# UltraSoundToGo

## HIGH PERFORMANCE PORTABLE 3D ULTRASOUND PLATFORM





Prof. Giovanni De Micheli, EPFL



Prof. Luca Benini, ETHZ

Prof. Jean-Yves Meuwly, CHUV

Prof. Joseph Sifakis, EPFL

Prof. Lothar Thiele, ETHZ

Prof. Jean-Philippe Thiran, EPFL

## What it's about…

*Developing a prototype of next-generation, high-quality, mobile ultrasound imaging device.*

## Context and project goals

Ultrasound imaging is an important biomedical technique for analyzing soft tissues in the human body, with both diagnostic and therapeutic applications. Ultrasound images are formed by emitting ultrasound waves in the medium of interest and recording the backscattered waves on an array of transducers. Conventional 2D ultrasound image beamforming techniques are then used to create an image from the received echoes. Ultrasound imaging is the most widely-used medical imaging technique, because of its relative low cost, non-invasiveness and non-use of ionizing radiation, i.e. lack of adverse effects. It is widely used in prenatal care, for mammography and for many other applications (cardiac, renal, liver and gallbladder analysis, imaging of muscles and superficial structures such as testicles, thyroid, etc.). Because of the real time nature of ultrasound, it is often used to guide surgical procedures. Furthermore, ultrasound is increasingly used in remote diagnosis cases where teleconsultation is required. The worldwide outreach of ultrasound diagnostic for prenatal care and for mammography would be widely improved by the construction of high-performance and safe portable devices, especially for emergency, prenatal care and mammography.

Yet, ultrasound imaging has limitations. The quality of the resulting images is often poor compared to more expensive procedures, such as Computed Tomography and Magnetic Resonance Imaging. Also, the image acquisition relies on manually rubbing a probe on the patient's body, and experience and skill are required for the best diagnostic results - as opposed to the other imaging techniques, where the medical personnel is not in direct physical contact with the patient. For both reasons, trained sonologists must be in charge of operating the ultrasound scanners, rather than more generic personnel. Moreover, ultrasound imaging devices are usually bulky and power-hungry, making them non-portable and unsuitable for field operation in absence of a stable power supply. Miniaturized, lower-power ultrasound imaging devices exist, but they provide medium quality at best.

UltrasoundToGo intends to develop a high-performance, low-power signal processing platform for ultrasound imaging applications, targeting future 3D portable ultrasound systems. The motivation of this work is to provide the means for achieving a portable medical system that can provide high-quality images while being battery operated, and thus much more usable in medical emergencies and developing countries or areas where energy availability is sporadic. The improved image quality and the flexibility of the platform are intended to make ultrasound imaging devices much easier to use also by non-specifically-trained personnel. UltrasoundToGo also envisions telemedicine scenarios, where high-quality images could be effortlessly and safely scanned by general practitioners and sent to specialists for analysis.

UltrasoundToGo will rely on innovation from both the hardware and software side. From the hardware side, UltrasoundToGo will improve on existing industrial and academic works by leveraging cutting-edge programmable chips - off-the-shelf parts and new architectures - to provide high-bandwidth signal processing and advanced computing capabilities in a low-power envelope, compatible with battery operation. From the software viewpoint, UltrasoundToGo will innovate in the signal processing and image processing departments, leveraging a highly-parallel algorithmic approach for optimal platform utilization and efficiency. One of the distinctive features of the system will be to support a qualified software deployment and maintenance model whereby new real-time control and analysis algorithms can be downloaded on the platform infield, under end-user control. This model is supported by a formally well-defined and sound programming model and verification methodology for guaranteeing correctness and quality of results.

## How it differentiates from similar projects in the field

The project investigators bring significant expertise in the latest chip architectures and programming paradigms, and intend to use them to devise a highly optimized platform that can process ultrasonic echoes more efficiently than any existing device.

Areas of research include improvements in image quality, reductions of system cost, enhancements in portability, and new programming methods aimed at guaranteed imaging performance.

## Quick summary of the project status and key results

At the halfway mark, UltrasoundToGo has achieved significant breakthroughs in the design of innovative ultrasound imagers. This was achieved with a blend of expertise in electronic design, software methods, and image processing techniques, and the feedback of hospital and external experts of medical ultrasound.

