# Image Modalities: Ultrasound 3D

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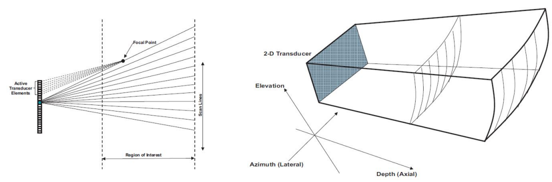
## Abstract

*The main purpose of this lab is to get a general understanding of ultrasound systems performance,and problems related with the acquisition of a clear image using this kind of systems. The main differential of the method is that it is not invasive, so it could be an alternative sensible organs, for the control of the treatment and evolution of several patients or pregnant women.*




(a) Sound wave focusing (b) Transducer's detail

Figure 2: Sound wave propagation

## 1. INTRODUCTION

Ultrasound systems are based on devices that allows to send sound waves with a known wavelength and receive the echo that is produced by the bouncing of the same wave with tissues. The difference in the reception time for waves emitted at same moment allows the recognition of various tissues. The waves are emitted

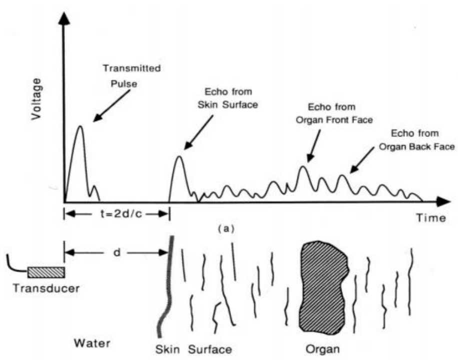



Figure 1: Voltage/time representation of US system

by one probe which has matrix of piezoelectric sensors inside. This probe acts as emitter and transmitter and is implemented with several shapes.

This is a very expensive element of the device, due to the accurate impedance it should have to match between the device and the human skin. The way and the size of this probe will influence on the resolution and conversion process of the image acquired.

Figure 3: Linear, curved and sector transducers

Except on the case of the linear array transducer, the acquisition of the image is made in polar coordinates $(\rho, \theta)$, that should be converted into Cartesian coordinates in order to be readable and storable for the devices. It is part of the preprocessing, that could be structured as is illustrated in [REFERENCE].

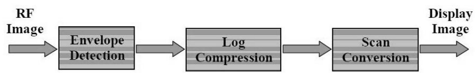



Figure 4: Preprocessing structure

### 1.1. Envelope Detection

Envelope detection is nothing but getting the pulses inside a shape (for example a Gaussian) and this will improve the propagation characteristics of the resulting sound wave. Logarithmic compression.

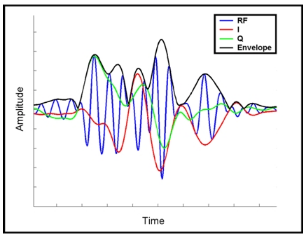



Figure 5: Envelope representation over US signal

### 1.2. Logarithmic Compression

In general, the digitized signal is stored in the computer memory in one of 256 values. Each value represents an echo amplitude. Sometimes, 256 values produce a noisy, or fuzzy, image. Using a logarithmic transformation of the signal levels, certain values can be eliminated. This results in a cleaner image and is ideally suited for eliminating low-level noise. Log compression reduces the dynamic range of the displayed image, that is, fewer shades of grey are displayed.

### 1.3. Scan Conversion

This is traditionally the stage at which interpolation between envelope signal lines occurs, to determine the echo amplitude values that must be written to a display memory whose read-out is in rectangular coordinates, even though the echo lines may have been collected in a polar coordinate system.

## 2. Dicom files

Dicom is a standard for medical image files, that is nowadays use for most of the medical equipment providers and medical environment in general. This file has already the information of the patient, avoiding any mismatching between patient and image.

### 2.1. Dimensionality of data, number of pixels and size of them

Given a Dicom file the lecture from a computer of the header of the file could provide all the technical information and the personal details of the patient. The image has a format of *4D 8uint*, and this means that it is a sequence of 3D images over a period of time. The number of pixels per frame is 904 x 186 (width, height), and if the total amount of pixels during the sequence is 2.1018 x $10^7$.

### 2.2. Volume histogram visualization

The study of the histogram for all the pixels in the image could be useful for enhancing or changing the contrast, allowing with simple operation to get a cleaner image even before filtering. For the implementation of the volume histogram it is necessary to reshape the 4D matrix that represent the image during time into an array with all the pixels. After getting the array the histogram will be compute as a simple one.

