Computer-Augmented Point-of-Care Ultrasound

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Disclosure

- Funded by an NIH R01 grant to Kitware.
  - *NIH NIGMS / NIBIB R01: Slicer+PLUS: An Open-Source Platform for Point-Of-Care Ultrasound*

- Kitware
  1. Collaborates on grant-funded research, creates scientific software, and gives it away for free.
     - VTK (used by Osirix), ITK, CMake, 3D Slicer, ParaView
  2. Consults on scientific computing projects.

Point-of-Care Ultrasound (Pre-Hospital)

- Far-forward medics and EMS personnel lack portable, easy-to-use diagnostic devices for:
  - Intra-abdominal bleeding, Pneumothorax, Traumatic brain injury, … Trauma Patient Triage

- When EMS ultrasound is conducted by experts, patient management is altered in 37% of cases. [Walcher 2002]

- Even after hours of training, pre-hospital personnel are not sufficiently proficient in FAST for over 48% of trauma patients. [Melanson 2001]

Other Point-of-Care Ultrasound (POCUS) Applications

- Vascular access
  - Hospitals require the use of ultrasound for guidance, confirmation, and documentation
- Scoliosis screening in schools
  - And monitoring those with scoliosis, without x-rays
- Monitor progression of TBI, mildly elevated ICP
  - Without invasive an procedure

Point-of-Care Ultrasound

1. To achieve its broad potential, point-of-care ultrasound must be approached as a <u>new diagnostic modality</u>, not simply as portable, rugged ultrasound.

2. Point-of-care ultrasound will become <u>the most common</u> type of ultrasound exam.
   - Shaping the future of ultrasound

Philips Lumify

Future: Computer-Augmented Point-of-Care Ultrasound

1) Task-specific devices

BladderScan

2) Apps for computer-assisted image analysis

- Display results (red light / green light),

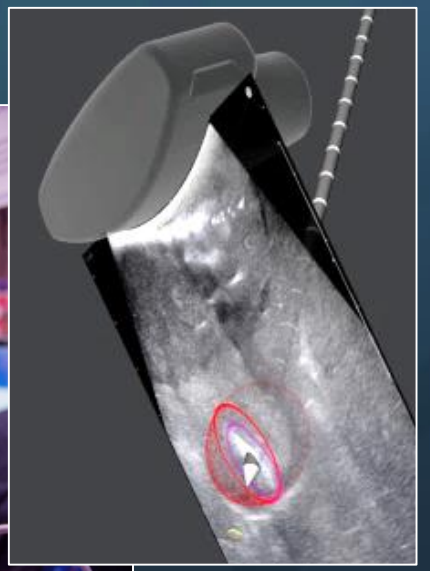
not B-Mode images.

