# DEVELOPMENT OF AUTOMATIC LIVER SEGMENTATION METHOD FOR THREE-DIMENSIONAL COMPUTED TOMOGRAPHY DATASET

**CHEW CHIN BOON**

**UNIVERSITI SAINS MALAYSIA**

**2018**

# DEVELOPMENT OF AUTOMATIC LIVER SEGMENTATION METHOD FOR THREE-DIMENSIONAL COMPUTED TOMOGRAPHY DATASET

**by**

**CHEW CHIN BOON**

**Thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Engineering (Electronic Engineering)**

**JUNE 2018**

# ACKNOWLEDGEMENT

First of all, I want to express my greatest gratitude to my supervisor, Associate Professor Dr. Haidi bin Ibrahim. Through his guidance, this final year project is able to be complete in time. Without his dedicated guidance and advices, this project could not be done smoothly.

Secondly, I would like to thank my examiner for this project, Associate Professor Dr. Dzati Athiar bt Ramli. She had provided invaluable comments on the progress report and also during the pre-viva session.

Next, I would like to thank the final year project coordinators, Associate Professor Dr. Bakhtiar Affendi bin Rosdi, Associate Professor Ir. Dr. Mohamad Kamarol bin Mohd Jamil and Associate Professor Dr. Rosmiwati bt. Mohd Mokhtar for the effort on arranging and conducting seminars for final year students so that the final year students can grasp the overall idea on the final year project also the way to prepare the report, thesis and technical paper.

Besides that, I also want to thank my family and friends who always provide me moral supports in doing this project. They have motivated me a lot in many ways so that I can complete my project.

Lastly, I would like to thank the School of Electrical and Electronic Engineering, Universiti Sains Malaysia for providing me the chance to pursue my study here. Millions of thanks to all the lecturer in Universiti Sains Malaysia who have taught me before and guide me. They have provided me the knowledge and foundations in the aspect of becoming an engineer.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ASD | Average Symmetric Surface Distance |
| CT | Computed Tomography |
| DSC | Dice Similarity Coefficient |
| GUI | Graphical User Interface |
| MICCAI | Medical Image Computing and Computer-Assisted Intervention |
| MRI | Magnetic Resonance Imaging |
| MSD | Maximum Symmetric Surface Distance |
| MSE | Mean Square Error |
| NLM | Non-Local Means |
| PET | Positron Emission Tomography |
| RF | Radio Frequency |
| ROI | Region of Interest |
| RVD | Relative Volumetric Difference |
| RMSD | Root Mean Square Symmetric Surface Distance |
| SLIVER07 | Segmentation of the Liver Competition 2007 |
| SI | Similarity Index |
| 3D | Three Dimensional |
| 2D | Two Dimensional |
| VD | Volume Difference |
| VOE | Volumetric Overlap Error |
| WHO | World Health Organization |

# PEMBANGUNAN ALGORITMA PERUASAN HATI AUTOMATIK DARIPADA DATASET TOMOGRAFI BERKOMPUTER TIGA DIMENSI

## ABSTRAK

Tomografi berkomputer (CT) selalunya diguna sebagai modaliti pengimejan perubatan bagi hati. Peruasan imej hati adalah penting kerana ia merupakan awalan bagi diagnosis hati. Peruasan manual dapat memberi keputusan yang baik berdasarkan kemahiran pakar radiologi tetapi prosesnya membosankan dan memakan masa disebabkan oleh bilangan imej yang dihasilkan pengimbas CT asdalah besar. Ramai penyelidik cuba membangunkan dan mencadangkan cara peruasan imej hati yang boleh dikelaskan kepada peruasan secara automatik dan separuh automatik. Kedua-dua cara ini dapat mempercepatkan masa peruasan. Kontras yang rendah pada sempadan hati dengan organ-organ berjiranan, kepelbagaian yang tinggi bagi bentuk-bentuk hati, kemunculan hingar dalam gambar dan kemunculan patologi hati akan menjejaskan ketepatan peruasan imej hati dan menyebabkan peruasan imej hati amat mencabar. Oleh itu, kaedah peruasan automatik telah dicadangkan dan dibina dalam projek ini untuk menambah baik ketepatan peruasan hati dan masa yang diperlukan untuk peruasan hati. Algoritma yang dicadangkan boleh dibahagikan kepada dua bahagian. Bahagian pertama adalah membangunkan atlas kebarangkalian. Atlas kebarangkalian memberi tahu keberangkalian sesuatu voxel adalah hati atau tidak dan memberi panduan dalam peruasan hati. Atlas kebarangkalian lokasi serta keamatan akan dibina dengan 20 dataset yang didapati dari SLIVER07. Atlas yang dibina akan menjadi pembimbing dalam peruasan. Bahagian kedua adalah memperuaskan imej hati dengan mengunakan atlas kebarangkalian yang telah dibina. Imej hati yang telah diperuaskan akan diperhaluskan dengan menggunakan morfologi tutup dan ditapis dengan penapis median 3D. Algoritma yang telah dicadangkan kemudiannya diuji dengan 19 dataset yang diguna untuk membina atlas sebab dataset asas sebenar diperlukan dalam penilaian. Prestasi algoritma tersebut dinilai dengan VOE, RVD dan DSC. Keputusan peruasan hati secara purata bagi VOE adalah 26.50%, RVD 15.09% dan DSC 0.8421. Masa diambil untuk peruasan adalah 366s secara purata. Keputusan peruasan ini adalah berdaya saing. Namun, penambahbaikan masih boleh dibuat.

