

Accelerating ultrasound image analysis research through publically available database

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ABSTRACT

Ultrasound is widely used intra-operatively to provide real-time feedback in image guided intervention procedures. Registration of pre- and intra-operative images is a crucial step in the procedure. Unfortunately, real-time US images often have poor signal-to-noise ratio and suffer from imaging artifacts. Hence, registration using US images can be challenging and significant preprocessing is often required to make the registrations robust. The amount of preprocessing required can be reduced by incorporating US physical imaging process. However, progress in this research is hampered due to lack of publicly available database for training and testing image analysis algorithms that take in to consideration ultrasound physical process. We present here a new database that we are building to archive and distribute ultrasound images of an abdominal phantom acquired at different image acquisition parameters. The database contains tracking information of the transducer in addition to the 2D ultrasound image slices. We believe a publicly available database like this one will provide a valuable resource for the research community and it will be instrumental in developing a collaborative scientific community needed to advance the field.

1. PURPOSE

There are many publicly available medical databases for conventional 3D images such as CT, MRI, Mamography[LIDC][RIDER][JSRT]. Digital Chest X-ray images with and without lung nodules along with ground truth location and diagnosis is available at JSRT image database [JSRT]. Lung Image Database Consortium (LIDC) provides CT image database with lung lesions marked by up to four radiologists [LIDC]. Image archive of CT lung cancer patients is made available in Reference Image Database to Evaluate Response [RIDER]. BrainWeb contains simulated 3D MR data using normal and multiple sclerosis models with different acquisition parameters [BrainWeb]. Andreopoulos & Tsotsos' Cardiac MRI Dataset contains cardiac MR images with expert segmentations of the left ventricle's muscle-containing wall [A&T]. Mammography images with normal and abnormal findings along with location information are available in Digital Database for Screening Mammography [DDSM] and Mammographic Image Analysis Society [Mini-MIAS] database. Multimodality datasets for evaluation of registration methods with information about center of rotation, evaluation criteria, and starting positions is available at Image Science Institute: Registration database [ISI].

For ultrasound, the effort is very limited. Mercier et al [Mercier2012] have built an online database consisting of pre- and postoperative magnetic resonance and intraoperative ultrasound images acquired from brain tumor patients. Images of patients obtained from ultrasound sensors for medical analysis of the heart is available at NCSU Image Archive [NCSU-IA]. Tian et al have created a digital database of screen sonography with associated ground truth to evaluate and compare performance of computer-aided diagnosis [Tian2008]. Database containing paired ultrasound and MRI of tongue movements and shapes to evaluate informational content of ultrasound tongue images has been reported in [Cleland2011]. However, these databases do not provide information about the image acquisition parameters and lack probe tracking data.

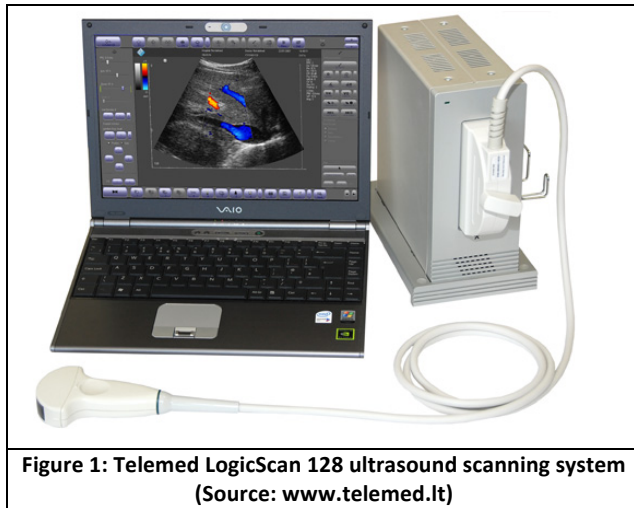
With the aim of providing the research community a valuable US database that aids in the development of US image registration algorithms and 3D volume reconstruction algorithms, we have developed an ultrasound database of meta files that not only include image acquisition parameters, but also location of the US probe for each slice of the recorded US image.

2. METHOD

To generate publicly available database, we used a TeleMed Ultrasound System and multi-modality abdominal phantom. We describe the two briefly below.

