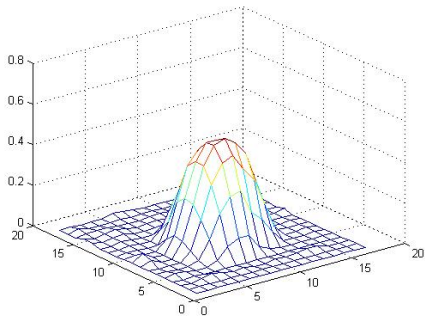


Figure 3.a : 3D Mesh for real nodule

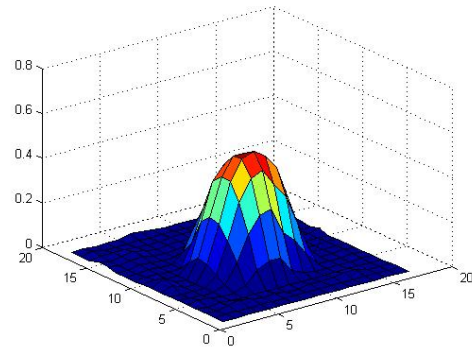
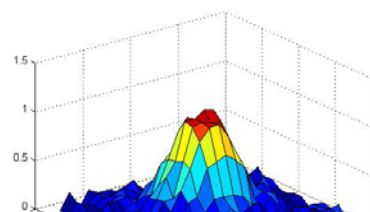
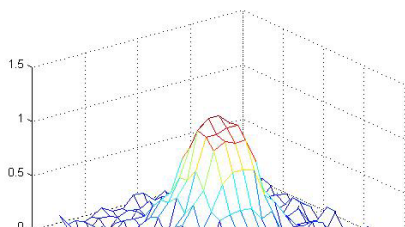


Figure 3.b : 3D surface for real nodule

3. Using Gaussian structure (a) and random asymmetric matrix a synthetic nodule is created.



4. A synthetic nodule, which developed using Gaussian, is inserted into CT image. The following fig shows an inserted synthetic nodule and real nodule of the CT image.

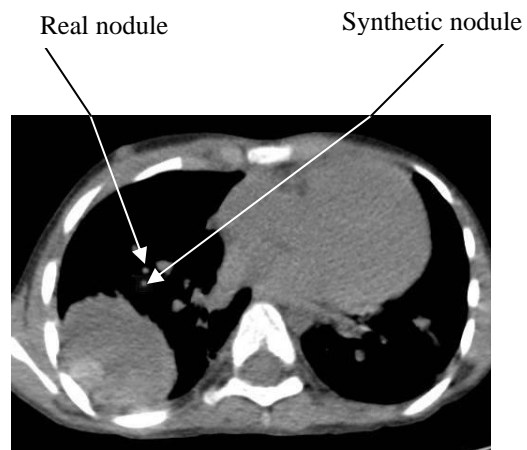
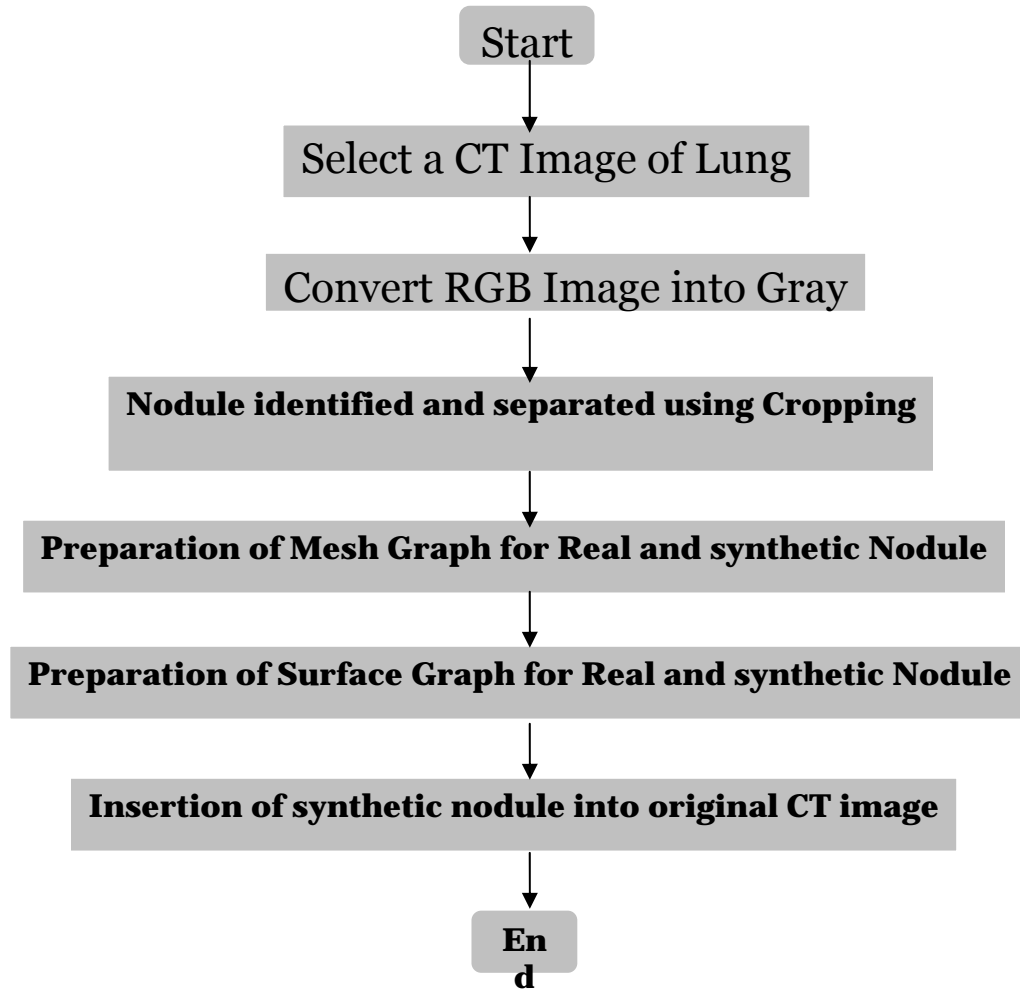


Figure 5: Image containing real and synthetic nodules

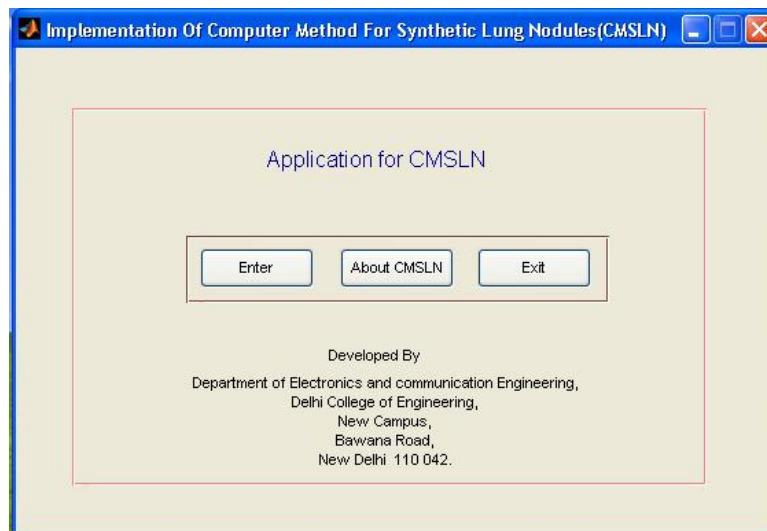
## 5.2 Flowchart



## 5.3 User Manual for implementation of CMSLN

### Application for CMSLN

This software is designed to identify a real nodule and measure its parameters. A synthetic nodule is created by using these parameters based on Gaussian structure. Invoking the software prompts with the main entry screen having the following buttons embedded with it, viz., “Enter”, “Exit”, “About

