Ministry of education and science of the Russian Federation
Federal state-founded educational institute of high professional education

«NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY»

Institute Cybernetics
Educational programme Computer Science and Engineering
Department Software Engineering

MASTER THESIS

Research title
Segmentation of the Lungs Based on CT Images

UDC 616-003.7.620.179.152.1

Student

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Tomsk – 2017

Планируемые результаты обучения по ООП

Код Результата	Результат обучения (выпускник должен быть готов)
Профессиональные компетенции	
Р1	Применять глубокие естественнонаучные и математические знания для решения научных и инженерных задач в области информатики и вычислительной техники.
Р2	Применять глубокие специальные знания в области информатики и вычислительной техники для решения междисциплинарных инженерных задач.
Р3	Ставить и решать инновационные задачи инженерного анализа, связанные с созданием аппаратных и программных средств информационных и автоматизированных систем, с использованием аналитических методов и сложных моделей.
Р4	Выполнять инновационные инженерные проекты по разработке аппаратных и программных средств автоматизированных систем различного назначения с использованием современных методов проектирования, систем автоматизированного проектирования, передового опыта разработки конкурентно способных изделий.
Р5	Планировать и проводить теоретические и экспериментальные исследования в области проектирования аппаратных и программных средств автоматизированных систем с использованием новейших достижений науки и техники, передового отечественного и зарубежного опыта. Критически оценивать полученные данные и делать выводы.
Р6	Осуществлять авторское сопровождение процессов проектирования, внедрения и эксплуатации аппаратных и программных средств автоматизированных систем различного назначения.
Универсальные компетенции	
Р7	Использовать глубокие знания по проектному менеджменту для ведения инновационной инженерной деятельности с учетом юридических аспектов защиты интеллектуальной собственности.
Р8	Осуществлять коммуникации в профессиональной среде и в обществе в целом, активно владеть иностранным языком, разрабатывать документацию, презентовать и защищать результаты инновационной инженерной деятельности, в том числе на иностранном языке.
Р9	Эффективно работать индивидуально и в качестве члена и руководителя группы, в том числе междисциплинарной и международной, при решении инновационных инженерных задач.
Р10	Демонстрировать личную ответственность и ответственность за работу возглавляемого коллектива, приверженность и готовность следовать профессиональной этике и нормам ведения инновационной инженерной деятельности. Демонстрировать глубокие знания правовых, социальных, экологических и культурных аспектов инновационной инженерной деятельности.
Р11	Демонстрировать способность к самостоятельному обучению, непрерывному самосовершенствованию в инженерной деятельности, способность к педагогической деятельности.

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«NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY»

Institute Cybernetics
Educational programme Computer Science and Engineering
Department Software Engineering

APPROVED BY:
Head of department
_____ _______ M.A.Ivanov
(Signature)(Date) (Name)

TASK
For the final qualifying research

Form:

Master thesis

To student:

Group	**Name**
8ВМ5И	Nadine Suzanne Francis

Title:

Web application to manage and monitor many Linux servers	
Approved by the rector's order (date, ID)	

Date of research completion:	02.06.2017

TECHNICAL TASK:

Initial data *(Product requirements, User services, Description of solution, Market analysis, Impact on the Environment)*	The purpose of this thesis is to identify lung segments from CT images, with the help of image processing and machine learning. This helps in the identification of many diseases more accurately and also helps in surgery.

List of tasks must be presented in the thesis *(Review. Related research, Task description, Research procedure, Development and design procedures, Results obtained, Additional chapters, Appendix, Conclusion).*	Introduction, Overview of Technologies used in Segmentation, Methods and Procedures used in Identifying and Segmenting the Lungs, Algorithm to Segment Lung Images, Testing and Analysis, Management of Finances and Efficiency of Resources, Social Responsibility, Conclusion
List of graphical data:	Presentation

Consultants

Part	Consultants
Financial management, resource efficiency and resource saving	N.O. Chistyakova, Associate professor, PhD
Social responsibility	Y.V. Anischenko, Associate professor, PhD

Date of task obtaining	22.03.2017

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Associate professor	S.V. Axyonov	PhD		

The student gets the task:

Group	Name	Signature	Date
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Ministry of education and science of the Russian Federation
Federal state-founded educational institute of high professional education

«NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY»

Institute Cybernetics
Educational programme Computer Science and Engineering
Educational level Master
Department Software Engineering
Research period Summer term 2016-2017

Form:

Master thesis

CALENDAR RATING PLAN
Of the final qualifying research

Date of research completion:	02.06.2017

Checkpoint date	Research section	Max score
22.03.2017	*Overview of Technologies used in Segmentation*	*10*
29.04.2017	*Methods and Procedures used in Identifying and Segmenting the Lungs*	*20*
15.05.2017	*Algorithm to Segment Lung Images*	*20*
20.05.2017	*Testing and Analysis, Management of Finances and Efficiency of Resources*	*20*
25.05.2017	*Social Responsibility*	*20*
30.05.2017	*Presentation*	*10*

The task was given by:

Position	Name	Academic degree	Signature	Date
Associate professor	S.V. Axyonov	PhD		

ARGEED BY:

Head of department	Name	Academic degree	Signature	Date
Head of department	M.A. Ivanov	PhD		

TASK FOR
«FINANCIAL MANAGEMENT, RESOURSE EFFICIENCY AND RESOURSE SAVING» PART

To student:

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Institute	**Cybernetics**	**Department**	**Software Engineering**
Educational level	**Master**	**Educational programme**	**Computer Science and Engineering**

Initial data to «Financial management, resource efficiency and resource saving » chapter:	
1. *Costs of research, including technical, financial, energy, information and human costs* 2. *Norms of expenditure of resources* 3. *The taxation system used, the rates of taxes, discounting and lending*	*Work with related research presented in articles, journals, bulletins, and official documents*
List of tasks:	
1. *Evaluation of commercial and innovative potential* 2. *Development of the charter of the technical project* 3. *Planning of management process: structure and schedule, budget, and risks* 4. *Estimation of resource, financial and economical efficiency*	*Analysis of potential consumers. Assessment of the quality and prospective of the project. Research planning.*
List of graphical data:	
1. *«Portrait»of consumer* 2. *Market segmentation* 3. *Assessment of the competiveness of solution* 4. *FAST diagram* 5. *SWOT matrix* 6. *Calendar and budget of the research* 7. *Assessment of resource, financial and economical efficiency* 8. *Potential risks*	

Date of task obtaining	

The task was given by the consultants:

Position	Name	Academic degree	Signature	Date
Associate professor	N.O. Chistyakova	PhD		

The task was accepted by the student:

Group	Name	Signature	Date
8ВМ5И	Nadine Suzanne Francis		

TASK FOR
«SOCIAL RESPONSIBILITY» PART

To student:

Group	Name
8ВМ5И	Nadine Suzanne Francis

Institute	**Cybernetics**	**Department**	**Software Engineering**
Educational level	**Master**	**Educational programme**	**Computer Science and Engineering**

Initial data to «Social responsibility» chapter:	
1. Description of work place: *Harmful factors in the industrial environment* *(meteorological conditions, harmful substances lighting, noise, vibrations, electromagnetic fields, ionizing radiation)* *dangerous industrial factors* *(mechanical, thermal, electrical, etc.)* *negative impact on the environment* *(atmosphere, hydrosphere, lithosphere)* *emergency situation(industrial, natural, ecological types)*	*Work place located in the office 421 in the Institute of Cybernetics Building*
2. Legislative and normative documents on the topic	*State standards, GOST, SNiP, NPB, SanPiN, federal laws*
List of tasks:	
1. Analysis of the identified harmful factors of the industrial environment in the following sequence: *the physical and chemical nature of harmfulness, its relation to the topic being developed;* *the effect of the factor on the human body;* *reduction of permissible norms with the required dimensionality (with reference to the relevant normative and technical document);* *proposed remedies*	Identification of all the harmful factors when researching, including physical, chemical and biological
2.Analysis of identified hazards of the industrial environment in the following sequence *mechanical hazards (sources, means of protection;* *thermal hazards (sources, means of protection);* *electrical safety (including static electricity, lightning protection - sources, protective equipment);*	Identification of the all possible hazards when researching

fire and explosion safety (causes, preventive measures, primary means of fire extinguishing)	
3.Protection of the environment: *protection of the residential area* *analysis of the impact of the facility on the atmosphere (emissions);* *analysis of the impact of the object on the hydrosphere (discharges);* *analysis of the impact of the object on the lithosphere (waste);* *develop solutions to ensure environmental safety with references to environmental standards.*	Identification of the all possible kinds of waste when researching
4.Protection in emergency situations: *List of possible emergencies on the site;* *Choice of the most typical emergency situation;* *Development of preventive measures to prevent emergencies;* *Development of measures to improve the stability of the facility to this emergency situation;* *The development of actions as a result of the emergencies and measures to eliminate its consequences*	Identification of the all possible emergencies when researching
List of graphical data:	
Graphical plans	

Date of task obtaining	

The task was given by the consultants:

Position	Name	Academic degree	Signature	Date
Associate professor	Y.V. Anischenko	PhD		

The task was accepted by the student:

Group	Name	Signature	Date
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Lung Segmentation Based on CT Images

Nadine Suzanne Francis
Supervisor: Sergey V Axyonov
Thesis and Final Project
6/6/17

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Introduction

Computer Tomography is a diagnostic imaging method which helps in the detection of diseases concerning different parts of the body as these are typically a combination of x-ray images taken at various angles, thus providing more accurate detection results [1]. Concerning the cardio- vascular system, high resolution computer tomography (HRCT) is used, which in turn helps diagnose diseases that cannot be or is difficult to detect through physical examination, such us tumors, cancer, pneumonia, etc. Since the degree of accuracy obtained from these images is very high, it can also be used for segmentation of the lungs. Segmentation of the lungs help in identifying the problem area more easily and also helps in identifying the exact location of each segment which further helps in surgery thus making it more convenient for doctors. Any default in lung segmentation can lead to false identification of different segments and eventually to wrong identification of the disease concerning the affected segment.

When the lung has a high density of pathologies, it becomes even more difficult to segment it as it becomes more difficult to detect its different segments and also more difficult to detect the borders of various segments [2]. Moreover, detection and segmentation must be performed with even more accuracy, because elimination of any intricate detail in any of the images can lead to fatal results. It can even lead to the death of the patient, if some pathology that had to be detected was carelessly eliminated while attempting to segment the lungs.

Various methods to segment the lungs for the analysis of particular diseases and also to segment the airway of the lungs has been tried before but there is no successful method to segment the entire lung for surgical and analytical purposes has been implemented.

Segmentation of fixed structures like the brain has been far more easier to implement and successful. However lungs have dynamic chest volumes during respiratory cycles and hence segmentation should be able to address these changes. Moreover, some if the lungs have been found with abnormalities, algorithms are not able to identify accurate lung volumes [1, 2]. In recent research, these problems are being slowly overcome as researchers are trying to use a three-dimensional rendering of CT images, so that a percentage of the lung volume could be calculated based on the pathologies that exist in the lungs but there is usually a change in the yielding rate of serial CT images.

In the past, segmentation of lungs was carried out manually from the inputs provided by the radiologists who have expertise in diagnosing anatomic boundaries and lung pathologies. Due to the progress of software and computational efficiency in recent times, lung segmentation could be carried out automatically instead of manual intervention. Currently, a single Lung Segmentation Methode cannot be used as it is not improvised enough to accurately segment the lungs. Clinically these methods have not been used as their efficiency is not enough to take the risk of using them in hospitals. Most of the methods that exist use a particular subset to identify abnormalities in images. However, thy usually fail to identify lesions in the lung or near the lung. They also fail in accuracy and computational efficiency.
The method provided in this paper, tries to provide a better method to segment the lungs, which does not eradicate any abnormalities from the lung and also tries to increase the efficiency in segmentation. Added to this, it also tries to reduce computational costs and also reduce the time consumed to perform segmentation.

Chapter 1: Overview of Technologies Used in Segmentation

1.1 Widely Used Methods in Lung Segmentation Using CT Images

Medical Image Segmentation usually works with by incorporating the following two tasks:

- Object Recognition
- Object Delineation.

During object recognition, we get insight into the image and all details related to the image under examination. It is considered to be a high level process [3]. Though it is easy for a human being to carry out this task, it can be done faster with the help of computational objects. During this process, user interaction is required to determine the left and the right lung.

Object delineation tries to identify the boundaries of the object and its composition as a whole. It is usually regarded as a low-level process [4]. It is difficult to gauge the total spatial extent of an object and hence delineation is almost impossible to perform without the help of computational objects. Usually, the user information provided during object recognition is processed so that the exact boundary could be gaged during this process.

Segmentation of the cardio vascular system is rendered as a challenge as changes in the pulmonary inflation with regard to the elastic chest wall create large variability in volumes and margins when automation on the segmentation of the lungs takes place. In addition to this, pathologies that exist in the lungs usually interfere with software when trying to locate the boundaries of the lungs. For instance, any pathological condition along the pleural margin of the lungs may result in a faulty delineation which in turn marks segment boundaries outside the lungs because its pathological conditions are very similar to the tissue of neighboring organs that are located next to the lungs. Most of the segmentation processes that have been identified for the lungs work well only when the availability of attenuations present is little or none. These methods are very effective in calculating the volume of lungs with the initiation of computer-aided detection systems [9]. But in extreme cases where pathological conditions are existent, those segmentation methods fail to perform efficiently [11, 12]. In other words, consolidation and cavities lead to inaccurate boundary identification. Moreover, the availability of pneumothorax or pleural effusion on an image provides extremely distorted results which in turn lead to incorrect quantification of the lungs.

The following methods in Table1 are the most widely used methods when segmenting the lungs with CT Images:

Table 1: Five Major Classes of Lung Segmentation

Method	Best Suited For
Region-Based	Normal lungs with limited abnormalities.
Neighboring Anatomy-Guided	Pleural area of the lungs or atelectasis.
Threshold-Based	Normal lungs and isolated abnormalities like tumors, nodules and cavities.
Shape-Based	Abnormal pathological lung structures.
Machine Learning Based	Pathological condition with signature patterns like GGO, septal line and consolidation.

A brief description on how each method works, its advantages and disadvantages and also its accuracy along with its computational cost is provided below. Most techniques are used combined with one another and sometime also make use of primitive pre or post processing steps which helps in eradicating noise and other artifacts that usually distract the segmentation process.

1.1.1 Region-Based Methods

In region-based segmentation methods, the small patch (seed) is commonly used to determine the region. Once the seed point is selected, which is a set of voxels, it becomes the representative of the target region to be segmented and a predefined neighborhood prototype is used to extract the desired region [15]. These seed points are usually selected either manually or automatically. Different methods use different criteria for determining the various segmentation boundaries. For example, one possible prototype could be region to grow until the edge of the lung is detected. Comparatively another prototype can utilize region homogeneity can and thereby lead to segmentation convergence.

These methods are also used for delineation of airways and pathologic conditions with homogeneous contents such as cavities. This shows that even a single segmentation algorithm can be used to portray and quantify multiple organ and sub-organ structures [15, 18]. For instance, a single region-based segmentation algorithm may be applied to multiple structures in pulmonary images, a cavity in the right upper lobe, the airways, and the lung fields.

This segmentation method is efficient in extracting homogeneous parts of the lungs with no to a few pathologic conditions. They usually generate more precise lung segmentation results without causing false segments in outer border regions which have similar attenuation values [12, 16, 18, 23]. However, when these methods are prone to a high magnitude of noise, the precision of the neighborhood criteria usually suffers from false outputs within the lung and thus may require further processing.

Seed selection requires manual interplay before the segmentation process [26], to find the most applicable voxel or region with which the delineation technique will start. Processing posterior to delineation will include removing unnecessary noise, controlling parameters and smoothing images which take place before the segmentation process. Removal of artifacts should also be carried out prior to delineation. Removal of any pathological artifacts that are in vicinity of the lungs is carried out by cutting out the lung regions from the CT image and then delineation is staged on the new image where pathologies do not exist. Last, but not least, for challenging cases such as when nodules or pathologic conditions are near the lung boundary, attenuation is remapped to the lung region as well as enhancing the lung boundary with edge detection is performed for accurate segmentation without witnessing failure [12, 24, 25, 19].

Region based segmentation has proven to be very efficient the time taken to segment the cardio vascular system and the cost of computation are within utility bounds for clinical purposes [22]. The location of the seed points helps in determining the reproducibility of the respective segmentation method, scilicet to the fact that the method is based on seeding. Thereby the reproducibility and the robustness are different for different region based methods. For example, the fuzzy connectedness method has proven to be more robust when compared with the other region based methods.
Region based segmentation is further sub-divided into five categories based on criteria involved for segmenting the lung. They are:

- Region Growing
- Fuzzy Connectedness
- Graph Cut

- Random Walk
- Watershed

NOTE:	Region-Growing is the best method of segmentation among all the Region-Based methods of segmentation.

1.1.1.1 Region Growing

This algorithm begins with a seed pixel and then analyses the neighbor pixels surrounding it [17]. If neighbor pixels comply with a certain criteria, then they are included into the region. This continues until no more neighbor pixels can be included in the region. The difference between pixels intensity value and the regions mean is the criteria used to determine if two pixels can lie in the same region. If this difference is invariably small, it is added to the region. If the difference is greater than a certain threshold value, it is considered to be part of another region.

The main aim of this algorithm was to remove all the dark area that does not belong to the lungs, so the seed pixel is selected from the dark area and from which growing can continue, which means, similar pixels can be added [18]. This is done till the region grows or until it collides with another region or it reaches a different intensity area. This method completes when there are no more pixels to be classified, and the original gray scale image has been segmented into the lungs and trachea. In this method, however, some of the segmented pixels lie outside the lung parenchyma, so only a negative of the image could be created to get only the inside structure of the lung [17, 18]. This method is efficient and robust while dealing with variations in attenuation by reinforcing spatial neighborhood information and a regional term.

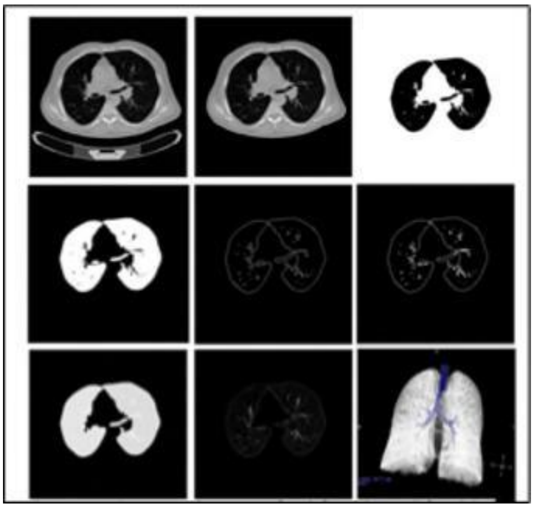


Figure 1: Various Stages in Segmentation of the Lungs Using Region-Growing Method

1.1.1.2 Fuzzy Connectedness

In this method, the intensity information of the lung regions is utilized. The process involves growth of regions in the left and right lungs to meet each other at the correct location [22]. This method is usually performed on 2-D slices and it focuses mainly on the gap between two regions than the entire lung itself. The algorithm first searches for connection areas in the lungs and then search for accurate lines separating different sections of the lungs based on how the lung is to be sectioned.

This method however has several limitations. There is no accuracy in the detection of connecting areas and can result in multiple optimal connecting paths. Detection is done using iterative morphological operation which is time consuming and inaccurate. As only 2-D slices are used, a false optimal path may be created around the lung area thereby compromising the separation. 3-D slices can be used to enhance the results, but this still does not provide accurate separations.

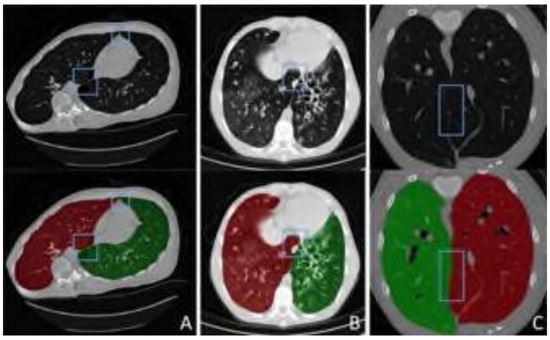


Figure 2: Various Stages in Segmentation of the Lungs Using Fuzzy Connectedness Method

1.1.1.3 Graph-Cut

In this method, the CT images are modeled with Gaussian mixture models (GMMs), and optimized distribution parameters are obtained with expectation maximization (EM) algorithm [20]. With these parameters, improved regional penalty item is constructed in the graph cuts energy function. The Sobel operator is used to detect and extract the edges of the lungs, which in turn is used to improve the boundary penalty item of graph cuts energy function. This helps in obtaining the improved energy function of graph cuts algorithm and therefore helps in segmenting the lung with the minimum cut theory.