# DEVELOPMENT OF AUTOMATIC LIVER SEGMENTATION ALGORITHM FOR THREE DIMENSIONAL COMPUTED TOMOGRAPHY DATASET

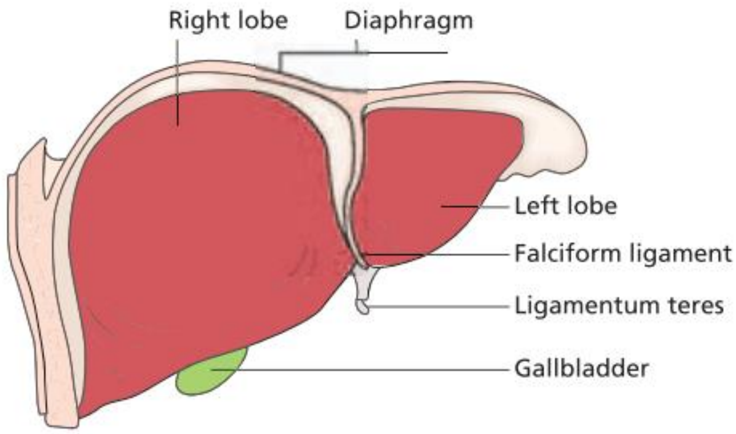
## ABSTRACT

Computer tomography (CT) is usually used as the medical imaging modality for liver. Liver segmentation is important as it is preliminary for liver diagnosis. Manual segmentation can provide good result based on the skill of radiologist but the process is tedious and time-consuming due to large number of slides produced by the CT scanner. Many researchers try to develop and proposed various liver segmentation methods which can be classified into automatic and semi-automatic segmentation. Both methods are able to speed up the segmentation time. The low contrast of liver boundary with neighbouring organs, high shape variability of liver, presence of noise in image and presence of various liver pathologies make liver segmentation very challenging. Despite that, automatic segmentation is still the more desirable method to be use due to its efficiency and convenience. Therefore, an automated liver segmentation algorithm is proposed and developed in this project to improve the accuracy and time required for liver segmentation. The proposed algorithm can be divided into two parts. The first part is to build the probabilistic atlas. Probabilistic atlas provides the probability for a voxel to be a liver and act as a guide for segmentation. Both the location based and intensity based probabilistic atlas are built from the 20 datasets obtained from SLIVER07. The atlases act like a guide for segmentation. The second part is to use the probabilistic atlas built to segment the liver. The segmented liver will be refined by the probabilistic atlases itself and then further refine by morphological closing and 3D median filter. The proposed algorithm is then tested by the 19 datasets that are used to train the atlases as the ground truth datasets are required for evaluation. The evaluation on the performance is based on volumetric overlap error (VOE), relative volume difference (RVD) and dice similarity coefficient (DSC). The proposed algorithm provided mean VOE of 26.50%, mean RVD of 15.09% and mean DSC of 0.8421. The time required for segmentation is 366s. The segmentation results from the algorithm developed are competitive. However, improvements still can be made.

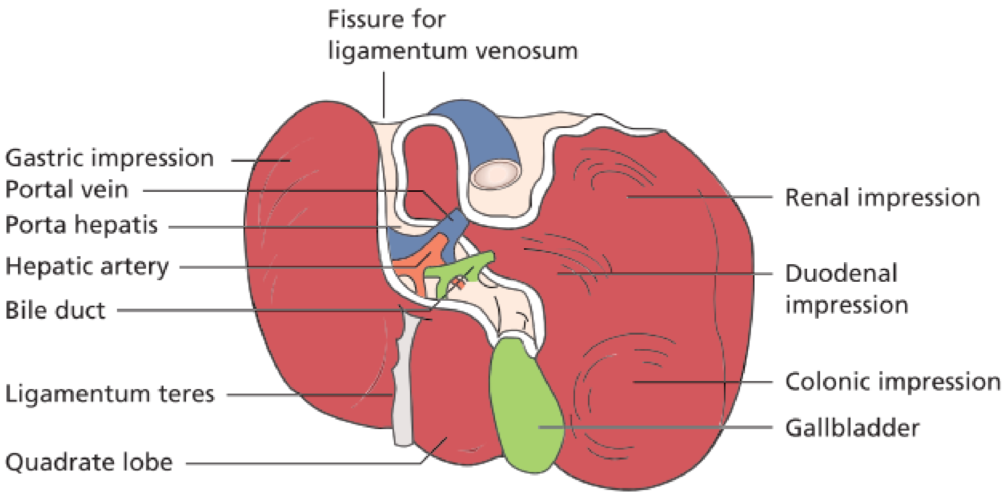
# CHAPTER ONE
# INTRODUCTION

## 1.1 Background

Liver is the largest organ in human body. Its weight is about 1200g to 1500g. The average size of liver is 15cm in width [1]. It is located at the upper right quadrant of the human body and just below the diaphragm. Figure 1.1 shows the anterior view and interior view of liver respectively [2]. As shown in Figure 1.1(a), liver is basically separated into two portions which are right lobe and left lobe [2].




(a)




(b)

Figure 1.1: (a) Anterior of liver, (b) interior view of liver [2]

Liver plays an important role in the digestive system. Liver along with other organs like gallbladder, pancreas and intestine, helps people to digest, absorb and process foods that are consumed. Liver's main functions are to clean the blood from digestive tract, detoxify chemicals and metabolize drugs. It helps in albumin synthesis, ketogenesis and lactate metabolism [3]. Liver also produces a special type of protein that is useful for blood clotting and other functions. Liver is the central to the metabolism of fat, carbohydrate and protein [2]. Besides, liver is also one of the important organ for acid-base regulation. This helps to regulate the blood pH and this is important for regular cellular and organ function [3].

Since liver is one of the organs that involves in blood pH regulation and also part of the digestive system, failure of liver can be catastrophe. Failure of liver will cause acid-base disorder. Patients with acid-base disturbance will have the problem of respiratory alkalosis and metabolic disorder [3].

Since liver helps in filtering blood, it makes liver a cancer prone organ. Due to industrialization, liver disease become one of the widespread diseases between humans [4]. Liver diseases can be viral hepatitis, non-alcoholic fatty liver disease, alcoholic liver disease, liver cancer and tumor. Liver disease is one of the major mortalities in the world. According to World Health Organization (WHO), liver cancer caused 745517 deaths worldwide in 2013. Excessive alcohol intake is one of the causes for liver disease [5]. According to World-Cancer-Report-2014, liver cancer is one of the most common causes of cancer deaths which brings 745000 deaths. Unhealthy diet and physical inactivity are the factors for the cancer. Furthermore, the availability and quality of treatment and diagnosis test are also the factors that contribute to the deaths due to cancer [6].

To treat the liver disease like liver tumor, several approaches can be used as the treatment. If it is in the early stage, taking medicine will be enough. If it is in the late stage where it become a serious case, treatment like surgical operation and ablation should be used. Compare to surgical and vascular interventional approaches, ablation is much safer and provide faster recovery [7]. No matter which approaches is to be used, a planning is required before treatment. Therefore, to have more precise preoperative planning and liver surgery, researchers and doctors develop computer imaging techniques to extract region of interest [8]. This is important as a good extracting method could help to provide doctors an accurate liver model so that they can have a better planning before having operations on the liver. With this, the success rate for the operation on liver could increase and the patients will have a greater chance for recovery. Not only that, a good liver segmentation could help doctors to diagnose better so that the disease can be detected earlier and an early treatment can be imposed to the patient. This could help to increase the survival rate as treatment can be done before the situation become worse [6].

There are several types of imaging techniques method to analyse the liver. For example, ultrasonography, magnetic resonance imaging (MRI) and computed tomography (CT). Ultrasonography uses high frequency sound wave where no radiation is emitted but it is not accurate. MRI uses radio waves and strong magnetic field which emits high radiation but it is very accurate. Computer tomography (CT) uses X-ray examination which emits radiation and it gives accurate results [9]. There is a trade-off in the image accuracy and the emission of radiation.

