

# Direct Co-Calibration of Endobronchial Ultrasound and Video

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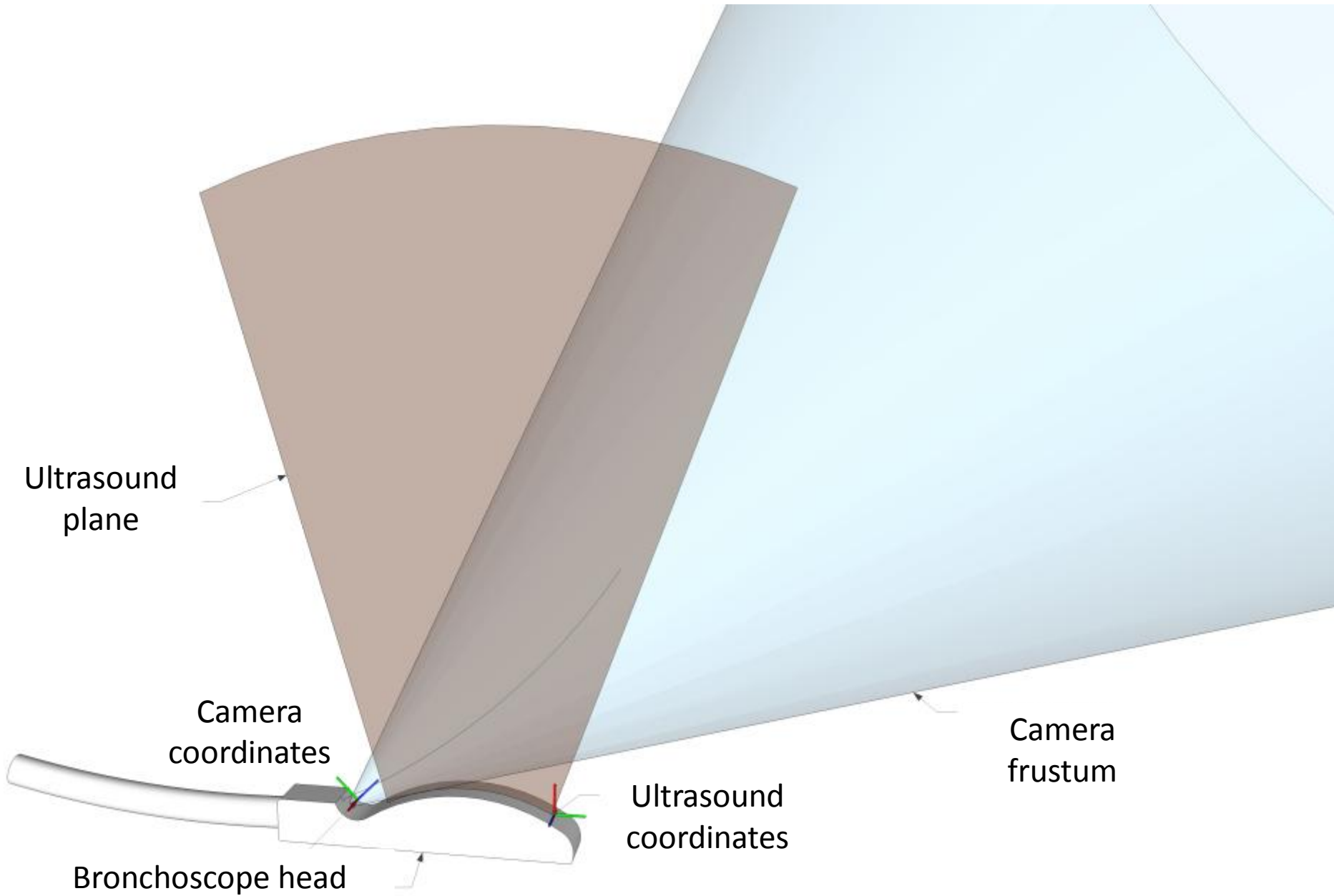
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# Introduction