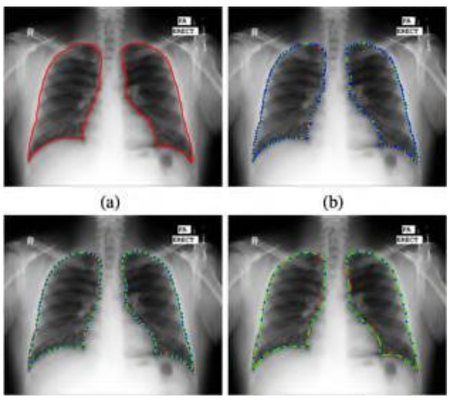


Figure 3: Various Stages in Segmentation of the Lungs Using Graph Cut Method

1.1.1.4 Random Walk

In this graphical segmentation method, images are segmented using Random Walk algorithm. The seed points are usually used as input parameters to the algorithm [21]. Using the output values, the segmentation is usually performed with very high accuracy.

The graph-cut and the random walk segmentation algorithms are graph-based segmentation algorithms. These two methods usually provide high accuracy and hence are considered globally optimal. In the graph-cut algorithm, edges and attenuation provide necessary information to build an energy function which thereby helps in the segmentation process. But the probability of each pixel is usually computed using the random walk algorithm, during which each pixel's random walk occurs first in the background or foreground cues that are provided by the users. Even though random walk and graph-cut segmentation algorithms are very efficient and accurate segmentation methods, they have not been very successful when moderate to high amounts of pathologic conditions exist in the lungs.

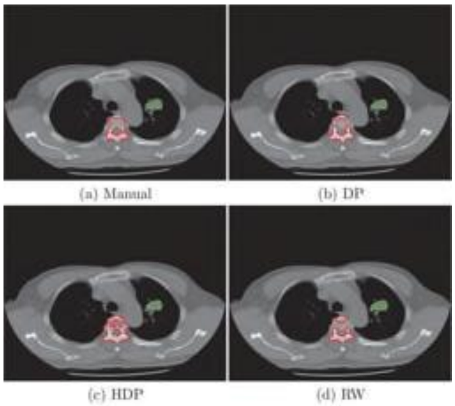


Figure 4: Various Stages in Segmentation of the Lungs Using Random Walk Method

1.1.1.5 Watershed

The primary concept elemental to this segmentation method originates from geography [22]. The concept is that of a landscape or topographic relief that is flooded by water, with watersheds being the dividing lines of the domains of attraction of rain falling over the region. Although watershed transformation is computationally feasible and could be considered efficient, it usually results in over-segmentation and hence is a less feasible choice for lung segmentation.

To sum up, region based methods are faster and work well with images that have little or no pathologies in them. The main drawback of this method is that when images contain a high value of attenuation or when some pathological conditions overlap the borders of CT images, it becomes difficult to identify and thereby even more difficult to segment the lung.

1.1.2 Neighboring Anatomy-Guided Method

These segmentation methods adopt spatial context of anatomic objects neighboring the lung, like the spine, rib cage and heart. It uses these anatomic objects as benchmarks to delineate the lungs with higher optimal accuracy. The primary reason for the use of anatomic objects is mainly owing to restriction of search space which in turn helps in eradicating false outputs from suboptimal segmentations [3, 26]. Once the position of neighboring objects is determined, it is easier to limit the algorithm to not encompass them within its perimeters and hence segmentation takes place only within the lung area.

Due to the existence of extreme imaging artifacts, lung regions are not delineated readily. This dilemma is conveniently handled by these segmentation methods [26]. Due to the existence of information dealing with neighboring structures, lung image segmentation benefited to a greater extent as interactions with neighboring objects made the algorithm more foreseeable and reliable.

Even in the existence of discriminative attenuation and texture information, these methods have proven to provide segmentation results with high accuracy. This further goes on to say that due to the understanding the algorithm has about neighboring objects, even if there is high intensity of fluids within the lungs, this method can provide excellent segmentation.

Despite neighboring anatomy guided segmentation method being highly accurate, their outcomes mainly decent on the fact that neighboring objects do not contain any deformity, which in most cases is difficult to guarantee as there may exist multifocal areas of disease in organs surrounding artifacts lung regions [27]. The method's efficiency also depends on the extents on artifacts that endure in the lungs. As the number of artifacts increase, the slower is the process of segmentation.

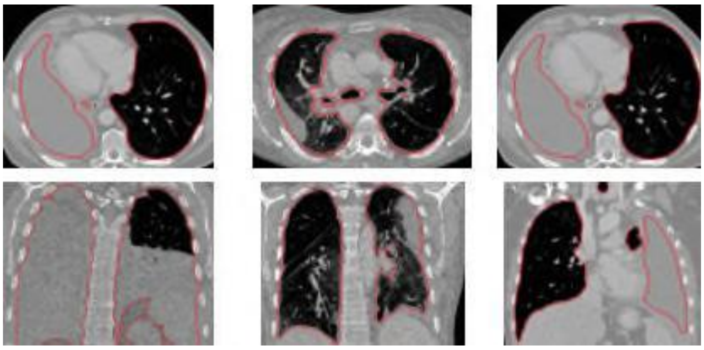


Figure 5: Neighboring Anatomy Guided Segmentation Producing Successful Delineation

On the whole, this segmentation method works well when attenuation or pathologies exist in a CT lung image. Failure occurs only is number of pathologies is extensively high or neighboring organs coexist with artifacts.

1.1.3 Threshold Based Methods

These segmentation methods are the most fundamental and easily expressible method of all segmentation methods. Due to its clarity in being understood, it is used in all communication systems and archiving of pictures [29]. During this method, images are segmented through the creation of binary particles which are calculated from the value obtained from image attenuation, which in turn are obtained from relative attenuation of structures that exist within the images. The attenuation value that is determined is termed as threshold. These thresholds are used to create segments by grouping all elements with the same attenuation values together and they are grouped only if the satisfy the thresholding interval.

These methods are usually straightforward and effective and help in the segmentation of images, with different region being well contrasted. This method usually displays good results for CT images in comparison to images obtained from other imaging resources [2]. As the attenuation values are measured in Hounsfield units. These units have well-defined ranges for various tissue components involving CT images. Nonetheless, these techniques do not typically consider boundaries or spatial information of the respiratory system. In addition, these techniques are highly sensitive to noise and imaging artifacts and always provide false results in the presence of such artifacts. Due to the lack of spatial information and variability during the application of this method, leads to faulty segments.

During segmentation, the upper and lower limits of the thresholding interval allow the selection of lung regions [9, 11]. Due to the presence of stable attenuation values of air and lung parameters for lungs with minimal or no pathologic conditions, it is enough is appropriate threshold parameters are selected. On the contrary, including pathological areas inside the lung this segmentation approach as the interval usually excludes adjacent tissues from the lung and as pathologic regions have more or less the same attenuation values when compared to those of soft tissues will render it difficult to delineate the lung boundaries correctly due to the presence of abnormal imaging markers. Eradicating false outputs will require various morphologic operations in order to correct the resulting segmentation procedure.

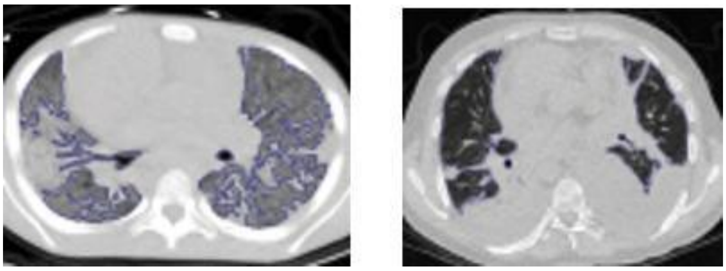


Figure 6: Inaccurate Boundary Identification Using Threshold Based Method

Overall, this method is very efficient and fast and easy to understand and execute. The main drawback of this method is that it is unable to identify segments in the presence of attenuations.

1.1.4 Shape Based Methods

Adopting information based on the shape of anatomic organs such as lungs has become extremely popular for the segmentation of medical images. Abnormalities that exist in CT images cannot be identified or rectified using thresholding methods, but when taking the shape of the image into consideration, these abnormalities a=can be handled fairly well. There are two shape based approaches which contribute in identifying the lung border. They are:

- Atlas Based
- Model Based

The algorithm underlying both methods is described below.

1.1.4.1 Atlas-Based Methods

These methods use information based on the shape of the target organ for recognition and delineation. An atlas is made up of a template with an image of the target organ and also of the thoracic regions along with its corresponding labels [17, 30]. Segmentation is performed by registering the template image to the target image. Once both images are aligned, labels that exist on the atlas are propagated onto the target image. The main problem concerning this method is alignment and although it could be done sub-millimeter accuracy, it is rather difficult to execute.

Segmentation of the lungs with mild to moderate potholes can be done with the atlas method. Nonetheless, it is often difficult to create a robust atlas due to the presence of large inter-subject variabilities and differences related to the abnormalities. For instance, it may be difficult to analyze scoliosis, if the atlas was created by adopting a population of normal spines.

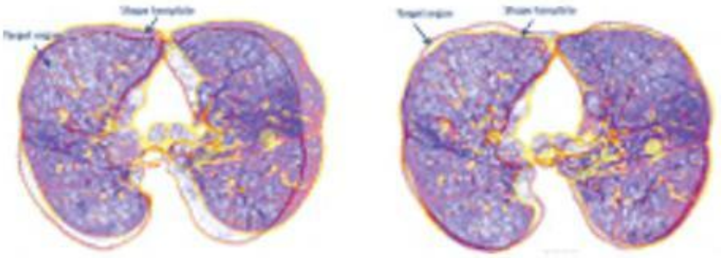


Figure 7: Atlas Based Method for Segmenting Lungs

1.1.4.2 Model-Based Methods

These methods also use prior shape information which is similar to atlas-based methods. But in order to receive better shape variabilities, this segmentation method uses an optimization procedure to fit either statistical shape or appearance models of the lungs to the target image. The objective of these models is to endure the variation that may happen in the target organs that are under study. The anticipated shape gray-scale structure of the target object is used as the sole idea behind the segmentation process [17]. Delineation takes place only when the model identifies the most suited match of data sets for segmentation.

This approach is in accordance with the top-down strategy in which recognition is followed by delineation. In contrast to other low-level methods like thresholding-based and region-based, model-based uses data from both global and local variation of the shape and texture. As a result of this, these methods are very effective in dealing with segmentation of abnormal lungs. Atlas method measures variation during training, knowledge is captured into the system, and hence mild to moderate number of abnormalities are handled very well. However, a prior model which tries to understand diverse demographics is usually difficult to develop. In addition to this, segmentation of the lungs may fail if the model is not initiated close enough to the actual boundary of the lungs.

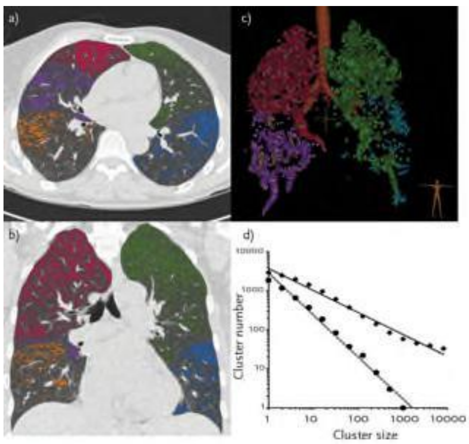


Figure 8: Model Based Lung Segmentation and Graph Showing Inaccuracy in Segmentation

1.1.5 Snakes, Active Contours, and Level Sets

These shape based segmentation methods are also known as boundary based image segmentation method. Boundary-based image segmentation is further subdivided into snakes [31], active contours [17] and level sets [32]. Object boundaries are located with the help of boundary curves which are defined with the influence of internal forces that originate from within the curve and also from external forces calculated from image data. Both these internal and external forces are derived in accordance that boundary curves conform to the object boundary or features internal to the image. When segmentation of the lungs is concerned, snakes and level sets are used rarely. Although when initialization points of these images are located beside the correct boundary they provide efficient and desirable results, this method often fails when initialization of the algorithm is found nowhere next to the actual boundaries. Moreover, if lung images contain pathological conditions, an incorrect lung boundary may develop while using these methods or boundary curve will stop evolving and lung boundaries will stop converging if pathologies are identified in the development process.

Multiple active contour models are used for the segmentation lungs and also for boundary detection. The images are first grey-level thresholded and then edges are detected. The detected edge points are then organized into strokes and a set of weights is assigned individually to each of them. The weights are a soft assignment of the stroke to each of the active contours [3]. These weights usually rely on the distance between the stroke points, the active contour units, information of gradient direction and on the size of each stroke. Both the weights and the minimization of the energy of active contours are calculated using the generalized expectation-maximization algorithm [12]. This method is very effective in segmenting lung structures. The only disadvantage of this method is that active contours are decided on the intensity gradients in the image and hence they vary non-uniformly. Hence contour points may appear on non-target areas outside the lungs.

The efficiency of these segmentation methods depends on the quality of the registration or localization algorithms, which is often time consuming.

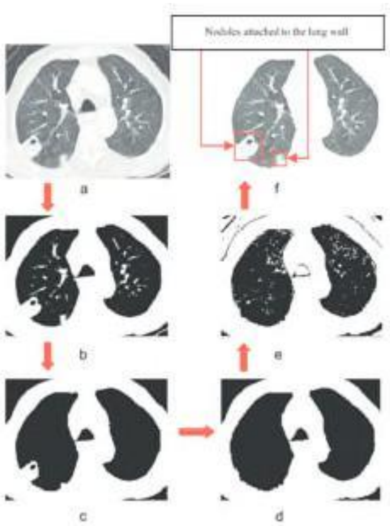


Figure 9: Stages in Segmentation Using Snake Segmentation

To sum up, this method is very efficient when the target image and the template image are mapped accurately to each other. Unfortunately, these methods produce false results when the boundary of the image is not determined correctly.

1.1.6 Machine Learning Based Methods

In these segmentation methods, segments will be developed by learning intricate details and data sets from the images [2, 25, 26]. The algorithm usually adjusts its parameters until it is able to identify and understand disease patterns. Lung abnormalities can be predicted from the information that has been analyzed from the images. This information is included during segmentation so that the algorithm is able to identify correct lung edges. These methods use a set of training data which contain image patches or small image blocks along with the label of the anatomic object. The training data helps in identifying to which observation a new anatomic class belongs. A set of quantifiable properties known as features helps in determining each individual observation. The labeling helps in the selection of the most appropriate set of features.

Image attenuation is the simplest feature that exists. However, complex image processing required the use of even more extravagant features. A researcher named Hua et al combined a thresholding-based segmentation with a dynamic programming method to separate right and left lungs, and then it was succeeded by a sequence of morphologic operations to smooth the irregular lung edges along the mediastinum. Hua et al [2] also used a graph-search algorithm by combining attenuation, gradient, boundary smoothness, and rib information for the segmentation of diseased lungs. Another researcher named Mansoor et al [26] developed a machine learning-based algorithm which was used to detect a large spectrum of pathologic conditions, and this method was joined with region-based segmentation of the lungs and also with neighboring anatomy–guided segmentation correction methods.

This algorithm primarily examines each pixel to understand its class label and hence they are also known as pixel- or voxel-based classification methods [28]. Though it is expensive computationally to assess every pixel in order to identify all pathological conditions, segmentation and classification have high accuracy. The presence of parallel computing also helps in making this method more captivating.
In spite of these segmentation methods being used for computer-aided pulmonary detection of abnormality that exist in the lung, the lung has to be segmented first before identification of pathologies. However, this is erroneous, if this segmentation method cannot separate abnormal tissue from normal tissue. With the help of CT images, abnormalities are successfully detected and are included while delineating the lungs.

These segmentation methods are considered as the essence of lung segmentation because every single pixel is examined and both the normal lung along with it pathologies are presented on a single framework [28]. Since these methods are reproducible, they are highly desirable. However these methods also have its disadvantages. The method mainly depends on the complexity of the feature set and hence is very expensive and also structural information cannot be identified as only small patches of information can be detected and sent as features. Moreover, it is very difficult to extract anatomic and psychologic conditions as the classification model might become oversized. They also have minimum efficiency when compared to other methods as they have to be assessed pixel by pixel.

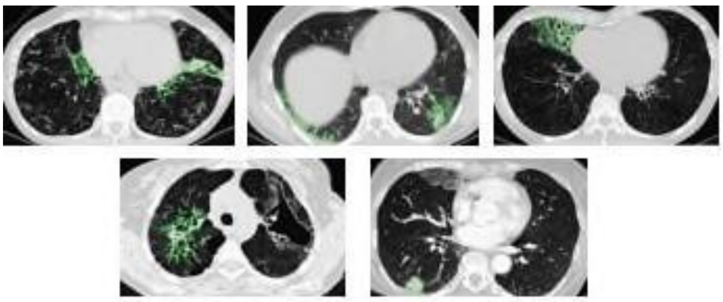


Figure 10: Successful Segmentation Using Machine-Learning Methods

Thus it could be concluded that machine learning based methods works efficiently in identifying pathologies. But however, this method is very expensive and cannot separate pathologic tissue from normal tissue.

1.2 Lung Segmentation Using Hybrid Methods in Hospitals

In hospitals, there is no single solution that could provide results for the segmentation of lungs with pathologies. But when two or more solutions are incorporated with one another, hospitals receive at least some kind of outcome. When prying into recently developed practical methods, many segmentation strategies have been concatenated with each other so that a generic global solution could be formed.

Let us take into consideration the work of the researcher Mansoor et al [26]. He proposed a segmentation method of a pathological lung that combines region-based method that of with neighboring anatomy and also a machine learning-based method for the delineation of the lungs. This framework considers the following ways of execution. First it used a modified fuzzy connectedness segmentation algorithm which is used to extract the initial lung parenchyma. Then abnormal imaging patterns that remained unrecognized during the first stage were retrieved using textual based local features. This phase also included a neighboring anatomy-guided segmentation approach so that abnormalities of organs situated near the lungs could be identified. This textual information usually refers to the spatial arrangement of an image or patterns that are repeated in a given image region.

Another Hybrid method described by Hua et al [27] suggested a graph cut algorithm to find the boundary of the lung. Before actually discovering the lung boundary, pathologic regions were first detected and included in the process. But the drawback of this method is seed sets had to accurately be defined in order to identify objects in the background and foreground. These methods are very efficient and feasible when trying to segment lungs with varying number of abnormalities, but not feasible otherwise and remain rather expensive.

1.3 Evaluation of Efficacy in Existing Segmentation of Images

For In order to measure the efficacy of segmentation, precision, accuracy and efficiency has to be considered. Precision is analyzed by segmenting of lungs repeatedly on different images and the differences in the results are recorded statistically. Accuracy is analyzed by checking if segmentation agrees to the ground truth. Efficiency is analyzed by comparing the computational time to the user time in order to train algorithms. These three factors are measured together to determine the efficacy of existing segmentation. The main aim of automated segmentation is to reduce human intervention or manual labor that is involved in the process and also to provide precise outcomes.

To calculate the spatial overlap or accuracy, the dice similarity coefficient [33] is used and is given as:

$$\mathbf{DSC}(\mathbf{V}_{GT},\mathbf{V}_{test}) = 2\,\frac{|\mathbf{V}_{GT} \cap \mathbf{V}_{test}|}{|\mathbf{V}_{GT}| + |\mathbf{V}_{test}|}$$

where V_{GT} is standard segmentation and V_{test} is segmentation using a method. The intersection determines the overlapping area between the reference standard and the test segmentation.

The Haussdorf distance [33] is also used to determine the distance between two boundaries to analyze the similarities between real and images segmented through these methods. These values proved that the method may have sensitivity less than 50%.

Sensitivity and specificity are also used to evaluate accuracy of segmentation [34]. Sensitivity is used measure the ratio of actual positives that are identified correctly to all positives. Any false positive identified incorrectly are called false negative. Sensitivity is calculated for false positives as follows:

Sensitivity = TP/P = TP/ (TP + FN).

where FN denote the false negatives.

Specificity is used measure the ratio of the negatives that are correctly identified to all negatives. Specificity for false negatives is calculated as follows:

Specificity = TN/N = TN/ (TN + FP)

where FP denotes false positives, or incorrectly identified positives.

A perfect segmentation should be 100% sensitive and 100% specific. Unfortunately, existing methods do not provide this value.

Two other metrics that are used to predict efficacy are efficiency and precision. When calculating precision, al lot of details deviates from being absolutely precise. When calculating efficiency [34], the more efficient methods proved to be expensive.

1.4 Summary

In this chapter, the current methods that are used in segmentation of images of the cardio vascular system and also those that are presently in trend are described. The advantages and disadvantages related to these methods are also stated along with the performance measure in real life.