Commonly, radiologist is the one who outline the liver region from medical images and the entire process is time consuming [10]. Therefore, a good segmentation method will be crucial in overcoming this problem. There are several types of segmentation method that can be used. For example, thresholding method, marker controlled watershed, region growing method, label connected component method, clustering method and neutrosophic set. These methods can be combined as they might give a better result if compared to just solely depend on one of the methods [9].

Liver disease is one of the major cause of illness and death. Hence, technology and the way to improve the liver segmentation method should be done continuously so that the reliability and success rate of the liver treatment can be increased from time to time. Besides, making the segmentation process using automated or semi-automated method could help to reduce the contradiction between radiologists too as the same setting will provide the same segmentation result. Until now, liver segmentation has been extensively studied. However, due to non-rigid shape of liver, liver segmentation still remained a challenging task [11]. Therefore, this project is carried out to help in developing an alternative 3D segmentation algorithm for liver and is expected to help in improving the liver segmentation performance in terms of accuracy and processing time.

This project will be contributing more to the medical field and also the advancement of image processing.

## 1.2 Problem Statements

Liver segmentation is a challenging task as livers has large variations in shape and its intensity is similar to the other body tissues [12]. Many methods and techniques of liver segmentation have been developed but most of them are time consuming and results produced are not satisfactory [9].

Foruzan et al. [13] proposed thresholding method while Elmorsy et al. [14] proposed a region growing method. These methods required human interactions. For thresholding method, the thresholding values need to be set manually and it will affect the segmenting result. For region growing method, seed point need to be defined and human interaction is most likely required for it. Although many algorithms had been proposed, but liver segmentation is still an open problem as there are still a lot of improvements should be done [9][12][15]. Therefore, there is still needs for liver segmentation method to be improved.

Farzaneh et al. [16] proposed a location and intensity based probabilistic atlas method to perform segmentation. This is an automatic segmentation method which yields promising results but there are still rooms for improvements. Location based probabilistic atlas provides the probability for a voxel to be liver with known spatial location while intensity based probabilistic atlas provides the probability for a voxel to be liver with known intensity value. The reliability of location based probabilistic atlas depends on the registration method used. The registration methods and refinement methods used will greatly affect the segmentation results and are worth discovered. Combinations of segmentation methods can also be used to improve the segmentation results.

## 1.3 Objectives

The objectives of this project are:

1. To develop algorithm to create liver atlas, which can be used for liver segmentation.
2. To develop a segmentation technique, which able to extract liver region with high accuracy, and short processing time.

## 1.4 Project Scope

In this project, only the datasets of liver computed tomography (CT) obtained from the website "Sliver07" will be used [17]. The datasets obtained is used for training and testing of algorithm. The algorithm is developed by using MATLAB R2017b.

Besides that, the proposed algorithm is only meant for the segmentation of healthy liver as the algorithm proposed is sensitive to intensity and location of liver. The dataset provided does not include the information on the status of liver. Large variations in location and intensity will affect the performance of segmentation. Hence, this proposed segmentation algorithm is more suitable to be used in early checking.

The performance of the proposed algorithm will be evaluated using volumetric overlap error (VOE), relative volume difference (RVD) and dice similarity coefficient (DSC). The processing time is included in evaluation too. The proposed algorithm will generate the segmentation mask according to the specific segmenting dataset and save in png file to ease the inspection by visual.

## 1.5 Project Contribution

This project provides an alternative segmentation algorithm for liver. This project aims to develop a 3D segmentation algorithm for accurate liver segmentation which requires short processing time. Therefore, this project could help doctors to diagnose better and improve the survival rate for those who get chronic liver diseases. This project mainly contributes in the medical field and helps in the advancement of image processing.

## 1.6 Chapter Organization

This report consists of five chapters. Chapter One is the introduction of the project. This chapter provides the background, problem statement, objectives, and scope of project.

Chapter Two is the literature review of the project. This chapter explains the imaging modalities used for medical image of liver. This chapter also discusses the liver segmentation algorithm developed and used previously.

Chapter Three is methodology of the project. This chapter explains the concepts and algorithm for liver segmentation in this project. The details of liver CT datasets used are shown and explained here. Furthermore, the process of algorithm development and also the segmentation algorithm itself are explained in here. Besides that, the experiments in obtaining the suitable parameters to be use in segmentation is discussed too.

Chapter Four is result and discussion for the project. In this chapter, the results of the experiments in obtaining the suitable parameters are shown and discussed. The intensity based and location based atlases are analysed and discussed here. The segmentation results are shown and discussed. The evaluation on results are made in this chapter also.

Chapter Five is the conclusion for the project. In this chapter, conclusion for the entire project is made and suggestions on the future improvement are given.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

Medical image provides certain information about the internal body structure of patients which is crucial for diagnosis purposes [18]. Doctors will read the medical image of the patients to get to know more about the health situation of the patients.

Image segmentation is a process of separating image into several parts. In medical field, medical image usually will be segmented for diagnosis purposes. Liver segmentation is prerequisite before planning for the treatment can be carried out. Many segmentation methods has been proposed by researchers along with pre and post processing for the image refinement [12]. Hence, literature review is done to know the state of art for liver segmentation methods so that improvements can be made on the current methods.

## 2.2 Digital Images

Regardless of which imaging modality used, all the image is stored as digital image. A digital image is an image that has been discretized both in space and amplitude. A picture usually consists of matrix with rows and columns which indicates the spatial location of the pictures and the values of the matrix elements indicates the intensity or grayscale of that corresponding point of the image. The elements that made up a picture is called pixel. For 3D image, the elements are called voxel. The image gray level indicates the intensity and its value is determined by the bit depth. The bit depth will give impact to the image contrast resolution. A CT slice is usually 512rows × 512columns with bit depth of 16bits [18]. Figure 2.1 shows one of the examples of digital image [16]. It is a CT image of liver and it is one of the slices from a complete 3D CT image. The image is obtained from CT scanner and the data obtained is stored digitally.

Figure 2.1: Example of liver digital image (CT) [16]

## 2.3 Medical Image Modalities

There are several types of medical image modalities. There are modalities that uses ionizing radiation and non-ionizing radiation. Examples of modalities with ionizing radiation are radiography, fluoroscopy, mammography, computed tomography (CT), and nuclear medicine. While for non-ionizing radiation, there are ultrasound and magnetic resonance imaging [18]. For now, contrast-enhanced computed tomography is the most commonly used approach for liver disease monitoring [12].

Different modalities are used by radiologist and doctor for diagnosing liver. The working principles of computed tomography (CT), magnetic resonance imaging (MRI) and ultrasonography are discussed in the subsections below as liver diagnosis usually use these modalities.

