The 13th Industrial Electronics Seminar 2011 (IES 2011)
Electronic Engineering Polytechnic Institute of Surabaya (EEPIS), Indonesia, October 26, 2011

# Anaesthesia Fluid Detection in 3D Contrast Enhanced Ultrasound Image

Sylmina Dalily Alkaff (sylmina.alkaff@nl.yokogawa.com)
Yokogawa Europe BV, Amersfoort, The Netherlands

***Abstract***

*Ultrasound medical image has disadvantage on displaying anaesthesia fluid due to its low intensity. Using contrast agent to enhance brightness of fluid area makes it possible to extract fluid area from acquired 3D image. This paper proposes an easy to implement approach to detect anaesthesia fluid. The approach will slice 3D image into arrays of 2D image, remove low intensities area from image, reconstruct fluid area to its original size, and combine 2D fluid area images into 3D visualization. The purpose of this paper is to help anaesthetist to confirm whether the operation is success and for further studying on how anaesthesia fluid spread.*

*Keywords*: Fluid Detection, 3D Ultrasound Imaging, Anaesthesia, Microbubble, Volume Visualization

## 1. Introduction

Ultrasound-based imaging system, or ultrasonography, has become an important part of anaesthesia procedure nowadays. It can display structure, needle, and surrounding tissue simultaneously, and allows a medical professional to observe the condition inside the scanned tissue area [1]. Until now the role of ultrasonography in anaesthesiology was to assist medical professional to successfully deliver the liquid by displaying needle and blood vessel in 2D plane using 2D transducer. This transducer requires an experienced user because it involves a manual position to guide the transducer directly to the desired position and to recognize the tissue structure.

However, since the introduction of new 3D transducer, it creates possibility on more detailed studies and diagnoses of inner organs because it is able to display them clearly. This transducer is also easier to use because the resulted image is generated from simultaneous reconstruction of two standard orthogonal 2D planes (X and Y), with the additional dimension of elevation [1]. Using this type of image, one can see width, height, and depth of the image without moving the tranducer. This transducer makes it easier for new anaesthetist to use it properly as guidance when injecting anaesthesia fluid. On anaesthesiology, 3D ultrasound image makes it possible to visualize the anaesthesia fluid area inside the body as shown in Figure 1.

This direct visualization allows anaesthetics to provide explanation during operation while making sure that local anaesthetic spreads to cover the entire of local anaesthetic [2]. Studying this spreading is necessary for anaesthetist to calculate and predict how effective their operation. Each patient produces different image and reaction to anaesthesia fluid depends on their physical characteristic. Patients with higher fat percentage require more anaesthesia fluid injected and it is more difficult for anaesthetist to distinct the nerve, needle, and anaesthesia fluid from fat. Patients with smaller blood flow will require more skillful anaesthetist not to accidentally inject the anaesthesia fluid to blood vessel instead. However, this importance matter has been neglected because of obvious disadvantage of ultrasound image.

