

The Design of a 3D Ultrasound Image Acquisition and Reconstruction System based on Mechanical Locators.

During the last year of graduation (2000-2001), my colleagues and I at Cairo University decided to work on a project which combines both hardware and software engineering principals. We intended to work on a useful system that will help us in applying our hardware skills (working on IC's and other electrical components) in conjunction with our software skills (high and low level programming languages), and also to assist us in learning new techniques that will increase and develop our experience.

When physicians scan the patient's body manually using ultrasound probes or transducers, this manual procedure evolves in some distortions to the acquired image, besides the physician can not determine the distance to be scanned accurately. Also 2D viewing of 3D anatomy limits the physicians' ability to quantify and visualize most diseases, causing variability in the reported diagnosis and ultrasound guided therapy and surgery even though the acquired 2D image is free of any distortions. This occurs because the acquired images by the mechanical locator system are 2D, yet the anatomy is 3D; hence, the diagnostician must integrate multiple images in his mind. This practice is inefficient, and may lead to operator variability and incorrect diagnoses. In addition, the acquired 2D ultrasound image represents a single thin plane at some arbitrary angle in the body. It is difficult to localize and reproduce the image plane subsequently; thus using the mechanical locator system in conjunction with the volume reconstruction and visualization software will help in reconstructing a clear and error-free 3D volume which enables the clinician to "cut" the volume in any orientation to reveal the desired anatomy. This provides clinicians a better appreciation of the internal architecture of many organs and their interfaces with other anatomical structures.

So the main objectives of the project was to design an efficient and reliable system that produces no distortions to the acquired image and enables the operator to specify accurately the distance to be scanned by the mechanical locator system, and then displaying a 3D reconstructed volume from a set of acquired 2D images on an inexpensive desktop computer, so this low price system could compete with other similar biomedical related ultrasound mechanical locator scanner devices in the local market of my country.

We distributed the responsibilities in between us depending on the skills of each of us, so we divided the project into two main parts:

1. *Mechanical locator system design and image acquisition.*

The first part had to be accomplished in the first semester of the final graduation year and was subdivided into 4 parts, these parts consists from the design of the electric circuit which will drive all three systems (linear, tilt

and rotational scanning) to the other mechanical parts such as the motors, power screws, the attachments which will hold the transducers or probes, and the type of material that the housing of the systems will be made of, and finally the software program which will control the three systems. The 4 parts were:

a. Linear Mechanical Locator Scanning System

Is used to scan surfaces that do not contain many curvatures and permits the Ultrasound transducer to move smoothly (e.g. abdominal imaging).

b. Tilt (fan) Mechanical Locator Scanning System

Is used in specific areas in the human body where a tilt or fan movement is required because of the curved or nonlinear surface of the scanned area (e.g. fetus imaging).

c. Rotational Mechanical Locator Scanning System

Is mainly used in scanning parts of the body in which neither the linear nor the fan (tilt) scanning procedures can be used in these areas (e.g. transrectal imaging).

d. Driving the Mechanical systems

Development of a software program in order to control the movement of all 3 systems (see figure1).

2. *Volume reconstruction and visualization techniques.*

The second part was purely software, which was subdivided into 3 parts to be distributed on the group; this part was accomplished in the second semester of the final graduation year. The 3 parts were:

a. Volume reconstruction

This is the generation of a 3D representation of the examined structures from the acquired set of 2D images. The acquired series of 2D images are built into a 3-dimensional voxel-based Cartesian volume by placing each acquired 2D image in its correct location in the volume.

b. Interpolation of Images

Is the enhancement procedure of the displayed 3D volume, where the grey scale or color values of any voxels not sampled by the 2D images are calculated by interpolation between the appropriate images.

c. Volume visualization techniques.

Which are the rendering techniques that were used to visualize the 3D reconstructed volume in multiple ways depending on which part of the volume the physician wants to examine.

Summary

The development of such system assisted in the improvement of 2D scanning techniques; that is, motorized scanning is more accurate than manual. Besides the elimination of possible distortions that might occur to the 2D acquired image, and knowing the exact distance of the examined organ. By that, we insure that the video-frame grabber card in the used computer will receive error-free data to reconstruct a clear and fine 3D image out of the 2D scanned images. Also this project will improve the physician's ability to interactively view the organ under investigation in multiple simultaneous planes, and viewing the surfaces of structures using volume rendering techniques that allow better visualization of its internal architecture. These approaches as well, allow physicians to diagnose and detect disease, displaying volumes accurately, and plan and guide minimally invasive procedures which will enhance reported diagnosis and ultrasound guided therapy and surgery.