SYNTHESIS OF MEDICAL IMAGES FOR PRE-DEFINED SHAPES

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
ELECTRICAL ENGINEERING
(With Specialization in Measurement & Instrumentation)

By

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this Dissertation entitled, **"Synthesis of Medical images for pre-defined shapes"** in the partial fulfillment of the requirement for the award of the degree of Master of Technology in Electrical Engineering with specialization in **Measurement and Instrumentation** submitted in the Department of Electrical Engineering, **Indian Institute of Technology, Roorkee** is an authentic record of my own work carried out during the period from July 2005 to June 2006, under the guidance of **Dr. S. Mukherjee**, Professor, Department of Electrical Engineering, Indian Institute of Technology, Roorkee.

I have not submitted the matter embodied in this report for the award of any other degree or diploma.

Date:30 JUNE 2006 **(ARCHANA)**

Place: Roorkee

CERTIFICATE

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

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ACKNOWLEDGEMENT

"Thanks to the Almighty for helping me in each & every stage of life"

I would like to thank **Dr. S. Mukherjee**, Department of Electrical Engineering, I.I.T. Roorkee, who took great efforts in providing good guidance, invaluable suggestions and inspirational support and was enthusiastic about my work. I feel privileged to be associated with him and it was a great learning experience under his aegis and guidance. I owe him a great debt of gratitude.

Special, sincere and heartfelt gratitude goes to my ***Parents*** who have built my educational foundation & whose sincere prayers, best wishes and encouragement have been a constant source of assurance, guidance, strength and inspiration to me throughout my studies and they have given me the choice and chance to pursue what I desired. My friends Aparesh Sood and Krishna Roy have always been at my side in all the ups and downs of my M.Tech. life;without their support this work would have been incomplete.

Archana

(ARCHANA)

LIST OF ABBREVIATIONS

PACS : Picture Archiving and Communications System
DICOM : Digital Imaging and Communications in Medicine
CAS : Computer assisted surgery
IGT : Image-guided therapy
IGS : Image-guided surgery
CR : Computed radiography
CT : Computed tomography
NM : Nuclear medicine
US : Ultrasound
MR : Magnetic resonance imaging
DF : Digital fluoroscopy
3DCRT : Three dimensional conformal radiation therapy
IMRT : Intensity-modulated radiation therapy
CAD : Computer-aided diagnosis
PET : Positron emission tomography
RTP : Radiation Treatment planning
HIS : Hospital Information System
RIS : Radiology Information System
HIPAA : Health Insurance Portability and Accountability Act
BMP : Window Bitmap Format
JPEG : Joint Photographic Experts Group
TIFF : Tagged image File Format
GIFF : Graphic Interchange Format
IHE : Integrating the Healthcare Enterprise
ACR : American college of Radiology
NEMA : National Electrical Manufacturer Association
IOD : Information Object Definition
DIMSE : DICOM Message service Element

SOP : Service Object Pair
UID : Unique identifier
HL-7 : Health Level Seven
ANSI : American National Standards Institute
HU : Hounsfield Units
IDR : Integrated data Repository
DLLs : Dynamic Link Libraries
CBIR : Content Based Image retrieval
GDI : Graphics device interface
MRI : Magnetic resonance imaging
FMRI : Functional MRI
PET : Positron Emission Tomography
SPECT : Single Photon Emission Computed Tomography
MRA : Magnetic resonance angiography

ABSTRACT

Medical Image processing has assumed great significance as a result of rapid increase in the amount of patient data available. Many scenarios in medical treatment require specific information about the part being examined. The task of providing useful information to a practitioner requires extensive preliminary analysis. Several attempts have been made to automate this process by incorporating image processing techniques.

Because of the diverse range of medical images most of the techniques are specific to a particular set of images. Hence there arises a necessity to evaluate the algorithms on a common metric to determine their usefulness to a particular class of images. In the current work a methodology is proposed to create test image sets (synthetic images) which could be used as a common metric to evaluate the performance of algorithms for different pre-defined shapes. The tool developed in the current work also provides option for adding varying levels of noise to the test image.

The advantage provided by the tool is demonstrated by evaluating the performance of an existing algorithm. The results obtained can be used to determine the usefulness of the algorithm to specific cases.

Table of Contents

4. WINDOWS PROGRAMMING

5. DESIGN AND IMPLEMENTATION

CHAPTER 1

INTRODUCTION

In clinical practice medical imaging is a crucial component of a large number of applications. Usually several image modalities like computed tomography, Magnetic Resonance imaging, Angiography, Ultrasound are used to provide different kinds of information to physicians. The medical image data acquired during diagnosis is often used as aid in operations and intraoperative images are revised for follow-up. The introduction of digital technologies in medical imaging field and of PACS (Picture Archiving and Communications System) in hospitals is causing deep changes in the way medical images are used and distributed. Today, the specialized physician often performs his diagnosis by analyzing one or more medical images displayed on a diagnostic display, instead of looking at a radiographic film mounted on a diaphanoscope. A typical PACS installation provides for viewing stations in several rooms of the hospitals: a viewing station usually consists of a Personal Computer or a Workstation powered by dedicated software for the display, analysis and manipulation of DICOM (Digital Imaging and Communications in Medicine) standard-compliant medical images.

There are situations in which it could be useful to be able to display the medical images even outside the boundaries of the hospital's DICOM network, perhaps by a common Personal Computer with basic software installed. DICOM image viewer allows retrieving medical images created by hospital's modalities and stored into remote archives or PACS, displaying the digital medical images that are physically remote with respect to viewing site and that are reachable through the Internet or Intranet in several different ways, annotating them and performing several Image Processing operations on them.

Recent developments in computation technology have fundamentally enhanced the role of medical imaging, from diagnosis to computer assisted surgery (CAS). During the last decade, medical imaging methods have grown from their initial use as physical models of human anatomy, to applied computer vision and graphic techniques for planning and analyzing surgical procedures.

1.1 MOTIVATION

Advances in medical imaging have resulted in presence of diverse range of medical images. Automating the analysis of these images has resulted in a diverse range of image processing techniques that are suitable for particular image types. The suitability of these algorithms for a specific task is determined by comparing the automated analysis results with those performed manually.

However obtaining manual analysis for exhaustive testing of these algorithms is not feasible. Thus there arises a need for generating synthetic images to test applicability of the developed algorithms under different noise levels for certain collection of regular and irregular shapes. Lack of a publicly available tool to pursue an exhaustive testing of an automated image analysis algorithm necessitates work in this direction.

1.2 PROBLEM STATEMENT

The problem tackled in this thesis is to design and develop a synthetic image generation tool for medical images which is used to verify the accuracy of medical image processing algorithms by generating test images of pre-defined shapes.

1.3 ORGANIZATION OF THE REPORT

Chapter 2: It briefly provides the background required to better comprehend the report. Concepts such as Digital medical imaging, computed tomography, and medical image formats like DICOM, HL-7, and MFER are discussed.

Chapter 3: In this chapter the various steps in medical image analysis are described, giving a brief explanation of segmentation, registration and visualization.

Chapter 4: The tool in the current work was developed in VC++. The chapter gives a brief review of windows programming and Microsoft foundation class that were relevant to the development of the tool.

Chapter 5: The framework for developing synthetic images using the developed tool is presented in this chapter. This chapter also explains the data structures used for developing the tool with explanation about the various implementation details.

Chapter 6: Results and discussions on the suitability of image analysis algorithms are presented in this chapter.

Chapter 7: Concluding remarks and future works are presented in this section.

CHAPTER 2

MEDICAL IMAGING

Medical imaging technology has enormous potential to contribute to the improvement of health care in this new century. Medical imaging has been undergoing a revolution in the past decade with the advent of faster, more accurate, and less invasive devices. And yet, there are serious deficiencies in imaging and other technology penetration into the health care system which must be addressed. Medical images are acquired by a range of techniques across all biological scales which go far beyond the visible light photographs and microscope images of the early 20th century. Along with a need for image modalities, there arises a requirement for development of corresponding software, which includes improvement in signal and image processing analysis. Now-a-days, a key research area that is of particular interest is the formulation of biomedical engineering principles based on rigorous mathematical foundations in order to develop general-purpose software methods that can be integrated into complete therapy delivery systems. Such systems support the more effective delivery of many image-guided procedures such as biopsy, minimally invasive surgery, and radiation therapy. Imaging, or radiological science, has come to include not only diagnostic methods but treatments using image-guided methods. Increasingly, it depends not only upon the primary diagnostic technologies, but also on information science, networking, image-archiving and image-distribution, contrast agent development, instrumentation, and treatment using physical energies as diverse as high-frequency ultrasound, radiofrequency radiation, etc[10].

In order to understand the extensive role of imaging in image-guided therapy (IGT) and image-guided surgery (IGS) and to appreciate the usage of images before, during, and after treatment, analysis is focused on four main components namely localization, targeting, monitoring, and control.

Specifically, in medical imaging four key problems are addressed[27]:

1. Segmentation - automated methods that create patient-specific models of relevant anatomy from images.

2. Registration - automated methods that align multiple data sets with each other.
3. Visualization - the technological environment in which image-guided procedures can be displayed.
4. Simulation - softwares that can be used to rehearse and plan procedures, evaluate access strategies, and simulate planned treatments.

2.1 DIGITAL MEDICAL IMAGING: AN OVERVIEW

With the progress and advancement in the field of science and rapidly evolving techniques, computerized technology has brought a great revolution in the Hospitals and in the world of Medical Imaging. Medical Imaging over years has evolved in two complementary ways. Firstly, new imaging technologies or modalities have continuously been introduced. Secondly, the field is being transformed from analog imaging to digital imaging. Today, medical images are mainly interpreted by physicians, who can often make diagnoses from the interpretation of such images. Furthermore, computers have helped to make the interpretation easier.

Digital medical imaging technologies allow acquisition of high-resolution cross-sectional images of the human body and have significantly improved the quality of medical care available to patients[3]. Thanks to new medical equipment and modalities, images of almost any organ can be produced, often in high resolution. The revolution in medical imaging is being fueled not only by new medical imaging technology but also by advances in computer hardware and software. New systems such as spiral computed tomography or multi-slice computed tomography would not be possible without today's faster processors. Large mass-storage systems such as the optical disk enable the storage of the massive amount of data from diagnostic imaging systems. Better software algorithms for image analysis and compression make the process more accurate and efficient[13].

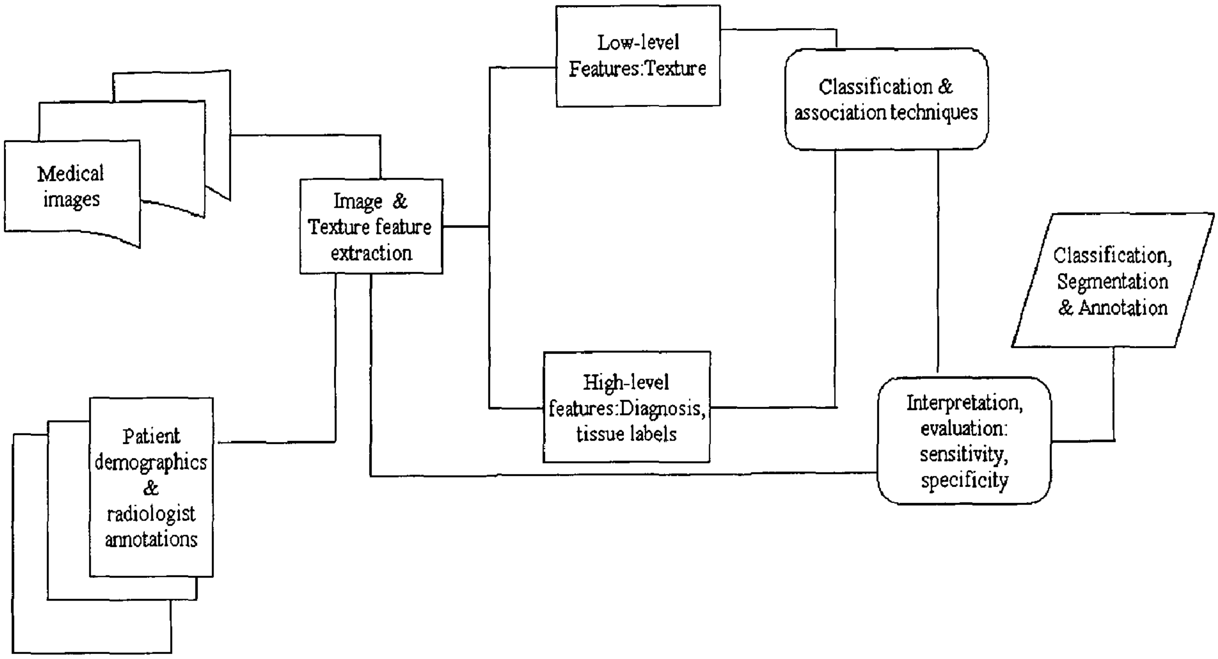


Figure 2.1. Steps performed to obtain the preliminary results in image analysis

Texture quantification and classification of normal tissue in medical scanning involves 2 steps:

In the texture quantification, a set of texture descriptors are calculated for each region of interest in the training and testing sets. Generally, two different texture models are used to generate these descriptors: the co-occurrence matrix model and the runlength encoding model. From the co-occurrence model, ten texture descriptors are calculated in order to quantify the spatial dependence of gray-level values; from the run-length model, eleven descriptors are calculated in order to quantify the differences between fine and coarse textures.

In the classification step, a decision tree classifier can be built using the 21 texture descriptors and names of the tissues as class labels. There are many classifiers that can be used to discriminate among the organ tissue classes in the feature space. From the decision tree, a set of the most important decision rules were generated to be used for classification of the regions, and to derive the most relevant texture descriptors for specific organs.

The various imaging modalities available for radiologists and surgeons offer new opportunities for a deeper insight into the pathological situation within the human body for the purpose of diagnosis and therapy. The seven major modalities are: digitized plain film, computed radiography (CR), computed tomography (CT), nuclear medicine (NM), Ultrasound (US), magnetic resonance imaging (MR) , and digital fluoroscopy (DF)[20].

With the advent of medical imaging, modalities that provide different measures of internal anatomical structure and function, physicians are now able to perform typical clinical tasks such as patient diagnosis and monitoring more safely and effectively than before such imaging technologies existed. The move from two-dimensional (2D) images to three-dimensional (3D) data sets improves the understanding of the geometrical situation (e.g., position of a tumor within the surrounding tissues) with the advent of medical imaging over the past decades. Combined with precise registration techniques, instruments can be guided and precisely be positioned during the intervention. The wealth of images can only be exploited when different modalities are fused and presented to the physician in an intuitive and easily understandable way.

Some of the new modalities such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are inherently digital in nature because of their need for signal processing and electronic data acquisition. Diagnosing, staging, and re-staging of cancer, as well as monitoring and planning of cancer treatment, has traditionally relied on anatomic imaging like Computed tomography (CT) and Magnetic Resonance Imaging (MRI). Older modalities such as X-ray and ultrasound are entering the digital age. New uses for diagnostic imaging such as interventional radiology and electrophysiology have been developed. Spatially accurate medical imaging is an essential tool in three dimensional conformal radiation therapy (3DCRT) and intensity-modulated radiation therapy (IMRT) treatment planning[17].

The term Digital Mammography refers to the technology that is used for the electronic capture and display of x-ray images of the breast. Breast cancer, a leading cause of death in women, is detected with digital mammography and ultrasound. In this process, film is not essential but it may be used as a recording medium for viewing and storing digital mammography images. The interpretation of breast images can benefit from computer technology with advances in CAD. Computer-aided diagnosis (CAD) can be defined as a diagnosis made by a radiologist who uses the output from a computerized analysis of medical images as a second opinion in detecting lesions and in making diagnostic decisions. The final diagnosis however is made by the radiologist.

Anatomical imaging has high sensitivity for detection of structural changes, but a low specificity for further characterization of these abnormalities. Single photon emission computed tomography and positron emission tomography (PET) are imaging techniques that provide information on physiology rather than anatomy. These modalities have been used for evaluation of tumor metabolism, differentiation between tumor reoccurrence and radiation necrosis, detection of hypoxic areas of the tumor, and other functional imaging.

One of the disadvantages of anatomical imaging techniques like CT and MRI is its inability to characterize the tumor. Tumors need to be characterized whether they are benign or malignant and if malignant it would be helpful to know whether the proliferation is slow or fast. Necrotic, scar, and inflammatory tissue often cannot be differentiated from malignancy based on anatomic imaging alone. For that purpose, Radiation treatment planning is very useful. Radiation treatment planning requires an accurate location of the tumor and the normal tissue and also knowledge of the size of the tumor for contouring the treatment volume. Although positron emission tomography (PET) provides necessary functional information for Radiation Treatment planning (RTP), it has a few limitations. The spatial resolution of PET is too poor to give accurate quantitative information. The greatest limitation in using PET for RTP is its lack of anatomical information. This limitation of PET is overcome by evaluating PET and CT images together. Fused PET and CT images give better diagnostic evaluation than PET or CT images used alone .But fusion of PET and CT images are meaningful only when they are correctly spatially registered. Hence a proper spatial registration is required for accurate delineation of tumor volume.

There are many advantages of digital medical imaging. Once an image is in digital form it can be sent over telephone lines or microwave links to a specialist at a remote location. The radiologist can then view and overlay images from different modalities on his workstation, which can be located in hospital or at home. He may even access the images over the Internet[18].

2.2. MEDICAL IMAGE ACQUISITION:

The characteristic of medical image is used to extract valid region of image by integrating region growing, edge detecting and Hough transform, and to remove background by digital subtraction. There are three ways to digitalize x-ray imaging, that's Computed Radiography (CR), Digital Radiography (DR) and video digital acquisition. Both CR and DR convert x-ray analog imaging information to digital image. Video digital acquisition performs A/D convert directly upon video signal produced by x-ray detector, and acquires images by single frames or by series. Video digital acquisition is suitable for the digitalization of continuous dynamic x-ray fluoroscopy image signal, although its inferior image quality compared with x-ray radiography, CR and DR, The main difficulties in video digital acquisition are x-ray fluoroscopy image detection noise and digital quantum noise, and the trouble in manual adjusting imaging contrast and resolution; besides, device background signal is also an important issue responsible for the degradation of acquired signal[20].To resolve problems associated with it , self-adaptive acquisition parameters setting and noise suppression in medical X-ray imaging can be implemented.

To resolve problems associated with digital video acquisitions, we use digital subtraction technique to realize image pre-enhancement (i.e. background removing) for self-adaptive acquisition, and monitor the dynamic range of image valid region to search for the best acquisition working point automatically [22,18]. Finally, acquisition parameters are studied by expert judgment and adjusting to improve their universality for various samples. The system construction is:

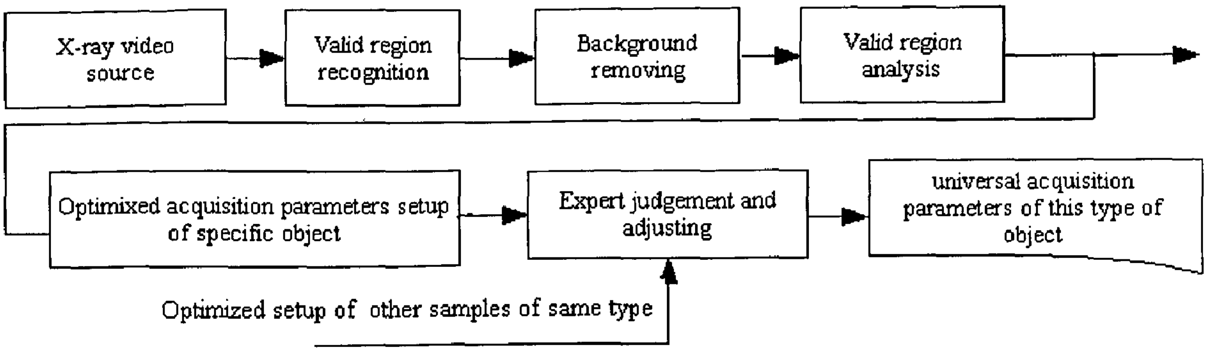


Figure 2.2. Self-adaptive digital acquisition

2.3. COMPUTED TOMOGRAPHY

Computed Tomography uses X-rays to generate cross-sectional, two-dimensional images of the body. In Computed Tomography, a finely collimated X-ray beam is directed upon the patient. As the X-ray tube travels 360° around the patient, X-rays are emitted toward the patient. As these X-rays interact with the various tissues in the patient's body, some of the X-rays are attenuated by the tissues while others are transmitted through the tissues and interact with a sensitive electronic detector. The transmitted radiation is then measured by a ring of sensitive radiation detectors located on the gantry around the patient. After the amount of radiation has been measured, the detector converts the amount of radiation received into an electronic signal that is sent to a computer. The computer then performs mathematical calculations on the information received and reconstructs the desired image[2]. Furthermore, the final image is generated from these measurements utilizing the basic principle that the internal structure of the body can be reconstructed from multiple X-ray projections. CT systems provide gray scale display of linear attenuation coefficients that closely relate to the density of the tissue. The attenuation measurement for a CT detector element is given by Equation (1) and Equation(2). Equation (1) represents attenuation measurement for homogenous object and Equation (2) represent attenuation measurement for inhomogeneous (heterogeneous) objects.

$$p(\bar{x}) = \ln[\frac{Io}{I(\bar{x})}] = \mu(\bar{x}) \qquad ...(1)$$

$$p(\bar{x}) = \ln[\frac{Io}{I(\bar{x})}] = \int_{L} \mu(\bar{x}) d\bar{x} \qquad ...(2)$$

where $p(\bar{x})$ is We measured projection data for attenuation along the x direction Io is the intensity of the x-ray beam measured without the patient in the way for that detector element. $\mu(\bar{x})$ is the measured attenuation coefficient as a function of location in the patient.