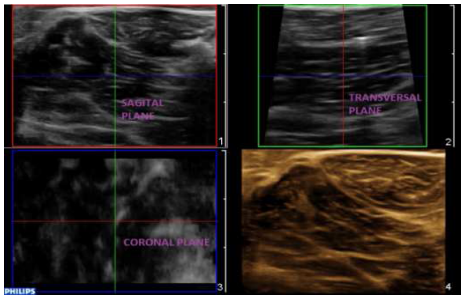


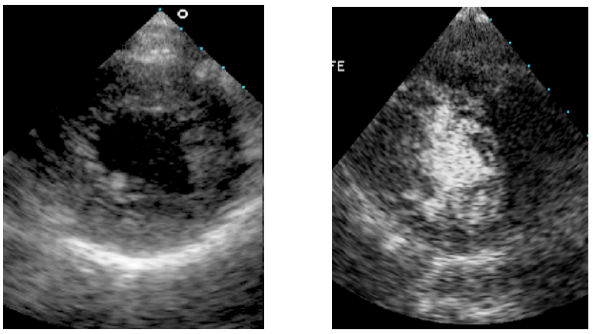

**Figure 1.** 3D Image Acquired from 3D Transducer

Ultrasound image has a disadvantage in displaying fluid since it uses brightness mode for acquisition which serves as image distinguisher. Obviously, the higher intensity the object is; for example needle and bones; the clearer its image will be. Fluid, such as water, blood, anaesthesia fluid, and fat, has quite low intensity, in which they will be seen as dark area on the image [3]. A contrast agent therefore is used in order to enhance brightness on fluid area. This medical contrast agent is a substance to enhance the contrast of structures or fluids within the body in medical image. Ultrasound contrast agents rely on the different ways than other contrast agents in which sound waves are reflected from interfaces between substances [4]. These contrast agents take a form of the surface of liquid, containing small-encapsulated bubbles, which very efficiently scatter ultrasound, are known as microbubble (Figure 2).

**Figure 2.** Microbubble

ISBN: 978-979-8689-14-7

Microbubble is widely known first as medium for echocardiography. It is usually used to detect abnormal flows between the chambers of the heart [5]. Applying contrast agent for anaesthesiology currently is still not acknowledged, even though it definitely helps anaesthetist. This contrast agent is produced from combination of liquid and gas; both must not has hazardous effect on body. It has a tremendous difference in acoustic impedance as compared to surrounding fluid due to the large difference in density, elasticity, and compressibility, thus making them have high degree of echogenicity. The echogenicity difference between the gas in microbubble and the surroundings soft tissue is immense. Therefore ultrasonic imaging using microbubble contrast agent enhances reflection of the ultrasound wave, producing a unique sonogram with increased contrast.



*(a)* *(b)*

**Figure 3.** (a) Normal Ultrasound Image (b) Contrast Enhanced Ultrasound

Figure 3 clearly describes the difference of fluid area on ultrasound image using and without using a contrast agent. In this example, it is quite easy to distinct fluid area without using contrast agent, however, there are several parts of the body which are more complicated than this one.

## 2. Image Acquisition Method

The images used in finding fluid area and testing the approach are obtained using Phillips Ultrasound System, iU22, with VL13-5 3D Transducer. This system has been used by anaesthesia department of Catharina Ziekenhuis, Eindhoven, The Netherlands, for anaesthesia procedures by using 2D transducer. The scanning mechanism consists of holding the transducer in place as it makes contact with the patient's anatomy or phantom tissues with a needle.

The 3D transducer is able to produce 3D and 4D image. While 3D image is a 2D image sequences, 4D image is constructed from sequences of 3D volume image. 3D image will be used for projecting anaesthesia fluid area and it will be extracted using QLAB software; special software designed by Phillips for further manipulation and diagnosing [6]. The images are taken during various local anaesthesia operations done by anaesthetist and ensuring that the ultrasound machine can see the produced contrast agents. Since QLAB software is not well developed to manipulate the image in order to automatically retrace fluid area detected on 3D images, MATLAB is employed to develop the detection approach. This is how the whole process work:


**Figure 4.** System Design

## 3. Fluid Detection Method

The main objective of this approach is to detect anaesthesia fluid enhanced by ultrasound contrast agent in each 2D slices and reconstruct them back to its 3D projection. The images are extracted from 3D Ultrasound image on a specific slice plane. 3D image will project anaesthesia fluid in three different planes (sagital, coronal, and transversal plane), where the approach will process only one plane to reduce time duration. The chosen plane must be able to present how the fluid spread inside human body; in most cases, it is on sagital plane.

By using contrast agent, it is ensured that the enhanced fluid area will be the brightest spot in 3D image. The approach will be coded in MATLAB, mostly using Image Processing Toolbox. The proposed approach will first slice 3D image into arrays of 2D plane to simplify further parts. After that, it will filter unwanted area and focus on enhanced fluid area by detecting the edges. Since there might be parts of fluid area are filtered, a set of morphological operation is required to return the detected fluid area into its original state. Last step will be to combine detected fluid area in arrays of 2D back into its 3D projection. The approach constructed in 5 modules as follows.