Telemed Ultrasound System

Telemed Ultrasound systems based on LogicScan series ultrasound scanners are color Doppler



scanners that are highly portable PC controlled ultrasound systems used to acquire and display real time high resolution ultrasound data in various modes, such as B-mode, M-mode, B+B mode among others. Unlike other ultrasound devices, this scanner is PC controlled with USB 2.0 connectivity. The scanner ships with Telemed's SDK which provides direct access to the cine buffer to store or manipulate the US images. A variety of ultrasound probes is available to be used with the scanner. We use C3.5/60/128Z curvilinear probe which has frequency range of 2.0 – 5.0 MHz and 65 degree/mm field of view.

Multi-modality abdominal phantom

The multi-modality interventional 3D abdominal phantom Model 057 [CIRS, Norfolk, VA] provides a representation of an adult abdomen, designed to address various needs associated with liver biopsy (Figure 2). The phantom can be imaged under MRI, CT and ultrasound. It simulates the abdomen from approximately the thorax vertebra T9/T10 to the lumbar vertebra L2/L3 using simplified anthropomorphic geometry. The main structures included in the phantom are the liver, a portion of the lung that surrounds the liver, portions of the portal vein, abdominal aorta and inferior vena cava, and partial kidneys. Within the liver, multiple simulated liver lesions that range from 5–15 mm in size (average, 10mm) are present. Apart from liver biopsy, the phantom is also a useful tool for a variety of applications - such as, training



of different abdominal scan techniques, developing imaging protocol, and system testing and validation.



Figure 3: GUI used to control B-mode acquisition parameters. Functionality to save the acquisition parameters, capture single and multiple US images is also provided.

A custom designed Visual Basic application, and PLUS (Public software Library for UltraSound) [PLUS] were used to build the database. The Visual Basic application communicates with the Telemed US scanner, and is capable of controlling B-mode controls of the scanner (Figure 3). The following acquisition parameters can be controlled: Depth, Gain, Frequency, Time Averaging, Dynamic Range, Power, and Time Gain Compensation (TGC) at 5 different depths. The acquisition parameters can be saved to a .txt file using the 'Save B mode control values' button. The GUI also provides functionality to save single US image or multiple images to file. PLUS, an open source toolkit for developing ultrasound guided image intervention was used for temporal and spatial calibration of the US and tracker systems, and to capture the metaIO images in a format that records both the US image and the transducer position and orientation data. Transducer tracking was performed using Micron Tracker, Claron Technology Inc [MicronTracker].

The arrangement used to generate the datasets is modeled in Figure 4. Markers detectable by Micron Tracker were placed on the probe and the phantom. The tracker was positioned such that the markers were visible in both the left and right cameras of the tracker during the entire duration of image acquisition.

