MR-Guided Mixed Reality for Breast Conserving Surgical Planning

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Stanford University

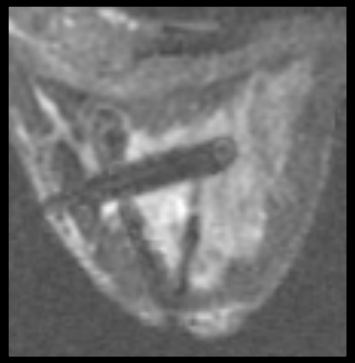
SCIT

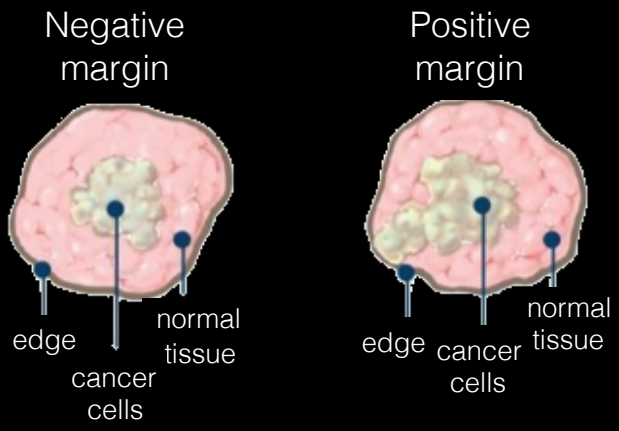
Stanford MEDICINE

MRI Guided Mixed Reality for Surgical Planning

- Early stage breast cancer treatment is removal of tumor - lumpectomy

Post wire-localization





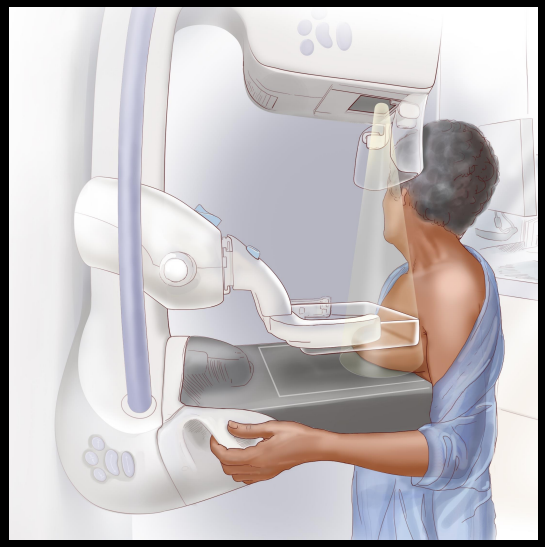
24%

Wilke et al., 2014

- close margins
- mastectomy
- 3mm Ductal Carcinoma in situ (DCIS) at biopsy site