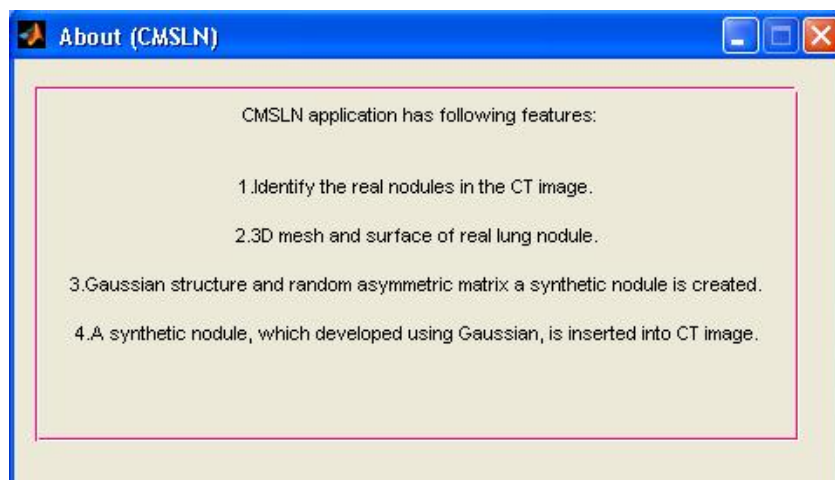


Function of the buttons

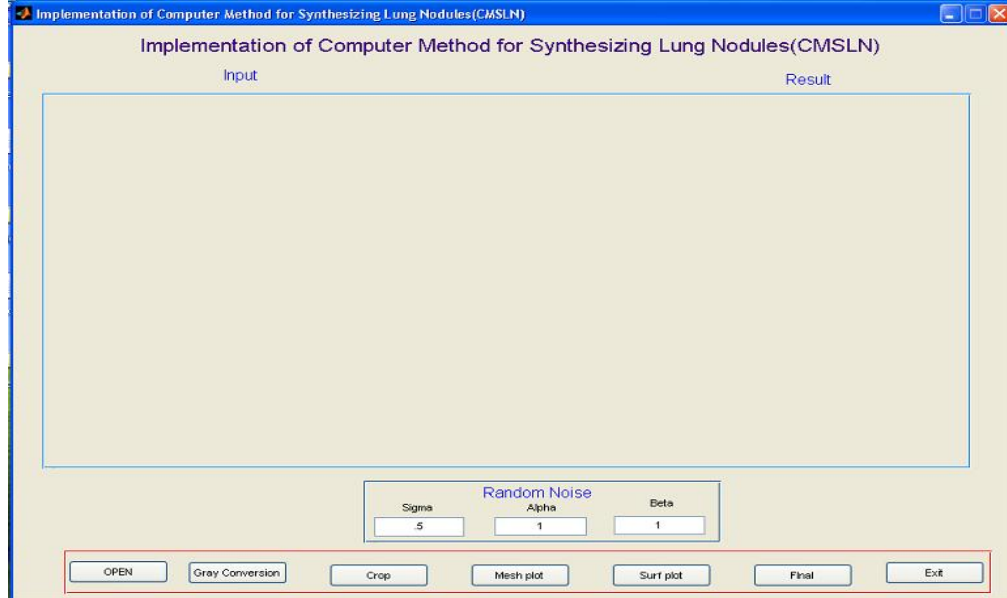
**Enter** – User logs in to the software by clicking this button.

**Exit** – User exits the utility.

**About** – Pops up a brief note about the utility

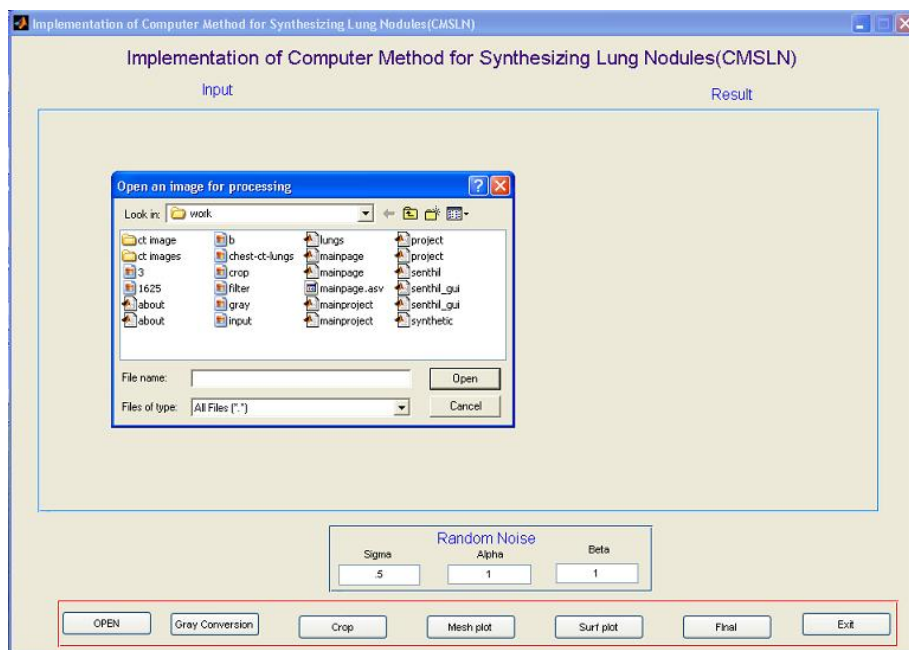


Entering the software prompts the user with the main window as shown below.



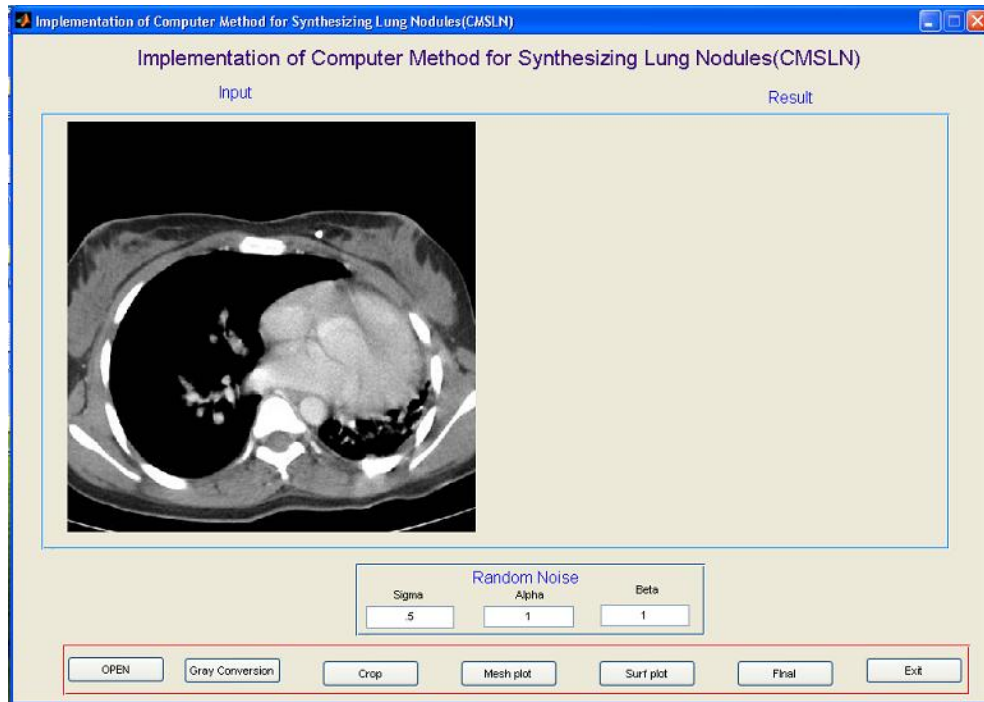
**Function of Open button:** to open the existing image for analysis.