To sum up the gist of the entire chapter, all current segmentation methods, though they segment images, some of them are very primitive, some cannot identify pathologies and the others are computationally very expensive to perform. When two or there of the above suggested methods are joined together and then carried out, they do provide better results but they are rather time consuming and also expensive.

From the calculation of their efficacy that is provided, it can be seen that more research is required to provide some better methods to improve segmentation which in turn would greatly help hospital to study diseases and pathologies related to the lungs and also help them to segment lungs automatically which in turn will help to serve as surgery guidelines or also in identifying problem in certain segments.

Chapter 2: Methods and Procedures Used in Identifying and Segmenting the Lungs

Most methods that have been described for segmentation and those which are clinically used today, though effective in segmenting the lungs have not been successful in identifying segments of the lungs but rather well defined features that exist in them. In this research, the methods used help in identifying the lung structure and eradicating unwanted elements from the lungs, thus illuminating a few of the lungs segments. In this work, first the border of the lungs are detected using Canny Method [35] and noise is filtered out using the median filter. Using the median filter on Canny Detected Images tends to highlight the noise alone and remove every other feature of the lungs. Hence the Canny Detected Image and the Median filtered image [43] are subtracted from each other to remove the noise. Finally an Erosion filter is used to remove veins or shorter neighboring pixels and leave only lines that join the lung borders thus providing us a clear image of the lung segments. For lungs with disabilities or huge particles in it, a Blob filter could also be used to filter out these huge particles.

Each method and its mechanism are explained below in order to give us a clearer idea of how the program is able to detect segments. For the detection of lungs segments on CT Images, only images with clear lung segment borders have to be considered.

2.1 Canny Method for the Detection of Lung Borders

This method was developed by John F Canny in 1986 [35]. Even though this edge detection method is quite old, it is one of the most widely used methods for the detection of image edges. The main reason for edge detection is to eliminate a most of the unwanted parts from the image and retain only the most prominent ones. The algorithm was developed and made optimal with respect to the following criteria.

Detection	-	Where the probability for real edge points to be detected is maximized and false detection of non-edge points probability is minimized.
Localization	-	Where the real edges and detected edges should be as close as possible.
Number of Responses	-	Where a real edge should not provide more than one detected edge.

With the help of Cranny's mathematical formula know as 'Calculus of Variations' [36], detection of edges were made more optimal based on the definition of the edges present which is approximated by the first derivative of a Gaussian Function [35, 36]. It is a multi – stage algorithm which used many stages of filtering to obtain the end result. It helps in extracting structural information from different objects of vision and reduces the data that needs to be processed.

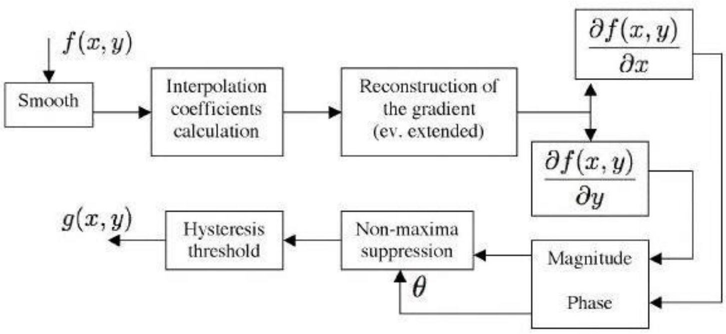


Figure 11: Diagrammatic Representation of Canny Detection Algorithm

2.1.1 Canny Edge Detection Process

The process can be broken down into five [37] stages:

- The image is blurred or smoothed to remove noise with the help of a Gaussian Filter.
- Finding the image's gradient intensity.
- In order to overcome a spurious response to edge detection, non-maximum suppression is applied.
- Potential edges are identified by applying direct threshold.
- Edges are tracked with the help of hysteresis where the edges are finalized by suppressing all weak edges that are not connected to strong edges.

These five stages and their functionality along with their mathematical formula are explained in detail below.

2.1.1.1 Image Smoothing Using Gaussian Filter

Due to the presence of noise in images, the image has to be filtered in order to eradicate false detection that is caused by noise. In canny method, the first step is to use a Gaussian filter to remove noise where the image is made slightly smoother by removing only obvious noise with the help of a filter kernel [38]. The filter kernel which is of size (2k+1) x (2k+1) is usually calculated using the equation.

$$H_{ij} = \frac{1}{2\prod\sigma^2} \exp\left(-\frac{(i-(k+1))^2 + (j-(k+1))^2}{2\sigma^2} \right)$$

Where $1 \leq i, j \leq (2k + 1)$. The size of the Gaussian kernel plays a very important role as the performance of the detector depends on it. If the size of the kernel is larger, its ability to detect noise [37, 38] is lower. In most cases, a 5 x 5 sized kernel is good but the size also varies according to the image that has to be detected.

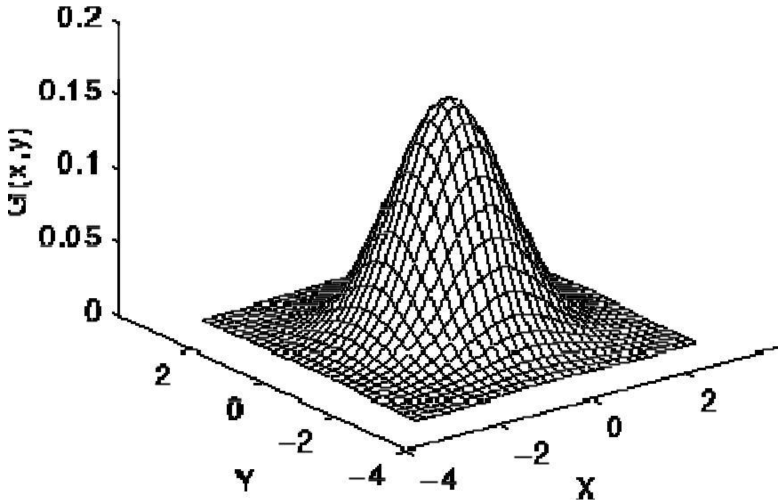


Figure 12: Kernel Representation of the Gaussian Filter

2.1.1.2 Finding the Gradient Intensity of the Image

The second step is to use four filters [38] to identify horizontal diagonal and vertical edges of the blurred image as the edge may point in more than one direction. An edge detection operator is used to return the first derivative in the vertical direction (G_x) and also in the horizontal direction (G_y). From these two values the edge gradient can be obtained using the following formula.

$$G = \sqrt{G_x^2 + G_y^2}$$

$$\Theta = \mathrm{atan2}(G_y, G_x)$$

Where G is got using hypot function [38] and atan2 is the arctangent function with two arguments. The edge direction is then rounded off to one of the four angles representing the vertical, horizontal and the two diagonals. Depending on the color region, each edge direction will be set to its specific angle value.

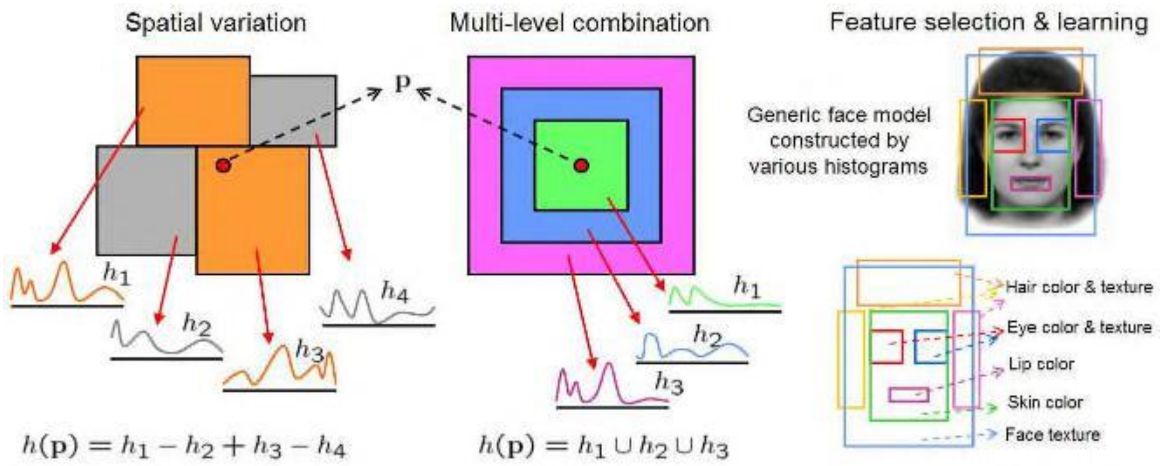


Figure 13: Identification of Facial Features using Gradient Intensity

2.1.1.3 Non-Maximum Suppression

Once gradient calculation of each edge is performed, the edges are made thinner using non – maximum suppression [38, 39]. The edges obtained from the previous stages are very blurred. In order to perform edge detection, an edge should have only one accurate response. Non – maximum suppression is used to suppress all gradient values to zero except for the local maximal which is the location of the sharpest change in edge intensity value.

For some images, the continuous gradient directions are classified into a small set of discrete directions, and then move a 3x3 filter over the output of the previous stage. At every pixel, edge strength of the center pixel is suppressed by setting its value to 0. But this is done only if its magnitude is not greater than the magnitude of its two neighbors in the gradient direction.

For more accurate implementations, two neighboring pixels use linear interpolation to straddle the gradient direction. If the gradient angle lies between 45° and 90°, interpolation [39] between gradients at the north and north east pixels will give one interpolated value, and interpolation between the south and south west pixels will give the other. The gradient magnitude at the central pixel must be greater than both of these for it to be marked as an edge. Also, the sign of the direction is irrelevant when calculating non - maximum, i.e. north–south is the same as south-north.

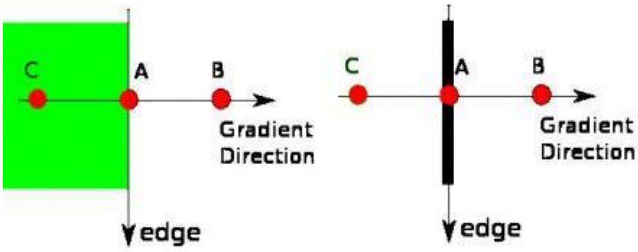


Figure 14: Performing Non-Maximum Suppression on the Image

2.1.1.4 Direct Threshold

The output of non maximum suppression is then taken with the remaining edge pixels [39] which in turn provide a more accurate representation of the real edges in the image. However, a few edge pixels caused by noise and color fluctuation still reside in the image. Hence, edge pixels with a weak gradient value are filtered out and only high gradient value edge pixels are preserved. This depends on the selection of high and low threshold values. If the gradient value of an edge pixel is larger than the high threshold value, it is marked as a strong edge pixel, if it is smaller than the high threshold value and larger than the low threshold value, it is marked as a weak edge pixel and if the value of an edge pixel is smaller than the low threshold value, it will be suppressed. The two threshold values are defined empirically and their definition will depend on the content present in the input image.

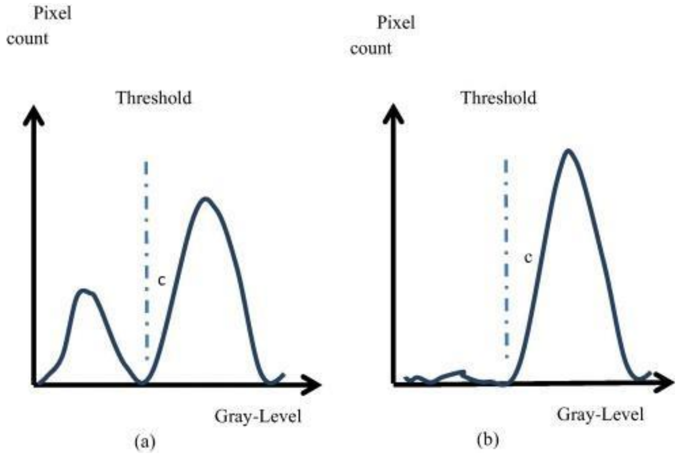


Figure 15: Optimal Threshold Selection in Gray Level Histogram a) Bimodal b) Unimodal

2.1.1.5 Hysteresis Tracking

The image obtained from the previous stage containing strong edge pixels [40] should certainly be involved in the final edge image, as they are extracted from the true edges of the input image. However, the weak edge pixels have to be extracted from the true edge. To achieve an accurate result, the weak edges caused due to noise or color fluctuations should be removed. Usually a weak edge pixel caused from true edges will be connected to a strong edge pixel while noise responses are unconnected. To track the edge connection, blob analysis is applied by looking at a weak edge pixel and its neighborhood pixels. A weak edge pixel is preserved only if there is one strong edge pixel that is involved in the blob.

The Canny algorithm can be used in any environment. Usually, if the amount of smoothing that the image requires is high, a long time is taken for the computation and smoothening of images. In such cases Canny filters have proved to be quite efficient and computation does not take long for any desired amount of smoothing. This method is useful to detect the border of lung images as lung images contain a huge amount of noise and this method helps in eradicating most of the noise.

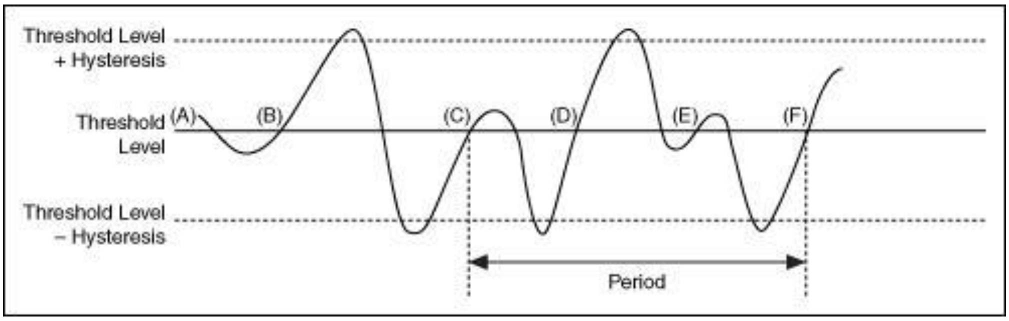


Figure 16: Level of Hysteresis Based on Strong and Weak Edges

2.1.1.6 Canny Method on CT Lung Image

The CT Lung Image undergoes the above described methods in order to remove noise [40] and detect only the borders. It first undergoes smoothing and passes through the Gaussian filter to first remove obvious noise. The image is slightly blurred after undergoing Gaussian filtering. This blurred image then is used and the edges of this blurred image are detected using gradient intensity. Once the edges are obtained, these edges are thinned using non maximum suppression and the real edges of the lung image are identified by applying the direct threshold formula. Finally weak edges are eliminated from the border using hysteresis tracking and the canny detected lung image is provided.

2.2 Using Median Filter on the Canny Image

A median filter is a nonlinear filter [41] which helps in removing noise from images. It is very popular as it is very effective in removing noise while preserving the edges in an image. It works by moving through the image pixel by pixel and replacing each value with the median value of its neighboring pixels. The pattern created by its neighbors is called "window", which slides pixel by pixel over the entire image. The median value is calculated by first sorting all the pixel values from the window in numerical order, and then replacing the pixel being considered with the median pixel value.

Median filter works on the principle of neighborhood averaging. In this averaging method, isolated out-of-range noise is suppressed, but it also blurs sudden changes. For example particular features in a line, sharp edges, and other image detail all corresponding to high spatial frequencies. It usually to some extent, eradicates out-of-range isolated noise from various features in the image such as edges and lines.

In other words, the median filter replaces a pixel by the median [42] or the middle value instead of the average value of all pixels in the neighborhood ω,

$$y[\, m, n \,] = \text{median}\{x[\, i, j \,], (\, i, j \,) \in \omega\}$$

where ω represents a neighborhood pixel which is defined by the user and is centered around the location [m, n] in the image. During filtering, the neighboring pixels are ranked according to their intensity [42, 43] and the median value becomes the new value for the central pixel. Median filters are excellent at rejecting certain types of noise, which include, “shot «or impulse noises in which some individual pixels take on extreme values. Median filters have the following advantages:

- The contrast does not reduce across steps as the output values consist only of neighbourhood pixels and not average pixels.
- Based on the contrast of the image, these filters do not shift boundaries as seen in conventional smoothing filters.
- Since median filters are less sensitive to extreme values when compared to the mean filter, extreme values or outliers can be removed more effectively.
- These filters provide a more robust average values than actually the mean value because of their ability to resist outliers.
- The output pixel is usually a neighbouring pixel and hence edges do not contain unrealistic values.
- Edges are degraded very minimally and hence these filters can be applied repeatedly.

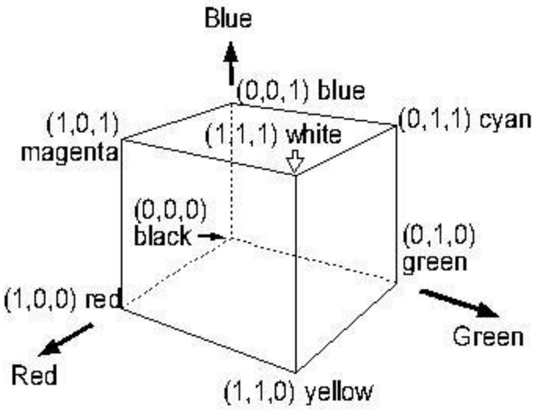


Figure 17: Quantization of Color Pixels Using a Median

When creating median filters, the following considerations have to be taken into consideration:

- Median filters are more expensive to compute when compared with smoothing filters [44]. But this can be reduced with the use of more clever algorithms that save time by using repeated vales as neighbourhood pixels are determined across the image.
- The formula should be taken into account when summing filtered images.

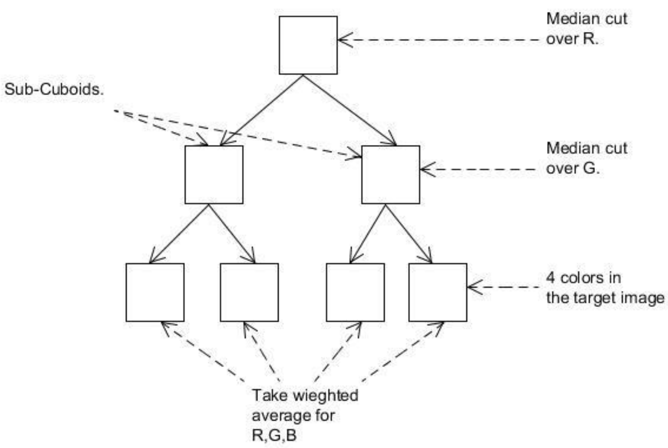


Figure 18: Distribution and Selection of Each Color Pixel Through the Median Filter

2.2.1 Use of Hybrid Median Filters

The main problem with median filters [41, 44] is they tend to erase line that is narrower than half the width of neighborhood lines and corners can also be rounded off. In order to prevent such errors, hybrid median filters are preferred. These filters are a three step ranking process that uses 2 subgroups of 5 x 5 neighboring pixels. These subgroups are usually got from pixels that a parallel to the frame edges and form an angle of 45 degrees to the edges and are also centered to the reference pixel.

Hybrid medians [45] work in the following way. The median of a subgroup of pixels is determined. Then these two values are compared to the original pixel value. The median for these three values are then determined and is taken as the output pixel value. If a pixel contains a large neighborhood, additional subgroup orientations are defined.

2.2.2 Median Filter in Lung Segmentation of the Canny Detected Lung Image

The median filter detects only the noise present in the Canny Image and displays the noise. As median filters have to eradicate noise and the canny filter is already a noise detecting method, the median filter tries to provide a clear image on the amount of noise that is left in the already noise reduced image.

2.3 Finding the Differences Between Canny and Median Filtered Images

In general, finding the difference involves performing calculations on two images, corresponding to the corresponding pixel color components. The resulting values from performing these calculations represent a single image without the noise factor. The extent of eliminating noise mainly depends on the image retrieved from median filtering and the difference algorithm that is applied between the two images.

2.3.1 Calculating the Difference Based on the Color Components of the Pixels

In this method, the data obtained from the underlying pixel of the image is taken and byte arrays are formed by creating copies of this data. The data obtained from these pixels usually represent a single color component which is either alpha, red, green and blue. After acquiring data components from each pixel and storing them in the byte array, both byte arrays of both images are iterated at the same time based on the size of the array. If dimension of both images entering the system ma re not the same, iteration of each data buffer occurs separately and their sizes will also differ.

During each iteration, the loop counter is iterated in such a way so that each iteration is treated as a complete pixel value. Each data buffer that was retrieved contains an individual color component which includes either alpha, red, green or blue. Ordering of color components to identify differences occurs exactly opposite to that of the expected order. As each entire pixel is iterated, the first counter value will equate only to the blue component. Red and green component values are accessed only when they are added to the color counter. Finally a new instance is created and updated based on the resulting byte array data buffer.

