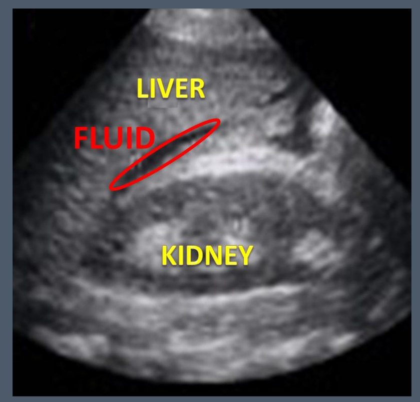

Computer-assisted FAST exams for in-field triage

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ABSTRACT

- Far-forward, medical personnel lack portable, easy-to-use diagnostic devices to detect intra-abdominal bleeding (IAB).
- We propose that in-field ultrasound systems that combined
  - rugged, low-cost, highly portable ultrasound probes,
  - "Ultrasound Spectroscopy" imaging protocols and advanced machine learning algorithms [Aylward 2016], and
  - intuitive graphical user interfaces

  can be used by far-forward medical personnel for the pre-hospital identification of trauma patients that require priority, life-saving treatment and transport to address severe IAB or elevated intracranial pressure as indicated by an increase optic nerve sheath diameter
  [Aylward 2017 – Podium Presentation @ SOMSA 2017]
- This poster focuses on Ultrasound Spectroscopy and machine learning algorithms for automated detection of IAB.
- Tissue phantoms demonstrated that our system can provide dramatic improvement over b-mode ultrasound for computer-assisted blood detection.

BACKGROUND

- The Focused Assessment with Sonography in Trauma (FAST) exam has the potential to diagnosis IAB.
- When in-field 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]
- There is no currently available technology to allow medics or physicians with limited ultrasound training to perform FAST.
- For American soldiers, 67% of prehospital potentially survivable deaths [Eastridge 2012] and 48% of potentially survivable patients that died of wounds [Eastridge 2011] were from truncal injuries. While some penetrating injuries to the trunk are obvious, for many fragmentation and vehicle related injuries trauma within the pleural or peritoneal cavities can be subtle.

ACKNOWLEDGEMENTS

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  - Completed: NIH/NINDS: "Multimodality image-based assessment system for traumatic brain injury" (R44NS081792)
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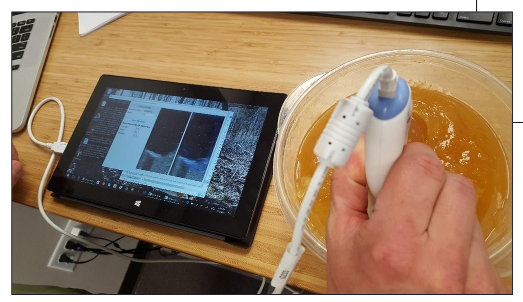
LOW-COST ULTRASOUND PROBES

- Interson SiMPLi™ Series
- Linear Array (Samll Parts) / Convex Array (General Purpose)
- Variable focal depths, beam steering
- Variable powers and frequencies
- Scan depth: 10 cm / 20cm
- Exports B-mode and <u>RF data</u> via <u>USB</u>
- Target price: $700-$1200



