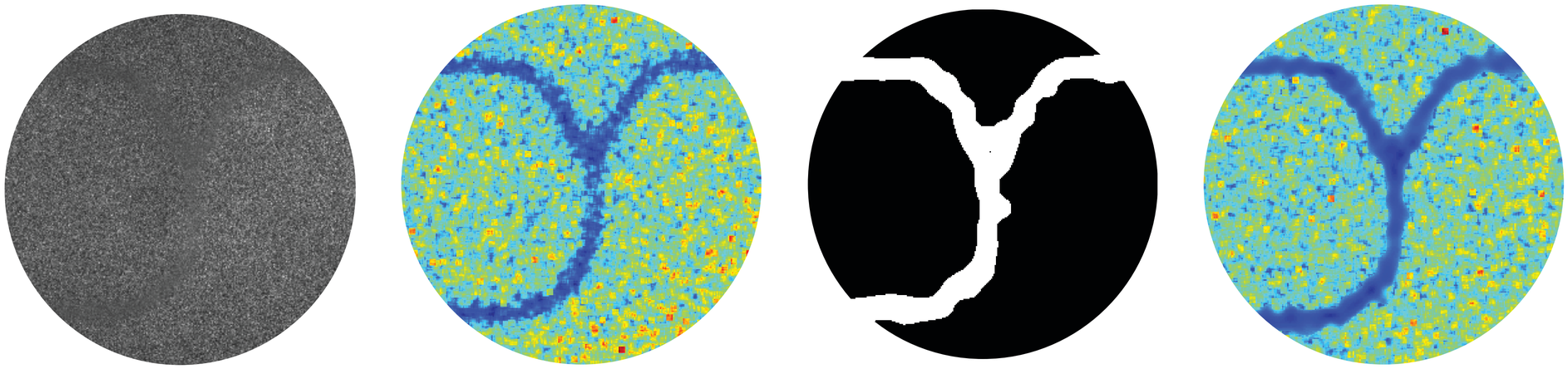


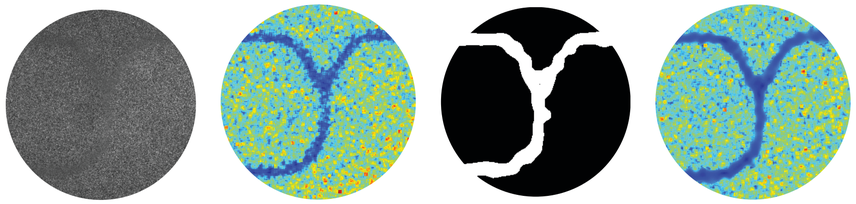
Blood Vessel Visualization of Raw Speckle Images

Wavelet Approach

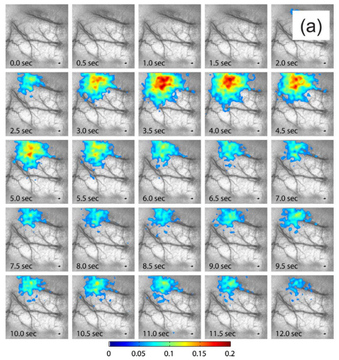
Francisco López-Tiro

Introduction

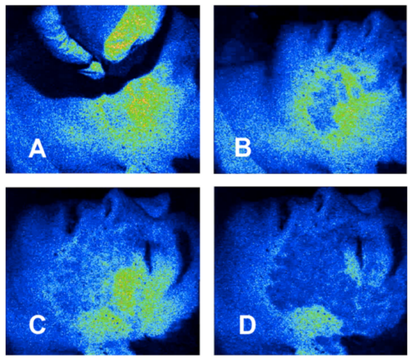
Visualization and localization



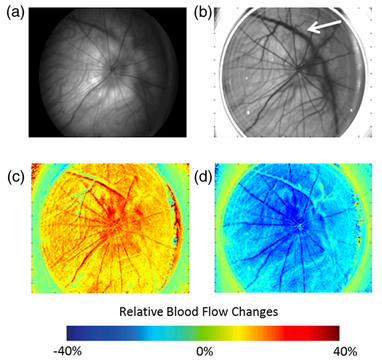
- **Visualization and localization of blood vessels (VLBV)** is important for different biomedical applications, such as neuroscience, dermatology and ophthalmology[1].



(a) Brain activation and blood flow changes in the brain[1].



(b) Assessment of photodynamic therapy in Port Wine Stains[2].



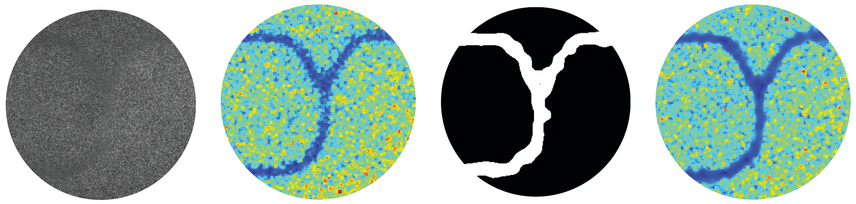
(c) Visual stimulation and blood flow analysis in the retina[3].

- **Laser Speckle Imaging (LSI)** is the most widely used non-invasive technique for measuring blood flow and is based on the speckle phenomenon[4].

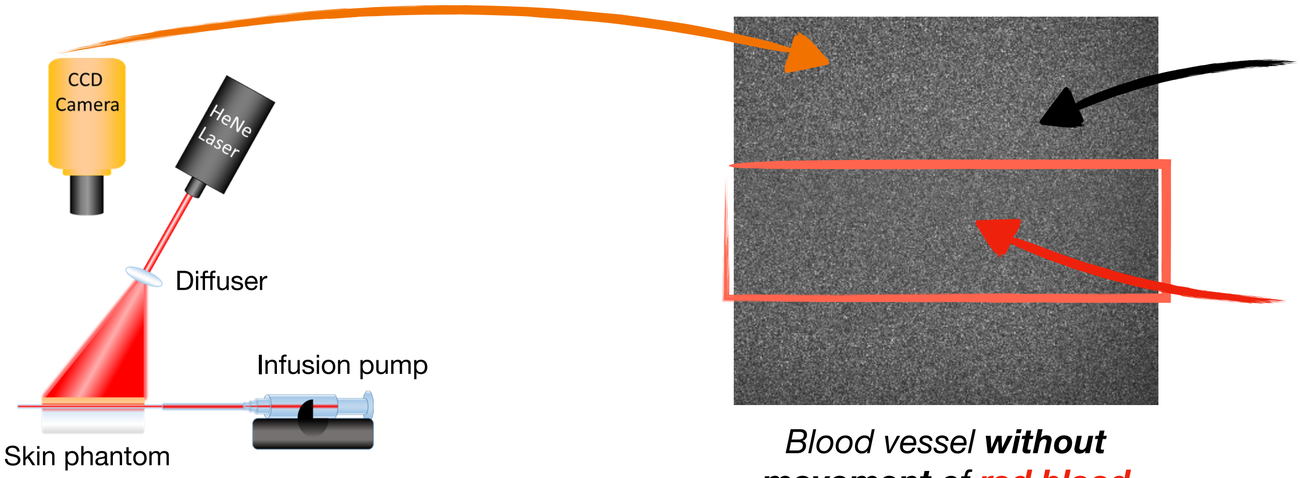
[1][Boas et al., 2010]. *"Laser speckle contrast imaging in biomedical optics"*. Journal of biomedical optics.
[2][Choi et al., 2016]. *"The role of laser speckle imaging in port-wine stain research: Recent advances and opportunities"*. IEEE Journal of Selected Topics in Quantum Electronics.
[3][Ponticorvo et al., 2013]. "*Laser speckle contrast imaging of blood flow in rat retinas using an endoscope"*. Journal of biomedical optics.
[4][Briers, et al., 2013]. *"Laser speckle contrast imaging: theoretical and practical limitations".* Journal of biomedical optics.