Analysis of a CT image needs the user to open the image. The open dialog box helps the user to select the image for processing from the disk. When the user click the open button the following screen will appear for selecting the existing image.

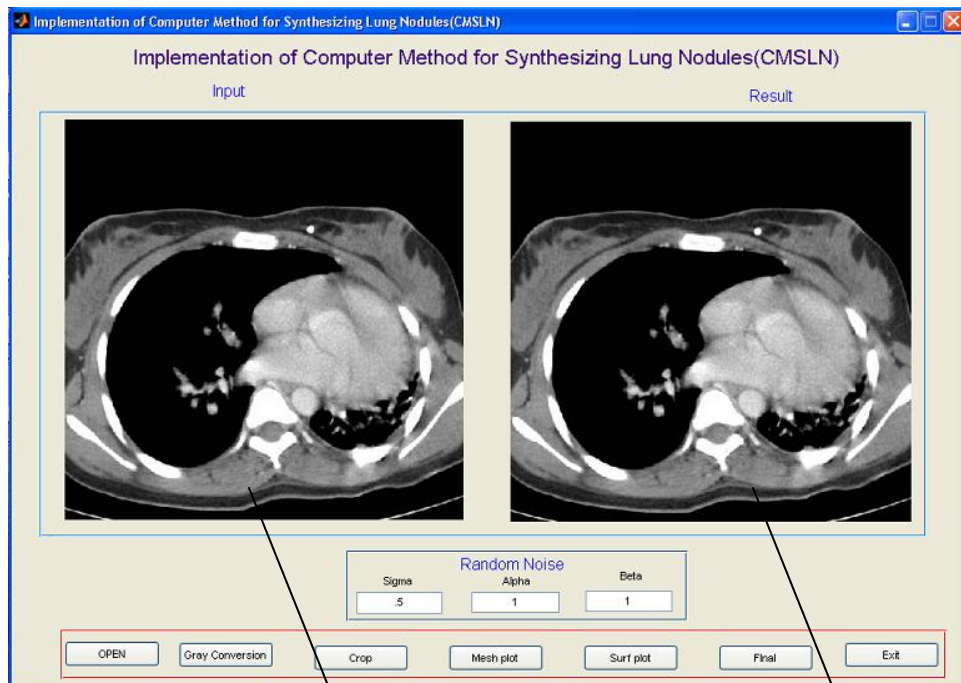


After open CT Image it show's the below windows

After selecting the existing image from the hard disk, the image will appear in the screen. The following screen shows the example of selected image.



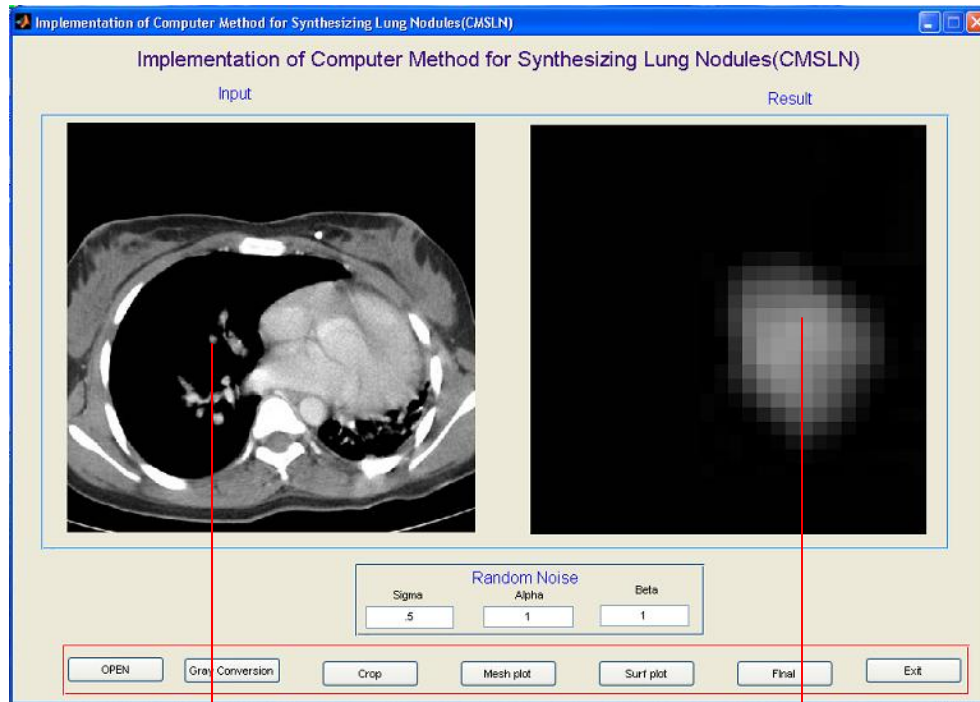
**Function of Gray Conversion button:** to convert the existing image into gray scale image.



Existing CT image

Gray Scale CT image

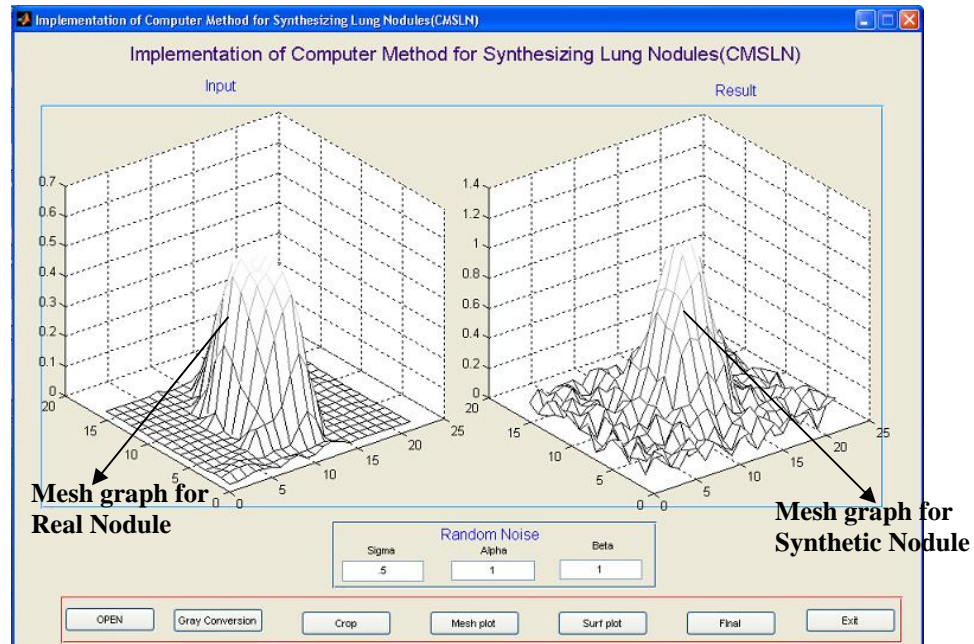
**Function of Crop button:** This button is used to crop the real nodule, which is identified by the user in the gray scale image.