New image processing techniques have been devised to achieve the same or better contrast than traditional methods of imaging, using up to 30 times fewer insonifications. This translates into the possibility of improving frame rates or designing lower-power transducers.

On the hardware side, the architectural design for a breakthrough chip to reconstruct 3D ultrasound images has been completed. This design can reconstruct 3D volumes with unprecedented quality at 15 fps with just 30W of power, or standard 2D images in just 300 mW. Preliminary studies also show that key portions of 3D ultrasound imaging could be implemented on off-the-shelf FPGAs, still maintaining high quality standards.

Software techniques have been developed to allow for the automatic mapping of software parts of the imager onto the hardware infrastructure. These techniques allow for correct-by-construction software implementations, guaranteeing safe execution that meets the requirements of medical applications. While doing this, optimizations have been devised to improve memory occupation by up to 100X.

## Success stories

For many of the research groups in the project, the main background is in various fields of engineering rather than in biomedical applications. During the first two years of the project, significant expertise was acquired by constant interactions both across engineering domains and with medical professionals, leading to relevant formation opportunities for junior and senior staff alike.

Particularly valuable was the experience of Mr. Marcel Arditi, an ultrasound imaging expert, who, after a year-long collaboration of the project as a part-time consultant, actually left his industrial position to join EPFL to work on this project and others.

Very valuable insight was also acquired in multiple discussions with Germany's Fraunhofer Institute for Biomedical Engineering (IBMT), which was contacted as an ideal complement the expertise and goals of UltrasoundToGo. IBMT is a leading institution in the design, prototyping and testing of ultrasound imaging probes. It is hoped that further collaborations with IBMT will be possible to further the scope of UltrasoundToGo

## Main publications

Pirmin Vogel, Andrea Bartolini, Luca Benini, Efficient Parallel Beamforming for 3D Ultrasound Imaging, GLSVLSI'14 Proceedings of the 24th edition of the great lakes symposium on VLSI, Houston, Texas, USA, pp. 175-180, May 2014.

Stefanos Skalistis, Alena Simalatsar, Modeling of Reconfigurable Medical Ultrasonic Applications in BIP, Proceedings of the 5th Workshop on Medical Cyber-Physical Systems, Dagstuhl, Germany, pp. 66-79, 2014.

Aya Ibrahim, Pascal Hager, Andrea Bartolini, Federico Angiolini, Marcel Arditi, Luca Benini, Giovanni De Micheli, Tackling the Bottleneck of Delay Tables in 3D Ultrasound Imaging, Proceedings of the DATE Conference, Grenoble, France, 2015, pp. 1683-1688.

Aya Ibrahim, Alena Simalatsar, Stefanos Skalistis, Federico Angiolini, Marcel Arditi, Jean-Philippe Thiran, Giovanni De Micheli, Assessment of Image Quality vs. Computation Cost for Different Parameterizations of Ultrasound Imaging Pipelines, Proceedings of the 6th Workshop on Medical Cyber-Physical Systems, Seattle, USA, April 13th 2015.

Andreas Tretter, Harshavardhan Pandit, Pratyush Kumar, Lothar Thiele, Deterministic Memory Sharing in Kahn Process Networks: Ultrasound Imaging as a Case Study, Proceedings of the 2014 IEEE 12th Symposium on Embedded Systems for Real-time Multimedia (ESTIMedia), pp. 80-89, 2014.

Pascal Alexander Hager, Pirmin Vogel, Andrea Bartolini, Luca Benini, Assessing the Area/Power/Performance Tradeoffs for an Integrated Fully-Digital, Large-Scale 3D-Ultrasound Beamformer, Proceedings of the 2014 IEEE Biomedical Circuits and Systems Conference (BioCAS), pp. 228-231, Lausanne, CH, Oct 2014.

O. Bernard, M. Zhang, F. Varray, J. P. Thiran, H. Liegbott, D. Friboulet, Ultrasound Fourier Slice Imaging: a novel approach for ultrafast imaging technique, Proceedings of the 2014 IEEE International Ultrasonics Symposium (IUS), pp. 129-132, Oct 2014..

Andreas Tretter, Pratyush Kumar, Lothar Thiele, Interleaved Multi-Bank Scratchpad Memories: A Probabilistic Description of Access Conflicts, Proceedings of the 52nd DAC Conference, San Francisco, CA, USA, June 2015, p. 22.

> "Improving medical diagnostic imaging through state-of-the-art digital electronics"