A COMPUTERIZED SYSTEM FOR DIAGNOSTIC PARAMETERS ESTIMATION IN RETINAL IMAGES

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Abstract

The capillary network in the retina can be readily imaged using a normal fundus camera, therefore its analysis may provide an early warning about serious cardiovascular diseases. An important sign is the **generalized arteriolar narrowing**, usually expressed by the **Arteriolar-to-Venular diameter Ratio (AVR)**.

The current procedure requires **long** and **cumbersome manual measurements**. I developped an objective, fast and user-friendly **computerized system** to quantitatively assess these **vascular parameters** in retinal images

Purpose

- An important sign of retinopathy is the **generalized arteriolar narrowing**, usually expressed by the Central Retinal Arteriolar Equivalent (CRAE), the Central Retinal Venular Equivalent (CRVE) and the **Arteriolar-to-Venular diameter Ratio (AVR=CRAE/CRVE)**.
- The current procedure requires **long** and **cumbersome manual measurements** (about 15 minutes per image using the IVAN system).
- I developped a **computerized system** to quantitatively assess the **vascular parameters** in retinal images in an objective, fast and user-friendly way.

Methods

- The first, totally **automated phase** performs image luminosity equalization and contrast enhancement, tracing of the vascular network with vessel caliber estimation, vessel map identification, vessel classification as either arteries or veins.
- In the second, **computer-aided phase**, users evaluate the results provided and confirm them or apply the needed corrections via a user-friendly editing interface. The vascular parameters are eventually computed.

1) Image enhancement:
provides contrast and luminance uniformity both intra- and inter-image [1].

2) Vessel axis detection:
starting from a set of seed points, optimal cost paths are extracted to connect them [2].

3) Vessel caliber estimation:
diameters are extracted by a fast 1-dimensional matched filter technique [3]

4) Vessel map identification:
- segments belonging to the same vessel are linked using caliber, color, direction and closeness informations
- biforcations (yellow circles in figure) and crossing points (red circles in figure) are detected

AUTOMATED | **COMPUTER-AIDED**

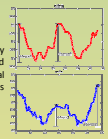
Vessel tracing → Optic Disc **placement** → Vessel tracking **editing** → New vessel **adding** → Artery/Vein Classification → Classification **correction** → • CRAE • CRVE • AVR computing

Probabilistic multiclassification

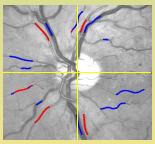
A double probability to be vein is assigned to each vessel:

Red values of central axis samples
(mean and variance- grater in arteries- in a sample neighbourhood)

Central axis reflex
(mean value along a vessel of central peak in red channel trasversal profile - grater in arteries)



- unsupervisioned classification
- fuzzy-C-mean
- image subdivsion into four quadrants



A sigmoidal probality function is calculated for each different image: a vessel with a probability greater than 0.5 is considered as a vein

Vein probability for each vessel:

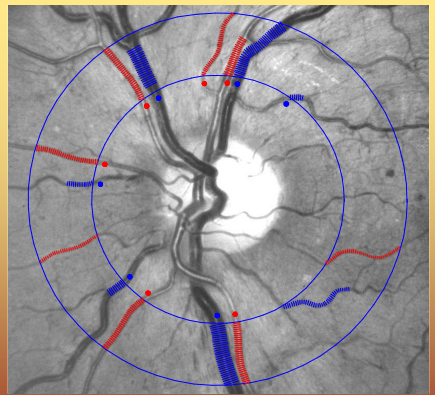
$$p_v = \frac{n_v}{n_v + n_a}$$

nv= pixels classified as vein
na= pixels classified as artery

True veins are in blue, true arteries in red, a classification error is present for vessel nr.40

Mean probability between the two methods is calculated, then adjusted to satisfy these constraints:

1) at least six arteries and six veins are present
2) at crossings, vessels belong to different classes



Only diameters of the 6 major arteries and the 6 major veins (vessels with red/blue dots) are used.
Parameters are calculated using the Knudtson formulas.

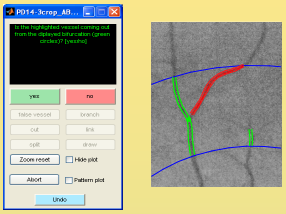
CRAE	149.10
CRVE	304.94
AVR	0.49

Graphical User Interface

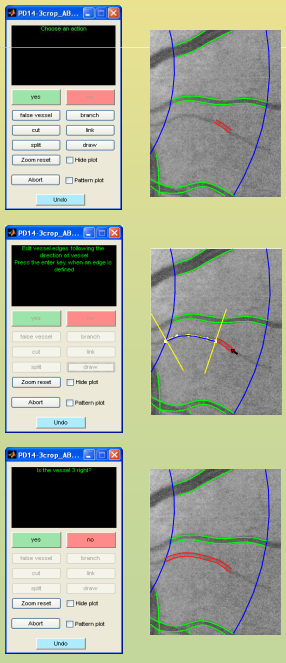
The computer-aided procedure **guides** users in problematic situations and **suggests** the more principled operations to be accomplished (1).

Users have **complete freedom** to edit on their own every critical situation (2).

1) Bifurcation
(AVR formulas by Knutdson consider only trunks diameters)



2) Tracking editing
(e.g. in the case of under-segmentation)



Results

- **Repeatability** of the complete system was assessed by having three trained users independently analyze **20 DCCT** and **18 ETDRS** images.
- The average time required to analyze one image is 4 min (range 2-6 min).

CRAE

	User A	User B	User C
User A	-	0.96	0.92
User B	0.96	-	0.96
User C	0.92	0.96	-

CRVE

	User A	User B	User C
User A	-	0.97	0.98
User B	0.97	-	0.96
User C	0.98	0.96	-

AVR

	User A	User B	User C
User A	-	0.97	0.97
User B	0.97	-	0.98
User C	0.97	0.98	-

Inter-user correlation on DCCT images

CRAE

	User A	User B	User C
User A	-	0.97	0.94
User B	0.97	-	0.94
User C	0.94	0.94	-

CRVE

	User A	User B	User C
User A	-	0.98	0.99
User B	0.98	-	0.98
User C	0.99	0.98	-

AVR

	User A	User B	User C
User A	-	0.98	0.97
User B	0.98	-	0.97
User C	0.97	0.97	-

Inter-user correlation on ETDRS images

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Discussion

- Vascular parameters estimated by the proposed system were compared with those obtained on the same images by using the IVAN system (University of Wisconsin).
- **Very good correlation** between the two systems:

CRAE

	User A	User B	User C
DCCT	0.85	0.84	0.91
ETDRS	0.90	0.91	0.94

CRVE

User A	User B	User C
0.99	0.97	0.98
0.99	0.98	0.98

AVR

User A	User B	User C
0.92	0.91	0.92
0.96	0.94	0.97

Correlations with IVAN on DCCT and ETDRS datasets

- The implementation of the system as **web-based service** is under development.

References:

[1] M. Foracchia, E. Grisan and A. Ruggeri, "Luminosity and contrast normalization in retinal images," Med Image Anal, vol. 9, pp. 179-90, 2005.

[2] E. Poletti, D. Fiorin, E. Grisan, A. Ruggeri: 'Retinal Vessel Axis Estimation through a Multi-Directional Graph Search Approach', World Congress 2009 in Medical Physics and Biomedical Engineering, 7-12 September, Munich (DE)

[3] D. Fiorin, E. Poletti,E. Grisan, A. Ruggeri: 'Fast adaptive axis-based segmentation of retinal vessels through matched filters', World Congress 2009 in Medical Physics and Biomedical Engineering, 7-12 September, Munich (DE)