Real Nodule

Real Nodule after cropping

**Function of Mesh Plot button:** The Mesh Plot button gives the mesh graphs of real nodule and synthetic nodule. The synthetic nodule is automatically created using Gaussian formula.

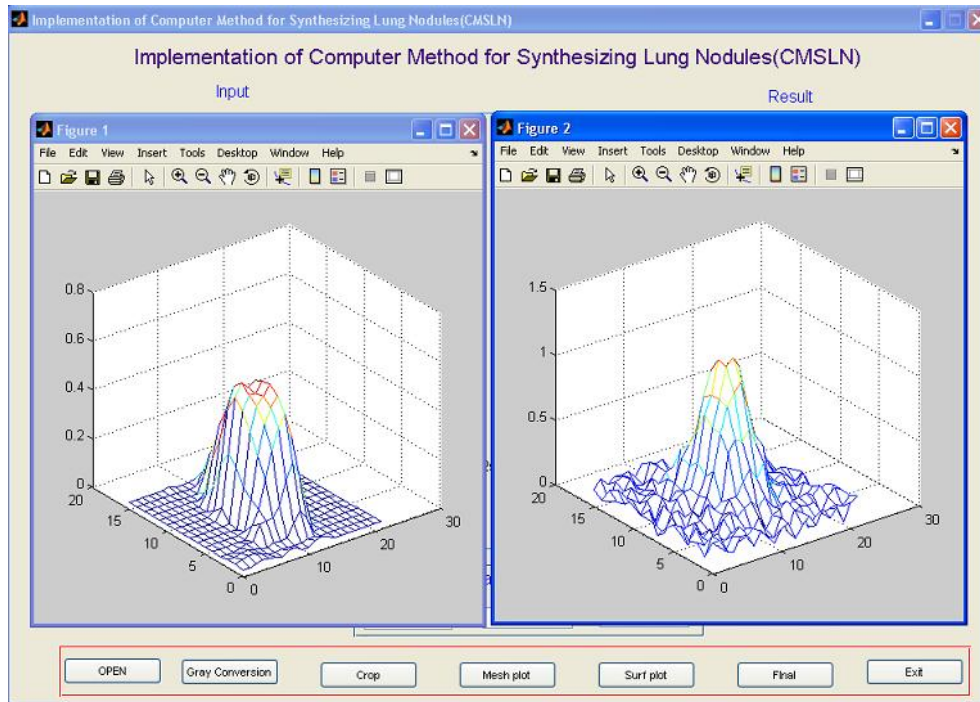


Mesh graph for Real Nodule

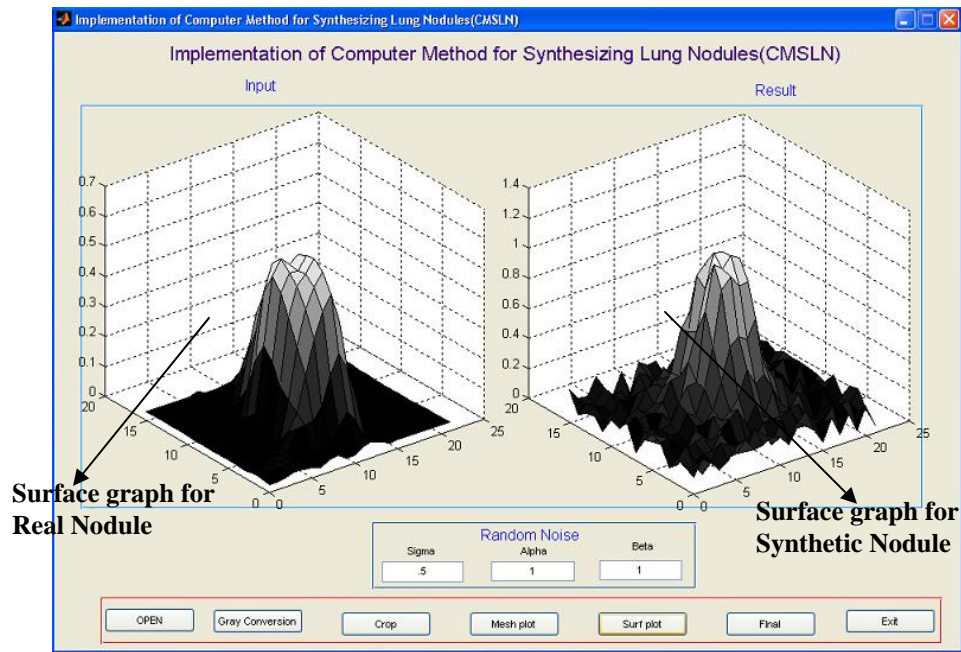
Mesh graph for Synthetic Nodule



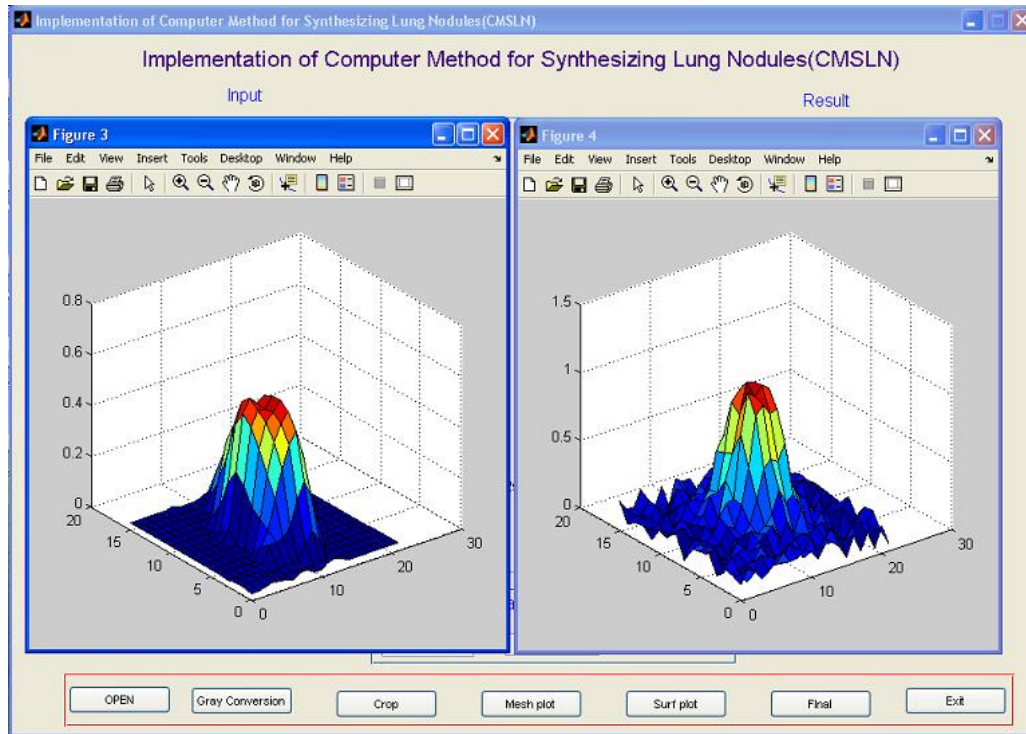
The Following screen shows two different files, figure1 and figure 2 which are mesh plots of real and synthetic nodule.



