Verasonics®
The leader in Research Ultrasound™

Essentials of Ultrasound Imaging Course

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Verasonics, the leader in research ultrasound, provides the Essentials of Ultrasound Imaging Course - a complete educational package for institutions and organizations interested in offering a comprehensive ultrasound curriculum. This unique, ready-to-teach curriculum provides educators with the elements required to offer a graduate-level ultrasound course, including the basic physics and instrumentation needed to understand pulse-echo imaging.

The course allows students and industry professionals lacking knowledge about basic ultrasound concepts to couple education of ultrasound theory with hands-on experiences using a Vantage® or Vantage *NXT* Research Ultrasound System in a laboratory setting.

Overview

The curriculum for the Verasonics ***Essentials of Ultrasound Imaging (EoUSI) Course*** offers a fast-track introduction to the science, physics, and technology of ultrasound imaging in ten modules, while using the select Vantage or Vantage *NXT* Systems as the educational lab platform.

The presentation of the material is unique in two ways:

First, principles introduced in the provided lectures are revealed by interactive software simulators that embody key equations, allowing students to engage with the concepts with minimal mathematical background, gaining understanding that normally requires significant mathematical sophistication to acquire. The simulators are powerful enough to allow in-depth exploration of the material with quantitative virtual experiments done numerically. Knowledge of MATLAB® scientific programming language is not required, nor is a MATLAB license required to run the simulator software.

Second, the concepts are demonstrated through experiments run on a Vantage or Vantage *NXT* Research Ultrasound System through software scripts and laboratory imaging kits designed for this course. The use of a Vantage or Vantage *NXT* System provides unparalleled insight into each step of ultrasound image creation including transducer operation, different types of beamforming, signal processing, and image formation. Imaging principles are brought to life by hands-on experiments, which produce quantitative results.

Course Content

A comprehensive overview introduces the major functional blocks of two types of ultrasound imaging systems: a commercial system with delay and sum hardware beamforming tailored to scanline imaging, and select configurations of the Vantage or Vantage *NXT* Research Ultrasound System with a unique and flexible software-based architecture. Signal processing, beamforming, and imaging formation are described and experienced through interactive modules and laboratory exercises. Interactive simulators demonstrate the basics of wave propagation, refraction, reverberation, reflection, scattering, imaging, and Doppler imaging. In addition, an introduction to transducers, diffraction, acoustic fields (both continuous wave and pulsed), focusing, plane wave compounding, power law absorption, and heating is included. The course builds on the principles presented to introduce advanced topics and growth areas in ultrasound research.

Course Audience

This course is ideal for entering graduate students and/or new engineers in industry; however, the material would appeal to a wider circle of students and instructors. The secondary audience includes those who are involved in, or starting, ultrasound research and development, who may not have a comprehensive background to fully comprehend the latest developments in this arena. This could include scientists and engineers from other disciplines, physicians, sonographers, managers of research or engineering groups, or anyone curious about ultrasound science.

Note:

- Familiarity with MATLAB is not required, but interesting analysis can be done using acquired data at the instructor's discretion.
- Student knowledge of Vantage or Vantage *NXT* System programming is not required; GUI-driven imaging and data acquisition programs are provided.
- This is not a Vantage or Vantage *NXT* System training course, this is an educational offering that should be taught by an instructor familiar with ultrasound technology.

Course Elements

- Essentials of Ultrasound Imaging Curriculum Packet: 10 lecture modules in PPT, 9 lab lectures in PPT plus Lab Instructor Manual, EoUSI Simulators in Windows and macOS.
  - EoUSI Simulators are interactive, near real-time simulation programs in executable form, with instruction manual. No extra licenses are required, simulator packages have a 12-month lifespan.
- EoUSI Custom Phantom with a set of special targets that reinforce physics concepts through student labs
- ***Essentials of Ultrasound Imaging***, by Szabo & Kaczkowski (Elsevier, 1st Edition). Each textbook chapter provides explanations of the concepts and equations related to the simulators and experiments.

More information on the EoUSI Curriculum Packet elements:

- Lecture presentation slides, each lecture is approximately 45-60 minutes long.
- Student labs consisting of instructive lectures, simulation exercises and a series of experiments for students to acquire ultrasound data using a Vantage or Vantage *NXT* System (1-2 hours each).
  - Students will learn to conduct a series of experiments using a Vantage or Vantage *NXT* System to acquire ultrasound data.
  - The instructor may choose to collect data sets for distribution to students.
- A suite of interactive simulation programs to illustrate course principles for use during the lectures and labs.