### 3.1. Simultaneous Image Processing

Since there is numerous numbers of slices must be processed, it might take some time to apply the approach directly to the resulted array of images. Therefore, processing slices of image simultaneously is employed to reduce the processing time by using advantage of Parallel Computing Toolbox provided by MATLAB. The main task of this section is to apply image processing module to each image simultaneously and save the resulting image in another set. The first portion of this module applies the main algorithm to one of selected 2D image, while the second portion will slice 3D image into 2D image arrays, select a slice of image from the array and directs it back to the first portion.

### 3.2. Data Normalization

Normalization is needed to create constant dynamic range of data voxel intensities by doing some adjustment. Each acquired image data will have different range of intensities with different variations. The data quality depends

on the patient's condition and the characteristic of the contrast agent. Mueller [7] suggested a filter for removing high frequency noise and brings out low amplitude speckle noise for signal processing on ultrasound image. This module is constructed based on this idea.

Since the region of interest in the image has high intensity, some unwanted data (low intensity objects) are removed or reduced by doing this step. Data normalization uses statistical approach, where a mean ($\mu$) is the data average value while standard deviation ($\sigma$) represents the spread of the data around the mean. The enhanced fluid area always has higher intensity then a standard deviation from its mean ($>\mu+\sigma$) because the mean of acquired 3D image is quite low (the bright areas are usually just a small part of the image). Therefore this value ($\mu+\sigma$) can be used to extract a certain range of data intensity to separate fluid area from its surrounding.

Figure 5 is one of the sliced acquired images for this experiment. The brightest area of this image is where the contrast agents or the anaesthesia fluid is located. By using this formula,

$$roi = |data - (mean + std)|,$$

it will eliminate most of the unwanted area on the image and the resulted image will only project enhanced fluid area and probably few other areas which managed to pass the filter.

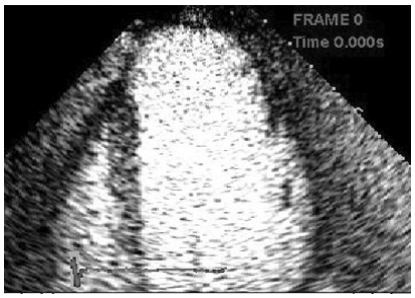



**Figure 5.** Original Acquired Enhanced Image

**Figure 6.** After Data Normalization

As shown in Figure 6, the filtered image contains most of the expected fluid area. However, it doesn't have the same brightness as the original and some parts are eliminated by the formula. Therefore it is important to restore expected fluid area into its original size and shape.

### 3.3. Edge Detection

This module is to mark the extracted fluid area to be prepared for next step and to restore to original size and shape. It can be accomplished by detecting the border of the area. There are many methods available to detect the edge of an object, such as Sobel, Prewitt, and Roberts approximation method, Laplacian or Gaussian method, zero-cross method, and Canny method [8]. This module uses Sobel approximation method since it will return the edges at those points where the gradient of the image is maximum. This module will also converts the image into black and white version for easier edge detection.

The resulted image then is transformed back to its brightness status even though there are still some part of the fluid area which hasn't displayed as whole as given in Figure 7.

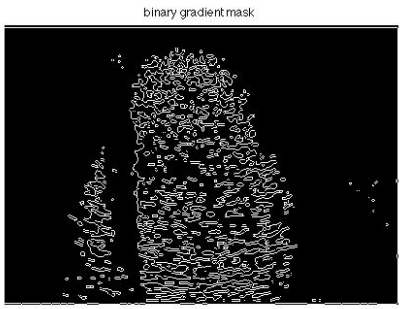



**Figure 7.** Result of Edge Detection

### 3.4. Morphological Operation

Morphological Operation is one of available tools offered in Image Processing Toolbox of MATLAB. This module will manipulate the shape of fluid area to restore its original state. Since the result in edge detection returns an image where only lines of edges available in the image, this step will dilate the detected edges. Dilation is the most basic morphological operations. It will add pixels to the boundaries of objects in an image. The number of pixels apply on the objects depends on the *structuring element* used on the operation. A structuring element is a matrix consisting of 0s and 1s and it is possible to have arbitrary size and shape. Since the last result contains small fluid areas, using two lines as its shape is enough to trace the edge and dilate them.