Introduction

Laser Speckle Imaging (LSI)



- Speckle is a scattering phenomenon. It appears by interaction between photons, of a coherent light laser, and a rough surface such as biological tissue[5].



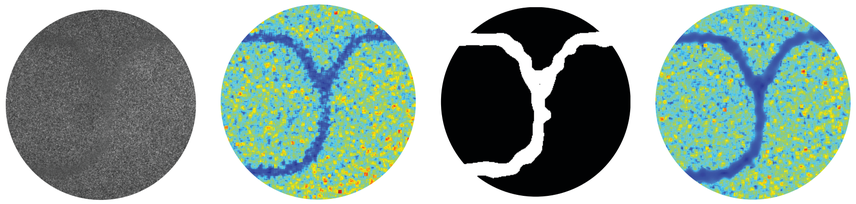
(a) Experimental setup (b) Speckle image

- The movement of particles (i.e. blood cells) inside a rough surface generates a **blurring effect (BE)**. LSI technique is used to analyze the **BE**[6].

[5][Aizu and Asakura, 1991]. *"Bio-speckle phenomena and their application to the evaluation of blood flow"*. Optics & Laser Technology.
[6][Draijer et al., 2009]. "*Review of laser speckle contrast techniques for visualizing tissue perfusion"*. Lasers in medical science.

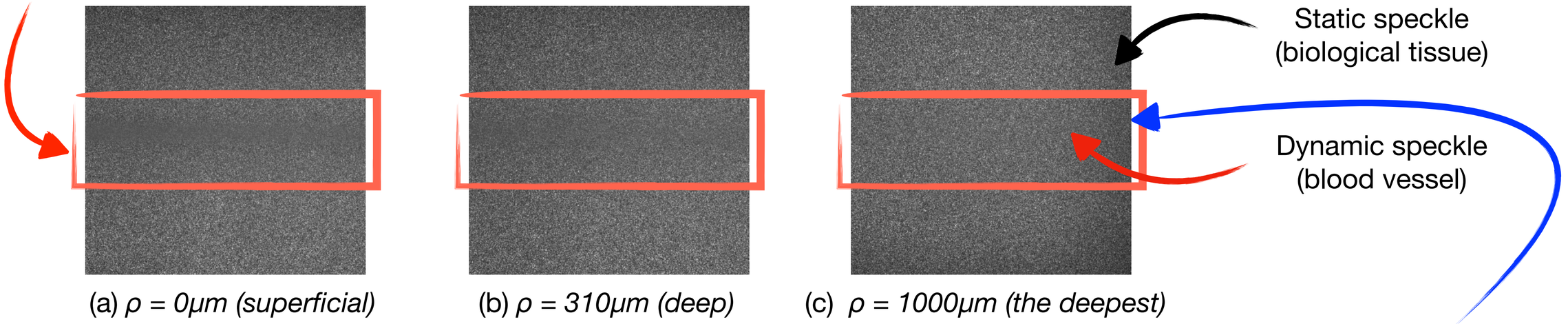
Introduction

Laser Speckle Imaging (LSI)



- The main limitation of **LSI** is related to **VLBV**. Speckle images noise increases when the depth of the blood vessels (ρ), inside the skin, is higher. It is due to strongly scattering of static structures[7].

This is a good BE!



(a) ρ = *0μm (superficial)* (b) ρ = *310μm (deep)* (c) ρ = *1000μm (the deepest)*

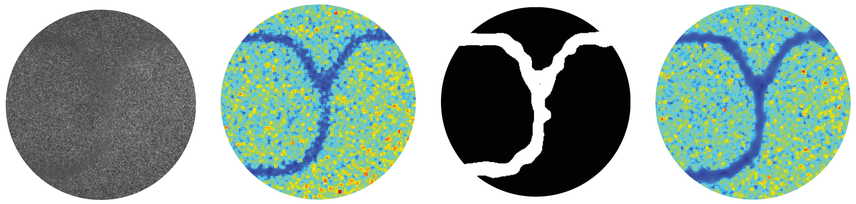
Visualization of straight in-vitro blood vessels in a speckle image to different depths (ρ).

This is a bad BE!

[7][Vaz et al., 2016]. *"Laser speckle imaging to monitor microvascular blood flow: a review"*. IEEE reviews in biomedical engineering.

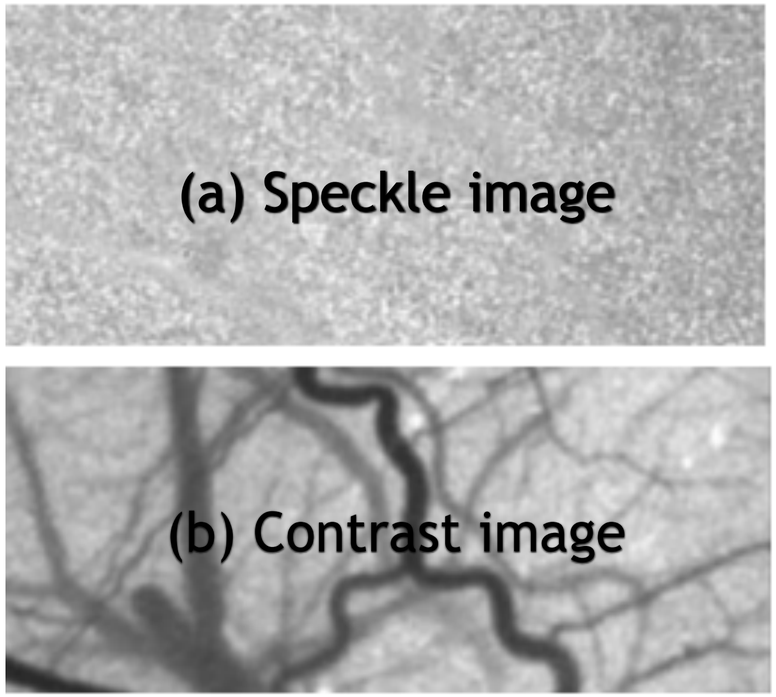
Introduction

Laser Speckle Imaging (LSI)



