Automatic Generation of Synthetic Retinal Fundus Images: Vascular Network

Retinal Image Analysis (RIA) aims to develop computational and mathematical techniques for helping clinicians with the determination of retinal biomarkers that signal risk (e.g., CVD, neurodegenerative, diabetes). Validating RIA algorithms requires ground truth in the form of significant volumes of images annotated by medical experts. Obtaining such annotations is expensive, laborious, and not always feasible. This motivates the creation of a realistic synthetic dataset with known characteristics. This work is part of an ongoing project aimed to generating synthetic fundus images. Here we focus on the retinal vasculature (arteries and veins) and their integration with synthetic non-vessel regions (i.e., retinal background, fovea, and optic disc) to yield full fundus camera images.

1. Vascular Morphology
An example-based method, the Active Shape Model, is used to synthesize realistic vessel paths. Vessel shape annotations were collected from 50 retinal fundus images of the GoDARTS bosoresource. Vessel shapes are aligned into a common coordinate system using a rigid transformation. We generate each new synthetic vessel using PCA.

Spatial density distribution map of all bifurcation points annotated on real images.

Probability score for each point of the vessel to become a bifurcation point.

Example of synthetic vascular tree

2. Vascular Texture
An approach based on Kalman Filtering combined with an extension of the Multiresolution Hermite vascular cross-section model has been developed capturing the transition of intensities between vessels and background.

Data collection
Cross-sections spaced by 5px along the vessel centreline. Intensity RGB profile extraction
Green channel fitted with a weighted Nonlinear Least Squares model using a 6-parameters Extended Multiresolution Hermite Model (EMHM).

Generation of Vessel Textures
16 EMHM parameters
5x2 background texture descriptors
For a total of 975 artery and 1593 vein profiles collected from 15 healthy subjects of HRF database.

Results
The proposed method is able to generate realistic synthetic vascular networks (up to third-generation vessels). Morphological properties guarantee the correct flow of the blood and the oxygenation of the retinal surface observed by fundus cameras. The realism of our synthetic retinal images has currently been demonstrated by qualitative assessment and an initial quantitative analysis.

Conclusions
The proposed approach consists of a learning phase and a generation phase. In the former phase, data describing vascular morphology and texture are collected from annotations of real images. Models are specified and their parameters learned from the training data. In the latter phase, the models obtained are used to create synthetic vascular networks. Arteries and veins are created separately with the same protocol, and then combined together.

Methods
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Example of synthetic vascular tree

Synthetic vessels are then connected to create the vascular network skeleton.

See reference for more information.

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References