Every acquired CT slice is subdivided into a matrix of up to 1024 ×1024 volume elements (voxels). Each volume element (voxel) has been traversed during the scan by numerous X-ray photons and the intensity of the transmitted radiation measured by electronic detectors. From these intensity readings, the density or attenuation value of the tissue at each point in the slice can be calculated. Specific attenuation values are assigned to each individual voxel[16]. The viewed image is then reconstructed as a corresponding matrix of picture elements (pixels). Each image consists of a matrix of *pixels* whose ***CT numbers*** (measured in Hounsfield Units,*HU*) represent attenuation values for the volume elements (*voxels*) within the slice. The quality of the image relates to the fidelity of the CT numbers and to the accurate reproduction of small differences in attenuation (low contrast resolution) and fine detail (spatial resolution).

2.3.1. WORKING OF COMPUTED TOMOGRAPHY:

1. Motorized table moves the patient through a circular opening in the CT imaging system.

2. As the patient passes through the CT imaging system, a source of x rays rotates around the inside of the circular opening. A single rotation takes about 1 second. The x-ray source produces a narrow, fan-shaped beam of x rays used to irradiate a section of the patient's body .The thickness of the fan beam may be as small as 1 millimeter or as large as 10 millimeters. In typical examinations there are several phases; each made up of 10 to 50 rotations of the x-ray tube around the patient in coordination with the table moving

through the circular opening. The patient may receive an injection of a "contrast material" to facilitate visualization of vascular structure[15].

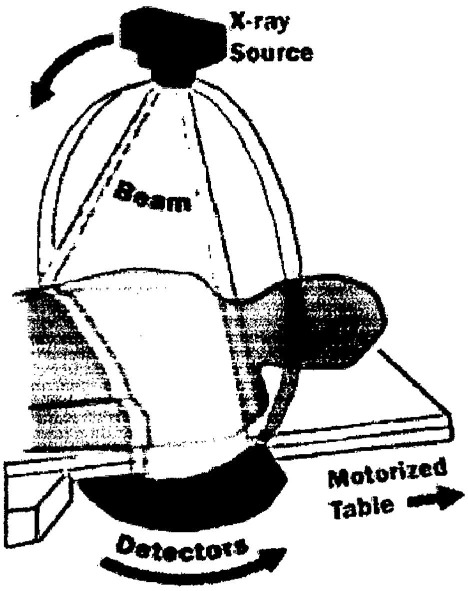


Figure 2.3.Working of CT

3. Detectors on the exit side of the patient record the x rays exiting the section of the patient's body being irradiated as an x-ray "snapshot" at one position (angle) of the source of x rays. Many different "snapshots" (angles) are collected during one complete rotation.

4. The data are sent to a computer to reconstruct all of the individual "snapshots" into a cross-sectional image (slice) of the internal organs and tissues for each complete rotation of the source of x rays .

2.3.2. CT NUMBER / HOUNSFIELD UNIT

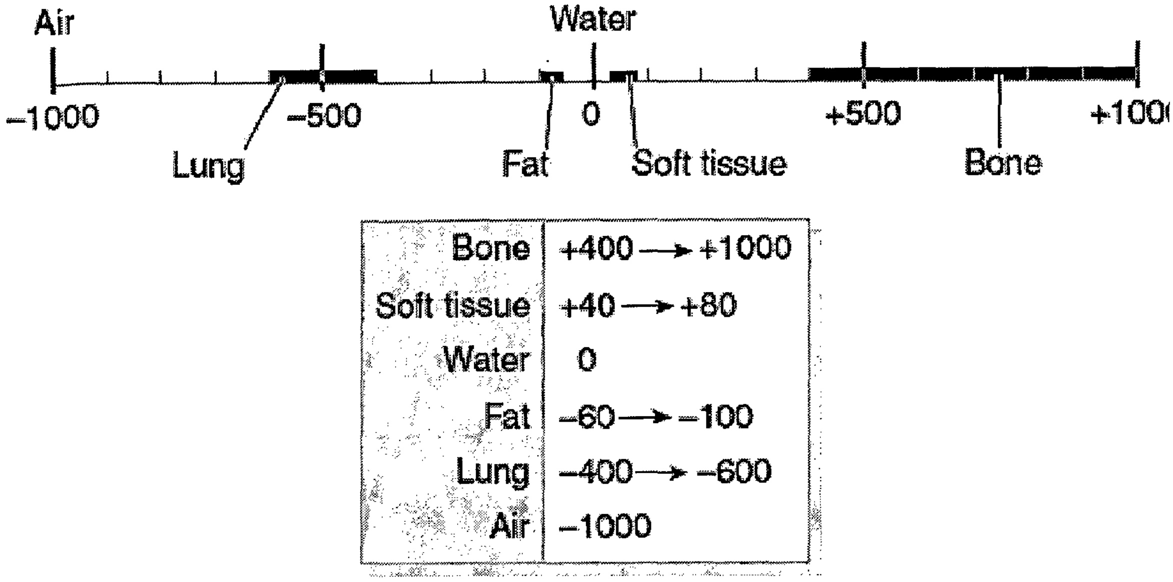
The reconstructed CT image is a two dimensional matrix of numbers, with each pixel corresponding to a spatial location in the image and in the patient. Usually the matrix is 512 pixels wide and 512 pixels tall covering a 50 cm x 50 cm field of view. The numeric value in each pixel represents the attenuation coefficient as a gray level in the CT image. These numbers are called Hounsfield units or CT numbers[23]. Each pixel is assigned a numerical value (CT number), which is the average of all the attenuation values contained within the corresponding voxel. These CT numbers give the attenuation of the object at that particular location. This number is compared to the attenuation value of water and displayed on a scale of arbitrary units named Hounsfield units (HU) after Sir Godfrey Hounsfield. This scale assigns water as an attenuation value (HU) of zero. The range of CT numbers is 2000 HU wide although some modern scanners have a greater range of HU up to 4000. Each number represents a shade of grey with +1000 (white) and –1000 (black) at either end of the spectrum.

The reconstruction process generates a matrix of Hounsfield units which give the linear attenuation values normalized to the attenuation of water.
This normalization is given by Equation (3).

$$CTNumber(HU) = 1000\left(\frac{\mu_{pixel} - \mu_{water}}{\mu_{water}} \right) \qquad \ldots(3)$$

where $\cdot_{water}$ is the attenuation coefficient of water and the values of both $\cdot_{Pixel}$ and $\cdot_{water}$ are taken at the effective energy of the scanner. Thus, 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 .CT number gives an indication of the type of tissue. Water has a CT number of zero. Negative CT numbers are typical for air spaces, lung tissues and fatty tissue. Values of μ_{pixel} greater than $\cdot_{water}$ correspond to other soft tissues and bone.CT number is a very important concept in medical imaging. Radiologists occasionally make critical diagnostic decisions based on CT number of particular regions of interest. Also attenuation values given by CT numbers are used to calculate the dose delivered to the tumor in RTP. CT number is an important parameter in CT images which must be frequently checked for accuracy[21].

The performance of a CT scanner can be determined by measuring the CT values for a known electron density object. The measured CT values are compared with the manufacturer values to check the performance.



Bone	+400 → +1000
Soft tissue	+40 → +80
Water	0
Fat	-60 → -100
Lung	-400 → -600
Air	-1000

Figure 2.4. Range of CT for different tissues

2.3.3. WINDOW LEVEL (WL) AND WINDOW WIDTH (WW):

Whilst the range of CT numbers recognized by the computer is 2000, the human eye cannot accurately distinguish between 2000 different shades of grey. Therefore to allow the observer to interpret the image, only a limited number of HU are displayed. A clinically useful grey scale is achieved by setting the WL (Window level) and WW (Window Width) on the computer console to a suitable range of Hounsfield units, depending on the tissue being studied.

WINDOW LEVEL (WL): Window level is expressed in HU and is defined as the central value of the window used for the display of the reconstructed CT image. It should be selected by the viewer according to the attenuation characteristics of the structure under examination. The window width covers the HU of all the tissues of interest and these are displayed as various shades of grey. Tissues with CT numbers outside this range are displayed as either black or white.

WINDOW WIDTH (WW): Window width is defined as the range of CT numbers converted into grey levels and displayed on the image monitor. It is expressed in HU. The window width can be selected by the operator according to the clinical requirements, in order to produce an image from which the clinical information may be easily extracted. In general, a large window (for instance 400 HU) represents a good choice for acceptable representation of a wide range of tissues. Narrower window widths adjusted to diagnostic requirements are necessary to display details of specific tissues with acceptable accuracy.

Both the WL and WW can be set independently on the computer console and their respective settings affect the final displayed image. For example, when performing a CT examination of the chest, a WW of 350 and WL of +40 are chosen to image the mediastinum (soft tissue) whilst an optimal WW of 1500 and WL of –600 are used to assess the lung fields (mostly air)[25].

These values are particularly important for X-ray /CT/PET scanners that tend to generate consistently calibrated intensities so for every image specific C:W pair can be used. For e.g., 400:2000 might be good for visualising bone, while 50:350 might be a better choice for soft tissue.

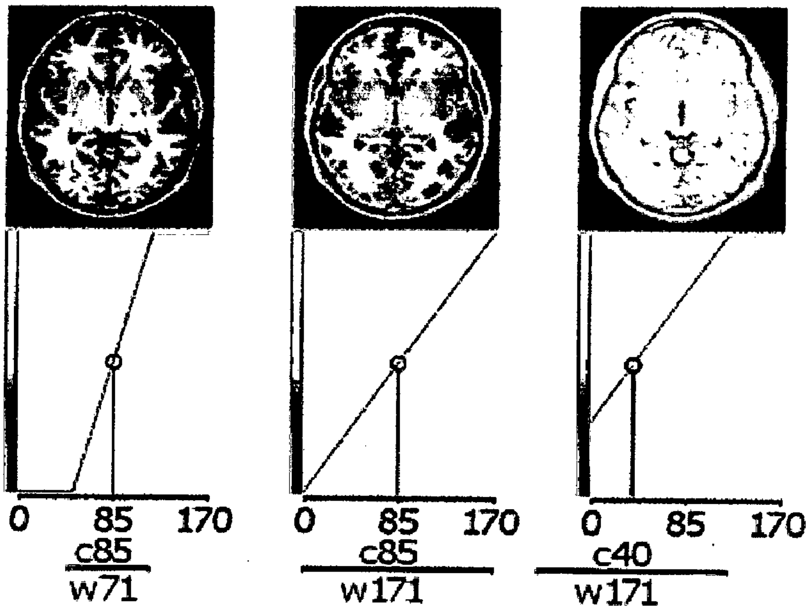


Figure 2.5.Window level and window width

The figure 2.5. illustrates the concept of changes to 'window center' and 'window width'. Along the top row three views of the same image with different C:W settings can be seen. The bottom row illustrates the colour mapping for each image (with the vertical axis of the graph showing rendered brightness and the horizontal axis showing the image intensity). Consider the image with intensities ranging from 0 to 170. A good starting estimate for this image might be a center of 85 (mean intensity) and width of 171 (range of values), as shown in the middle panel. Reducing the width to 71 would increase the contrast (left panel). On the other hand, keeping a width of 171 but reducing the center to 40 would make the whole image appear brighter.

2.4. MEDICAL INFORMATION SYSTEM

Broadly, three types of medical information systems form the backbone of current information systems in hospitals and medical Web services environment. They are as follows:

1. **HIS** (Hospital Information System)
2. **RIS** (Radiology Information System) and
3. **PACS** (Picture Achieving and Communication System)

HIS (Hospital Information System) is an enterprise-wide system used for administrative services such as patient and visit management, operation planning, billing, amongst others.

RIS (Radiology Information System) is a management system for medical imaging facilities (radiologists) and covering applications including patient registration, examination scheduling and control, report generation and transcription, speech recognition.

HIS and RIS systems have overlapping services to fulfill: one on an enterprise the other on a department level.

PACS (Picture Achieving and Communication System) is responsible for all image management services. It transfers patient data to examination facilities (modalities), announces finished procedures, and stores, prints, burns CDs, archives or forwards the generated image data[4] .

In X-ray imaging system X-ray source yields x-ray and Image enhancer converts the x-ray attenuated by body into visible light .Optics and CCD camera converts visible light into electrical signal, and then encodes it into video signal. Sensitive film receives x-ray irradiation directly and undergoes photochemical reactions to produce plain film for diagnosis. TV monitor displays x-ray video image to be observed by the doctor. Digital video system acquires video signal, performs image processing and connects withPACS.

The Main sources of artifacts in X-ray imaging are due to noise in image enhancer, digital quantum noise in CCD camera, and electrical noise, truncation noise and quantization noise in acquisition process; furthermore, because of device degradation and other reasons, there is non-uniform background signal in devices even with no observe object , these noises will affect image quality[3].

According to noise analysis and the demand for adjusting image contrast and resolution, digital video processing system can be processed as figure 2.6. Host should analyze the inputted signal while sampling and quantization to adjust grabber board setting for valid signal to utilize the dynamic range sufficiently, and to make device working in linear range to suppress electric al noise and truncation noise.

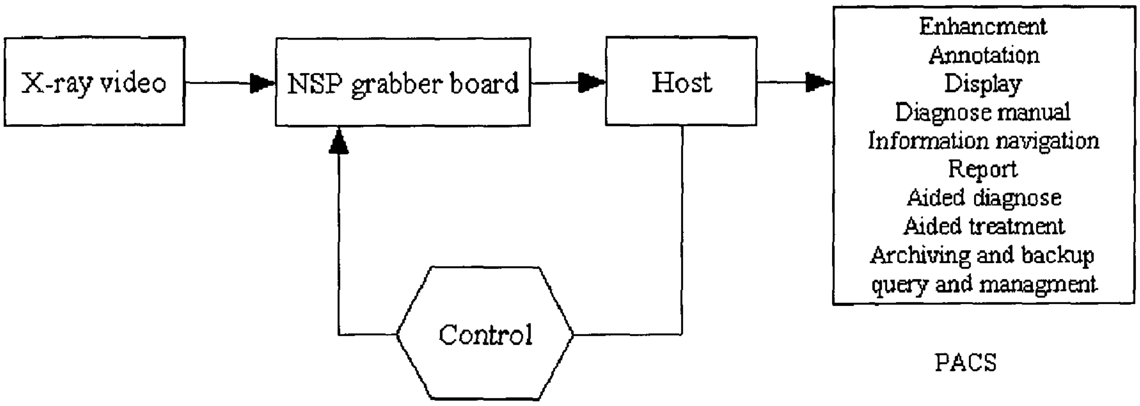


Figure 2.6.Connection of digital video system with PACS

2.5. MEDICAL IMAGE FORMATS

Privacy protection of medical images has always been an important issue in the management of patients' medical records. As part of Health Insurance Portability and Accountability Act (HIPAA), a set of standards for privacy protection of health data issued by the federal government took effect on April 14, 2003. Constant efforts are being made to provide security solutions to ensure

(i) Medical image transmission cannot be accessed by unauthorized parties (confidentiality),

(ii) Images are not modified during transmission (integrity), and

(iii) Images have originated from the correct sources to the claimed receivers (authentication). Continuously updated Digital Imaging and communication in Medicine (DICOM) standards provide guidelines to ensure authentication, integrity and confidentiality of medical images. Security measures in DICOM and the research on medical image security focus on secure storage and secure transmission, before reception[9].

At its most basic level, computers store and work on digital values of zeros and ones, known as bits. These bits of data are then used to represent meaningful information, depending on the context. For example, the bit sequence 01000001 might represent the number 65 in a calculator program, while the same sequence might represent the letter 'A' in a word processor program ,or the color 'Dark Grey' in a graphics program.

Without contextual information, data in a computer becomes meaningless. Information about the data (known a metadata) is just as important as the data itself. An image file format is a standardized specification to encode information about an image into bits of data for storage. In a nutshell, an image saved and encoded to a known image format identifies itself as an image, and provides useful information such as its size, bit depth etc. to ease interaction with the file. Any program which adheres to the format standard may then open the file and display the image[28].

There are different types of image file formats, like **BMP** (Window Bitmap Format), **JPEG** (Joint Photographic Experts Group), **TIFF** (Tagged image File Format) and **GIFF**

(Graphic Interchange Format). In Contrast to these general purpose image formats, **DICOM** (Digital Imaging and Communications in Medical) was designed specifically for use in the medicine industry, defining a specific file format and a set of communication protocols.

Medical Web services have been standardized by the **DICOM** and **HL7** communication protocols and are profiled by the IHE (Integrating the Healthcare Enterprise) technical framework. Standardization efforts have improved the stability of Medical Web services and range of applications. In an Internet-based medical environment with high security standards, communication is strongly restricted and conventional systems fail to deliver.

2.5.1. DICOM FORMAT

Digital Imaging and Communications in medicine (DICOM) is a standard which has been jointly developed by the *American college of Radiology* (ACR) and *National Electrical Manufacturer Association* (NEMA). The Digital Imaging and Communications in Medicine (DICOM) Standard has been developed to meet the needs of manufacturers and users of medical imaging equipment for interconnection of devices on standard networks. Its multiple parts provide a means of expansion and updating, and the design of the standard was aimed at allowing simplified development for all types of medical imaging. DICOM also provides a means by which users of imaging equipment may assess whether two devices claiming conformance will be able to exchange meaningful information. The future additions to DICOM include support for creation of files on removable media (such as optical disks or high-capacity magnetic tape), new data structures for x-ray angiography and extended hard copy print management

DICOM is a standard for exchange of medical images and other information. It is a defacto standard for telemedical data. DICOM standard covers Client/Server communications used to exchange Patient and Examination information. The standard covers objects like patients , medical procedures ,images, films, printers, and examination modalities. Additionally, notifications, data query, and exchange services based on these objects (for e.g. features of visible anatomic structures or features of diagnosis) are defined[5]. This standard allows different manufacturers' equipment to communicate for e.g., all CT images will be stored in the same format irrespective of manufacturer & header information pertaining to the CT images and CT images will also be stored in the same format irrespective of which devices generated the image. DICOM standard has been developed to meet the needs of manufacturers and users of medical imaging equipment for interconnection of devices on standard networks[4].

DICOM is a global Information-Technology standard that is used in virtually all hospitals worldwide. Hospitals, clinics, imaging centers and specialists need DICOM standard. The use of DICOM is various fields are listed below.

Radiology - Breast imaging
Cardiology - Radiotherapy
Oncology - Ophthalmology
Dentistry - Pathology
Surgery - Veterinary
Neurology - Pneumology

Its current structure, which was developed in 1993, is designed to ensure the interoperability of systems used to produce, store, display, process, send, retrieve, query or print medical images and derived structured documents as well as to manage related workflow. By purchasing only equipment and information systems that conform to the DICOM Standard, we can ensure that these tools will work together to produce, manage and distribute our images regardless of our previous, current or future vendors.

BASIC DICOM FILE STRUCTURE

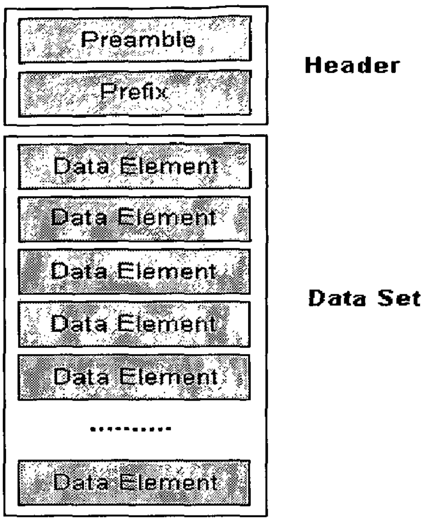


Figure 2.7(a).

Basic DICOM file structure

Figure 2.7(b).

Example file structure of DICOM

Popular Analyze format stores the image data in one file (*.img) and the header data in another file (*.hdr) while single DICOM file contains both a header (which stores information about the patient's name, the type of scan, image dimensions, etc), as well as all of the image data (which can contain information in three dimensions).

