

A Flexible Research Interface for Collecting Clinical Ultrasound

Kris Dickie^a Reza Zahiri^a Laurent Pelissier^a Corina Leung^a

^aUltrasonix Medical Corporation, 130-4311 Viking Way, Richmond BC, Canada V6V 2K9

ABSTRACT

The Sonix RP is an easy to use ultrasound imaging device that is capable of acquiring high quality images. In addition to supporting the acquisition of multiple data types such as RF, elastography, and color doppler data, the machine is an open ended system providing users with full control over imaging parameters through an investigational research interface. Since the Sonix RP is PC based and it supports open-source software development toolkits, programs can be developed and executed directly onto the device, thus eliminating the need for extra hardware that is often required for data collection and analysis. Due to these advantages, many universities and research institutes have successfully used the Sonix RP to test and implement their customized solutions for different applications.

Keywords: Sonix RP, ultrasound, data acquisition, research

1. INTRODUCTION

Ultrasound is one of the most inexpensive and safest methods to capture real-time medical images. The advantages of this imaging modality has made it popular for many medical applications such as elastography imaging,¹ radio-therapy,² and image guided interventions.³ The latest PC technologies have made it possible to create new interfaces for collecting images and data for research purposes particularly for the applications mentioned. The acquisition of clinical images for research purposes is not a new topic, however many obstacles have stood in the way of acquiring high quality images using a simple method. Today a majority of image data acquisitions require video capture boxes that convert an analog signal into a digital format. A common technique for ultrasound data capture in the past required the use of a frame grabber card inside of a PC that is connected to the clinical machine.⁴⁻⁶ Although this method can be used with many devices, it comes with disadvantages such as lossy data capture, extra hardware, and the fact that the analog signal does not provide meaningful information about the images being captured. This data capture technique also hinders clinical ultrasound scanners from being used for research purposes, especially for developing new ultrasound processing algorithms where *radio-frequency (RF)* signals need to be collected for further analysis.

With the advent of PC based systems being used in the design of medical equipment, the ability to overcome obstacles in data acquisition has been much improved. In the past, research platforms and *ultrasound research interfaces (URI)* were developed on commercially available ultrasound systems for the purpose of raw data acquisition. This is not an easy task as many clinical ultrasound systems do not provide adequate information on the data processing chain. Researchers had to modify the hardware on a Technos MPX medical ultrasound system by installing an analog front end for waveform generation and an RF-Grabber board for collecting RF signals.⁷ Much work was involved to obtain the RF data and to implement a separate beam forming and data processing algorithm for this system. While the software based modification developed on a Hitachi HiVision 5500 machine⁸ enabled users to capture RF data in real time, there was the limitation that ultrasound transmit and reception beamforming parameters could not be modified. The URI that is available on the Seimens Antares system⁹ allows for control over receive parameters, however, transmit beam former parameters such as aperture and pulse shapes cannot be user-adjusted. In addition, researchers are limited to using ultrasound transducers supported by the clinical scanner. This may pose limitations in research applications which require customized

Further author information: (Send correspondence to)
Kris Dickie: E-mail: kris.dickie@ultrasonix.com, Telephone: 1 604 437 9500

probes with different frequency ranges and the optimization of the transmit beam such as in ultrasound contrast-enhanced imaging.¹⁰

The Sonix RP research interface was developed by Ultrasonix Medical Corporation to ease ultrasound data acquisition and post processing of these images. The system is equipped with an investigational research package that includes pre-beam forming real-time acquisition software, video capture, RF mode, and *SDK (Software Development Kit)* for client applications. With flexible control of the complete ultrasound signal path in an open architecture, Sonix RP is the only open research-driven ultrasound system in the market. The research platform offers access to pre and post beamformer RF and provides adjustable parameters to control filtering, envelope detection, and compression, making it possible for in depth data analysis. The SDKs provided allow programs to be developed and executed directly onto the device thus eliminating the need for additional hardware. In addition, custom ultrasound transducers can be easily integrated onto the device allowing researchers to use the system for many different applications. With the Sonix RP, the user experience is greatly improved and users can tailor the system to their working environment while still maintaining the clinical integrity of using a robust medical device.