Hardware/Software Prerequisites

- Vantage 64, 64 LE, 128 or 256 (Standard or High Frequency - Image Reconstruction Option required for Vantage 64) OR Vantage *NXT* 64, 64LE, 128 or 256 (Mid or High Frequency - Image Reconstruction Option required for Vantage *NXT* 64)
- UTA 260-S, 260-D, or 260-MUX OR Vantage *NXT* UTA 260-S, Vantage *NXT* UTA 260-D, or Vantage *NXT* 260-MUX
- L11-5v Linear Array Transducer
- MATLAB software (version 2022a or newer)
- Imaging-resolution phantom (similar to CIRS Fathom Image Quality Phantom)

Student Prerequisites

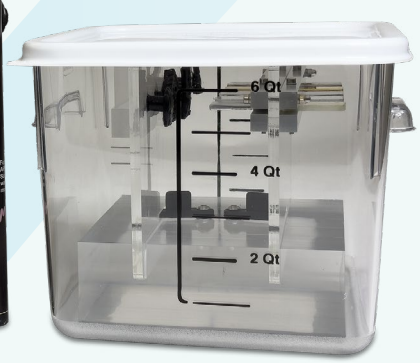
- General understanding of basic physics
- College level algebra, trigonometry and calculus

Student Requirements

All students enrolled in an EoUSI Course should acquire these items before the course begins:

- ***Essentials of Ultrasound Imaging***, by Szabo & Kaczkowski (Elsevier, 1st Edition)
- Essentials of Ultrasound Imaging Simulators – download Windows or macOS version from Verasonics, free of charge

Imaging-resolution Phantom
(Available via purchase from Verasonics or lab-owned)



EoUSI Custom Phantom
(Available via purchase from Verasonics)

Module 1

Introduction to Imaging & Imaging Systems

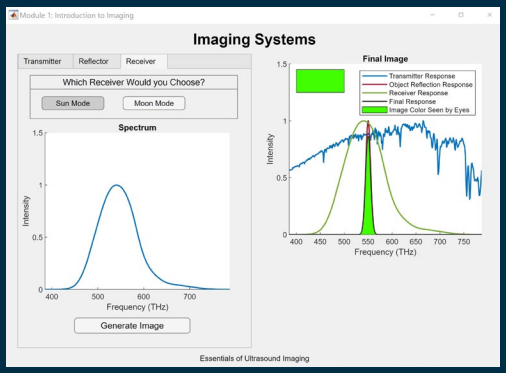
Description

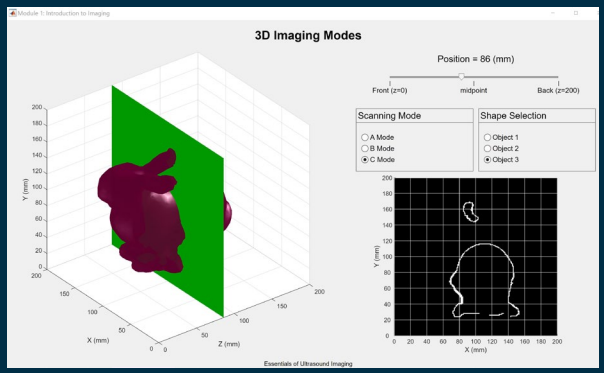
Topics covered: Types of imaging, introduction to imaging systems, waves, spectra, transmitters, receivers, scanning, comparison of ultrasound medical imaging modalities, advantages, limitations, introduction to ultrasound imaging systems and physical processes (block diagram level), ultrasound research systems, course overview, A, B and C imaging modes and lines, 2D and 3D imaging.

Hands-on Lab: Introduction to basic imaging with a linear array transducer and imaging of 3D objects.