The next step in finding the does not include any technical implementation. Only two byte values which determine single color components are required from both images. The color component values usually range from 0 to 255 and are inclusive of both. Sometime when trying to calculate, the values do not end up within this range. Hence values less than 0 are set to 0 and values more than 255 are set to 255. This process is known as clamping. Then the same color component from both images is taken and the difference between them is calculated. Since the median image consists of the uneradicated noise and the canny image consists of the bordered image, a clearer image with only border and sections will be retrieved.

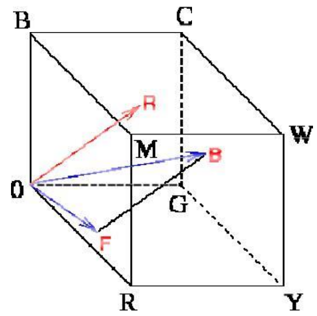


Figure 19: Finding the Difference of Pixel with the Help of Vector Representation

2.3.2 Identifying Differences Between CT Lung Image and Median Filtered Image

The two images are taken and their pixels are compared by subtracting the pixels of the median filtered image from the CT lung image. Once all the same pixels are eliminated, a lung image with minimal noise is obtained.

2.4 Using Erosion Filter

Erosion and dilation methods [46] are a part of morphological operations. Mathematical morphology [47] is a technique used for the analysis and processing of geometrical structures based on various mathematical theories like set theory, lattice theory [49], topology and random functions. It is known for its application to digital images, graphs, surface mass solids and other similar spatial structures. Many topological and space related geometry concepts which include size, shape, convexity and geodesic distance evolved due to mathematical morphology and this technique is usually applied to both continuous and discrete spaces.

It was originally developed only for binary images and later extended to grayscale images [47, 48]. It mostly deals with describing shapes using sets. In image processing, mathematical morphology is used to investigate the interaction between an image and a certain chosen structuring element using the basic operations of erosion and dilation. It is very different when compared to traditional linear image processing, as it is basically non-linear in nature and thus uses a totally different kind of algebra than linear algebra.

In practical image processing, morphology can be applied to a finite set P if:

We can partially order elements of the set for all a, b, c ϵ P

$a \leq a$
$(a \leq b, b \leq a) \Rightarrow a = b$
$(a \leq b, b \leq c) \Rightarrow a \leq c$

Each non-empty subset of P has a maximum and a minimum.

For dilation and erosion we consider two cases:

- Any finite set of real or integer numbers is a suitable set P.
- The set of all subsets of a superset S is a suitable set P.

Case 1: Any Finite Set of Real or Integer Numbers is a Suitable Set P

The ordering of sets is defined as in ordinary calculus. The maximum and minimum [48] are also defined like in normal mathematics. This means morphology can be applied to grey-scale images or subsets of images, because the collection of grey values can be viewed as a finite set P with ordering, maximum, and minimum well defined.

Case 2: The Set of All Subsets of a Superset S is a Suitable Set P

The ordering of sets is defined by the subset relation. The maximum and minimum are defined by the union and intersection operators respectively. Besides finite sets of real and integer numbers and the set of subsets, more abstract sets P [48, 49] can be constructed. Mathematical morphology can be applied to any of these sets. We can extend the partial ordering to digital images by applying the rules to the individual pixels. For instance, for two images f and g, the relation f ≤ g holds only if

$$\mathbf{f \leq g \Longleftrightarrow \forall x : (f(x) \leq g(x)),}$$

where "∀x" refers to all possible pixel locations. The maximum and minimum of two images can also be defined in terms of pixels:

$$\mathbf{(\max\{f, g\})(x) = \max\{f(x), g(x)\}}$$

$$\mathbf{(\min\{f, g\})(x) = \min\{f(x), g(x)\}.}$$

Ordering of sets and determination of maximum and minimum are the key basis of mathematical morphology. The operator used in the detection of maximum and minimum values is the only basic operators that are used in morphological application of images. This method also helps in retaining the order of the images which is also known as their maxima or minima values.

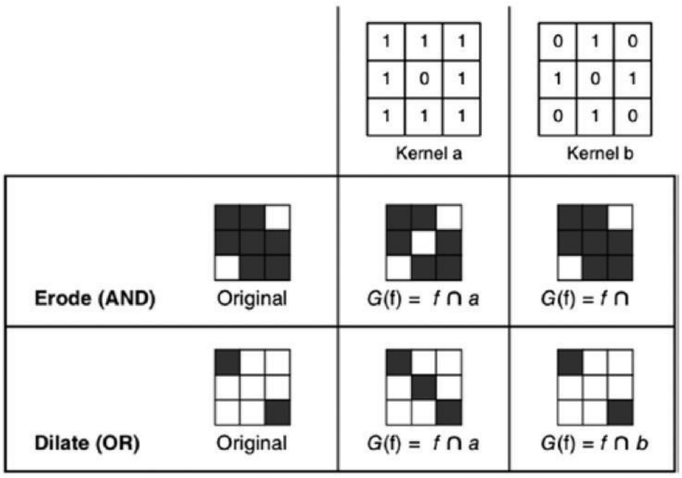


Figure 20: Erosion and Dilation of Pixels using Kernels

2.4.1 Morphological Operator Properties

The complement of a set [50] may be defined as all elements that do not belong to that set. In the case of an image f, the complement fc is defined as f mirrored in a central grey-scale line. For an image, the complement can be written as

$$\mathbf{fc(x, y) = L + M - f(x, y)}$$

Thus complementing the results twice in the original set or function (Xc)c = X, and (fc)c = f. A quicker way of understanding if the image obtained is complimentary to the image sent, check if the sum of two corresponding pixels ends in 8. Recomplimenting the obtained image should return the original image.
Complimenting both sets and images give consistent results. If we represent the set X as a function an image, f can be defined as,

$$\mathbf{f(x, y) = 1, \text{ if } (x, y) \in X\ 0, \text{ elsewhere}}$$

In this way, by applying the complement as defined for images will give the same result as applying the complement to the set of values X. Using this formula, a set can be converted to a binary image.

Dual operators are then applied to the complimenting image. Let $\phi 1$ and $\phi 2$ be the dual operators that are applied to the complimenting image obtained from f, then

$$\mathbf{\forall f: (\phi 1(fc) = (\phi 2(f))c)}$$

Many of the pairs of morphological operators are said to be dual. These include erosion and dilation, and opening and closing. Some operators are self-dual and are represented mathematically as

$$\mathbf{(\phi(fc) = (\phi(f))c)}$$

The median filter from the previous stage is self-dual. An operator ϕ is said to increase only if it does not alter the order of images:

$$\mathbf{\forall f, g : (f \leq g \Rightarrow \phi(f) \leq \phi(g))}$$

An operator ϕ is extensive if the output is always calculated to be larger than the input.

$$\mathbf{\forall f : (f \leq \phi(f))}$$

If the reverse holds true, then anti-extensive can be represented as

$$\mathbf{\forall f : (\phi(f) \leq f)}$$

An operator can be called idempotent if and only if when applying the operator more than once has no effect which can be represented as

$$\mathbf{\forall f : (\phi(\phi(f)) = \phi(f))}$$

Both increase in value and anti-extensivity are desired properties for many operations and image processing techniques. They also form the basic idea of many theoretical calculations when morphology is concerned.

2.4.2 Correlation of Sets with Images

Morphological operators are defined as sets and these set operators are then used on images, therefore relationship between sets and images is defined in order to transfer functions [50, 51] used by set-operators to images. In the previous step, a method to correlate binary images with a set X was defined so that all the pixels with grey value 1 was correlated into the set $\{(x, y)|f(x, y) = 1\}$. This idea is expanded further so that we can a relationship between grey valued images and sets is defined with regard to each specific grey level in the image as a set and the image f is regarded as a stack of sets F with the relation

$$\mathbf{F(c) = \{(x, y)|f(x, y) \leq c\}.}$$

Using this formula, any operators that are defined only for sets could be applied to images. The operators are applied to all the level of sets within the stack F(c) [51] which in turn is used to recreate the image. Though the operation sounds tedious or almost impossible in theory, it is simplified to a great deal in programming. These sets are then used to create the erosion and dilation filters which provide the required output for lung images.

2.4.3 Morphological Erosion

Morphological operations use a structuring element S to interact with an image, thus being able to interact with an image thus the use of mathematical operations [52]. The structuring element is usually small when compared with the image. In the case of digital images, simple structuring binary elements are used which includes crosses and squares. In binary images, bright pixels are given high grey values and dark pixels end up with low grey values. Object pixels [51, 52] take the grey value 1 and are displayed as black whereas background pixels take the value 0 and appear as white. This helps in enhancing the clarity of binary images.

The structuring element S is defined as follows to create a more intuitive effect:

- The structuring element can be placed anywhere in the image.
- If the structuring element hits the set, the origin of the structuring element is part of the dilated set.

If the structuring element is not symmetrical, then the transpose of the element [53] is used in the procedure mentioned above. The transpose of the element is nothing but the structuring element mirrored in the origin:

$$\mathbf{S = \{s| (-s) \in S\}}$$

Erosion ε(X) of a set X with structuring element S is given by the following formula

$$\mathbf{\varepsilon(X) = \{x|\forall s \in S, x + s \in X\}}$$

Thereby the structuring element in the image processing method is replaced by the following method based on the formula mentioned above:

Place the structuring element anywhere in the image

Is it fully contained by the set (*i.e.*, a subset)? Then the origin of the structuring element is part of the eroded set.

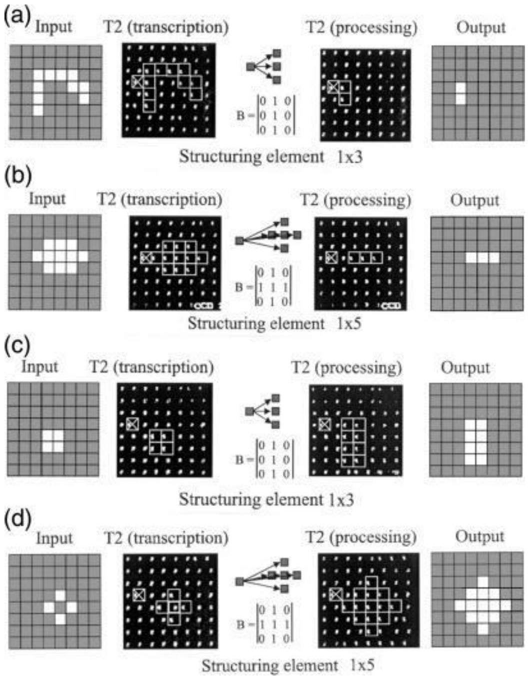


Figure 21: Using Different Structuring Elements on the Input Image

Using the relation between sets and images, formulas for erosion ε and dilation δ of the digital image f can be calculated with the help of a structuring element S and the formula is given as:

$$(\varepsilon(f))(x) = \min f(x + s) \; s \in S$$
$$(\delta*(f))(x) = \max f(x - s) \; s \in S$$

Where x and s represent the vector quantities [54] for the image f. The negative sign in the definition of the dilation represents a counter-intuitive. To avoid this, an alternative is used as follows:

$$(\delta(f))(x) = \max f(x + s) \; s \in S$$

Although a number of theoretical steps is necessary to arrive at the above formulas for dilation δ and erosion ε, their application to digital images [53, 55] is more or less straightforward.
Erosion ε can be computed for the image f at each pixel (x, y) by centering S at (x, y), and then taking the minimum of all pixels in f that are 'hit' by S. For instance, the erosion at (2, 2) gives us the minimum of the values {1, 3, 3, 1, 1} which is 1. Dilation is also computed in the same way, except that the maximum is now considered instead of the minimum. During erosion and dilation padding of values with −∞ and ∞ is considered in order to process the image better.

2.4.4 Erosion and Dilation Properties

While performing eerosion and dilation [56], the following properties have to be taken into consideration. The erosion operation usually erodes chunks of pixels at the boundaries of the images, while dilation does the opposite. In accordance with the non-linear character of morphological operations, erosion cannot be considered as the inverse of dilation. In other words the inverse of either operation does not exist. For example many different input images can have the same erosion and trying to reverse the operation does not return the input image. Many special properties hold for erosion and dilation when given a symmetrical common structuring element for simplicity. They are given below.

Both erosion and dilation are dual operations.

$$(\varepsilon(f))c = \delta(fc)$$

Both erosion and dilation are increasing operations.

$$f \leq g \Rightarrow \varepsilon(f) \leq \varepsilon(g)\ \delta(f) \leq \delta(g)$$

If a part of the structuring element belongs to the origin of the image, then dilation becomes extensive and erosion, anti-extensive.

$$0 \in S \Rightarrow \varepsilon(f) \leq f\ f \leq \delta(f)$$

The structuring element can be broken into one directional piece. In such cases, erosion or dilation can be carried out as one-dimensional erosion and dilation.

$$S = \delta S1(S2) \Rightarrow \varepsilon S(f) = \varepsilon S1(\varepsilon S2(f))$$

$$\delta S(f) = \delta S1(\delta S2(f))$$

2.4.5 Applying Erosion Filter on Lung Image with Minimal Noise

Finally the output image from the previous stage is taken and passed through the erosion filter so that only the segments of the lung image is detected and the output is provided.

2.5 Summary

In this chapter, the method used in the detection of lung segments is explained in detail. When segmenting the CT lung images the following point s has to be taken into consideration.

Works only on CT images where segments of the lungs are clearly seen by the human eye, otherwise segments could be lost.

In case of holes or abnormalities in the lungs, blob filtering should also be used with erosion filter to remove the abnormality and preserve the borders.

In the method explained to segment the lung CT images, the image first undergoes canny edge detection in which it undergoes five separate processes of filtering to identify the edges of the lung image and to reduce obvious noise. This image is then passed through a median filter to identify the remaining unnecessary noise. The original CT image and the noise are subtracted from each other by comparing and removing matching pixels to provide a lung image with minimal or no noise. This is finally passed through an erosion filter so that remaining unwanted features are removed and only the visible segments of the lung are displayed.

Chapter 3: Algorithm to Segment Lung Images

In this chapter, the functioning of the program and the underlying algorithm to make the program work is explained in detail. The language used to create the software is C# and all the algorithms explained in Chapter 2 are used for the segmentation of lung images. The explanation to the program software is broken down to give a better understanding of what really happens when segmentation take place. We start with CT lung image requirements and finish of with the explanation of integral parts that help the algorithm provide its output of a segmented image.

3.1 Software Requirements

Accurate medical image segmentation plays a key role in contouring in radiotherapy planning. Computed topography (CT) imaging is one that is used extensively in radiographic techniques for diagnosis, study for clinical purposes and treatment planning. This review gives us a detailed idea of automated segmentation and is discussed very specifically for CT images. The study also tries to identify major problems that are encountered in the segmentation of CT images, and the relative merits and limitations of methods currently available for segmentation of medical images.

With rapidly ascending use of Computed topography (CT) imaging for diagnosis, treatment planning and clinical studies, computers have become a necessity and help in assisting radiological experts in clinical diagnosis, treatment planning. The goals of our program are to do the following.

- To segment the lung for a large number of cases can with good accuracy, meaning that the results are not when considered for lung images with different abnormalities.
- To achieve fast and accurate results with the use of high-speed computers.

Thee techniques used for the segmentation of images are usually specific to the application, type of imaging and also the modality and type of body part to be studied. For instance, segmentation of the brain is different from the segmentation of the thorax region as the brain has more prominent volume which the thorax is more prominent in detection of motion. Similarly segmentation of the lungs is very different and requires different CT image specifications when compared with the brain and thorax.

In the segmentation of lung images, it is important that the texture of segments of the lungs is of better quality in the CT images that are used in the program. A machine learning algorithm can only learn something that can be visible or understandable to the human brain. So a better output of the segments is provided if they are of better texture. Another reason for the availability of clear segments is due to the many filters that are used. Some filters tend to remove weak pixels and thus might remove segments that need to exist in the segmented lung image. When considering lung images with disabilities or tuber Coloma, it will be close to impossible to eradicate the structure from the lung image without the help of a blob filter. This filter helps in removing deformities that exist as a group of pixels inside the lungs. Blob filter helps in removing a group of pixels that don’t serve the purpose of the output based on the thickness or the number of pixels grouped together.

3.2 Class and Method Hierarchy

As image processing produces excellent results when coded with c#, this language is used in building the lung segmentation software. The program is decomposed into the following classes which provide individual functioning of each method for segmenting the lung:

- Detection of lung borders and removing obvious noise from CT lung images
- Detect noise that wasn't removed from the image
- Subtract the remaining noise from the image
- Removal of veins and deformities from the lung image.

3.2.1 Detection of Lung Borders and Removing Obvious Noise from CT Lung Images

In order to carry out this task runs five different tasks separately and these five stages are defined in the Canny.cs. The five tasks include:

- Smoothing or blurring the image to remove noise
- Finding Gradients for edge detection
- Non maximal suppression or removal of weak pixels
- Discovering Potential Edges through double thresholding
- Edge tracking with the help of hysteresis.

3.2.2 Smoothing or Blurring the Image to Remove Noise

Noise is removed from the image with the help of a Gaussian filter with a specific kernel size (N) and Gaussian envelope parameter sigma and is defined in the program using the following method. The size of the kernel, the sigma value and the total number of pixels in the image is passed to the method as parameters. Mathematical formula pi is used to calculate the size of the kernel N and the Gaussian kernel is passed as an int matrix into the method

private void GenerateGaussianKernel(int N, float S, out int Weight)

In this method D1 and D2 are used to calculate to what extent the Gaussian filter should filter the image and their formulas are described in this method.

```
D1 = 1 / (2 * pi * Sigma * Sigma);
D2 = 2 * Sigma * Sigma;
```

The Gaussian kernel is the calculated based on the size of the kernel and also creating a matrix for the pixel. This process is divided into three steps. The first step is to determine half the size of the kernel calculates the matrix for the first half of the kernel.

```
for (i = -SizeofKernel / 2; i <= SizeofKernel / 2; i++)
   { for (j = -SizeofKernel / 2; j <= SizeofKernel / 2; j++)
      { Kernel[SizeofKernel / 2 + i, SizeofKernel / 2 + j] = ((1 / D1)*(float)Math.Exp(-
           (i*i+j*j)/D2)); if (Kernel[SizeofKernel / 2 + i, SizeofKernel / 2 + j] < min)
              min = Kernel[SizeofKernel / 2 + i, SizeofKernel / 2 + j]; }}
```

The second part is to determine the maximum value and the minimum value in the kernel and then fill the borders of the kernel with the given matrix values.

```
if ((min > 0) && (min < 1))
    {for (i = -SizeofKernel / 2; i <= SizeofKernel / 2; i++)
        {for (j = -SizeofKernel / 2; j <= SizeofKernel / 2; j++)
            {Kernel[SizeofKernel/2+i,SizeofKernel/2+j]=(float)Math.Round(Kernel[SizeofKernel/
             2+i,SizeofKernel/2+j]*mult, 0);
            GaussianKernel[SizeofKernel/2+i,SizeofKernel/2+j]=(int)Kernel[SizeofKernel/2+i,
             SizeofKernel/2+j];
            sum = sum + GaussianKernel[SizeofKernel / 2 + i, SizeofKernel / 2 + j];}}}
```

Once the border matrix values of the kernel are determined, the rest of the kernel matrix are filled with the rest of the values in the third step using the border as its gauge to identify up to where the values have to be filled.

```
Kernel[SzeofKernel/2+i,SizeofKernel/2+j]=(float)Math.Round(Kernel[SzeofKernel/2+i,SzeofKernel/2+j], 0);
GaussianKernel[SizeofKernel/2+i,SizeofKernel/2+j]=(int)Kernel[SizeofKernel/2+i,SizeofKernel/2 + j];
sum = sum + GaussianKernel[SizeofKernel / 2 + i, SizeofKernel / 2 + j];
```

Finally the entire kernel is finalized by equating the weight of the kernel to the sum of the kernel.

```
Weight = sum;
```

The next method helps in creating the Gaussian filter. It first gets the Gaussian kernel that was created in the previous method and then creates the filter using the Gaussian kernel matrix.

```
private int[,] GaussianFilter(int[,] Data)
```

The working of the method involves the creation of the filter with the help of the Gaussian kernel. By identifying each kernel and the matrix values created the filter is created to filter of the input image.

```
GenerateGaussianKernel(KernelSize, Sigma, out
KernelWeight); for (i = Limit; i <= ((Width - 1) - Limit); i++)
      {for (j = Limit; j <= ((Height - 1) - Limit);
        j++) {Sum = 0;
          for (k = -Limit; k <= Limit; k++)
          {for (l = -Limit; l <= Limit; l++)
            {Sum = Sum + ((float)Data[i + k, j + l] * GaussianKernel[Limit + k, Limit + l]);}}
          Output[i, j] = (int)(Math.Round(Sum / (float)KernelWeight));}
```

The next step deals with filtering out the original image through the canny filter by calculating the borders of the image. The parameters passed to the method include initial image data and the Gaussian filter.

```
private float[,] Differentiate(int[,] Data, int[,] Filter)
```

The width and the height of the filter are determined with the help of GetLength() method. The number output pixels are calculated as a matrix of height and width values.

```
Fw = Filter.GetLength(0);
Fh = Filter.GetLength(1);
float[,] Output = new float[Width, Height];
```

Then the pixel values for the output image are calculated based on the height and width of the original image in relation to the height and width of the filter and passing each pixel of the original image though the matrix filter values and summing them up to get the noise free image.

```
for (i = Fw / 2; i <= (Width - Fw / 2) - 1; i++)
        {for (j = Fh / 2; j <= (Height - Fh / 2) - 1;
           j++) {sum = 0;
              for (k = -Fw / 2; k <= Fw / 2; k++)
              {for (l = -Fh / 2; l <= Fh / 2; l++)
                 {sum = sum + Data[i + k, j + l] * Filter[Fw / 2 + k, Fh / 2 +
              l];}} Output[i, j] = sum;}
```

After passing the image through the filter, a method to identify canny edges is used to detect the edges of the filtered image.

```
private void DetectCannyEdges()
```

The input to this method is the Gaussian filtered image. The sobel masks are calculated to detect the edges by identifying the derivative of the edges.

```
FilteredImage = GaussianFilter(GreyImage);
DerivativeX = Differentiate(FilteredImage, Dx);
DerivativeY = Differentiate(FilteredImage, Dy);
```

The gradient magnitude of the image is then calculated based on the derivative values of x and y that are obtained as a result of deriving the height and width of the image.

```
for (i = 0; i <= (Width - 1); i++)
        {for (j = 0; j <= (Height - 1); j++)
           {Gradient[i, j] = (float)Math.Sqrt((DerivativeX[i, j] * DerivativeX[i, j])+
                    (DerivativeY[i, j] * DerivativeY[i, j]));}}
```

From the output obtained from gradient magnitude, non maximum suppression is calculated to identify all the weak edge pixel values and remove them.

```
for (i = 0; i <= (Width - 1); i++)
        {for (j = 0; j <= (Height - 1); j++)
           {NonMax[i, j] = Gradient[i, j];}}
```

Then the values of the pixels are calculated based on the position of the edge they belong to meaning, horizontal edge, vertical edge or 45 degrees or negative 45 degree axis and then the values are determined.

```
if (((-22.5 < Tangent) && (Tangent <= 22.5)) || ((157.5 < Tangent) && (Tangent <= -
              157.5))) {if ((Gradient[i,j]<Gradient[i,j+1])||(Gradient[i,j]<Gradient[i,j-1]))
                    NonMax[i, j] = 0;}
```

In a similar manner, all the edges are calculated by changing the angle from -22.5 degrees to -112.5, -67.5 and -157.5 degrees.

