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A flexible and configurable hardware for the Combined EIM and Ultrasound device

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Abstract. One of the current methods in breast cancer detection is Sonography, also known as Ultrasound imaging. Sonography is effective for imaging soft tissues of the body and returns a high resolution image. Its operation is highly subjective depending on the operator and the images do vary with positioning. At the University of Sussex we have successfully built an automated and repeatable Ultrasound scanner and combined and reconstructed the data in 3D. Ultrasound imaging does have its limitations when it comes to cancer detection and diagnosis. The Sussex EIM (Electrical Impedance Mammography) device is a novel imaging system developed at the University of Sussex for the detection of breast lesions *in-vivo* using quadrature detection of impedance. Combining the high resolution images of Ultrasound with the parametric data of EIT would give a more precise diagnosis. This paper describes how we have achieved a totally configurable system where we have combined our current EIT technology for breast cancer detection to the 3D Ultrasound scanner we have built. This was done with a quick turn-around in development time using off-the-shelf hardware and a 3U PXI Chassis. The system is based around a National Instruments PXI (PCI eXtensions for Instrumentation) chassis which is a modular electronic instrumentation platform.

1. Introduction

Ultrasound is a high frequency sound, above the human audible threshold, which travels freely through fluid and soft tissues but is reflected when it reaches a change in ‘acoustic density’. Sonography, also referred to as Ultrasound imaging, is a widely used medical imaging and diagnostic technique. [1] Ultrasound imaging is non-invasive [1][2] and is effective in imaging soft body tissue. Subcutaneous body structures such as muscles, tendons, breasts etc. are normally scanned at high frequencies (7-18MHz) [1][4], which provide high axial and lateral resolution. Internal organs are scanned at lower frequencies (1-6MHz) [1][4], which results in a lower axial and lateral resolution but greater penetration. Typically the same Ultrasound machine can do both high and low frequency scans by using interchangeable transducers which are placed directly on, and moved over, the patient by a trained professional. This introduces a subjective factor during a scan, which may have negative implications in the diagnoses. By sweeping the transducer on the patient a 2D image representation of a slice into the body is created. 3D images can be generated by acquiring and collating a series of 2D images. To eliminate operator error and introduce consistency, the 3D scanning process can be mechanized.

At the University of Sussex we have been working on the development of an automatic 3D scanner for breast cancer detection using commercially available control hardware. The system combines electrical impedance measurements, [3][5][8] which is able to provide parametric imaging [6][7][8] at

a modest resolution, with 3-dimensional ultrasound measurements. This 3-dimensional [9][10] multi-modality will produce superimposed high resolution images with tissue property information therefore complementing the two technologies and achieve a more accurate diagnostic result.

With the Sussex Mk4 EIM system we managed to achieve a high specification, flexible, software configurable system to be used for clinical trials in the United Kingdom by using off-the-shelf hardware from National Instruments (NI). Taking advantage on the modular architecture of the NI hardware we have merged the control and acquisition of the 3D Ultrasound scanner to the existing Sussex Mk4 device. This paper will try to explain in more detail the set-up and configuration of the extended dual modality system.

2. PXI Set-up

The system set-up, is based on a PXI (PCI eXtensions for Instrumentation) Chassis with a number of dedicated PXI modules controlled by proprietary software. PXI is a modular instrumentation platform originally introduced in 1997 by National Instruments [11]. PXI is promoted by the 54-member PXI Systems Alliance (PXISA) and has become an industry standard in computer based instrumentation with over 1150 different modules, varying from Data Acquisition, Signal Generators to Motor Controllers and Image Grabbers [12]. PXI is based on CompactPCI, and offers all of the benefits of the PCI architecture including performance, industry adoption, COTS technology. Most PXI instrument modules are register-based products, which use software drivers hosted on a PC to configure them as useful instruments, taking advantage of the increasing power of PCs to improve hardware access and simplify embedded software in the modules. The modules are categorized in Board Series depending on their purpose (e.g. Data Acquisition, Motion etc). Each Board Series has a Product Family categorized on the hardware capabilities of the modules (e.g. DAQ 12-bit, 14-bit) etc. Naturally the higher the hardware specification the more expensive the module is. The open architecture further allows hardware to be reconfigured to provide new facilities and features that are difficult to emulate in comparable bench instruments [11]. The wide variety of the off-the-shelf high specification modules allowed us to concentrate our efforts on the requirements of the integrated system. For the purpose of this paper we will demonstrate the system using the Product Family (e.g. PXI-62XX) so that it complies with the purpose of maximum flexibility.

The software is written in LabVIEW™ (Laboratory Virtual Instrumentation Engineering Workbench), a fast prototyping, graphical programming language based on data flow concepts and good user interface development features [11]. The PXI modules come equipped with driver installation software and API which is easily called and controlled by LabVIEW™. This speeded up development time and ensured full system integration compatibility in our system. The software was installed on a dedicated, high specification Microsoft Windows based Personal Computer

3. EIM System

The Sussex Mk4 system uses a quadrature method for impedance detection [6]. The device uses a fully programmable planar array of electrodes. The control method employed is such that any two electrodes apply current to the breast whilst any other two, similarly non-invasive, electrodes detect the developed potential difference under the direction of proprietary software. The currents injected are provided by a signal source with available output frequencies that are continuous over a wide bandwidth.

