A Joint Probabilistic Model for Speckle Variance, Amplitude Decorrelation and Interframe Variance (IFV) OCT Angiography

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Introduction

- Optical Coherence Tomography Angiography (OCTA) is a non-invasive imaging technique for blood flow visualization in living tissue.
- OCTA signals describe the differences in a series of repeated OCT scans at the same location. Small differences suggest static tissue, whereas large differences suggest moving particles which are usually found in blood vessels.
- Various implementations of OCTA difference measures exist, including Speckle Variance OCTA (SV-OCTA) [1] and Amplitude Decorrelation OCTA (AD-OCTA) [2]
- In contrast to SV-OCTA, AD-OCTA lacks an objective function which prevents mathematical modeling of, e.g., denoising post processing tasks.
- We present an objective function that exactly leads to the AD-OCTA formula described in [2] and use it to improve the understanding about the relation between both aforementioned measures.
- We further introduce the Interframe Variance OCTA (IFV-OCTA) measure which can be seen as a link between the SV- and AD-OCTA measures.

Materials and Methods

- The **SV-OCTA** measure simply describes the variance σ^2 in the sequence of a voxel's OCT intensities a_i by assuming normally distributed data with mean μ.
- $L_{SV} = \prod_{i=1}^{N} p(a_i \mid \mu, \sigma_{SV}^2) \rightarrow \max_{\sigma_{SV}^2} \qquad \rightarrow \sigma_{SV}^2 = \frac{1}{N}\sum_{i=1}^{N}(a_i - \mu)^2$
- If the objective function is set up as a difference of subsequent normalized voxel intensities, a derivation for σ leads to the common **AD-OCTA** formula.
- $L_{AD} = \prod_{i=1}^{N-1} p\left(\frac{a_i}{\sqrt{a_i^2+a_{i+1}^2}} - \frac{a_{i+1}}{\sqrt{a_i^2+a_{i+1}^2}} \mid 0, \sigma_{AD}^2\right) \rightarrow \sigma_{AD}^2 = \frac{1}{N-1}\sum_{i=1}^{N-1}\frac{(a_i-a_{i+1})^2}{a_i^2+a_{i+1}^2}$
- To bridge the gap between the two measures, we define Interframe Variance OCTA (**IFV-OCTA**) as the difference of voxel intensities without normalization.
- $L_{IFV} = \prod_{i=1}^{N-1} p(a_i - a_{i+1} \mid 0, \sigma_{IFV}^2) \qquad \rightarrow \sigma_{IFV}^2 = \frac{1}{N-1}\sum_{i=1}^{N-1}(a_i - a_{i+1})^2$

Results and Discussion

- Since vessels are more backscattering than surrounding tissue, the intensity dependency of SV- and IFV-OCTA especially improves small vessel visibility.
- Furthermore, the low OCT-signal intensity below superficial vessels reduces the appearance of shadowing artifacts, while these are clearly visible with high intensities ("decorrelation tails") in the AD-OCTA image.
- The advantage of the AD-OCTA measure resides in the decoupling of the OCTA values from the local OCT-signal intensity which differs at each voxel. This might be desirable for algorithmic and more quantitative analyses.
- A more subtle difference arises from the pairwise differences in the IFV- and AD-OCTA formulas, which cause a dependency on the time delay between the pairs' acquisitions (the interscan time).
- This dependency plays an important role in the context of Variable Interscan Time Analysis (VISTA) [3], an approach to derive relative blood flow speed estimates from OCTA, which we want to investigate further in the future.

Conclusions

- We set up an objective function for AD-OCTA to put it in a probabilistic context with SV-OCTA to improve its theoretical foundation and algorithmic usability.
- We introduced IFV-OCTA to bridge the gap between SV- and AD-OCTA and thereby make the differences between these measures more intuitive.

	SV-OCTA	IFV-OCTA	AD-OCTA
Independant of OCT signal intensity	No	No	Yes
Dependant on the interscan time	No	Yes	Yes

Table 1: Main differences between the discussed OCTA measures.