Another difference between DICOM and Popular Analyze format is that the DICOM image data can be compressed (encapsulated) to reduce the image size. Files can be compressed using lossy or lossless variants of the JPEG format, as well as a lossless Run-Length Encoding format (which is identical to the packed-bits compression found in some TIFF format images).

The Image in the figure 2.7(b) shows a hypothetical DICOM image file. In this example, the first 794 bytes are used for a DICOM format header, which describes the image dimensions and retains other text information about the scan. The size of this header varies depending on how much header information is stored. Here, the header defines an image which has the dimensions 109x91x2 voxels, with a data resolution of 1 byte per voxel (so the total image size will be 19838). The image data follows the header information (the header and the image data are stored in the same file

Transfer Syntax Unique Identification' reports the structure of the image data, revealing whether the data has been compressed. DICOM viewers can only handle uncompressed raw data. DICOM images can be compressed both by the common lossy JPEG compression scheme (where some high frequency information is lost) as well as a lossless JPEG scheme (Huffman lossless JPEG).Apart from transfer syntax UID, the image is also specified by the Samples per pixel, Photometric Interpretation & the Bits Allocated .For most MRI and CT images, the photometric interpretation is a continuous monochrome (e.g. typically depicted with pixels in grayscale). In DICOM, these monochrome images are given a photometric interpretation of 'MONOCHROME1' (low values=bright, high values=dim) or 'MONOCHROME2' (low values=dark, high values=bright). However, many ultrasound images and medical photographs include color, and these are described by different photometric interpretations (e.g. Palette, RGB, CMYK, YBR, etc). Some colour images (e.g. RGB) store 3-samples per pixel (one each for red, green and blue), while monochrome and paletted images typically store only one sample per image[29]. Each images store 8-bits (256 levels) or 16-bits per sample (65,535 levels), though some scanners save data in 12-bit or 32-bit resolution. So a RGB image that stores 3 samples per pixel at 8-bits per can potentially describe 16 million colours (256 cubed).

2.5.2 HL-7 FORMAT

HL7 is a Standards Developing Organization accredited by American National Standards Institute **(ANSI)** to write standards representing a consensus of various entities in the healthcare arena.

HL7 is an acronym for “Health Level Seven”. It is a protocol that specifies the exchange of data between healthcare applications. HL7 is also the term given to a collection of standardization protocols published for the industry. The HL7 protocol was designed to be flexible enough to be implemented in a variety of platforms and environments. HL7 specifications define an ideal presentation of information, or encoding rules. The broad objective is to provide comprehensive standards for the electronic exchange of data among healthcare applications. The title HL7 conjures images of a packet of compact disks, manuals and clever icons. In reality, every HL7 version is a four-inch thick, three-ring notebook, with thousands of pages of detailed interfacing information. The prime objective of HL7 is to simplify the implementation of interfaces between healthcare software applications and various vendors, so as to reduce the need for custom interface programming[4].

The integrated data Repository (IDR) has adopted the HL7 standard as the preferred protocol for immunization transactions. Even though an HL7 message is a simple ASCII string, some interface partners may not have the capability to exchange messages using HL7.

2.5.3. MFER: MFER is a medical waveform description standard for "Interchange of waveform information", "Waveform database", "Electronic Health Record", "Research, Investigation, Signal processing" and so on. MFER is a format standard for medical waveforms such as electrocardiogram, electroencephalogram and respiration waveforms

MFER describes the standard 12 lead ECG waveforms and HL7 describes the patient information and observation result. With this combination, the readability and understandability is greatly improved.

MFER has two main components, sampling information and frame information. The attributes of sampling information are sampling frequency (sampling interval), sampling resolution and optional attributes if necessary. The Frame information is composed with data block length, channel and sequence number.

CHAPTER -3

MEDICAL IMAGE ANALYSIS

3.1. METHODOLOGY OF MEDICAL IMAGE ANALYSIS:

Medical Image analysis method is an essential reference that details the primary methods, techniques and approaches used to improve the quality of visually perceived images, as well as, quantitative detection and diagnostic decision aids. Accurate analysis and interpretation of radiological and diagnostic applications largely revolve around one process, medical imaging and computerized medical image analysis. The complexity of this process–from instrumentation and computerized data collection to image reconstruction methods–calls for a specialized knowledge of image acquisition techniques. And gaining that specialized knowledge demands a resource like Medical Image Analysis.

To successfully detect and diagnose disease, it is vital for medical diagnosticians to properly apply the latest medical imaging technologies. It is a worrisome reality that due to either the nature or volume of some of the images provided; early or obscured signs of disease can go undetected or be misdiagnosed[14]. To combat these inaccuracies, diagnosticians have come to rely on applications that focus on medical image analysis.

Medical Image Analysis includes state-of-the-art coverage of:

- Medical imaging modalities and their role in radiology and medicine.
- The principles, instrumentation, and data acquisition methods of medical imaging, from X-ray radiograph imaging to ultrasound.
- Image reconstruction algorithms used and investigated in different imaging modalities.
- Two, three, and multi-dimensional methods for image visualization.
- Recent breakthroughs in medical imaging, processing, analysis, and interpretation.

The image analysis technologies allow medical doctors to improve their diagnosis. The Figure 3.1. illustrates cardiac boundary detection technology for ultrasound systems. The technology, called Advanced ACT, has made it possible to track the cardiac boundary automatically by newly developed active contour model and mitral annulus tracking technology.

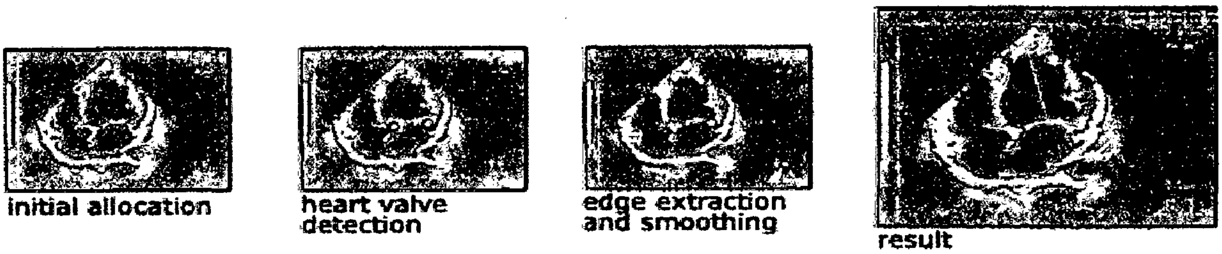

initial allocation heart valve detection edge extraction and smoothing result

Figure 3.1. Medical image analyses for cardiac boundary detection

Medical imaging analysis addresses four key issues

(1) **Segmentation** - automated methods that create patient-specific models of relevant anatomy from images.

(2) **Registration** - automated methods that align multiple data sets with each other.

(3) **Visualization** - the technological environment in which image-guided procedures can be displayed.

(4) **Simulation** - softwares that can be used to rehearse and plan procedures, evaluate access strategies, and simulate planned treatments.

3.2. SEGMENTATION: The key challenge for the neurosurgeon during brain surgery is to remove as much as possible of a tumor without destroying healthy brain tissue. This can be difficult because the visual appearance of healthy and diseased brain tissue can be very similar. It is also complicated by the inability of the surgeon to see critical structures underneath the brain surface as it is being cut.

Image segmentation is the process of identifying anatomical structures in volumetric imaging data. Therefore, different biomechanical properties and parameters can easily be assigned to the different cells or objects composing the mesh. Boundary surfaces of objects represented in the mesh can be extracted from the mesh as triangulated surfaces, which is convenient for running an active surface algorithm .

Image segmentation was originally applied to binary images in 1960s, and later, when imaging technology improved, it progressed to grayscale and eventually colour images (Jain, Murty and Flynn, 1999).Segmented images improves image analysis, especially for image querying and retrieval (Winter and Nastar, 1999).

Image segmentation is a process of dividing an image into distinguishable or disjoint homogeneous regions or classes, where all the pixels in the same class must have some common characteristics. We do this by translating the image into the feature space and try to find the boundaries between the different features[8]. Image segmentation is one of the primary steps in image analysis for object identification. One of the common problems encountered in image segmentation is choosing a suitable approach for isolating different objects from the background. In medical applications, image segmentation is used to classify different anatomy features, such as bones, muscles, and soft tissues. Image segmentation remains one of the major challenges in image analysis. In medical applications, skilled operators are usually employed to extract the desired regions that may be anatomically separate but statistically indistinguishable.

Segmentation is divided into two main tasks: recognition to determine roughly the location of the structure, and delineation to determine the precise spatial extent of the structure.

Segmentation can also be classified into two main categories: **supervised** and **unsupervised.**

Supervised segmentation: In cases where the number of different types of features is small, supervised segmentation is used where a priori knowledge of the features exists (Ruzon, 1997). Algorithms that use supervised learning are provided with a set of training data where each data sample is labeled according to its specific features. Using the training data, algorithms can learn to classify new data inputs based on the set of labels in the training data set. Supervised learning has prior knowledge of the possible classes for the data sample it uses.

Unsupervised segmentation: In cases where the number of different types of features is large or assumptions on the features cannot be made, unsupervised segmentation must be used. Unsupervised learning does not use training data; instead data are classified based on the features present in the total data sample set (Duda, Hart and Stork, 2000).

Image segmentation can also be divided into two groups based on the number of images used: a single image segmentation where a single grey scale image is used and multi-spectral image segmentation where multiple grey scale images is used.

Segmentation techniques are divided into three main categories: edge based segmentation that rely heavily on image intensity ,region based segmentation that attempts to construct a region of interest rather than simply separating regions with edges and global knowledge-based segmentation, which employs global properties of an image to separate it into objects.

3.2.1 EDGE-BASED TECHNIQUES

An edge can be defined as a sudden change in the grey or intensity level of an image. An edge-based segmentation technique is used in many image-processing areas such as pattern recognition, pattern matching, and feature extraction. Generally, edge-based techniques find an edge in an image by looking at the discontinuity in the intensity function or steep intensity gradient in an image. Using first derivative functions, an edge can be found when the derivative of the image's intensity value is at a maximum. This is called a first order differential method.

The Gaussian filter is robust against noise but the results are not localized (i.e. may detect wrong edges) [8].

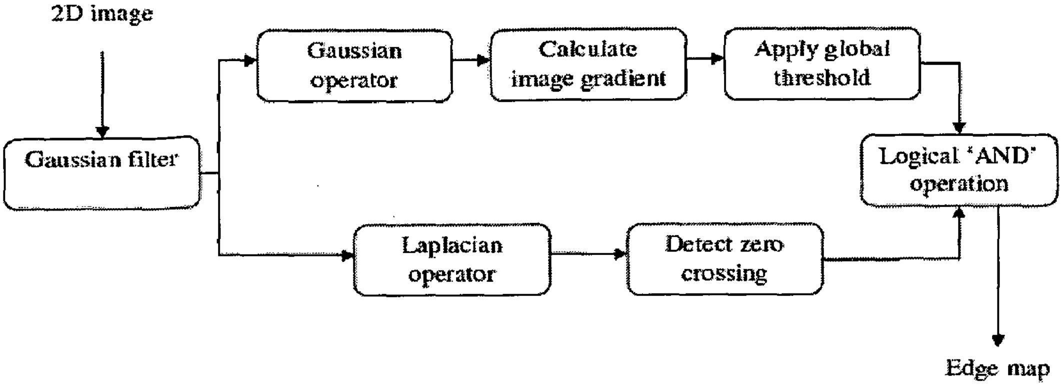


Figure 3.2 Edge-based technique

3.2.2 REGION-BASED TECHNIQUES :

There are two types of region-based segmentation approaches.

A. REGION GROWING TECHNIQUE :

A region growing technique (Figure 3.3) is the opposite of an edge detection technique. Instead of finding edges, this technique attempts to construct regions from a set of edges. This technique uses region homogeneity, which could be grey intensity, texture, or a combination of these two properties. Region growing usually starts with a single pixel or a group of pixels. This region will then grow and merge with its original region if the neighboring pixel's intensity value falls below a certain threshold of its original region value. This operation will precede recursively until all the pixels in an image have been evaluated against the original pixel value.

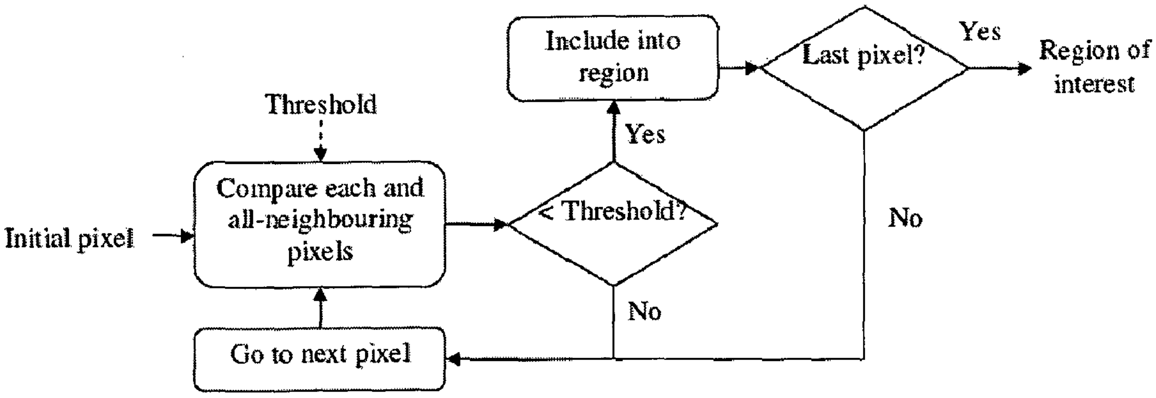


Figure 3.3. Block diagram of the region growing approach.

B. REGION SPLITTING AND MERGING TECHNIQUE

Region splitting divides the region into smaller regions based on homogeneity criteria. The initial region, which could be whole or part of an image, is then evaluated against the criteria. If the initial region meets the homogenous condition, it will leave the initial region and evaluate the next region. If the initial region does not meet the homogenous condition, the region is divided into four quadrants, and each region is evaluated against the homogenous condition (Figure 3.4).

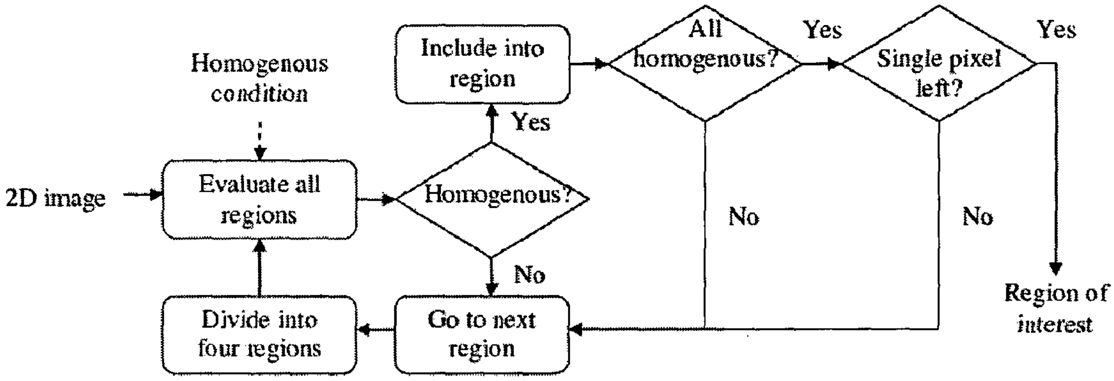


Figure 3.4. Block diagram of the region splitting and merging technique.

3.2.3 GLOBAL KNOWLEDGE-BASED TECHNIQUES

The global knowledge based technique uses global information of the image to segment structure of interest. Active Contour Models is the technique that uses global information of image to segment out the desired region of interest.

Snakes: Active Contour Models (ACM)

Snakes provide a powerful tool for semi-automatic segmentation. This model deals with the broken edge problem in many other segmentation techniques such as an edge detection technique. In addition, snakes can be customized and they are not too difficult to implement[19]. The snakes' energy functions are used in many deformable shape techniques, for example in. The energy terms associated with the snakes are discussed below. Representing the position of a snake parametrically by

$$v(s) = x(s)y(s)$$

The energy functions for this technique can be parameterized as

$$E_{snake} = \int_0^1 E_{snake}(v(s))ds$$

$$Esnake = \int_0^1 E_{\text{int}}(v(s) + E_{image}(v(s)) + E_{con}(v(s))ds$$

Where

*E*int represents the internal energy of the spline due to tension,

*E*image represents the image gradient force, and

*E*con represents the external constraint forces.

The **internal energy** of the spline is due to bending and can be written, as follows:

$$E\,\text{int} = (\alpha(s)\,|\,v_s(s)\,|^2 + \beta(s)v_{ss}(s)\,|^2)/2$$

Where:

first-order term that makes the snakes act like a membrane,

second-order term that makes the snakes acts like a thin plate.

Image Forces

Image E is expanded to reflect the three external energy components: lines (line*E)*, edges (Edge *E)*, and terminations (term *E)*.

$$E_{image} = w_{line}E_{line} + w_{edge}E_{edge} + W_{term}E_{term}$$

Where:

w_{line} determines how much the influence of the line attraction in external is Image energy,

wedge determines the gradient of the image, and

wterm determines the weight for the termination of a line or a corner.

The line attraction (line *E)* depends on the image intensity, and depending on the value of *line w,* the snakes will be either attracted to light lines or dark lines,

$$E_{line} = I(x,y)$$

The snakes find edges in an image by locating the contour with a large image Gradient. Thus, we have,

$$E_{edge} = -|\nabla I(x, y)|^2$$

The termination function can be computed using the curvature of the level lines in a Slightly smoothed image.

3.3. REGISTRATION:

Biomechanically,Image acquisition, visualization and accurate registration of scans of particular body part acquired during surgery has the potential to be a significant aid to the automatic interpretation of interoperative images and to enable prediction of surgical changes. Increasingly sophisticated multimodality image fusion and registration techniques have been developed to improve image acquisition quality and speed. In MRI, Image registration image registration in order to align the acquisitions involves both affine registration (to capture translation, rotation, scaling differences)and a biomechanical simulation of brain deformation.

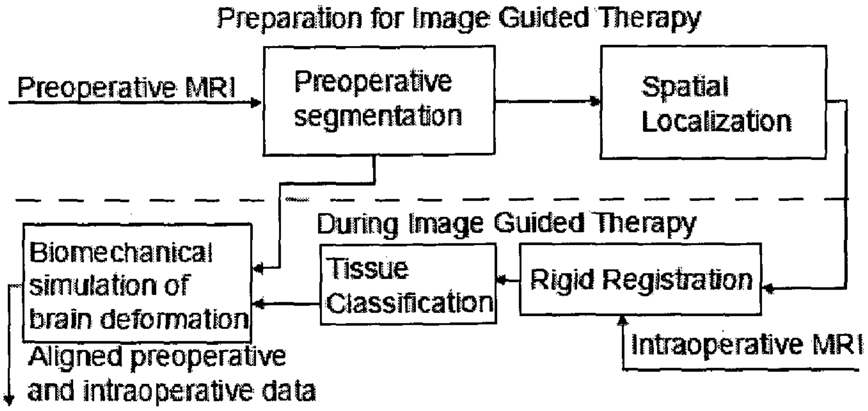


Figure 3.5. Schema for Intraoperative Segmentation and Registration

Figure illustrates the processing steps that take place before and during the therapy procedure.

During surgery, intraoperative data is acquired and the preoperative data (including any MRI, FMRI, PET, SPECT or MRA scans that are appropriate) is aligned with the intraoperative data using an MI based rigid registration method [12, 20]. The intraoperative image data then together with the spatial localization model forms a multichannel 3D data set. Each voxels of the combined data sets is then represented by a vector having components from the intraoperative MR scan, the spatially varying tissue location model and if relevant to the particular surgery, any of the other preoperative image data sets.

For the first intraoperative scan to be segmented a statistical model for the probability distribution of tissue classes in the intensity and anatomical localization feature space is built. The statistical model is encoded implicitly by selecting groups of prototypical voxels which represent the tissue classes to be segmented intraoperatively (less than five minutes of user interaction). The spatial location of the prototype voxels is recorded and is used to update the statistical model automatically when further intraoperative images are acquired and registered. This multichannel data set is then segmented with NN classification [26]a standard classification method which computes the type of tissue present at each voxel by comparing the signal of the voxel to classify with the signal of previously selected prototype voxels of known tissue type. The segmentation of the intraoperative data helps to establish explicitly the regions of tissues that correspond in the preoperative and intraoperative data.

3.4. VISUALIZATION: Computer visualization is a needed dimension in medicine. Volume visualization of tomographic volume data in medicine, as obtained in computer tomography (CT) or magnetic resonance imaging (MRI) is an important aid for diagnosis, treatment planning, surgery rehearsal, education and research. Doctors, surgeons, and scientists gain valuable insight into human physiology and pathology with visualizations that employ techniques such as volume rendering and virtual simulation.