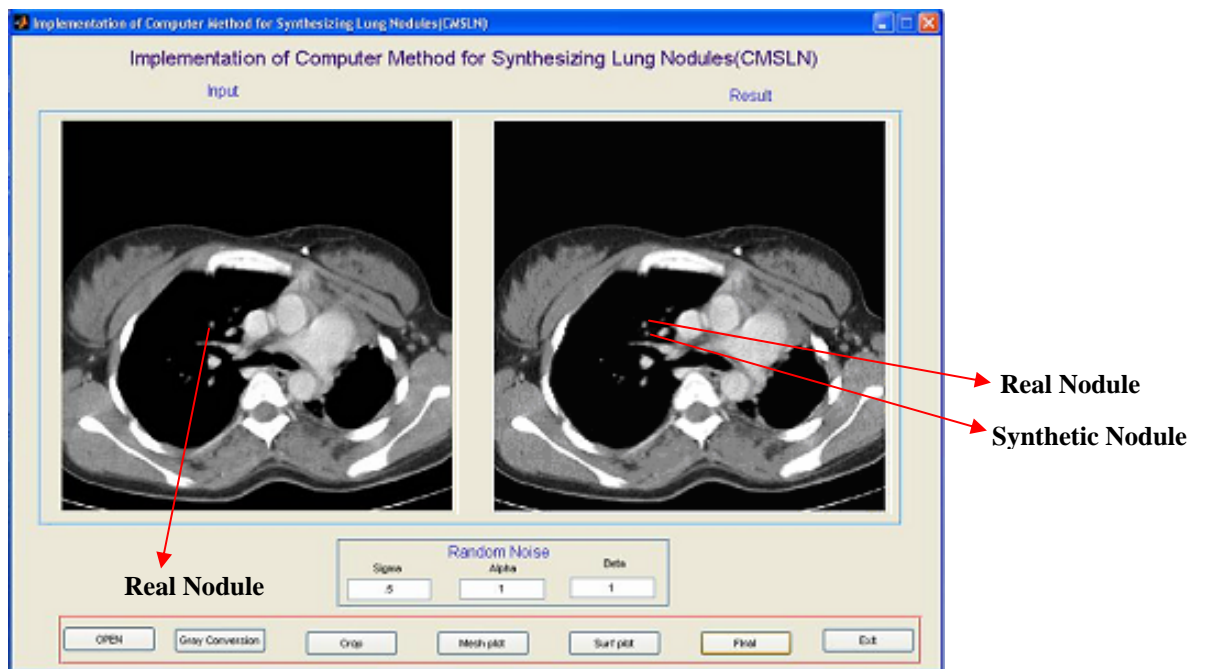
**Function of Surf Plot button:** The Surf Plot button gives the surface graphs of real nodule and synthetic nodule. The synthetic nodule is automatically created using Gaussian formula.



The Following screen shows two different files, figure3 and figure 4 which are Surface plots of real and synthetic nodule.



**Function of Final button:** The Final button gives the result of insertion of synthetic nodule into the original CT image. After the insertion of the following screen shows the real nodule and synthetic nodule.



***Chapter 6***

***Conclusion***

## ***6.0 CONCLUSION***

This software application provides to develop synthetic nodules based on structure of real lung nodules by using Gaussian formula. On visual comparison of CT image containing real and synthetic lung nodules, it is found that both the nodules appear to be similar. It is difficult to tell the real and synthetic one apart. Moreover, this software application helps to create a number of synthetic nodules by manipulating the magnitude and standard deviation of the Gaussian formula. This provides to prepare a data base. As the size of lung nodules varies according to the stage of lung cancer, this database would be extremely helpful for the radiologist to analyses the lung nodules.

### ***6.1 Scope for future work***

- A databank of different synthetic nodules with different parameters could be stored. This may be very much useful in analyzing the lung cancer at on early stage.
- This databank could be combined with the CT scan unit which may provide the sample data of synthetic nodules with different parameters for immediate references for the Radiologist.
- The implementation of this software may give good support to the Radiologist to concentrate only on affected nodules and avoid taking unnecessary CT image of the other parts of the lung.

*Appendix I*

**Software  
Coding for CMSLN**

## Software Coding for CMSLN

The coding for CMSLN is designed and developed in MATLAB® software.

### System Requirements

Windows 9X or above and

MATLAB®

### MATLAB codings

```
% -----%
function varargout = about(varargin)

gui_Singleton = 1;

gui_State = struct('gui_Name',    mfilename, ...
                  'gui_Singleton', gui_Singleton, ...
                  'gui_OpeningFcn', @about_OpeningFcn, ...
                  'gui_OutputFcn', @about_OutputFcn, ...
                  'gui_LayoutFcn', [], ...
                  'gui_Callback', []);

if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end

% End initialization code

% -----
```

```

% --- Executes just before about is made visible.

function about_OpeningFcn(hObject, eventdata, handles, varargin)

handles.output = hObject;

% Update handles structure

guidata(hObject, handles);

% UIWAIT makes about wait for user response (see UIRESUME)

% uiwait(handles.figure1);

% -----

% --- Outputs from this function are returned to the command line.

function varargout = about_OutputFcn(hObject, eventdata, handles)

varargout{1} = handles.output;

% -----

function varargout = mainproject(varargin)

% Begin initialization code -

gui_Singleton = 1;

gui_State = struct('gui_Name',    mfilename, ...
                  'gui_Singleton', gui_Singleton, ...
                  'gui_OpeningFcn', @mainproject_OpeningFcn, ...
                  'gui_OutputFcn', @mainproject_OutputFcn, ...
                  'gui_LayoutFcn', [], ...
                  'gui_Callback', []);

if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

```

```

if nargin
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end

% End initialization code

% -----%

% --- Executes just before mainproject is made visible.

function mainproject_OpeningFcn(hObject, eventdata, handles, varargin)

% This function has no output args, see OutputFcn.

% hObject    handle to figure

% eventdata  reserved - to be defined in a future version of MATLAB

% handles    structure with handles and user data (see GUIDATA)

% varargin   command line arguments to mainproject (see VARARGIN)

% Choose default command line output for mainproject

handles.output = hObject;

% Update handles structure

guidata(hObject, handles);

% UIWAIT makes mainproject wait for user response (see UIRESUME)

% uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.

function varargout = mainproject_OutputFcn(hObject, eventdata, handles)

```



```

% varargout cell array for returning output args (see VARARGOUT);
% hObject handle to figure
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
% Get default command line output from handles structure
varargout{1} = handles.output;

% --- Executes on button press in enter.
% -----%

function enter_Callback(hObject, eventdata, handles)
% hObject handle to enter (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
close(mainproject);
open(mainpage);
% -----

% --- Executes on button press in about.
function about_Callback(hObject, eventdata, handles)
% hObject handle to about (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
open(about);

% --- Executes on button press in exit.
function exit_Callback(hObject, eventdata, handles)
% hObject handle to exit (see GCBO)