Visualization and localization of blood vessels

- Physical methods
  - Exposure time
    Non-invasive
  - External agents
    Invasive
- Computational methods
  - Slow dynamics
  - Fast dynamics
    - Contrast
      Non-invasive
      - Speckle Flow Index
    - Other
      representations

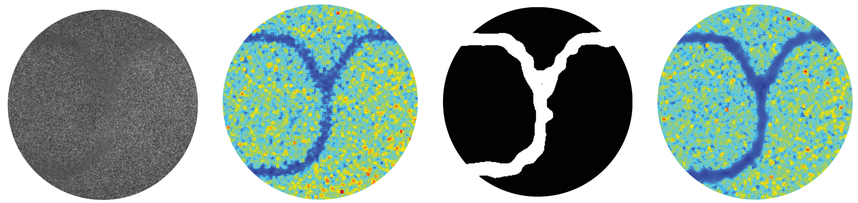


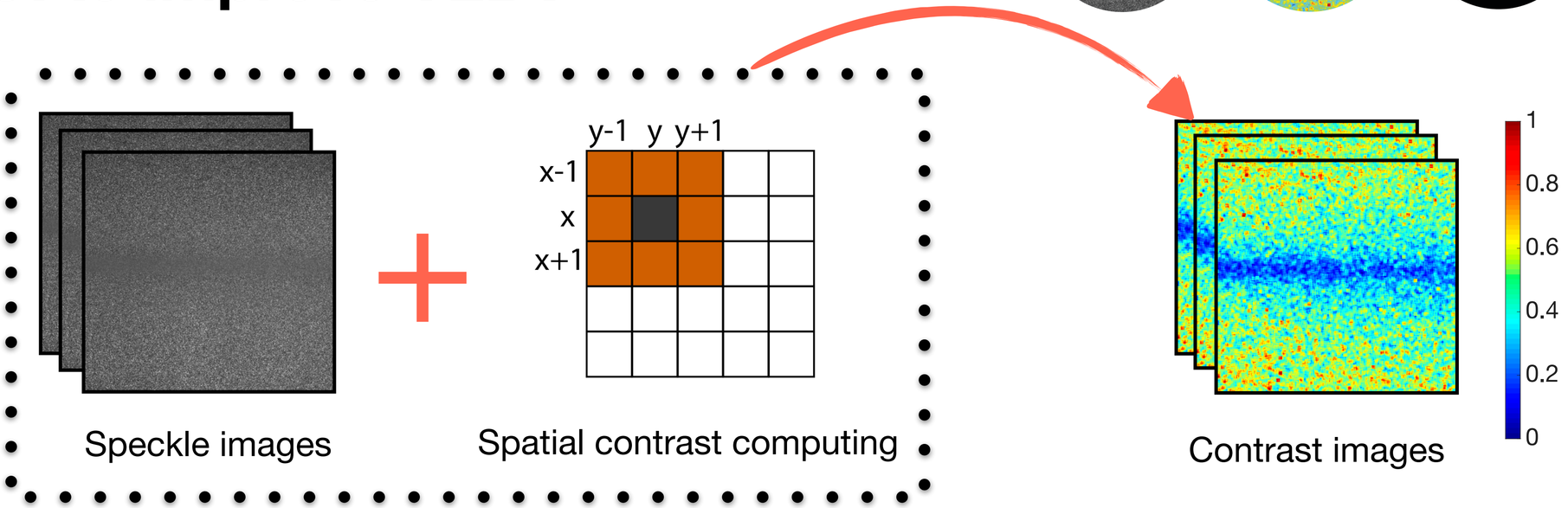
Computational methods[7].
Fast dynamics with contrast representation.
(a) speckle image, and (b) contrast image.

[7][Vaz et al., 2016]. *"Laser speckle imaging to monitor microvascular blood flow: a review"*. IEEE reviews in biomedical engineering.

Concepts

Contrast to improve VLBV





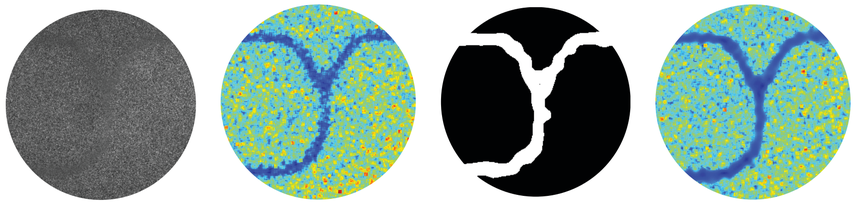
- Contrast (K) in speckle images can be calculated using traditional methods, such as spatial contrast (sK)[7].

- K is the ratio between standard deviation and the average intensity, σ(W) and I(W), respectively, in a dxd analysis window.

[7][Vaz et al., 2016]. *"Laser speckle imaging to monitor microvascular blood flow: a review"*. IEEE reviews in biomedical engineering.

State of the art

Related work



Work	Improve	Sample	Resume
Morphological Approach[8] (MA)	Localization	In-vitro B-S (0 to 900um)	Contrast + mathematical morphology
Principal Component Analysis[9] (PCA)	Both	In-vitro S (0 to 1mm)	PCA processing + contrast, and K-Nearest Neighbors
Space-directional Contrast[10] (sdK)	Visualization	In-vitro S (0 to 400um)	Contrast processing with an anisotropic window in 4 directions
Gaussian Sliding Window[11] (GSW)	Visualization	In-vivo	Contrast + gaussian filtering
Homogeneity representation[12] (HR)	Localization	In-vitro B-S (0 to 900um)	Homogeneity and kurtosis analysis
Haar wavelet[13] (Haar)	Visualization	In-vivo	Contrast + Wavelet Transform (simple level)
Ours - Wavelet Approach (WA)	Both	In-vitro B-S (0 to 900um)	Contrast + Wavelet Transform (automatic selection of level) + area criteria

[8][Morales-Vargas et al., 2018]. *"A morphological approach for locating blood vessels in laser contrast speckle imaging"*. In 2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), IEEE

[9][Arias-Cruz et al., 2019]. *"Visualization of in vitro deep blood vessels using principal component analysis based laser speckle imaging*". Biomedical Optics Express.

[10][Perez-Corona et al., 2018] *"Space-directional laser speckle contrast imaging to improve blood vessels visualization"*. In 2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), IEEE.