Finally post hysteresis is calculated on the canny edges which is done based on the width, height and limit of each detected canny value.

```
for (r = Limit; r <= (Width - Limit) - 1; r++)
        {for (c = Limit; c <= (Height - Limit) - 1; c++)
          {PostHysteresis[r, c] = (int)NonMax[r, c];}}
```

The minimum and maximum values of post hysteresis is then determined by removing all the unwanted values and keeping only the strong canny edge values. Hysteresis is calculated to then identify the most accurate edges and delete false edges by using the hysteresis method.

```
private void HysterisisThresholding(int[,] Edges)
```

This is done by comparing the height of the original image with that of the filtered image and positioning remaining pixels along the real line border with the help of the points obtained from edgemap and traversing methods.

```
for (i = Limit; i <= (Width - 1) - Limit; i++)
        {for (j = Limit; j <= (Height - 1) - Limit;
          j++) {if (Edges[i, j] == 1)
            {EdgeMap[i, j] = 1;
             Travers(i, j);
             VisitedMap[i, j] = 1;}
```

The final method decided in the Canny Class is the traversing method that is used in hysteresis. Traversing helps to identify which point comes after the other while tracking the edge border. Tracking occurs with the position of the pixel with respect to the x and y axis. In this way all the edge points are determined.

```
if (EdgePoints[X + 1, Y] == 2)
        {EdgeMap[X + 1, Y] = 1;
         VisitedMap[X + 1, Y] = 1;
         Travers(X + 1, Y);
         return;}
```

The canny image is then displayed with only edges that are detected and obvious noise is removed. This is done with help of the canny display method.

3.2.3 Median Filtering to Obtain Unrecognized Noise

Filtering of unrecognized noise uses two classes namely:

- StreamUtils.cs
- MedianFilter.cs

The underlying working of the median filter class is defined in StreamUtils.cs. In this class the position of each pixel is identified by the position of its neighboring pixel. First method is to read the input image this is done by trying to identify pixels from the bitmap image that is taken as input.

```
public static PGM ReadFromBitmap(Bitmap bmp)
```

In this method, the pixels of the image are taken and calculated and saved in terms of their red, blue, green and grey color components values into a PGM object which contains a file matrix to save the component color values. The pixels are traversed based on the height and width of the image. The pixel values are returned with respect to their position according to the x and y axis. They are usually defined as follows.

```
for (int x = 0; x < bmp.Width; x++)
        {for (int y = 0; y < bmp.Height; y++)
           {int rgb = bmp.GetPixel(x,
            y).ToArgb(); int red = rgb & 255;
              int green = (rgb & 65280) / 256;
              int blue = (rgb & 16711680) / 65536;
              int gray = (red + green + blue) / 3;
              pgm.Pixels[x, y] = (short)gray;}
```

The next method is to get the value of all neighboring pixels in every direction. This is done with the help of the following method.

```
public short GetNeighbor(int x, int y, Direction direction)
```

In this method, the position of each pixel with respect to the x and y axis is taken as input along with its direction in the image. It starts with the neighboring pixel x and y axis to be -1 and then traverses according to the direction.

```
switch (direction)
{case Direction.NorthWest:
 case Direction.North:
 case Direction.NorthEast:
 case Direction.East:
 case Direction.SouthEast:
 case Direction.South: case
 Direction.SouthWest: case
 Direction.West:}
```

In each case, the x and y position of the neighboring pixel is analyzed and calculated based on its direction by adding or subtracting 1.

After identifying the position of the neighboring pixel, its x and y values are stored with the help of a pixel matrix based on the height and width of the image.

```
if (neighborX >= 0 && neighborX <= this.Size.Width - 1)
        {if (neighborY >= 0 && neighborY <= this.Size.Height - 1)
           {return (this.Pixels[neighborX, neighborY]);}}
```

The next step is to determine the position of all pixels around a given pixel based on their x and y values. This is done with the help of the following method.

```
public List<int> GetAllNeighbors(int x, int y)
```

In this method, the x and y value of the pixels are all taken into a list . Then the position of the particular pixel is first determined. And finally the position of all surrounding pixels is determined.

```
List<int> allNeighbors = new List<int>();
        allNeighbors.Add(this.Pixels[x, y]);
        allNeighbors.Add(GetNeighbor(x, y, Direction.NorthWest));
```

All valid neighbors are finally returned by the following statement. The position of the neighboring pixel is added to the list using the AddRange method.

```
validNeighbors.AddRange(from neighborPixel in allNeighbors where neighborPixel != -1
select neighborPixel);
```

After finding the unrecognized noise using the MedianFilter class, the new image with only noise is create using the method.

```
public static void DrawToGraphics(PGM pgm, Graphics g)
```

In this method, the new image that contains only unrecognized noise is drawn in argb format using the Pen option and DrawRectangle method.

```
Pen pen = new Pen(Color.FromArgb(gray, gray, gray),
1); g.DrawRectangle(pen, x, y, 1, 1);
```

The final bitmap is then created using the following method where the graphic image is then converted into a bitmap image where the PGM object is passed as input. This PGM object contain all the pixels in terms of their x and y axis.

```
public static Bitmap CreateBitmap(PGM pgm)
```

The CreateBitmap method takes the graphic points and creates a bitmap with it. The format of the bitmap is 24 byte argb color image.

```
Bitmap bmp = new Bitmap(pgm.Size.Width, pgm.Size.Height,
PixelFormat.Format24bppRgb); Graphics g = Graphics.FromImage(bmp);
DrawToGraphics(pgm,
g); return (bmp);
```

The unrecognized noise is then identified by a class called the MedianFilter.cs. In this method, all the noise that is not detected in the canny detector is detected here. Since the median filter is applied to an already filtered image. The output obtained is only the unrecognized noise. The input parameter to this method is only an input image of the PGM format which contains x and y pixels.

```
public static PGM ApplyMedianFilter(PGM inputImage)
List<int> validNeighbors = inputImage.GetAllNeighbors(x, y);
validNeighbors.Sort();
int medianIndex = validNeighbors.Count / 2;
short medianPixel = (short)validNeighbors[medianIndex];
outputImage.Pixels[x, y] = medianPixel;
inputImage = outputImage.Clone();
```

Median filtering takes place by getting all neighboring pixel values in terms of x and y axis and sorting all valid neighbors. The median all the valid pixels is calculated and the index of these pixels is determined. All indexes are then taken and form the final image. This image is then formed using the PGM Clone method.

```
public PGM Clone()
```

The final image is cloned with respect to the height and width of the original image and x and y pixel value of each pixel.

```
newImage.Pixels[x, y] = this.Pixels[x, y];
```

3.2.4 Identifying Differences Between Noise and Original Image Using Image Arithmetic

The differences between noise and original image are determined by the following classes:

- ImageArithmetic.cs
- ColorCalculator.cs
- ImageProcess.cs

ImageAritmatic.cs is a class that is a single extension method targeting the ImageProcess class. This class requires two bitmap images as input objects and also requires a difference value indicating the subtraction of noise to perform.

```
public static Bitmap ArithmeticBlend(this Bitmap sourceBitmap, Bitmap blendBitmap,
ColorCalculator.ColorCalculationType calculationType)
```

It is only within this method that the difference is obtained. This method accesses the underlying pixel data of each lung CT image and creates byte arrays where copies of x and y pixel values are stored. Each color component in the array data buffer represents a single color component, which is alpha, red, green or blue and these values are stored separately in the byte array.

```
BitmapData sourceData = sourceBitmap.LockBits(new Rectangle(0, 0, sourceBitmap.Width,
sourceBitmap.Height), ImageLockMode.ReadOnly, PixelFormat.Format32bppArgb);
```

We can access underlying pixel data of each input image with the help of Bitmap.LockBits method. This method iterates both byte array data buffers simultaneously, having set the for loop condition to regard the array size of both byte arrays. Scenarios where byte array data buffers will differ in size occurs when the source images specified are not equal in terms of size dimensions.

```
for (int k = 0; (k + 4 < pixelBuffer.Length) && (k + 4 < blendBuffer.Length); k += 4)
        {pixelBuffer[k] = ColorCalculator.Calculate(pixelBuffer[k], blendBuffer[k],
         calculationType); pixelBuffer[k + 1] = ColorCalculator.Calculate(pixelBuffer[k + 1],
         blendBuffer[k + 1], calculationType);
         pixelBuffer[k + 2] = ColorCalculator.Calculate(pixelBuffer[k + 2], blendBuffer[k +
         2], calculationType);}
```

Each iteration increments the loop counter by a factor of four allowing us to treat each iteration as a complete pixel value. Remember that each data buffer element represents an individual color component. Every four elements represent a single pixel consisting of the components which represent the color.

```
graphicsResult.CompositingQuality = CompositingQuality.HighQuality;
graphicsResult.InterpolationMode = InterpolationMode.HighQualityBicubic;
graphicsResult.PixelOffsetMode = PixelOffsetMode.HighQuality;
```

The task of performing the actual arithmetic has been encapsulated within the static Calculate method, a public member of the static class ClassCalculator. The Calculate method is more detail in the following section of this article. The final task performed by the ArithmaticBlend method involves creating a new instance of the Bitmap class which is then updated using the resulting byte array data buffer previously modified.

```
if (calculationType == ColorCalculationType.SubtractLeft) {
intResult = color1 - color2;}
else if (calculationType == ColorCalculationType.SubtractRight)
{ intResult = color2 - color1;}
```

The algorithms implemented in ImageArithmatic are encapsulated within the ColorCalculator.calculate method. When implementing this method no knowledge of the technical implementation details are required. The parameters required are two byte values each representing a single colour component, one from each source image.

```
byte[] pixelBuffer = new byte[sourceData.Stride * sourceData.Height];
```

Color component values can only range from 0 to 255 inclusive. Calculations performed might result in values which do not fall within the valid range of values. Calculated values less than zero are set to zero and values exceeding 255 are set to 255, sometimes this is referred to as clamping.

```
if (intResult < 0) {resultValue
        = 0; } else if (intResult
        > 255) {resultValue =
        255; } else

        {resultValue = (byte)intResult; }
```

In the difference algorithm, the pixels are calculated by subtracting the value of the first colour component parameter from the second color component parameter.

```
if (calculationType == ColorCalculationType.SubtractRight) {
intResult = color2 - color1;}
```

Finally the output of the method is an image without any noise but the image will contain blood veins along with the original outer border.

3.2.5 Eroding Blood Veins

The final step is eroding blood veins and retaining only segments of the lungs. This is done with the help of an Erosion filter.

```
Erosion filtere = new Erosion(); Bitmap
img1 = filtere.Apply(ctBitmap);
pictureBox2.Image = img1;
```

This erosion filter is defined from Aforge.net library. This library consists of all filters to filter images in different ways. This library is very effective and the Erosion filter used identifies lines of different sizes and lengths and eliminate the shorter lines based on the number of pixels.

3.3 Adding Color to the Segments.

The final step is to add color so that the segments can be identified more clearly. This is done by calculating the red, green and blue component values of each pixel and identifying the best color to apply to all segments

3.4 Interface of the Application

In the application interface, a clear picture of how the application looks is given. The first picturebox contains the original CT lung image and the second picturebox contains the segmented lung image. The load image button helps us to load many images simultaneously at the same time. The median filter button enables us to apply the median filter to the image. The save button helps us to save the particular image and the color button helps us to apply color to the different segments of the image. The save all button helps us to save all the images at the same instance. The trackbar at the end helps us view through all CT lung images and all segmented lung images at the same time. The label under the trackbar gives us the number of the particular image being displayed.

Figure 22: Lung Segmentation Application Interface

3.5 Summary

In this chapter, the underlying algorithm for the segmentation of CT lung images is described in detail and the code in relation to the most integral parts of the C# code for the proper functioning of the program has been explained. The output screen of and the functioning of each feature has also been explained in detail.

Chapter 4: Testing and Analysis

Testing helps in understanding a product's characteristics and how well the product functions. In testing, all the attempts that failed to produce the output of the product are also discussed. Many attempts were made in trying to identify the lung borders. The first attempt involved extraction of lung images and the second attempt involved Canny Detection of lung images in which Canny detection proved to be superior to the former method. After detection of edges, a filter needed to be used to remove unrecognized noise. For this purpose, first detection was done with a mean filter, a fuzzy filter and a median filter. Then removing this noise was done by arithmetic method and a few of them were tested to see which method served the purpose. Finally both erosion filter and blob filtering was used to remove unnecessary pixels and preserve the segments. This was carried out on 20 CT lung images to make sure detection was good overall.

4.1 The Detection of Borders to Reduce Noise

This was carried out by two methods given below. The testing of these two methods and their result are explained in detail below:

- Extraction of CT Lung Borders
- Canny Detection of CT Lung Borders

In the extraction of these lung image edges, images of various modes were fed into the system to identify which mode would suit the segmentation of lung images. Based on the information provided by lung images in each mode, the best mode for the detection of edges was selected. The results were as follows.

Lung Edge Detection with Lung Mode

In this mode the lung segments could be clearly identify. As the contrast in this mode is of high frequency and the segments are clearly shown in this mode, it was easier to identify the segments and this mode is easy to use.

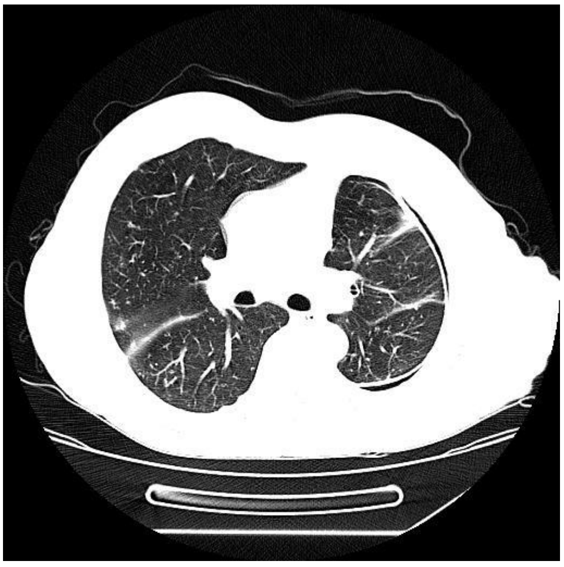


Figure 23: CT Lung Image in Lung Mode

Lung Edge Detection with Whole Mode

In this mode, the lung image is blurred and as the segments can only be seen at a higher contrast, this mode cannot serve the purpose of identifying lung segments. The results of extraction with this method are shown below.

Figure 24: Whole Mode Unable to Identify Segments

Lung Edge Detection with Pleural Mode

The pleural mode, although being clearer than the lung mode wasn't able to serve the purpose of segment detection as segments again could not be identified as the mode shows us only tissues related to the lung and if they are affected in any way. The results of this mode are also displayed below.

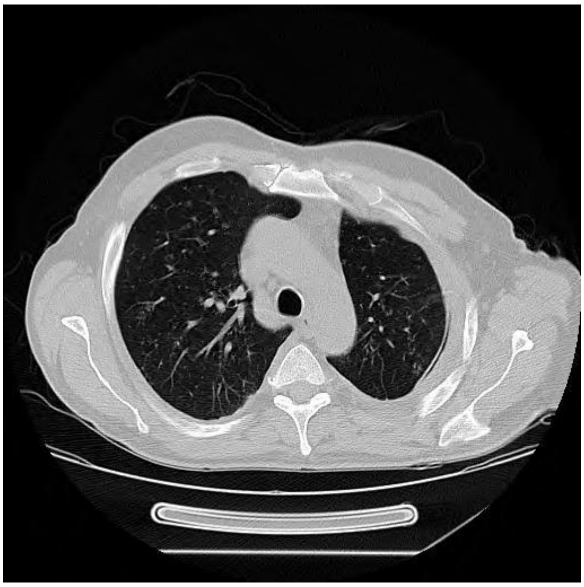


Figure 25: Pleural Mode Showing Only Pleural Tissue

Lung Edge Detection with Bone Mode

In this mode, all bone related entities are highlighted and therefore cannot be used for the segmentation of the lungs. This mode is helpful in identifying problems with bone tissues surrounding the lungs.
Hence looking at all the modes, the lung mode served the purpose of identifying lung segments and this was tested on many patients' lung images.

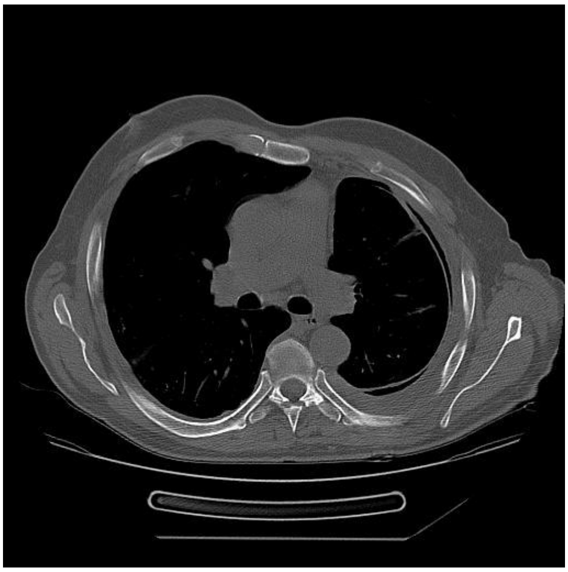


Figure 26: CT Lung Image of Bone Tissue

4.1.1 Extraction of CT Lung Borders

In the extraction method, the images are taken from the lung mode and then passed in to the system. The lung borders can clearly be seen but so can other factors of noise. In this extraction method, threshold values are used to describe different feature related to the lungs. These threshold values are provided as check boxes and they can be added or eliminated by selecting the particular checkbox containing the particular feature. But this method could not provide the expected result.
Extraction of Lung Images was done with different filter sizes. As the size of the filter increases the contrast of the extracted image also increases. But segmentation cannot be seen in the extracted image as it contains too much noise.