Current Breast Imaging Techniques

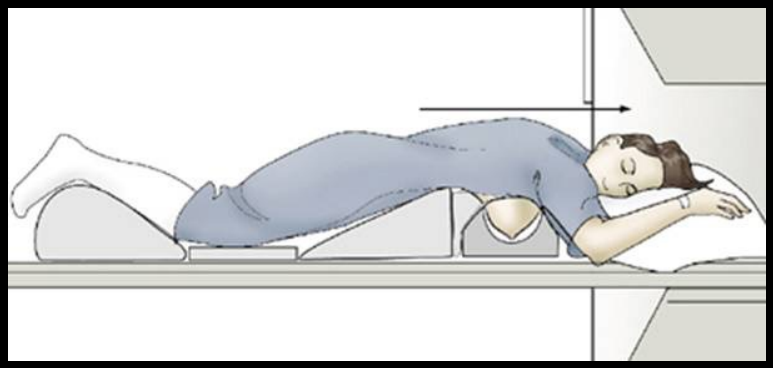
Mammography



http://www.cancer.gov/

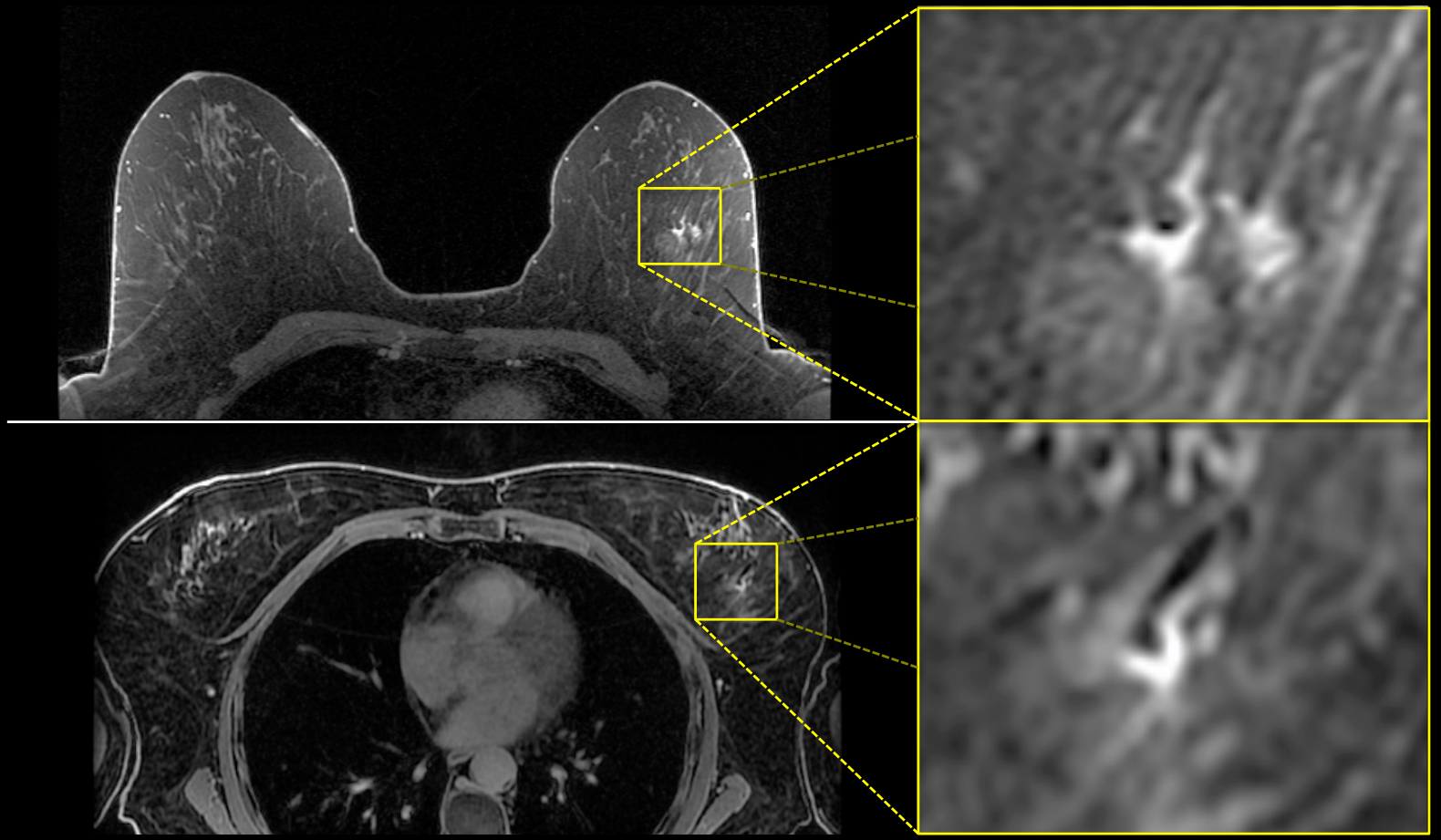
Surgery

MRI



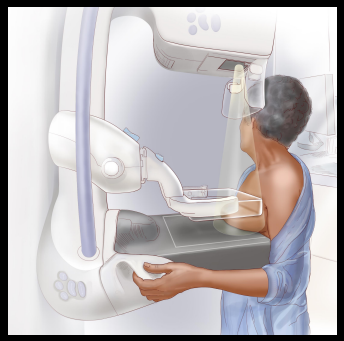
http://weill.cornell.edu/mri/MRI/Chest/breast_mass_mri.htm

Prone vs. Supine Breast MRI



Objective

Mammography



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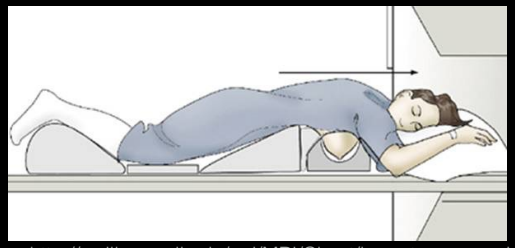
Surgery