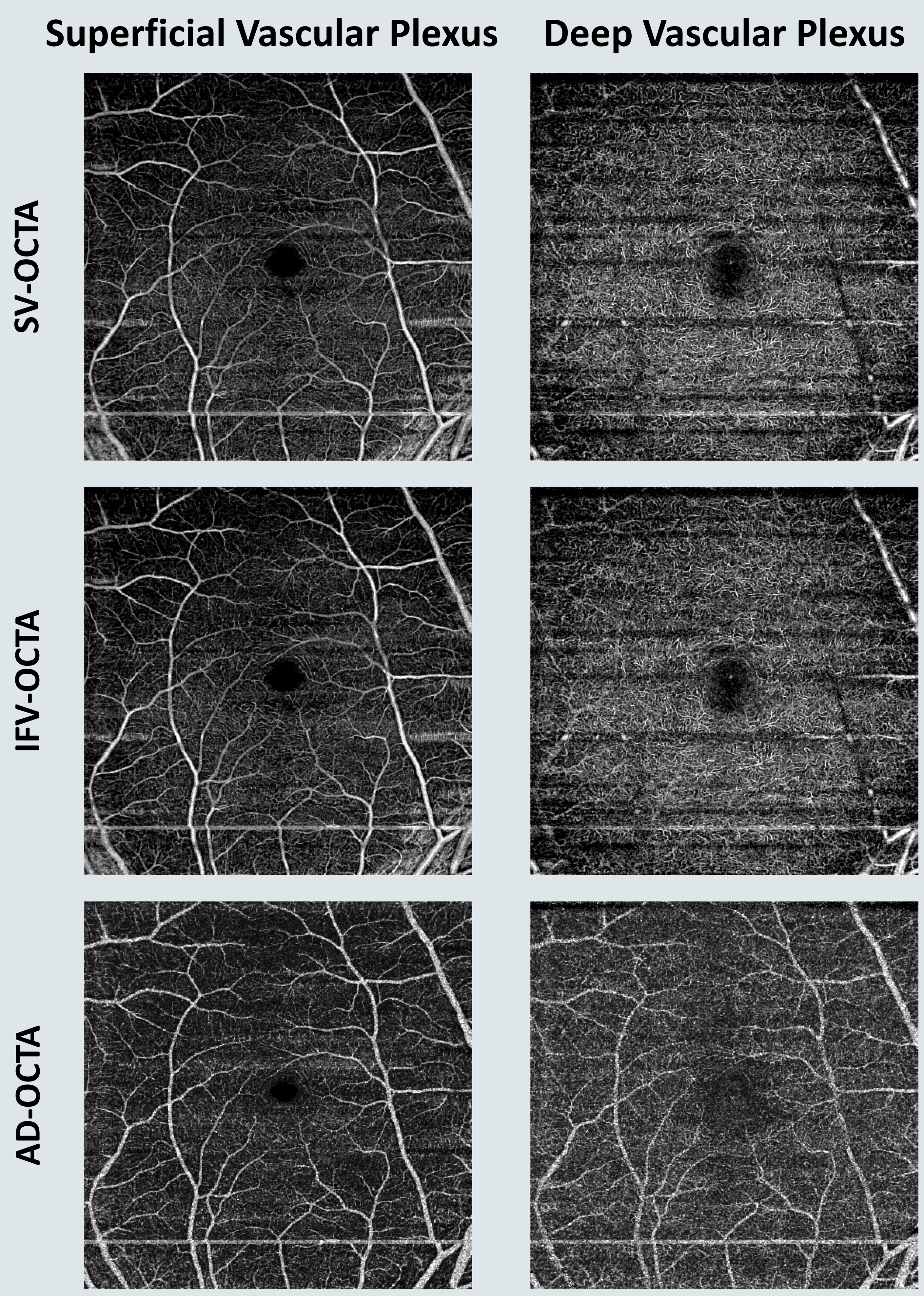

Figure 1: Extracted en-face slices at the superficial and deep vascular plexi of a 25 y/o normal subject. Projections were formed using median filtering with radius 1 px and Gaussian windowing along depth with $\sigma = 1$ px. A logarithm transform was applied to the SV- and IFV-OCTA measures to both improve contrast and allow for a fair visual comparison.

References

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