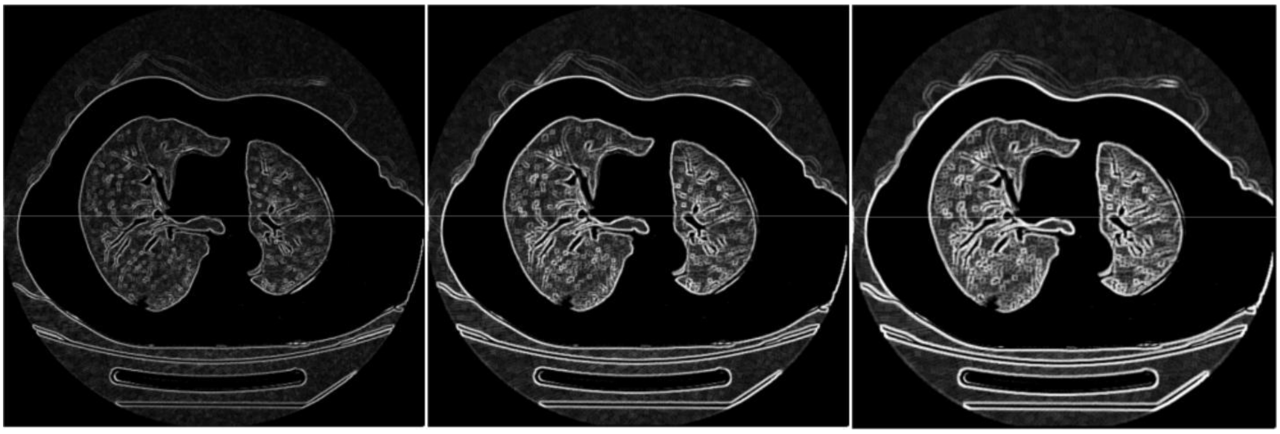


Figure 27: (From Left To Right) Extracted Lung Images with Filter Size 3, 5 and 7

4.1.2 Canny Detection of CT Lung Borders

Using the Canny method proved to be more useful for the segmentation of images as it provided an output lung image with reduced noise. Since it goes through five stages of filtering, the result of reduced noise in each stage can be seen. The images show us how noise reduces at each stage of Canny Detection.

4.1.2.1 Using the Gaussian Filter

The Gaussian filter usually makes use of two values which help in calculating the filter size and also helps in understanding how the image has to be filtered. The Gaussian masks size and the sigma value helps in the calculation of the filter size. However combination of mask and sigma is very important and are taken as paired values. These values are usually paired as follows.

The Gaussian mask can either be 2 with sigma being 0.85. In this case the Gaussian filter that is created is too small and most of the details are eliminated thus leaving the output image even without segments. The output using this filter unfortunately cannot be converted as the mean of sigma cannot be found.

When the Gaussian mask size is 5, sigma is taken as 1. When filtering using this Gaussian mask and sigma, the output image removes most of the noise and the detection of the border is very clear the image below shows us Gaussian detection with this filter.

Figure 28: Gaussian Filtered Image Blur with Gaussian Filter Mask 5 and Sigma 1

Another combination includes Gaussian mask being 9 and sigma being 2. In this case the filter does not remove a lot of noise and the filtered image is not very clear as a lot of disturbance appears in these images. The output using this filter is shown below.

Thus of all Gaussian filters, the filter that was created with Gaussian mask size as 5 and sigma as 1 proved to be the best for detecting segments and so this filter is used to detect Gaussian edges. The Clarity of the output image depends on the high and low threshold value created to identify the image.

Figure 29: Gaussian Filtered Image Blur with Gaussian Filter Mask 9 and Sigma 2

4.1.2.2 Performing Non Maximum Suppression on the Gaussian Image

Performing non maximum suppression is rather a straightforward method and it deals with detecting all real pixels and eliminating falsely determined pixels. This helps in reducing the number of unwanted pixels in the output image. The output of this stage is shown below. In the image, it can clearly be seen that the output has reduced number of pixels when compared to the Gaussian compared image.

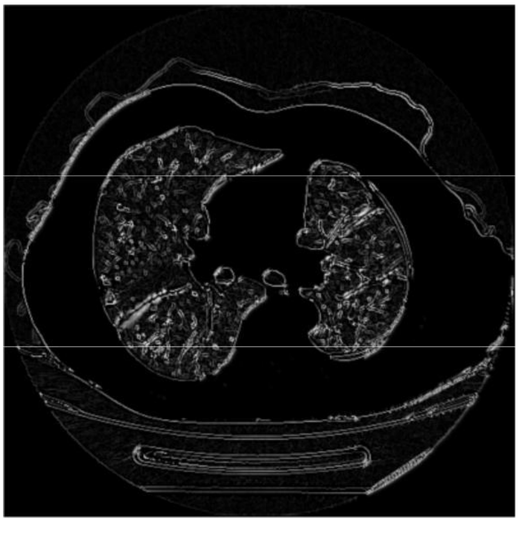


Figure 30: Detection of Lung Borders Using Non Maximum Suppression

4.1.2.3 Detecting Strong Edges

Strong edges that prevail in the non maximum suppressed image is detected and produced as output. These pixels will be present in the final image. This method helps to understand the prevailing structure of the lung image. The output is shown below.

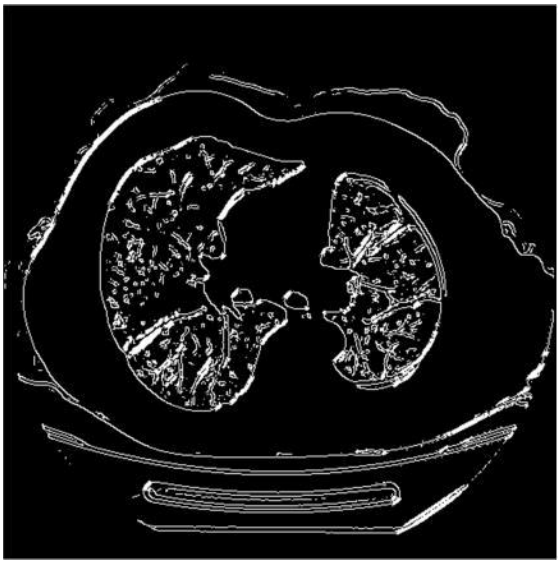


Figure 31: Detecting Strong Edges

4.1.2.4 Detecting Weak Edges

In most image border detection methods, the weak pixels are usually not included in the output and are removed or left out. But leaving out weak pixels of CT lung images can be risky as some detailed information on the lungs might be eliminated. So it is very important that all weak edge be detected and added to the final image. The detection of weak edges of the lungs is shown below.

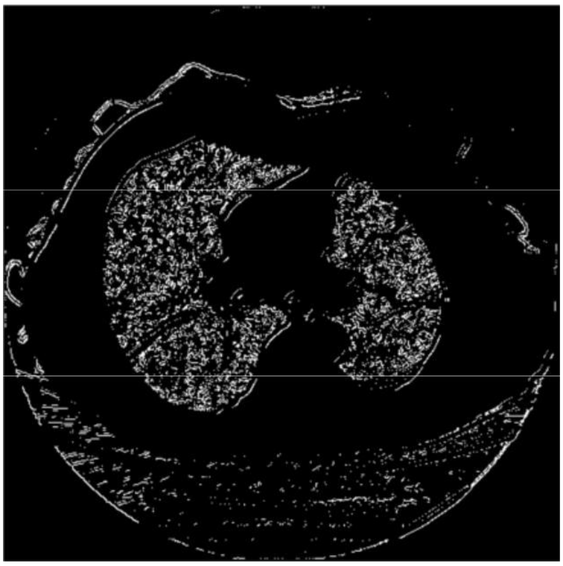


Figure 32: Detecting Weak Edges

4.1.2.5 Combining All Methods and Finding the Edge Map for the Canny Image

Finally combining all the above methods together, an edgemap is detected and all the most important features of the lungs are identified. Using all the above filtering and detection methods, obvious noise or unwanted features, that is, features that do not include segments are identified and displayed below.

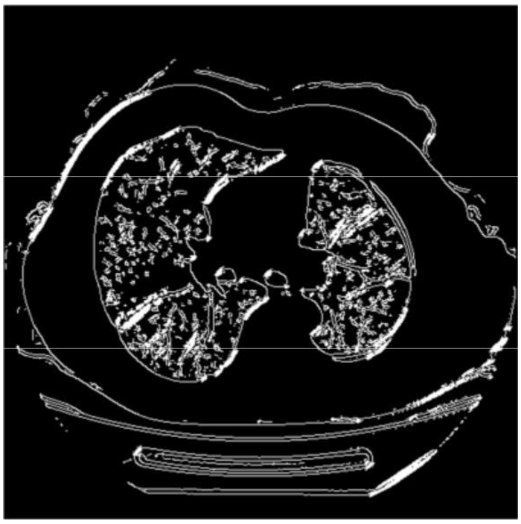


Figure 33: Detection of Lung Border with Reduced Noise

4.2 Reducing Unfiltered Noise

For removing the noise that was unidentified in the canny detection of lung images, two methods were considered.

- Using a mean filter.
- Using a median filter.

Both methods were performed to identify which method would remove all noise without leaving traces of unwanted features in the lung images

4.2.1 Using a Mean Filter

The main idea in this to use one of these two filters is to identify all the unfiltered noise. The mean filter removes noise by blurring the entire image. This does not serve our purpose as the lung image that is obtained from this method is so blurred that even the segments get erased. The output image obtained from this method is shown below.

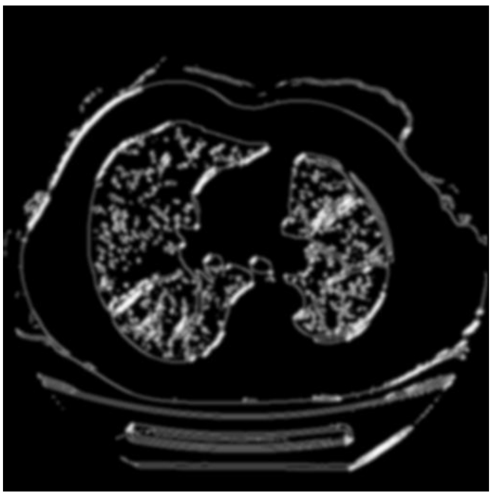


Figure 34: Blurring the Entire Image Using a Mean Filter

4.2.2 Using a Median Filter

Unlike the mean filter, the median filter blurs unwanted features of the lung image leaving the lung border intact. However, when applying the median filter on the canny images leaves us only with the unidentified noise and removes everything else. This serves our purpose as removing this noise from our original image gives us an image with almost no noise.

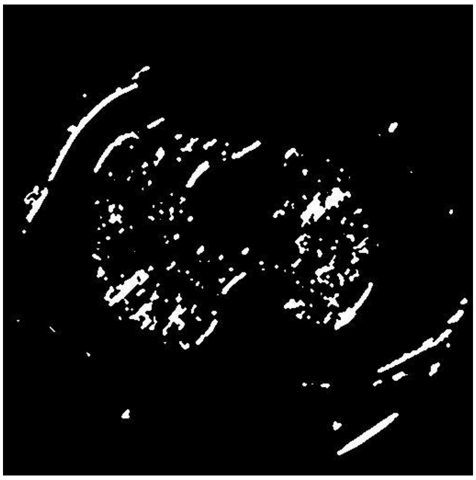


Figure 35: Identifying Noise Using a Median Filter

4.3 Performing Image Arithmetic on the Real Lung Image and the Noisy Image

Now using the noise obtained from the mean filter, we try removing this noise by using image arithmetic methods. Two methods were tried on these images out of which one was chosen.

4.3.1 Difference Between Lung Image and Noisy Image

The difference between the original image and the noise was identified and it gave us a lung image without noise. The image of the lung image that contains only the segments and the blood vessels or veins is shown below.

Figure 36: Reducing Detected Noise

4.3.2 Maximum Intensity of the Lung Image

Another image arithmetic method that was experimented was to find the maximum intensity of the image. Unfortunately, trying to compare the original image with the noisy image using maximum intensity eliminated the lung segments.

This was the first experiment that was performed after which difference between the images were considered and positive results were obtained from the difference method. Hence the difference method is used to eliminate noise.

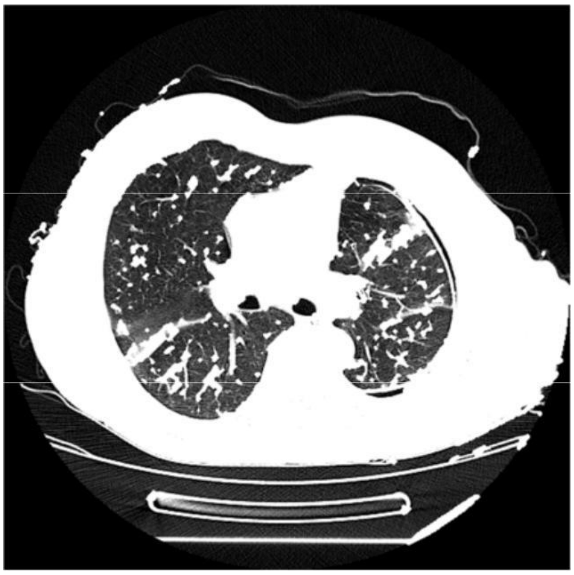


Figure 37: Image with Maximized Intensity

4.4 Identifying Lung Segments

Once the lung image is free from noise, the only features that are left in the image are the blood vessels, veins, any huge abnormalities like wholes or unwanted particles and the segments. Now we have to first eliminate any abnormalities the lung has. Once abnormalities have been eliminated, the system has to identify the difference between veins, blood vessels and lung segments. For these two steps the following two methods are used in the system.

4.4.1 Eliminating Abnormalities

All the abnormalities of the lung were eliminated using the Blobs Filtering method. This method calculates the number of pixels that are together and then removes them if they do not match the required number of pixels, thus removing most of the abnormalities that are discovered in the lung. The image is shown below.

Figure 38: Eliminating Abnormalities

4.4.2 Detecting Lung Segments and Eliminating Veins

The final step is to separate lung segments from blood vessels and veins and then remove blood vessels and veins and keep only segments. This is identified by calculating the length of the segment lines and blood vessels. The length of the line is calculated by joining neighboring pixels till the borders of the lungs. If the pixel along with its neighbors does not reach the border, they are eliminated. The picture of the lung with only segments is shown below.

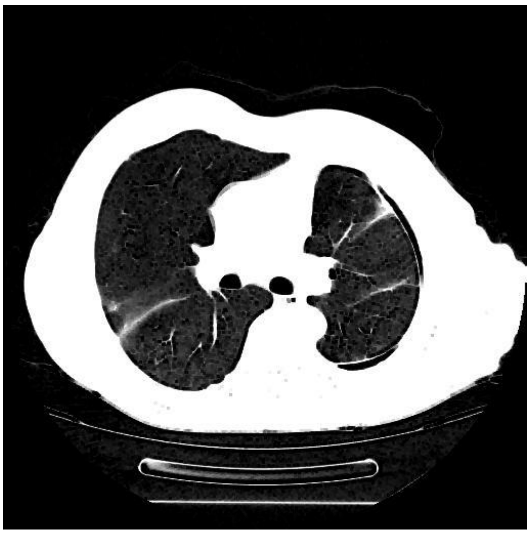


Figure 39: Eliminating Vein and Detecting Lung Segments

4.5 Applying Color to the Segments

In order to make lung segments more prominent, color is applied to the segment lines, this helps to identify the segments more clearly. The image with colored lung segments is given below:

Figure 40: Segments with Color

4.6 Summary

In this chapter, all the methods that were used to build the system to segment the lungs are described briefly along with the output for each step. The failed attempts in executing different parts of the system are also explained in this chapter. The final result provides lung images with colored segments. The only disadvantage of this system is that the segments can only be identified if they are visible by the human eye. In some CT lung images, these segments are not very clear. Therefore only clear segments of the lungs are detected and displayed.

Chapter 5: Management of Finances and Efficiency of Resources

Financial Management [57, 58] plays an important role in the economic and non economic activities in any project which in turn helps in deciding if the project utilized finances in a profitable [58] manner. Nowadays it has encountered many innovative and multi dimensional functions in the field of business with the help of industrialization and thus has become an essential part in corporate, business, economics, and mathematics and also in engineering.

Efficient and effective procurement of finances help in proper utilization of funds in the business for the particular product. Objectives of profit management are broadly divided into two types:

- Profit Maximization
- Wealth Maximation

5.1 Profit Maximization

It is the measuring technique [58] required to identify the efficiency of profit of the product at hand. This technique aims at maximizing the profit of the product. It consists of the following features.

- It helps in the maximization of shares which turn helps in maximizing the business
- It helps in considering all ways of attaining profit for the product at hand
- It identifies the efficiency of the business at hand and shows the current positon of the business.
- Identifies the risks involved with the business and tries to eradicate them.

Profit maximization however has the following drawbacks:

Very Vague	- Profit may not be defined precisely or correctly and some unnecessary opinions about the income earned arise out of concern for the development of business and the product.
Time and Value of Money is Ignored	- It does not take into consideration the amount of time involved and inflow of income and its value. This causes differences in terms of cash inflow and net income for a particular period of time.
Risks are Ignored	- Risks are not taken into consideration for a particular firm which may either be internal or external and this affects the economic status of the company as a whole.

5.2 Wealth Maximization

The term wealth means shareholder wealth [59] or the wealth of the persons those who are involved in the business concern. Wealth maximization is also known as value maximization or net present worth maximization. This objective is a universally accepted concept in the field of business.

The main aim of the business under concern in this concept is to improve the value or wealth of the shareholders.

It usually considers the comparison of the value of the product to its cost associated with the business concern. Total value detected from the total cost is calculated for the business operation. It provides an abstract value of profit for the business.

Both time and risk of the business are taken into consideration.

- It ensures that resources are allocated efficiently.
- It ensures the society stays economically interest with the product or business.

Wealth maximization also has its disadvantages:

- It may not be suitable for present day business activities or the product might be outdated [60] thus leading to low income.
- It is nothing but an indirect method of profit maximization.
- It usually creates ownership-management controversy.
- Management alone enjoy certain benefits and not the share-holders.
- The ultimate aim of the wealth maximization is to maximize the profit.
- It can only be activated with the help of a person in a profitable position of the business concern.

Financial Management also encounters a huge number of problems [61] in every project. Some of these problems include promotion of young developed enterprises accounting problems in income and capital, administrative problems in the expansion of the project area and recouping of a corporation which has experienced financial difficulties.

In regard to this project, financial management has to be applied in order to understand the projects area of profit or loss. SWOT Analysis [62] helps in identifying both aspects that is the positives and the negatives that are related to the project. Performing a SWOT analysis of your product won't take much time, and doing it forces you to think about your business in a whole new way. The whole point of a SWOT analysis is to help you develop a strong business strategy by making sure you've considered all of your business's strengths and weaknesses, as well as the opportunities and threats it faces in the marketplace.

SWOT as the name suggests, is an acronym for Strength, Weaknesses, Opportunities and Threat [62, 63]. Strengths and weaknesses are internal to the company and they can be changed over time but not without some work. On the other hand, opportunities and threats are external and they are out there in the market, happening whether you like it or not and these factors cannot be changed.

Once the strength and weaknesses related to our product ids identified, it is essential to make an analysis of our competitors in order to estimate objectively if our product could compete with other similar products in the market. This is revealed through market segmentation. It is a term used to refer to splitting of prospective buyers into groups, or segments. These buyers have common needs and respond similarly to the marketing action of that particular segment. It allows companies to target different categories of consumers who identify the entire value of the segment's services [64] differently from another set of consumers with different needs. The main objective of this method is to reduce the risk associated with the company by determining which property of the product has the most chance of gaining popularity. It also helps in determining the best way to deliver a product to a market so that the company increases its overall efficiency [62, 64] by focusing its limited resources on efforts that produce the best return on investment.

If the product is successful and wants to be used in further development we have to determine its potential for future development. This is done with the help of QuaD technology [66]. Management of quality plays an important role in both clinical and fiscal control [67]. In addition to meeting the requirements of quality, it is important in controlling losses from risk that might occur in the product, supporting and improving client satisfaction, and controlling unneeded resource consumption. It is also imperative to have a system in place that can objectively evaluate peer performance [67, 68], and provide staff with the necessary information to make informed decisions. It also provides full automation and control over quality management processes.

Thus we apply a mathematical modelling [68] to our thesis work to identify all the economic aspects related to our project and would also simplify the work laid out for companies and also other clients. Convenience of using the product will also be improved in this method in order to reduce cost and investment.

5.3 Consumers of the Research Project

It is important to understand the consumers related to the product as it helps identifying their needs and working in order to achieve our target income. The potential consumers of the product become the target audience and their requirements are what the product is aiming to achieve. Identifying consumers is done by market segmentation where the product is split among small segments of consumers with similar interests.