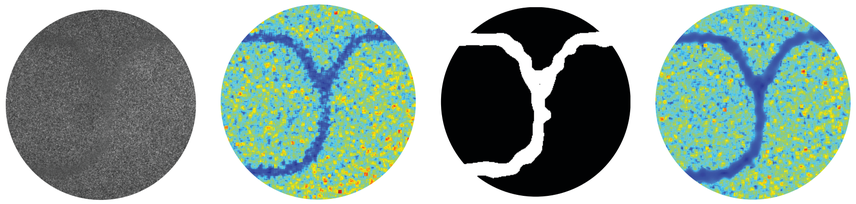
[11][Postnikov et al., 2019]. *"Gaussian sliding window for robust processing laser speckle contrast images"*, International journal for numerical methods in biomedical engineering.

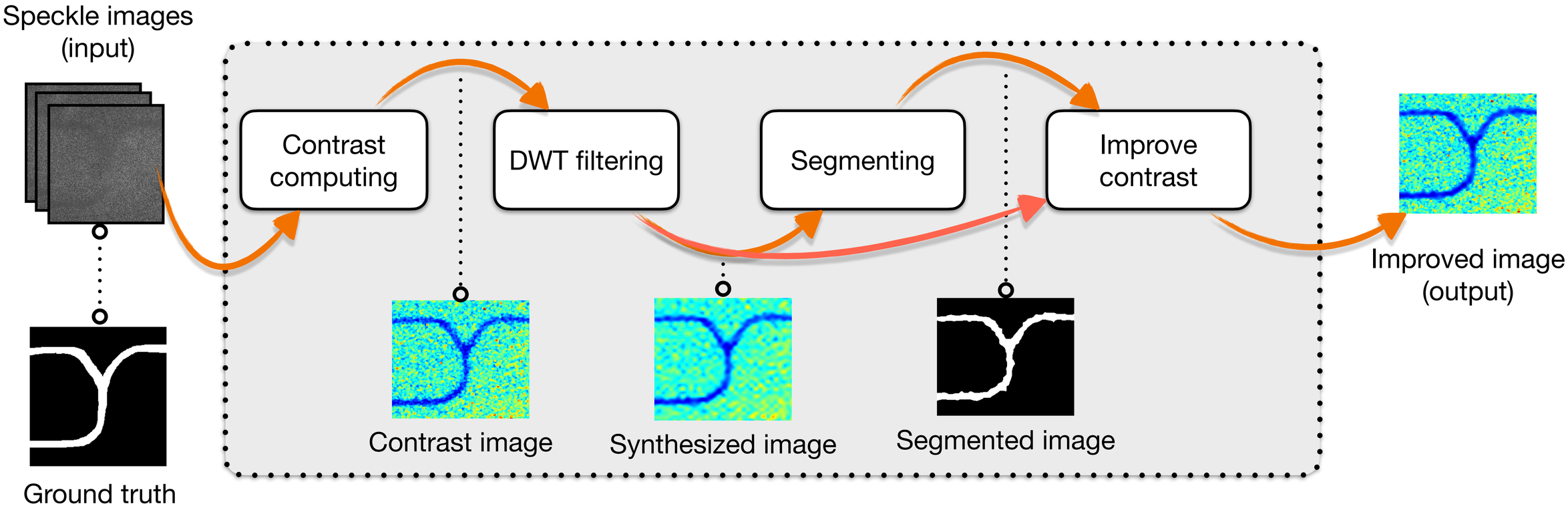
[12][Peregrina-Barreto et al., 2017]. *"Use of kurtosis for locating deep blood vessels in raw speckle imaging using a homogeneity representation*". Journal of biomedical optics.

[13][Postnikov, et al., 2018]. *"MATLAB for laser speckle contrast analysis (LASCA): a practice-based approach*". Saratov Fall Meeting 2017: Fifth International Symposium on Optics and Biophotonics: Laser Physics and Photonics XIX; Computational Biophysics and Analysis of Biomedical Data IV.

This work

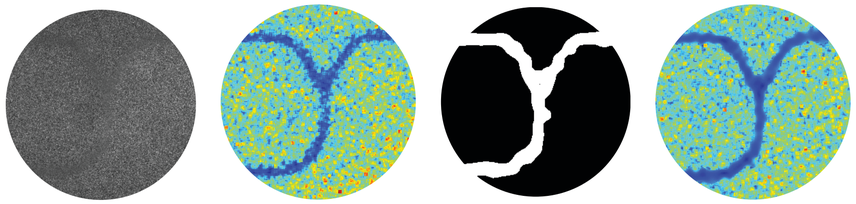
Methodology



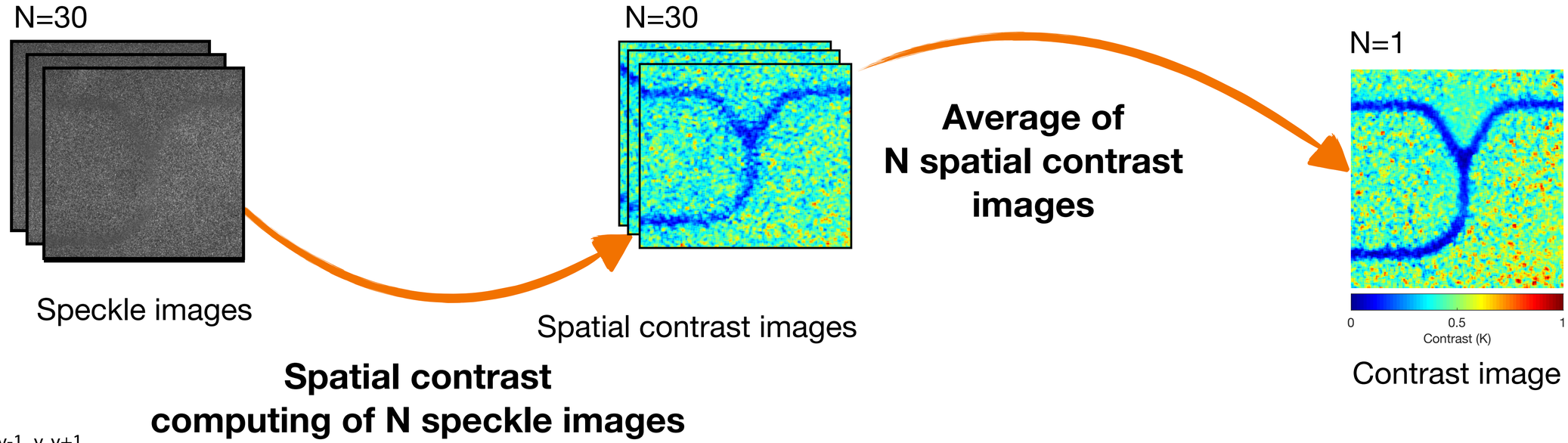


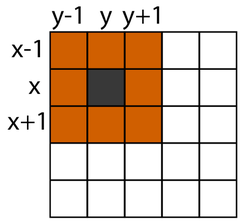
This work

Contrast computing



- Contrast (K) in speckle images can be calculated using traditional methods, such as spatial contrast (sK)[7].