Simulation programs:

- Imaging System Simulator
- Secret Objects Simulator
- 3D Imaging Modes Simulator





Module 2

Rays & Waves

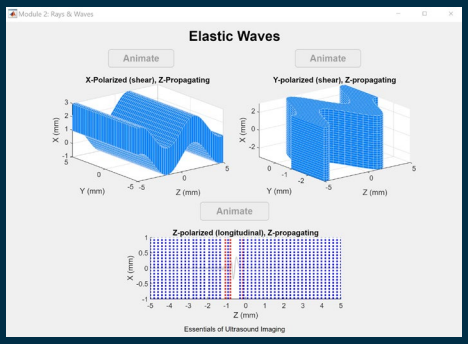
Description

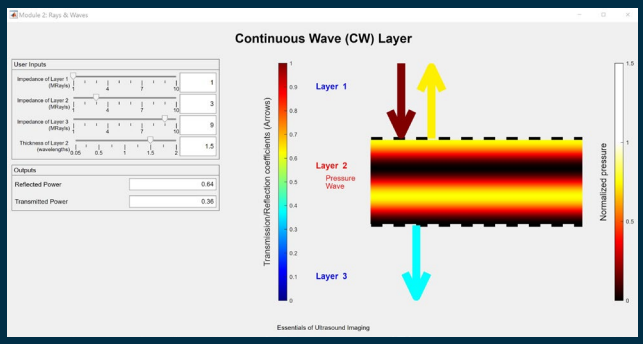
Topics covered: Types of propagating elastic waves, acoustical/electrical analogies, wavefronts, reflection, refraction, scattering, finite layers, and resonance.

Hands-on Lab: Imaging through refractive media.

Simulation programs:

- Elastic Wave Simulator
- Expanding Waves Simulator
- Pulse Reverberation in Layer Simulator
- Continuous Wave Layer Simulator
- Oblique Refraction Simulator
- Pulse Delay Simulator





Module 3
Signals

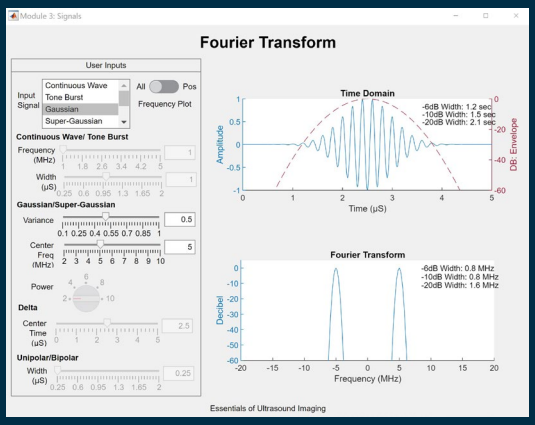
Description

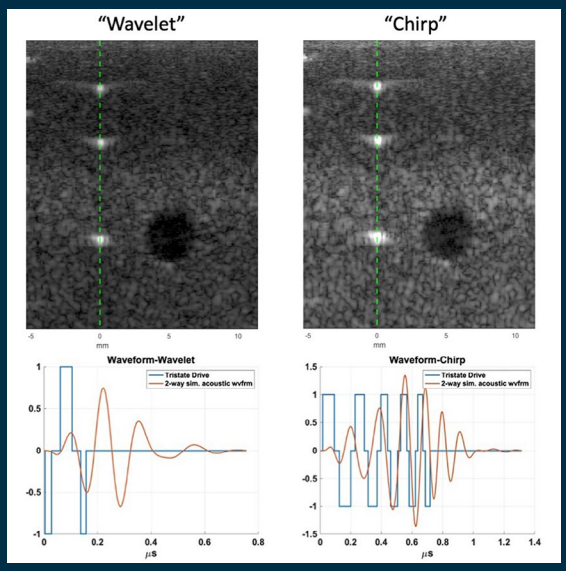
Topics covered: Signals in time, spectra, Fourier transforms, filters, drive waveforms, convolution, ABCD matrix representation, absorption.

Lab Simulator Exercises: Generating different shaped pulses and imaging various thin targets, A-line analysis..