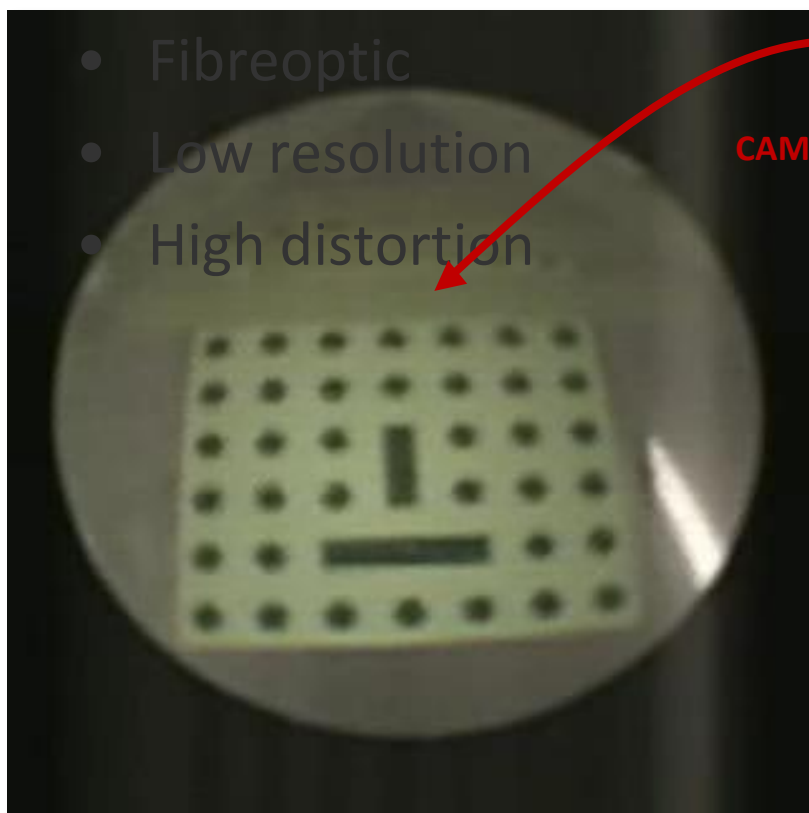
- Endobronchial ultrasound (EBUS)
- Navigation solutions may require US/Cam calibration