2. METHODOLOGY

2.1 System Architecture

Figure 1 shows a block diagram of the Sonix RP system architecture. Transducer arrays plug into the front block of the device and are used for transmitting ultrasound echoes. The ultrasound beamformer focuses and receives the signals for processing. The signal undergoes envelope detection, compression and filtering. Communications between the CPU and the ultrasound module allow for data to be transferred and displayed using a graphics card.

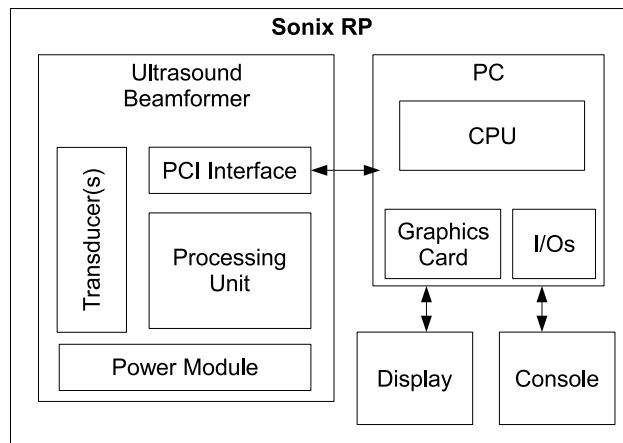


Figure 1. Sonix RP system architecture

2.2 Sonix Research Package

The Sonix RP ultrasound software is designed with a simple to use graphical interface to capture high quality images and data directly from the device without the need for third party hardware. The exam software used on the machine is responsible for both the display and image acquisition. The user is able to switch between clinical and research modes through a button on the console. In research mode, additional side menus provide the user with full control of the ultrasound transmit, receive, and filter parameters. Since many researchers utilize Matlab for data analysis, we have also integrated the ability for the exam application to open Matlab windows for viewing individually stored image frames such as pre-scan B mode, and RF. In addition, Matlab data analysis scripts are provided for users to perform offline data analysis and post processing. For added research flexibility,

the Sonix research interface does not limit users to specific ultrasound probes. By using a probes setup program, researchers are able to integrate customized probes to be used on the device. In addition, the Sonix RP also supports multiple SDKs so that custom programs can be developed and executed directly onto the machine.

2.3 Data Acquisition

The exam software supports the acquisition of multiple types of image data obtained through a programmable cine storage interface. Once the user is satisfied with their scan, they can freeze the acquisition to gain access to the data to recall and display the cine buffer, or the block of memory that stores a limited set of data. The length of acquisition stored in the buffer can vary depending on the memory size allocated for the cine, the depth of acquisition, and the number of scan lines or ultrasound beams used to create a single image. Because the Sonix system is PC based, it is very flexible to change the amount of memory used for cine buffer allocation. Figure 2 shows the data storage screen that is available in research mode. Once imaging is frozen, the user can select a range of frames to store to disk as a dataset. This range can be specified also as a retrospective time parameter. The files stored to disk can later be opened up on the system or another computer for analysis and processing. Some of the more useful data types provided by the Sonix machine include B-mode, *radio-frequency (RF)*, color doppler, and elastography data, the details of which are discussed in the following subsections. Figure 3 also show examples of the images obtained in these imaging modes.

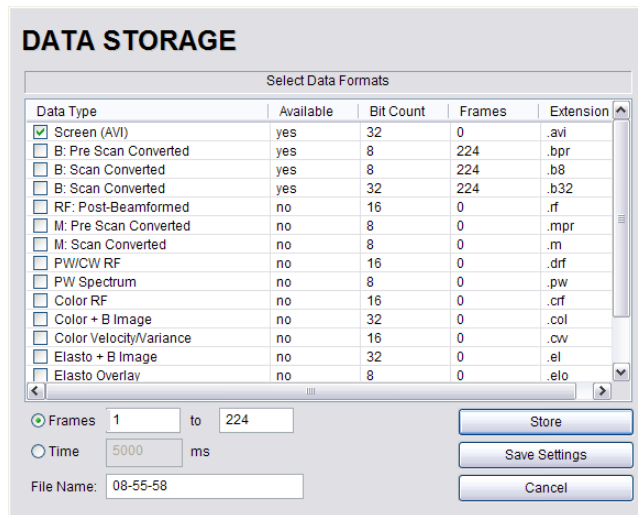


Figure 2. Data storage dialog that is available on the Sonix RP exam software in research mode.