3.5. SIMULATION: Simulation refers to the artificial (and almost always simplified) representation of a complex real-world process with sufficient fidelity to achieve a particular goal, such as in training or performance testing. In recent years simulators have seen increasing use in training health care providers. We discuss selected goals and applications of simulation in medicine:

1. **Teacher and training**:
    - a. Technical procedures (e.g., insertion of vascular catheters)
    - b. Heart sounds and lung sounds
    - c. Interactive physiological modeling
    - d. Avoiding the need for animal experimentation in biological and medical education (e.g. teaching sessions concerning cardiopulmonary physiology or pharmacology).
    - e. Reducing the need for clinical training using real patients in socially difficult situations.
    - f. Practicum for medical students during anesthesia or emergency medicine rotations.
2. Human performance evaluation (e.g., responding to simulated critical incidents in the emergency room or operating room)
3. Human factors engineering and usability engineering studies for medical equipment.
4. Studies in cognitive engineering (e.g. development of cognitive process models)

CHAPTER 4

WINDOWS PROGRAMMING

4.1. INTRODUCTION TO WINDOWS PROGRAMMING:

Windows program use the event-driven Programming model, in which applications respond to events by processing messages sent by the operating system. An event could be a keystroke, a muse click ,for a command for a window to repaint itself, among other things. The entry point for a window program is a function named Winmain( ),but most of the action takes place in a function known as the window procedure. The window procedure processes messages sent to the window.WinMain creates that window and then enters a message loop, alternatively retrieving messages and dispatching them to the window procedure. Messages wait in a message queue until they are retrieved. A typical Window application performs the bulk of its processing in response to the messages it receives, and in between messages, it does little except wait for the next messages to arrive.

The message loop ends when a WM_QUIT message is retrieved from the message queue, signaling that it's time for the application to end. When the message loop ends, WinMain returns and the application terminates.

Windows uses a call-based interface to access the operating system. The Windows call-based interface is a rich set of system-defined functions that perform all necessary operating system-related activities, such as memory allocation, outputting to the screen, creating windows, and the like. These functions are called the Application Programming Interface (API). An Application Program calls the API function to communicate with Windows. Windows API functions are contained in Dynamic Link Libraries (DLLs), which each program has access to when it is executed. The Windows API functions are stored in a relocatable format within a DLL. During the compilation phase, when your program calls an API function, the linker does not add the code for that function to the executable version of your program. Instead, it adds loading instructions for that function, such ass what DLL it resides in and its name[6,7].

Dynamic linking has some very important benefits. First, since virtually all programs will use the API functions, DLLs prevent disk space from being wasted by the significant amount of duplicated object code that would be created if the API functions were actually added to each program's executable file on disk .Second, updates and enhancements to Windows can be accomplished by changing the dynamic link library routines. Existing application programs do not need to be recompiled.

There are two versions of Windows API .The first is called Win 16, which is the 16-bit version of the API utilized by Windows 3.1.The other is called Win 32, which is the 32-bit versions of the API utilized by all 32-bit versions of Windows, such as Windows95/98/NT.Win 16 supports 32-bit,flat addressing ,while Win 32 supports 32-bit,flat addressing.

Because Win 32 supports full 32-bit addressing, it makes sense that integers are also 32-bits long. This means that types **int** and **unsigned** will be 32 bits long, not 16 bits long, as is the case for Windows 3.1.If we have to use a 16-bit integer, it must be declared as **short**.

Another result of 32-bit addressing is that pointers no longer need to be declared as **near** or **far**. Any pointers can access any part of memory. In a Win 32 environment, both **far** and **near** are defined.

4.2. COMPONENTS OF A WINDOW

Each Window in a Window application is defined by certain attributes, called its class.

In a traditional style program, a Window class must be defined and registered before a window can be created. When we register a Window class, we are telling Windows about the form & function of the Window or style & type of the Window.

All Windows have a ***border*** that defines the limits of the Window and is used to resize the Window.

At the top of the Window are several items. On the far left is the ***System menu icon*** (also called the Bar icon).Clicking on this box displays the system menu. To the right of the System menu icon is the Window's title at the far right are the ***Minimize, Maximize*** and ***Close icons***. The ***client area*** is the part of the Window in which your program activity takes place. Most Windows also have ***horizontal*** and ***vertical scroll bars*** that are used to move text through the window.

4.3. THE WINDOW PROCEDURE

All Windows Program must contain a special function that is not called by your program but is called by Windows. This function is generally called the Window function or the Window Procedure or Callback function. The Window function or the Window Procedure or Callback function is called by Windows when it needs to pass a message to your program. It is through this function that Windows communicate with your program. The Window Function receives the message in its parameters[7].

All Windows communicate with your program by sending it messages. All Windows application must establish a message loop (usually inside the WinMain ( ) function. All Windows programs begin execution with a call to the Winmain ( ) function.
This Message Loop reads any pending message from the application's message queue and then dispatches that message back to Windows, which then calls your program's Window function with that message as a parameter.

In addition to receiving the messages sent by Windows, the Window function must initiate any actions initiated by a message. Of course, programs need not respond to every message that Windows sends. For messages that programs doesn't care about, we can let Windows provide default processing of them. Since there are hundreds of different messages that Windows can generate, it is common for most massages to simply be processed by Windows & not by your program.

In a traditional Windows Program, the Window Procedure is a function provided by us. In an MFC-based program, the Window Program is provided by MFC. This is one of the benefits of using MFC for Windows programming.

4.4. MICROSOFT FOUNDATION CLASSES:

The Microsoft Foundation Classes (MFC) was created to make programming for the Windows environment easier and the code that you produce more portable. Writing Windows programs using the traditional, API-based approach is both a challenging, and, at times, frustating job. Furthermore, in a traditional-style API-based Windows program, the programmer, must manage all of the details explicitly.MFC provides a faster and easier way to produce solid code. Put simply, Windows is the most important operating system for which programs are being written – and MFC is the fastest way that we can write programs for it.

MFC is a system of C++ classes designed to make Windows programming easier and quicker. MFC consists of a multi-layered class hierarchy that defines approximately 200 classes. These classes allow us o construct a Window application using object-oriented principles. MFC provides you, the programmer, with a framework upon which you can build Windows applications.

MFC offers the convenience of reusable code. Because many of the tasks common to all Windows Programming are provided by MFC, you don't need to re-create these each time you write a new program. Instead, the programs can simply inherit this functionality from MFC as needed. Also, MFC programs are highly portable, because, the interface provided by Foundation Class Library is largely independent from the details of its underlying implementation.

Another way that MFC simplifies Windows programming is by organizing the Windows Application Programming Interface (API). An Application program interfaces the windows through the API, which contain several hundred functions. Because the Microsoft Foundation Classes encapsulate much of the API in a set of logically related classes, the API is easier to manage.

A small number of classes defined by MFC do not directly relate to Windows programming. For example, MFC defines classes that create strings, manage files, and implement exception handling. Some elements of MFC, like general purpose classes can be used by windows and non-windows programs[6].

In a MFC Program, we can define our own Window Class, but we don't have to. Instead, we can use the default class provided by MFC. This is another benefit of writing Windows program using the Microsoft Foundation Classes.

CHAPTER 5

DESIGN AND IMPLEMENTATION

5.1 Tool Features

The tool developed in this thesis provides an easy interface for the programmer to synthesize test images. Some advance features are also included to provide better viewing experience to the programmer and to the practitioner. The features provided are listed below.

1. Large set of tools are provided for creation of Synthetic Images[1]. The toolbox has options to allow the user to draw both regular and irregular shapes.
2. Semantic information for each voxel is maintained by the system, which can be enquired easily. Semantic information generally refers to CT value associated with each voxel. However other information can also be associated with each voxel.
3. The synthetic image creator tool supports image control features such as Zoom In /out, scrolling through sequence of images in the same file, moving shape within image area, mouse interaction etc. These features allow users to interact with the image at different levels of detail.
4. The characteristic feature of the developed tool is the ability to add any number of layers to the image. The purpose of these layers is to segregate the information into different components. This option coupled with transparency feature allows the programmer / practitioner to view only a selected portion of the image. This feature can be used to generate image volume (set of images)[24].
5. An easy to use layer cumulating functionality is provided. The objective of this feature is to accumulate the data available in different layers.
6. The tool gives provision for the user to set the transparency level for each layer in the image. This can be set by providing appropriate value for the Alpha channel. A value of 1 for the alpha channel indicates completely transparency and a value of 0 indicates the layer is opaque.

5.2 Framework

The framework of the system used to obtain the synthetic images is shownbelow

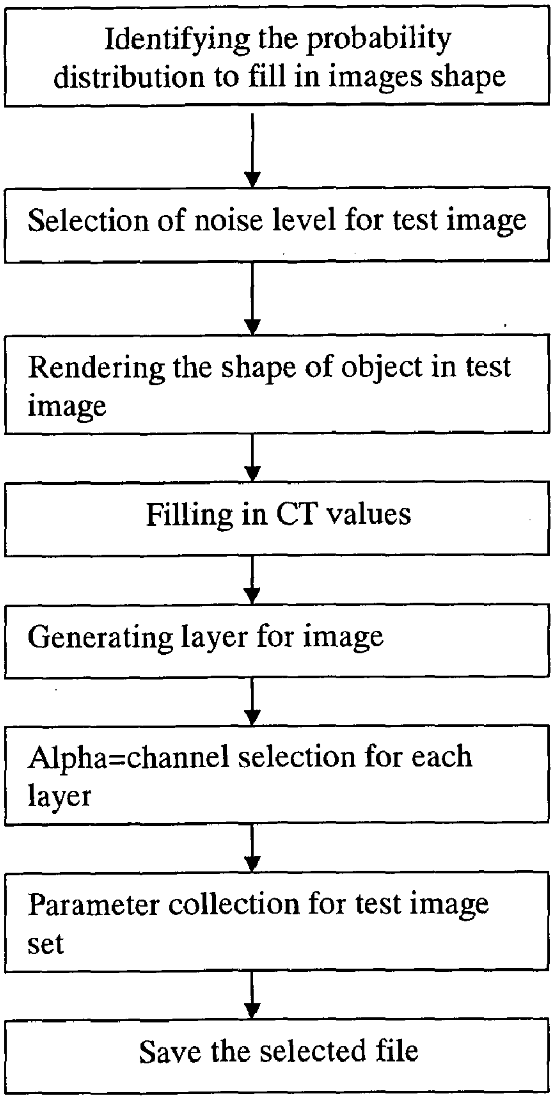


Figure 5.1. Procedure to obtain synthetic images

5.3 Data Structures

The implantation of the tool required the usage of a few data-structures. A brief review of the data structures and their usage in this thesis are discussed below.

5.3.1 Doubly linked list

In this thesis a doubly linked list is used to store the relative arrangement of layers. The reason for selecting a doubly linked list is because layer addition and deletion becomes simple and is relatively faster. To add a new layer a node is added to the list, with corresponding information updated in the data field of the node. To remove a layer the reference pointers are updated and the node is removed from memory. A brief introduction of DOUBLY LIKED LIST along with an explanation of the various operations available is explained below.

Linked list is a data structure used for storing a collection of elements where each element in the list has a reference to next element in the list. Linked List is generally used when insertions and deletions of elements in the list are frequent. The basic element of a linked list is a node. For a doubly linked list each node consists of three fields. A data field, a pointer to the next element in the list and a pointer to the previous element in the list. This allows easy access to list items in backward as well as forward direction enabling deletion operation in linear time.

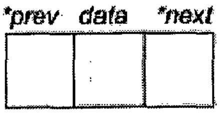


Figure 5.2. Structure of a node in Doubly linked list

A doubly-linked list is created as follows.

- For each new element to be added to the list a node is created.
- The data field is updated with the value of the data item to be inserted.
- Each node includes pointers to the previous and next nodes. These pointers are updated to accommodate the new node into the list.

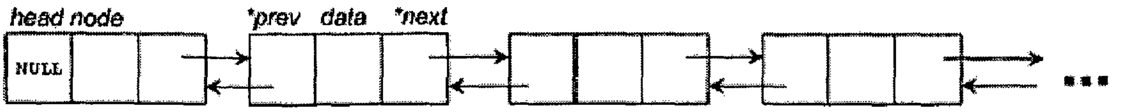


Figure 5.3. Doubly linked list.

Insertion in Doubly Linked List

Figure 5.4.illustrates the procedure to insert an element into the linked list.

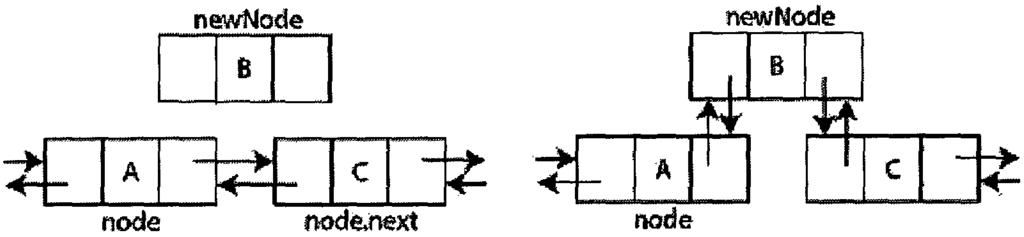


Figure 5.4. Inserting a new node

A new node is inserted into the list using the following procedure

- Identify the position to insert the element
- Update the next and previous pointers of the new node, predecessor node and successor node.

Deletion in Doubly Linked List

The removal of a node from a doubly linked list involves the followingtask

- Update the next, previous pointers of the predecessor node and successor node respectively.
- Remove the node from memory

5.3.2 VOXEL: Dicom standard specification stipulates two major components of medical image data. The first being the header information and the next being the image data. The image may contain information of a single image or a sequence of images. The header information is stored using a struct. The image data is represented using voxel. Voxel represents a value in three dimensional spaces. This is analogous to a pixel which represents 2D image data.

Depth information is added to the image using a process referred to as Voxelization. This is achieved using a set of cross-sectional images known as a volumetric dataset. These cross-sectional images (or slices) are made up of pixels. The space between any two pixels in one slice is referred to as interpixel distance, which represents a real-world distance. And, the distance between any two slices is referred to as interslice distance, which represents a real-world depth .The dataset is processed when slices are stacked in computer memory based on interpixel and interslice distances to accurately reflect the real-world sampled volume.

Additional slices are usually created and inserted between the dataset's actual slices so that the entire volume is represented as one solid block of data. The dataset now exists as a solid block of data and the pixels in each slice have taken on volume. Hence the pixels are referred to as voxels.

5.4 Implementation of Basic Functionalities:

The synthetic medical image creator tool has been implemented in a modular fashion. The tool has been designed to make use of the object oriented principles. The tool provides facilities to enable the programmer to check the viability of any implemented algorithm in a layered manner. The objective of the design has been to facilitate the batch segmentation on a medical image with ease.

Application Programming Interface

The most important classes of the API for the application at hand are

1. CImageLayer
2. CFullLayerControl

CImageLayer: The class CImageLayer provides a Bitmap layer abstraction to the programmer. The most important elements of the CImageLayer are the CBitmap and the CRgn objects of the MFC 6.0 library. A brief overview of these classes have been provided below.

1. **CBitmap:** Bitmaps are encapsulated by **CBitmap**. To create and manipulate bitmaps, the MFC library provides the **CBitmap** class. The use of this class depends on the type of bitmap that needs to be created and on the usage of that bitmap. One way to use a bitmap is to display a picture on a window. To do this, there must first be a picture resource. Although the Image Editor built-in Microsoft Visual C++ is meant to help with regular application resources, it has a problem in handling a bitmap that displays more than 16 colors. The solution to the problem is to import the bitmap that is to be used. Once the bitmap is ready, the **CBitmap::LoadBitmap ( )** method is called to display the function.

The following procedure is used to display the bitmap.

1. Obtain the device context so that the program can output to the window.
2. Obtain an equivalent memory device context that will hold the bitmap until it is displayed. (A bitmap is held in memory until it is copied to our window).
3. Select the bitmap into the memory device context.
4. Finally, copy the bitmap from the memory device context to the window device context. This causes the bitmap to actually be displayed.

A bitmap is a resource that must be removed before our application ends. Generally, this is done automatically when a CBitmap object is destroyed. However, a bitmap can also be manually by calling the function CGdiObject::DeleteObject( ),which has the following prototype:

BOOL CGdiObject::DeleteObject( );

The function returns nonzero on success and zero on failure.

The object of **CBitmap** is used to store the bitmap of the synthetic image created using the synthetic image creator tool provided by the software. The bitmap is set using the Update Bitmap function of this class. The function can be extended to map the bitmap based on the CT range of the layer. The class also stores the CT range to record the CT range for each layer. The various options to map the bitmap to the synthetic image are as follows

1. A single gray color filled for the full CT range based on the average of the CT range for the layer.

2. Fractal based approach can also be used to fill the bitmap using the CT range. the fractal based approach appears to be fast, efficient, and promising way to provide the shades to the synthetic image. The fractal based approach give a subjective appearance close to the real medical image. A bigger advantage of the approach is to map the Bitmap in coloured approach. the colours can either be chosen randomly, or the palettes can be used to provide flexibility to the user to change the colours according to the preferences of the user.

3. Mapping using segmentation of image from the real medical image.

4. Texture based approach: Texture based approach allows bitmaps to be copied from other bitmap. these bitmaps can be build using any more specialized tool for bitmap drawings such as MSPaint, Corel Draw, etc

The appearance of the bitmap is just for user's visibility, the CT range provides much better means for the segmentation and other activities. It basically provides the semantics to the layer.

2. CRgn: The CRgn class encapsulates a Windows graphics device interface (GDI) region. CRgn provides an abstraction of the region; it enables easy access to the areas covered by the single layer. A region is an elliptical or polygonal area within a window. To use regions, we use the member functions of class **CRgn** with the clipping functions defined as members of class **CDC**. **CDC** encapsulates device-context support. The member functions of **CRgn** create, alter, and retrieve information about the region object for which they are called.

CRgn provides functions for creating geometrically shaped regions, combining existing regions to create more complex regions, and performing certain operations such as hit-testing a region or retrieving a region's bounding rectangle. The CDC class provides tool for drawing with a region once it's created for e.g. filling a region with a brush color or using it to clip other drawing operations.

Regions are used primarily for clipping; you can select a region into a device context by using the device context's SelectObject( ) or SelectClipRegion( ) function. Thereafter, all GDI-rendering functions performed in the device context are clipped to the specified region.

We can specify complex regions that have overlapped borders, simple regions that do not have overlapping borders, or null regions where there is no specified region data. Many of the functions use and return the type of region specified by the COMPLEXREGION, SIMPLEREGION, and NULLREGION flag values. If an error occurs when combining or selecting regions the ERROR flag is returned.

To create an initialized CRgn object, we must construct it by using the default CRgn constructor and then use one of the creation functions, such as CreateRectRgn( ) for rect angles, reateEllipticRgn( ) for ellipses, CreatePolygonRgn( ) for polygons, or CreateRoundRgn() for rounded rectangles. Other functions are available that initialize from structures or create multiple polygons.

2. **CFullLayerControl**: the class CFullLayerControl creates a doubly linked list of the CImageLayer to implement the layering concept. The layering concept provides a lot of flexibility to the system.

5.5 Implementation of Special Features

Alpha Channel: An alpha channel is an extra channel that certain image file formats support. Put differently, alpha channel is a semi–transparent part of the image with any background image behind it. Usually, a color image file is composed of 3 channels: Red, Green and Blue. A transparency channel may be added to describe the importance of each pixel when composited over another image. This transparency channel is called the alpha channel.