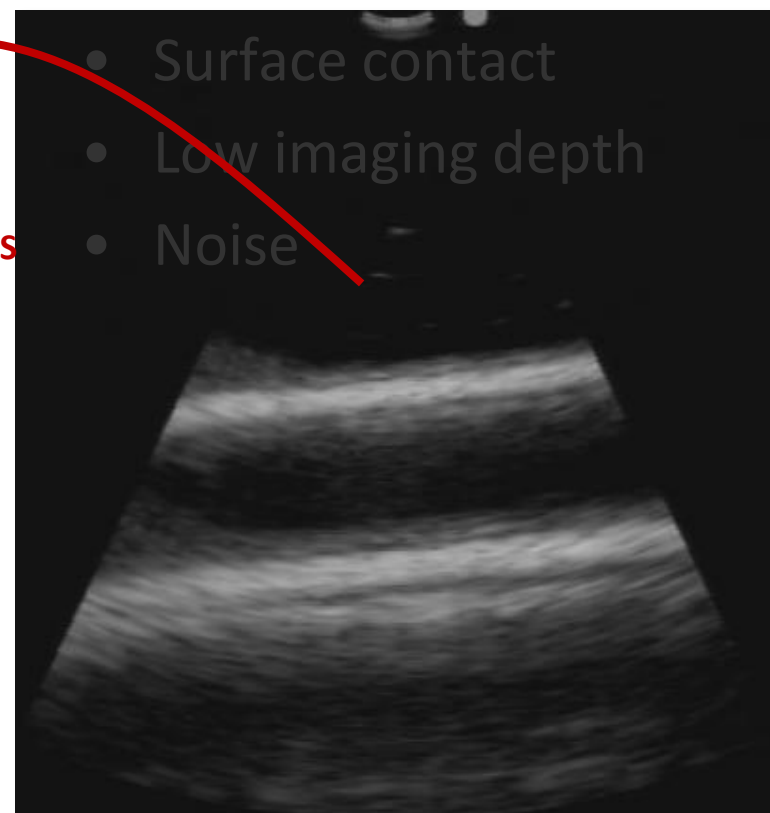


# Introduction

## Camera

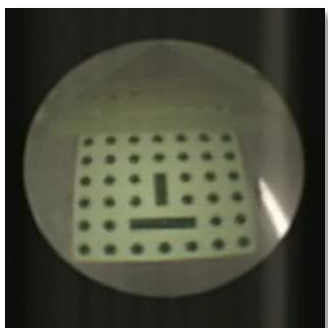


## Ultrasound



# Method

$$\lambda \cdot \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = [K \mid \mathbf{0}] \cdot {}^{CAM} H_{US} \cdot \begin{pmatrix} u \cdot s_u \\ v \cdot s_v \\ 0 \\ 1 \end{pmatrix}$$



- $\lambda$  Image scaling
- $(x, y)$  Camera image coordinates
- $K$  Camera matrix
- $(u, v)$  Ultrasound image coordinates
- $(s_u, s_v)$  Ultrasound scaling

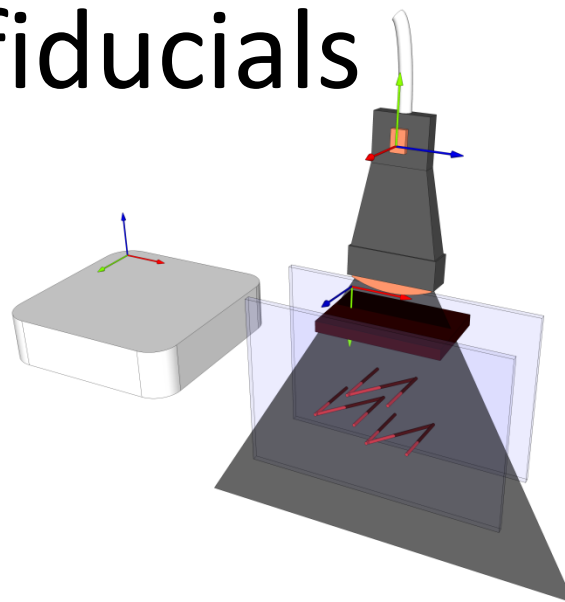
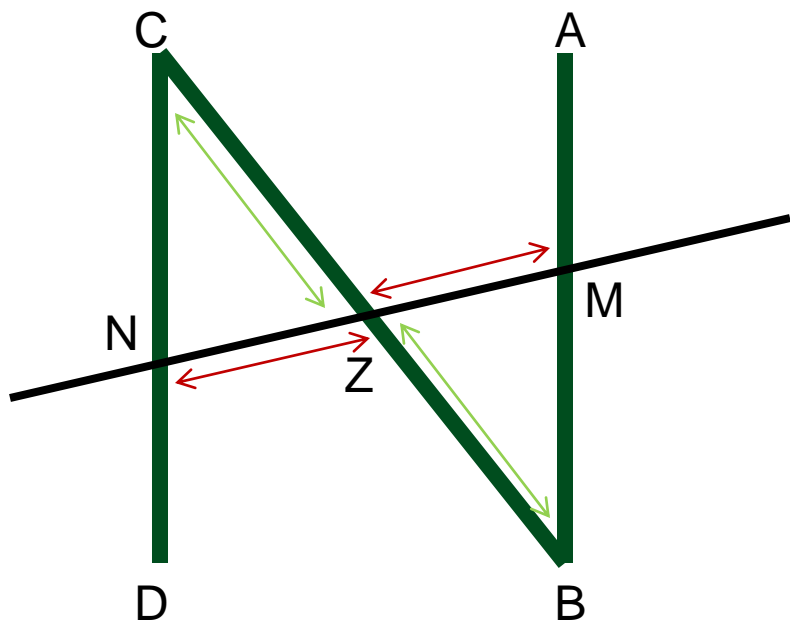
# Method

