

## VBM currently implemented in Lirot.ai

**Remarks:** All black borders are removed then the image is padded so to resize the image to a squared dimension. Finally, the image is resampled to 1444x1444 pixels. Biomarkers highlighted in blue can be computed for arterioles (A) or venules (V). All biomarkers are evaluated within a region of interest (ROI), which is by default the full 1444x1444 pixels image or can be selected to be a 500 pixels width circle around the optic disc.

Name	Definition
Area	Area of the blood vessels computed by summing the number of pixels within the segmented A or V regions. Expressed in square pixels. <a href="#">[1]</a>
TortuosityIndex	Tortuosity measure based on the overall arc-chord ratio. <a href="#">[1]</a>
MedianTortuosity	Median of the per vessel tortuosity. The tortuosity is computed by the arc-chord ratio. <a href="#">[1,2]</a>
Length	Cumulative length of the segmented blood vessels. It is computed as the distance to traverse the entire skeleton. Expressed in pixels. <a href="#">[1]</a>
MedianBranchingAngles	Median value of the branching angle distribution evaluated for all blood vessels. It is expressed in degrees. <a href="#">[1]</a>
StartingPoints	Number of skeleton points situated on the optic disc. <a href="#">[1]</a>
EndPoints	Number of skeleton points terminating blood vessels. <a href="#">[1]</a>
BranchingPoints	Number of skeleton points where blood vessels branch into two smaller blood vessels. <a href="#">[1]</a>
D0	Also known as the box-counting dimension, is a measure of the space-filling capacity of the pattern. <a href="#">[3,4]</a>
D1	Also known as the entropy dimension, is a measure of the distribution of the pattern. <a href="#">[3,4]</a>
D2	Also known as the correlation dimension, is a measure of the correlation of the pattern. <a href="#">[3,4]</a>
SL	Range of fluctuation in the fractal dimension. It provides information about the complexity of local variations in the image. <a href="#">[5]</a>
CRAE_K	Central Retinal Artery Equivalent (CRAE). Estimation of the caliber of the central retinal arteriole computed using Knudtson formula. <a href="#">[6]</a>
CRAE_H	Central Retinal Artery Equivalent (CRAE). Estimation of the caliber of the central retinal arteriole computed using Hubbard formula. <a href="#">[7]</a>
CRAE_num_vessels	The number of vessels used to apply the CRAE recursive formulas. If this number is less than six then it may suggest that some arteries connected to the disc were not detected or are not visible.

CRVE_K	Central Retinal Vein Equivalent (CRVE). Estimation of the caliber of the central retinal vein computed using Knudtson formula. [6]
CRVE_H	Central Retinal Vein Equivalent (CRVE). Estimation of the caliber of the central retinal vein computed using Hubbard formula. [7]
CRVE_num_vessels	The number of vessels used to apply the CRVE recursive formulas. If this number is less than six then it may suggest that some veins connected to the disc were not detected or are not visible.

Complementary features:

Disc_center_x	X axis coordinate of the optic disc center.
Disc_center_y	Y axis coordinate of the optic disc center.
Disc_radius	Radius of the smallest circle that encapsulates the optic disc.
ROI_size (-1 = No ROI)	Pixel size of the region of interest (ROI). If the user decides to use an ROI it will be fixed to a 500 pixels width circle around the optic disc. If no custom ROI is selected then the whole image is processed and ROI_size=-1

References:

- [1] Martínez-Pérez ME, Hughes AD, Stanton AV, et al. Geometrical and Morphological Analysis of Vascular Branches from Fundus Retinal Images. In: Delp SL, DiGoia AM, Jaramaz B, eds. Medical Image Computing and Computer-Assisted Intervention – MICCAI 2000. Springer; 2000:756-765.
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- [3] Stosic T, Stosic BD. Multifractal analysis of human retinal vessels. IEEE Trans Med Imaging. 2006;25(8):1101-1107.
- [4] Chhabra A, Jensen RV. Direct determination of the  $f(\alpha)$  singularity spectrum. Phys Rev Lett. 1989;62(12):1327.
- [5] Macek WM, Wawrzaszek A. Evolution of asymmetric multifractal scaling of solar wind turbulence in the outer heliosphere. J Geophys Res Space Physics. 2009;114(A3).
- [6] Hubbard LD, Brothers RJ, King WN, et al. Methods for evaluation of retinal microvascular abnormalities associated with hypertension/sclerosis in the atherosclerosis risk in communities study. Ophthalmology. 1999;106(12):2269-2280.
- [7] Knudtson MD, Lee KE, Hubbard LD, Wong TY, Klein R, Klein BE. Revised formulas for summarizing retinal vessel diameters. Curr Eye Res. 2003;27(3):143-149