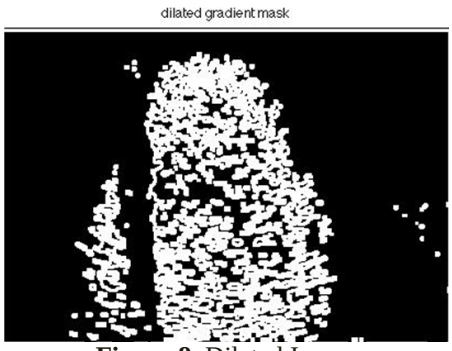



**Figure 8.** Dilated Image

After the image is dilated, the fluid area is almost the same as its original size and shape. The result still contains some black areas inside the fluid area due to its low intensity, as shown in Figure 8. MATLAB Image Processing Toolbox has a function to fill in those holes. This operation will detect the holes first by comparing the surrounding value and add more pixels to the area.

The fluid area in Figure 9 is completely detected and presented in black and white version after comparing with the original image. This is the last stage on detecting fluid area on each slice of 3D image. The result from the detection algorithm is a black and white image. This type of image is chosen for the purpose of the next step: fluid volume visualization.

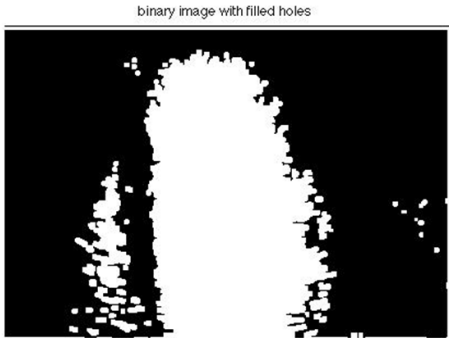



**Figure 9.** Fill Hole Function Resulted Image

3.5. Fluid Volume Visualization

Volume visualization is the creation of graphical representations of data sets that are defined on three-dimensional grids. Volume data set are characterized by multidimensional arrays of scalar or vector data [8]. These data are typically defined on lattice structures representing values sampled in 3D data. Since the data set of image result from fluid area detection section consist of single values for each voxel coordinates, the next step is to enhance scalar volume data and visualize it into 3D space. This was the particular reason of choosing black and white image because it will only visualize the fluid area of each image.

These images already contain the third coordinate, hence it doesn't require any segmentation to 3D coordinate. In order to be able to visualize the spreading, all the 2D plane images need to be displayed on 3D view and remove the background. Only by displaying these slices of image in 3D view, it is possible to see the spreading.

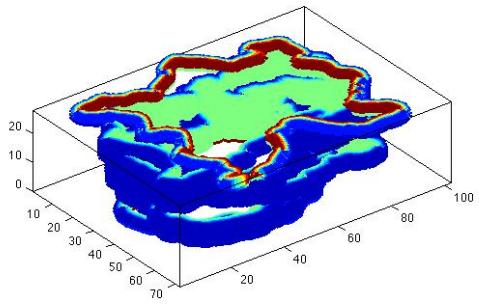



**Figure 10.** Displaying 2D Slice Image in 3D View

Figure 10 is the 3D visualization of 2D image slices in which they are actually not connected yet. Therefore we need to connect the edge of each area. The visualization should be in a cylindrical form to produce a clearer image then spreading the images all over 3D plane as shown in Figure 11.

