The Verasonics Ultrasound Engine

A New Paradigm For Ultrasound System Architecture

Verasonics announces the release of a revolutionary ultrasound system architecture that performs high quality imaging for a fraction of the cost of premium systems. The architecture also enables straightforward implementation of newly developed imaging approaches which cannot be implemented on current systems. This flexibility is due to the elimination of custom integrated hardware conventionally used for signal processing, and the transition of all beamforming and application specific processing tasks to innovative software algorithms running on a host computer. Verasonics' approach leverages the low cost and rapid performance gains of personal computing technology by the development of a flexible high bandwidth data acquisition system that communicates with the host via standard PCI-express. The system offers a high level software development environment for efficient implementation of traditional as well as new ultrasound modalities. The result is premium performance and unparalleled market differentiation: competing systems simply cannot achieve the high dynamic range, rapid frame rates, and real-time imaging mode combinations that are straightforward to implement on the Verasonics platform. Moreover, Verasonics provides a unique system simulation tool that permits application development at real-time frame rates without the acquisition hardware, further facilitating innovation. Initially developed specifically for medical ultrasound imaging, the Verasonics system is also suitable for use in non-destructive evaluation, underwater acoustics, and many other applications requiring broadband multichannel data acquisition and flexible processing. Systems are currently available in single or dual board configurations, with 64-transmit/32-receive channels per 11"x14" board mounted in a custom chassis, and are compatible with Windows, linux, and Mac OS operating systems.

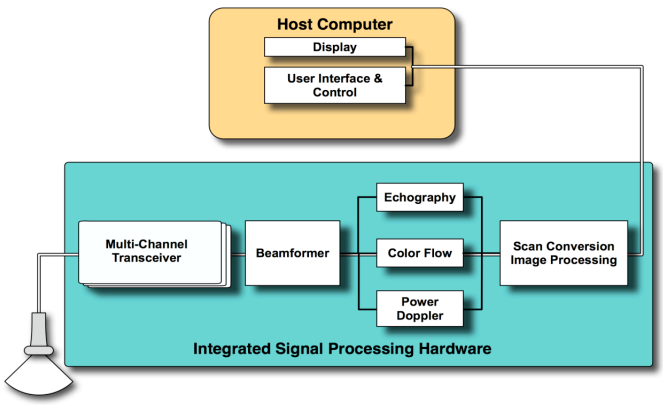

Figure 1. Conventional Flow-through Data Ultrasound System Architecture

Premium ultrasound systems use a minimum of 128 channels, sampled at 30 MHz or more to form images and present blood flow data. In a flow-through architecture, the data is collected and processed serially via a selected path. In particular, beamforming is performed in dedicated hardware using a fixed algorithm. Frame rates are limited by the slowest element in the chain, and processing capability is designed to meet the most challenging scenario. Often, such processing power is much more than is needed, and produces redundant information that is further processed downstream. Redesign of processing hardware is time consuming and expensive, inhibiting adoption of new imaging modalities.

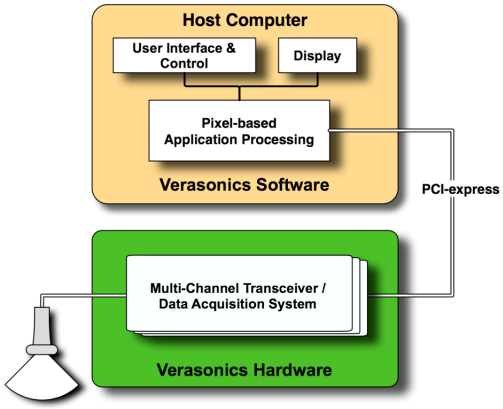

Figure 2. Verasonics Software-Based System Architecture

The Verasonics architecture pairs a flexible data acquisition system with a desktop computer to achieve high performance ultrasound imaging. Un-beamformed data from each transducer element is available for processing on the host, and Verasonics' Pixel-based processing software uses only the most significant portions of the data to optimize performance. Design cycles for software applications are far shorter than for custom hardware, and flexibility of the system in terms of both transceiver sequencing and data processing permits rapid development of new applications that are currently impossible to implement on traditional platforms.