2.3.1 B-Mode Data

B-mode data represent the cross-sectional image composed of many scan lines. These cross-sectional gray scale images are usually used for clinical purposes but researchers have also found it to be useful for verification when analyzing or processing raw RF data. The ultrasound machine has the ability to store pre-scan converted as well as post-scan converted images.

2.3.2 RF Data

The collection of RF data is one aspect that is becoming increasingly important in ultrasound research. RF data is used for a variety of purposes, including image processing, tissue characterization, beamforming techniques, and other signal processing applications. RF provides more information than standard grey scale ultrasound images and it is the base of all modalities that run on modern ultrasound systems.

Greyscale ultrasound images, though useful for research, suffer from the fact that they cannot be processed back into native RF form, whereas an RF signal, through envelope detection and compression can be processed into a standard ultrasound B-mode image. The Sonix ultrasound system provides three novel methods to collect

RF data from a clinical scanner. Different collection methods may be more useful than others depending on the application of use. The first method of acquisition is using the clinical software with the research interface. In this scenario, the user scans the patient or subject of interest as normal in a special RF collection mode. The mode displays a standard B image along with an RF spectrum for visualization of a single amplitude line (A-line). An important feature of this acquisition method is the fact that corresponding ultrasound images can be stored alongside the RF data collected. This provides an important reference of what was actually being imaged so that users can verify the captured data prior to processing the RF data itself.

2.3.3 Color Doppler Data

Color Doppler ultrasound permits the simultaneous display of B-mode data and a color-coded map representing the velocity and variance of blood flow. The flow information is obtained through transmitting multiple pulses (ensembles) and estimating the velocity changes based on the calculated time between received echoes. This imaging mode is especially useful for monitoring heart rate, detecting arterial blockage, and blood flow characteristics. The Sonix RP research interface allows users to acquire color RF data, processed B and color image in XRGB format, as well as the color velocity and variance data.

2.3.4 Elastography Data

Elastography imaging relies on RF signal analysis to calculate tissue displacement as it is being compressed. Once analyzed, the displacement is mapped to a visualization that is overlaid on top of a standard B mode image. This imaging mode allows the ability to differentiate tissue stiffness in the body and is especially useful for the characterization of abnormalities in tissues such as cysts and lesions. The data that can be stored in elastography mode include the B-image and elasto overlay.

3. APPLICATIONS

The Sonix RP has been used extensively for many applications some of which are described in the following sections.

3.1 Strain Imaging

One of the more common research topics in ultrasound is elastography imaging. There have been a variety of research labs using the Sonix RP to acquire RF data for elastography purposes, and then process it offline once RF files are stored to disk.¹ These same labs have also experimented with using the software development tools to capture RF data in real-time and display an elastography image on the screen while the user is scanning the subject. Through these methods and research, Ultrasonix has been able to work with researchers to create an elastography imaging modality that is commercialized on its clinical ultrasound systems. In the recent years, elastography has been researched extensively for the purpose of tumor detection especially in the breast¹¹ as well as for the detection of plaque in arteries.¹² Research has also been conducted in bringing strain imaging to the third dimension.¹³

3.2 Tissue Characterization

Another popular research area is the analysis of RF signals for tissue characterization. Time series of RF signals have been studied for tissue typing and results have shown promise for the detection of prostate cancer cells.¹⁴ In addition, RF signals have also been analyzed for non-medical applications such as for grading the quality of beef.¹⁵