```

```

% eventdata reserved - to be defined in a future version of MATLAB
% handles structure with handles and user data (see GUIDATA)
close(mainproject);
function varargout = mainpage(varargin)
if nargin == 0 % LAUNCH GUI
    fig = openfig(mfilename,'reuse');
    % Use system color scheme for figure:
    set(fig,'Color',get(0,'defaultUicontrolBackgroundColor'));
    % Generate a structure of handles to pass to callbacks, and store it.
    handles = guihandles(fig);
    guidata(fig, handles);
    if nargout > 0
        varargout{1} = fig;
    end
elseif ischar(varargin{1}) % INVOKE NAMED SUBFUNCTION OR
CALLBACK
    try
        if (nargout)
            [varargout{1:nargout}] = feval(varargin{:}); % FEVAL
switchyard
        else
            feval(varargin{:}); % FEVAL switchyard
        end
    catch

```

```

                disp(lasterr);
            end
        end
    end

% -----%
function varargout = open_Callback(h, eventdata, handles, varargin)
[filename pathname]=uigetfile('*. *','Open an image for processing');
x=imread([pathname filename]);
axes(handles.axes1);
imshow(x);
imwrite(x,'input.jpg');
handles.x=x;
guidata(h,handles);
% -----%
function varargout = gray_Callback(h, eventdata, handles, varargin)
x=handles.x;
gray=rgb2gray(x);
axes(handles.axes2);
imshow(gray);
imwrite(gray,'gray.jpg');
gray1=gray;
axes(handles.axes1);
imshow(gray1);
b=gray1;
handles.b=b;

```

```

guidata(h,handles);

% -----%

function varargout = crop_Callback(h, eventdata, handles, varargin)

b=handles.b;

[b1 rect]=imcrop(b);

handles.rect=rect;

handles.b1=b1;

axes(handles.axes2);

imshow(b1);

imwrite(b1,'crop.jpg');

z=im2double(b1);

%z1=im2double(b1);

handles.z=z;

guidata(h,handles);

% -----%

function varargout = mesh_Callback(h, eventdata, handles, varargin)

z=handles.z;

[row column]=size(z);

[X,Y]=meshgrid(1:column,1:row);

axes(handles.axes1);

%mesh(X,Y,z);

mesh(X,Y,z);

figure(1);

mesh(X,Y,z);

```

```

row1=ceil(row/2);

column1=ceil(column/2);

sigma=str2num(get(handles.sigma,'string'));

for i=0:(row1-1)
    for j=0:(column1-1)
        z_part4(i+1,j+1)=exp(-1*(i^2+j^2)/2*sigma^2);
    end
end

z_part3=fliplr(z_part4);
z_part2=fliplr(flipud(z_part4));
z_part1=flipud(z_part4);
z_final(1:row1,1:column1)=z_part2;
z_final(1:row1,column1+1:2*column1)=z_part1;
z_final(row1+1:2*row1,1:column1)=z_part3;
z_final(row1+1:2*row1,column1+1:2*column1)=z_part4;

%axes(handles.axes1);

%mesh(z_final);

%figure(1);

%mesh(z_final);

% ----- %

```

```

% Adding random number from uniform distribution

A=0.2*rand(size(z_final));

alpha=str2num(get(handles.alpha,'string'));

beta=str2num(get(handles.beta,'string'));

z_final1=alpha*z_final+beta*A;

handles.synthetic=z_final1;

guidata(h,handles);

axes(handles.axes2);

%figure(1);

mesh(z_final1);

%figure,imshow(e);

figure(2);

mesh(z_final1);

% -----%

function varargout = surf_Callback(h, eventdata, handles, varargin)

z=handles.z;

axes(handles.axes1);

surf(z);

figure(3);

surf(z);

[row column]=size(z);

row1=ceil(row/2);

column1=ceil(column/2);

```

```

sigma=str2num(get(handles.sigma,'string'));
for i=0:(row1-1)
    for j=0:(column1-1)
        z_part4(i+1,j+1)=exp(-1*(i^2+j^2)/2*sigma^2);
    end
end
z_part3=fliplr(z_part4);
z_part2=fliplr(flipud(z_part4));
z_part1=flipud(z_part4);
z_final(1:row1,1:column1)=z_part2;
z_final(1:row1,column1+1:2*column1)=z_part1;
z_final(row1+1:2*row1,1:column1)=z_part3;
z_final(row1+1:2*row1,column1+1:2*column1)=z_part4;
% Adding random number from uniform distribution
A=0.2*rand(size(z_final));
%A=rand(size(z_final));
alpha=str2num(get(handles.alpha,'string'));
beta=str2num(get(handles.beta,'string'));
z_final1=alpha*z_final+beta*A;
axes(handles.axes2);
surf(z_final1);
figure(4);
surf(z_final1);
% -----%

```

```
function varargout = final_Callback(h, eventdata, handles, varargin)

%Adding synthetic image to original image

gray_image=handles.b;

crop_image=handles.b1;

synthetic=handles.synthetic;

[m n]=size(synthetic);

%synthetic_image=synthetic*255;

synthetic_image=synthetic*100;

synthetic_image=round(synthetic_image);

rect=handles.rect;

im_x=ceil(rect(2));

im_y=ceil(rect(1));

add_image=gray_image;

%x_pos=im_x+m;

%y_pos=im_y+n;

%add_image(x_pos:x_pos+m-1,y_pos:y_pos+n-1)=synthetic_image;

x_pos=im_x+m-5;

y_pos=im_y+n-20;

add_image(x_pos:x_pos+m-1,y_pos:y_pos+n-1)=synthetic_image;

axes(handles.axes1);

imshow(add_image);

imwrite(add_image,'addimage.jpg');

axes(handles.axes2);

imshow(gray_image);
```



```
% --- Executes on button press in exit.  
function exit_Callback(hObject, eventdata, handles)  
% hObject    handle to exit (see GCBO)  
% eventdata  reserved - to be defined in a future version of MATLAB  
% handles    structure with handles and user data (see GUIDATA)  
close(mainpage);  
% -----(Code End)-----%
```

*Appendix II*  
**Outputs of CMSLN**

## **Output of CMSLN**

A CT image of some patients, who have lung cancer, were collected from a leading medical institute for this experiment. The experimental Result of Two patients are shown below.

