Research Project Description

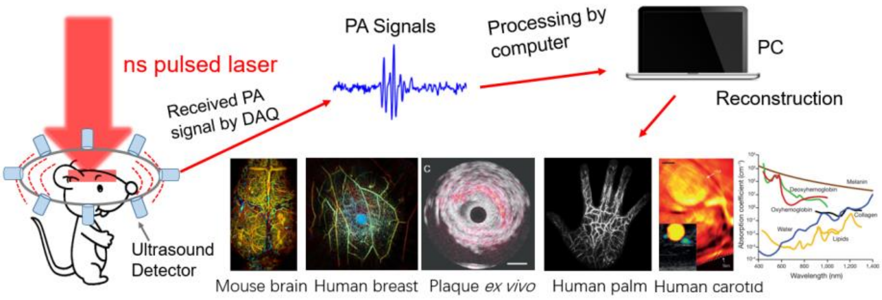
Background

As discussed in the class, analog circuits are widely used to amplify and process various sensors' acquired analog signals, such as temperature (tested almost every day after Covid-19 breakout), humidity, vibrations, voices (including audible and ultrasonic waves), vision (e.g. scattered photons detected by camera), electromagnetic waves (5G, WiFi, Bluetooth, UWB, etc.), and even gravity waves (Nobel prize in 2017).

However, the analog signals acquired by the sensors are always weak. Take gravity wave as an example, a huge laser interferometer (https://www.ligo.caltech.edu/page/ligo-gw-interferometer) is built to detect the ultra-weak gravity wave. Besides the huge sensor, low-noise amplifier and advanced signal processing algorithms are also key to recover the signals from noisy background of the universe. Technically speaking, improving the signal-to-noise ratio (SNR) is very important.

The LIGO system

Moving back to daily life from the universe, the method of improving SNR is also key in medical imaging devices. Take the emerging photoacoustic (PA) imaging technology as an example (What is PA imaging? Visit: https://www.science.org/doi/10.1126/science.1216210 and our lab website: www.hislab.cn), the physical process includes both light and sound propagation in highly scattering biological tissues, which lead to severe PA signal attenuation and SNR degradation. The way to improve the PA signal's SNR is of great importance to image quality.



Photoacoustic effect

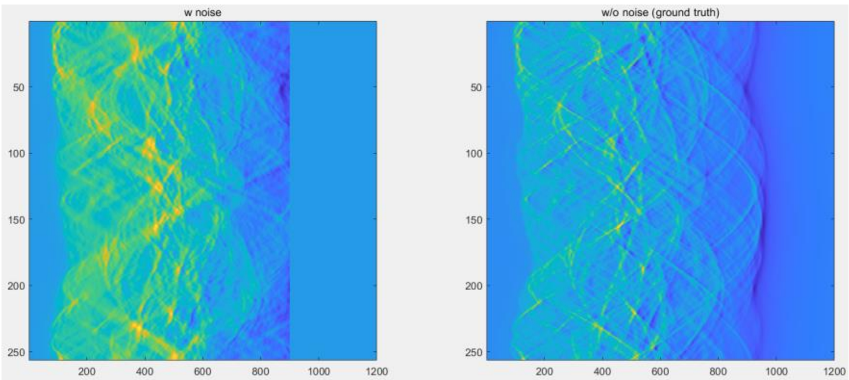
To be more specific, PA imaging of human brain is the most challenging clinical application in this domain. Up to now, there is still no transcranial human brain PA imaging results reported (The only reported human brain results are on patients with hemicraniectomy after removing the skull: https://www.nature.com/articles/s41551-021-00735-8). Why is human brain imaging is so challenging to PA imaging? Because the thick skull scatters and attenuates the light and sound dramatically.

PA imaging of patients with hemicraniectomy

Although experimentally performing the transcranial human brain imaging is currently impossible, numerical simulations can be studied if we can build a realistic model in computer. In 2021, we released the photoacoustic digital brain dataset generated from MRA images (https://arxiv.org/abs/2109.09127). Jiadong Zhang (TA of our class) is the co-first author. By simulating the PA imaging based on the numerical model, we could obtain the PA signals from the human brain with noise.

Dataset

We provide eight paired human brain photoacoustic sinogram in the folder. In folder 'Signal-withnoise', we have the sinogram with noise. In folder 'Ground_truth', we have the corrected sinogram as ground truth. All data are provided with '.mat' format, and you can open them with Matlab/Python or other software easily.



A typical sonogram of PA signals

Objective

To recover the true PA signals from the noisy PA signals. Compare the recovered PA signals with the given ground-truth PA signals, and calculate the similarities quantitatively.

Submission

A **technical report**, describing your method, results, discussion, and conclusion. **Source code** needs to be appended.

Submit your report (with source code) to TA: ee115a_fall@163.com

Deadline: 9 Jan. 2022