### 2.3.1 Computer Tomography (CT)

In computer tomography (CT), collimated X-ray beam is used as the source to obtain the image. The X-ray tube will rotate around the patient. Scintillation detectors are used as sensors to detect the X-ray beam. The attenuation of X-ray beam detected will be the function of tissue density. Figure 2.2 shows the situation of a patient taking a CT scan [19]. Every tissue in the body has different attenuation coefficient. The higher the attenuation coefficient, the greater the amount of X-ray will be absorbed. Hounsfield Units is used to represent the absorption value of the X-ray. It is scaled from +1000 to -1000 where +1000 signifies maximum X-ray absorption and -1000 signifies minimum X-ray absorption. The digital readings obtained from the detectors will then gone through computer processing to get the image. Usually, air with least attenuating will be represented as black while the bone which is highly attenuating will be represented as white in the CT scan image. The image obtained is the thin transverse of body [18]. Figure 2.3 shows the image obtained from CT scan [20].

CT scan images usually have good contrast resolution. Tissues with same density will have same intensity and this makes the tissues easier to be classified. The tomographic acquisition has also overcome the problem of superposition of images due to the overlapping of body structures. However, it requires high cost equipment and procedure. It also uses high dose of ionising radiation which is not good for health [18].

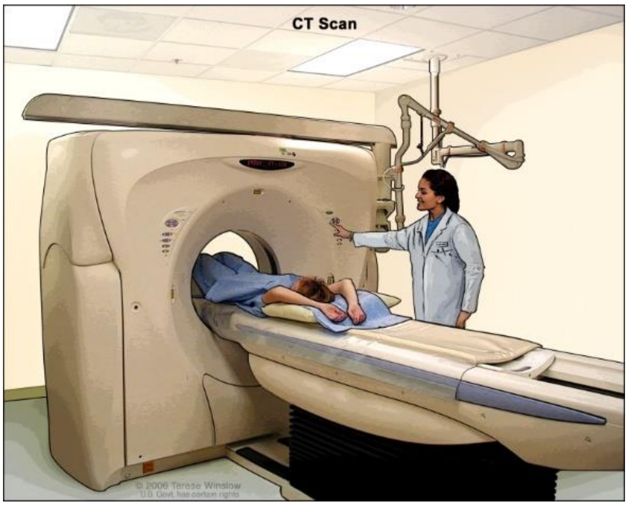



Figure 2.2: CT scan of abdomen [19]

Figure 2.3: Abdominal CT image [20]

### 2.3.2 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) uses high intensity magnetic field as its source to obtain the image. Today, helium-cooled superconducting magnets are used to generate the magnetic field. Patient is placed under the strong magnetic field and the hydrogen ion, $H^+$ (also known as hydrogen nuclei or proton) in the water and fat molecules of the body will respond to the magnetic field where they will align according to the magnetic field. When a radio frequency (RF) is applied to the magnetized nuclei, it will move away from its position. Different body tissues will have different response to the magnetic field. When the radio frequency is removed, the nuclei will decay and return to the previous position with certain energy released in the form of RF. The energy will be received by the detector, which is RF coil. After that, the signal received will be calculated and converted into image [18][21]. Figure 2.4 shows the MRI scanner.

The relaxation time T1 and T2 can also obtained through MRI scan. The T1 relaxation time also known as spin-lattice relaxation time. It is the time required for the longitudinal magnetization to recover to 63% of its initial value. T1 value varies for different tissue. The difference of T1 values is the basis of T1-weighted contrast on MRI image. T2 relaxation time also known as spin-spin relaxation time. It is the time for the transverse magnetization to drop to 37% from its maximum value during dephasing when the $90^o$ RF pulse is off. Value of T2 varies for different tissue. The difference of T2 values can be used to generate T2 weighted signal in MRI. T2* is the overall relaxation time. It is usually shorter than T2 as T2* considered extrinsic magnetic inhomogeneities which is not included for the case of T2 [21]. Figure 2.5 shows the T1 weighted MRI image of liver [22].


Figure 2.4: MRI scanner [23]

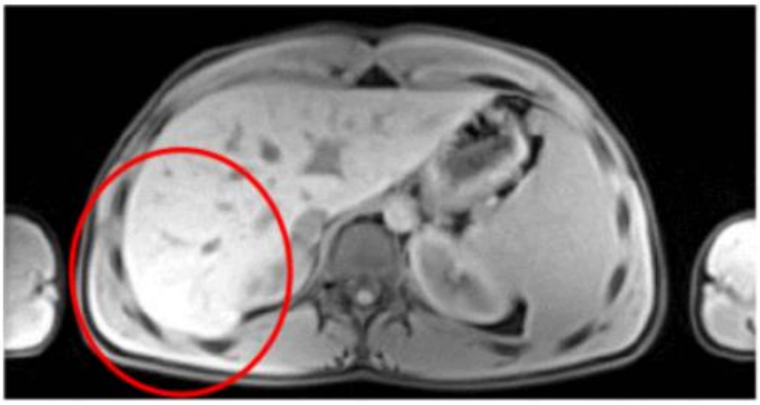


Figure 2.5: T1 weighted MRI image of liver [22]

### 2.3.3 Ultrasound Imaging

Ultrasound imaging uses high frequency sound waves to scan the internal organs of body. The sound wave has frequency more than 20kHz which exceed the human's hearing threshold. Ultrasound imaging is non-invasive, non-ionizing, cost effective and portable. Since it is non-ionizing, it is safer. A gel will be applied to the patient before the ultrasound examination carries out to prevent air pockets formed between the skin of patient and the transducer (probe). The high frequency sound wave is emitted by transducer of the machine which is made of piezoelectric crystal. The sound wave travels through the body and reflect accordingly when encounter different tissues. The transducer also acts as the receiver which receive the reflected sound form the body and convert it into electrical signal. The signal is then being processed into pictures [18][24]. Figure 2.6 shows the situation of ultrasound imaging examination [25]. Figure 2.7 shows an example of ultrasound image of a liver [26].

