Improving Ultrasonic Tumour Therapy With Passive Acoustic Detection

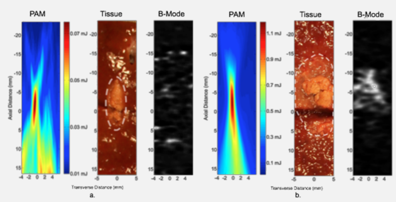

Figure 1: Results of Ex-vivo Preclinical Studies to Show Agreement of PAM and Lesioning in Ablated Tissue.

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- Christian Coviello, Institute of Biomedical Engineering, University of Oxford

The Challenge:

Developing an economical and effective system for monitoring high intensity focused ultrasound (HIFU) surgery of cancerous tumours using ultrasonic hydrophone arrays.

The Solution:

Combining NI PXI Express hardware and LabVIEW software allowed for rapid data acquisition from a 32 channel custom array of sensors at 50MS/s.

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Treatment for Abdominal Solid Tumours

Abdominal tumours in organs such as the kidney and the liver are fairly common in the UK with 3,594 new liver cancer cases in 2008 and 9,286 kidney cases in 2009, occurring most frequently in the elderly. Early detection through improved imaging means that tumours are often small (<4 cm in diameter) when diagnosed, and since the vast majority of these small tumours are locally confined at diagnosis, they can be cured.

Typically, these cancers are treated surgically, with excision of the tumour from the kidney or complete kidney removal. Cure rates with surgery are high, with 5- & 10-year cancer-specific survival rates of over 90%. However, kidney cancer surgery can be risky and is associated with complications in over 20% of cases. This rate rises even further in patients aged over 80.

Non-Invasive Surgery

High intensity focused ultrasound (HIFU) is an emerging, completely non-invasive therapy that lets a surgeon heat a small target region deep inside the body to high enough temperatures to destroy cancer cells without damaging any surrounding healthy tissue. When compared to traditional or minimally invasive surgery these treatments generally lead to shorter hospital stays, less pain, lower complication rates and quicker recovery. This is because it requires no skin or tumour puncture and is therefore not associated with any risk of bleeding or seeding of new tumour sites

HIFU therapy does however suffer from a number of limitations that hamper widespread uptake, and foremost amongst these is a lack of real time monitoring that provides quick and effective feedback to the surgeon as to how effective a treatment has been.

Passive Acoustic Mapping as a Monitoring Tool

In the quest to find a monitoring tool, one key phenomena that can be exploited during ultrasound therapy is acoustic cavitation, which describes the nucleation and oscillation of microscopic bubbles caused by the acoustic waves travelling from a HIFU transducer through the body. The oscillating and collapsing bubbles produce acoustic energy that can be passively detected by an array of sensors. By collecting these signals together and applying array processing methods to the data, a spatial map of activity is created of which the process is termed *passive acoustic mapping (PAM)*.

The ability of a clinician to exactly determine what is happening in the patient throughout the treatment cycle means a reduced chance of over treatment, improved safety margins, and shorter treatments. Further, passively mapping the acoustic emissions can be done cheaply and in real-time; an improvement over currently available methods of monitoring HIFU. Magnetic resonance imaging, for example, is orders of magnitude more expensive and B-mode imaging is not sensitive enough which can lead to overtreatment as shown in the figure 1.

Integration With a Clinical Device

A key requirement when retrofitting a multi-element passive cavitation detector onto an existing, CE-marked clinical HIFU system is that the new sensor should not affect the therapeutic field significantly. The detection array was designed to consist of 8 dart-shaped flexible sub-arrays that conform to the shape of the HIFU transducer when mounted on it. Each sub-array consists of 4 elements, manufactured using printed sensor electrodes on a thin and acoustically transparent peizo-polymer. The sub-arrays can then be installed so as to use the full aperture of the therapy transducer whilst minimising the effect on the treatment.

To collect the data from these array elements we opted to use the NI 5752 adapter module for the NI PXIe-7962R FlexRIO card. Designed specifically for ultrasound applications, this allowed us to simultaneously acquire all 32 channels our array at 50MS/s, giving access to the full time domain data.

