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)

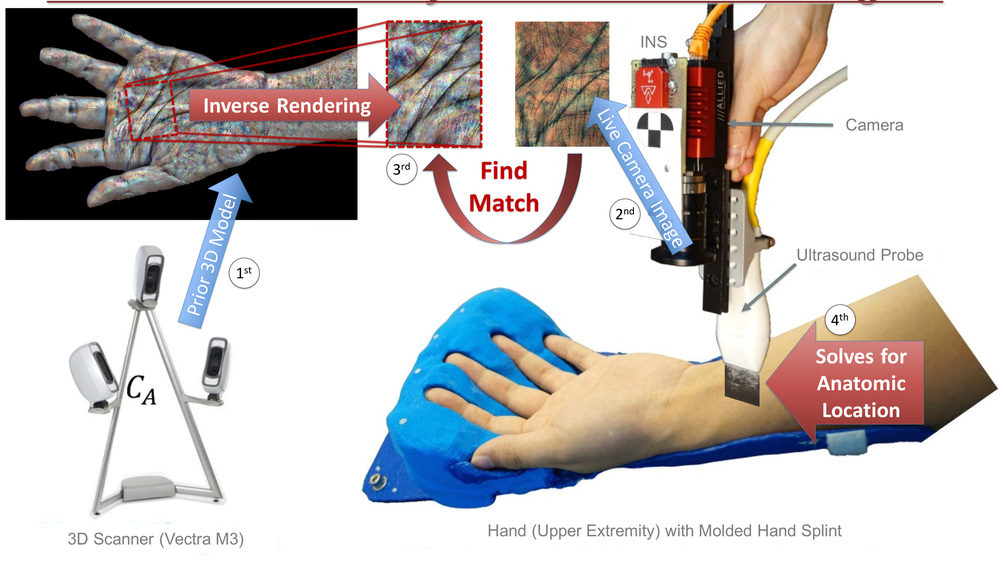
Prior 3D Surface Map:

- 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

Where inside the body are the ultrasound images?



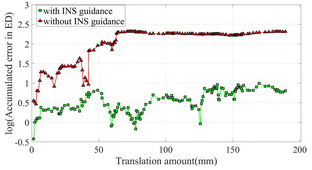
Real-Time Process:

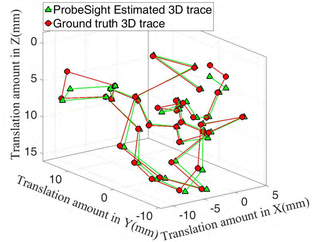
- Optimized pose of virtual camera yields pose of ultrasound image in anatomic coordinates
- Rotation: Provided by inertial navigation system (INS)
- Translation: Solve for camera pose using inverse rendering (OpenDR)

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