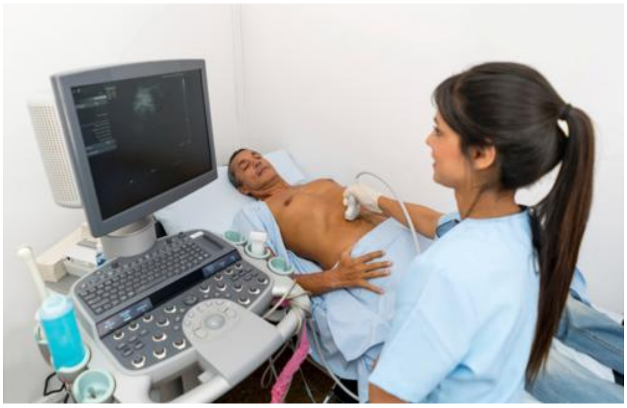


Figure 2.6: Ultrasound imaging [25]

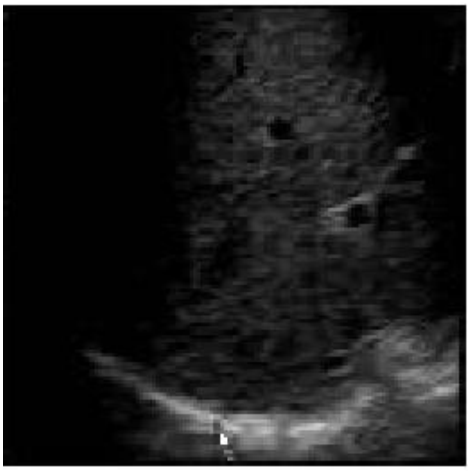


Figure 2.7: Ultrasound image of a liver [26]

### 2.3.4 Comparison Between The Imaging Modalities

In this section, comparison between CT scan, MRI and ultrasound imaging was made. There are trade-offs between these imaging modalities. Ultrasound imaging is relatively low cost. It uses ultrasound wave, a high frequency sound wave which is above human's hearing threshold is used as the source. Hence, there is no ionizing radiation presence throughout the examination process. This means that it is safe to use. Besides that, the ultrasound imaging machine is also portable. It is able to move to the bedside of patient which is very convenient. However, ultrasound imaging is dependent on the operator. It is not suitable to be used by obese patient because the ultrasound wave will scatter through fat and produce low quality image. Ultrasound imaging also produce poor visualisation for structures with bone and air [18].

MRI uses high intensity magnetic field and RF as its source to obtain the image. There is no ionizing radiation presence in the MRI examination. Therefore, it is relatively safe to be used. MRI able to obtain image in all planes which brings convenience during diagnosis. MRI also provide good contrast details for soft tissues. There will be no bony artifacts too as the bones do not give any signal. However, MRI requires expensive equipment and high operating cost. The MRI scanning takes long time and it provides poor images for lung. Besides that, it is also contraindicate to patients with pacemakers and metallic foreign bodies [18].

CT uses collimated X-ray beam as its source to obtain image. It provides good contrast resolution. Tissues with similar physical density can be easily classify [18]. These information can be useful for the segmentation process [9]. There will be no problem on the superposition of images of the overlapping structures as tomographic acquisition is used. Furthermore, the image produced can also be viewed in multiple planes (pixel) or as volume (voxel). CT is also useful in tumor staging. However, CT requires expensive equipment. There is also presence of ionizing radiation in the process which is not good for health. Besides, high contrast objects in the body will cause artifact in the results too [18]. The advantages and disadvantages of the three modalities are summarized in Table 2.1.

Table 2.1: Comparison between imaging

| | **CT scan** | **MRI** | **Ultrasound Imaging** |
|---|---|---|---|
| Source | Collimated X-ray beam | High intensity magnetic field and RF | Ultrasound wave |
| Advantages | • Good contrast resolution<br>• No problem of superposition of images<br>• Image produced can view with multiple planes or as volume<br>• Able to scan all parts of body<br>• Use for tumor staging | • Non-ionizing radiation<br>• Able to obtain image in all planes<br>• Good soft tissue contrast detail<br>• No bony artifact | • Low cost<br>• Non-ionizing<br>• Safe<br>• Portable |
| Disadvantages | • Expensive equipment and procedure<br>• Presence of ionizing radiation<br>• High contrast object in body causes artifact | • Expensive cost<br>• Slow process<br>• Poor image quality for lung<br>• Contraindicate to patients with pacemakers and metallic foreign bodies | • Dependent on the operator’s skill<br>• Poor images for obese patients<br>• Poor visualisation for structures with bone and air |

## 2.4 Image Pre-Processing

Image pre-processing is a process to improve an image from its unwanted distortion or noise for further processing later [27]. Image pre-processing might also include registration, rotation and resizing [28]. Usually, before liver segmentation is carried out, some pre-processing procedure like filtering will be carried out to remove the noise from the medical image. For instance, type of noise that might be present are speckle noise, Poisson noise, Gaussian noise and salt and pepper noise [26][29]. The presence of Gaussian noise in CT images is usually due to the sensor noise because of the poor lighting or noise from the electronic circuit. Salt and pepper noise is also known as impulsive noise, shot noise or spike noise. Salt and pepper noise is usually caused by sudden disturbance to the image signal. Events like memory cell failure and synchronization error will cause this kind of noise [30]. There are many types of filter that can be used to remove these noises so that the quality of image can be improve and it is crucial for further processing. For example, there are median filter, wiener filter, Entropy filter, Gaussian filter and many more [26][29]. Median filter is a filter that is able to preserve the edges of image while removing noise. Median filter can be used to remove salt and pepper noise. Wiener filter can be used to remove distortion while Gaussian filter is used to blur an image or remove noise from image. Mean filter is also an alternative filter used to remove impulsive noise and also Gaussian noise [30]. The following subchapters will explain more details on the filters.

### 2.4.1 Gaussian Filter

Gaussian filter is a linear and non-uniform low pass filter. It is usually used to blur the image or remove the noise in image. It is a very good smoothing operator but relatively not a good filter to salt and pepper noise if compared to the other filters. The filter function is defined as equation (2.1) [30].

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{\frac{-(x^2+y^2)}{2\sigma^2}} \tag{2.1}$$

where $x$ and $y$ are the coordinate of the image and $\sigma^2$ is the variance of the distribution [30].

By using equation (2.1), a kernel matrix, which is also called a mask can be used to filter the noise in image. The selected portion of the image will be multiplied by the kernel or mask and the resulting value will replace old pixel value. By doing this, the pixel with noise will be suppress. The greater the σ value, the greater the less frequencies are suppressed [30].

Chen et al. [31] proposed region growing method for liver segmentation. The image modality used is CT image and consist of noise. Two image pre-processing steps had been taken to enhance the CT image. Anistropic filter is first introduced to remove noise and sharpen the discontinuities in the homogeneous region while maintaining the details of the image. Then, Gaussian filter is applied to preserve intensity of liver region and at the same time reduce the effect of non-liver region. This is to make the image more adaptive or more suitable to be segmented [31]. Zhanpeng et al. [32] proposed watersheds and region merging methods to segment the liver. Gaussian filter is also used before the segmentation to smooth the image as the CT image contains noise [32].