MRI

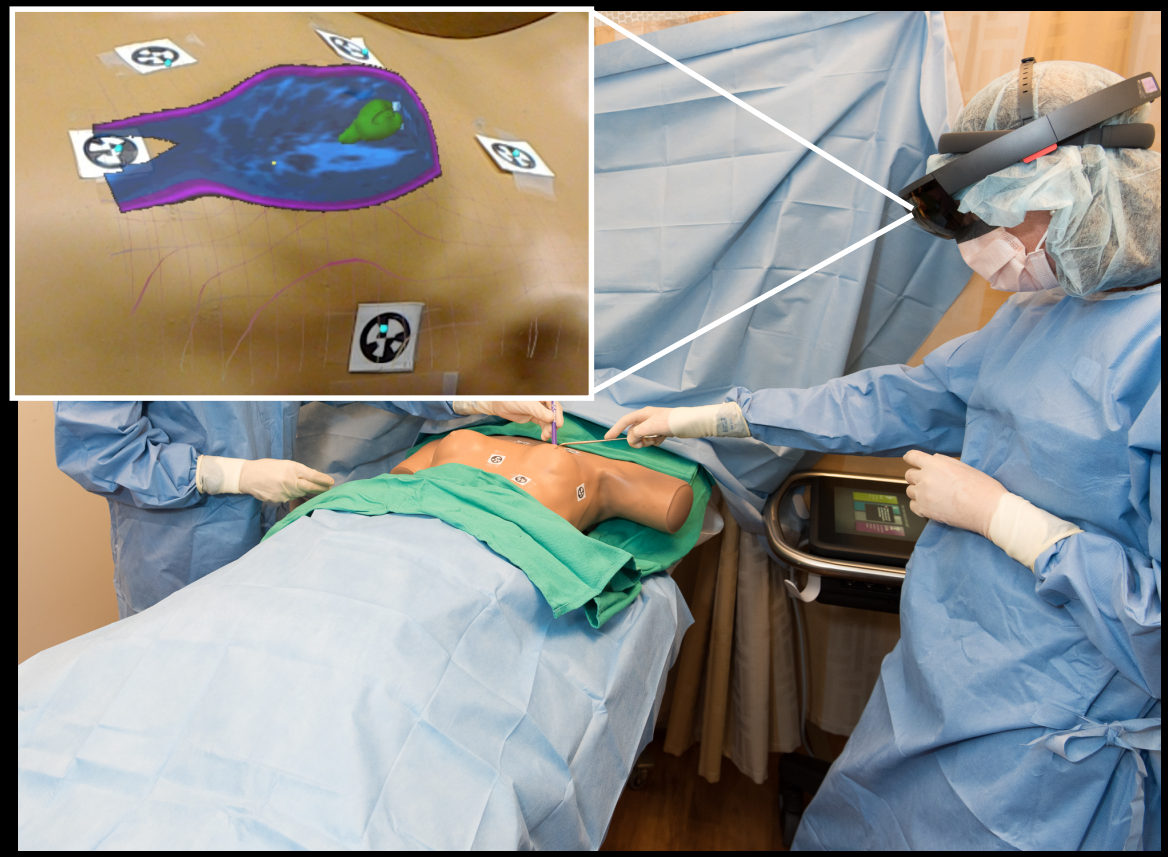


http://weill.cornell.edu/mri/MRI/Chest/breast_mass_mri.htm

To enable surgeons to do more definitive surgeries by

- acquiring MR images in close to surgical position - supine instead of prone breast MRI
- Projecting these 3D MR images on to the patient for surgical planning