1) Task-Specific Devices

Clear Guide

Sonivate

InnerOptic



Clarius

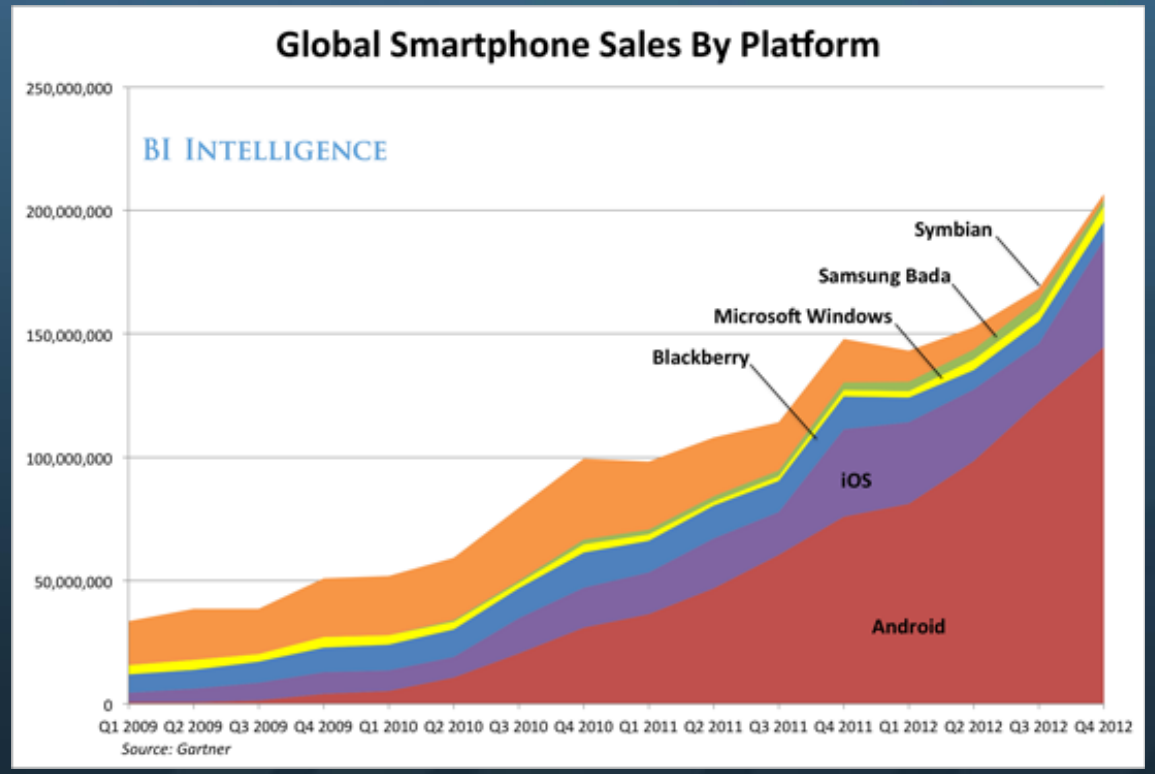
Butterfly Networks

2) Apps for computer-assisted image analysis

= Open / standard hardware platforms

= A.I. (Deep learning / Neural Nets)

Interson

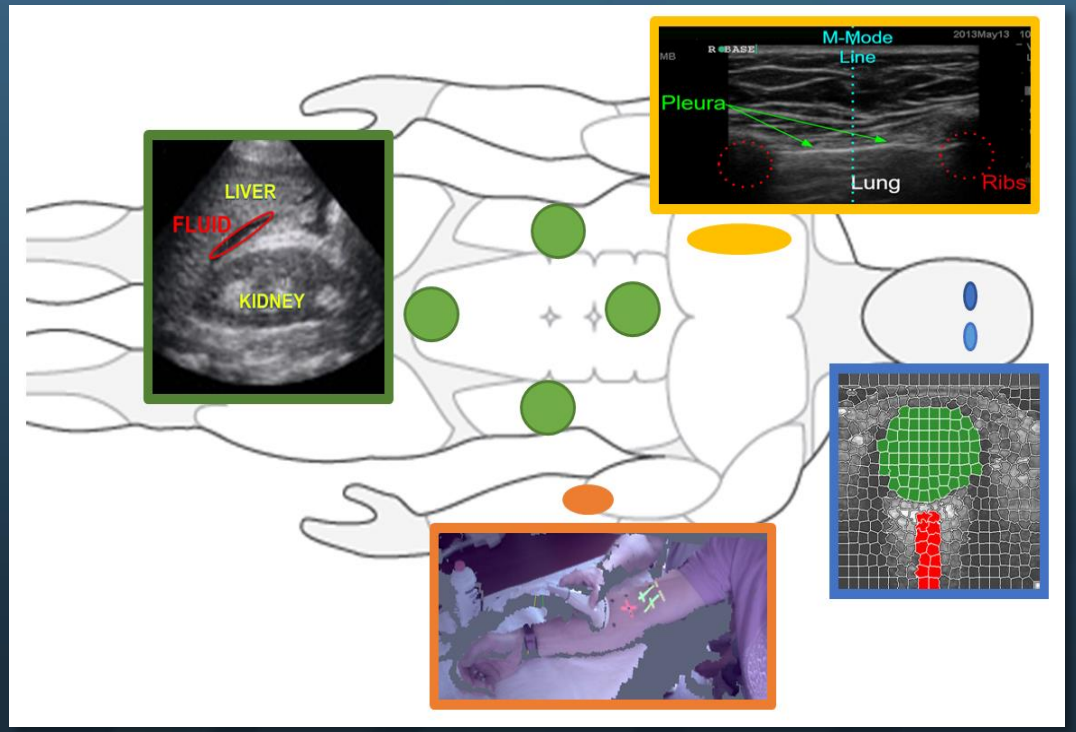


Windows (PC Clones) > MacOS

Android (Samsung, HTC, …) > iOS

A.I. in Point-Of-Care Ultrasound

- FAST (Intra-abdominal bleeding)
- TBI (Intracranial pressure: ICP)
- Pneumothorax
- Hemothorax
- Renal dysfunction
- Guidance: paracentesis, peripheral vascular access
- General medicine: Scoliosis