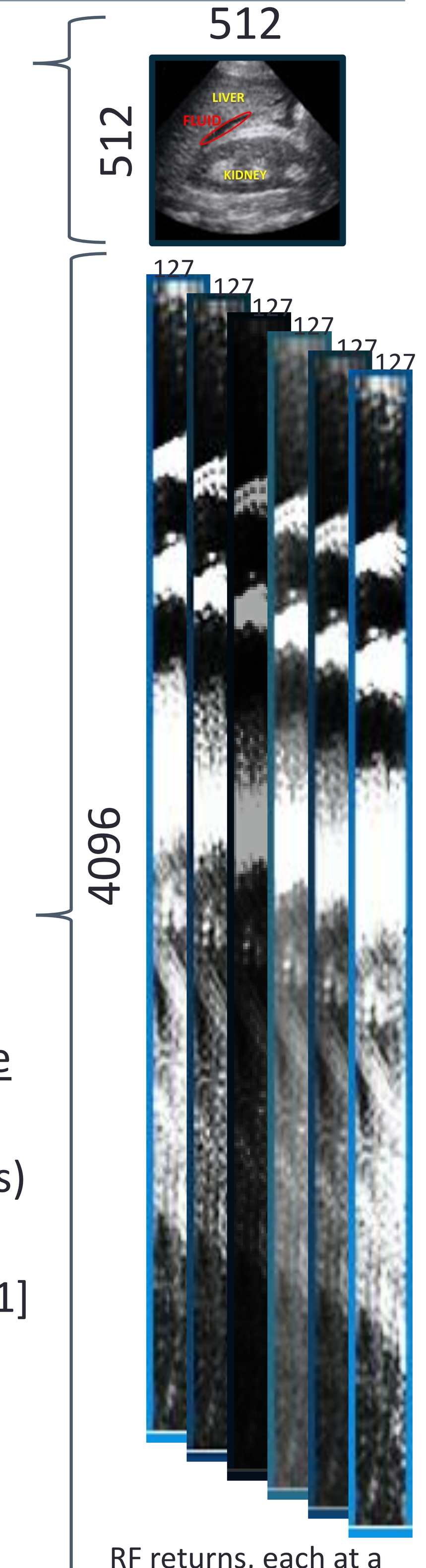
ULTRASOUND SPECTROSCOPY

<u>**B-Mode Imaging**</u>

- A general-purpose visualization method.
- <u>Each pixel is a single value from a single pulse.</u>
  1) Pulse is centered on a single frequency, at one power
  2) Each pixel is the power envelope of a window of the returned RF signal, i.e., strength of signal integrated across a period of time.
  3) Data is shown as a gray-scale image
- Under utilization of ultrasound pulse generation capabilities
- Over-simplification of returned signal
- Images vary by a small amount per probe, due to manufacturing variations