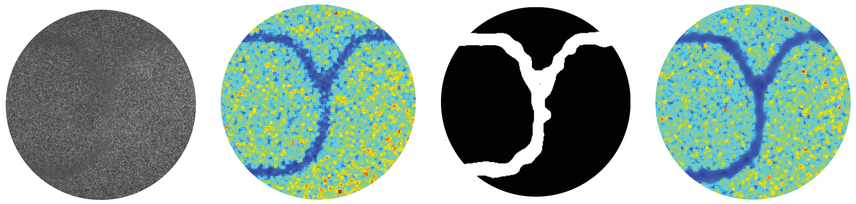




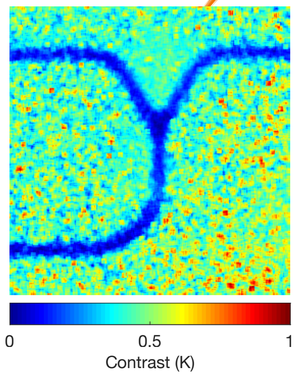
[7][Vaz et al., 2016]. *"Laser speckle imaging to monitor microvascular blood flow: a review"*. IEEE reviews in biomedical engineering.

This work

DWT filtering

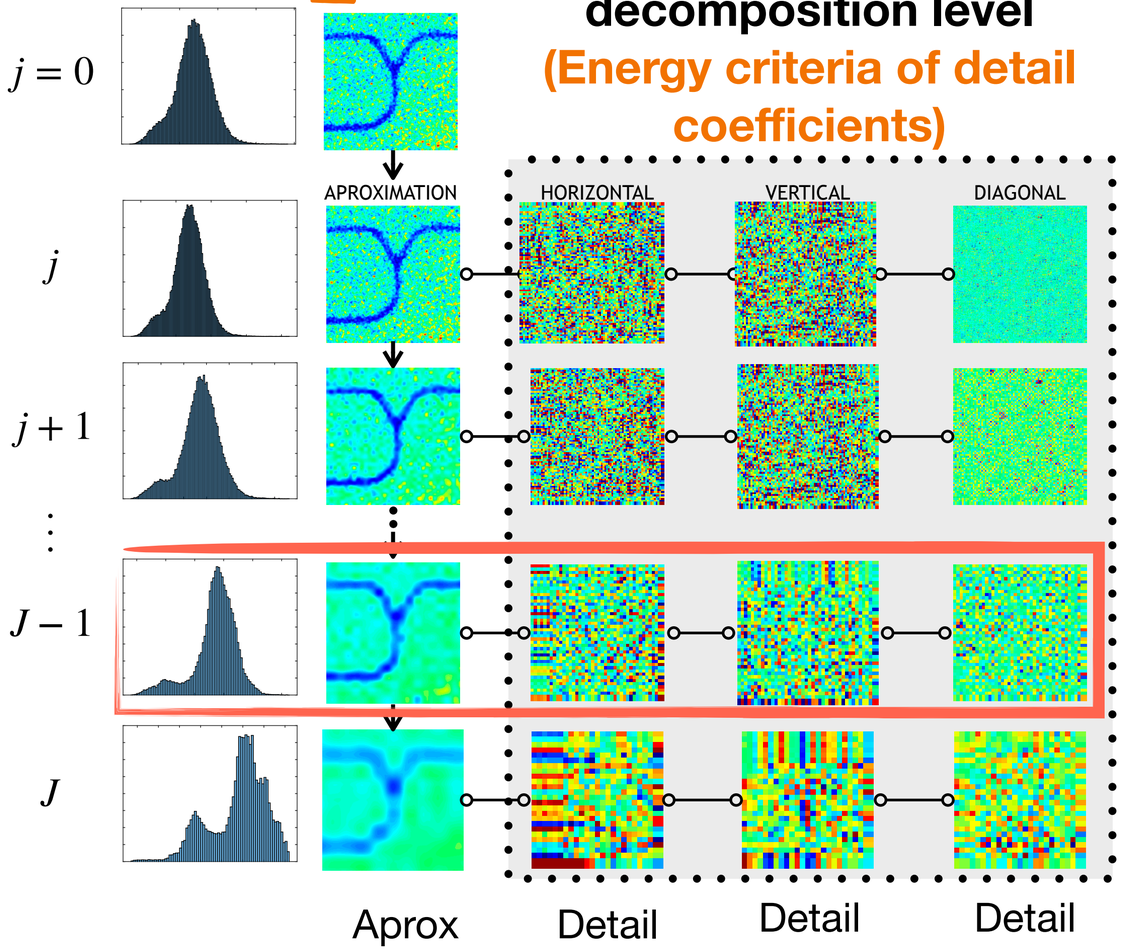


N=1



Contrast image

Automatic selection of decomposition level
(Energy criteria of detail coefficients)



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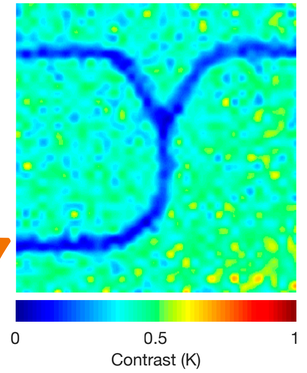
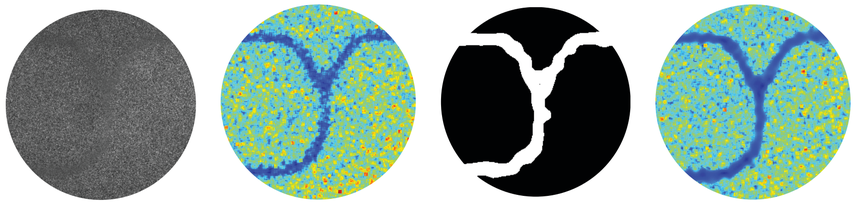


