VisibleUS: From Cryosectional Images to Real-Time Ultrasound Simulation

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Introduction and Related Work:

Ultrasound imaging is essential in musculoskeletal medicine due to its real-time feedback, non-invasive application, and accessibility [PMGU17]. However, interpreting ultrasound images presents these key challenges:

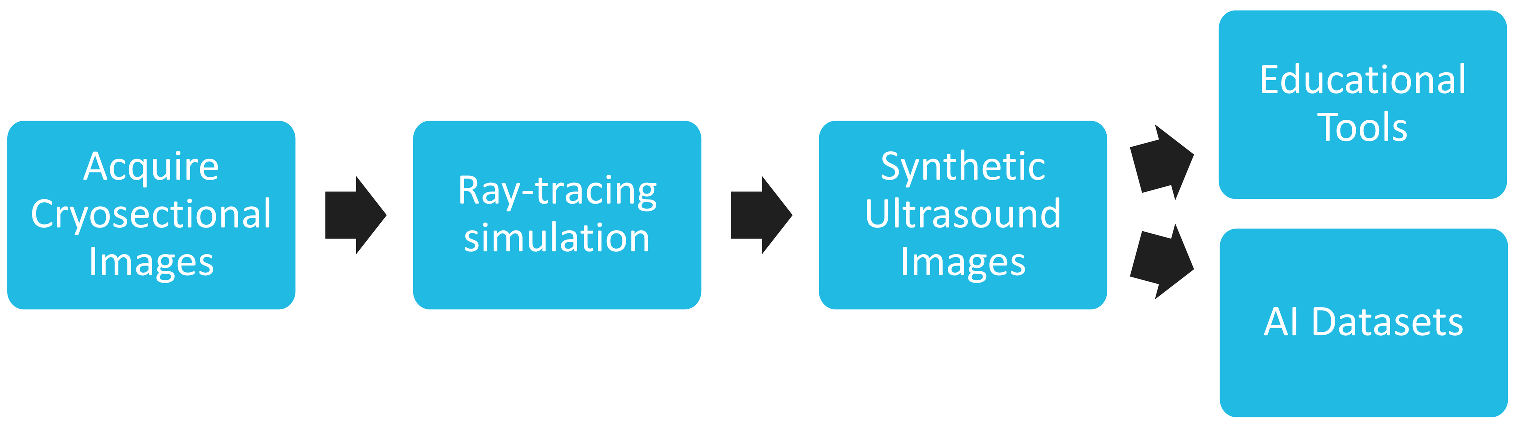
- High variability in image appearance depending on probe positioning, tissue composition, ultrasound system parameters, etc.
- Difficulty distinguishing anatomical structures, especially for inexperienced users.
- Lack of realistic, high-fidelity training tools.

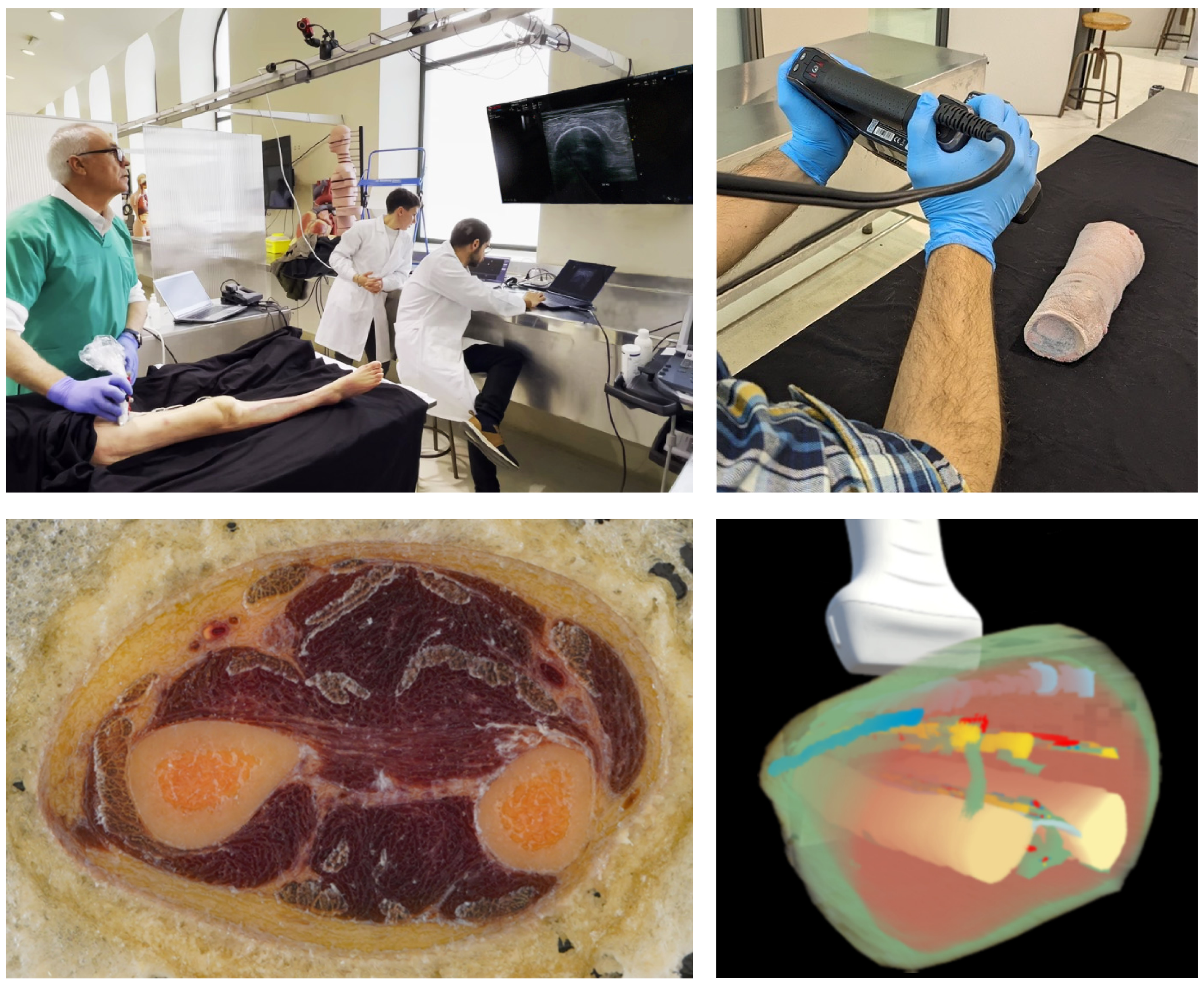
Ray-tracing-based ultrasound simulators have been explored to improve realism by modeling wave propagation and tissue interaction[RPAS09][APD∗24]. However, these systems typically rely on simplified surface models, limiting internal anatomical detail. The Voxel-Man project [BLH∗04] demonstrated the educational value of cryosection data but did not include real ultrasound simulation.