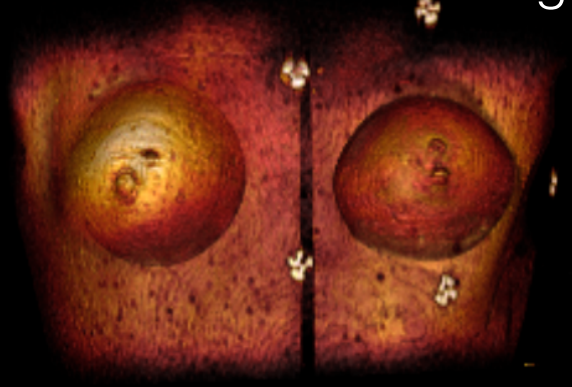
HoloLens - for Surgical Planning



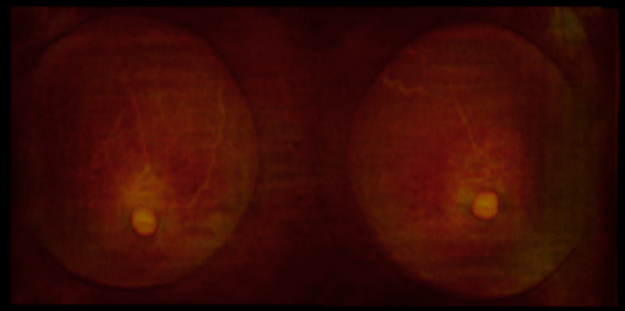
Phantom MRI Dataset

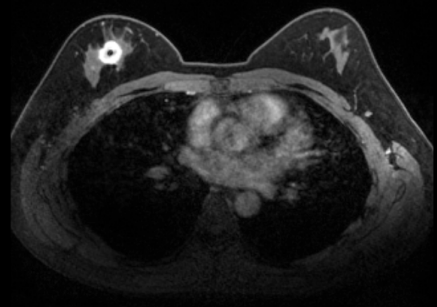
3D Surface Rendering

2D Slice



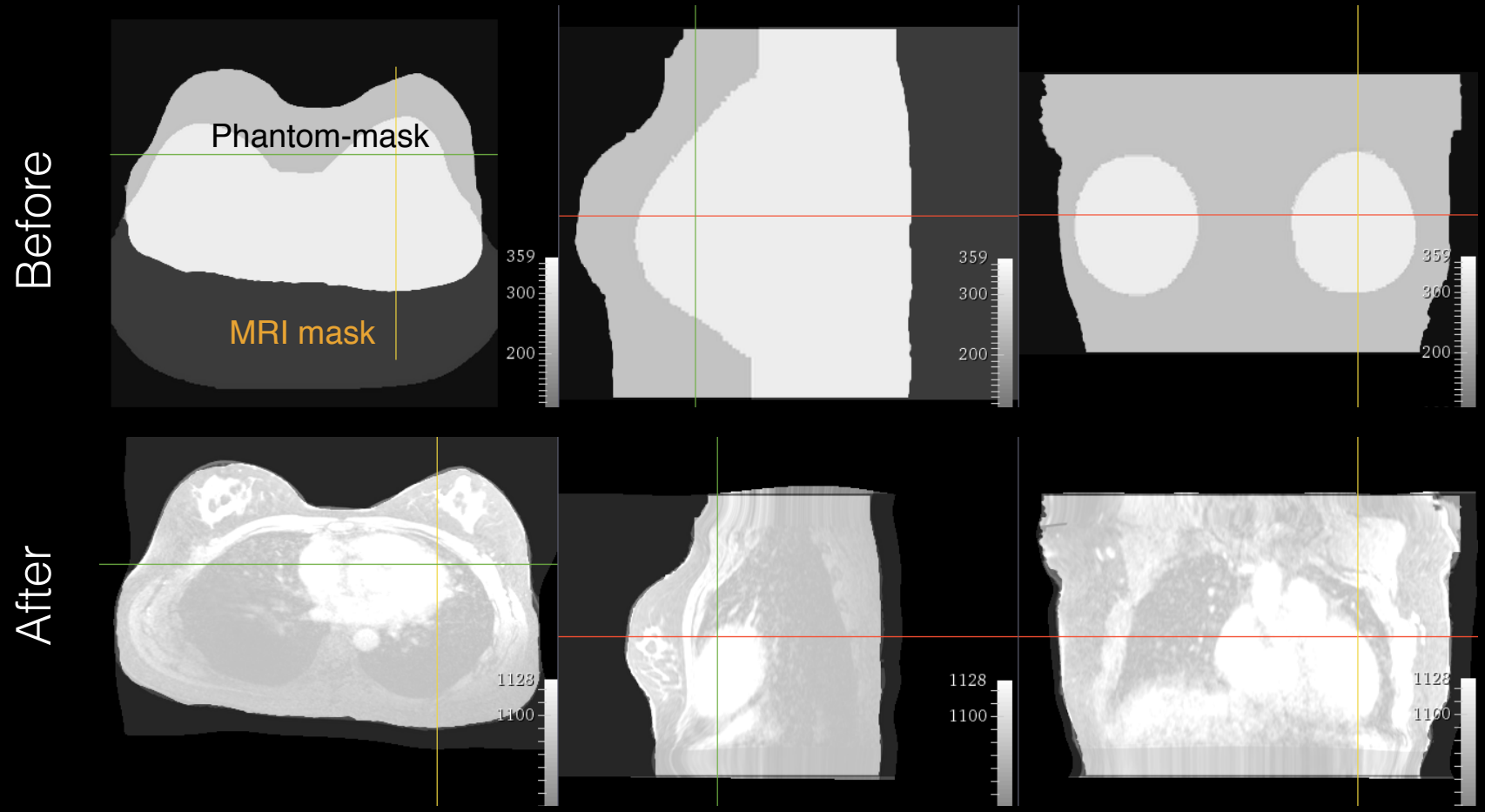
Patient MRI





https://wiki.cancerimagingarchive.net/display/Public/QIN+Breast+DCE-MRI

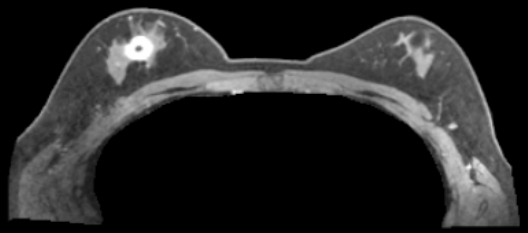
Deformable Registration



https://www.slicer.org/

Segmentation

Warped dataset



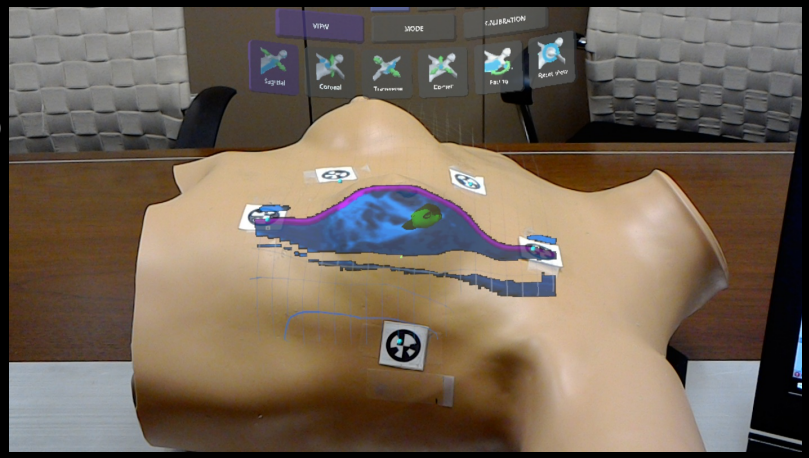
Tumor

Chest

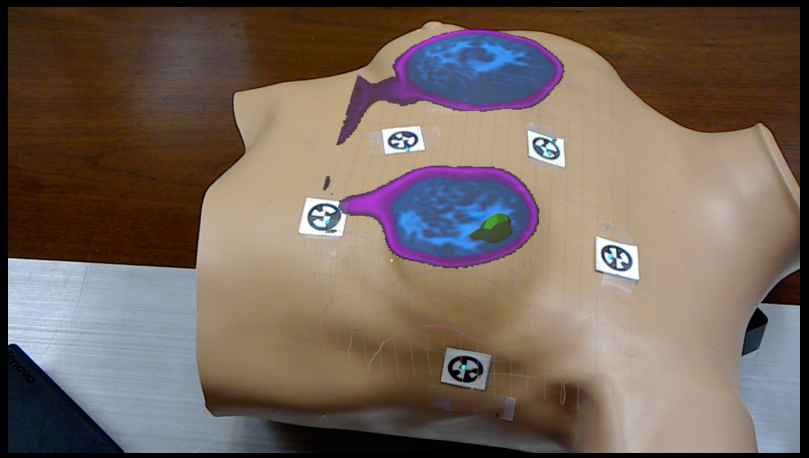