Ultrasound Spectroscopy

Analyze RF returns from
multiple powers and multiple frequencies

	Power	Freq.
1	15%	2.5
2	15%	3.5
3	15%	5.0
4	30%	2.5
5	30%	3.5
6	30%	5.0

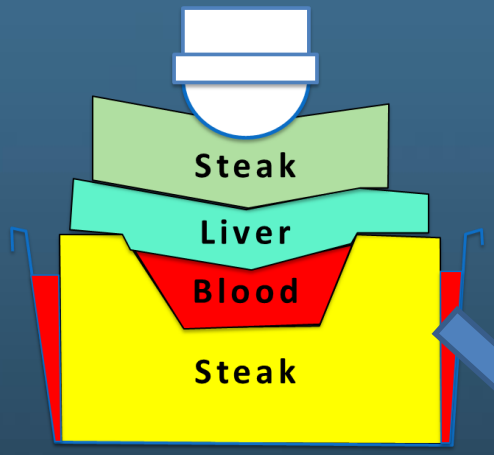
- Pre-processing
  - "Quantitative Ultrasound" [Lavarello 2011]
- RF Characterization
  - Chebyshev Polynomial Coefficients
  - Legendre Polynomial Coefficients
  - Linear Fit (Slope, Intercept)
  - Backscatter Coefficient Estimation