VisibleUS Project:

The goal of VisibleUS is to design and implement a simulation system capable of producing realistic ultrasound images from cryosection images using a real-time ray-tracing approach. The project aims to:

- Leverage RGB cryosectional volumes for tissue texture and boundary information.
- Simulate acoustic effects such as attenuation, reflection, and speckle generation.
- Enable real-time rendering suitable for interactive training environments.
- Generate labeled datasets suitable for training machine learning models.





From cryosectional images to ultrasound simulation:

At the core of the VisibleUS project is an algorithm that generates real-time ultrasound images from 3D cryosectional data. This algorithm simulates ultrasound wave propagation through tissue, accounting for phenomena such as:

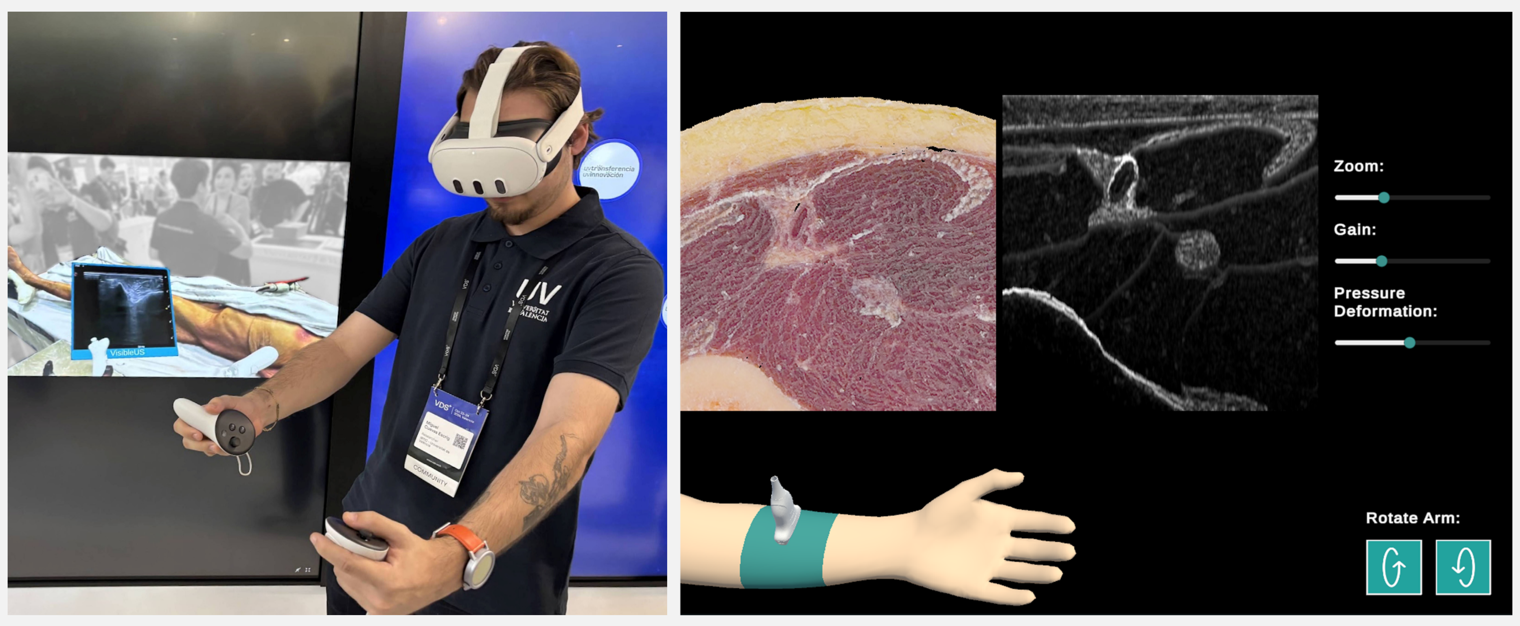
- Echo generation at tissue boundaries.
- Attenuation of energy through different tissue types.
- Speckle formation based on actual anatomical textures.