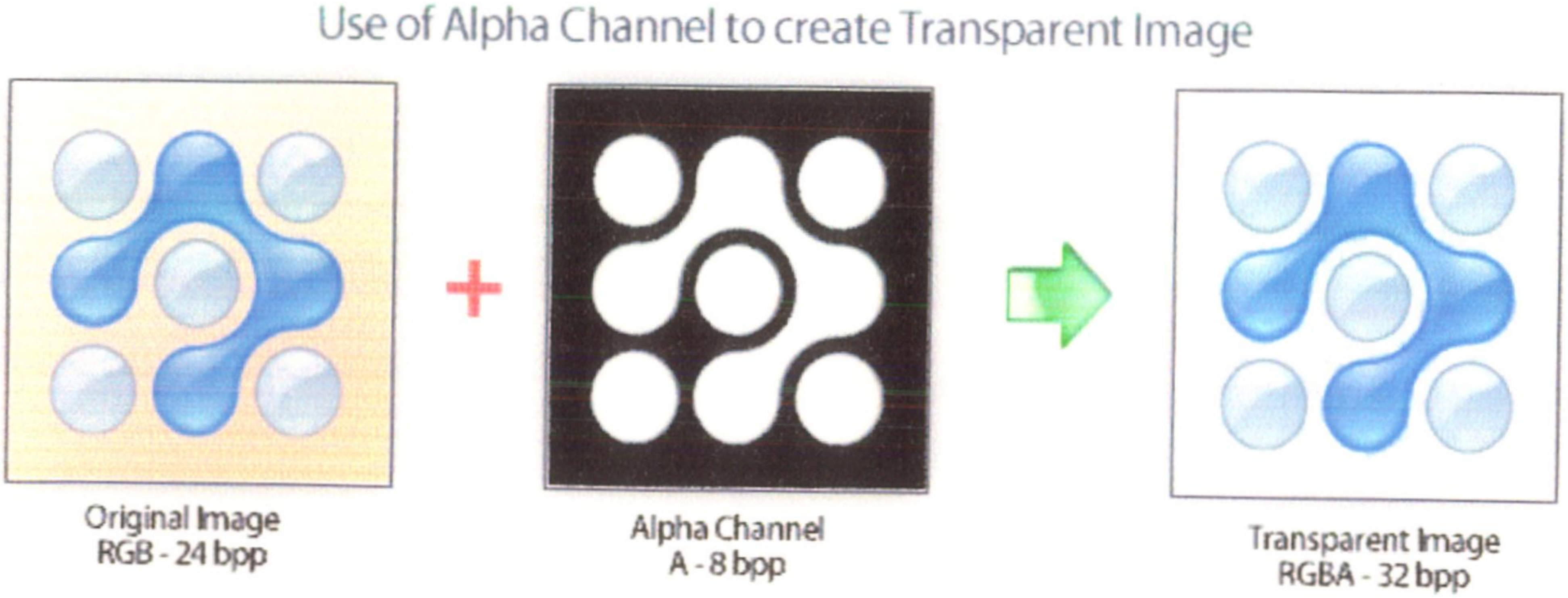


Figure 5.5. Illustration of Alpha Channel

Modes control how graphic images and, to a certain extent, text are displayed on the screen. For example, let's say we create a graphic using an image editing program, add text to it, apply some effects, and then import it into a display or interaction icon. From

5.6 Random Walker's Algorithm

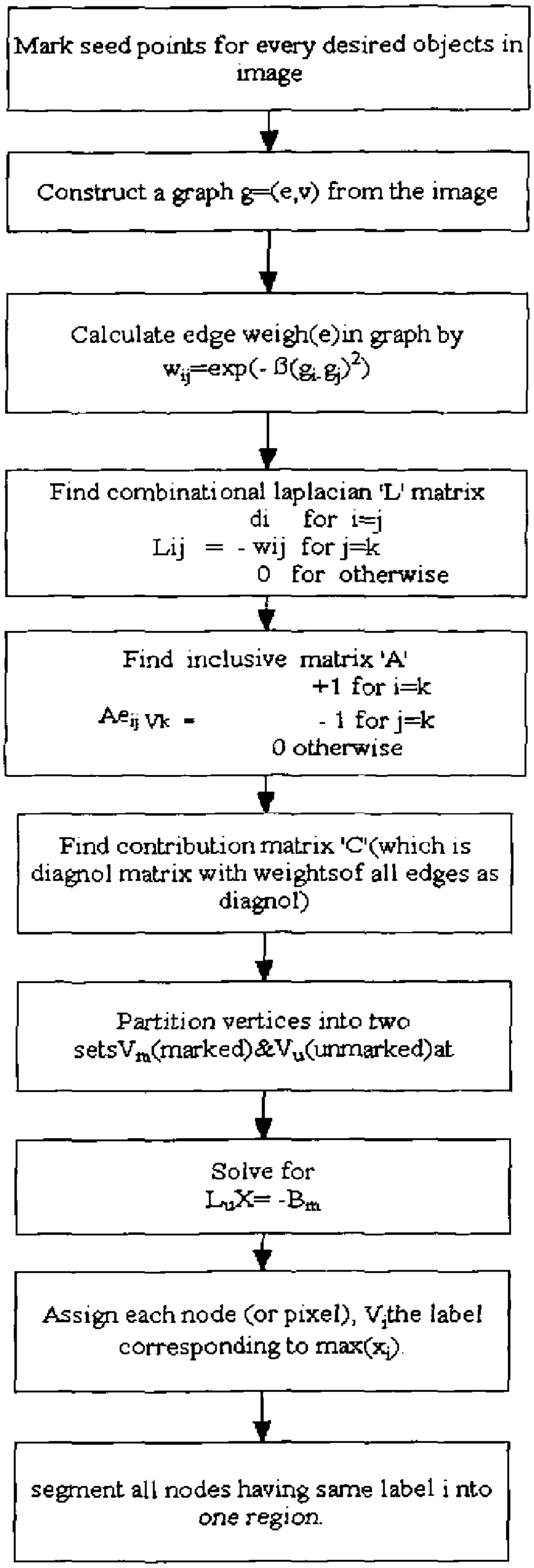


Figure 5.6 Flow chart of Random Walkers Algorithm

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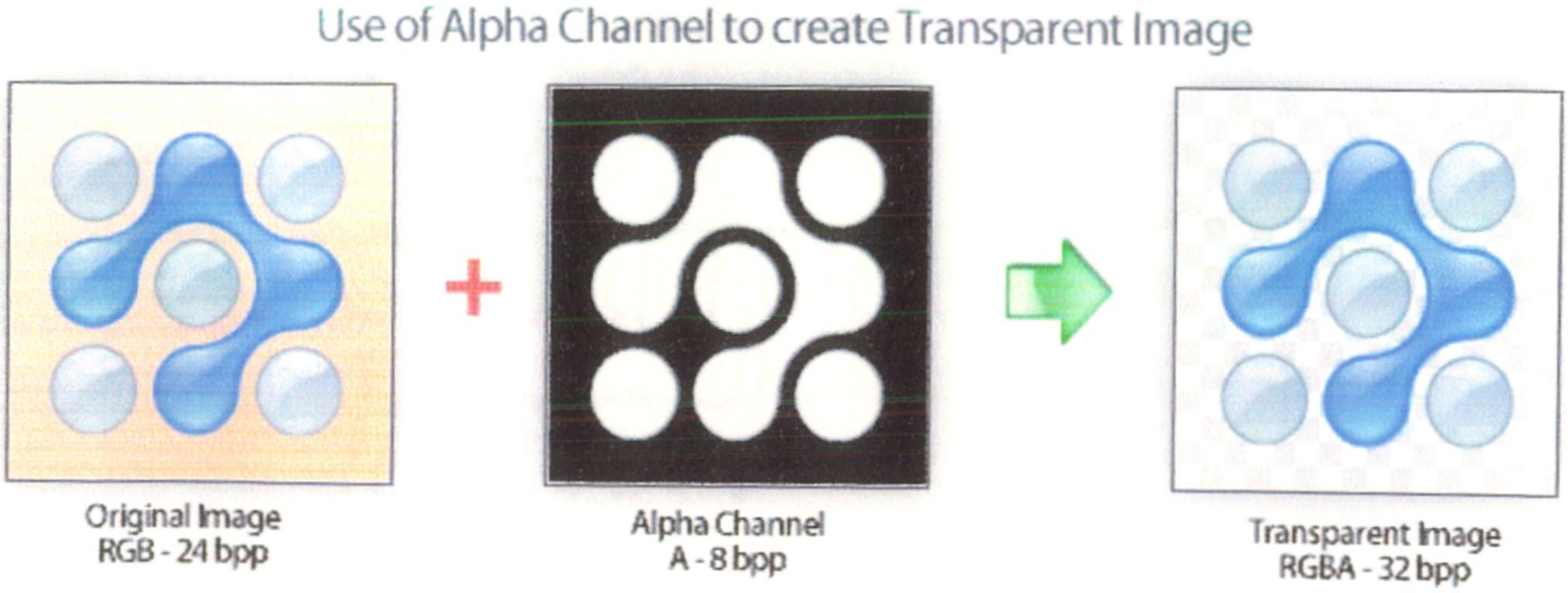

Figure 5.5. Illustration of Alpha Channel

Modes control how graphic images and, to a certain extent, text are displayed on the screen. For example, let's say we create a graphic using an image editing program, add text to it, apply some effects, and then import it into a display or interaction icon. From there you can choose the mode of display for the graphic. Alpha channels are masks through which you can display images. The alpha channel is an 8-bit channel, which means it has 256 levels of gray from 0 (black) to 255 (white). White acts as the visible area; black acts as a transparent area. The level of gray in between determines the level of visibility. For example, 50 percent gray allows for 50 percent visibility. Alpha channels are usually used with 16.8M color RGB images. The resulting image is called RGBA (RGB+A, A means alpha channel).

The illustration below shows how the alpha channel is applied to the original image to remove (visually) the orange gradient background. The result produces a 32 BPP (Bit per pixel) transparent image. The grey checkboard-like pattern shows the transparency of the image.

5.6 Random Walker's Algorithm

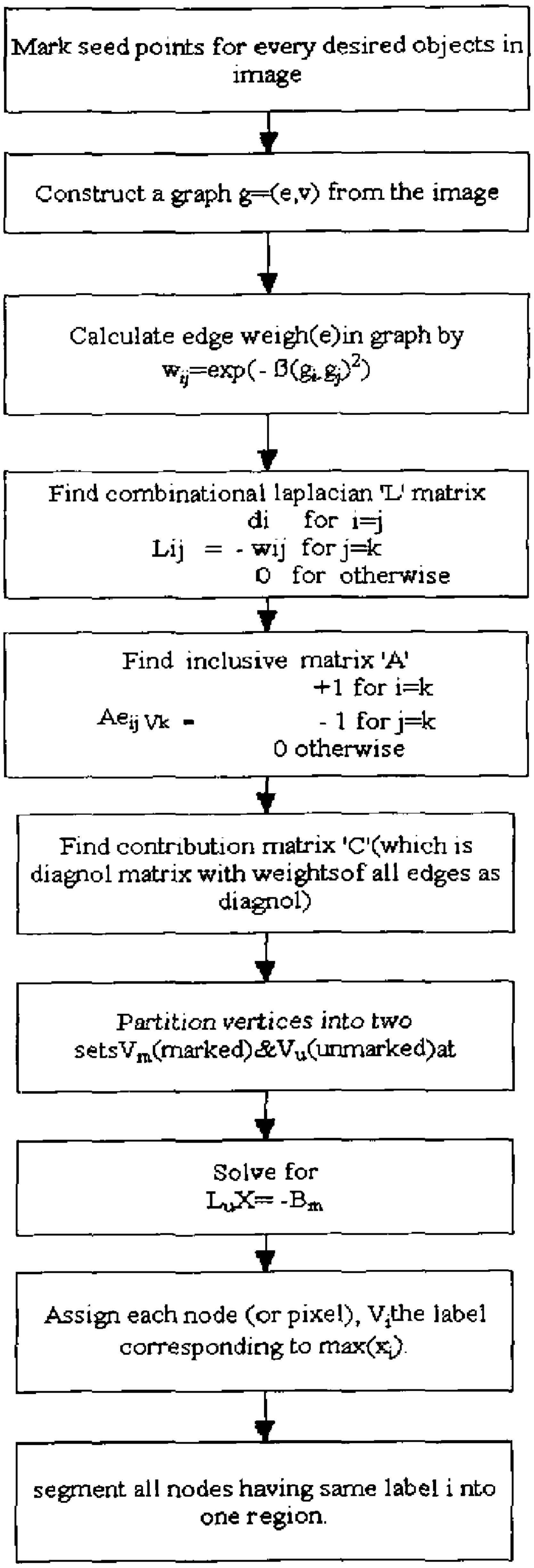

Figure 5.6 Flow chart of Random Walkers Algorithm

CHAPTER 6

RESULTS AND DISCUSSION

The usefulness of the tool developed is illustrated by testing an image segmentation algorithm. We first illustrate the performance of the algorithm on real medical image. Figure 6.1 shows the MRI image of the brain. In this thesis we considered a region growing algorithm with seed points. The seed points of algorithm are represented as colored circles. The results of segmentation are shown in Figure 6.2. Although the segmentation appears to be satisfactory no quantitative analysis on the segmentation algorithm can be established. Figure 6.3 and Figure 6.4 illustrate the probability of each pixel in the image belonging to region specified by seed point 1 and seed point 2 respectively.

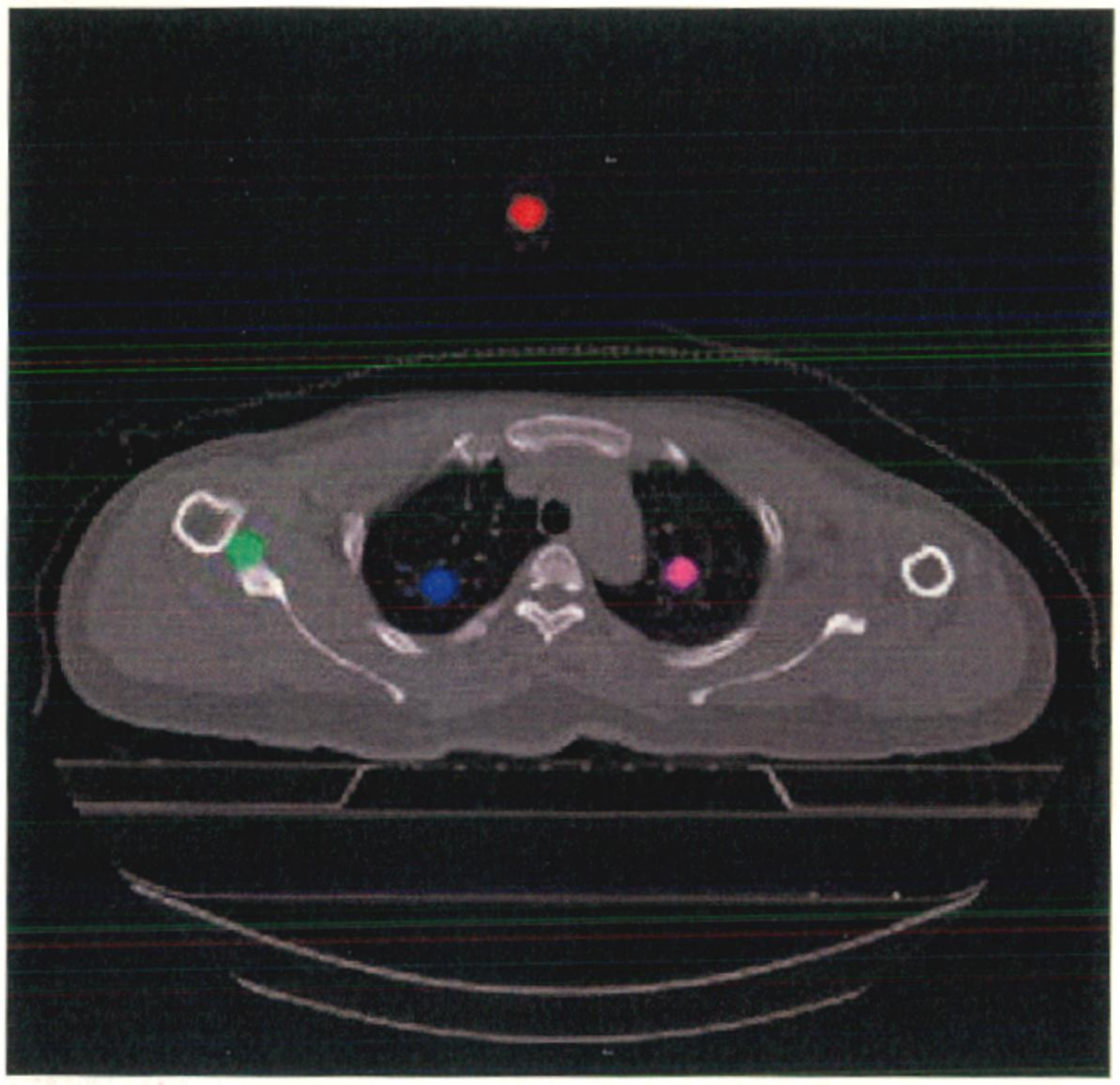

Figure 6.1. MRI image of Brain

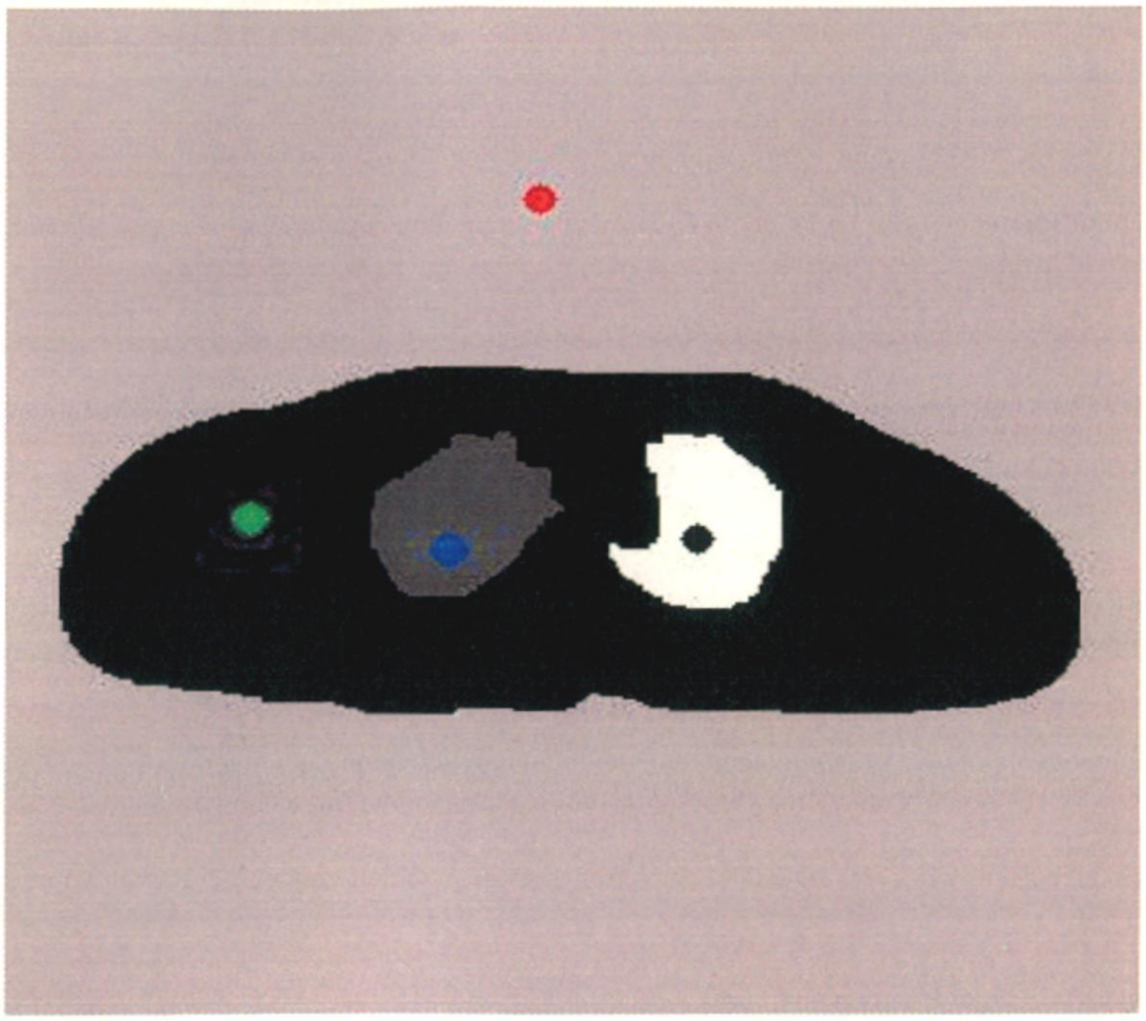

Figure 6.2. Segmentation results

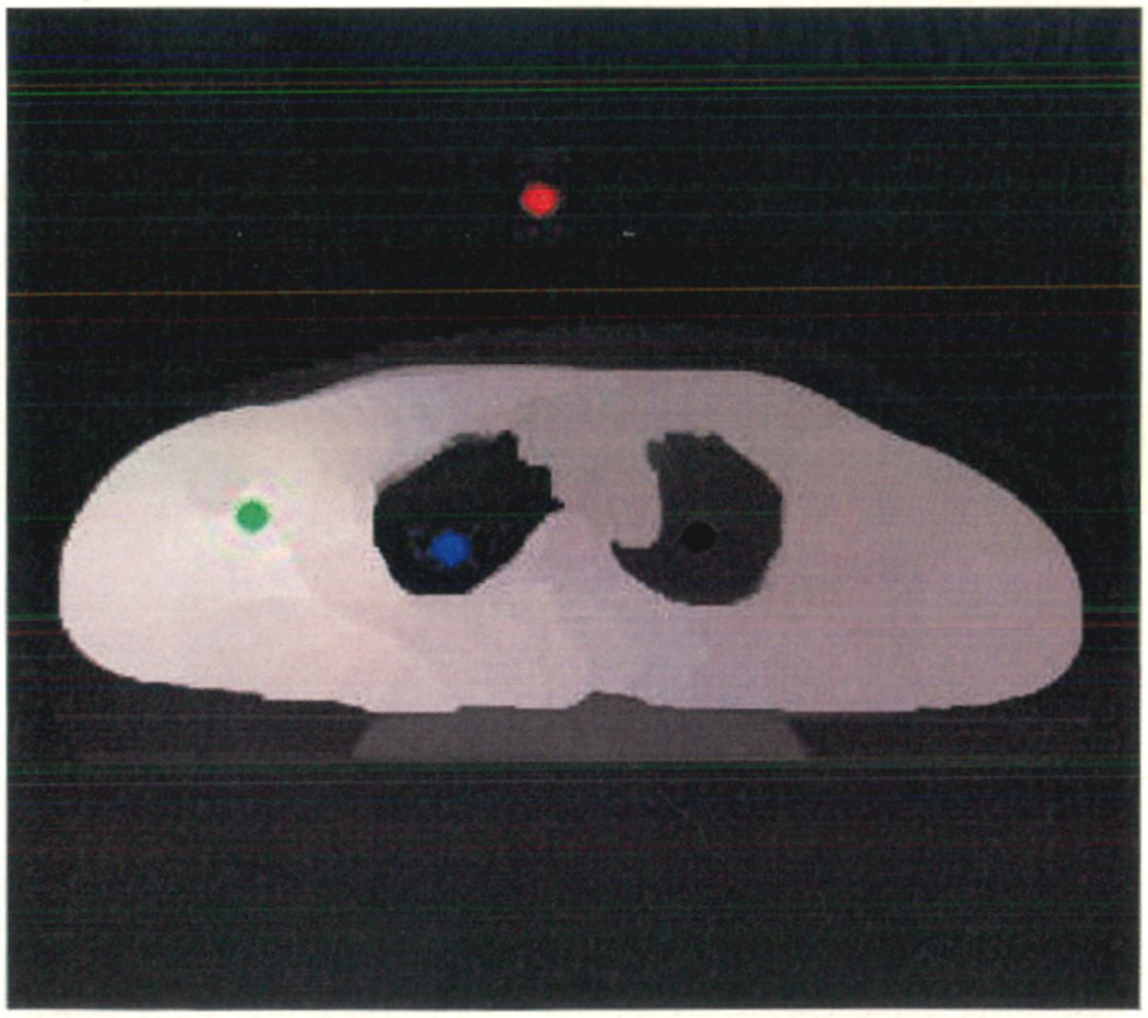

Figure 6.3 Distribution Map indicating probability of pixels belonging to Region 1