<u>**Ultrasound Spectroscopy**</u>

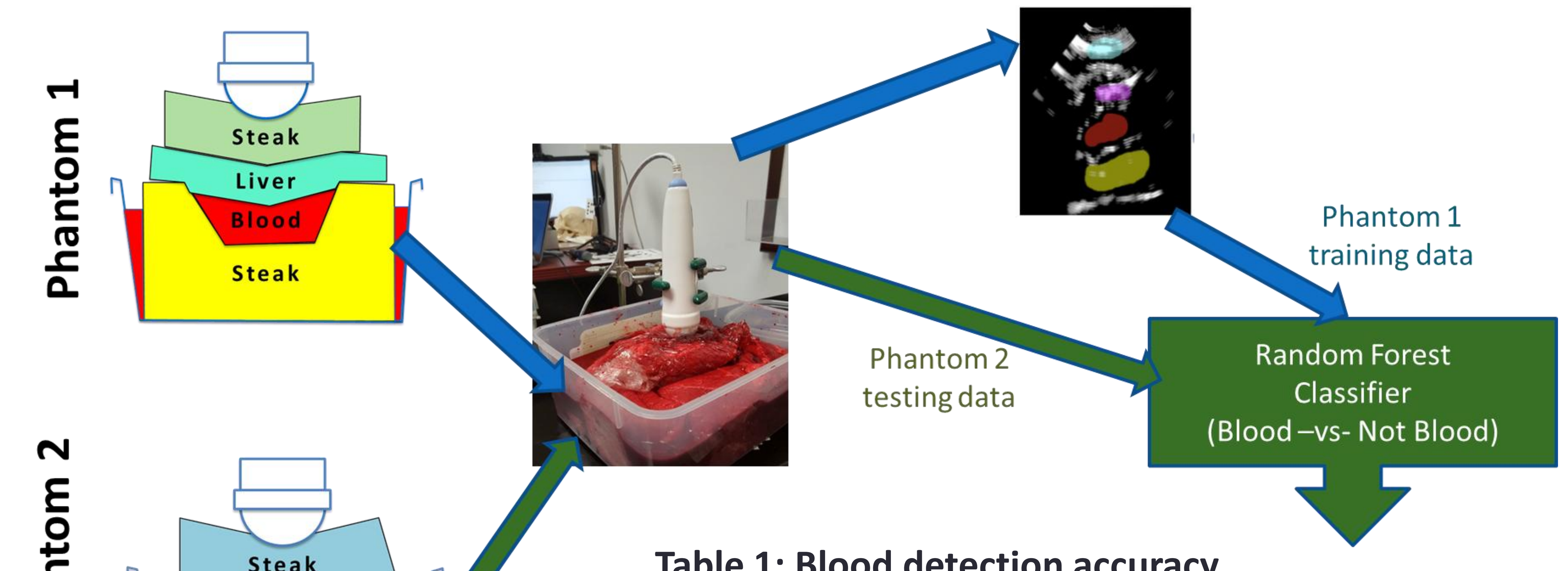
- An application-specific acquisition and analysis method.
- <u>Each pixel is a collection of RF signal features that summarize RF returns from multiple powers and multiple frequencies.</u>
  0) Probe normalization (eliminates manufacturing variations)
     - "Quantitative Ultrasound": planar reflector signal normalization, computed once per probe [Lavarello 2011]
  1) Pulses are generated at multiple powers and at multiple frequencies, with the RF return from each recorded.
  2) Each pixel summarizes each signal in its multiple RF windows by fitting polynomials to it:
     - Chebyshev Polynomial, Legendre Polynomial, Linear Fit (Slope, Intercept), Backscatter Coefficients
     - Polynomial coefficients are compact "features"
     - 102 features at each pixel, RF polynomial coefficients from 6 power/frequency combinations
  3) Classification at each pixel is performed using its 102 features, using a random forest classifier [LibRF]



RF returns, each at a different power and frequency

	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

EXPERIMENTS



<u>Table 1:</u> **Blood detection accuracy**

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

- Two different phantoms, with different compositions, were used for training and testing data
- True-positive and false-positive rates were computed using hand-labeled truth.
- <u>**Table 1:**</u>
  (1) Automated labels using **B-Mode** values from six different powers and frequencies
  (2) Automated labels using **Ultrasound Spectroscopy** from same set of powers and frequencies as in (1).
- <u>**Table 2:**</u>
  Factor analysis select most informative features for blood detection. Coefficients from every power and frequency are selected.

<u>Table 2:</u> **Informative Ultrasound Spectroscopy Features**

Pwr	Freq	Feature	
15	25	Chebyshev	Coef 3
15	35	Chebyshev	Coef 4
15	35	Legendre	Coef 2
15	35	Legendre	Coef 6
15	50	Chebyshev	Coef 3
15	50	Chebyshev	Coef 5
15	50	Legendre	Coef 3
30	25	Chebyshev	Coef 4
30	25	Legendre	Coef 0
30	25	Legendre	Coef 3
30	35	Chebyshev	Coef 4
30	35	Legendre	Coef 2

CONCLUSIONS

- Ultrasound Spectroscopy achieved 0.948 TRP and 0.005 FPR, outperforming previous techniques and providing important features for distinguishing blood from tissue.
- We are able to replicate and outperform related worked by others.
  - E.g., 0.74 TRP and 0.08 FPR using Backscatter, Slope, and Intercept parameters with a random forest classifier [Lavarello 2011]
- Significant work remains…
  - User interface (screen mounted on probe, to provide intuitive instructions)
  - Novel image generation: "IAB mode" is an ultrasound data visualization method that shows probability of blood at each pixel, instead of b-mode.
  - Optimize components of the system: power and frequency selection and classifier selection (e.g., deep learning)
  - Conduct study on patients with ascites and peritoneal dialysis patients as dialysate is slowly added.