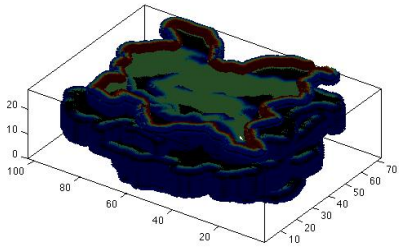



**Figure 11.** Final Result of Volume Visualization

## 4. Future Work

4.1. Position Detection

Currently this approach is not equipped with function to display where the exact detected anaesthesia fluid located in the image. In reference to Figure 4, it will be very useful to merge volume visualization with the original image so anaesthetics doesn't need to manually compare result on volume visualization with original image to ensure that they are the actual fluid area.

4.2. Implement to QLAB Software.

Currently anaesthetist could only access this approach after doing the anaesthesia operation and obtain the images. It will be more useful for diagnosing if this approach is implemented on the original Philip software, QLAB. The implementation will enable anaesthetist to study the spreading

with their patients or assistants and to ensure that the operation is successful.

4.3. More experiments with different patients

Patient's physical conditions have tremendous effect on the acquired image; for example their age, sex, and fat percentage. Therefore more experiments with different kind of patients are recommended for further testing of the approach.

## 5. Conclusion

Studying the anaesthesia fluid spreading is necessary for anaesthetist to understand how to calculate effectiveness of their anaesthesia operation and prepare for future operation. Current method to study the fluid is by using their knowledge and experience. Only experienced anaesthetics could easily detect where the fluid area is. Therefore, this paper proposes an approach to help them, especially new anaesthetic, to study more about anaesthesia fluid.

The proposed approach is using basic function available in MATLAB; therefore it is very simple and easy to understand. It also gives a volume vizualisation for the fluid area for measuring volume and spreading. However, due to research time shortage, this approach lacks function in displaying the exact location of fluid area on the image automatically. Currently anaesthetics needs to manually compare result on volume visualization with original image to ensure this approach detect the real fluid area.

This approach also cannot be used during anaesthesia operations because it needs to be implemented first in the imaging system as an add-on module. A collaboration with ultrasound imaging manufacture is needed for this implementation.

## 6. Acknowledgement

The inspiration and image provider for this paper, and many of the idea, are from Anaesthesia department of Catharina Ziekenhuis, particularly from Prof. dr. Erik Korsten. The writer would like to express her sincere gratidue to Prof. dr. Erik Korsten for his kind advice and support for the completion of this work.

## References

[1] Website of Ultrasound for Regional Anaesthesia. www.uscra.com
[2] Marhofer P, Willschke H, Manfred G, Stephan K. New Perspective in Regional Anesthesia: The Use of Ultrasound — Past, Present, and Future. Canadian Journal of Anesthesia 2005.
[3] Alkaff, Sylmina Dalily. Anaesthesia Fluid Detection using 3D Contrast Enhanced Ultrasound Imaging. Department of Electrical Engineering, Institute of Technology Sepuluh Nopember. 2010
[4] Van der Meer, Sander. Ultrasound Contrast Agents: Resonance of Coated Bubbles. Department of Physics of Fluids. University of Twente. 2006.
[5] Blomley, Martin J.K., Cooke, Jennifer C., Unger, Evan C., Monaghan, Mark J., and Cosgrove, David O. Microbubbles contrast agents: a new era in ultrasound. Clinical Review. 2001.
[6] Philips QLAB Quantification Software User Guide
[7] Mueller, Klaus. Lecture Note on Introduction to Medical Imaging: Ultrasound Imaging. Computer Science Department, Stony Brook University. [No Date]
[8] MATLAB Image Processing Toolbox User Guide

**Sylmina Dalily Alkaff** was born in Surabaya, Indonesia in 1988. She holds Engineer degree (Ing) in Electrical Engineering from Fontys Hogescholen, Eindhoven, The Netherlands and Bachelor Degree (ST) in Electrical Engineering from Institute of Technology Sepuluh Nopember (ITS), Surabaya, Indonesia. Currently, she works for Yokogawa Europe BV, The Netherlands.