Segmentation is performed on the basis of Segmentation criteria. The software dealing with processing for segmenting lung images mostly helps doctors and patients with surgery requirements. Proceeding from the chosen criteria of segmentation, the map of segmentation was constructed. Segments of the lungs are required to be identified in order to gauge which lobe is the holder of the disease and the second reason may be due to the requirement of surgery. It also helps in the identification of different lung diseases.

The following diagram represents patients with lung diseases based on the severity of the infection and the number of undiagnosed patients. Identifying segments makes the diagnosis of lung diseases easier and thus makes the product more desirable.

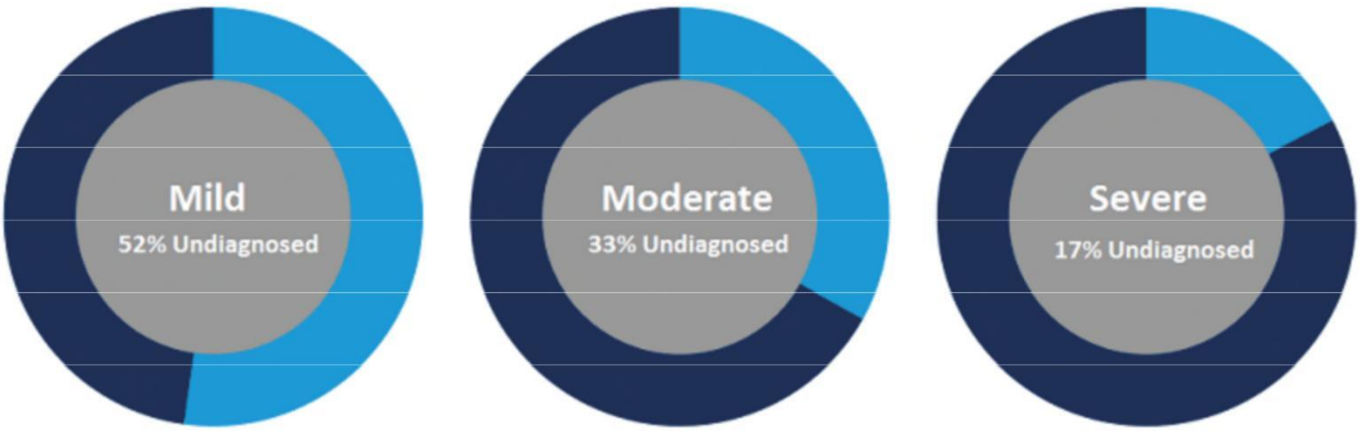


Figure 41: Patients with Lung Disorders According to the Level of Severity

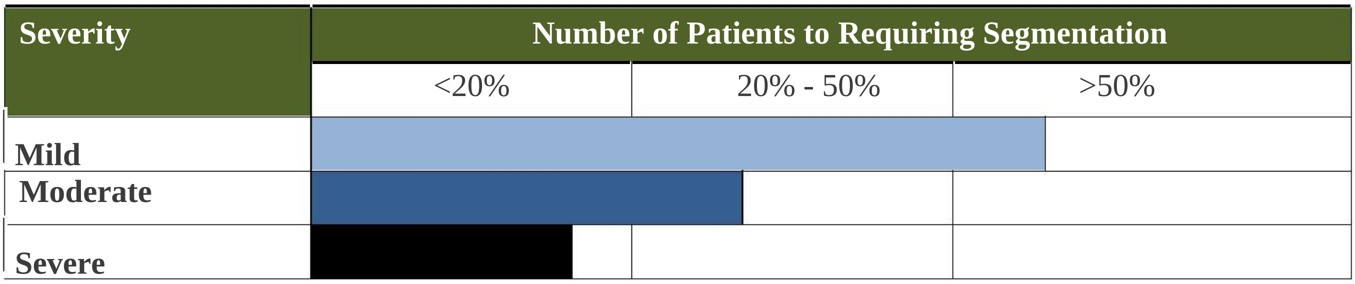
Taking the results of people diagnosed with fibrosis in 6 countries including the US, Japan, France, Germany, Italy, Spain and the UK. Still looking at the primary research survey, it was estimated that approximately 52% of the population with lung disorders remain undiagnosed. Therefore, it is likely that a large proportion of patients are not diagnosed with lung disorders until they have already reached moderate disease severity. This can be explained by the difficulty in recognizing the early symptoms of lung disorders, such as cough and dyspnea, which may be misinterpreted by patients as consequences of old age or smoking. Furthermore, mild lung disorder patients who do present for treatment are often initially misdiagnosed as having diseases which share common symptoms which require segmentation, such as bronchitis, asthma, or emphysema.

Table 5.1: Percentage of Severity of Lung Diseases in Various Countries

Severity	US	Japan	France	Germany	Italy	Spain	UK
Mild	45.6%	57.3%	51.3%	51.8%	57.8%	52.2%	49.8%
Moderate	29.3%	35.6%	33.1%	33.6%	35.7%	33.8%	30.6%
Severe	16.6%	17.0%	15.3%	17.2%	19.1%	20.2%	16.4%

The table above shows us the percentage of patient suffering from lung diseases and also the requirement of segmentation to identify the disease in undiagnosed patients in six different countries and these patients are categories according to the severity of the lung disorder. It can be seen that patients with milder symptoms have to be considered more as leave mild disorders unattended might lead to more complex problems. The percentage of patients who remain undiagnosed with mild disorders is higher and needs to be tended to. Segmentation will help in understanding their problems with the lungs more easily. Patients with moderate and severe disorders are also very important and segmentation can help in detecting which part of the lung needs to be tended to.

Table 5.2: Map of Services Market Segmentation in Development of the Software of Lung Segmentation Based on the Severity of Lung Diseases and if Segmentation is Required



On the segmentation map presented above, the color denotes the number of patients requiring segmentation and detection of lung segments in order to analyze diseases at different severity levels.

Patients with mild symptoms usually ignore their lung problems and this leads to more complex lung disorders. But being able to diagnose the disease along with the segment which is affected gives the doctor and the patient a clearer view of what could be at stake. For patients with moderate and higher level of severity, it becomes a necessity to diagnose and find out which segment is affected with the disease. The number of patients acting as target audience is also an important factor for market segmentation. The colors on the market segmentation map also explain the importance of identifying segments and the success this software would have in the future.

5.4 Analysis of Technical Solutions from Resource Energy and Resource Saving

In order to analyze the competitiveness of the project, accuracy and productiveness of each operation should be measured. The performance and the productiveness of the product could be calculated with the help of certain benchmarks. These benchmarks help in identifying technical and economic aspects and also the software development that was involved with the product. On the bases of these benchmarks, results of the product under performance were calculated and are presented in the scorecard table given below.

Table 5.3: Evaluation Card for Comparing Competitive Technical Solutions

Criteria for Evaluation		Criterion Weight	Scores			Competitiveness		
			S_f	S_{k1}	S_{k2}	C_f	C_{k1}	C_{k2}
1		2	3	4	5	6	7	8
Technical Criteria for Assessing Resource Efficiency								
1.	Improving User Productivity	0.1	4	5	4	0.4	0.5	0.4
2.	Easy to Use (Meets Consumer Requirements)	0.03	4	4	5	0.12	0.12	0.15
3.	Interface Quality	0.1	3	5	4	0.3	0.5	0.4
4.	Reliability	0.2	5	4	4	0.8	0.8	1
5.	Easy Operation	0.07	5	4	5	0.35	0.28	0.35
Economic Criteria of an Efficiency Assessment								
1.	Product Competitiveness	0.1	4	5	4	0.4	0.5	0.4
2.	The Level of Penetration of the Market	0.05	4	4	5	0.2	0.2	0.25
3.	Price	0.1	3	5	4	0.3	0.5	0.4
4.	Estimated Lifetime	0.1	5	3	4	0.5	0.3	0.4
5.	After-Sales Service	0.02	4	5	5	0.08	0.1	0.08
6.	Financing of Scientific Development	0.1	5	4	5	0.5	0.4	0.5
7.	Time to Market	0.03	5	3	5	0.15	0.09	0.15
Total		**1**				**4.1**	**4.29**	**4.48**

The software that is developed for the segmentation of the lungs is a real -time structural health monitoring system and was analyzed with the help of Tieto-Oskari Oy which helps in measuring, informing, collecting and saving the data provided by this model. The system can also be connected to the existing property automation system or remote monitoring service. Real-time monitoring helps to prevent big material and personal losses, and to schedule the maintenance and repair works ideally without disturbing the productive use of the software.

By analyzing the data provided by the evaluation table, it can be proved that the product being developed for fibrosis has many competitive advantages. It has a set of convenient, simple and understandable functions that could be even performed by untrained personnel which in turn is very important for the users of such applications. The framework is very understandable and the lung segments that are detected prove to be very clear and can also help in surgery. The software also provides color to the segmented lung area.

5.5 SWOT Analysis for Lung Segmentation

SWOT Analysis is carried out to understand the strengths, weaknesses, opportunities and threats of the research project. Albert Humphrey [62] is the scientist who developed this framework and he is also the one who tested this approach in 1960s and 1970s at the Stanford Research Institute (SRI). Thus SWOT analysis has been adopted by organizations of all types as an aid to making decisions. The four elements [63] that the name states can be explained as follows:

Strengths - The internal attributes and resources that support a successful outcome.

Weaknesses - The internal attributes resources that work against a successful outcome.

Opportunities - All external factors the project can capitalize on or use to its advantage.

Threats - External factors that could jeopardize the project.

Once all the SWOT factors have been identified, decision makers should be able to better ascertain if the project or goal is worth pursuing and what is required to make it successful. Often expressed in a two-by-two matrix [63, 64], the analysis aims to help an organization match its resources to the competitive environment in which it operates.

In order to provide a better understanding of the current state of research project, and also any potential strategies to achieve the stated objective, a SWOT Analysis can be undertaken. Consequently, the main objective is to apply this method of planning early in the life cycle of project with the intent that concepts described here can be used to strengthen and guide this emerging discipline. In practice, once an objective has been established, a multidisciplinary team [64] representing a broad range of perspectives should carry out SWOT analysis; which is typically presented in the form of a matrix with the four factors.

Thus the main objective of this paper has been to provide an early attempt at formally defining image segmentation with that of CT lung images. Further more it helps in outlining a key objective of this new field, and identifying a number of Strengths, Weakness, Opportunities and Threats (SWOT) [64] that project faces, with the intent that items described here can be used to strengthen and guide this promising new field. Thus a way is proposed to achieve this by developing a document where the practitioners can turn to for understanding and direction.

5.5.1 SWOT Matrix

The following sections represent a number of SWOT identified as we considered the past, present and future of research project. They are by no means the only possible items, and in several cases [65] depending on one’s perspective individual items could exist in more than one category.

Table 5.4: SWOT Matrix Table

	Strengths	Weaknesses
	S1. Simple and intuitive interface.	W1. No ability to create reminders.
	S2. Excellent data filtering	W2. Lack of using language choice.
	S3. Interest in improving application, investor's availability.	W3. A bit expensive.
	S4. Professional developers.	
Opportunities		
O1. Attracting demand for the product.	1.1. Detecting the border of an image is a kin to the way humans conceptually organize the landscape to comprehend it.	1.1. Under the guise of 'flexibility' current commercial object-based software provides overly complicated options.
O2. Rising cost of competitive development.	1.2. Using image-objects as basic units reduces computational classifier load by orders of magnitude, and at the same time enables the user to take advantage of more complex techniques.	1.2. There are numerous challenges involved in processing very large datasets. Detecting an inner fibrosis layer of an image of several tens of mega-pixels is a formidable task.
O3. Extension of the functional.	1.3. Image objects exhibit useful features for fibrosis detection(e.g. shape, texture, context relations with other objects) that single pixels lack.	1.3. Fibrosis is a well defined problem, in the sense it has a unique solution.
	1.4. Image-objects can be more readily integrated in vector GIS than pixel-wise classified raster maps.	
Threats		
T1. Lack of demand.	1.1. Sample and easy-to-use functionality helps to overcome the threat of lack of demand and declining	1.1. Lack of data filtering function in the application can lead to a decrease in

	Strengths	Weaknesses
	popularity.	demand.
T2. Decrease of such applications popularity.	1.2. Professional developers, the availability of investment and interest .In the promotion of applications allow us to compete in the market.	1.2. The lack of automatics reminders can be a problem in case of new competitive developments.
T3. Appearance of new competitive developments.	1.3. Methods have been successfully applied to many different problems, not only computer languages, and they can be easily adapted to this research.	

5.6 QuaD Technology

For an assessment of prospects of the created decision in the market the QuaD technology [66] (Quality Advisor) is used. This technology allows us to define prospects of its development by means of allocation and an assessment of indicators of quality and commercial potential of the projects.

To assess the quality of the development are selected indicators [66, 67] that are most important and decisive for the software of classification. If such factors as reliability and functionality are important to any user application, the quality of the interface and ease-to-use are particular importance for the software of classification, mainly due to the features of the user's interaction with information systems.

Table 5.5 presents evaluation results of the quality and commercial potential [68] of the project and competitive solutions within the assigned parameters.

Table 5.5: Scorecard of Comparing Competitive Technical Solutions

Criteria for Evaluation		Criteria Weight	Score	Maximum Scores	Relative Value (3/4)	Average Value (5x2)
1		2	3	4	5	6
Indicators for assessing the quality of development						
1.	Reliability	0.1	80	100	0.8	0.08
2.	Easy to use	0.05	90	100	0.9	0.045
3.	Interface quality	0.05	80	100	0.8	0.04
4.	Functional capabilities	0.15	80	100	0.8	0.12
5.	Additional features	0.05	75	100	0.75	0.0375
Indicators for assessing the commercial potential of development						
1.	Competitiveness	0.1	100	100	1	0.1

Criteria for Evaluation		Criteria Weight	Score	Maximum Scores	Relative Value (3/4)	Average Value (5x2)
2.	Market entry level	0.15	80	100	0.8	0.12
3.	Prospects of the market	0.2	90	100	0.9	0.18
4.	Price	0.15	80	100	0.8	0.12
Total		**1**				**0.8425/84.25%**

From the results scorecard shows that the weighted average value of the quality and availability of scientific development is 82.8%, which corresponds to prospective development by QuaD technology.

5.7 FAST Analysis

The object of FAST Analysis [69] is software of classification. The main function of the developed application is to give users of image processing to help segment the lungs for clinical purposes and also to help in identifying diseases. In addition to the main features, the application has a user interface, simplifying the work process, as well as a number of additional functions.

The main internal functions provided by the application, are: adding, editing, filtering data, and work with automatic reminders.

As an additional function, the application also provides opportunities to work in multiple languages and initialization calls.

Table 5.6 shows all the processes used in the application description of the functions and their ranks [70]. In the future, this classification can be used for optimization of a development project, as to improve the efficiency of the process by reducing the value of the property and the preservation of the required quality. It is necessary, first of all, to pay attention to the additional functions. If in case of savings, we will not use this function as it will not have a great effect on the functionality of the entire project.

Table 5.6: Classification of the Functions Performed by the Project of Study

Process Name	Function	Rank of Function		
		Main	Basic	Additional
Technologies for Lung Segmentation.	Giving users the ability to clearly recognise lung segments.	X		
Adding and Editing Data.	Allowing users to create, edit data of their customers.		X	
Filtering Data.	Allowing the user to filter data.		X	
Managing the Application in Different Languages.	Allowing the user to select convenient for using language.			X
Automatic Reminders.	Giving the users the ability to create appointments, notes, with the reminder possibility.			X
Call Initialization.	Allowing the user to call any existing			X

Process Name	Function	Rank of Function		
		Main	Basic	Additional
	numbers via the internet.			

For an assessment of the importance of functions, the method of arrangement of priorities is used. Settlement and expert determination of the importance of each function is the basis for this method. The first step in assessing the significance of the functions is to build the adjacency matrix (table 5.7)

Table 5.7: The Adjacency Matrix

	Function1	Function1	Function1	Function1	Function1	Function1
Function1	=	>	>	>	>	>
Function2	<	=	=	>	>	>
Function3	<	=	=	>	>	>
Function4	<	<	<	=	>	>
Function5	<	<	<	>	=	
Function6	<	<	<	<	<	=

The second stage of assessing the significance of the functions is to convert the adjacency matrix into a matrix of quantitative relations functions (table 5.8)

Table 5.8: Matrix Quantitative Relations Functions

	Function1	Function1	Function1	Function1	Function1	Function1	Total	
Function1	1	1.5	1.5	1.5	1.5	1.5	8.5	0.22
Function2	0.5	1	1	1.5	1.5	1.5	7	0.19
Function3	0.5	1	1	1.5	1.5	1.5	7	0.19
Function4	0.5	0.5	0.5	1	1.5	1.5	5.5	0.15
Function5	0.5	0.5	0.5	1.5	1	1	6.5	0.15
Function6	0.5	0.5	0.5	0.5	0.5	1	3.5	0.1
Amount							38	1

Note:	0.5 at 《<》 ;1.5 at 《>》 ; 1 at 《=》

From the result of FAST analysis, the least significant in the application is a function of 6 initialization call. This result is explained by the fact that this feature is optional, extends the functionality of the application. Compared with the basic functions of our application, the significance was lower. However, the introduction of call initialization function justified the involvement of a significant number of users. Therefore, in the presence of human, time and material resources to add all initialization function can lead to increased profits by attracting users. In case of lack of necessary resources introduction of function will be unjustified and expensive for the customer.

Final results of financial management, resource efficiency and resource conservation research project are presented at the table 5.9.

Table 5.9: Results of the Analysis and Valuation of the Project

Type of Analysis		Obtained Result
1.	Identification of potential consumers of research results.	Potential consumers of lung segmentation are patients with lung disabilities who require identifying the lung disorder and also for surgery.
2.	Analysis of competitive technical solutions.	Coefficient of lung segmentation is 4.1, 4.29 and 4.48
3.	SWOT-Analysis	They were defined by the strategy of Coefficient development: • The introduction of data filtering and automatic reminders. • Increase in the amount of available languages.
4.	Analysis of the prospects of the development of technology QuaD.	The weighted average value of the quality and availability of scientific development is 84.25%, which corresponds to prospective development by QuaD technology.
5.	FAST-Analysis	The least significant function in the application is call initialization and different languages because it is optional and extends the functionality of the application.

5.8 Summary

In this chapter, the financial aspects of lung segmentation are measured using different techniques in order to analyze if the product would bring a profitable outcome. The financial status of the product in the market is taken into consideration and further more analyzed on a detailed business perspective. Using all the techniques like SWOT Analysis, market segmentation, QUAD technology and FAST Analysis, a detailed explanation based on the financial aspects were successfully proved.

From the above theories, financial management for the detection of lung segments were analyzed and thus proved to produce positive results. This proves that the software when put in a competitive market would produce good results.

Chapter 6: Social Responsibility

Social Responsibility in any field means to provide a high standard of quality keeping [71] up to a certain specified standard with all safety ensured by qualified professionals to the existing population with no difference in class. When one talks about social responsibility it states that it is the responsibility that one takes to the society. Social responsibility when related to field of medical science and the computer technologies involved with it requires a large number of precautions and safety measures to ensure the welfare and lives of all people involved, be it the computer technician to the patient being diagnosed.

A very basic conflict that physician's face is abiding by the principles of fidelity [71] to that of the patient while also trying to adhere to the regulations of an economically driven health care system and this has created discontent for a large number of physicians as well as patients. Although there has been great economic prosperity in terms of safety, the health care costs are gradually increasing due to equipment non stability and basically rights of the patients are threatened. In order to ensure the safety regarding all fields of science only qualified technicians [74] should be employed and also if any rules or norms in the respective work ethic has not been satisfied it can be taken into argument and questioned before putting it to a test. When it comes to social responsibility every person is responsible. It need not specifically be the person handling any equipment physically. It also refers to the person who is in the surrounding common area from other fields of interest.

In this chapter, we therefore focus on the basic rules and norms involved not only in the working process but also all hazards involved with the respective situation. It also focuses on whether or not these conditions are suitable for health. Further more this paper focuses on all safety conditions on both ends from the developer to the user to avoid any unfavorable conditions that could be harmful to even life. This chapter also emphasizes on safety measures regarding the environment, fire breakout and even any extreme emergency. The goal of this chapter is also to provide some fundamental definitions that link patient safety with health care quality.

6.1 Occupational Hazards

The harmful and dangerous factors [73] that can have an impact on a person in due course of work are some of the occupational hazards that every person must take into consideration. Some of the factors are as follows:

- Harmful Factors
- Dangerous Factors

Harmful Factors

Some of the harmful factors involve the following:

- Increased or lowered humidity and air temperature.
- Increase of noise level.
- Raised level of electromagnetic and ionizing radiation.
- Insufficient illumination of workplaces.
- Physical overloads include eyestrain and overloads of muscular skeletal system.
- Psychological Overloads include mental strain, emotional stress and monotony of work.
- In direct contact with live parts during the repair of any personal computer.