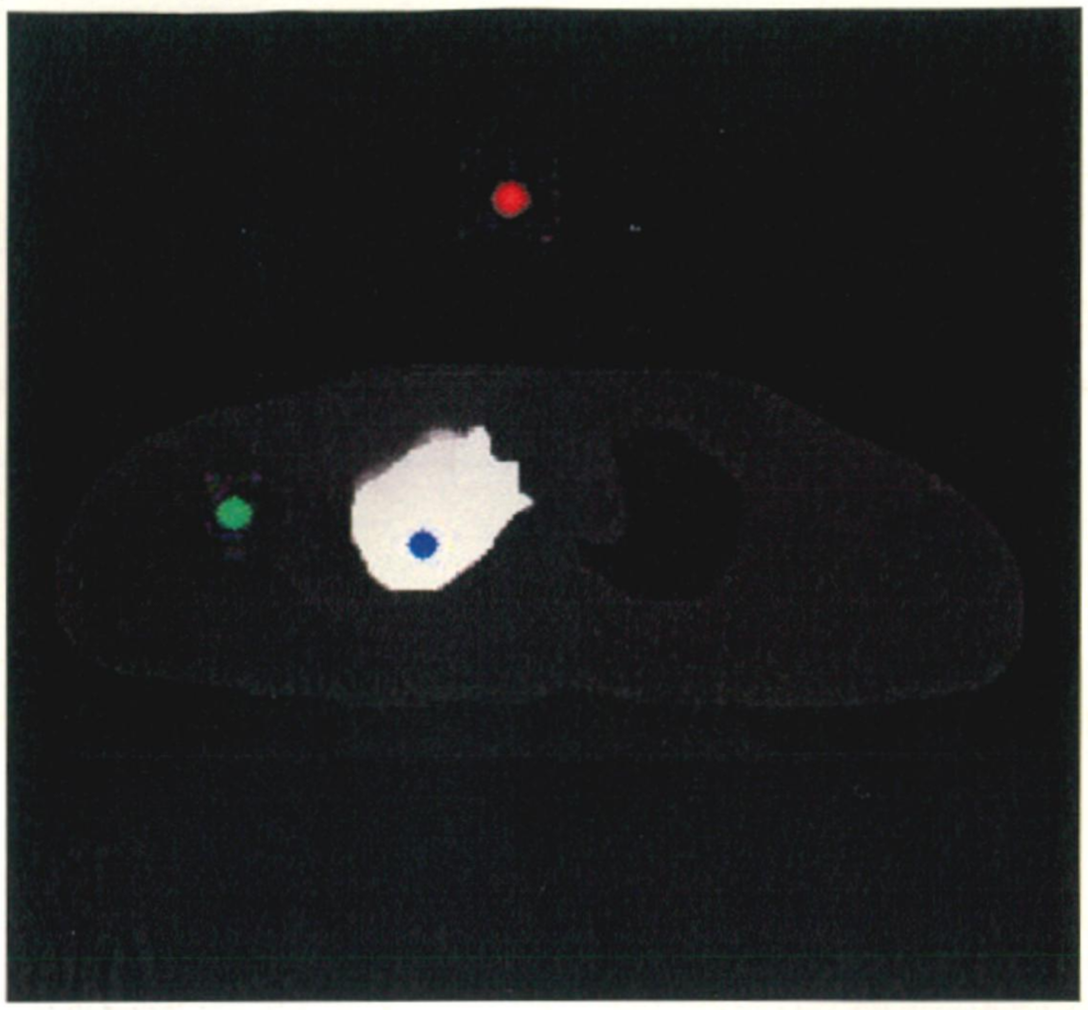

Figure 6.4 Distribution Map indicating probability of pixels belonging to Region 2

To establish the appropriateness of the algorithm to particular class of images the segmentation algorithm was tested with the synthetic images generated using the tool. The first image we considered is shown in Figure 6.5. The segmentation result is shown in Figure 6.6. As evident from figure the performance of segmentation on the shape considered is poor. The distribution map indicating the probability of pixel belonging to a prticular region is shown in Figure 6.7 and 6.8 respectively.

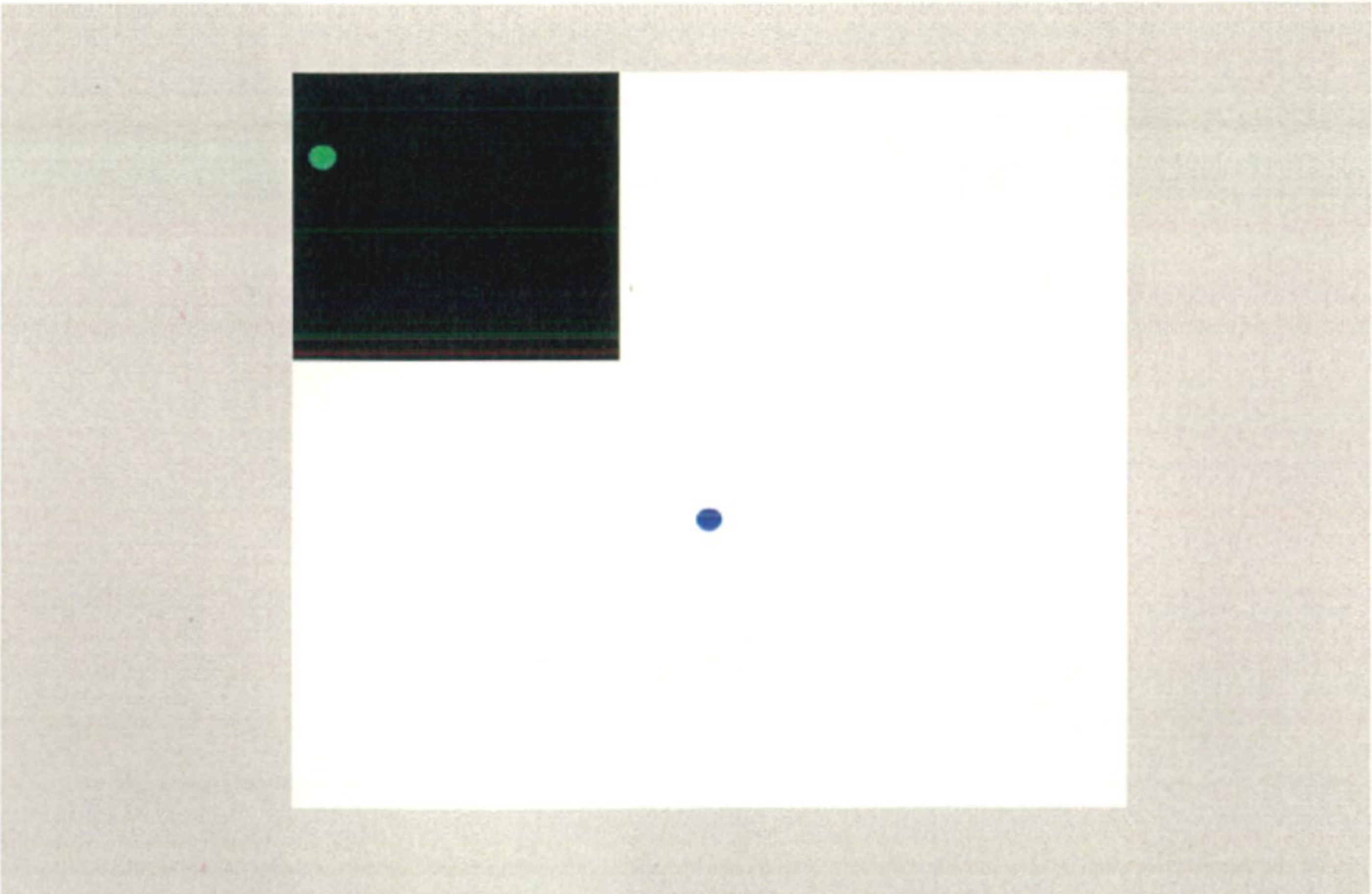

Figure 6.5. Test Case 1: Synthetic Image Generated without noise

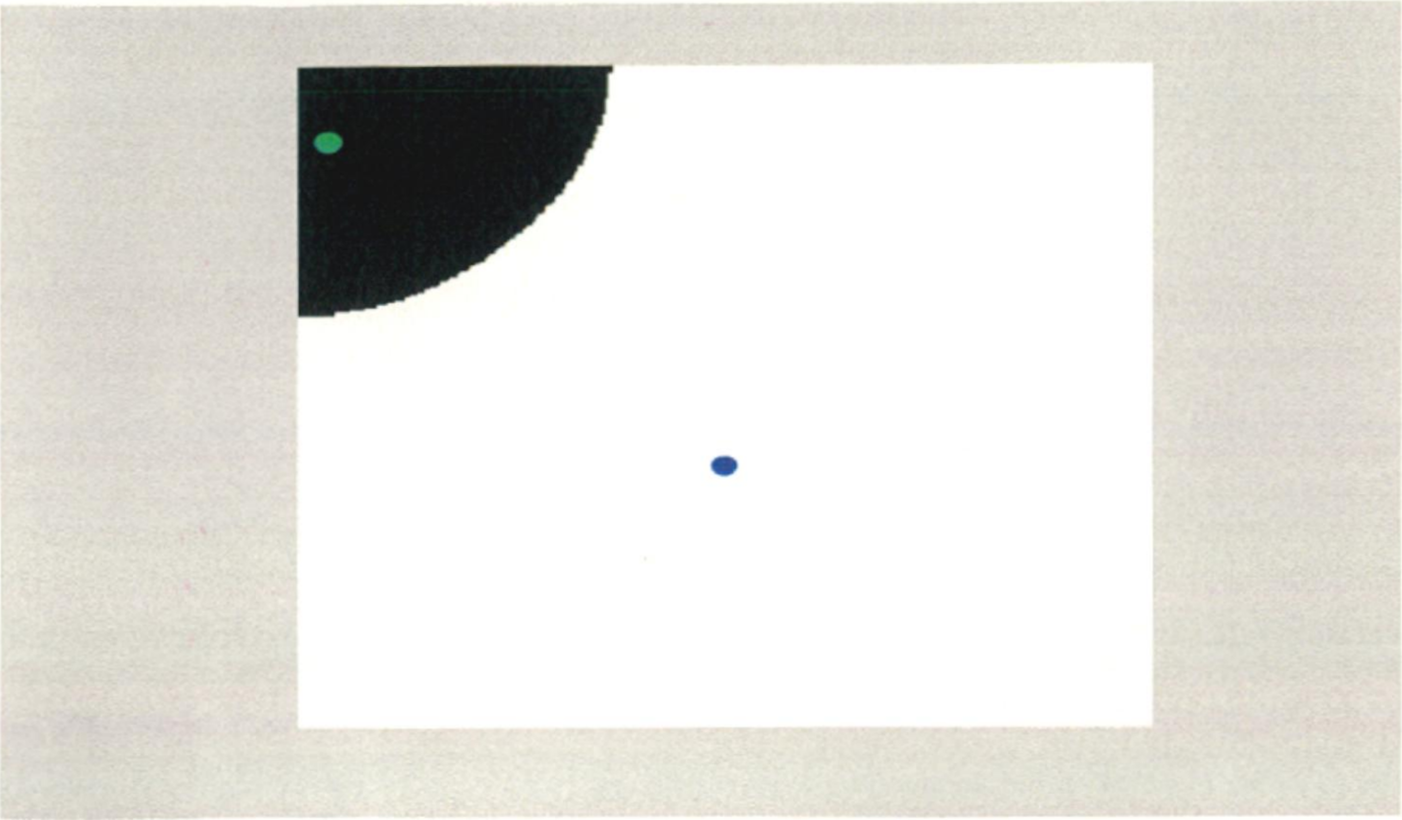

Figure 6.6. Result of Segmentation on Synthetic Image 1.

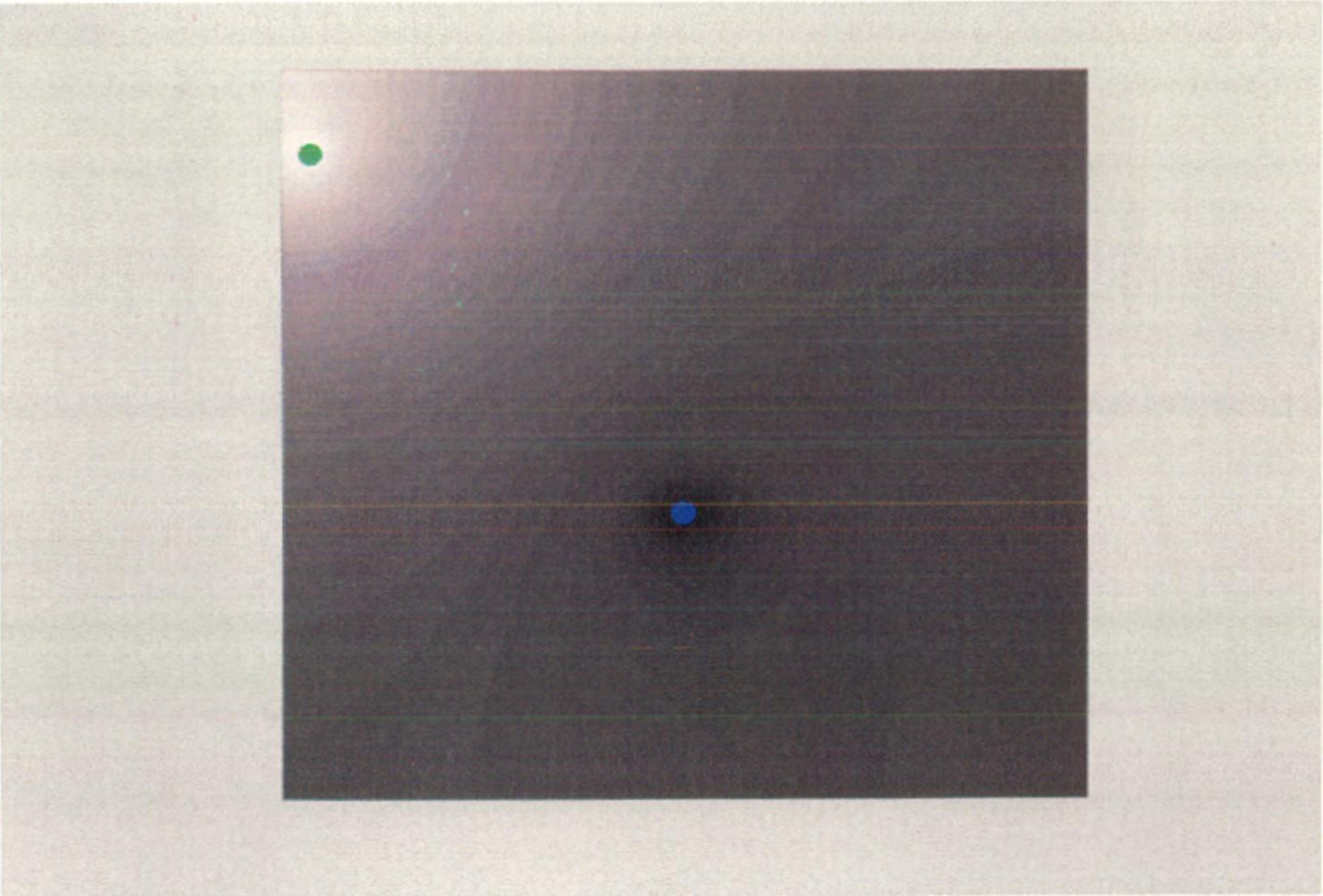

Figure 6.7. Distribution Map indicating probability of pixels belonging to Region 1

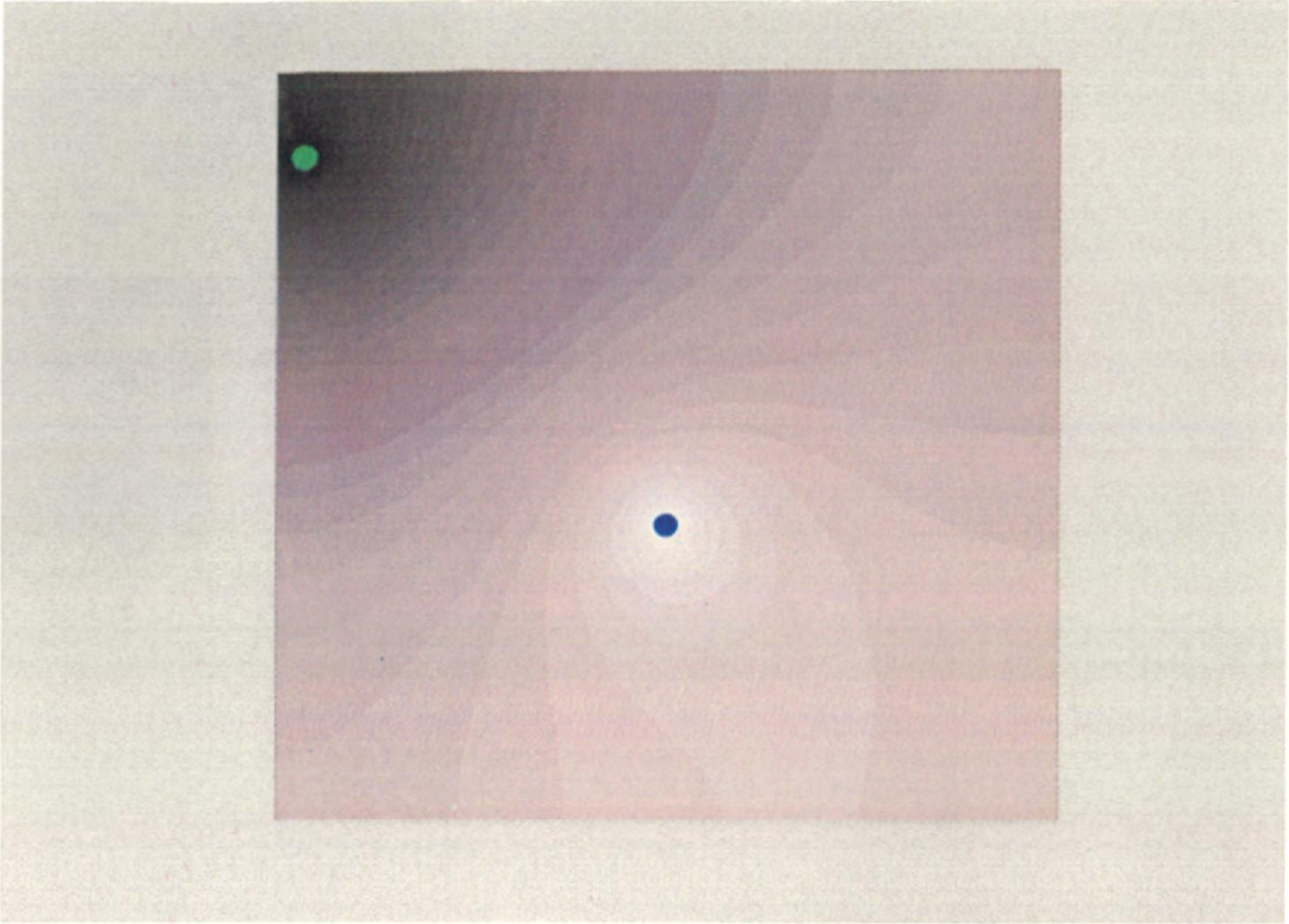

Figure 6.8. Distribution Map indicating probability of pixels belonging to Region 2

To test the performance of the algorithm in the presence of noise, synthetic images were generated with two kinds of noises that are generally present in images.