Simulation programs:

- Fourier Transform Simulator
- Fourier Filter Simulator
- ABCD Simulator
- Absorption Simulator





Module 4
Transducers

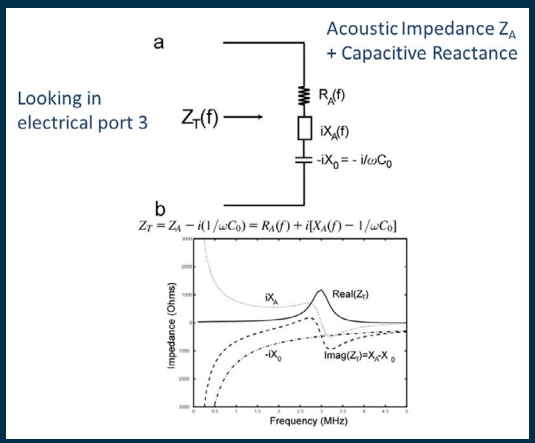
Description

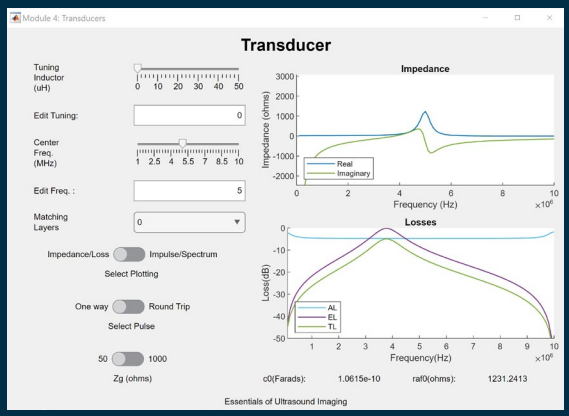
Topics covered: Piezoelectricity, construction of transducers, introduction to transducer equivalent circuit models, matching layers, ABCD matching circuits, transducer design goals (resolution, sensitivity, bandwidth), and array construction.

Hands-on Lab: Using different shaped pulses to reflect from various layered targets, A-line analysis.

Simulation programs:

- Transducer Simulator





Module 5

Beams & Focusing (Continuous Wave)

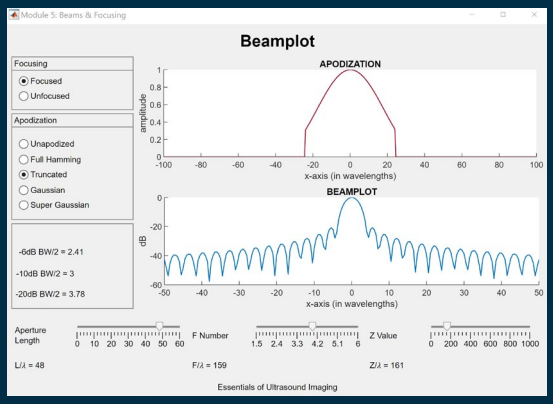
Description

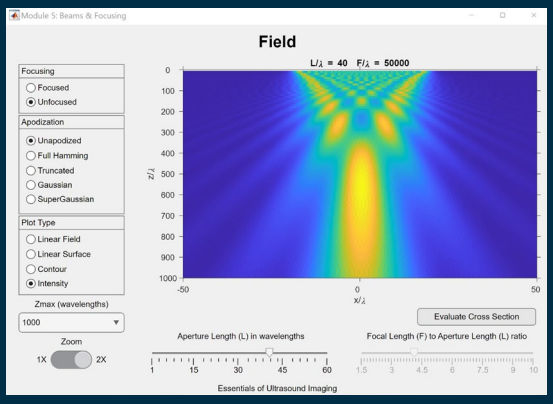
Topics covered: Diffraction, Fourier transforms for field simulation, apertures, focusing, depth-of-field, F-number, apodization, near and far field, focal zone, spatial impulse response, and beam plots.

Hands-on Lab: Visualizing the CW acoustic fields using the parameterizations described in the lecture and producing beam plots.

Simulation programs:

