

2024 CALTECH SURF

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RESEARCH – ACOUSTIC PINN

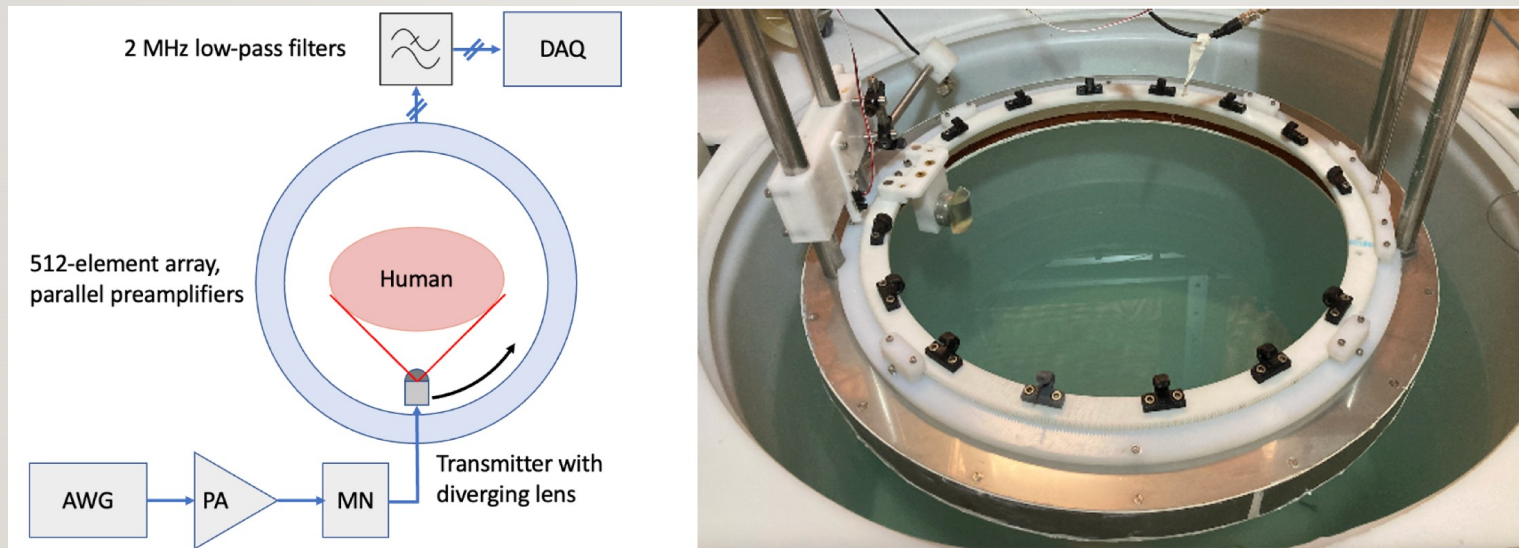


INTRO

- Since its introduction in the mid-20th century, ultrasound imaging has transformed healthcare by providing rapid and cost-effective insights into tissue structure and function. Although initial results were promising for disease diagnosis, bulky electronics and slow acquisition times required several minutes of mechanical scanning. Advances in transducers and electronics led to handheld probes, which are now widely used but require trained operators. These probes provide limited reflection-mode images with a narrow field of view (FOV) and struggle to visualize features behind bone or air pockets.
- Recently, smaller immersion tanks with various transducer arrays (planar, linear, ring, or hemispherical) have been explored for ultrasound tomography (UST) of the breast and limbs. These systems capture both reflected and transmitted signals, allowing for the recovery of reflectivity, speed of sound, and attenuation profiles. However, current system geometries and parameters (e.g., acoustic frequency, transmitter power, and detection sensitivity) are not yet suitable for whole-body human imaging.