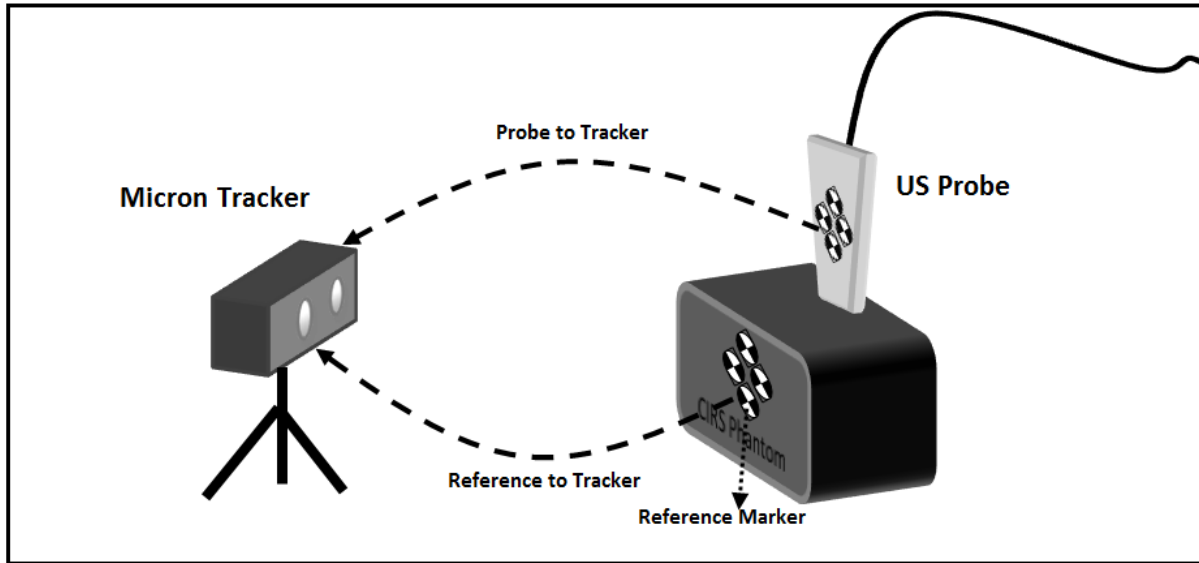


Figure 4: The setup used to acquire the images

Figure 5 shows the pattern in which the probe was maneuvered to acquire the images. The probe's initial position is shown as a dot and the final position by an arrow. Following the curved arrow from the 'dot' to the end of the arrow depicts the movement of the probe. The 2D slices depict the orientation of the probe. The probe was moved in the pattern shown in Fig 5a immediately followed by the pattern in Fig 5b in a smooth continuous motion without loss of contact between the probe and the phantom. The first sweep (Fig 5a) consisted of 3 overlapping sweeps with the probe held perpendicular to the surface of the phantom. This was followed by the second sweep (Fig 5b), consisting of 3 overlapping sweeps where the probe was tilted from 0 – 30 degrees with respect to the surface of the phantom as it was moved from front to back of the phantom. For each 2D slice, 'ProbeToTracker' and 'ReferenceToTracker' transforms have been recorded. The 'ImageToProbe' transform obtained after spatial calibration using the methods described in [PLUS] is saved in an xml file that is saved for each recording. The xml file contains additional information related to the tracker, image acquisition parameters, calibration, and co-ordinate transforms.

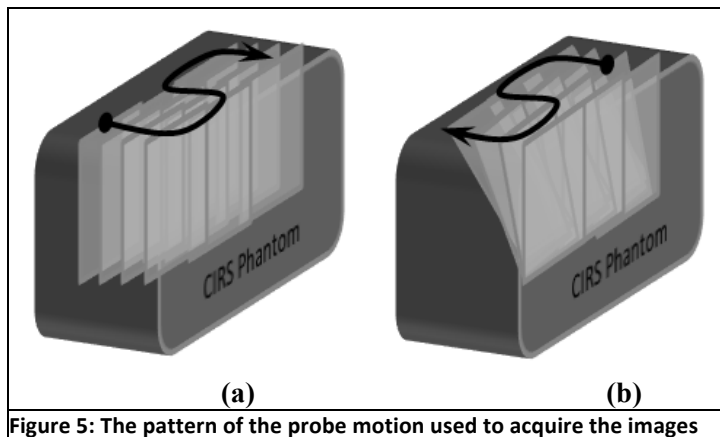


Figure 5: The pattern of the probe motion used to acquire the images

The acquired images are distributed using MIDAS [MIDAS]. MIIDAS is an open-source, scalable database system designed to store, search and retrieve scientific datasets and their associated metadata and files. MIDAS integrates multimedia server technology with ITK and VTK, open-source data analysis and visualization toolkits respectively. The server follows open standards for data storage, access, and harvesting. MIDAS has been optimized for storing massive collections of scientific data

and related metadata and reports. MIDAS is available under a non-restrictive (BSD) open-source license. A variety of data access methods are provided including web, file system and DICOM server interfaces. So, researchers can connect and download the dataset in a way that is convenient to them.