The simulator uses high-resolution RGB cryosection textures and voxel-labeled volumes to drive image generation. This enables the rendering of detailed internal features—including fibers, fascial planes, and bone interfaces—while maintaining real-time performance.

Results:

Educational Tools

To showcase the educational potential of the simulator, we developed several interactive tools that support ultrasound training. These are available in both web and virtual reality (VR) versions. Users can manipulate a virtual probe in six degrees of freedom and adjust imaging parameters such as zoom, gain, and pressure deformation. The simulator responds in real time, showing how changes in probe orientation and pressure affect the ultrasound image. This provides a highly interactive learning experience and helps users intuitively understand the link between anatomical structure and ultrasound representation.

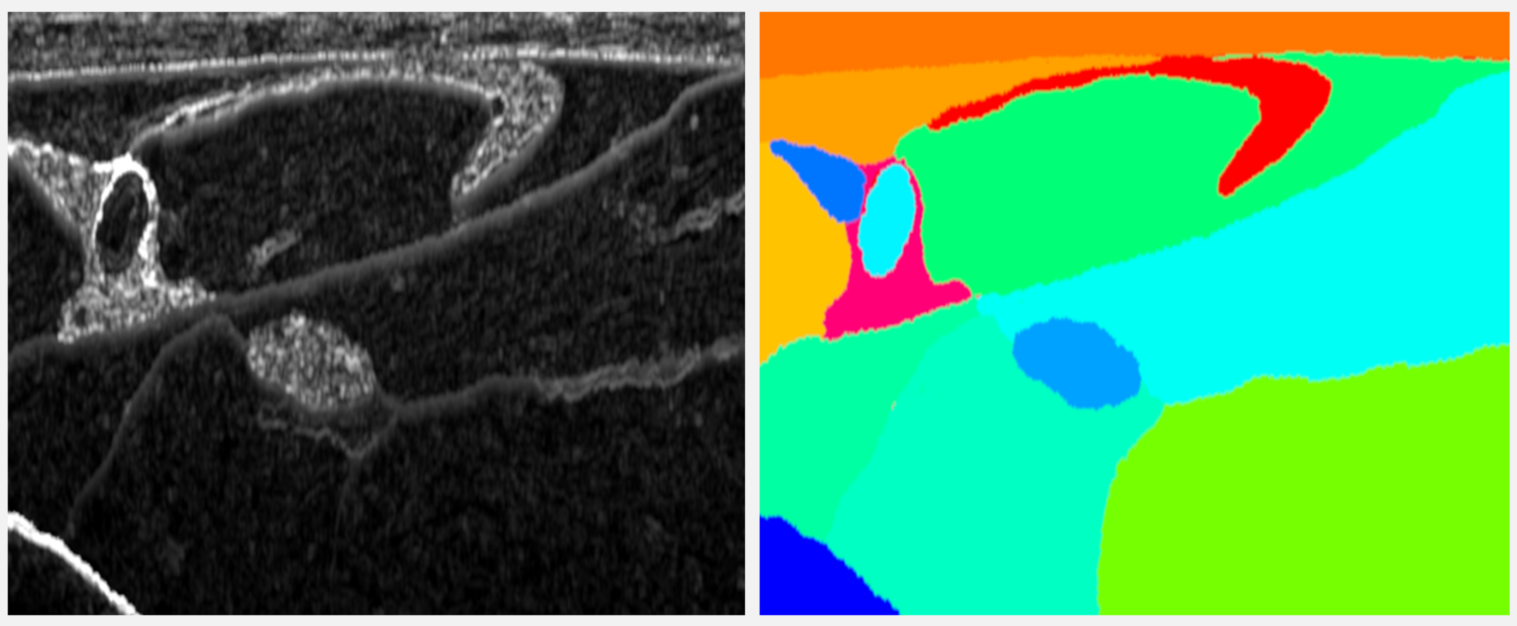


Synthetic Datasets for AI Training

The simulation framework also enables the generation of large datasets containing ultrasound images paired with pixel-level tissue labels suited for:

- Training AI models in segmentation and classification
- Research on multi-modal imaging (ultrasound + CT)

The outcomes of the project comprise real cadaver-derived imaging, including 6DoF-positioned ultrasound scans and CT volumes, making it suitable for training AI models in both simulated and real-world scenarios.



AFFILIATIONS

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