Benefits of the National Instruments Solution

The initial studies of HIFU monitoring were conducted using a conventional ultrasound scanner and a diagnostic linear array probe. While this allowed the ability to off-load the pre-beamformed signals from each array element, future development would have been limited to commercially available array probes, explicit limits on number of receive channels, as well as no direct path to actually displaying real-time passive acoustic maps.

National Instruments provided a refreshing alternative route that allowed for rapid development of a monitoring application using NI LabVIEW FPGA plus complete control and access to acquired data. Any conceivable array design could be integrated to the scalable PXI-based system, and designs are already in place for a 64 element array to be used with the system. Finally the possibility of on board pre-processing written in LabVIEW and embedded onto the FPGA on the FlexRIO is appealing as a move is made to more computationally complex methods for improved imaging in the future.

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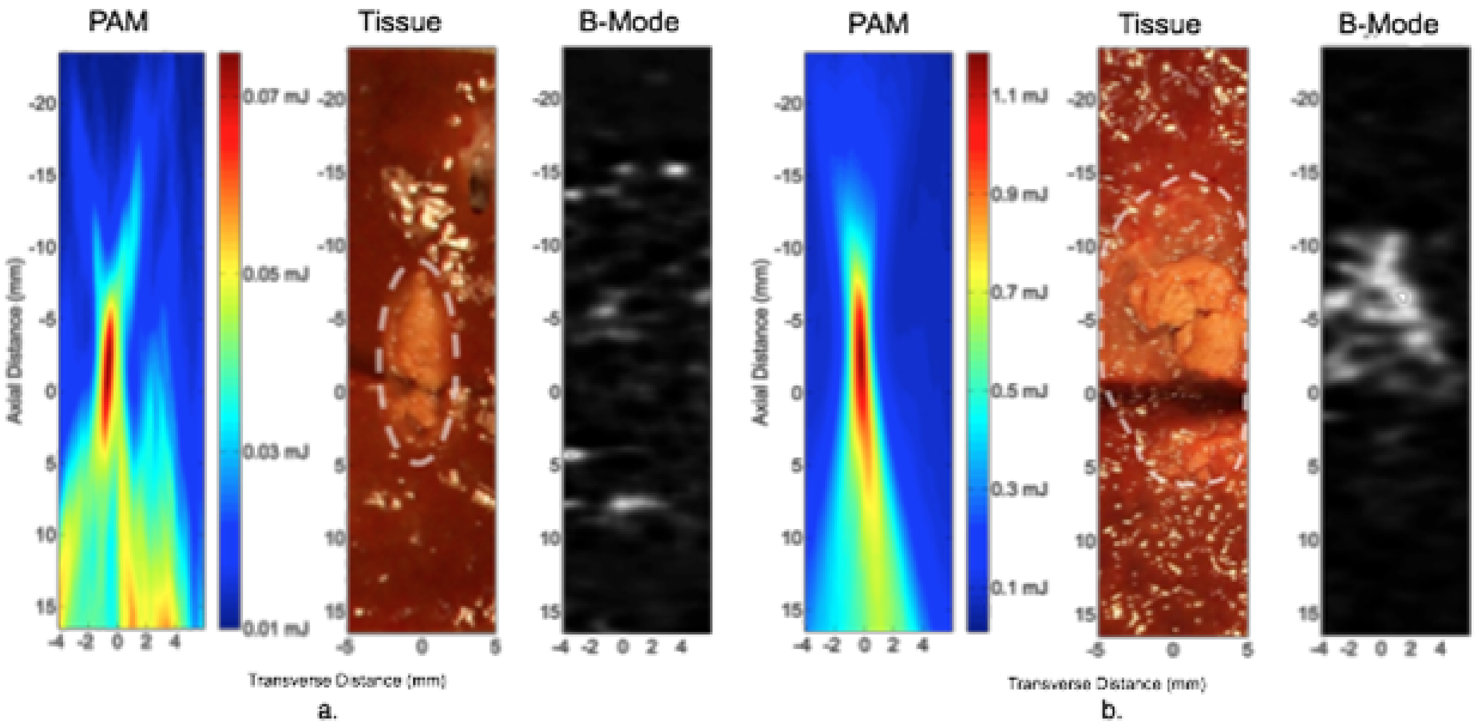

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Figure 3: The Therapy Transducer of the JC200 HIFU System (orange bowl shape) With the Gold Coloured Acoustically Transparent Ultrasound Detecting Arrays.