RF Data

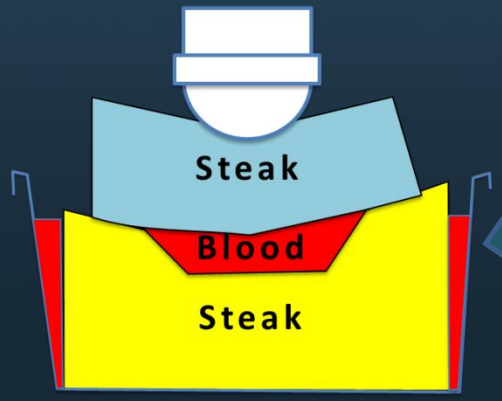
- Classification = Neural Network

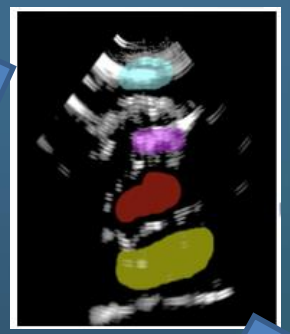
Preliminary Ex Vivo Tissue Experiment

Phantom 1



Phantom 2





Phantom 2 testing data

Phantom 1 training data

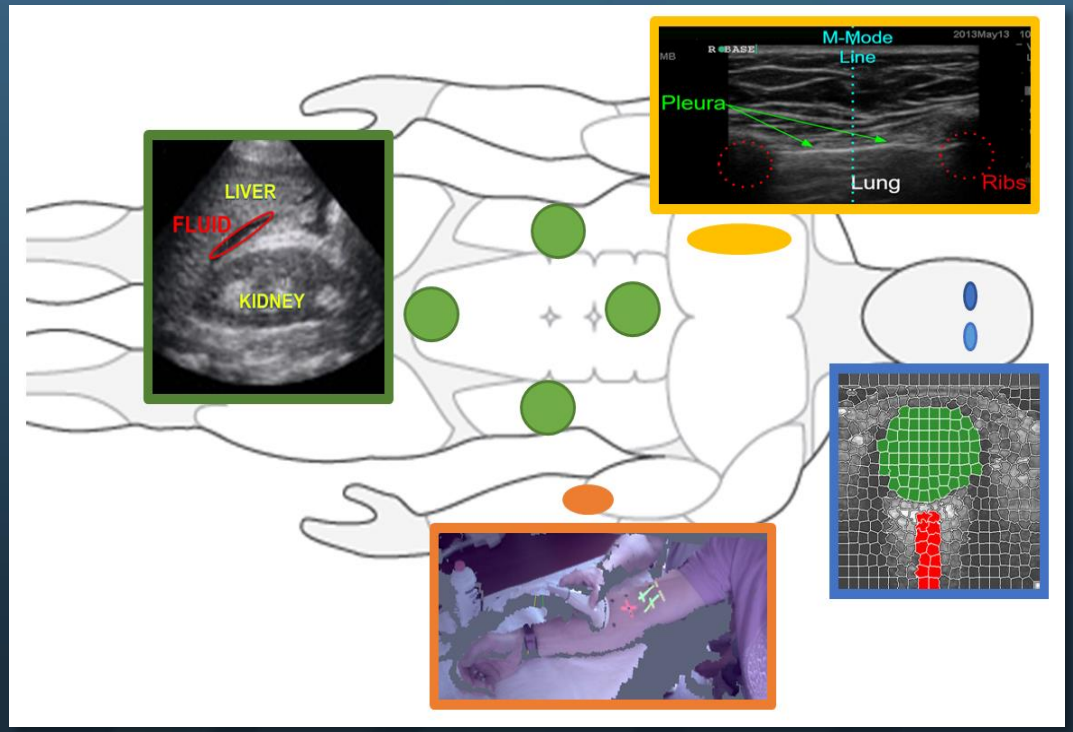
Random Forest / Deep Learning Classifier (Blood –vs- Not Blood)

Blood detection accuracy

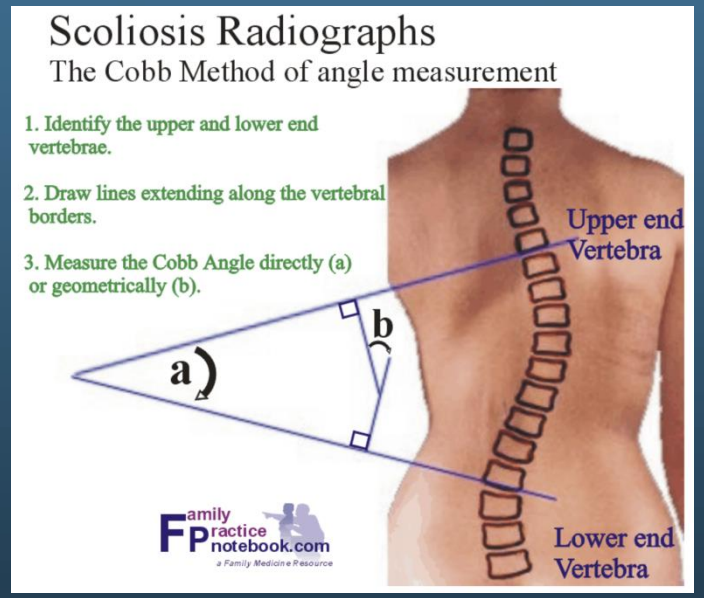
Pwr	Freq	Features	TPR	FPR	%Err
All	All	B-Mode Only	0.565	0.057	13.46
All	All	All (102 features)	0.948	0.005	1.51