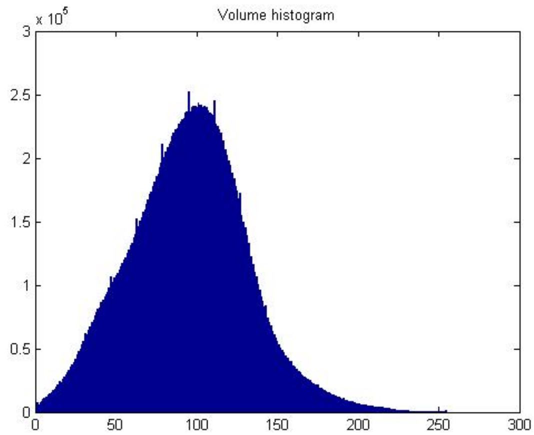



Figure 6: Preprocessing structure

### 2.3. Visualization of slices

The visualization of single slices using *Matlab* provides a view that is not easy to understand even for doctors.

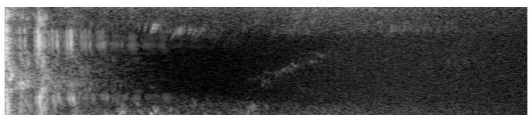


Figure 7: Slice of ultrasound image

### 2.4. Matlab code

The code implemented to get last results is in Figure 8

```
% Read info from dicom file
info = dicominfo('04534601.dcm');

% Storage the image of a dicom file
img = dicomread('04534601.dcm');

% Conversion of image from 'uint' to 'double'
% and reshape into column array
imgTotal = (double(img(:)'));

% Volume histogram
figure
hist(imgTotal, 400);
title('Volume histogram');

% Slice analysis
slice1=img(:,:,:,1);
figure(2)
imshow(slice1);
```

Figure 8: Matlab Code

## 3. Image Transformation

### 3.1. Distortion of the image

The image observed in Matlab from the DICOM file has a distortion that doesn't allow the correct interpretation of it. It is because of the format in which the image was stored.

### 3.2. Transformation of the slice

To have an understandable view for humans it's necessary a conversion from Cartesian to polar coordinates, to recover, the way the image was collected.

### 3.3. Problems for the conversion

The are some issues to consider before the implementation of the transformation of the image. Fist one is related with the point to be considered the origin in polar coordinates and the set up of initial and final radius $\rho_0$, $\rho_f$. The second one is related with the interpolation, of the points and step to consider for them.

#### 3.3.1. Interpolation methods. .

1. Nearest neighbour interpolation. This method allows an approximation giving more weight to the closer neighbour to the point being estimated. The easiest way to do it is just consider the closest neighbour and giving the same value to the point.

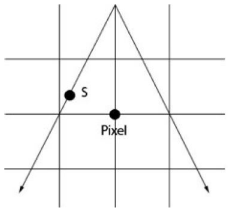



Figure 9: Nearest Neighbour Interpolation

$$\theta = round\left(tan^{-1}\left(\frac{x}{y}\right)\right) \tag{1}$$

$$r = round\left(\sqrt{x^2+y^2}\right) \tag{2}$$

2. Linear interpolation. It is an approximation that uses the two neighbours values of angle an radius to calculate the estimated value of the point.

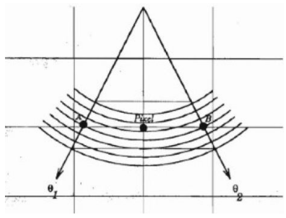



Figure 10: Linear Interpolation

$$Pixel = AxB + Bx(1-C) \tag{3}$$

It could be represented in Figure 10, where A is the value of pixel A along vector $\theta_2$, B is the value of pixel B along vector $\theta_1$ and C is the distance between the pixel and C.

3. Bilinear interpolation. This approximation is performed using four data from adjacent vectors to compute the pixel.

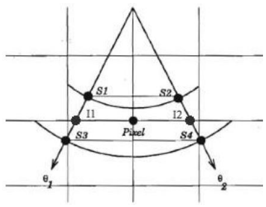



Figure 11: Bilinear Interpolation

$$I1 = S1 * X + S3 * (1-X) \tag{4}$$

$$I2 = S2 * Y + S4 * (1-Y) \tag{5}$$

$$Pixel = I1 * Z + I2 * (1-Z) \tag{6}$$

## References


[1] 'Signal Processing Overview of Ultrasound Systems for Medical Imaging' - Texas Instruments - Murtaza Ali, Dave Magee and Udayan Dagupta - November 2008

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[6] 'Image Formation and Image Processing in Ultrasound' - Jeffrey C. Bamber - Institute of Cancer Research and The Royal Marsden NHS Trust, Surrey, SM2 5PT