The tradeoff between performance and cost for the conventional ultrasound system

Medical ultrasound systems must provide high quality sonographic images at frame rates sufficient for real-time clinical visualization. To achieve desired spatial and temporal resolution, many independent signal channels are required and system designers have relied on dedicated hardware solutions to perform the data processing tasks for the large data flow. The processed information is greatly reduced in bandwidth

and is thus easily transferred to the host computer for annotation and display. The data flows continuously through a conventional system, with a dedicated processing path for each imaging mode (see Fig. 1).

Hardware-based systems are costly to build due to reliance on large, high density circuit boards with custom integrated logic circuits, coupled with relatively low manufacturing volume. Such systems are also expensive to develop and to upgrade because hardware design cycles are long. Premium systems are typically priced over $100,000, and many clinical sites choose to compromise by either purchasing used equipment, or by purchasing new systems in the mid- or low-end markets (nominally priced below $100,000, and below $30,000, respectively). These systems compromise on image contrast and resolution in order to reduce cost, often by using fewer channels and inferior transducer probes. In either case, customers do not have access to the latest developments in ultrasound methods and technology.

Verasonics' software-based architecture

Verasonics has been developing software-based ultrasound systems to greatly reduce both manufacturing cost and development time. Our innovative hardware and software solutions have permitted shifting most of the tasks conventionally requiring custom hardware to software running on the host computer *without compromising clinical performance*. Relatively inexpensive general purpose personal computers are now highly capable computational tools, commonly providing large memory sizes, very fast processing, and fast expansion bus communication to external devices. Nevertheless, software-based ultrasound systems are only practical if the standard "flow-through" data processing approach, in which all channel data are processed continuously as they are collected, is replaced by an algorithm which processes only those data that are required to form a given image. This new technique, called "pixel-based" processing, greatly reduces the memory bandwidth and processing load requirements of the system. Direct implementation of a conventional flow-through architecture in software would result in an unacceptable computational load, estimated to be at least two orders of magnitude too slow, and has likely led other designers to dismiss software-based approaches. The Verasonics architecture is diagrammed in Fig. 2.

Ultrasound processing using personal computers leverages the rapid gains in performance and high volume commodity pricing of the computer market. The flexibility gained by software processing provides enormous reductions in development cost and time to market for the ultrasound applications developer. Furthermore, recently developed ultrasound modalities that use new acquisition sequences and processing steps are impossible to evaluate on current hardware-based systems. The Verasonics platform provides the flexibility to implement such new approaches, and the performance that permits clinical evaluation of the new modalities.

Verasonics' data acquisition hardware

The Verasonics hardware "front end" is a programmable data acquisition system with analog transmit/receive circuitry, analog to digital conversion, local memory, and a PCI-express interface. The system sends a minimally processed data set to the host, retaining maximum flexibility for processing. No receive beamforming is done in hardware, and the data rate to the host is indeed very large: the acquisition system is able to transfer the equivalent of a 800 MB CD every second to the host, or alternatively, about 400 channels of 1080i high definition TV continuously, via standard PCI-express*. The resulting flexibility is an advantage to researcher and application engineer alike: it is straightforward to compare different processing schemes under realistic conditions. Implementation of new data acquisition sequences and beamforming algorithms for application development and optimization is feasible even with a production system. The Verasonics hardware performs a relatively simple data acquisition and data transfer function and thus does not require customization or redesign for a wide variety of applications.

Several signal processing approaches are combined in the Verasonics front-end to reduce the raw data rate without loss of information. The sampling frequency is adjusted to match transducer probe bandwidth, and quadrature sampling (that is, at 4 times the fundamental probe frequency) permits efficient post-processing of the data, for example, by removing the need for using the Hilbert Transform in Doppler processing. Programmable digital filters and delay lines permit fine tuning and calibration of individual channel response functions.