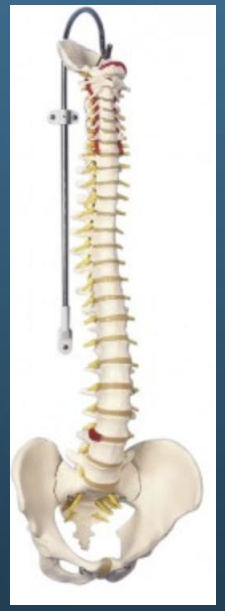
Demonstration applications

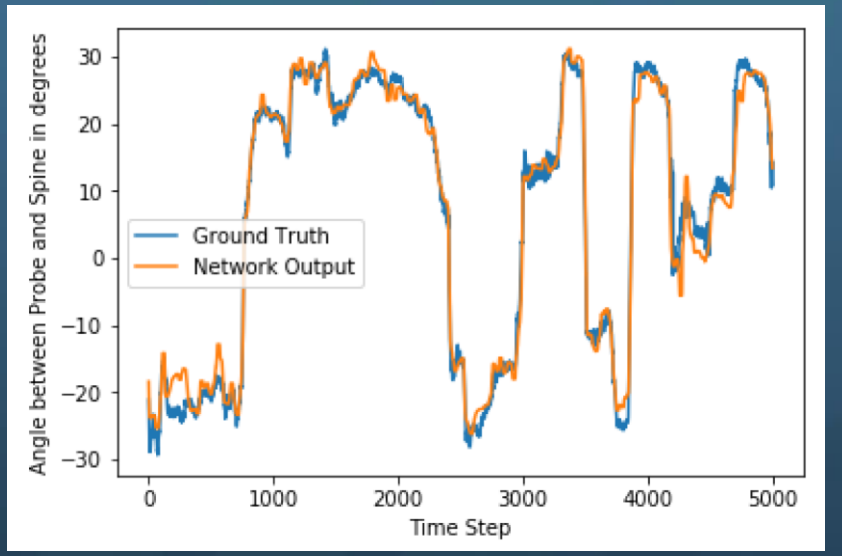
- FAST (Intra-abdominal bleeding)
- TBI (Intracranial pressure: ICP)
- Pneumothorax
- Hemothorax
- Renal dysfunction
- Guidance: paracentesis, peripheral vascular access
- General medicine: Scoliosis



Scoliosis detection and monitoring

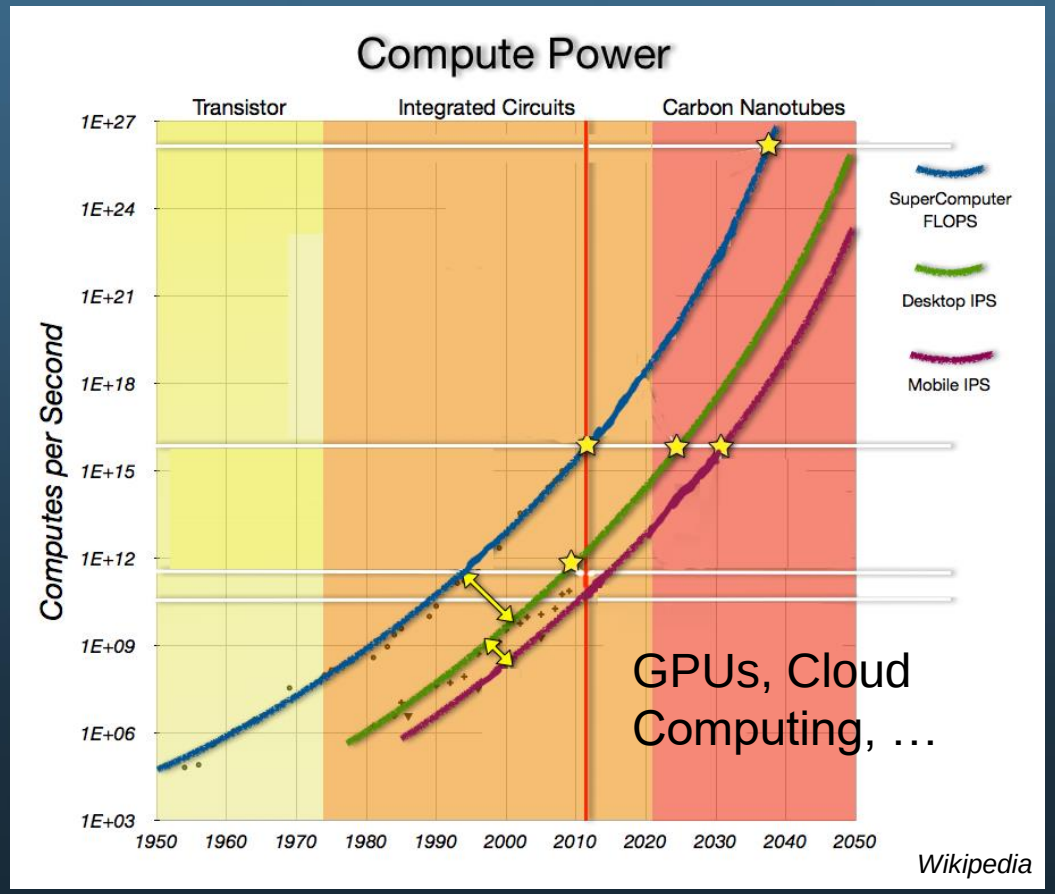






- Neural Network: Angle between probe and spine, from b-mode
- IMU: Angle between probe and vertical
- NN + IMU: Cobb Angle, between vertebrae and vertical

Computer-Assisted Point-of-Care Ultrasound



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Future directions in ultrasound?

