# Augmentation of Point of Care Ultrasound

Poster · January 2016



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## *Abstract*

Point of Care Ultrasound is being used in many different disciplines of medicine due to its availability, low cost and lack of ionizing radiation. It has the ability to diagnose internal bleeding in trauma, rule out ectoptic pregnancy, assess for gallstones and provide needle guidance during invasive procedures. External processing of ultrasound imagery allows it to serve as a low-cost non-invasive monitoring solution. A range of physiologic parameters can be extracted. Heart rate and respiratory rate can be estimated from the power spectral density of the cross sectional area of the internal jugular vein (IJV). Circulating blood volume can be estimated through ridge regression of features extracted from videos of the IJV. This paper provides preliminary proof-of-concept for the extraction of these signals from ultrasound imagery of the internal jugular vein.



***Keywords:***
***Point of Care Ultrasound, PoCUS, physiologic monitoring, vital signs, signal processing***


## Introduction

As ultrasound imaging technology becomes increasingly accessible with higher fidelity in lower cost systems, it has grown as a point-of-care technology. Physicians perform and interpret point of care ultrasound (PoCUS) at the bedside reducing the need for CT scans and the associated radiation exposure. It also has the potential to serve as a non-invasive monitoring solution. Monitoring vitals such as heart and respiratory rate is traditionally done with dedicated systems however this information can be extracted from dynamic ultrasound imagery along with a plethora of additional information. Sophisticated image processing techniques can estimate volume status, fluid responsiveness and pulse rate variation with this information presented to a physician at the bedside in real-time support of clinical decision-making.

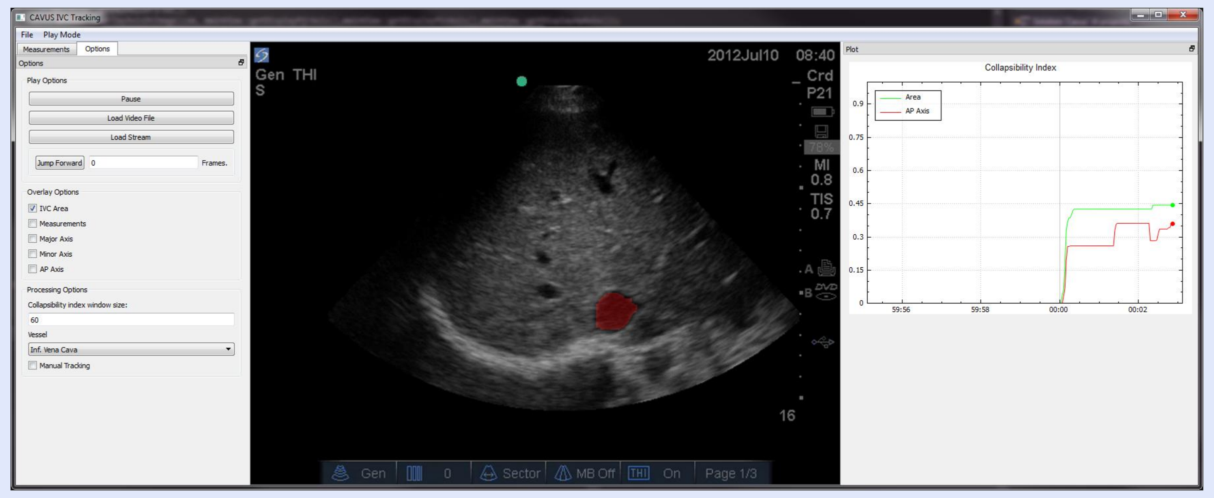

Fig. 1: Software providing real-time blood vessel segmentation, volume estimate and collapsibility index from ultrasound

## Adding features to Ultrasound

Some ultrasounds are limited to linear measurements using on-screen calipers. Speckle tracking, edge detection and object detection may be used to produce calipers which automatically snap to anatomy and measure changes with time[1]. Using watershed or active contour segmentation algorithms and a touch screen this may be extended to allow volume estimation from temporal changes [2] or left ventricular outflow tract for measurement of cardiac output [3]). Software using this approach was developed by Bellows et al [4] and is shown in Fig.1.

## Vitals monitoring

Features representing texture, motion and shape can all be extracted from the frames of an ultrasound video. Using the segmentation mentioned above, the plot of cross-sectional area (CSA) vs time can be used to extract information about a patient's vital signs. A plot of CSA vs time for a subject sitting at a variety of angles is shown in Fig. 2.