Once on the host, novel beamforming and image reconstruction techniques are used to further reduce the processing load to the minimum required to produce the image of interest. These include our patent-pending pixel-based processing technology, as well as processor specific optimization using SIMD programming (Single Instruction Multiple Data vector processing).

Pixel-based processing

The minimum data set required to form a high quality diagnostic image is far less than the full data stream coming from the transducer. The pixel-based

* Standard compressed 1080i HD data stream uses 2 MB/s

approach optimizes data collection and processing by identifying the set of data samples needed to produce each pixel in the final image. Thus, conventional beamforming and image processing steps are combined and reformulated as "image reconstruction" routines. Data that can be used for computing several different pixels is efficiently cached, and both the acquisition sequence and processing flow are designed together to optimize signal to noise ratio and frame rate, both clinically significant metrics.

The pixel-based processing algorithm is outlined in Fig. 3. The processing steps for each pixel are efficiently implemented using matrix operations with fixed coefficients that are only calculated once for a given user-defined region of interest (ROI) and stored in a LookUp Table (LUT); compiled software running on a general purpose central processing unit (CPU) can therefore achieve processing frame rates that rival or exceed those of conventional hardware-based designs.

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User defines image region (ROI)
Define associated "pixel space" grid
For each pixel,
    determine the data region used to reconstruct --> LUT1
    load data region
    process data --> LUT2
    generate intensity (color value) for each pixel
Annotate & display image frame
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Fig. 3 Pixel-based Image Reconstruction

Sequence Programming

The Verasonics system is extremely flexible to program because of the essential simplicity of the data acquisition hardware, and the use of a sequential modular programming structure. The operation of the system is defined as a chain of "events" that define transmit and receive conditions, application-specific image reconstruction procedures, and annotation and user display. Different imaging modalities are straightforwardly specified by different event sequences, all defined in software and saved in a control file. It is comparatively easy to optimize a sequence for a particular ultrasound mode, and to develop completely new ultrasound modalities than rely on sequences that are impractical to implement in a fixed-hardware environment.

Real-time system simulator

Finally, Verasonics introduces a unique capability: real-time simulation of the entire system, using a software simulator that runs on the system host computer (Windows, Mac OS X, and linux operating systems are supported). The simulator is very tightly integrated with the hardware system; indeed, the same sequence control file format used to program hardware execution is used to drive the simulator. The software architecture of the Verasonics system permits using different processing code for pre-recorded element-level data, making the simulator an invaluable development tool for optimization of processing schemes and evaluation of real-time frame rates. The complete compatibility of event sequence file structure permits instant porting of simulated control sequences to the hardware for experimental evaluation with the hardware and new target media. This unique capability can also be useful in manufacturing steps such as system verification or scanhead testing.

Summary

Verasonics has developed a software-based ultrasound system architecture that performs high quality imaging for a fraction of the cost of premium systems, and permits implementation of new imaging modes that are not currently feasible on conventional platforms. The approach replaces dedicated processing hardware underlying conventional designs with a high performance data acquisition system and software running on a desktop computer. Because no receive beamforming is done in hardware, element level data is available to the processing software for unequaled flexibility. Indeed, many new imaging techniques that are straightforward to develop on the Verasonics platform can simply not be implemented on conventional systems without comprehensive redesign. The system can be straightforwardly configured to provide very high frame rates, high dynamic range, various forms of compounding, and combined imaging modes. New ultrasound methods under development by the research community are such as thermal therapy monitoring, detection of internal bleeding or vascular stenoses, and tissue elastography, are for the first time straightforward to implement on a clinical instrument.

The new Verasonics ultrasound system ushers in the future of ultrasound system architecture by transferring all but data acquisition tasks to software. The flexibility of the software-based system reduces cost of both manufacturing and design, and encourages the implementation of new modalities that could not practically be attempted before.

Further information

For further information about the company and the product, please refer to the website.

http://www.verasonics.com/