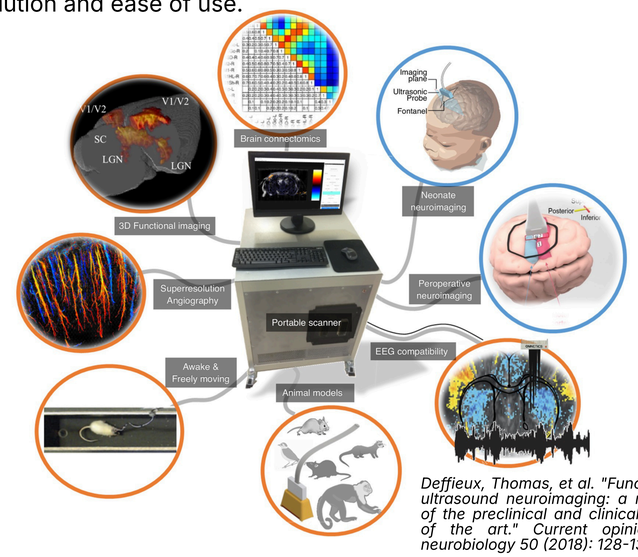
Developing an open-source pipeline for functional ultrasound imaging

Stefanos Florescu[1], Agnes Landemard[2], Michael Krumin[2], Matteo Carandini[2], Pieter Kruizinga[1,3]

(1) Erasmus University Medical Center (2) University College London (3) Delft University of Technology

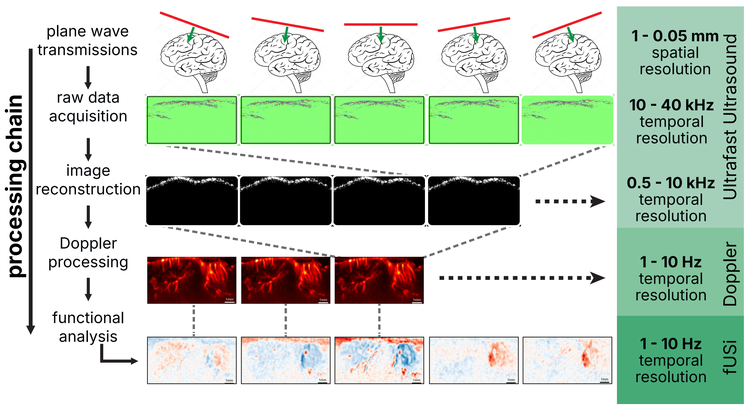
functional Ultrasound Imaging

Functional ultrasound imaging (fUS or fUSi) is an emerging neuroimaging technique that measures changes in cerebral blood flow as a proxy for neural activity. The advantages of fUSi compared to fMRI include affordability, high spatiotemporal resolution and ease of use.

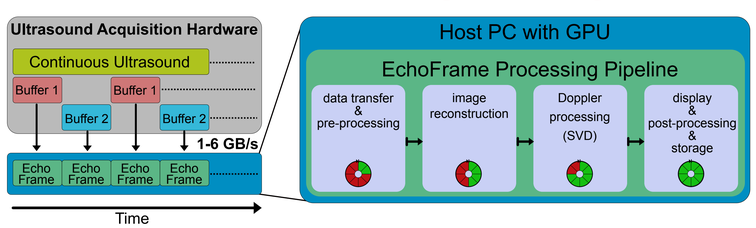


Deffieux, Thomas, et al. "Functional ultrasound neuroimaging: a review of the preclinical and clinical state of the art." Current opinion in neurobiology 50 (2018): 128-135.

Processing Pipeline



Ultrafast Processing Challenge



Problem

Although a commercial implementation of fUSi exists, a cheaper and open-source solution that makes use of existing widely available ultrasound hardware would better suit the needs of the research community.

Solution

EchoFrame, an innovative open-source reconfigurable processing pipeline, facilitating the execution of data transfer, image reconstruction, and display, crucial for real-time fUSi.