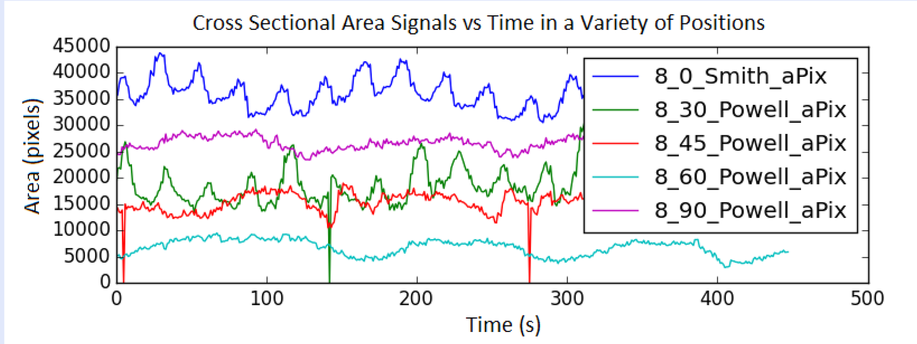


Fig. 2. Cross Sectional Area vs Time for a subject sitting upright at 90°, and also reclined at 60°,45°, 30° and finally laying flat at 0°

Using a Discrete Fourier Transform (DFT), pulse rate and respiratory rate can be extracted from the internal jugular vein as shown in Fig.3.

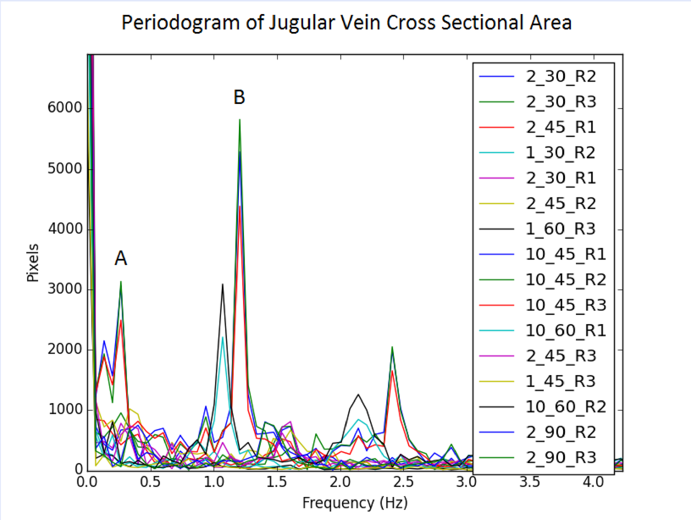


Fig. 3. Breathing rate (A) and pulse rate (B) from a number of different subjects (key) are seen in a Power Spectral Density estimation using a DFT.

Using a filter bank, the individual peaks and phase of the signals can be obtained to monitor pulse rate, pulse rate variation as well as inhalation and exhalation. An example depicting respiration filtered from an ultrasound signal is shown in figure Fig. 4.

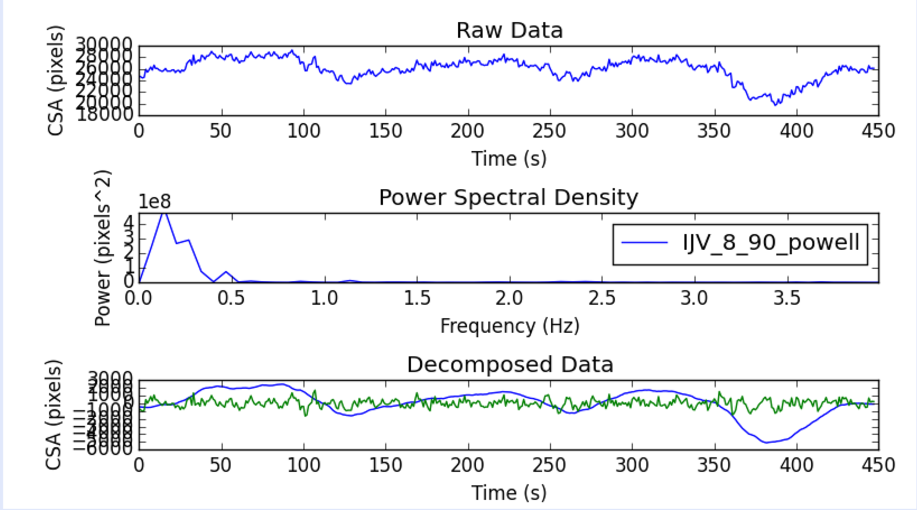


Fig. 5. Respiratory signal from ultrasound [top]. Respiration rate can be extracted from a PSD of this signal [middle]. The original signal can be decomposed [bottom] to extract a smooth respiration curve which rises with inhalation and falls with exhalation.