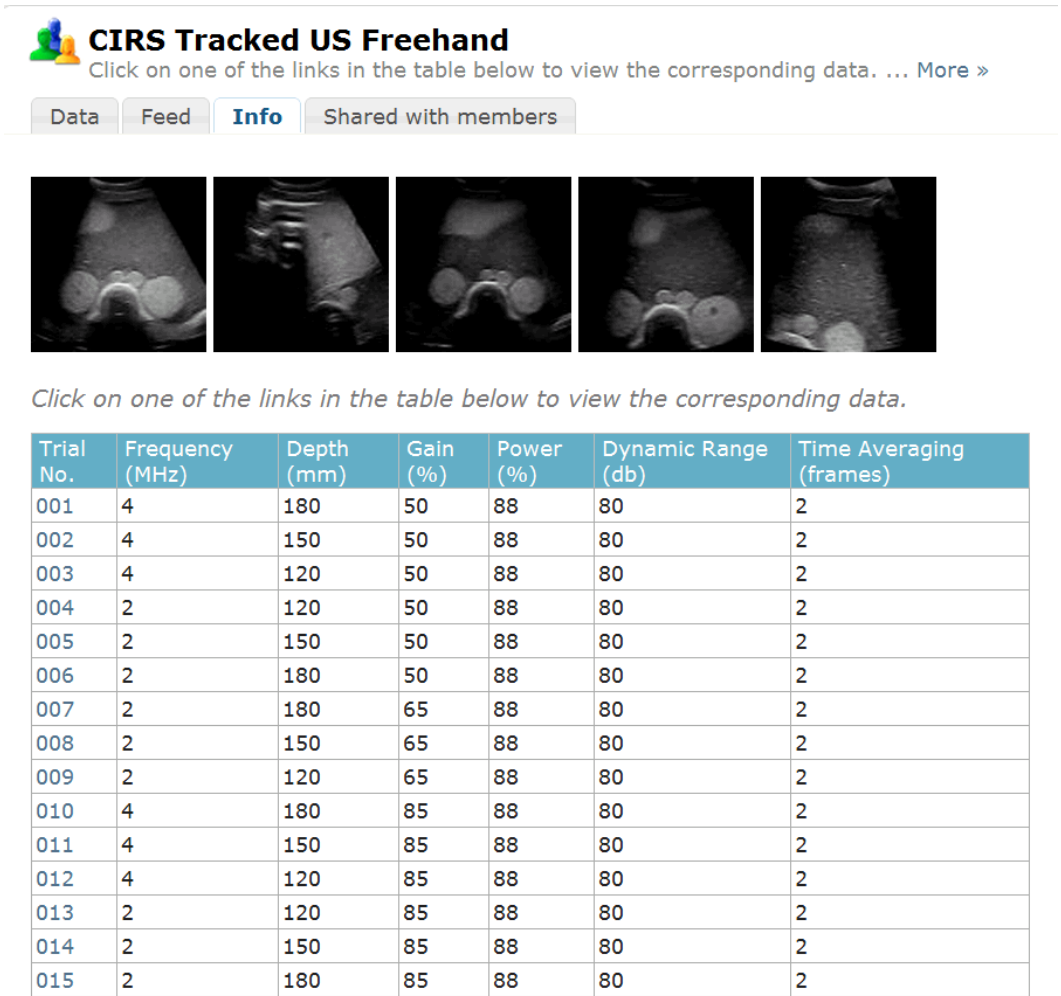


Figure 6: MIDAS frontend: Images of the abdominal phantom acquired at different acquisition parameters

Figure 6 shows the MIDAS interface we have designed to access the US database. Users can download the US meta-data corresponding to the image acquisition parameters they are interested in. Alternatively, they can download the entire database. Example images are shown in figure 7 consisting of two acquisitions (a) and (b) performed at 4 MHz, 180mm depth, and differing gain ((a) - 50%; (b) - 85%) .

CONCLUSION AND FUTURE WORK

We present here a new database that we are building to archive and distribute ultrasound images of an abdominal phantom acquired at different image acquisition parameters. The database contains tracking information of the transducer in addition to the 2D ultrasound image slices. We believe a publicly available database like this one will provide a valuable resource for the research community and it will be instrumental

in developing a collaborative scientific community needed to advance the field. In a follow up work, we plan on adding more US data acquired using a variety of US transducers such as linear and non-linear transducers with a frequency range of 2-10 Mhz. We also plan on acquiring US images of various other structures such as spine, heart, breast, blood vessels, spleen, etc.