### 2.4.2 Mean Filter

Mean filter is also called average filter. It is a linear filter and it operates by replacing the central value with the resulting average value from its neighbouring pixel and its own value. All the neighbouring pixel has equal weightage [33]. The filter function is defined as equation (2.2). Mean filter is easy to implement and useful in reducing both impulse noise and Gaussian noise. However, it causes the image to be blur and loss of details [30].

$$\tilde{x} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n} \tag{2.2}$$

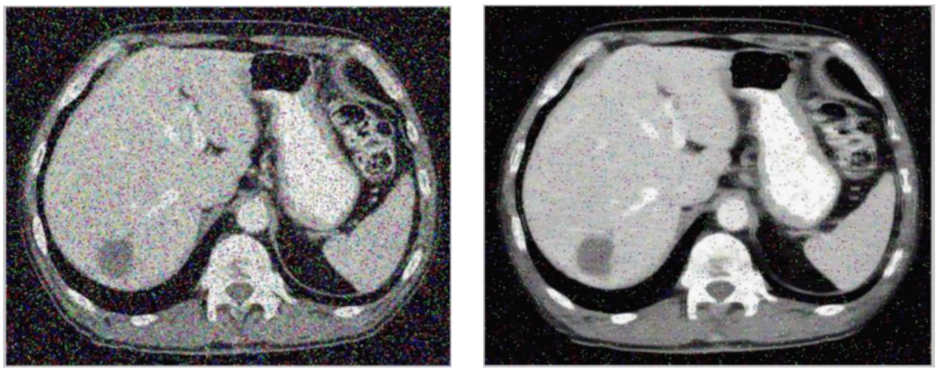
where *x* is the central pixel and *n* is the number of neighbouring pixel [30].

Mostafa et al. [34] tried region growing method to segment liver with different type of filters and compared the result. Mean filter was one of the filter used but it does not provide the best result [34]. Qi et al. [35] proposed a non-local means post filter with spatially adaptive filtering strength for whole body Positron Emission Tomography (PET) image. The proposed method used non-local means (NLM) method to smooth the image. NLM uses weighted average of pixels of the neighbouring pixels to smooth the central pixel. In this proposed method, spatially adaptive smoothing strength based on intensity are used [35].

### 2.4.3 Median Filter

Median filter is a non-linear filter to remove noise from an image. Unlike mean filter, the details and edges of the image are preserved after median filter is applied to the image. This filter is good in removing salt and pepper noise. Median filter operates by replacing the central pixel value with the median value of the neighbouring pixel. Hence, if compared to mean filter, median filter provides better result in the sense that its value does not affect by the extreme value of a single neighbouring pixel which is unrepresentative and create an unrealistic pixel value. Since the value of the central pixel came from its neighbouring pixel, hence the details of the image can be preserved [30][33].

Yugander et al. [36] proposed a distance regularized level set evolution based on fuzzy c-means clustering method to segment liver tumor. The proposed method is noise sensitive, therefore noise filtering must be done beforehand. Median filter was chosen to filter the noise as it can preserve the edges while removing impulsive noise. Figure 2.8 (a) shows the liver CT image with salt and pepper noise and (b) shows the results after denoising using median filter [36]. Aravinda et al. [37] proposed simple linear iterative clustering based liver tumor segmentation. In the proposed method, median filter also been used to remove the unwanted regions which do not contain any information about the tumor to simplify the segmentation [37].



(a) (b)

Figure 2.8: Liver CT image (a) with salt and pepper noise, (b) filtered by median filter [36]

### 2.4.4 Wiener Filter

Wiener filter is a type of restoration method. It can be used to remove distortion caused by linear motion or unfocussed optic in image and remove noise. It is sensitive to additive noise as it is uses inverse filtering. It is good in removing Poisson noise and speckle noise. It reduces the mean square error (MSE) between the original image and the recovered image [30][38].

Tasnim et al. [39] studied the speckle noise reduction from ultrasound B-mode images using different filters. Wiener filter was one of the filter studied. It was used to remove the speckle noise. In the study, Wiener filter provides good peak signal to noise ratio (PSNR), mean square error (MSE) and mean structure similarity index map (MSSIM) [39].

## 2.5 Image Segmentation Techniques

Image segmentation is a process of diving the image into parts. In medical field, liver segmentation is a prerequisite for the planning of liver surgery, treatment and post-treatment evaluation. Liver segmentation can be semi-automated where it requires user interaction or automated which does not require any interaction from user. Until today, liver segmentation remains challenging due to its high variability. There are many segmentation methods and algorithm proposed and they can be classified by the amount of shape information used. Examples of the segmentation methods are statistical shape models, probabilistic atlas, geometric deformable model, level set, region growing, graph cut, gray level based method, thresholding and methods incorporating machine learning algorithms [12]. Details on some of the segmentation methods are discussed in the following subchapters.

### 2.5.1 Thresholding

Thresholding method uses the intensity of the image to perform segmentation. It is an old segmentation method but simple to be implemented [9]. For example, one can select a threshold value, T as a reference. If the pixel value equal or exceed the threshold value, T, it will be classified into one group. If the pixel value is less than the threshold value, T, it will be classified into another group. The threshold is not necessarily to be a fix value but also can be in a range. The thresholding method can be classified into global thresholding and local thresholding. The global thresholding uses one fix value, T and apply to the entire image while the local thresholding uses a threshold value, T which will be varied according to the neighbouring pixel. Figure 2.9 shows the example of an image being applied with global thresholding [40].

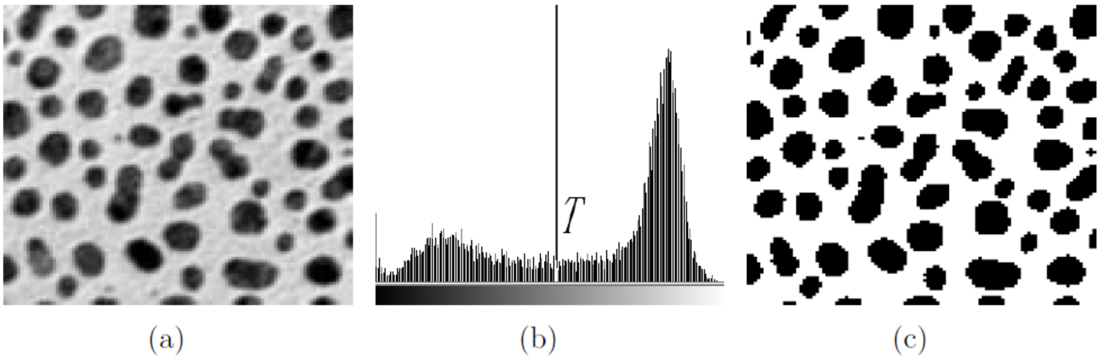



Figure 2.9: Global thresholding (a) input image (b) intensity histogram with threshold value, T (c) after global thresholding [33]

Thresholding method can be expressed in the equation (2.3).

$$b(x,y) = \begin{cases} 1 \text{ , if } I(x,y) > T \\ 0 \text{ , otherwise} \end{cases} \tag{2.3}$$

where the $b(x,y)$ is the binary image formed after the thresholding is applied, $I(x,y)$ is the pixel intensity of the original image and $T$ is the thresholding value [33]. The threshold value, $T$ can be selected manually or automatically. Automatic selection of threshold value can be done by conceptual or actual consideration on the histogram of image. Thresholding method is simple but there are some limitations in it. Thresholding method might cause the contiguous parts to be separated as it does not consider the spatial relation between pixels. Hence it only provides good result when the applied image is simple [33]. Therefore, for a complex image, thresholding method needs to be combined with other method to have a better segmentation and pre or post processing might be needed to enhance the result.