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Outline

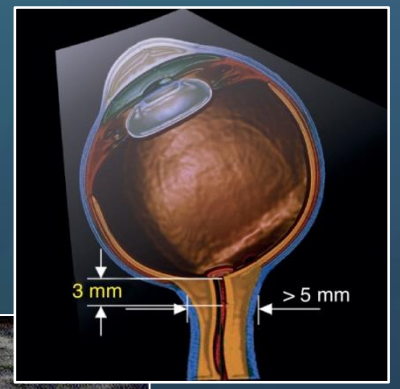
- FAST
- TBI
- Scoliosis
- Vascular Access / augmented reality

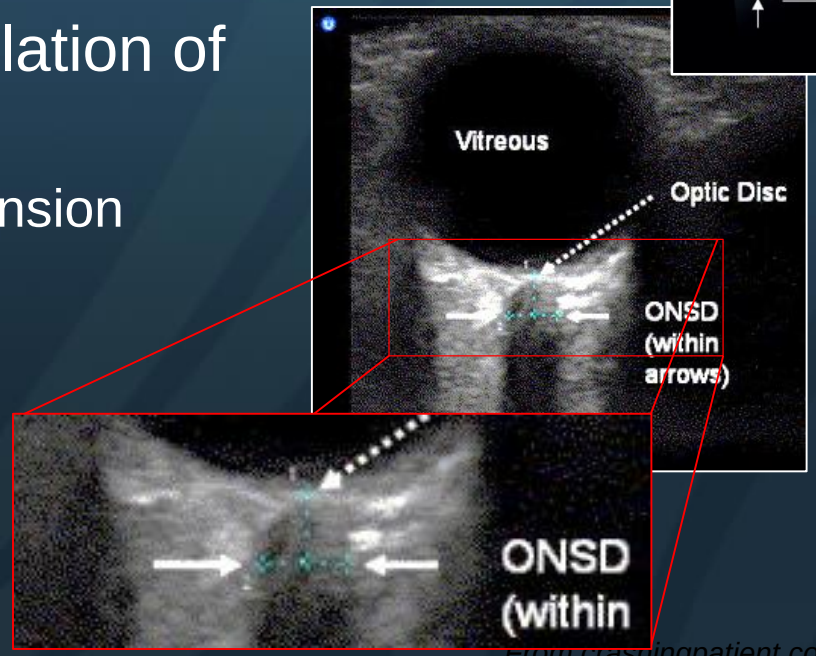
Optic Nerve Sheath Diameter (ONSD) and ICP

ONSD is an accurate and quick monitor for changes in ICP

Maissan IM , Dirven PJ , Haitsma IK , Hoeks SE , Gommers D , Stolker RJ - J Neurosurg. 2015 Sep;123(3):7437.

- 18 ICP-monitored patients in ICU
- Before, during, and after tracheal manipulation to increase ICP
- ICP above 20 mmHg is associated with dilation of ONSD > 5.0 mm
  - 20-30 mmHg = mild intracranial hypertension
  - 94% sensitivity
  - 98% specificity