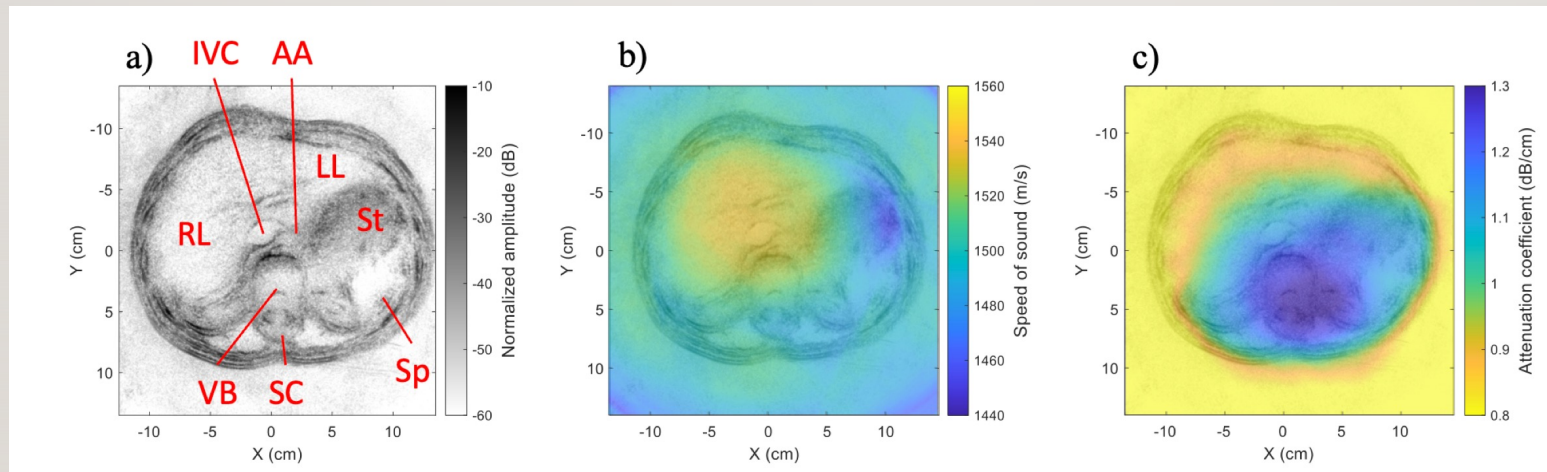
INTRO

- At COILab, we employ a custom circular array with 512 receiver elements and a single-element transmitter that rotates around the subject. This setup enables whole-body ultrasound tomography (UST) imaging of humans immersed in water, producing 2D isotropic images of reflectivity, speed of sound, and attenuation profiles. With full 360° viewing angles, we can penetrate tissues such as bone or air pockets, overcoming previous acoustic limitations.



INTRO

- However, factors such as transducer spatial and temporal sensitivity, transducer positioning errors, and noise affect limit reconstruction quality in transmission-mode profiles. In addition to these factors, having a 2D detection geometry can severely affect the quality of the speed of sound and attenuation images obtained from the system.