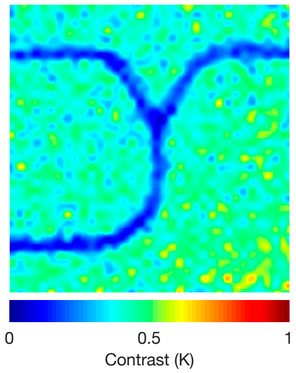
Synthesized image

This work

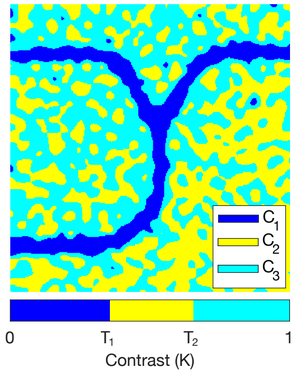
Thresholding and segmenting



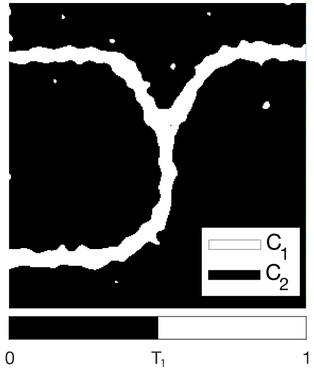
Synthesized image

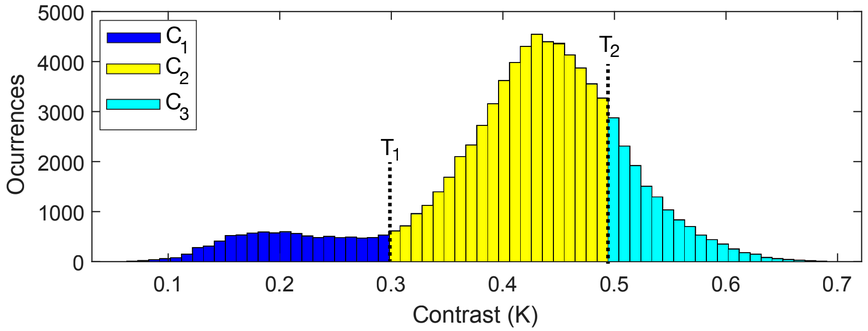


Quantized image

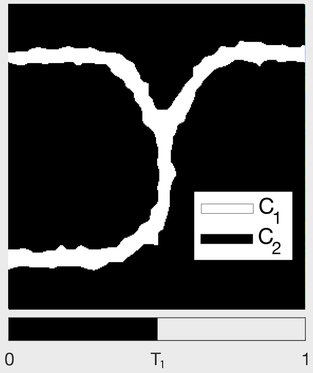


Thresholded image



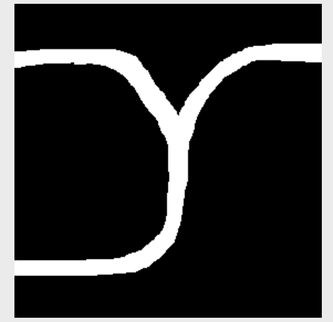


Segmented image



VS

Ground truth image

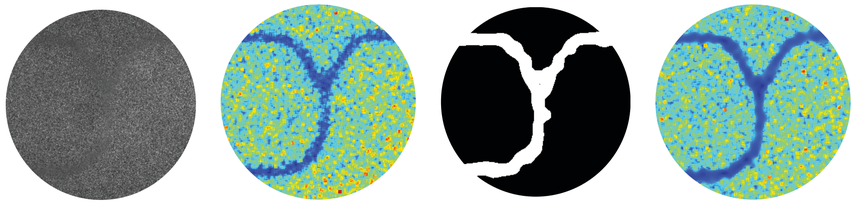


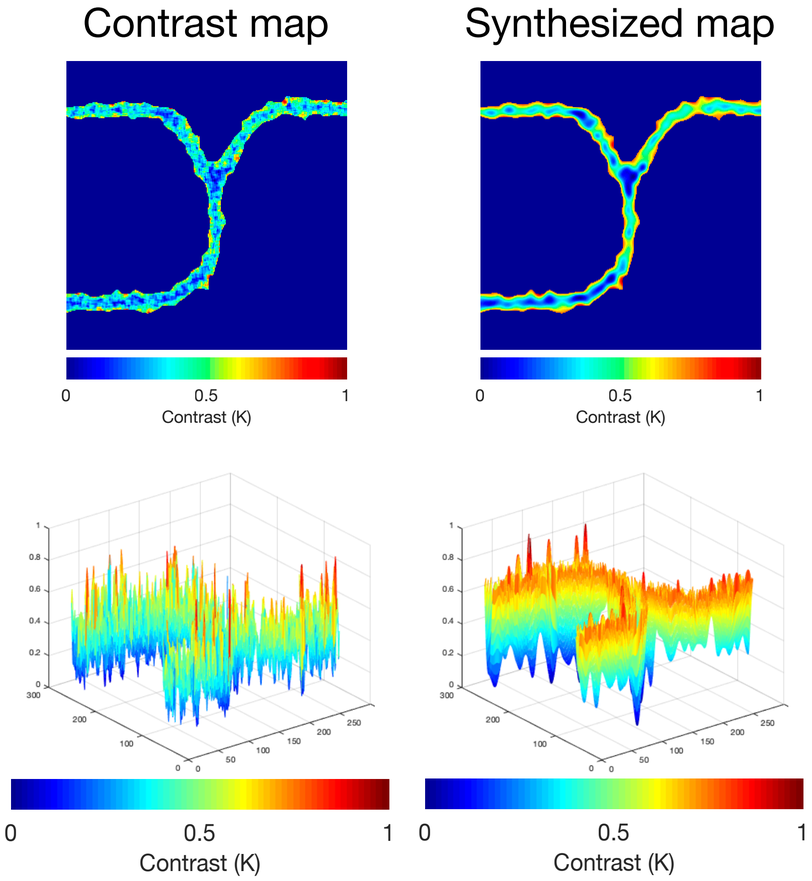
Performance with Jaccard Index (JI)