Foruzan et al. [13] had applied narrow-band thresholding method on CT image for liver segmentation. Some pre-processing steps like region extraction, interpolation, smoothing, selecting region of interest (ROI) and initial slice segmentation had been carried out. Expectation maximization algorithm with 4 Gaussian modes are applied to predict the mean and standard deviation of major components that contributes to the liver intensity range. For each mode, thresholding is applied to the CT slice in narrow region near to its mean value to obtain the possible pixels that belong to liver. Post-processing, K-means clustering is carried out after thresholding. With Intel® Core™ and 2GB RAM, the algorithm takes 18 to 22 minutes to finish the segmentation of liver dataset. The results of segmentation is quite promising too. Figure 2.10 shows the liver CT image that was applied with thresholding [13].

Figure 2.10: Thresholding of liver CT image [13]

Farzaneh et al. [16] used location and intensity based probabilistic atlases along with thresholding method for liver segmentation. The images are first normalized and thresholding method was used to segment the liver. The intensity and position based probability model were built after that. By using Bayesian theorem, the likelihood of the liver pixel in an image can be determined. Bayesian theorem can be expressed in equation (2.4) [16].

$$P(L|(i,j),I) = \frac{P(I,(i,j)|L)P(L)}{P(I,(i,j|L)) + P\left(I,(i,j)\middle|L^{'}\right)P(L^{'})} \tag{2.4}$$

where $P(L|(i,j))$ is the position probability, $(i,j)$ is the spatial coordinate of the pixel and $P(I|(i,j))$ is the intensity probability [16].

About one year later, Farzaneh et al. [41] proposed an improvement to their algorithm. Farzaneh et al. proposed the adaptive thresholding with the fix threshold value and superpixel approaches for the segmentation. The result of the adaptive thresholding is then used as the region of interest and modified using the anatomical information. The modified region of interest is used to perform final segmentation along with the superpixel. The results from the segmentation is shown in Table 2.2. It can be seen that the adaptive thresholding approach has bring improvement in performance and the implementation of superpixel approach after that provides better results [41].

Table 2.2: Comparison between different thresholding method and superpixel approach [41]

| Segmentation Result | **Previous Approach** | **Adaptive Threshold** | **Final Segmentation** |
|---|---|---|---|
| Dice | 88.3% | 90.7% | 93.5% |
| Jaccard | 79.3% | 83.1% | 87.9% |
| Sensitivity | 81.7% | 85.3% | 90.6% |
| Specificity | 99.5% | 99.6% | 99.5% |

Foruzan et al. [42] also proposed a method using intensity analysis and anatomical information in CT image for liver segmentation. A double thresholding method where the thresholding is adaptive is used. Before applying this thresholding method, a few pre-processing steps are carried out. Manual segmentation on the middle slice of CT image where the liver portion is big is carried out follow by the expectation maximization algorithm to estimate the liver intensity. Region of interest is then obtained by using the information of the ribs. After that, heart is segmented out from the upper slice of CT image to prevent leakage during segmentation of liver as it has the similar intensity as liver. Then the liver is segmented using the proposed thresholding method. The segmentation begins from the middle slice and then to the top and bottom slice. The intensity range obtained from liver's intensity histogram is divided into two regions called lower range ($R_L$) and upper range ($R_U$). $R_L$ and $R_U$ can be expressed as equation (2.5) and equation (2.6).

$$R_L: \mu - 2\sigma \le I \le \mu + 0.1\sigma \tag{2.5}$$

$$R_U: \mu - 0.1\sigma \leq I \leq \mu + 2\sigma \tag{2.6}$$

where the $\mu$ is mean, $\sigma$ is the standard deviation of the liver histogram and $I$ is the image intensity [42]. The threshold value for both regions are different. The threshold values are determined by performing a local analysis on each region. After that, inclusion or exclusion of image object are carried out based on Heuristic rule and then the segmented liver will be converted from gray-scale to colour for better visualization. The result of this algorithm is promising. By using a P4(3GHz) processor and 2GB memory personal computer, it takes 2.1s to 3.2s to process one slice of CT image. It has averagely 15.26% volumetric overlap error, -2.7745% relative volume difference, 5.1285mm average symmetric surface distance, 9.6895mm RMS symmetric surface distance and 65.9148mm maximum surface distance. These are evaluation of results for local dataset by the metrics provided by MICCAI 2007 [42].

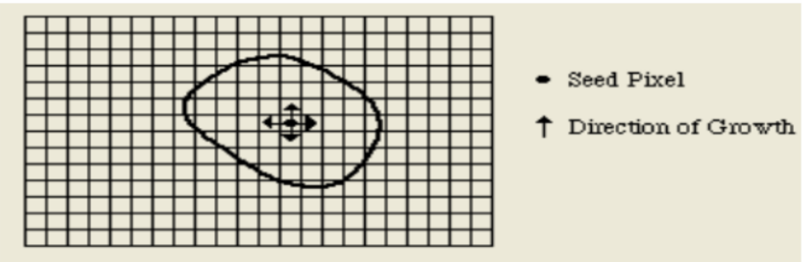
### 2.5.2 Region Growing

Region growing is an iterative segmentation method by setting a few seed points with predefined homogeneity criteria, pixels of the neighbour of seed points with similar properties which determined by the homogeneity criteria will be gathered to form a larger region. The homogeneity criteria can be set manually or automatically. Region growing method is simple and efficient. However, it has several limitations. Improper homogeneity criteria will cause leakage and it is hard to define the homogeneity as it is sensitive to noise [9][40]. Therefore, some pre or post-processing should be done to overcome these limitations. The segmentation needs to be refined. With the pre and post-processing steps taken, region growing methods still able to provide competitive results [12].

Elmorsy et al. [14] had proposed a region growing liver segmentation method with advance morphological enhancement. At first, the CT images of liver are applied with thresholding. The thresholding values are determined by analysing the intensity of the images. After that, region growing method is applied to the image. The seed points were manually selected and the homogeneity criteria is determined by the difference between the mean intensity of the region and the intensity of the neighbour pixel. The image obtained from the region growing method is then applied with morphological operation to refine the image. The morphological operation proposed is applied with adjustable structuring element size. The results obtained have average error percent of 5.01037% with 10 tests [14].

