A COMPUTERIZED ULTRASOUND PROCESSING, ACQUISITION AND DISPLAY
(CUPAD) SYSTEM*: RESEARCH IN ULTRASOUND IMAGE GENERATION

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In this paper we would like to outline the philosophy of our research program at the University of Kansas Medical Center and describe the structure of our research imaging system. The next two presentations will outline some of our hardware and software accomplishments and give initial clinical appraisal of our first images.

A diagrammatical representation of the information flow in a pulse-echo ultrasound imaging system is shown in Figure 1. The purpose of this system in clinical medicine is the most efficient transfer of relevant information to the physician to aid him in forming a diagnosis.

![Diagram of ultrasound imaging system](image)

Figure 1
Information Flow in an Ultrasound Imaging System

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The components of the imaging system are:

The patient, cross sectional anatomy to be scanned by an ultrasound beam;

The transducer, emitter of ultrasound pulses and detector of the resulting echoes;

The receiver, amplifies the low energy echo signals. The large dynamic range of echo energies is accommodated by logarithmic amplification as well as time variance of gain to compensate for tissue attenuation;

Video detection and signal processing, most clinical apparatus detects the echo amplitude with some analog signal processing;

The display, the ultrasound information is usually displayed in B-mode, in which a minified image of the patient cross section indicates the anatomical sites of origin of the received echoes;

The physician, the final image is formed in the visual cortex of the physician's brain. The physician will then interpret this image and use the information in forming a diagnosis.

The imaging machine has been divided functionally into acquire, process, and display units.

To realize an effective clinical imaging system, the information flow should be maximized. The eye-brain combination is already an optimized viewing system. Thus, the question becomes what ultrasonic data should be acquired and how to best acquire, process, and display it for the diagnosis of various disease states.

To answer these questions and learn how to build an effective clinical ultrasound imaging system, we began our present research program. In designing this program, some basic decisions were made.

1. Very sparse information was available for the design of an effective clinical imaging system. The judgment was made NOT to build a system that would compete with existing ones since this would involve many a priori decisions which would seriously constrain the data handling capabilities and flexibility of the system.
2. A system should be developed with as few a priori decisions as possible to be used as a research tool to learn how to best build an effective system for clinical use.

3. A digital computer should be a central component of the system because of its memory and computational abilities along with the flexibility and ease in implementation of software control. (Although we feel the computer is essential in a research system, it might not be necessary, desirable or even practical in a final clinical system).

4. The system should be of modular design for ease in changing data handling schemes.

5. The contact B-scan should be the mode of data acquisition due to its wide clinical acceptance; and

6. A sampling technique should be used in acquisition. One sample of the echo wave train is taken for each transmission pulse. There is a trade-off between data acquisition rate (scan time) and system flexibility. This low sampling rate was chosen to give increased flexibility in research while still permitting real time operation.

A block diagram of our research system, CUPAD, is shown in Figure 2. The ultrasound data is acquired by the ultrasonic scanner (a Picker EV-6) and digitized by a specially designed interface. The data is then transferred to a PDP-15 computer (64K of core, two 250K word fixed head disks and two 10.2 million word disk pack drives) in which it is processed and stored. At selectable intervals during the scan, the data is transferred to the MIPED System for display on color or black and white T.V.'s in a 128 X 128 resolution cell matrix coded in up to 16 colors or gray levels.

The MIPED System (Medical, Image, Processing, Enhancement and Display, NSF Grant GJ-28779) was built for Nuclear Medicine image processing. It also has standard feature extraction post-processing capabilities which will be used at a later stage in our research.

CUPAD will be used as a research tool to answer the questions:

1. What ultrasonic parameters are important for the diagnosis of various diseases, and

2. How to optimally acquire, process, and display this information.
A great deal of information is contained in the received echoes. The electrical signals obtained from the transducer allow independent or simultaneous measure of echo amplitude, frequency, phase, or transmission time delay.

Echo amplitude was chosen as the first ultrasonic parameter to investigate. The acquisition variables to be studied include: 1) digital resolution (up to 8 bit), 2) peak amplitude detection in each image resolution cell, and 3) measurement of the average echo amplitude in each resolution cell.

The processing variables to be studied include: 1) computing the average of all samples of each resolution cell, 2) storing the maximum value of the samples for each resolution cell, 3) correcting each individual sampled wave train for its calculated tissue absorption, 4) beam pattern corrections and 5) detection and removal of reverberations.

The display variables to be studied include: 1) color T.V. images with up to 16 color levels, 2) black and white T.V. images with up to 16 gray levels, and 3) display refresh rate.
Figure 3

Gray Level Stretching.
One possibility for displaying midrange amplitudes with high resolution.

In order to objectively evaluate the various data handling schemes which will be implemented at different times, it is essential that the same raw analog ultrasonic data be used. The tape recorder, Honeywell Model 96, 2 MHz, in Figure 2 is used for this purpose. It will be used in clinical examinations to record the data from the ultrasonic scanner in order to produce an archive of raw scan data.

The first experiments we will perform with CUPAD will be standardized measurements of echo amplitudes from anatomical regions of potential clinical importance for both normal and diseased tissue. This is an important measurement because we will then have the information necessary to acquire and display relevant echo amplitudes for medical diagnoses. Once acquired, they will be the proper data base for data handling studies.
Figure 3 illustrates one possible acquisition and display technique (gray level stretching) to be used if the relevant clinical information is limited to the range between $1/4$ and $3/4$ of the maximum amplitude. Echoes in the lower amplitude quartile are displayed as black and echoes in the higher amplitude quartile are displayed as white. The six remaining gray levels are then used to display the relevant amplitude midrange.