- Measure phantom in advance  
→ Allows calibration from single image pair
- Estimate camera pose using method of Wengert (also considering distortion and adjusting for velocity in water with refractive index 1.33)
- Estimate ultrasound pose using Z-fiducial method
- Combine series of images for increased accuracy

$$\lambda \cdot \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = [K \mid 0] \cdot {}^{CAM} H_P \cdot {}^P H_{US} \cdot \begin{pmatrix} u \cdot S_u \\ v \cdot S_v \\ 0 \\ 1 \end{pmatrix}$$

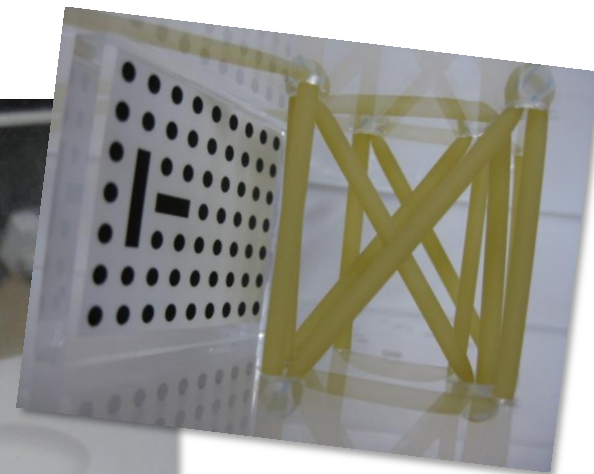
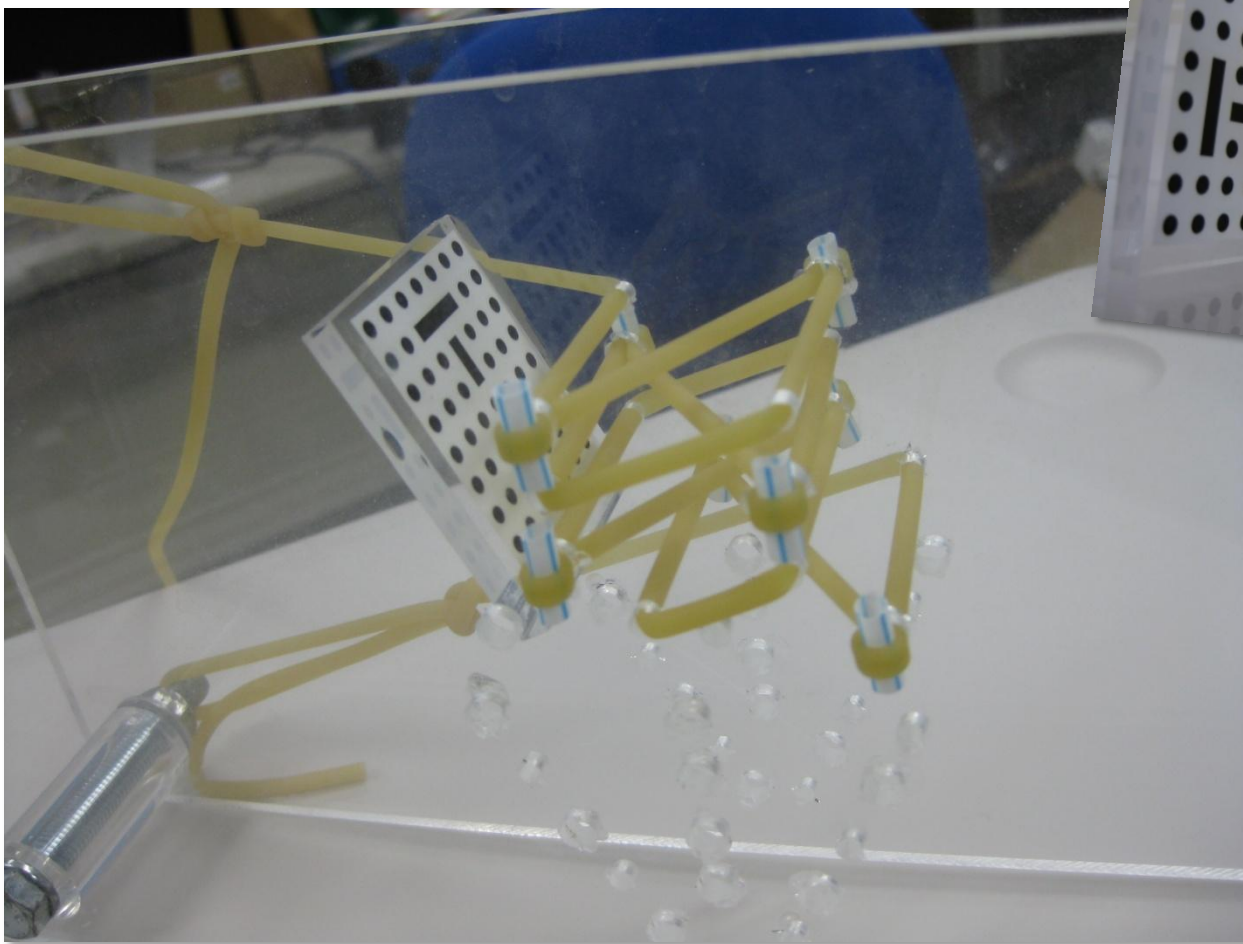
# Method: Z-fiducials