From crashingpatient.com

Traumatic Brain Injury: Increased ICP

23 images

Compared to an expert

$R^2 = 0.91$

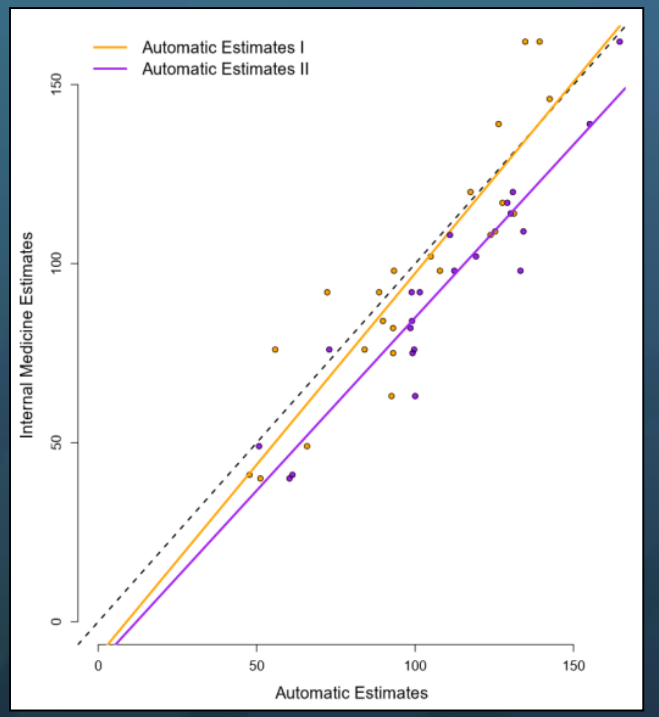
p-value = 2.0e-12

Compared with study mean

Auto $R^2 = 0.82$

Expert $R^2 = 0.84$

Med. students $R^2 = 0.78$ - 0.81