### ***Output result of Patient 1:***



Figure 1: Shows the CT image with real Nodule



Figure 2: Shows the Gray scale of CT image

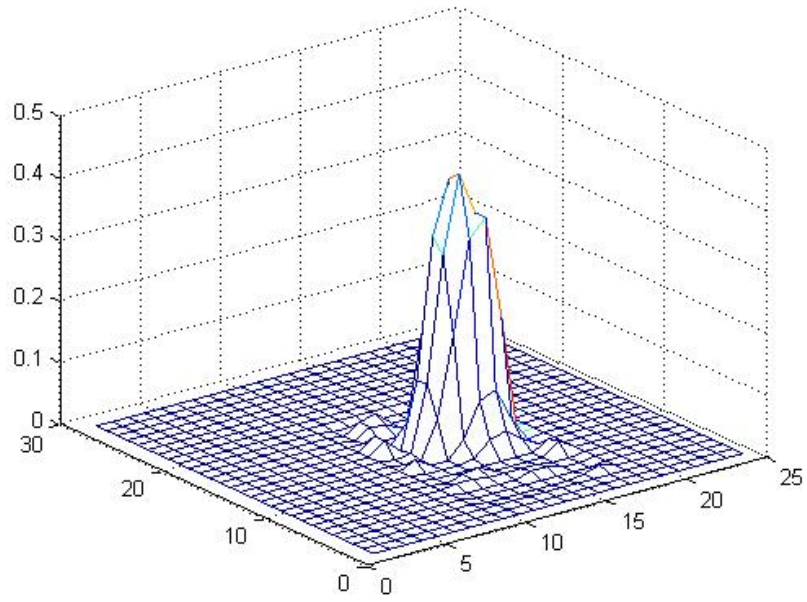


Figure 3: Shows the Mesh plot of real Nodule

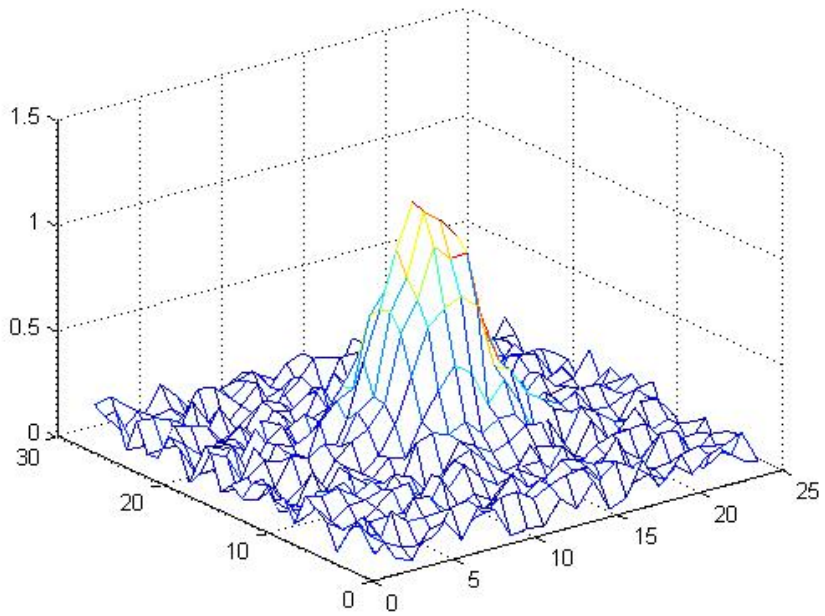


Figure 4: Shows the Mesh plot of Synthetic Nodule

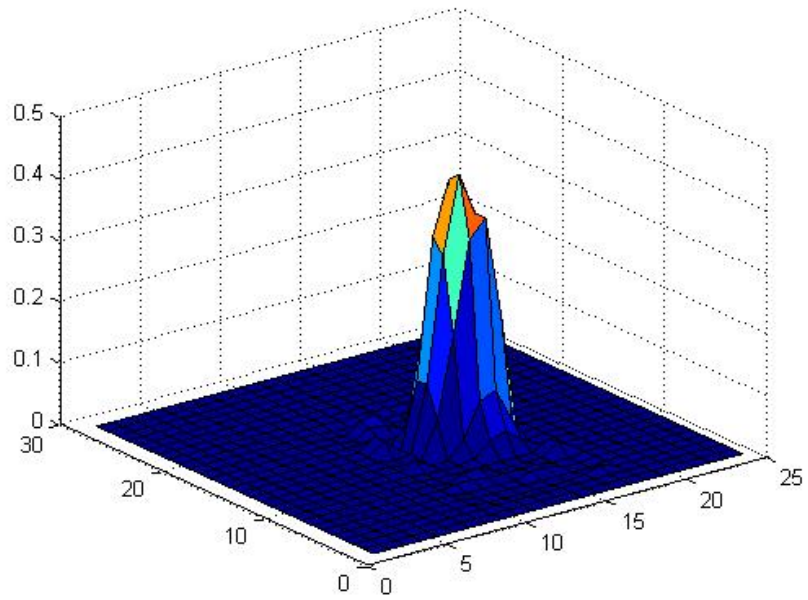


Figure 5: Shows the Surface plot of real nodule

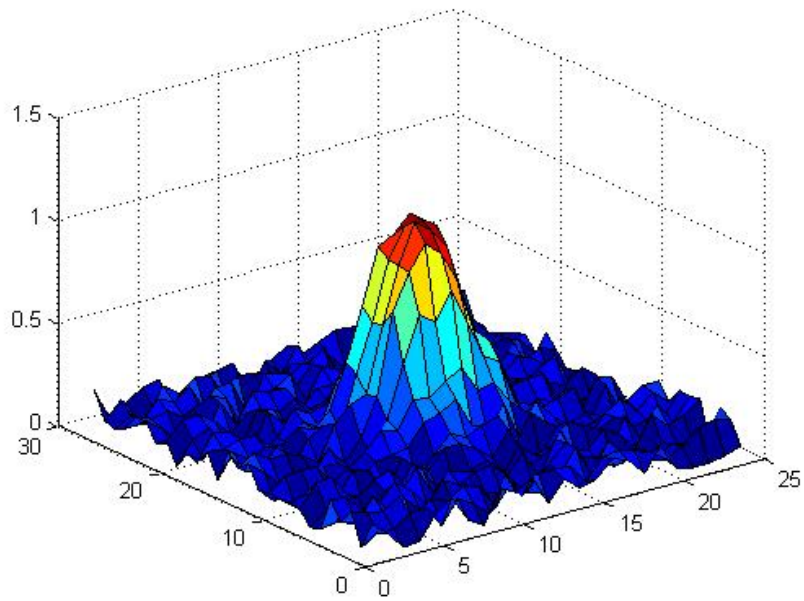


Figure 6 :Shows the surface plot of synthetic Nodule

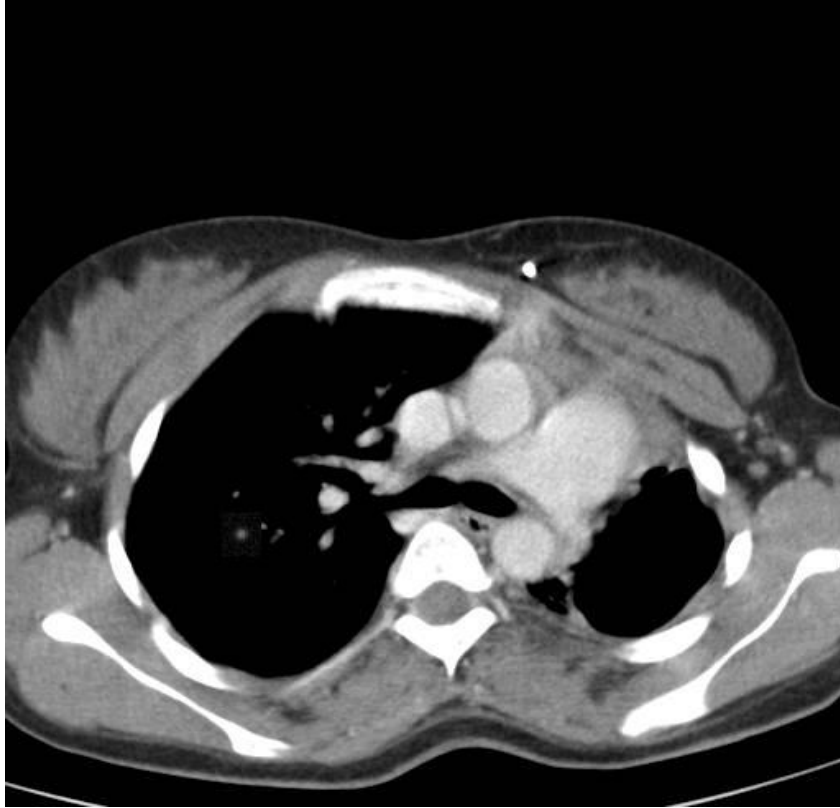


Figure 7: Shows the Real and Synthetic Nodule of CT image