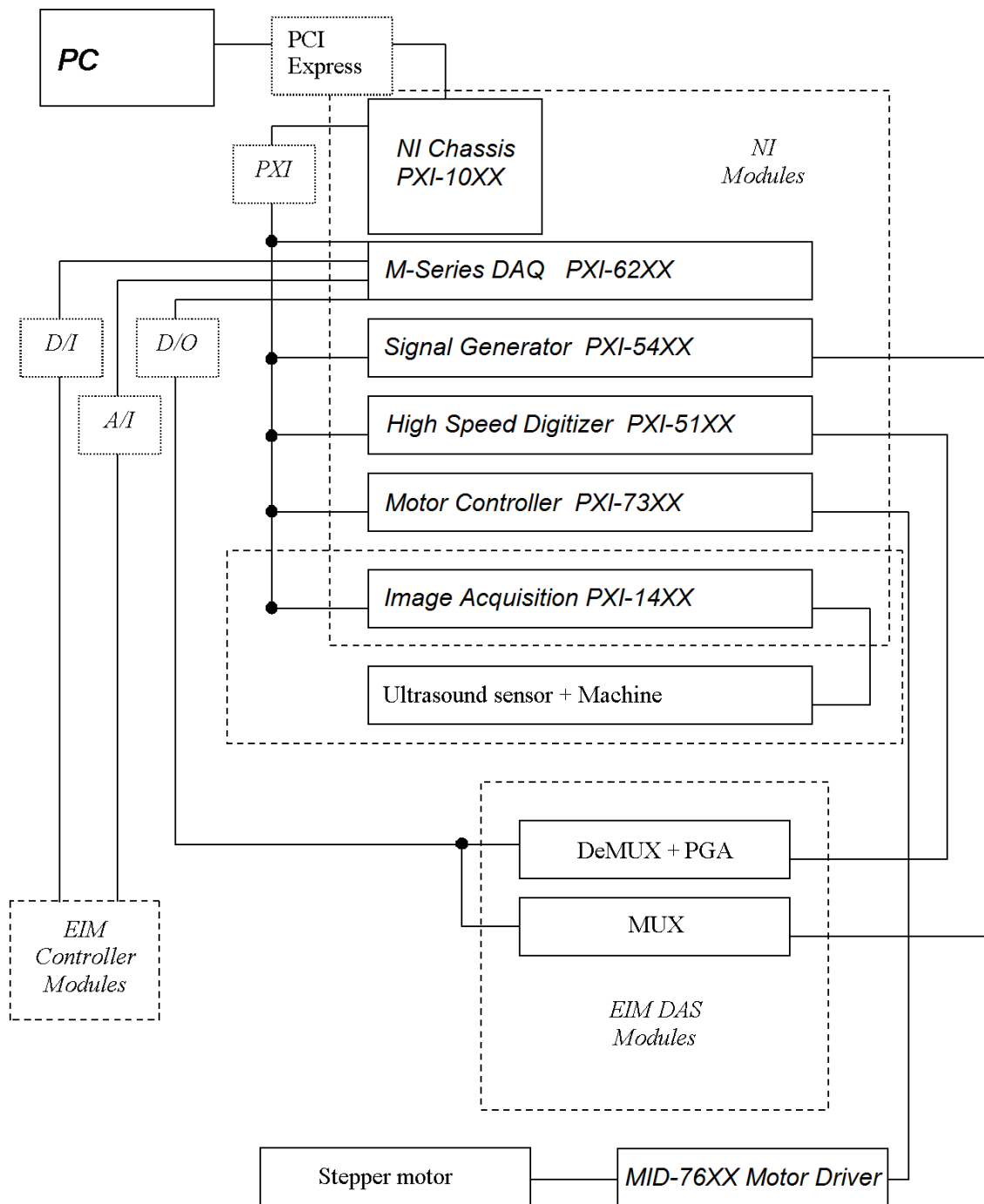


Figure 1. System Control and Acquisition diagram

Within the Sussex Mk4 EIM system a PXI54XX series function generator is used to provide signals to a voltage-to-current convertor for application to the body. The exact electrode combination is selected via a PCI-62XX module. Each electrode can be either configured, using a 32-bit parallel port, for current injection or voltage measurements; but each electrode can *only* be configured for either differential current injection (I+ or I-) or voltage measurement (V+ or V-) at one time. Due to the frequency range used the developed potentials are digitized via a PXI-51XX Digitizer Module for streaming to the computer.

4. Ultrasound

2D slices are captured as images via the video-out port available on standard medical ultrasound system in CCIR TV format (25Hz frame rate). Video capturing is done using a PXI-14XX Analogue Frame Grabber.

The movement of a 2D ultrasound transducer, permitting a 3D scan, is achieved by using a Motion Controller PXI-73XX connected to a MID-76XX drive unit to power the stepper motors.

5. Conclusion

The use of a PXI based setup proved successful in building a working system in record time. The module swapping and adding capability has proved very crucial in the integration of a dual modality scanner. Different module setups to increase the performance are being considered at the moment without major modifications. Based on our experience we advocate that a PXI system would be very beneficial in the further study of EIT and Ultrasound, or other, multi-modalities. By reducing time in the development of the scanner, we were able to concentrate more on the merger of Ultrasound high resolution images with EIM tissue property information therefore complementing the two technologies and achieving a more accurate diagnostic result.

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