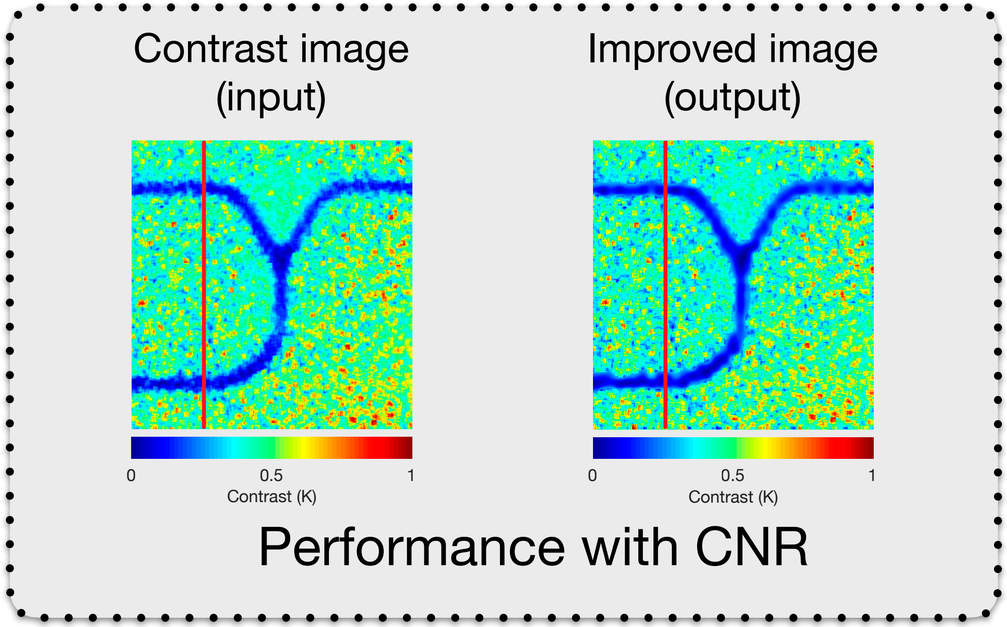
$$RI(A,B) = \frac{TP}{TP + FP + FN}$$

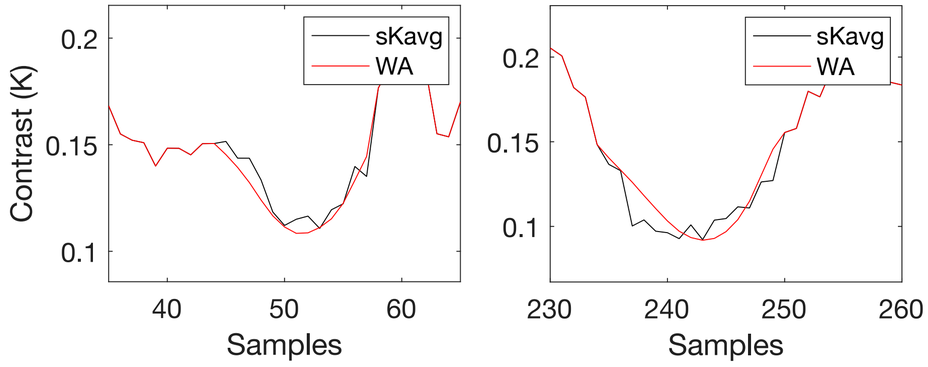
This work

Thresholding and segmenting



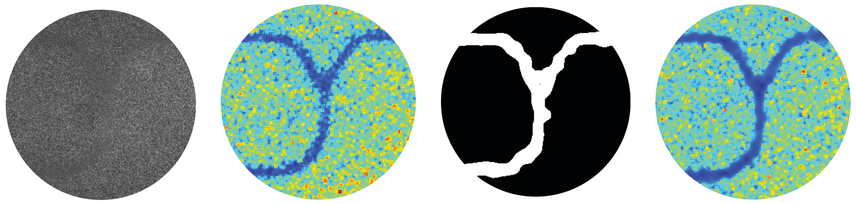






Experiments and results

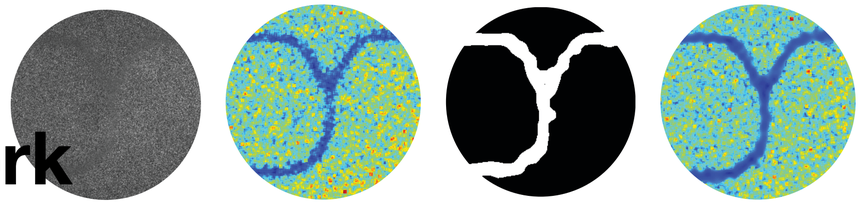
Dataset



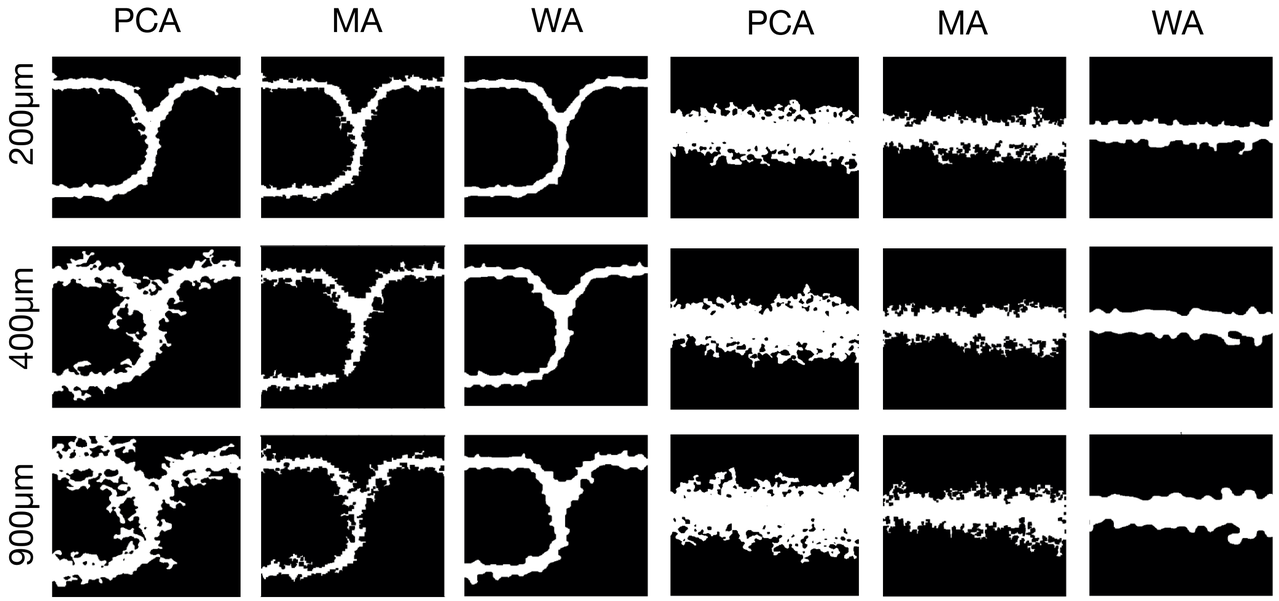
- The dataset consist of
  - **14 speckle packages**, each one of package contains 30 in-vitro straight or bifurcated blood vessels speckle images.
  - **8 blood vessels depths** (0*μm*, 200*μm*, 300*μm*, 400*μm,* 500*μm,* 600*μm,* 700*μm,* and 900*μm*).
  - The **dimensions of the in-vitro images for straight vessels and bifurcated** vessels are 344×329 pixels and 280×288 pixels, respectively
  - The **ground truth** (GT) is a binary image [0,1] and it is obtained by labeling of the blood vessel at 0*μm* depth.
  - The **contrast images** are calculated with the spatial contrast averaged algorithm (sKavg) with an analysis window W = 5 × 5.

Experiments and results

Localization: comparison with related work



Depth µm	PCA[9]	MA[8]	WA
0	35.62±03.26%	**50.31±00.04%**	**83.94±02.09%**
200	46.18±17.21%	**60.82±10.58%**	**74.24±04.89%**
300	**59.14±03.45%**	**70.74±00.42%**	**73.15±04.55%**
400	32.48±08.84%	**57.60±08.87%**	**59.81±11.83%**
500	25.80±06.57%	52.66±07.22%	45.36±11.67%
600	23.96±03.14%	43.89±01.53%	37.78±06.44%
700	23.42±03.85%	43.04±01.31%	38.13±08.58%
900	19.90±01.54%	29.64±13.21%	31.03±02.77%
Avg	**33.31±05.98%**	**49.74±18.49%**	**55.43±06.60%**



- The WA model is useful for improving contrast quality in blood vessels up to 500µm.