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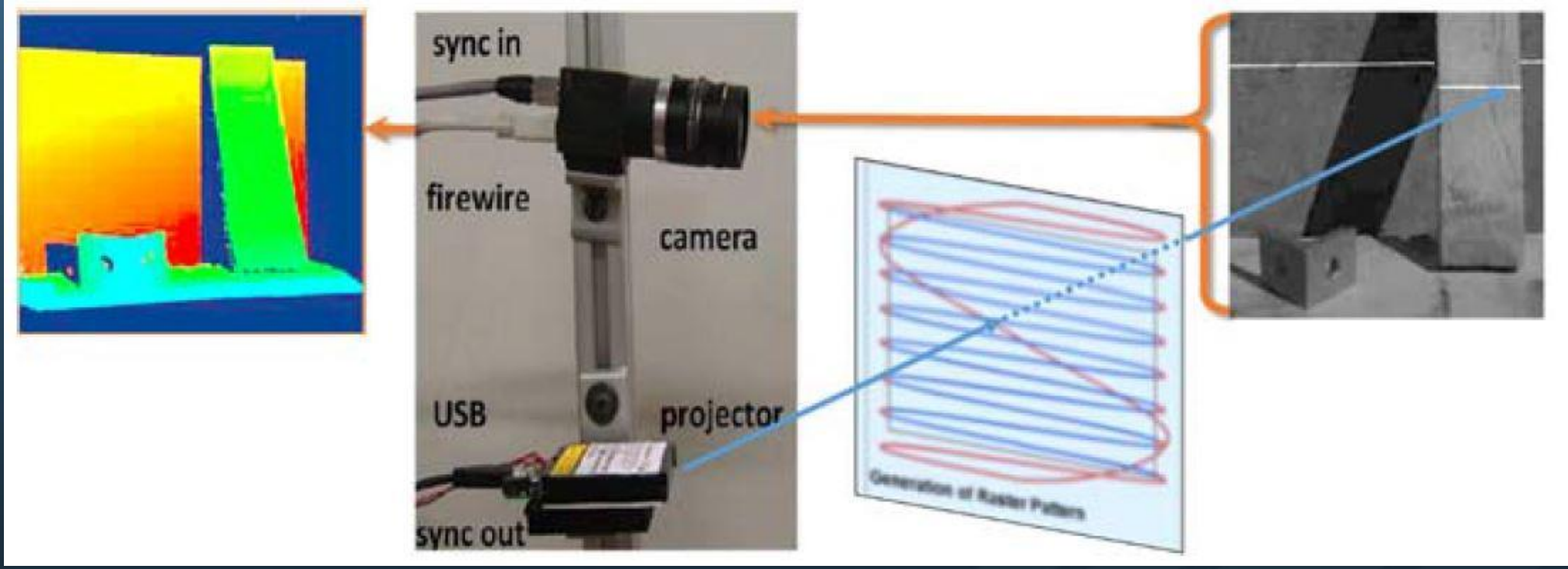
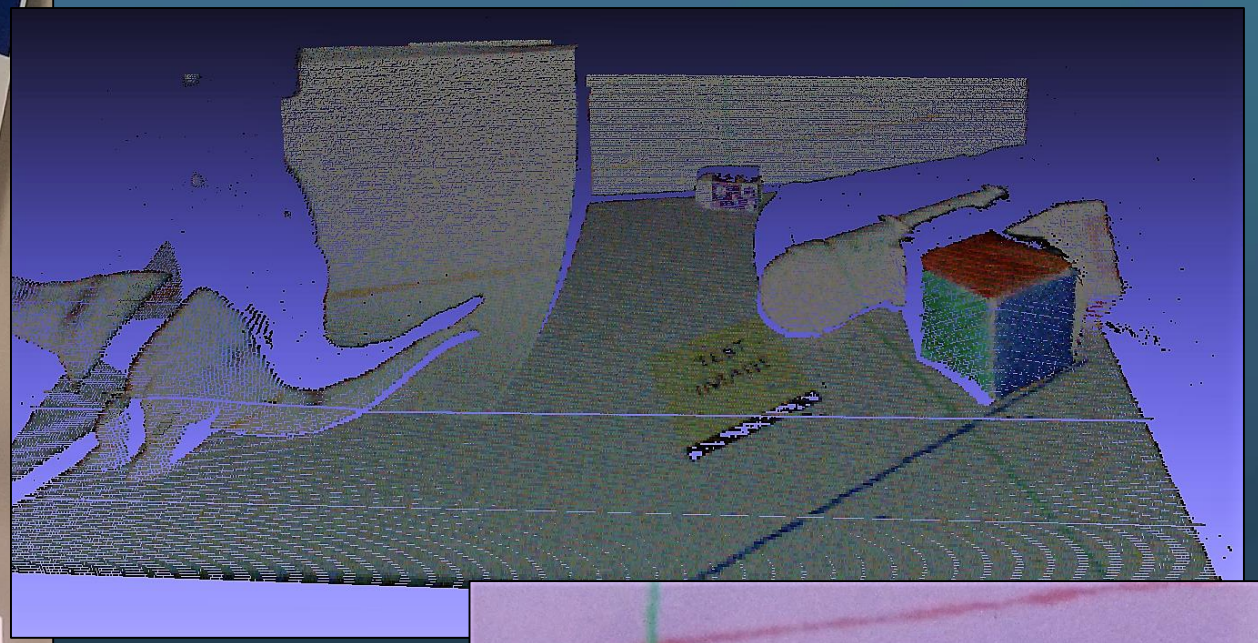
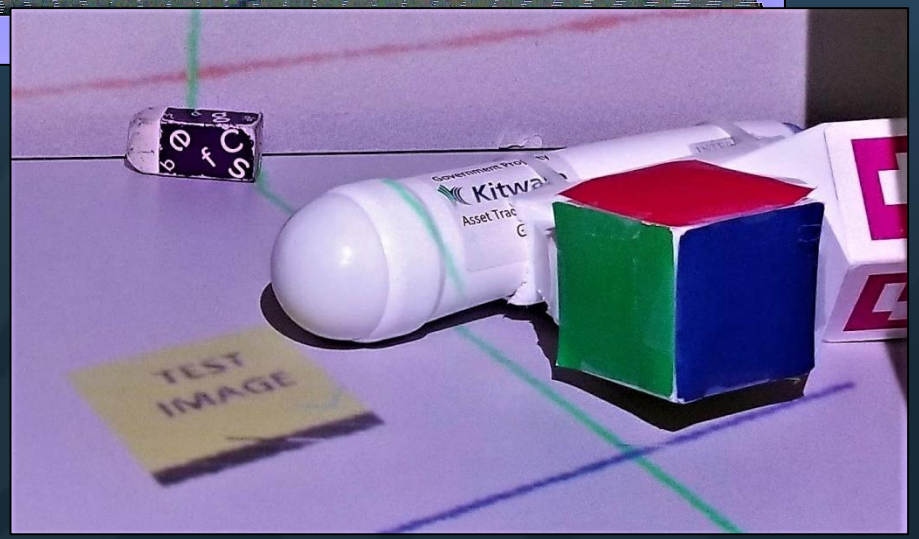
Ultrasound Augmentation

Carnegie Mellon University






TEST
IMAGE

Preliminary Results