1. Gaussian Noise
2. Salt and Pepper Noise

Testing Segmentation in the presence of Gaussian Noise

Synthetic images were generated in this dissertation with Gaussian noise of mean 0 and variance 0.0001. The generated synthetic image is shown in Figure 6.9. Each pixel in the image is added a random noise which forms a Gaussian distribution. The result of segmentation is shown in Figure 6.10. The results indicates a degradation in performance of algorithms with the addition of noise. The distribution map for both the images is shown in Figure 6.11 and 6.12.

The next case considered is a synthetic image with salt and pepper noise shown in Figure 6.13. The segmentation results and the corresponding distribution maps are shown in Figure 6.14, Figure 6.15 and 6.16 respectively.

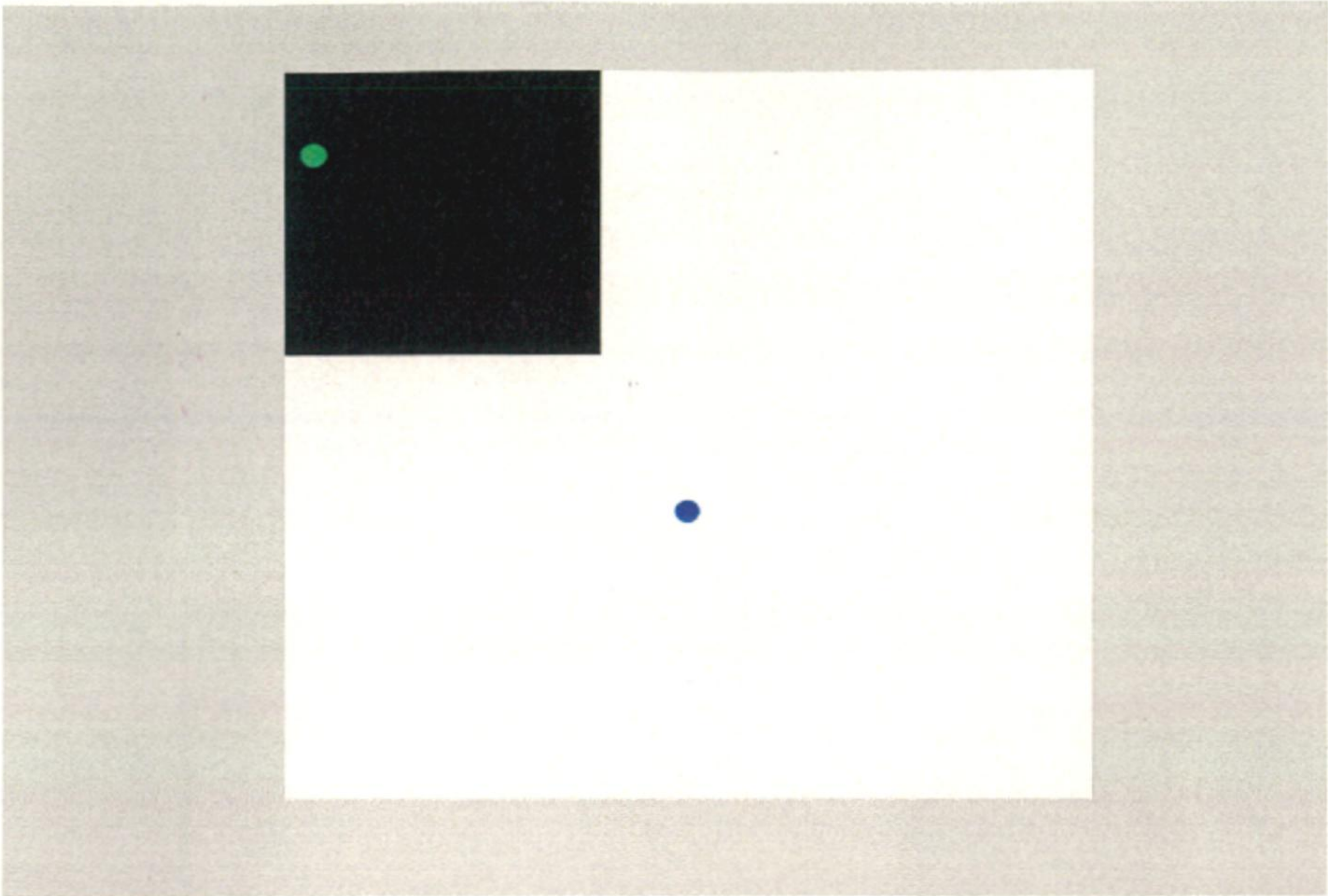

Figure 6.9.Test Case 2: Synthetic Image Generated with Gaussian noise

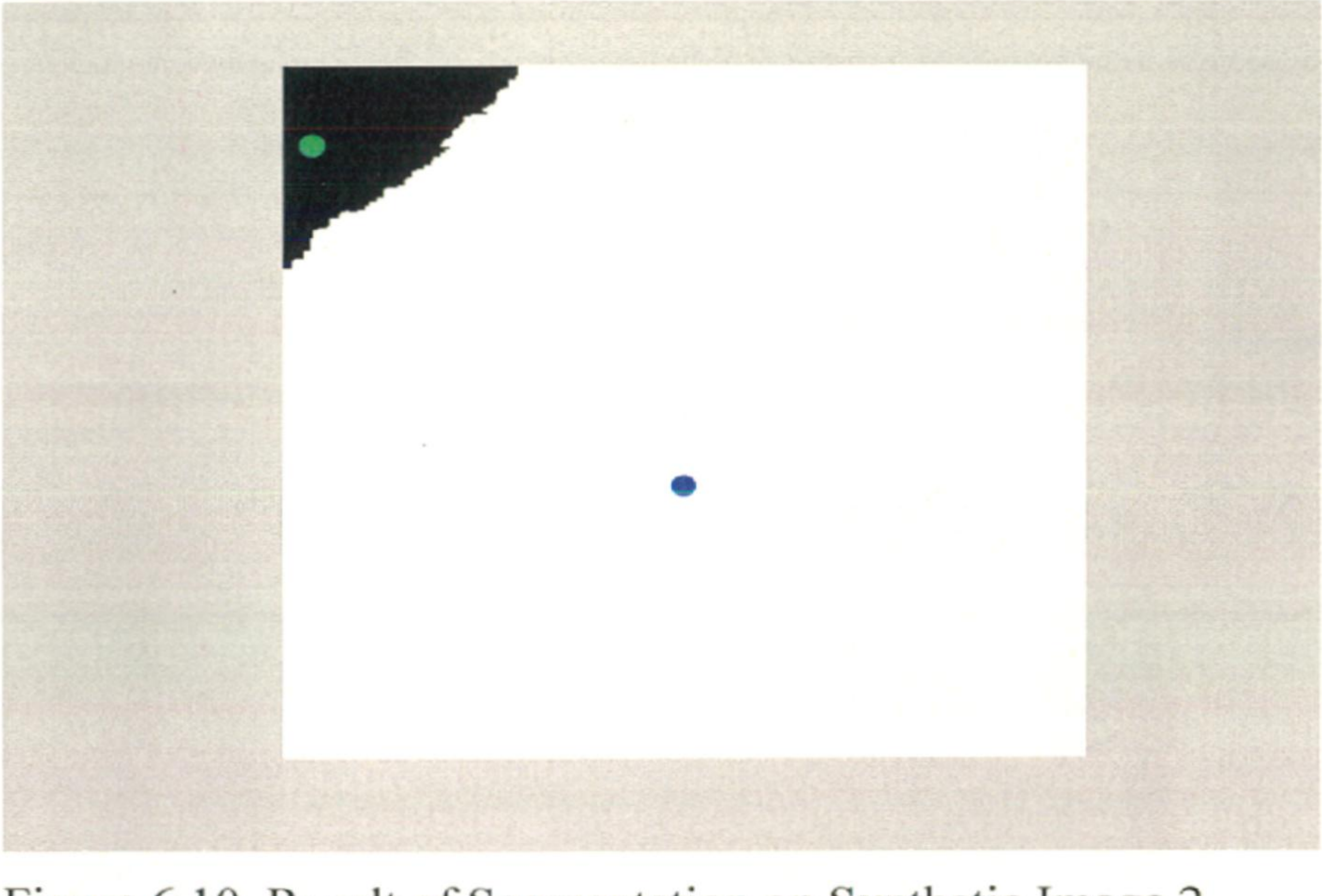

Figure 6.10. Result of Segmentation on Synthetic Image 2.

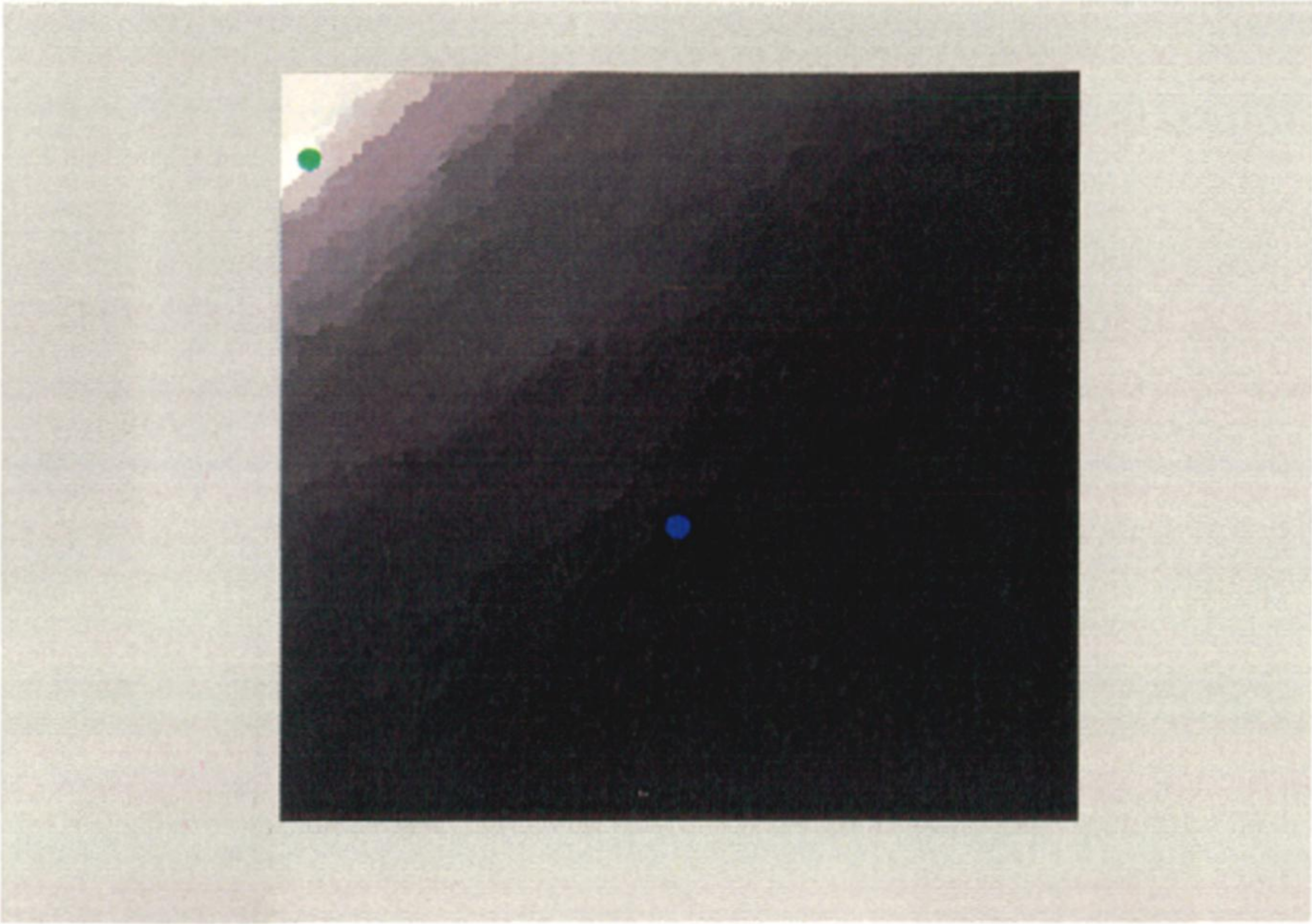

Figure 6.11. Distribution Map indicating probability of pixels belonging to Region 1

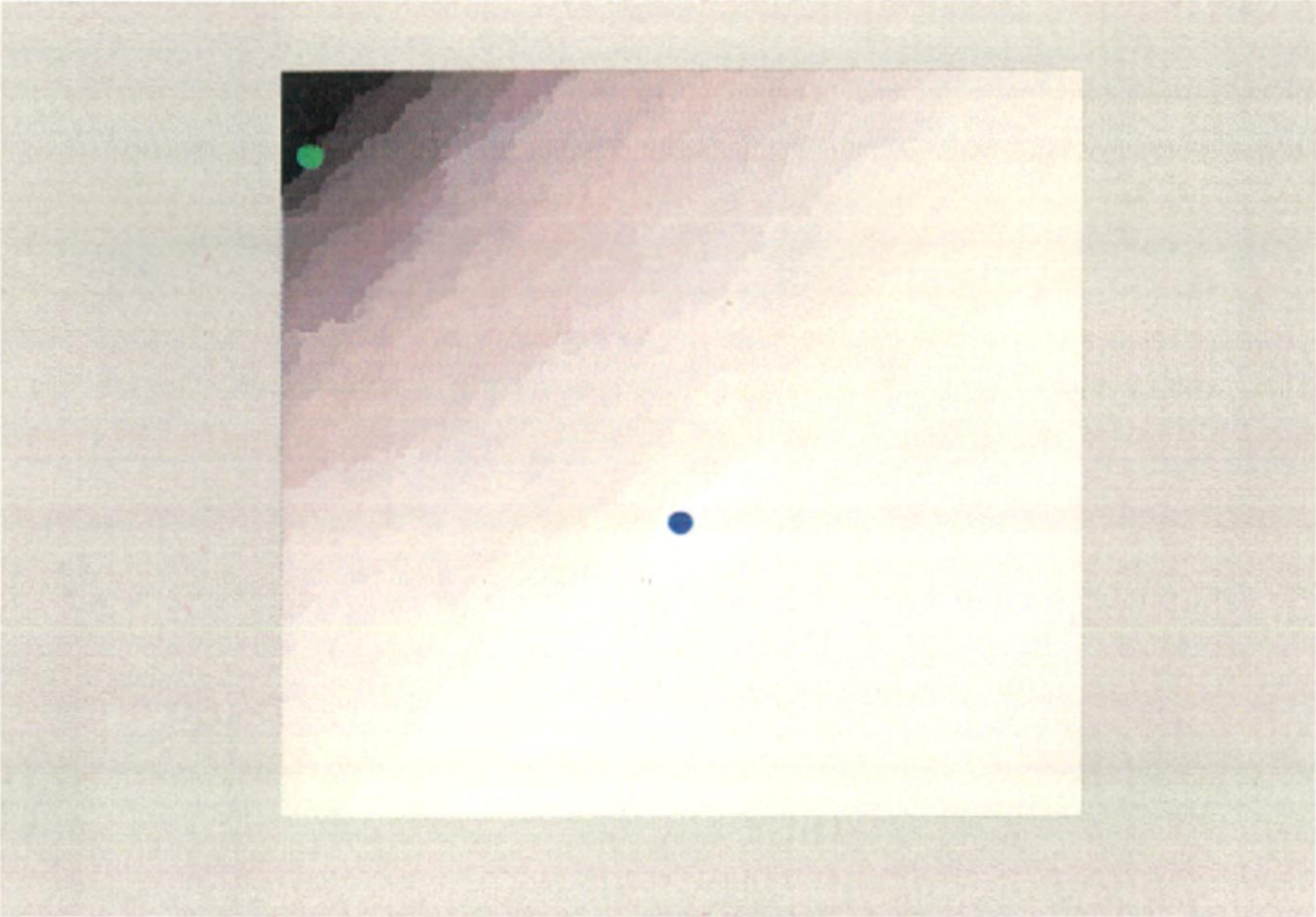

Figure 6.12. Distribution Map indicating probability of pixels belonging to Region 2