***Output result of Patient 2:***



Figure 1: Shows the CT image with real Nodule



Figure 2: Shows the Gray scale of CT image

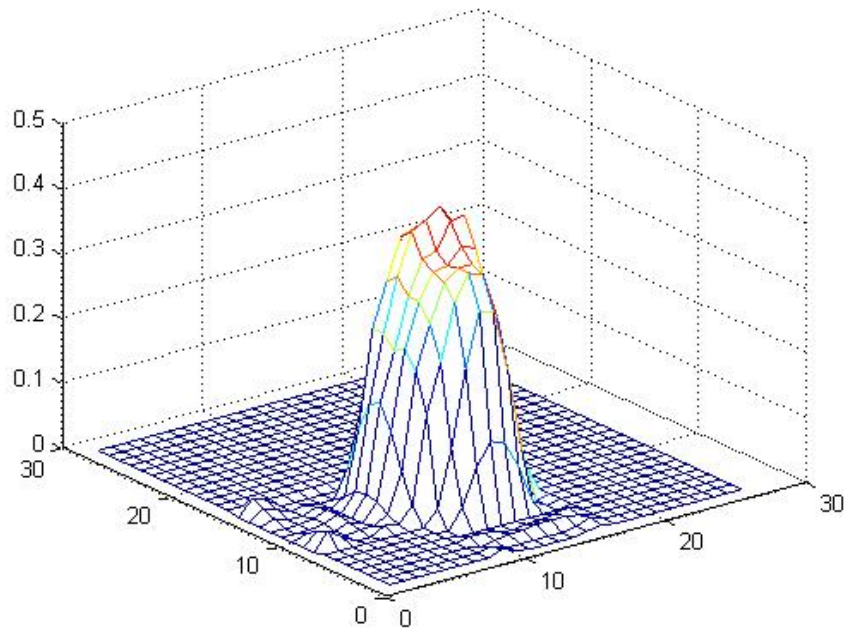


Figure 3: Shows the Mesh plot of real Nodule

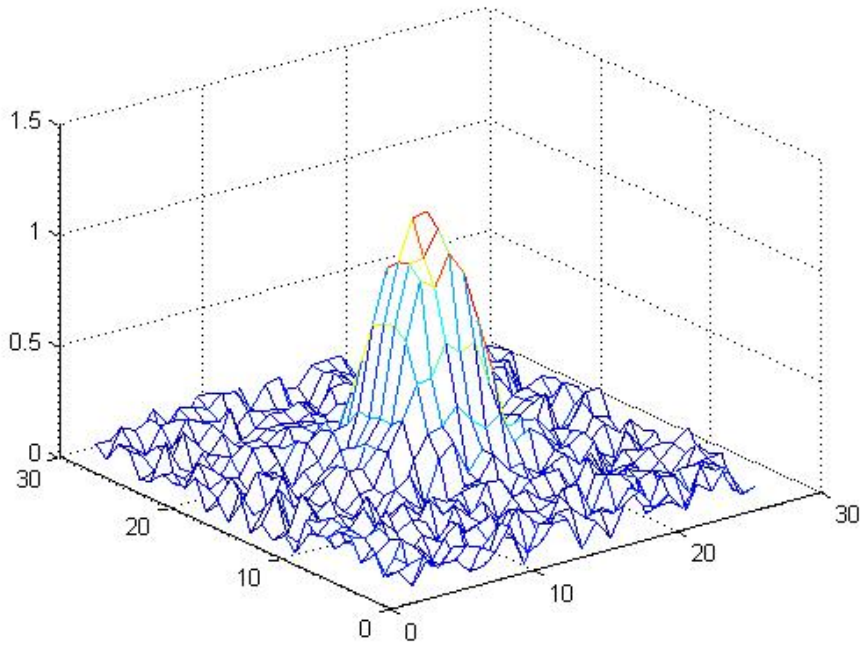


Figure 4: Shows the Mesh plot of Synthetic Nodule



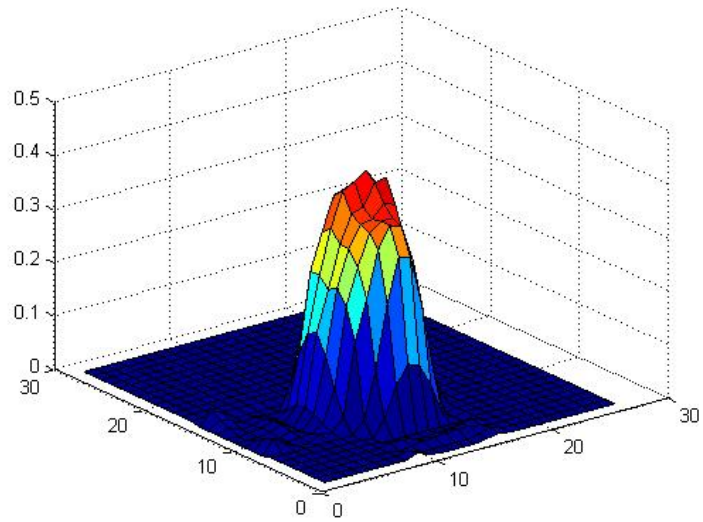


Figure 5: Shows the Surface plot of real nodule

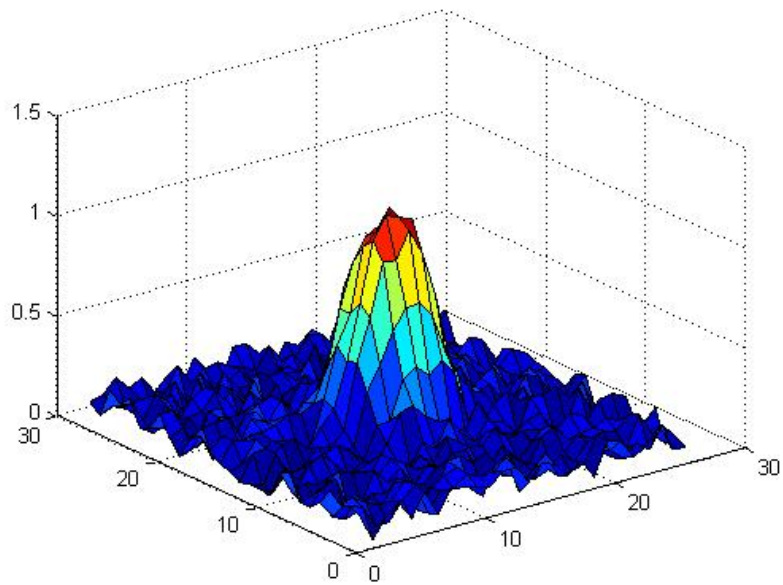


Figure 6: Shows the surface plot of synthetic Nodule



Figure 7: Shows the Real and Synthetic Nodule of CT image

# **References**

## References

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