$$Z = B + \frac{|BZ|}{|BC|} (C - B) = B + \frac{|MZ|}{|MN|} (C - B)$$



Method: [Hsu, P., Prager, R., Gee, A., Treece, G.: Real-time freehand 3D ultrasound calibration. *Ultrasound in Medicine & Biology* 34(2) (2008) 239-251]

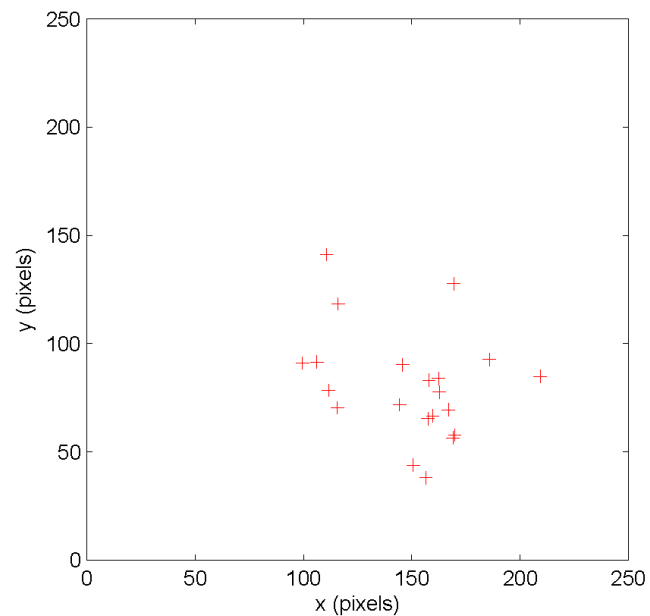
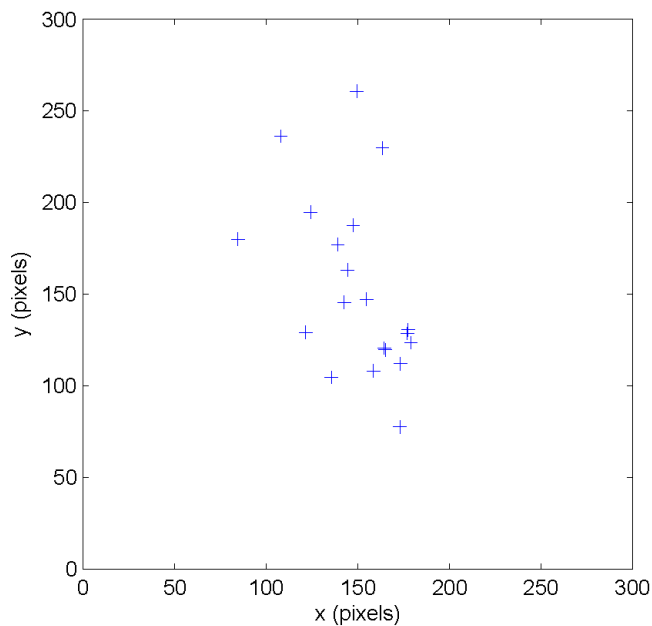
# Phantom