Dangerous Factors

- In contact with the dead parts, appearing under voltage (in the case of insulation of live personal computer parts).
- In contact with floor and walls, appearing under voltage.
- When possible short circuit in the high- voltage blocks such as the power units and the scan display unit.
- The above mentioned factors should always be taken into consideration while performing and activity or work in a given workplace of an organization.

6.1.1 Requirements That Are in Association with the Climate of the Working Area

Climate of the working area is also referred to as microclimate [74] and represents the climate of a very small area. This is very different from the climatic condition of the surrounding area or a large area. It is important that this microclimate is always set at appropriate temperature that is suitable for both, the employee so that he does not experience suffocation and also for the machine in order to avoid failure of any equipment.

Three main factors are the key entities that set the microclimate of a particular area. They are as follows:

- Velocity
- Relative Humidity
- Air Temperature Indoors

By combining velocity, humidity and air [71, 72] temperature, it should be ensured that the working environment is made comfortable and safe for all employees working in the particular firm. In the respective workplace, particular optimal parameters relative to the microclimate should be present in the workplace and this should be in accordance with all sanitary norms and rules that were mentioned earlier. The air temperature along with humidity should not exceed 22-24 degree Celsius and in summer it should not exceed 20 - 25 degree Celsius. In addition to this the relative humidity should not be more than 40 - 60 percentage with a velocity of 0.1 m/s. Thus in order to maintain a particular microclimate within this particular conditions, the usage of a heating or air condoning system is used respective to the climate in that particular area.

All parameters that are required for the microclimate environment are met while developing and executing the project and hence all sanitary norms and rules will be met. The requirements are the same even for medical field.

6.1.2 Office Requirements for Noise Levels

According to the regulation act of 2005, the control of noise at work requires [74] all employees to prevent and further more reduce risks to health and thus creating a safe environment from the exposure of noise at the respective workplace. Employees also have certain duties under the regulation act which are as follows:

- Action to be taken to reduce risks produced from noise exposure.
- Ensure that the legal limits of noise in the workplace are not exceeded.
- Take care of all possible risk that causes noise at work.
- Where there is a risk at health due to this, health surveillance is to be carried out.

- Provide employee with proper information, instruction and training.

The regulations to keep up to office requirements [74] will not comply to members of the public that are constantly exposed to noise which is away from the workplace or noise legal noise levels that will not cause any harm or risk of hearing. Also the noise regulating act requires the organization to take action if:

- The level of noise exposed by a specific employee is not in an average legal limit over working day
- The maximum noise that is the peak sound pressure to which an employee is exposed in a working day.

The average legal noise limits are as follows:

Lower Exposure Action Values	Upper Exposure Action Values
Daily or Weekly Exposure of 80 dB	Daily or Weekly Exposure of 85 dB
Peak Sound Pressure of 135 dB	Peak Sound Pressure of 137 dB

Noise in the production is one of the most common hazards [74, 75] that are caused and this causes a lot of inconvenience in the working environment. Noise can also affect the person in the following ways:

- It increases the fatigue of a person to a varied extent.
- Irreversible changes are also caused in the hearing of the concerning person.
- It can complicates the legibility of speech of the concerning person
- It causes a decrease in the working capacity as in the person finds it difficult to cope with the noise.
- The person can sometimes get psychologically affected and is seen by the person’s lack in attention.
- The number of errors performed by the person is also increased work vice.

According to the Sanitary Norms and Rules the noise level should not go beyond the specified value and should not be more than a 50 dBA. Thus if the noise is to be reduced all equipment creating such disturbances should be installed on special platform or foundation with shock absorb pads. Further more sound absorbing materials that have a maximum absorption with a coefficient that lie in frequency range between 63 - 8000 Hertz can reduce the noise level that is caused by various factors in a workplace with personal computer.

Thus according to all the norms and regulation mentioned above the research was carried successfully without causing much interference to the surrounding area by remaining within the legal noise limits.

6.1.3 Lightening Requirements

- While working, it is necessary for us to experience nominal working conditions and thus illumination [74] of the working area plays a very important factor for an individual to experience comfort at the workplace.
- Lighting in one of the most important factors that an employer must pay attention to, as very poor lighting may result in employees experiencing tiredness, increase in metal stress and also fatigue which is caused due to dimness of the surroundings and in contrast to this the light emitting from the computer appears very bright. This can even result in loss of eyesight in an individual.
- Lighting can be divided into three categories depending on the source from which the light emits. Based on the source, light can be classified into Natural, Artificial and Combined.

- Natural light is obtained from the sun and also relates to any light [76] that is diffused naturally. It usually varies depending on the time of the day, month of the year, location and region in which it is emitted. Artificial lighting is obtained from electrical sources. When there is insufficient supply of natural light, artificial light is used. A use of both natural and artificial light, results in combined light source. The Coefficient of Natural illumination (CNI) should be 3.5% in the case of upper or combined lighting and should be 1.2% in the case of side lighting.
- Light illumination on a computer screen should be around 300 - 500 lx in a working environment and this light should not create flares on the screen surface. In this case, light emitted from the screen should be more than 300 lx. In the case of artificial lighting, luminescent lamps should be used.
- General lighting should radiate in the form of solid or broken lines from the lamps and these lamps should be placed parallel to the line of sight of the user. The ripple ratio of illumination should be not more than 10%. Brightness of these should radiate at an angle between 50 and 90 degrees to the vertical. The protective angle of these lamps should be at least 40 degrees.
- For illuminations to be normalized it is necessary to purge the glass of window frames and lamps at least two times a year and also change fused lamps periodically.
- This calculation is used to a few points: to choose the lighting system, to determinate the required number of lamps, to define the type of lamps and their location. On the basis, we calculate the parameters of the artificial lighting.

6.1.4 Safety Measures in a Developmental Workplace

Safety Measures are the steps taken into consideration before performing any dangerous task. Some of the most dangerous factors exist in the field of software engineering. However the electrical factor proves to be a major threat to human life in any case. There are two factors that indicate safety which are the leading and the trailing factor [75]. The "leading" safety measures are indicators of where the organization is headed and they are measures of future performance. It can also be contrasted with the "trailing" indicators, which are indicators of past performance and they don't accurately indicate present and future safety conditions.

- Rules and regulation from the Electrical Installation Code (EIC) has to be endured while installation of any equipment takes place. According to rules and regulations of EIC,
- An alternating current voltage of about 220 volts is given to all the equipment’s power supply and hence should be taken into consideration.
- Depending on the room conditions, any danger involving electric shock can be increased or decreased.
- By the classification of the Electrical Installation Code (EIC), the rooms involved with the above procedures should be divided into three which are Rooms without any sort of increased danger, Rooms with increased danger and especially dangerous rooms.

The above given Voltage of 220 volts can be a threat to life, hence the following steps need to be ensured while working indoors for electrical safety:

- Electric current emergence can be prevented by protective grounding when electric devices are carried out. Hence according to the norms and rules of the installation code the resistance of the grounding device should be a maximum of 4 ohms at any given instance of time.
- Every current carrying part will have to be isolated so as to prevent human interference and it should be forbidden to use cables and wires with damaged or lost isolation of cables and wires, not insulated

current carrying parts, damaged sockets, temporary power supply [75] and this can be enhanced by the usage of knife switches, distributive boxes and other electro adjusting devices.

- All electrical networks must be protected to avoid any short circuiting. Hence, one must have high speed protection devices and thus ensuring there to be potentiality of response time for disconnection and selection by the use of circuit breakers and fuses.

Only qualified electricians should carry out a repair work, installation, dismantling and then assembly to avoid any harm to people around. Every single person in the organization needs to know the measures that need to be taken in the case of any medical help in the case of any potential damage caused by electric current. This need to be ensured in every room by keeping it well equipped with the right first aid kit for immediate medical aid to the person or even the surrounding. Further more, electrical safety is ensured for any computer user by the following requirements:

- In the case of a shutdown of any computer equipment, a common circuit breaker and an isolated separate shielded breaker must be used.
- Connections between the involved personal computers and its external devices should only be made with a proper disconnected power supply.
- To connect all the nodes of one personal computer a single phase power supply should be used and connect to other computer equipment.
- Any computer case and its external devices should be grounded radially by a single common point.
- Power outlets should be grounded by a third contour.

Potential damage caused by electric current causes a number of calamities most often because of device handling negligence. Any person involved in such situations need to know the following ways of when they should immediately disconnect a device:

- Sudden outbreak of smoke or fire in the building.
- Visible damage detected in the power cables or the switching devices.
- Any emergence of threat to life and health of the concerning person.
- Sudden emergence of a spark with the involved devices.
- Emergence of a burning isolation plastic smell which indicates that there is some damage in the cabling.

Disconnecting electric devices from their power supply is absolutely necessary if there is a breakout of fire or ignition. It is also very important to disconnect network supply by switching off the package switch or using a power breaker that can be found in the power board, in the case of absolute emergency. It is always appropriate that a qualified electrician disconnects the power supply in the affected room or building and the fire should be extinguished using a foamy fire extinguisher.

Let us consider research work in a room that does not exhibit any high risk since it is not characterized by the presence of any conditions such as high humidity (relative humidity is said to exceed 75% for a prolonged amount of time), high temperature (35 degree Celsius), conductive flooring and dust, simultaneous touches for connections to metal ground parts and also metal casing of all electrical equipment.

6.1.5 Patient's Safety Requirements

The research involves that of taking computer tomographic images of patients suffering from various lung problems and hence the safety of the patient should also be taken into consideration.
Sometimes the patient can be affected by some external means while studying the problem and can pose a serious threat to the life of the patient under supervision. The types of errors and harm can be thus classified regarding domain, or where they occurred across the spectrum of health care providers [74] and settings. The root causes of harm are identified in the following terms:

Latent Failure	-	Removed from the practitioner and involving decisions that affect the organizational policies, procedures, allocation of resources.
Active Failure	-	Direct contact with the patient.
Organizational System Failure	-	Indirect failures involving management, organizational culture, protocols/processes, transfer of knowledge, and external factors.
Technical Failure	-	Indirect failure of facilities or external resources.

Thus taking into account the above possibilities of an error or danger to the patient's life, intense care should be taken while scrutinizing the problem. The people involved in taken the computer tomographic images should make sure that all equipment is well maintained and should not be a threat to the life of the patient. Further more while diagnosing the patient's computer tomographic images using the program developed in the research, a second opinion should be taken from a specialist to confirm the identified problem before further analysis and treatment of the patient. By taking every possible detail into consideration, the patient's health is ensured and cannot cause any serious threat to the patient under study.

6.2 Safety Related to the Environment

Damage can be caused to the environment by violating any of the rules and norms [74, 75]. Therefore, an effort should be made not to cause too much of an impact on the environment and also thus the level of consequences that could be caused should be reduced. According to act 11 it states that "The rights and duties of citizens in the field of environmental protection" and also the Federal law of the Russian Federation of January 10, 2002 No. 7-F3 states that "About environmental protection". It is the right of every citizen to have a suitable environment to live in and thus any impact on any negative activity caused by any economic or any other activity could be created. This can be either due to emergency situation of natural and techno generic which is based on reliable information about a status of environment and also the person should compensate the harm done to the environment.

Let us consider a computer research that uses a rather small quantity of electric power, almost no noise, electro magnetic fields and ionizing radiations are in limits of admissible norms and therefore the working place in an office where the project was executed does not render any negative impact on the environment or nature. The only main waste that was involved is that of solid waste such as paper, boxes, disk and diskettes. This garbage is taken out the particular territory and stacked under that of home waste and was processed further so that no harm is felt on the environment.

6.3 Safety in the Incident of Fire

Measures to prevent fires and explosion [73, 75] by a single complex of organizational, technical, operation and also maintenance is known as fire safety. Thus prevention is based on the exclusion of conditions that are necessary for combustion and further more the implementation of safety principles. Any fire in the workplace can cause damage of the affected material and can be a threat to health and life if anyone is affected by it in the particular affected surrounding. Fire can be especially dangerous because it can damage all computers, hardware, tools and documents. Most important it can also create a fire in the surrounding area if it is not stopped in time. The following are some of the factors that could start a fire in a workplace.

- Fire breakout on the furniture and floor in the workplace due to fire safety infringement.
- Sudden electrical wiring short circuiting.
- Ignition of artificial lighting devices.
- Ignition of devices in the computing equipment

All work area corridors should have an OP5 power representation with a fire extinguisher and a de-energizer for the entire office space. The evacuation plan must be displayed on all doors in the case of a fire breakout. In order to localize small fires without the need of a firefighter, every building should consist of firefighter trunks, means for internal water to extinguish the fire, various other fire extinguishers, dry sand, asbestos, blanket and the like. Further more in order to extinguish the fire in the early stages, extinguishers should be used to a great extent. The fire extinguishers are usually divided into the following groups:

Carbon Dioxide Type Fire Extinguishers	-	The merit of this extinguisher is high extinguishing efficiency, safety of electronics, dielectric properties of carbon dioxide, which allows the use of these fire extinguishers, even when you can not disconnect the electrical installation immediately.
Foam Type Fire Extinguishers	-	This can be used to extinguish burning liquids, different materials, structural elements and equipment, except electrical equipment under voltage.
Gas Type Fire Extinguishers	-	This can be used for extinguishing liquid and solids, as well as electrical installations under voltage.

Thus the research project was developed in a room which exhibited 220 volts of electricity is used to supply all computer equipment and also lighting. If there is any misuse of equipment or even a short circuit of an electric chain there can be an ignition and thus could be a threat to life, destruction of equipment, documents and other available equipment's. At times ventilation can also be a cause of the ignition to take place. Some of the sources of ignition are Various electronic schemes of the personal computers, devices applied for maintenance, power supplying device, faulty air conditioners, violations caused by super heated elements, electric sparks and arches and fire combustible materials. Any room with strong combustible materials belongs to the category B that is the room is on the highest degree of fire and explosion hazards. Protection and prevention against the fire is compulsory and a complex obligation for organizational and technical actions that are directed on the safety of the people. There should be a condition established for proper fire extinguishing and also on the restriction of fire. Some of the organizational activities involves fire instructing, training the people on safety regulations and finally make manuals, posters and evacuation plans. Further more operating activities for the prevention involves the workplace user's compliance with operational standards of equipment, providing free approach to the equipment and finally Upkeep of insulation of live conductors.

6.3.1 Safety from Fire and Explosives

The most probable and destructive types of emergencies [76] is that caused by fire or even more some sort of explosion in the workplace. Fire prevention is only based on the exclusion of the condition that is necessary for combustion and furthers more the use of safety principles. Indoor fires are especially dangerous as it posses a threat to human life and health and it is also a threat to everything in the room such as computers and the equipment, tool, documents and also spread of fire to nearby areas. In any modern operating system, the electrical components are dense. In close proximity to each other are arranged all the connecting cables, patch cables and electric components. Hence when there is a flow of electric current, a certain amount of heat is used to raise the temperature to about 80 - 1000 degree Celsius. It is also possible to melt the insulation, and as a result of short circuiting it is accompanied by sparks and finally leads to unacceptable overload of circuit elements.

A few Sources that could start a flame indoors are as follows:

- Short circuit in an electrical writing
- Contact with building lightning
- Faulty electric equipment, failure in a an electrical writing, electrical sockets and switches;
- Faulty electric devices
- Non-compliance with measures of fire safety and smoking indoors also can lead to a fire
- Heating of location by electric heaters with open heating elements.

Thereby, excess of heat in a personal computer must be removed and this could be done by the use of an internal ventilator. Also in order to reduce the occurrence of fire breakouts indoors in the case of emergency, it is necessary to follow the precautions for any organizational fire prevention such as to smoke only in specially led out places, to hold periodically a personnel safety notification, to have an available plan for evacuation, to assign a location dedicated for safety in case of any emergency. It is necessary to observe the following technical fire prevention precautions which are as follows:

- Wherever it is possible to reduce the amount of easily flammable substances, have it replaced with the analogs resistant to burning
- To remove possible sources of ignition
- To have a mandatory fire extinguishing mean (fire extinguishers)
- To carry out the fire warning indoors
- To contain electric equipment in a good condition and whenever possible to apply the means to prevent the origin of a fire
- To have proper exits for people during the time of a fire emergency.

6.4 Workplace Requirements

In the workplace of this research a number of adverse effects could take place. Hence in order to avoid these effects on any person [74] involved with the personal computer by many harmful factors a number of hygienic requirements are developed to ensure the safety of the person in the work place. The following requirements need to be ensured for industrial health:

- General Requirements Related to the Workplace
- Leisure and Work Organization Requirements.

6.4.1 General Requirements Related to the Workplace

The general requirements that an organization requires should also be in concordance with the sanitary norms and rules that were mentioned earlier and are carried out based on this specification. They are as follows:

- Every room should have windows with blinds, curtains or external peaks especially those rooms with personal computers.
- The monitor should be placed perpendicular or atlas at an angle of 75 degrees in relation to the person’s viewing direction and body angle.
- A window opening aperture should be present near ever personal computer so that the light falls sideways and more preferably to the left. This helps to ensure that light enters the workplace of an organization and is in accordance with norms and work ethics.
- All the chairs that have been equipped in the working place needs to have a soft seat and suitable back rest making it comfortable for the user in the respective workplace. People are of various heights and weights and therefore it must be ensured that the seats are adjustable by height and also hold a convenient support around the waist
- The corners of any room should be avoided as in arrangement should be done only facing windows. Thus the respective distance from the wall to a personal computer must be a minimum a 1m.
- The operator’s hand should always maintain a correct posture and position in order to prevent the violation according to that in the loco motor system and also to the syndrome of constant loadings.
- The monitor, keyboard and the case of the computer have to face the person operating it directly as per the work ethic norms. Further more the distance between the operator and the monitor should be close to a 60 - 70 cm and the angle must be a 20 degree from the monitor to the level of eyes of the person operating.
- It is always better to set the personal computer in a way such that when looking away from the screen, it should always be possible to visualize any distant object present in the room. This has proven to be one of the most effective ways to unload any visual system.
- While taking into consideration the general set up of a number of computers in a single room of a workspace in an organization one has to make sure that the distance between the wall and the screen of the computer to be at least a minimum of 2m. Also the distance from the side of the wall to every adjacent computer should be not less than 1.2m.
- The space for feet has to be a minimum height of 600 mm, a minimum width of 500 mm and finally a minimum depth of about 450mm. Also, the support for the feet should also follow a specific requirement of a width that is not less than 300 mm with a slightly adjustable tilt angle of about 0 - 20 degree must be provided.

6.4.2 Leisure and Work Organization Requirements

The modes of work and rest while working with the personal computer should be organized according to the type of employment [74], There are three groups which are Group A that involves work by reading information from the screen of the personal computer with the preliminary inquiry, Group B which involves work with the input of information and Group C involves all types of creative work using dialogue mode with a computer.

Small intervals should be organized between every shift for optimum working capacity support and also saving health of many professional users. In order to prevent the development of fatigue [74], the following measures should be ensured.

- There should be proper ventilation in the room during any regulated interval
- Perform some athletic exercises for 3 - 4 minutes during any regulated interval.
- Exercises should be conducted for the eyes every 20 - 25 minutes.

6.5 Summary

In this chapter, all safety rules, ethics and specifications have been mentioned. Dangerous situation can arise at any point and time of the day. Hence every person in the workplace should know all safety speculations thoroughly to protect oneself and further more the surrounding. Also, the structure of the building is to be known in and out so as to be prepared incase of a fire breakout. All specification for internal wiring and cabling also needs to be done by qualified professionals to reduce the percentage of harm created. Also the patient's safety is the cornerstone of high quality health care and hence the patient's health should be taken into consideration at every step of the research. Thus the research was executed in a safe environment and it kept to all rules and speculations for the safety requirement in a workplace.

Conclusion

The ultimate aim of this thesis is to create software that segments the lungs, which was executed successfully and lung segments can be identified using it.

In order to perform segmentation, previously and currently used methods for the process of lung segmentation are discussed and analyzed to identify if any of these methods would suit our purpose.

In the execution of this thesis, first the edge of each lung is detected with using Canny Detection, then the noise is removed using a mean filter and finally Erosion filter is used so that only segments of the lungs are detected and the rest of the features eliminated. Finally color is applied to lung segment borders.

The language used in carrying out this task is C# as this language is very efficient for edge detection and filtering of images, hence segmentation of the lungs is faster and involves lesser overhead.

Once the software was created, a financial and economic research of the software was analyzed which involved a segmentation market table to analyze the audience for the software, a SWOT matrix table to analyze the advantages and disadvantages related to the software creates, a FAST analysis and QuaD analysis to calculate the efficiency of the software and also the future of the software. Based on the results obtained, a financial report was created and the software seems to produce positive results financially.

The final step involved analyzing the safety of using the product and this was carried out in every aspect that included human intervention and the environment. The result produced a report stating that the software created is safe and can be used.

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