- Beam Plot Simulator
- Field Simulator





Module 6

CW Array Beamforming & Heating

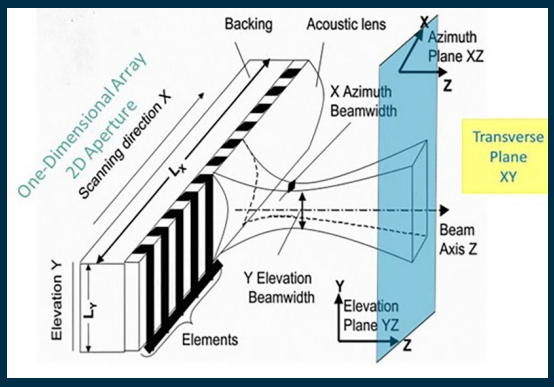
Description

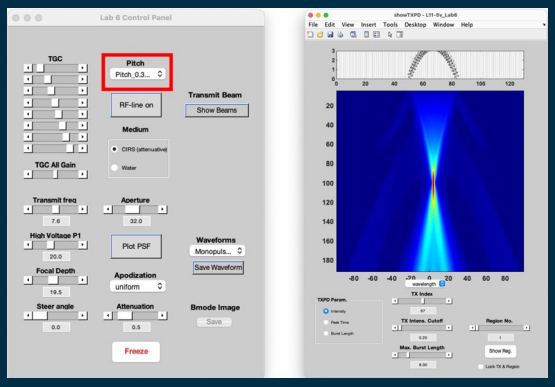
Topics covered: Rectangular array elements, element sampling, array directivity, array focusing and steering, three dimensional fields from arrays, absorption effects in time and frequency domains, effects of absorption on pulse shape and delay, viscoelasticity, properties of materials, ultrasound-induced heating, and tissues and plane wave compounding.

Hands-on Lab: Demonstrating steering and focusing on sparsely sampled arrays and grating lobes, elevation focus determination.

Simulation programs:

- Wavefronts Simulator
- Directivity Simulator
- Array 3D
- Continuous Wave Simulator
- Planewave Compounding Simulator





Module 7

Pulsed Phased Array Beamforming

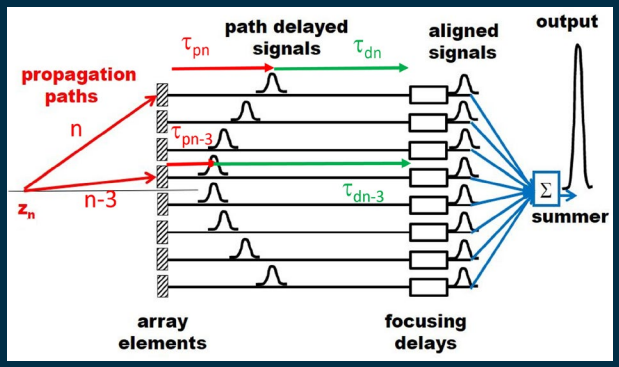
Description

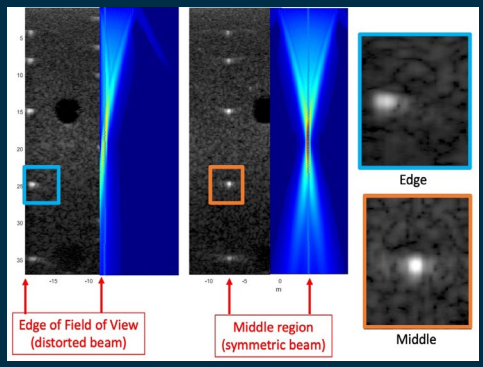
Topics covered: Wavefronts from arrays, focusing and steering with arrays, sampling effects, grating lobes, dynamic receive focusing, point spread functions, and types of arrays.

Lab Simulator Exercises: Demonstrating effect of pulse drive delays and apodization on steering and focusing, measurement of point spread function, effects of element periodicity on grating lobes, absorption measurements.

Simulation programs:

- Pulsed Array Simulator





Module 8

Ultrasound Imaging Systems & Display

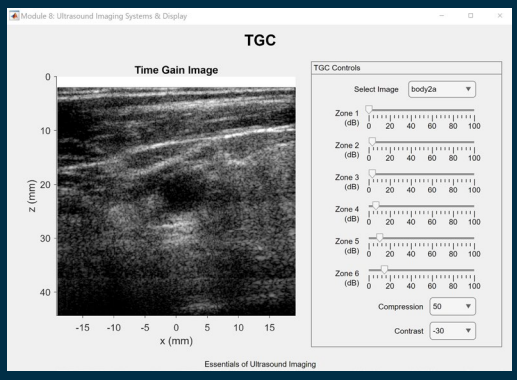
Description

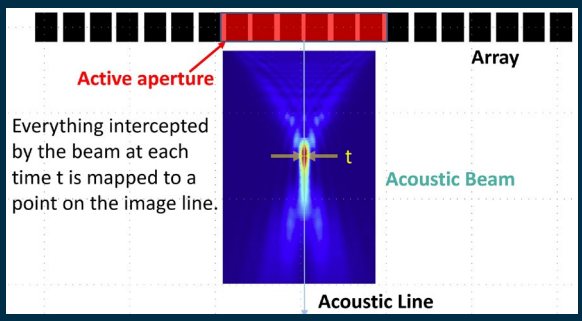
Topics covered: Block diagrams for physical processes and imaging system, imaging processing (back end), scanning methods, frame rate, image simulation and measurement. Introduction to scanning for images, time gain compensation, and plane wave compounding frame rate, speckle.