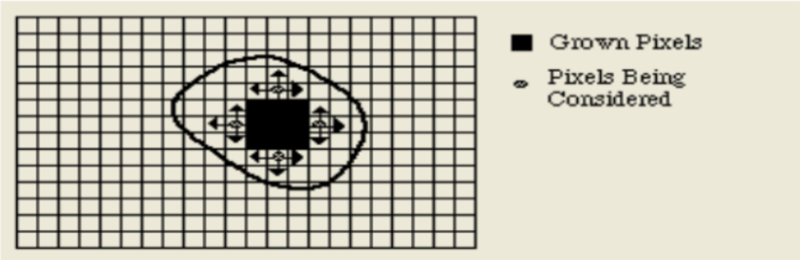
Mostafa et al. [43] proposed region growing segmentation with iterative K-means for CT liver image. Filters were applied before. Texture filter is used to obtain edges, median filter to remove noise and smooth the image without losing details of image and inverse contrast filter to reverse the output image. After filtering, iterative K-means clustering is applied to remove other organs which has similar intensity value as liver. After that, region growing method is used to segment the whole liver while the watershed method is used to obtain the region of interest (ROI). The results obtained have average similarity index (SI) of 92.38% which is higher than the result obtained by region growing only which has SI of 84.82% [43].

Abd-Elaziz et al. [44] also proposed a liver segmentation method which used region growing method. First, a 3×3 kernel median filter is applied to remove noise from CT image. Prior knowledge of liver in abdominal CT image was utilized to narrow down the search area of liver. The intensity of liver region is obtained by analysing the histogram of intensity of CT image. Liver which occupied larger portion of CT image will have higher value in the histogram. The intensity range of liver was set and used to convert the CT image to a binary one with pixels that having intensity within the intensity range set to one and the others to zero. Morphological erosion is applied to the image after that. Then, region growing is applied with the initial seed point being the centroid of the largest connected area in the eroded image. Figure 2.11 shows the example of the flow of region growing. The results obtained have standard deviation of sensitivity with 96.2% and specificity with 99.2% [44].




(a)

Figure 2.11: Region growing (a) initial seed, (b) growth [44]




(b)

Figure 2.11: Continue

Chen et al. [31] proposed region growing method for liver segmentation on CT image. Anisotropic filter and Gaussian function were used to remove noise and more suitable to be segmented. By using the prior knowledge on liver like the location, intensity and topological relation between slices, the criterion for slice-to-slice region growing is set. After region growing, morphological operation is done as the post-processing step to fill in the holes created during region growing. Figure 2.12 shows the result of one of the segmented liver CT image slice using the mentioned algorithm. The red portion is the segmented liver [31].

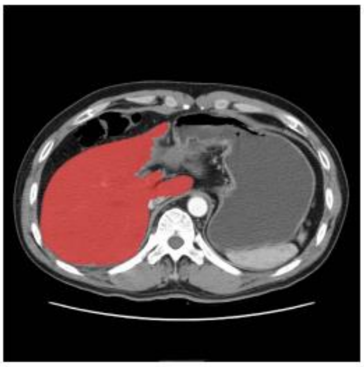
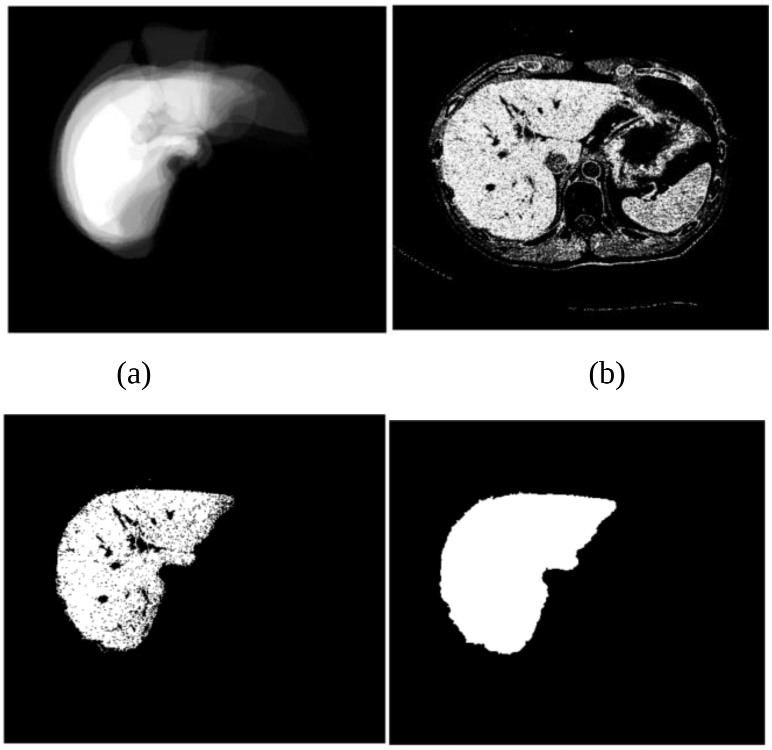


Figure 2.12: Result of region growing segmentation on CT image of liver [31]

### 2.5.3 Probabilistic Atlas

Probabilistic atlas segmentation method uses the prior shape and spatial location for segmentation. Since, it uses prior shape and spatial location, registration and normalization usually will be used to align the organs. By using information of the data sets like organs' spatial location, shape or intensities, a probabilistic atlas model can be built. Probabilistic atlas provides the probability of a pixel whether it belongs to liver or not based on the probabilistic atlas model built [12].

Farzaneh et al. [16] proposed location and intensity probabilistic atlases to segment liver. The images are required to normalize to perform this segmentation. In the proposed method, bones' locations were utilized to reposition the abdominal location and normalize the image. After the registration is done, position based probability atlas and intensity based probability atlas were built. Based on these two probability atlases, the pixels that belongs to liver from a test set can be estimated using Bayes theorem which given in equation (2.4). A rough segmentation is done by thresholding the probability. The obtained segmented liver is then used to refine the probability intensity value and a final segmentation is done by using the new refined intensity probability. Figure 2.13 (a) shows the image after being applied with location based probabilistic atlas, (b) shows the image after being applied with intensity based probability atlas, (c) shows the image after being applied with both location and intensity based atlas and (d) shows the final segmented liver. The obtained results from two males and one female for values of Dice/Jaccard volume overlaps are 89.75%/81.41%, 91.24%/83.90% and 86.37%/76.02% respectively [16].



(a) (b)

(c) (d)

Figure 2.13: Probability atlas (a) location based, (b) intensity based, (c) location and intensity based, (d) final segmentation [16]