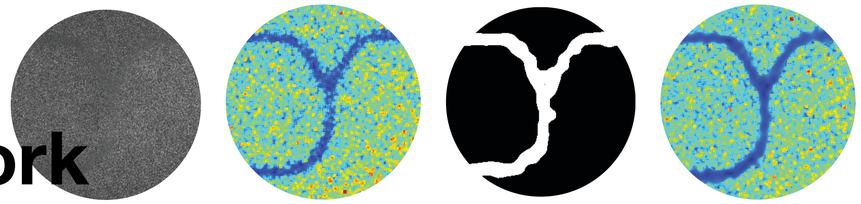
[8][Morales-Vargas et al., 2018]. *"A morphological approach for locating blood vessels in laser contrast speckle imaging"*. In 2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), IEEE

[9][Arias-Cruz et al., 2019]. *"Visualization of in vitro deep blood vessels using principal component analysis based laser speckle imaging"*. Biomedical Optics Express.

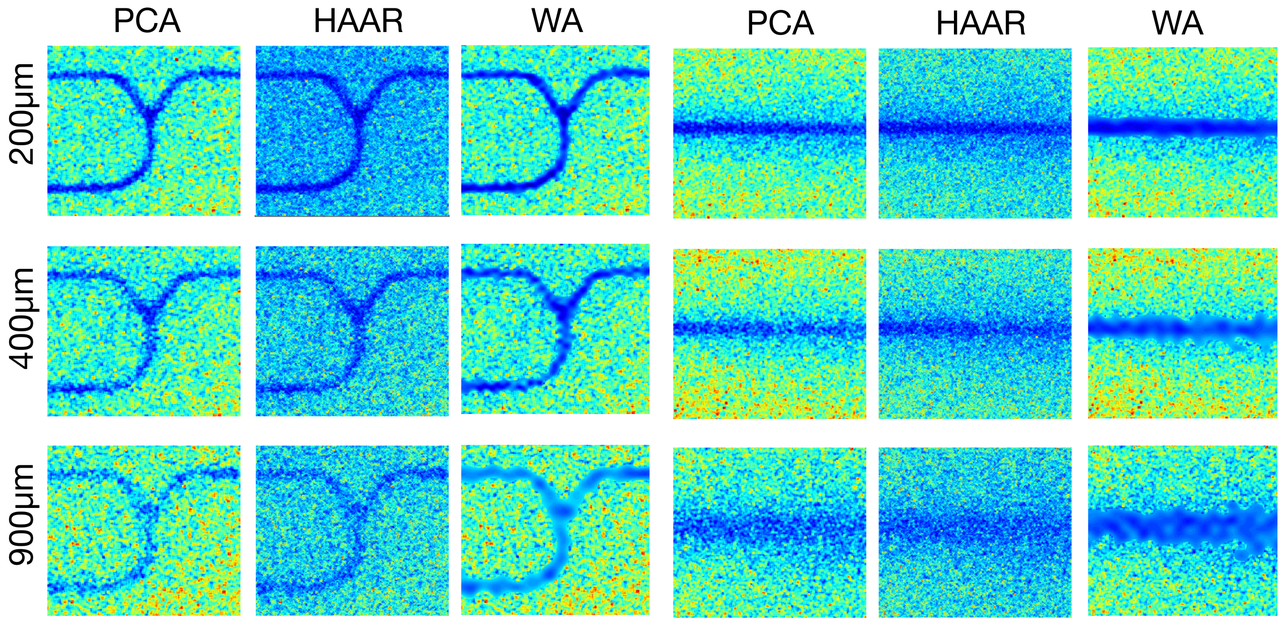
[13][Postnikov, et al., 2018]. *"MATLAB for laser speckle contrast analysis (LASCA): a practice-based approach"*. Saratov Fall Meeting 2017: Fifth International Symposium on Optics and Biophotonics: Laser Physics and Photonics XIX; Computational Biophysics and Analysis of Biomedical Data IV.

Experiments and results

Visualization: comparison with related work



Depth µm	PCA[9]	HAAR[13]	WA
0	2.64±0.42	1.86±0.23	**2.97±0.14**
200	2.29±0.28	1.54±0.51	**3.56±0.21**
300	2.12±0.33	1.37±0.49	**2.50±0.25**
400	1.90±0.38	1.26±0.55	**3.04±0.31**
500	1.46±0.77	0.95±0.53	**2.49±0.45**
600	1.31±0.79	0.84±0.38	2.29±1.54
700	1.12±0.91	0.72±0.52	1.66±1.98
900	1.09±0.79	1.15±0.23	1.28±1.04
Avg	**1.74±0.58**	**1.74±0.42**	**2.47±0.74**



- The WA model is useful for locating blood vessels up to 400µm.

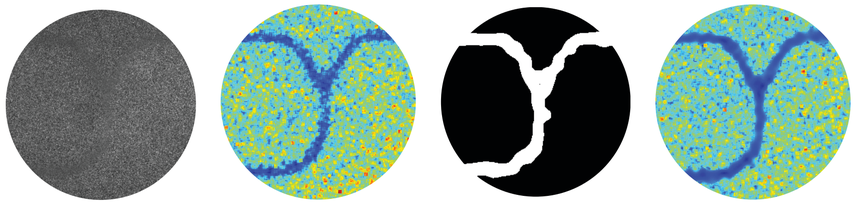
[8][Morales-Vargas et al., 2018]. *"A morphological approach for locating blood vessels in laser contrast speckle imaging"*. In 2018 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), IEEE

[9][Arias-Cruz et al., 2019]. *"Visualization of in vitro deep blood vessels using principal component analysis based laser speckle imaging*". Biomedical Optics Express.

[13][Postnikov, et al., 2018]. *"MATLAB for laser speckle contrast analysis (LASCA): a practice-based approach*". Saratov Fall Meeting 2017: Fifth International Symposium on Optics and Biophotonics: Laser Physics and Photonics XIX; Computational Biophysics and Analysis of Biomedical Data IV.

Conclusions

Wavelet Approach



- The visualization and localization is an important task to determine the presence of blood vessels in the biological tissue.
- This work presented a methodology based on a wavelet approach to attenuate noise in contrast images, and improve the localization of blood vessels.
- The results obtained have shown that automatic filtering reduces contrast noise from superficial (100μm) and deep (up to 500μm) blood vessels.

Thank you for your attention!

Questions?

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