3.3 Image Guidance

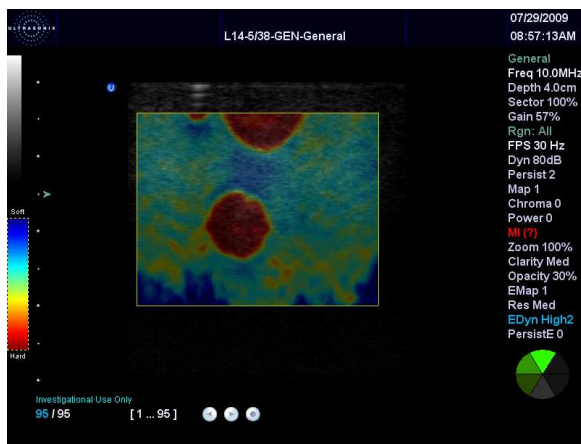
The rapid display capabilities of ultrasound has also made it a popular imaging modality for image guidance to benefit intra-operative procedures. The Sonix RP has been used for real-time image guidance in needle biopsy and therapy treatments. The *touchless* needle guide technique introduced by researchers at the University of British Columbia is able to track the position and orientation of the needle with an accuracy of one millimeter by utilizing the 4D ultrasound mode on the Sonix RP to map un-calibrated images of the needle to a 3D ultrasound volume.³ In another study, the Sonix RP was used for monitoring temperature maps in real-time to facilitate therapy treatments such as radiofrequency ablation.¹⁶



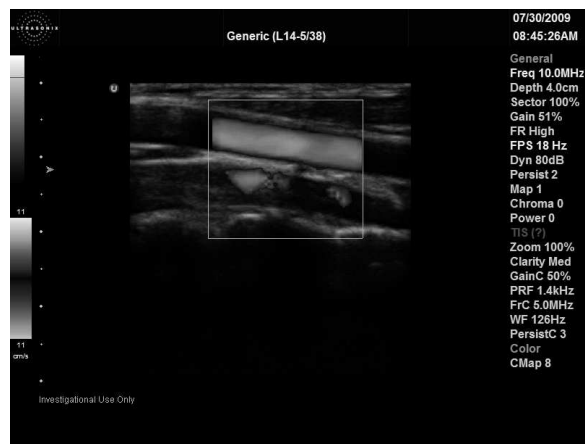
(a) B-mode Image



(b) RF Image



(c) Elastography Image



(d) Color Doppler Image

Figure 3. Some of the data types supported by the Sonix RP machine. Images show the (a) B mode image and (b) RF data of the liver collected using a convex C5-2/60 probe, (c) elastography image on a breast phantom and (d) color doppler image of the carotid artery using a linear L14-5/38 probe.

3.4 Research Tools

Many university researchers and institutes have greatly contributed to the Sonix RP research community by developing open source tools using our system. The SynchroGrab¹⁷ package allows the collection and synchronization of interspatial information between ultrasound images and performs volume reconstruction of the data for enhanced visualization. In addition, the Programmable Ultrasound Platform and Interface Library (PUPIL) package¹⁸ improves the visibility of a needle during ultrasound image guided procedures by performing automatic steering of the ultrasound beam towards the needle's direction. These tools provide invaluable information for a wide variety of research applications.

4. CONCLUSION

Many universities, research institutes and hospitals have been using the Sonix RP research interface with great success. The Sonix research interface has shown to be very useful in the acquisition of various forms of ultrasound data, especially RF signals. The system, through its PC based architecture and flexible interface has managed to overcome some of the previous hurdles of collecting clinically relevant data that is high in quality. This has made it possible for researchers to easily implement their own applications. As the research community continues to grow and adopt new equipment, the Sonix research interface will continue to expand as well, by offering new features, software tools, even higher quality images, and increasingly more open interfaces.