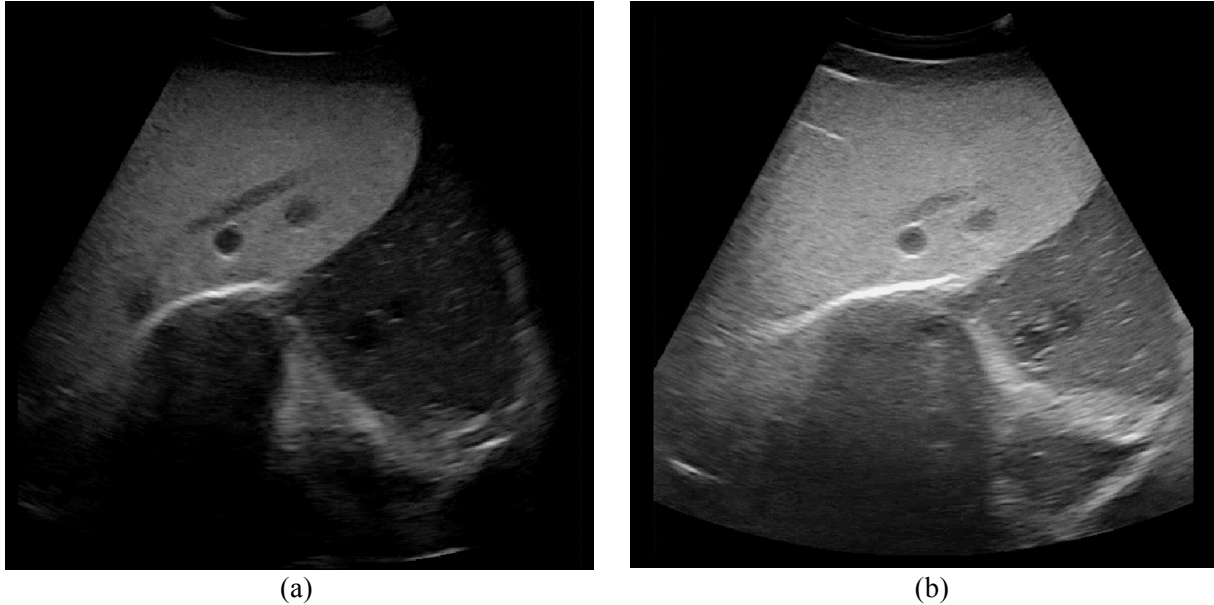


Figure 7: Images of the abdominal phantom acquired at 4MHz, 180mm depth with gain (a) 50% and (b) 85%

ACKNOWLEDGEMENT

This project was supported in-part by by NIH grant 1R01EY021641, NIH/NIBIB Grant No. 1R43EB014074-01, and NIH/NCI grant 1R01CA138419).

REFERENCES

1. [LIDC] <http://cancerimagingarchive.net/>
2. [RIDER] <http://cancerimagingarchive.net/>
3. [JSRT] <http://www.isi.uu.nl/Research/Databases/SCR/>
4. [BrainWeb] <http://www.bic.mni.mcgill.ca/brainweb/>
5. [A&T] <http://www.cse.yorku.ca/~mridataset/>
6. [DDSM] <http://marathon.csee.usf.edu/Mammography/Database.html>
7. [Mini-MIAS] <http://peipa.essex.ac.uk/info/mias.html>
8. [ISI] Image Science Institute: Registration database <http://www.isi.uu.nl/Research/Databases/GS/>
9. [Mercier2012] Mercier L, Del Maestro RF, Petrecca K, Araujo D, Haegelen C, Collins DL, 'Online database of clinical MR and ultrasound images of brain tumors', Med Physics, June 2012, Issue 39 Volume 6, pages 3253-61

10. [NCSU-IA] NCSU Image Archive
http://www.ece.ncsu.edu/imaging/Archives/ImageDataBase/Medical/Heart/CoronaryArtery_Ultrasound/
11. [Tian2008] Jia-wei Tian, Ying Wang, Jian-hua Huang, Chun-ping Ning, Han-mei Wang, Yan Liu, Xiang-long Tang, 'The Digital Database for Breast Ultrasound Image', JCIS-2008
12. [Cleland2011] Cleland, Joanne and Wrench, Alan A and Scobbie, James M and Semple, Scott(2011) Comparing articulatory images: An MRI / Ultrasound Tongue Image database. Proceedings of the 9th International Seminar on Speech Production . pp. 163-170
13. [PLUS] Lasso, A., T. Heffter, C. Pinter, T. Ungi, T. K. Chen, A. Boucharin, and G. Fichtinger, "PLUS: An open-source toolkit for developing ultrasound-guided intervention systems", 4th NCIGT and NIH Image Guided Therapy Workshop, vol. 4, Arlington VA, October 12-13, 2011, pp. 103, 10/2011.
14. [MicronTracker] <http://www.clarontech.com/microntracker.php>
15. [MIDAS] Kitware, Inc., Products Midas, Available at <http://www.kitware.com/products/midas.html>