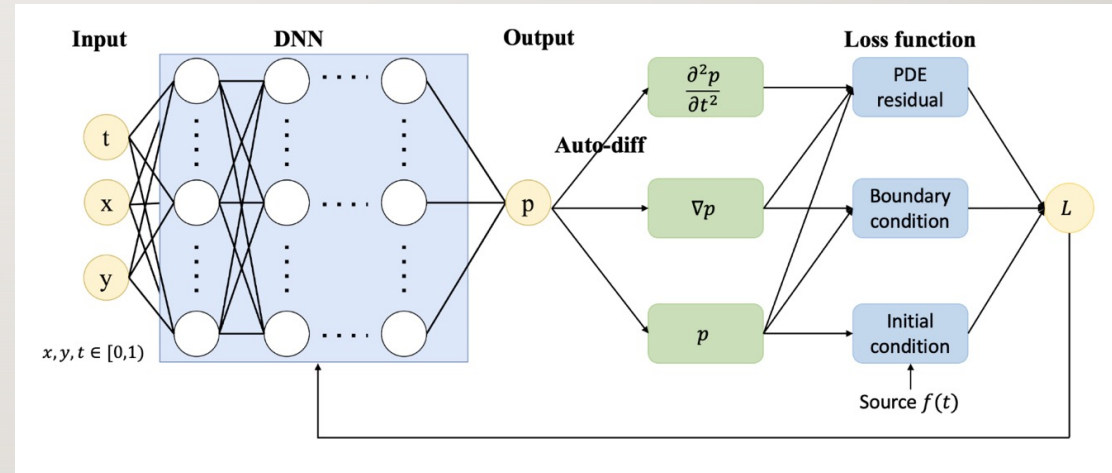


INTRO

- My project revolves around the utilization of the newly emerging physics-informed machine learning concept to enhance the images obtained from the whole-body human ultrasound imaging system which will increase the system's utility in diagnostic applications. Compared to numerical methods for solving partial differential equations (PDEs), physics-informed learning better integrates noisy data to address high-dimensional problems. It also excels at solving inverse problems compared to conventional methods due to its flexibility, continuous and over-parameterized representation, scalability, and efficient gradient computation. Additionally, unlike conventional machine learning approaches, physics-informed methods are more robust, interpretable, require less data, and remain faithful to the physical model while retaining all the other advantages of machine learning models.

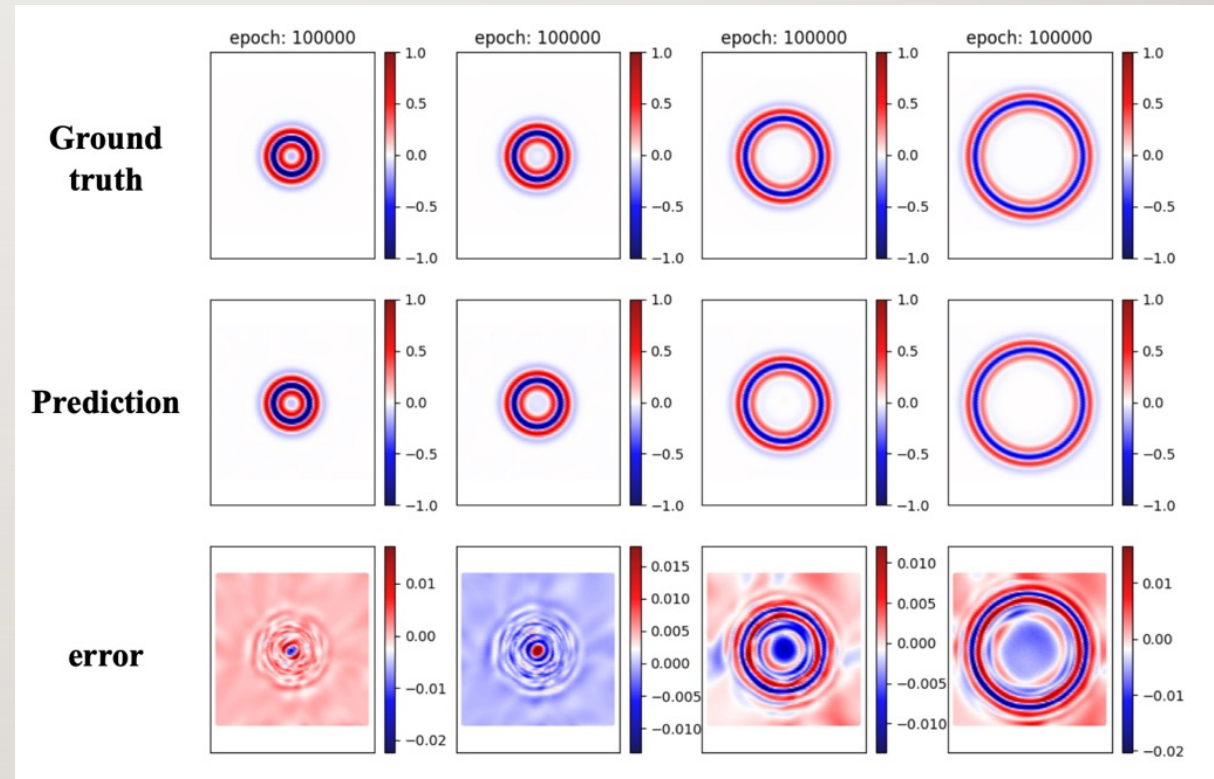
PHYSICS INFORMED NEURAL NETWORK (PINN)

