Ultrasound tracking using ProbeSight
Camera pose estimation relative to external anatomy by inverse rendering of a prior-high resolution 3D surface map

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Big Picture:
- ProbeSight: augmenting ultrasound with computer vision of the patient's exterior
- Freehand ultrasound tracking, in anatomical coordinates
- Could enable more accurate:
  • 3D ultrasound reconstructions
  • Longitudinal studies of the same anatomy
- Concept extends to most surgical tools: Make them aware of their anatomic context

Challenging natural skin features:
- Similar looking, often parallel and periodic
- Subtle; intensity features primarily from lighting/geometry
- Difficult to image from a distance (vs. contact fingerprinting)

Prior 3D Surface Map:
- High-resolution 3D surface map is preacquired
- This model serves as an atlas → anatomic coordinates
- Eliminates need for artificial skin markers

Inertial navigation system (INS):
- 3-axis gyroscopes, magnetometers, and accelerometers
- Kalman filtering → stable, accurate rotational pose
- However, INS translation estimates are noisy and drift

Real-Time Process:
- Optimized pose of virtual camera yields pose of ultrasound image in anatomic coordinates
- Rotation: Provided by inertial navigation system (INS)
- Translation: Solve for camera pose using inverse rendering (OpenDR)
  1. Acquire live image from camera mounted to ultrasound probe
  2. Undistort image and apply Contrast Limited Adaptive Histogram Equalization (CLAHE)
     • (A-priori 3D surface map was also preoperatively processed with CLAHE)
  3. Inverse rendering: search for virtual camera pose that produces an image matching the real image
     • Leverages OpenDR differentiable-rendering architecture → rapid gradient descent optimization

Results:
- Phantom Experiments: Accurate with OpenDR + INS
- Hand Experiments: Accuracy varies with anatomy
  • Need large visible creases, and...
  • Need visible shape boundaries

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Where inside the body are the ultrasound images?