Skin

Standard Viewing Planes

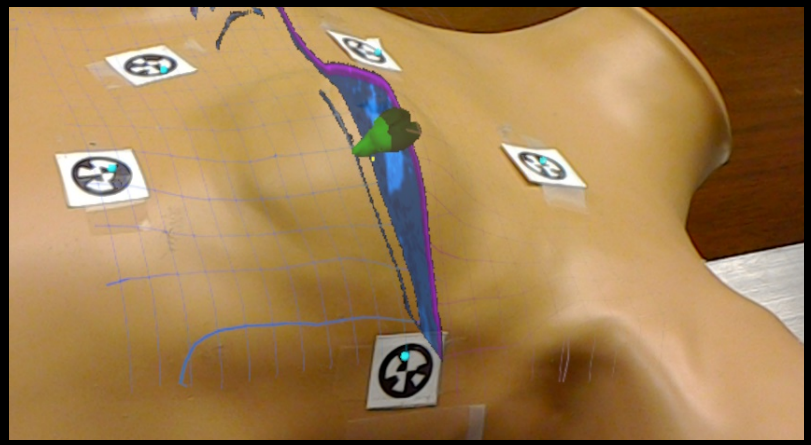
Serra View Sagittal



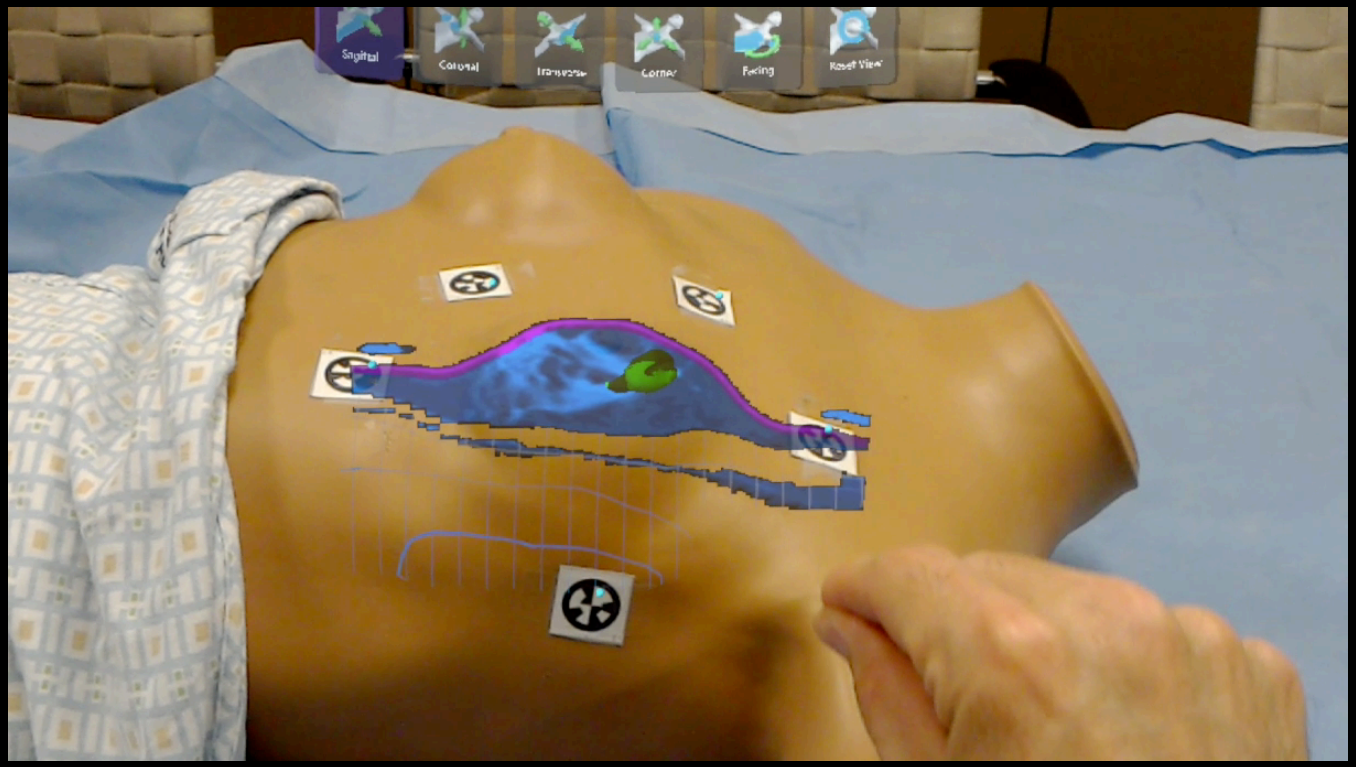
Serra View Coronal



Serra View Transverse



Scrolling through slices



Registration of Holograms to Patient

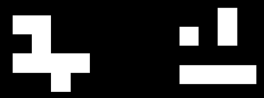
1. Manual Registration
    - Moving the head/camera position to align the holograms to the patient
    - Selecting the markers and adjusting the rotation using gestures
2. Automatic Registration
    - Integration of OpenCV for automatic recognition of the markers in patient
    - Alignment of the MRI markers to the recognized optical markers

Automatic Registration - Tag Recognition

Step 1:

1. Find the contours in the video frame
2. Approximate the contours by a polygon
    1. Remove those with corners ≠ 4

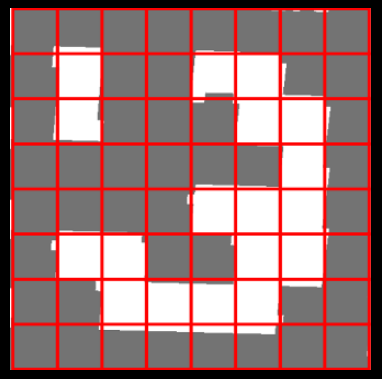
Example AR Tags



Step 2:

For each 4 sided polygon

1. Remove the perspective
2. Divide the matrix based on the marker size (4 x 4) or (5 x 5)
3. Read the bits and match it to the input dictionary (orientation)



Step 3:

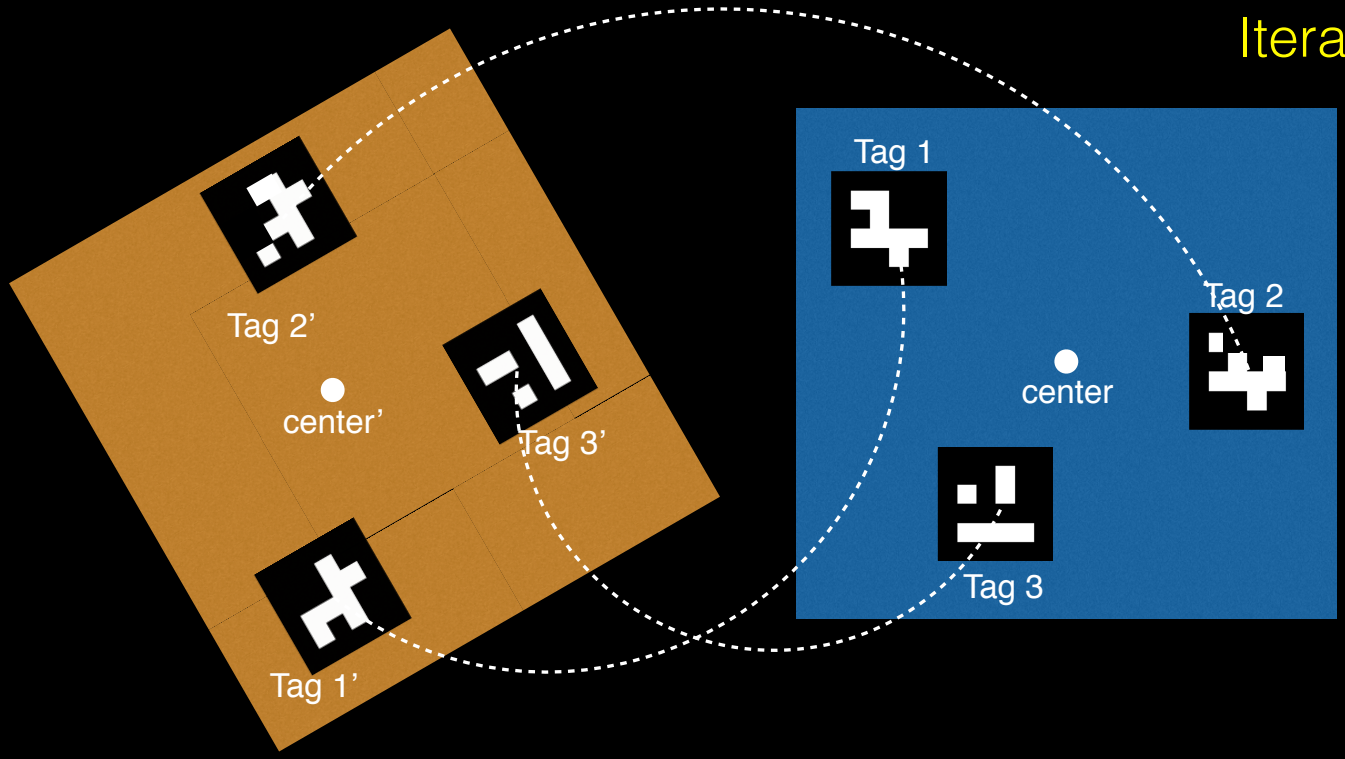
Given 2D image corners, 3D object corners

Output position, rotation

http://docs.opencv.org/3.1.0/d5/dae/tutorial_aruco_detection.html

Phantom-MRI Registration

Iterative Closest Point Algorithm



Phantom

MRI

Covariance Matrix

$(\text{Tag i'} - \text{center'}) \times (\text{Tag i} - \text{center})^T$

Singular Value Decomposition

R (rotation) = UV^T

t (translation) = center - R center'

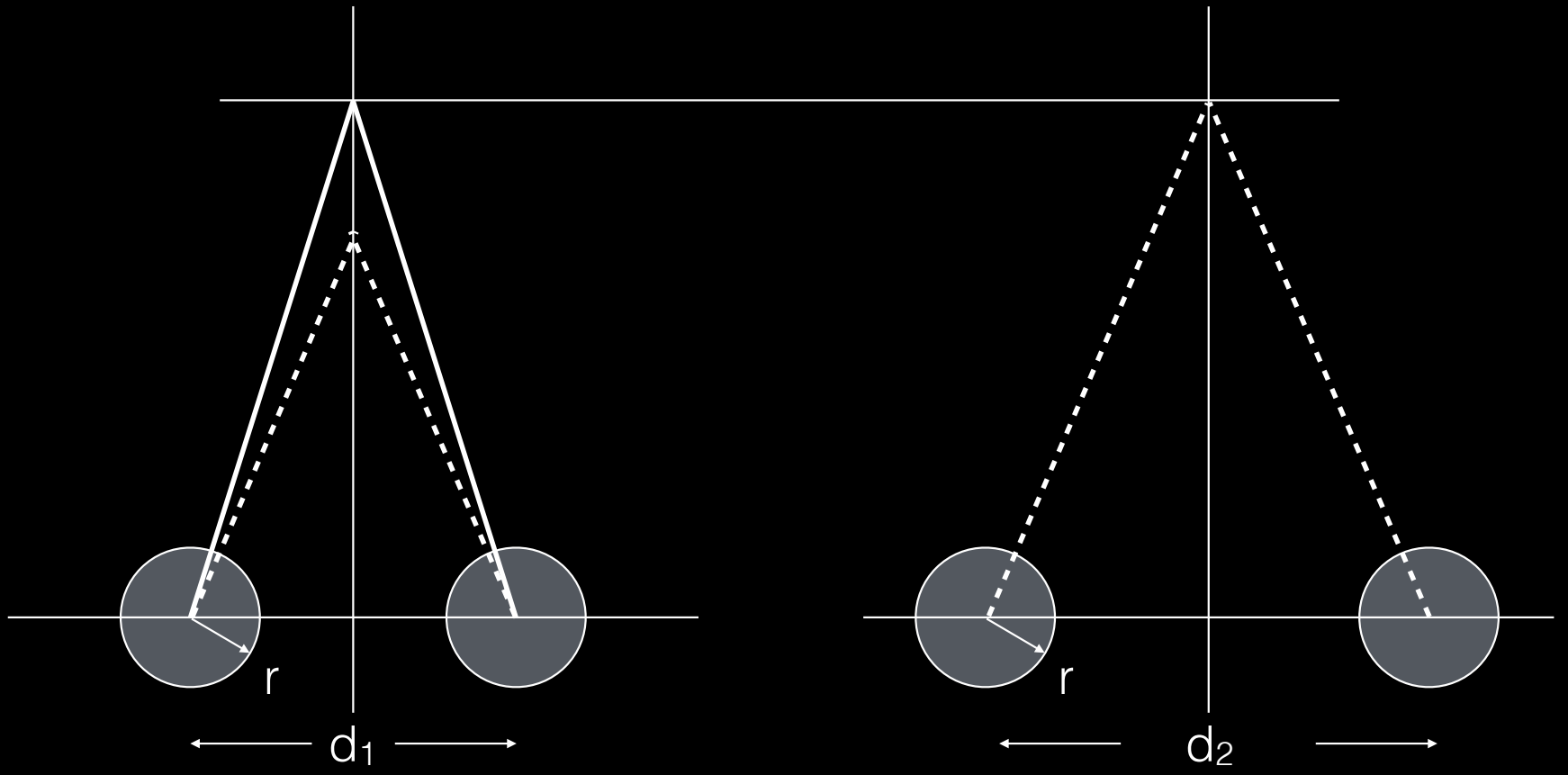
How well do we perceive the holograms?