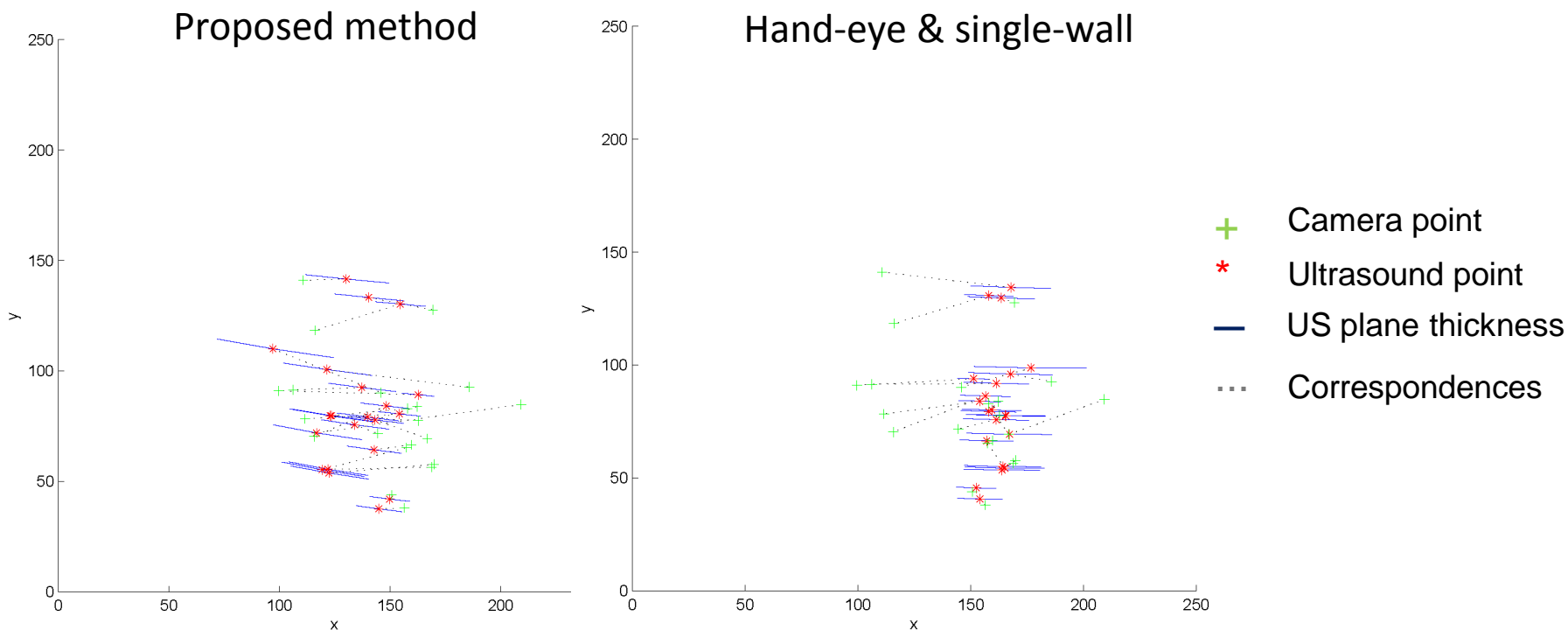
# Results

- Use tool tip to mark corresponding locations
- Move until tip is visible in ultrasound