The core of the EchoFrame pipeline is implemented in C/C++ and CUDA and example Matlab code for integration with a Verasonics ultrasound system and the RigBox toolbox for managing behavioral neuroscience experiments are provided.

Experimental Results with EchoFrame

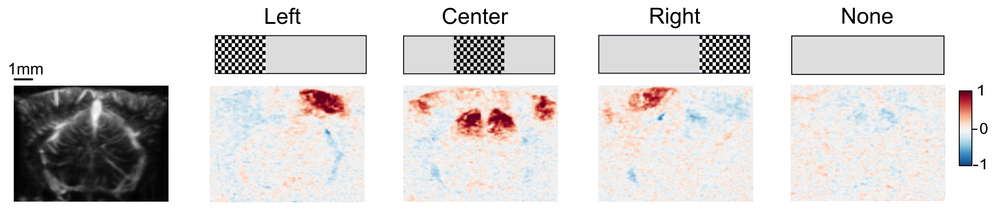
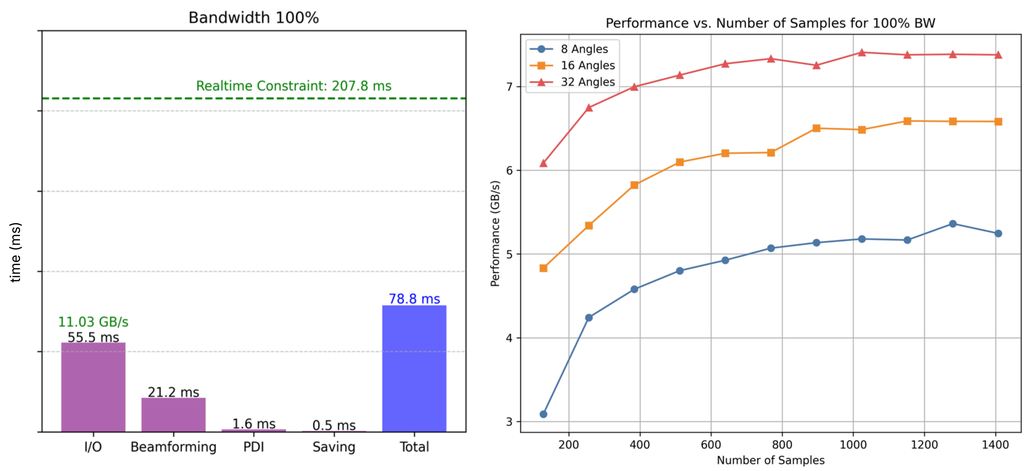


Figure 1 shows a coronal cross-section of a mouse brain. The data, reconstructed and saved using EchoFrame, show Power Doppler images from which four distinct functional responses were derived, corresponding to visual stimuli presented in three positions (“left”, “middle”, and “right”) and a control condition with no stimulus (“none”).

EchoFrame Performance Tests



Benchmarks were performed on a system with an AMD 7800X3D CPU,NVIDIA RTX4080 Super (16GB), 128GB DDR4 RAM, and 4TB PCIe5.0 NVMe SSD.

Conclusion

EchoFrame provides an open-source solution for those who want to set up fUSi in their lab to study brain wide activity through imaging of cerebral blood.

We expect EchoFrame to aid in the advancement of fUSi and to empower the neuroscience community to fully exploit the potential of fUSi.

What do you need ?

a) an ultrasound scanner with probe capable of transceiving several thousands of frames per second (by e.g. Verasonics or us4us).

b) a powerful PC with high-speed (1-6 GB/s) PC-ultrasound data-link, CUDA-enabled GPU (12 GB VRAM) and fast NVMe SSD for optimal performance.

c) EchoFrame software to process the fUSi data in real-time to facilitate continuous fUSi recordings.

www.verasonics.com

Availability & Contact Information

Available mid 2025 through GitHub

info@echoframe.org

Funding

NWO-groot (CUBE): 175.2017.008
EU Horizon Europe project Contract: 101095717
Simons Foundation: NC-GB-IBL-00002672-16
NIH: U19NS123716
Wellcome Trust: 223144