If the user is asked to draw the hologram that they are visualizing

- is the shape preserved?
- dimension?

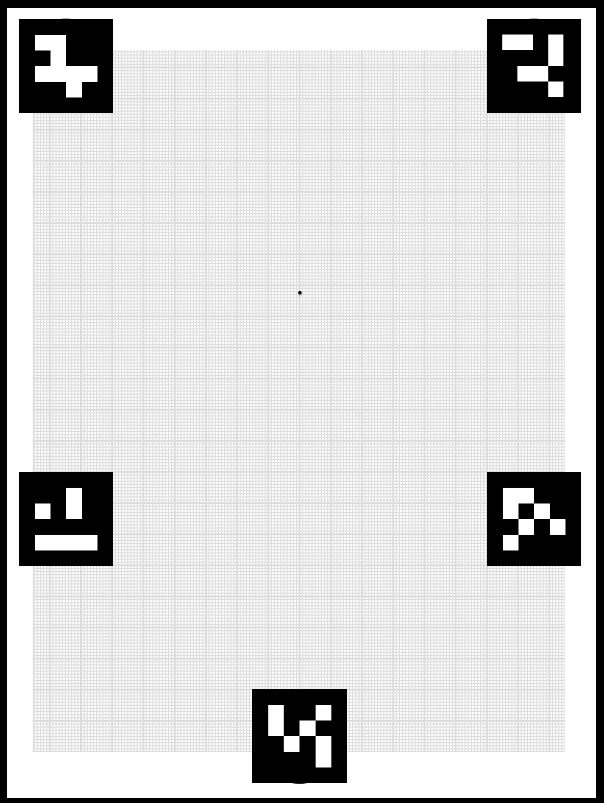
Perceptual Accuracy - Set up

Step 1: inter-pupillary distance measurement/ adjustment

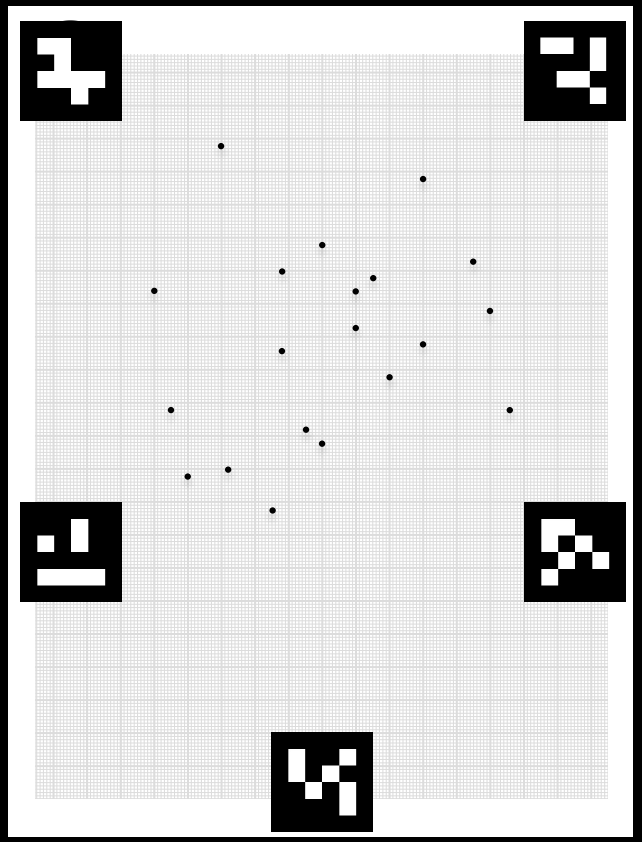


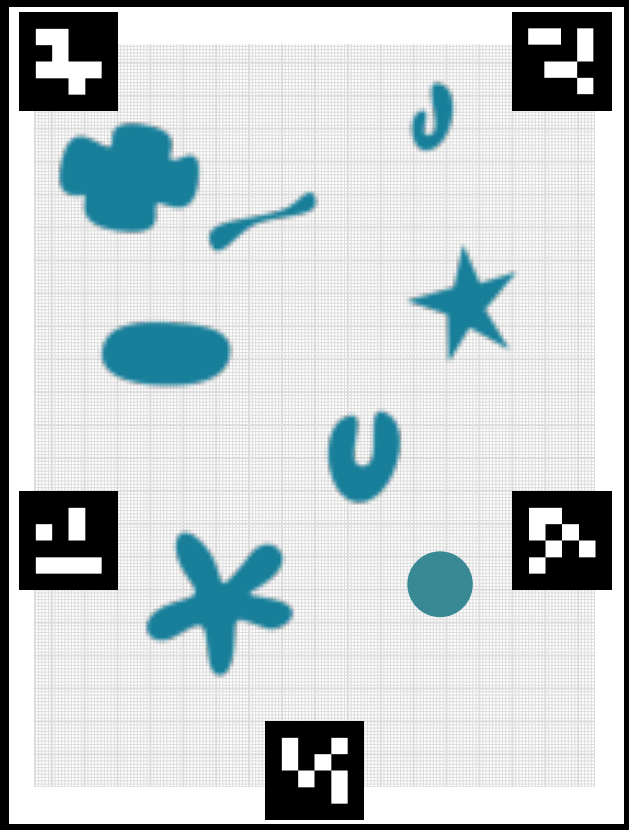
Perceptual Accuracy - Set up

Step 2: Tag tracking and adjustment of the tag position

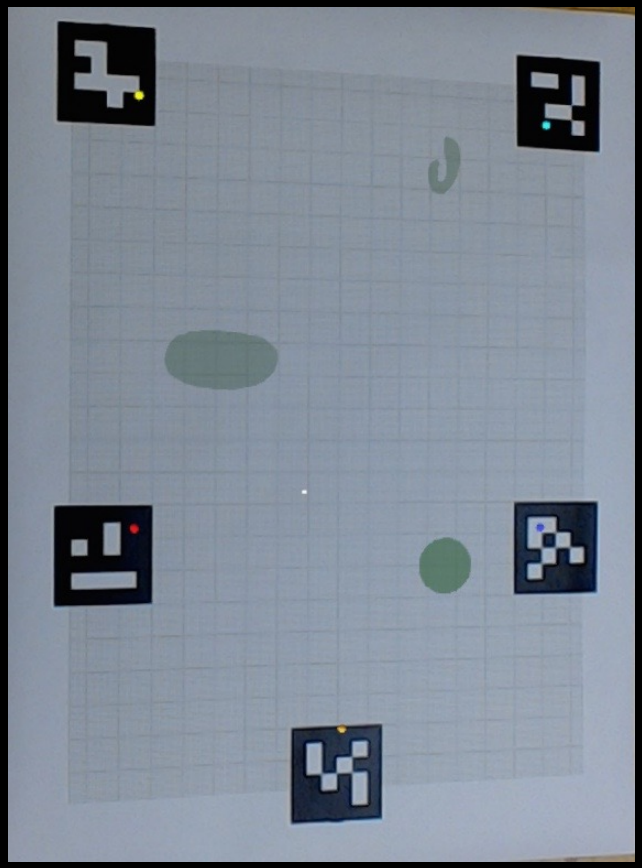


Perceptual Accuracy - Setup





Perceptual Accuracy



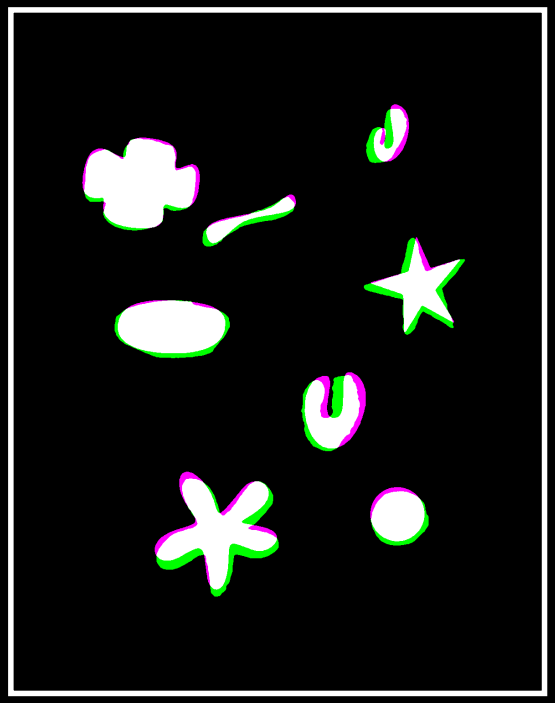


Image overlay of drawn shapes (green+white) and ground truth (magenta+white)

Perceptual Accuracy - Results

N=6 subjects

Dots	
Error in depth dimension (mean ± std. deviation)	-1.0 ± 3.5 [-6.1 7.1] mm
Error in right-left direction (mean ± std. deviation)	-0.2 ± 1.3 [-3.3 2.2] mm
Shapes	
Error in depth dimension (mean ± std. deviation)	-1.1±2.0 [-5.9 2.3] mm
Error in right-left direction (mean ± std. deviation)	0.1±1.2 [-2.2 3.0] mm
Margin Tolerance	[0.68 5.74] mm
Dice coefficient	[0.56 0.95]