- The input to the model consists of spatio-temporal collation points, and the output is the measured pressure at these points, denoted as $p(x, y, t)$. Using auto-differentiation, we obtain ∇p and $\frac{\partial^2 p}{\partial t^2}$ which are used for loss calculation, including the PDE residual loss, boundary condition loss and initial condition loss.

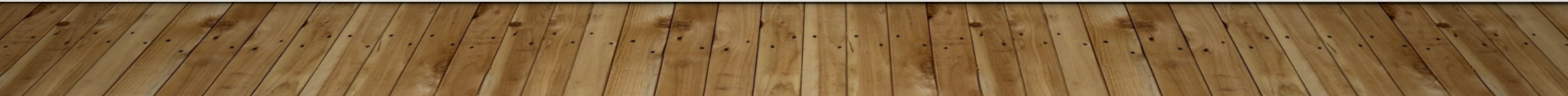


RESULT

- The result is shown in Fig. 2. In this scenario, a source is placed at the center, emitting a wave that propagates through a homogeneous medium. The peak error we can achieve is as low as 1.5%. We also tested our PINN model in an inhomogeneous medium and achieved the same level of accuracy.



LEISURE ACTIVITY



BRAUN ATHLETIC CENTER



- The Braun Athletic Center features the main gymnasium (used for intercollegiate competition as well as recreation); a 3,500-square-foot weight room including a Cybex Circuit, free weights and various cardiovascular machines such as treadmills, ellipticals, rowing machines, cross-trainers and upright and recumbent bikes; four racquetball courts; two international squash courts; a multipurpose room for group fitness activities and locker rooms with showers. This is where I usually went exercising after work.

PASADENA CITY HALL



- City Hall was designed by John Bakewell and Arthur Brown, drawing inspiration from the early Renaissance style of 16th-century Italian architect Andrea Palladio. This massive circular building rises vertically for six stories, with the fifth story standing 41 feet tall, featuring four large round arches and four smaller ones. It is one of the most popular tourist attractions and photography spots in Pasadena.

GRIFFITH OBSERVATORY

- Located on the south slope of Mount Hollywood in Griffith Park, the Observatory is literally in the center of metropolitan Los Angeles. The observatory is a popular tourist attraction with a close view of the Hollywood Sign and an extensive array of space and science-related displays.



MALIBU CREEK STATE PARK

- In 1962, 20th Century Fox built the Sersen Tank, named after special effects artist Fred Sersen, on their movie ranch. Holding 3 million gallons of water and featuring a large painted sky backdrop, it was constructed for "Cleopatra" and later used in films like "Tora! Tora! Tora!", "Planet of the Apes", and "The Towering Inferno." In 1982, the sky backdrop was removed, and the tank was filled with dirt. Despite being nicknamed "Skypool" in later years, it was never officially called that while under studio ownership.



THE HUNTINGTON GARDEN



- Henry Edwards Huntington's passion for art was largely shaped by Arabella and guided by art experts. He took advantage of the post-World War I European market, which was eager to sell. Before his passing in 1927, Huntington had accumulated what was described as "by far the greatest collection of 18th-century British portraits ever assembled by one individual." As per his will, this collection, valued at \$50 million, was made public in 1928.
- The Huntington is a must-visit destination in Los Angeles, featuring 130 acres of stunning botanical gardens and landscapes, complemented by a historic mansion, renowned art collections, and rare literary and historical treasures. The main exhibition hall of the library displays remarkable rare books and manuscripts, while the West Hall hosts rotating exhibits. The Dibner Hall of the History of Science offers a permanent exhibition focused on astronomy, natural history, medicine, and light.