Testing Segmentation in the presence of Gaussian Noise

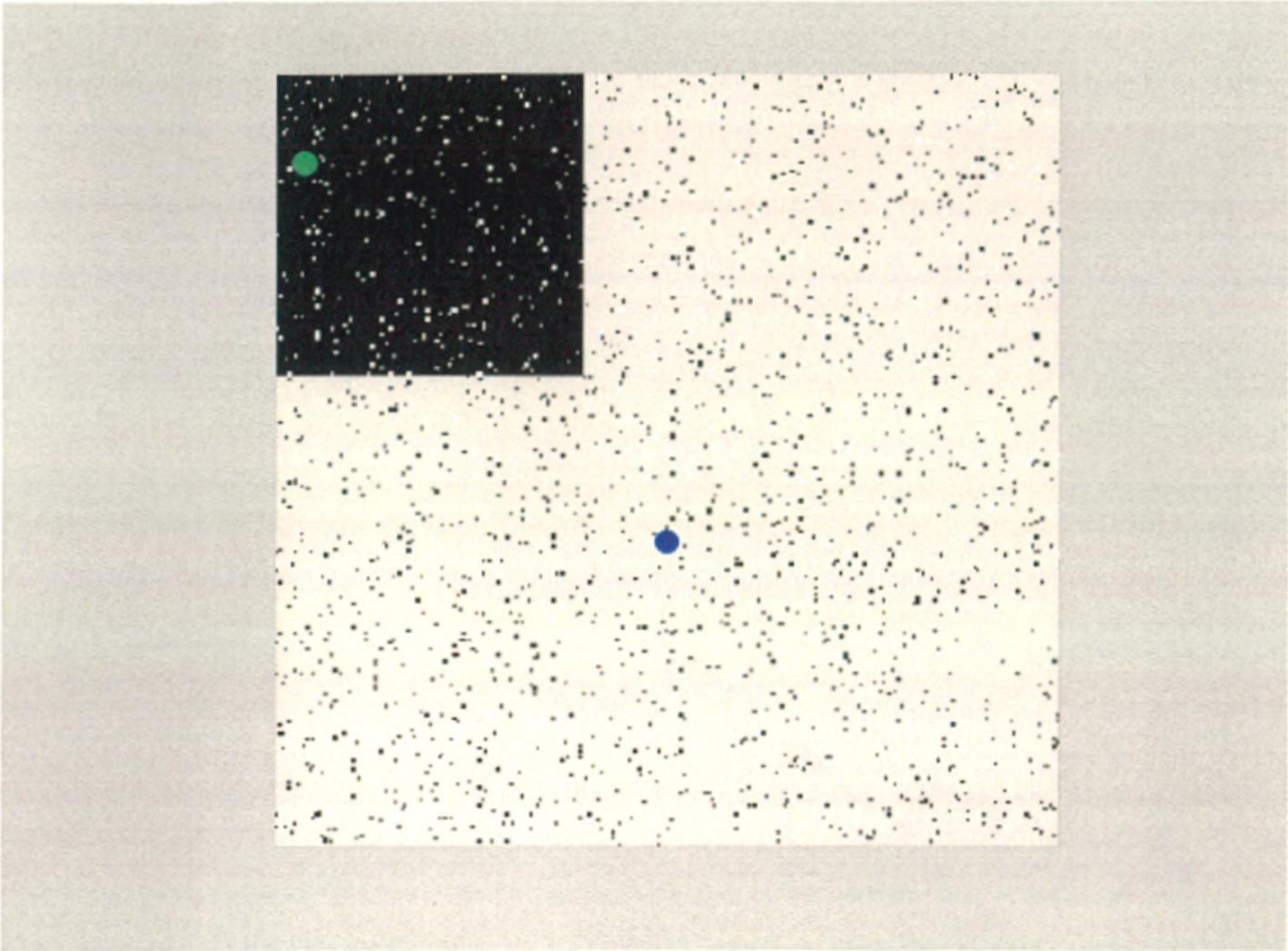

Figure 6.13 Test Case 3: Synthetic Image Generated with Salt and Pepper noise

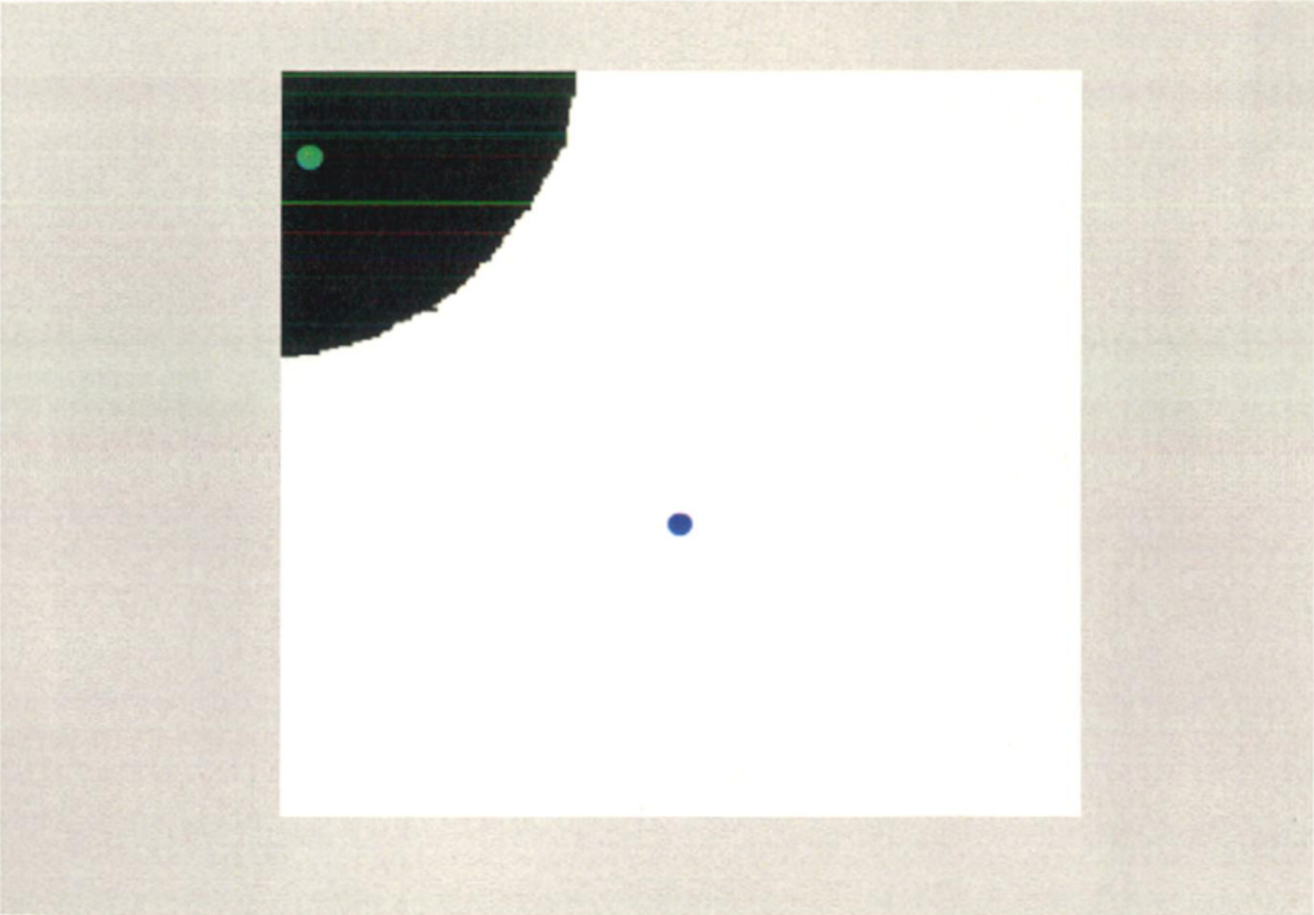

Figure 6.14. Result of Segmentation on Synthetic Image 3.

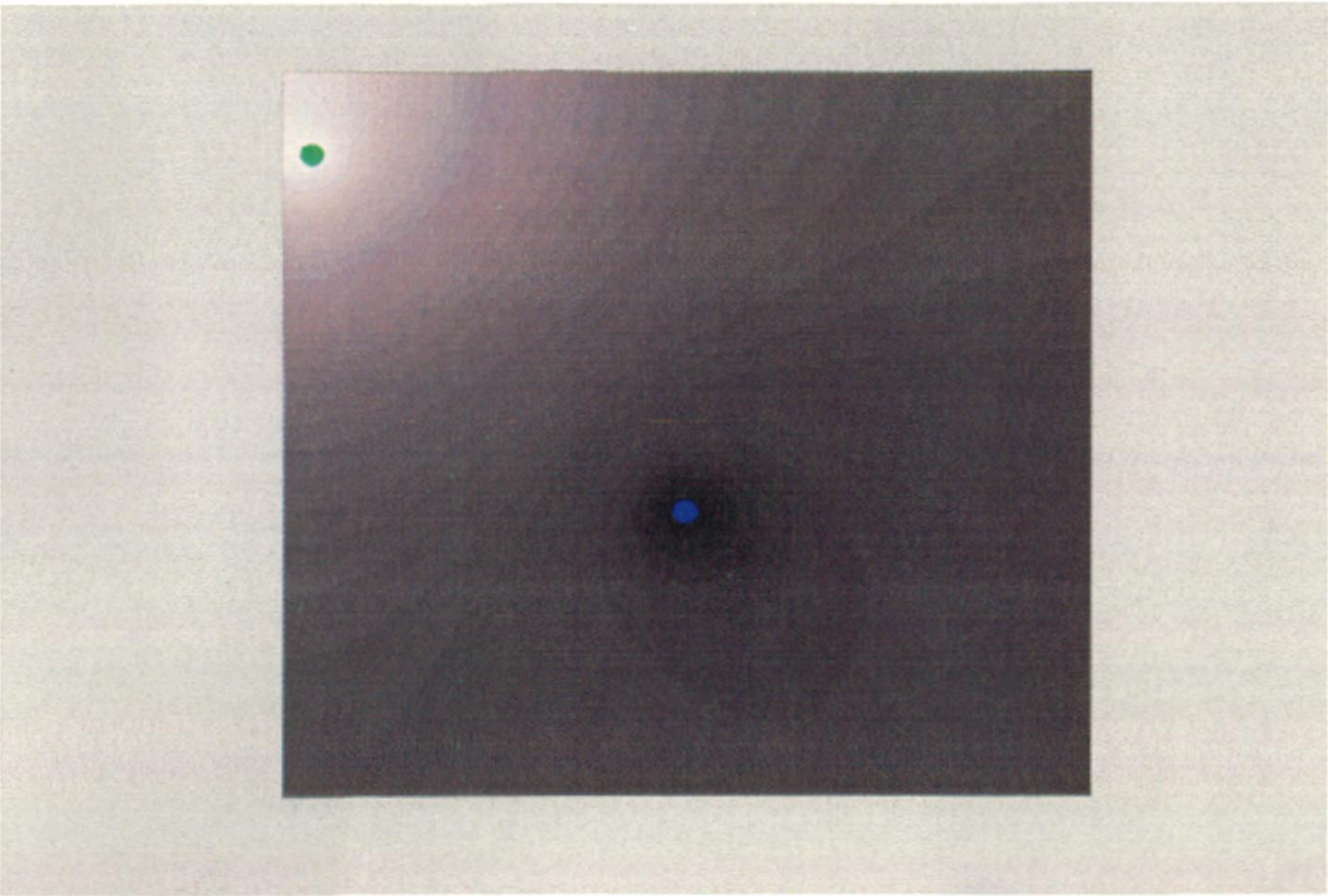

Figure 6.15. Distribution Map indicating probability of pixels belonging to Region 1

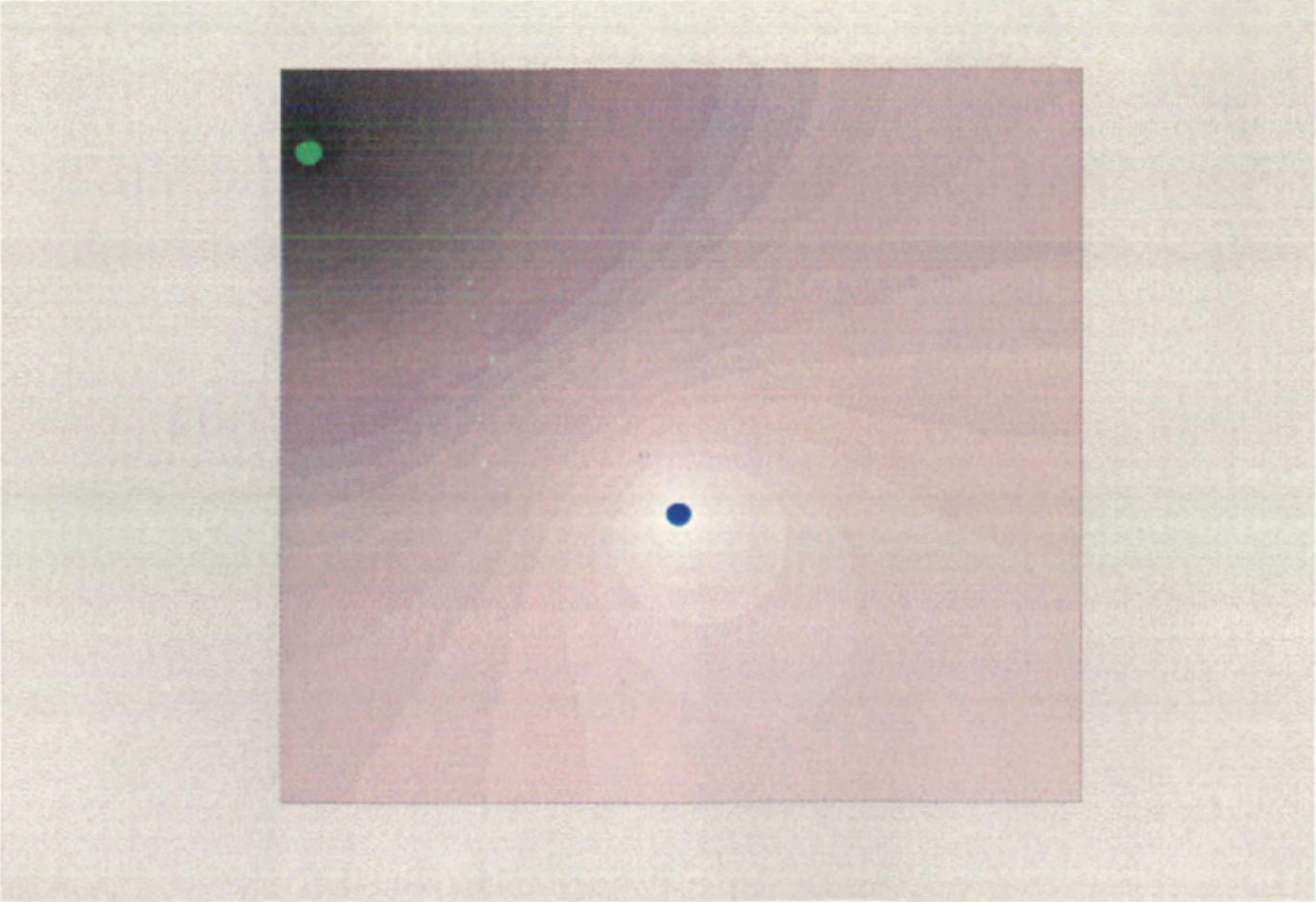

Figure 6.16. Distribution Map indicating probability of pixels belonging to Region 1

Synthetic image illustrating failure of algorithm:

Next we illustrate a case where the segmentation algorithm fails completely. The synthetic image generated with a square block of intensity 20 against a relatively light

background. Gaussian noise with mean 0 and variance 0.003 is added to the image. T
test image is shown in Figure 6.17 and the segmentation results are shown in Figure 6.18.

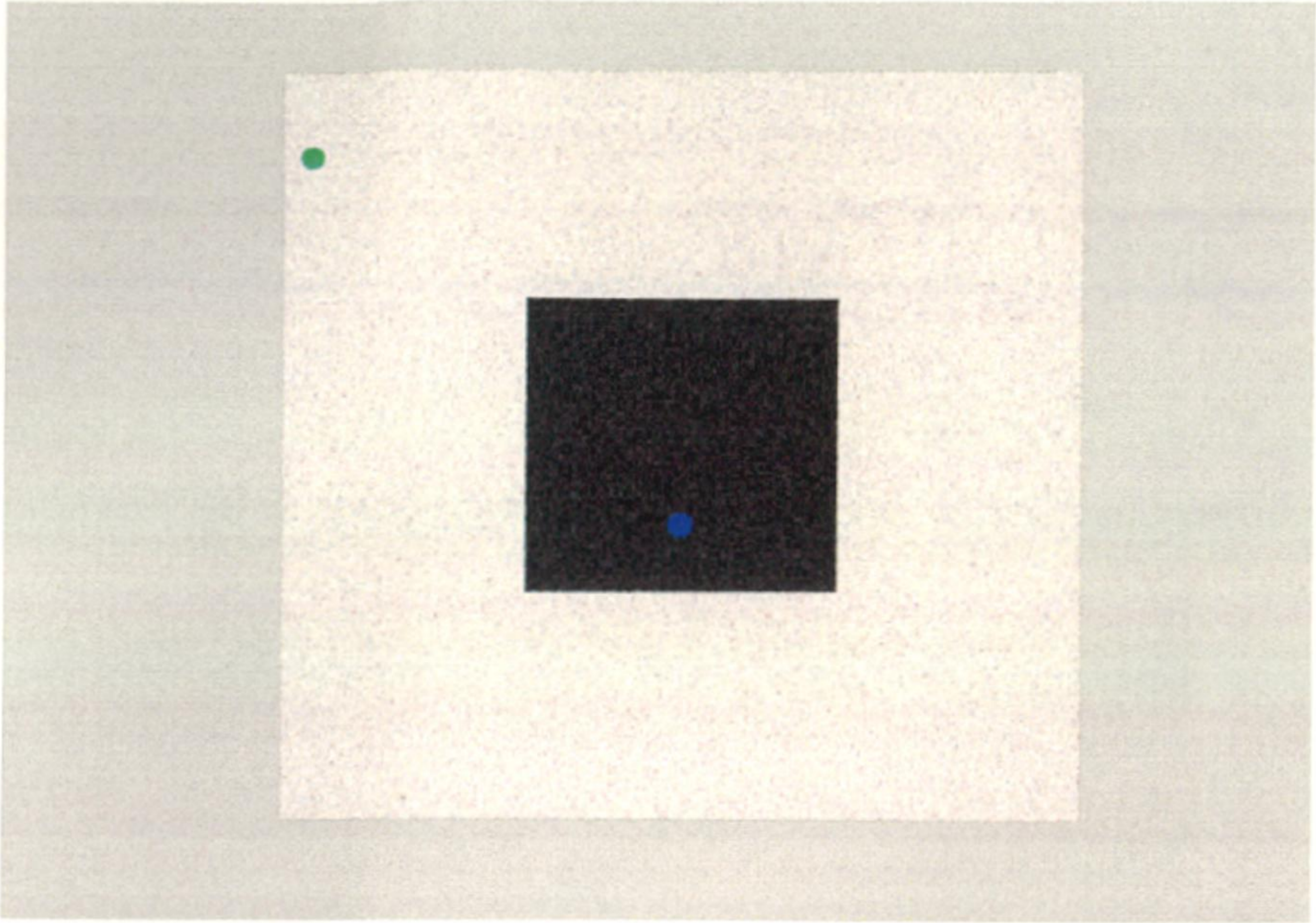

Figure 6.17. Test Case 3: Synthetic Image Generated with Salt and Pepper noise

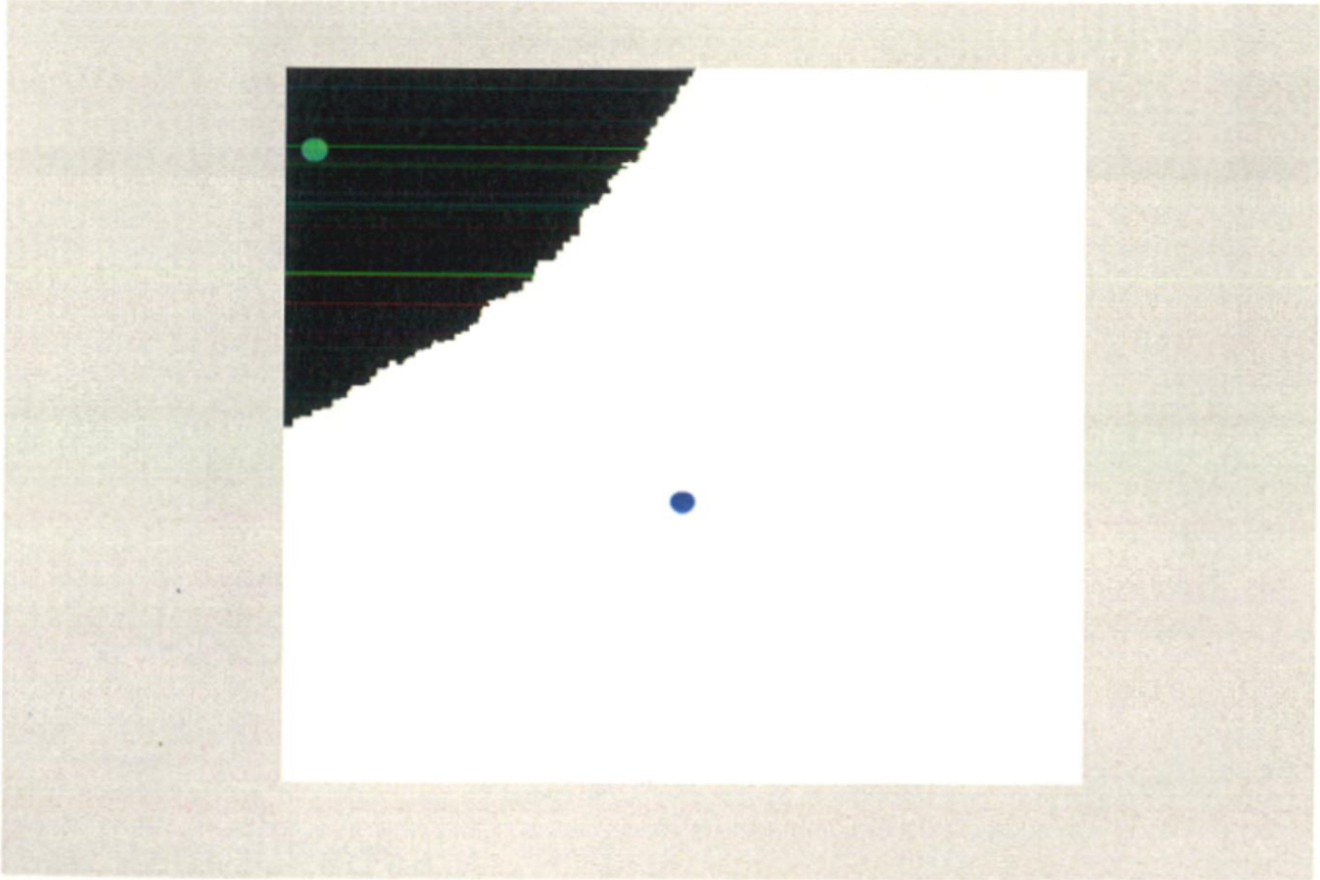

Figure 6.18. Result of Segmentation on Synthetic Image 4.

CHAPTER 7

CONCLUSION AND FUTURE WORKS

In the current work a tool was developed that allows programmers to generate synthetic images which could be used for verifying the suitability of the algorithm to certain class of shapes. The tool provides provision to incorporate various levels of noise in the generated synthetic image.

The tool also provides options for better viewing and analysis. The current tool has options for viewing the image at greater details or at a coarse level by providing options for zooming-in and zooming-out. The concept of layering and alpha-channel was introduced in the current work that allows users to segregate information across layers and view partial portion of image. In the current work ability to browse through different slices of the DICOM images was also provided.

In the current work the main focus was on providing a tool for synthetic image generation, this could be extended to model and characterize medical images aiding in efficient storage and retrieval of medical images. The tool could be extended as a multiple purpose viewer for medical images allowing users to integrate their algorithm into the tool to compare and evaluate the performance against other available algorithms.

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