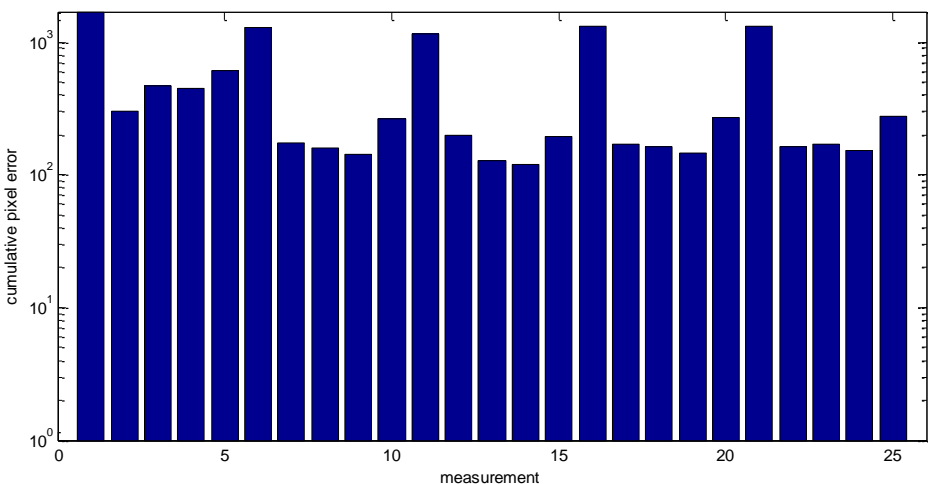
# Results

- Sample point locations
- Compute cumulative pixel distance of point pairs

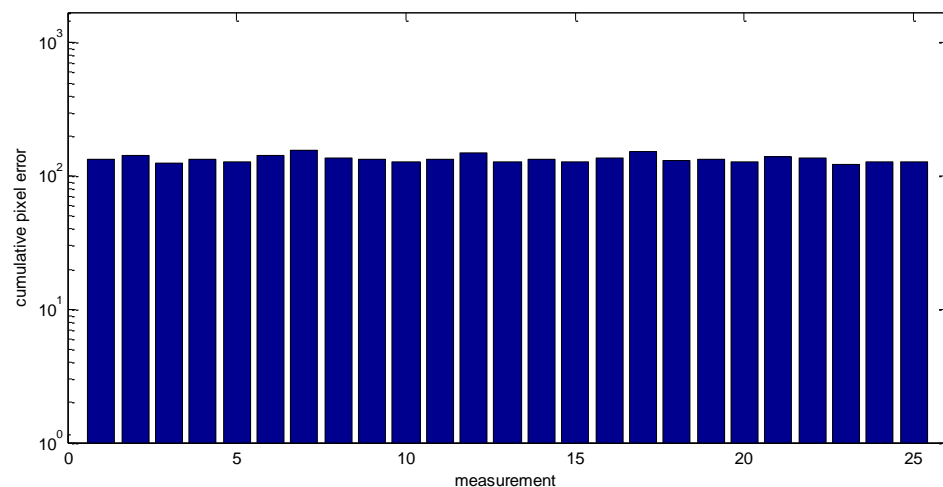


# Results

## Hand-eye & single-wall



## Proposed method



$$cpe = \sum_{i=1}^n \left| p_y^i - q_y^i \right|$$

# Conclusion

- Compared to hand-eye and single-wall:
  - Comparable accuracy
  - Higher precision
  - Faster
    - Build more complex phantom once
    - Calibrate quickly many times