Real-time Visual Analysis of Microvascular Blood Flow for Critical Care

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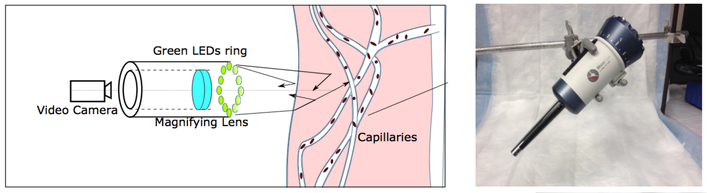
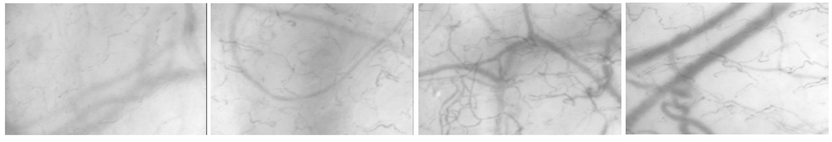
Motivation

Microvascular monitoring for disease diagnosis

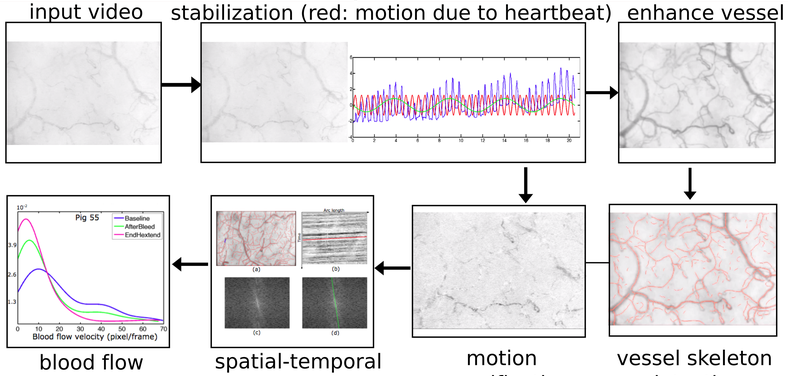
Sidestream dark field (SDF) imaging





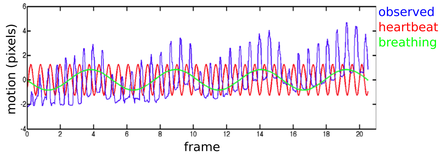
issues: subsurface scattering; lack of texture; sensor drifting; high imaging noise

Pipeline

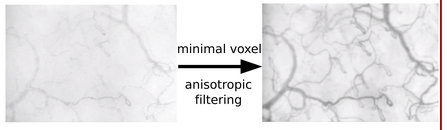


Details of the Pipeline

stabilization



enhance vessel



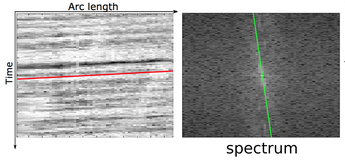
motion magnification

- Intuition: the frequency of intensity change depends on the flow speed
- Motion is amplified by magnifying the frequency corresponding components

skeleton detection

- Detected as the the ridges along vessel structure

Spatial-temporal analysis

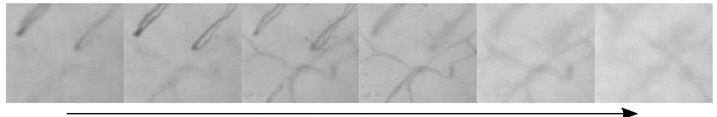


The dominant orientation is found by minimizing the inertia in the spectral domain

$$E = \int\int (r(f_x, f_y; \theta))^2 \, w(f_x, f_y) df_x df_y$$

Processing time:
~15fps
on a desktop computer

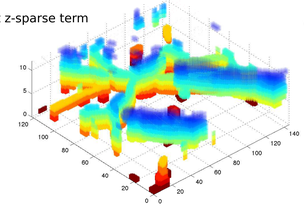
Recovering the depth of capillaries



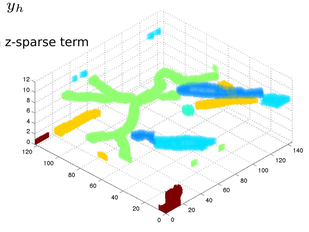
Binary Labeling in 3D: $\min_{l_x \in \{0,1\}} \sum E(l_x)$

$$E(l_x) = U(l_x) + \sum_{y_i \in \mathcal{N}_{24}} B_{\text{smooth}}(l_x, l_{y_i}) + \sum_{y_h} H_{sparse}(l_x, l_{y_h}) \text{ with } p(x) = p(y_h)$$

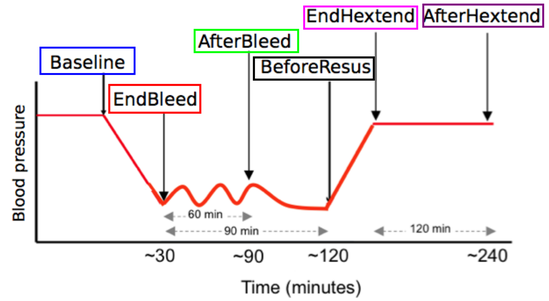
without z-sparse term



with z-sparse term

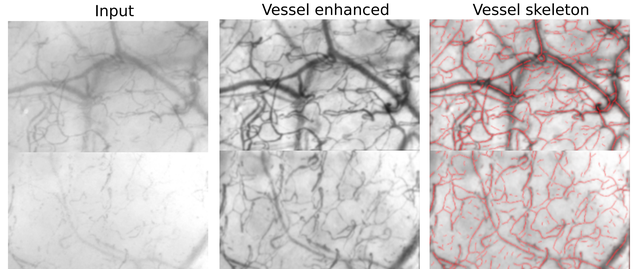


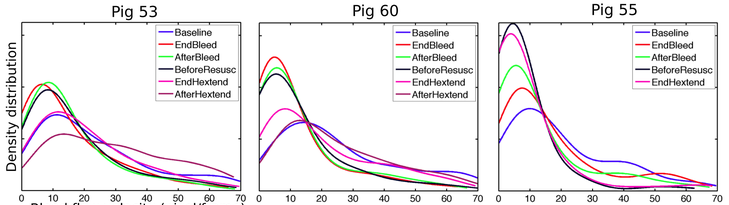
Experiments & Results



- In the experiment, 18 healthy pigs have been anesthetized and subjected to bleed for 2 hours.
- Then the subjects were fluid resuscitated to expand the plasma volume.
- Microcirculatory videos were captured at different stages of the experiment to monitor changes in the micro blood flow.

Baseline Before bleeding	EndBleed The bleeding is stopped
AfterBleed 60 min after bleeding	BeforeResus 90 min after bleeding
EndHextend End of resuscitation using Hextend	AfterHextend 120 after resuitation





Blood flow speed decreases due to bleeding. The resuscitation process results in the increase in flow speed Pig 55 died before the last stage. Notice the difference of speed changes between Pig 55 and Pig 53/60.-