REFERENCES

1. Turgay, E., Salcudean, S., and Rohling, R., "Identifying the mechanical properties of tissue by ultrasound strain imaging," *Ultrasound in Medicine and Biology* **32**(2), 221–235 (2006).
2. Serago, C., Chungbin, S., Buskirk, S., Ezzell, G., Collie, A., and Vora, S., "Initial experience with ultrasound localization for positioning prostate cancer patients for external beam radiotherapy," *Int. J. Radiation Oncology Biol. Phys.* **5**(1), 1130–1138 (2002).
3. Khosravi, S., Rohling, R., and Lawrence, P., "Image guidance using camera and ultrasound images," in [*Ultrasonics Symposium*], **2**, 2251–2254 (2007).
4. Bosch, J., van Burken, G., Schukking, S., Wolff, R., van de Goor, A., and Reiber, J., "Real-time frame-to-frame automatic contour detection on echocardiograms," *Computers in Cardiology* **12**, 29–32 (1994).
5. Wendelhag, I., Gustavsson, T., Suurkula, M., Berglund, G., and Wikstrand, J., "Ultrasound measurement of wall thickness in the carotid artery: fundamental principles and description of a computerized analysis system," *Clinical Physiology and Functional Imaging* **11**, 565–577 (1991).
6. Wenguan, L., Gussenhoven, W., Zhong, Y., The, S., Mario, C. D., Madretsma, S., Egmond, F. V., Feyter, P., Pieterman, H., Urk, H. V., Rijsterborgh, H., and Bom, N., "Validation of quantitative analysis of intravascular ultrasound images," *International Journal of Cardiac Imaging* **6**, 247–253 (1991).
7. Bertora, F., Pellegritti, P., and Questa, A., "A new flexible digital research platform based on a standard ultrasound scanner: Results and applicative perspectives," in [*IEEE Int. Conf. on Ultrasonics, Ferroelectrics and Freq. Control*], **3**, 2049–2052 (2004).
8. Shamdasani, V., Bae, U., Sikdar, S., Yoo, Y. M., Karadayi, K., Managuli, R., and Kim, Y., "Research interface on a programmable ultrasound scanner," *IEEE Transactions on Ultrasonics* , 159–168 (2008).
9. Ashfaq, M., Brunke, S., Dahl, J., Ermert, H., Hansen, C., and Insana, M., "An ultrasound research interface for a clinical system," *IEEE Transactions on Ultrasonics, Ferroelectrics and Freq. Control* , 159–168 (2008).
10. Solbiati, L., Tonolini, M., Cova, L., and Goldberg, S. N., "The role of contrast-enhanced ultrasound in the detection of focal liver lesions," *Eur. Radiol.* , 15–26 (2001).
11. Fleury, E., Rinaldi, J., Piato, S., Fleury, J., and Jr., D. R., "Features of cystic breast lesions at ultrasound-elastography," *Radiol. Bras.* **41**(3), 167–172 (2008).
12. Schmitt, C., Cloutiera, G., Maurice, R., Lanthier, S., Giroux, M., and Soulez, G., "Development of non-invasive vascular elastography for carotid artery plaque assessment," in [*Ultrasonics Symposium*], **1**, 389–392 (2005).
13. Awad, S. and Yen, J., "3-d strain imaging using a sparse rectilinear 2-d array," in [*Ultrasonics Symposium*], 228–231 (2007).
14. Moradi, M., Abolmaesumi, P., Siemens, R., Sauerbrei, E., Isotalo, P., Boag, A., and Mousavi, P., "Ultrasound rf time series for detection of prostate cancer: Feature selection and frame rate analysis," in [*Ultrasonics Symposium*], **2**, 2493–2496 (2007).
15. Amin, V., Wilson, D., Roberts, R., and Rouse, G., "Tissue characterization for beef grading using texture analysis of ultrasonic images," in [*Ultrasonics Symposium*], **2**, 969–972 (1993).
16. Daniels, M., Varghese, T., Madsen, E., and Zagzebski, J., "Non-invasive ultrasound-based temperature imaging for monitoring radiofrequency heating phantom results," *Phys. Med. Biol.* , 4827–4841 (2007).
17. Boisvert, J., Gobbi, D., Vikal, S., Rohling, R., Fichtinger, G., and Abolmaesumi, P., "An open-source solution for interactive acquisition, processing and transfer of interventional ultrasound images," –.
18. Rohling, R., Fung, W., and Lajevardi, P., "Pupil: Programmable ultrasound platform and interface library," in [*Medical Image Computing and Computer-Assisted Intervention (MICCAI)*], **2879**, 424–431 (2003).