These signals may have use in telemedicine or machine learning applications.

## Additional Measurements

Using classification and regression algorithms, the volume status of a subject may be estimated from these signals. Intravascular volume status is the amount of blood in a subject's circulatory system. It is normally difficult to estimate with common approaches involving placing a sensor near the heart via a central venous catheter. This process is invasive, risky and time consuming. An estimate can also be obtained by observing the way the internal jugular vein responds to pressure changes demonstrated as a result of increased or decreased blood volume. Features related to the texture, shape and motion of the contour can be extracted and filtered. After testing several alternative models, it was found that ridge regression on a set of features derived from shape descriptors (selected using Fisher's discriminant), volume status can be estimated with a 20% mean absolute error. A summary of the testing is shown in Fig.5.

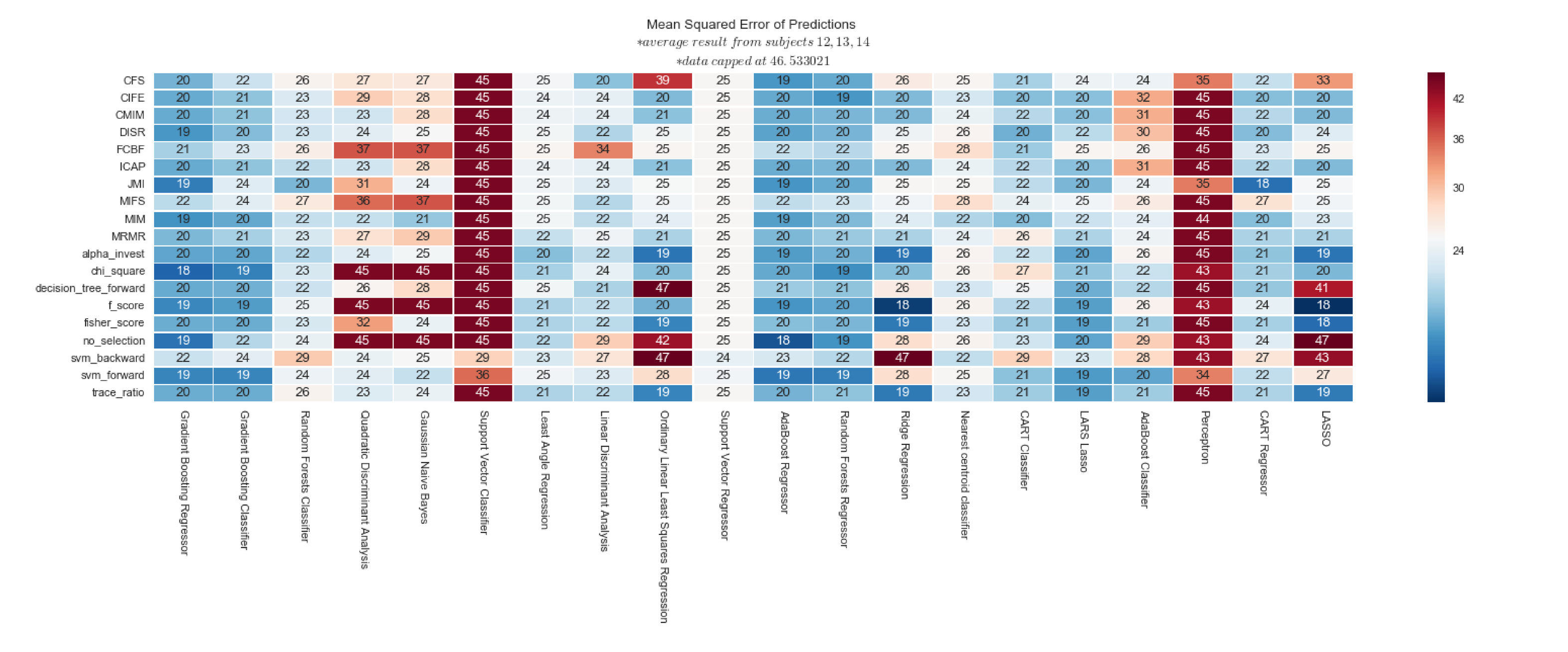


Fig.5.Error measurements for a variety of prediction algorithms (x-axis) vs feature selection methods (y-axis).


## References

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