Hands-on Lab: Learn about imaging controls, TGC effects, coherent vs. incoherent compounding approaches, wide beams, delay and sum beamforming, role of the reconstruction sound speed, examine tradeoffs between image quality and frame rate, contrast ratio for different imaging modes and settings of compression and gain.

Simulation programs:

- Scatter Imaging Simulator
- TGC Simulator
- Multifocus Simulator
- Video Simulator
- Speckle Simulator





Module 9
Doppler Imaging

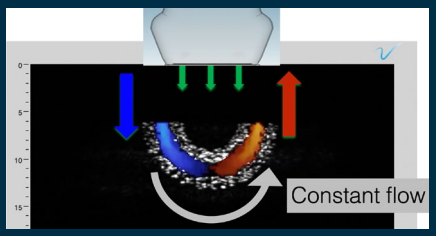
Description

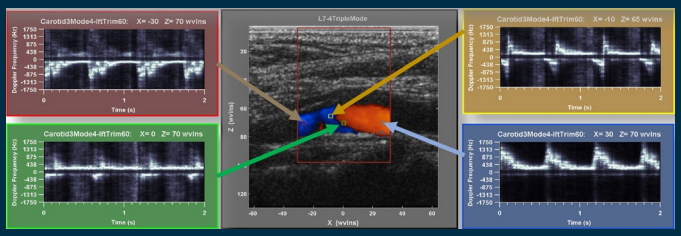
Topics covered: Principles of Doppler measurement and imaging of blood flow: introduction to continuous wave and pulsed wave Doppler and Doppler processing, color flow, power Doppler and vector Doppler imaging.

Hands-on Lab: Imaging using a moving points flow simulation, showing effects of pulse repetition rate, flow rate, geometry and direction on Doppler data and imaging for pulsed Doppler, Color Flow, Power Doppler.

Simulation programs:

- Color Flow Simulator
- Doppler Simulator
- Vantage Doppler Simulation Tool



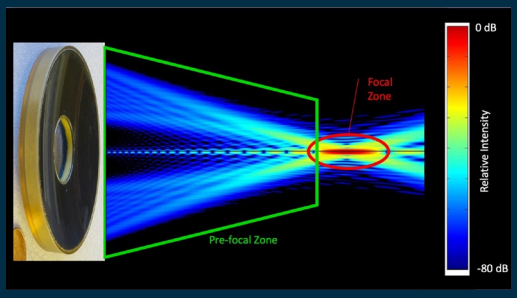


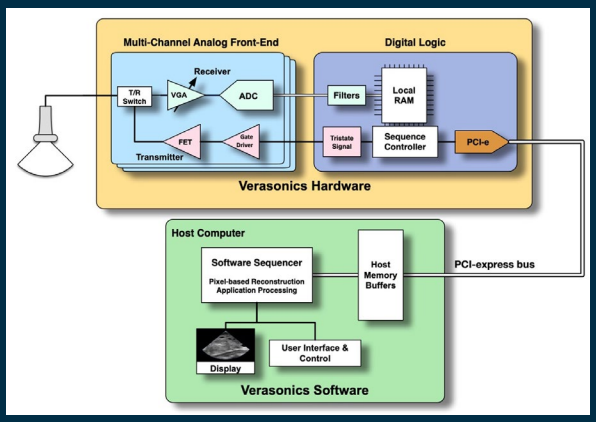
Module 10
Introduction to Advanced Ultrasound Imaging & Processing Methods

Description

Topics covered: Introduction to advanced topics (harmonic imaging, shear wave elastography and ultrafast imaging), selected research applications in ultrasound, advantages of ultrasound over other modalities.

Laboratory lecture: Examples of different modalities explained and demonstrated.





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