

Abstract

One of the main challenges remains the understanding of the diabetes effect in hemodynamic functionality (blood flow, oxygen perfusion etc.) and vascular geometric adaptation before the first lesions of diabetic retinopathy appear. Crucial and Important part is the study of the progress of diabetes through the screening program. Multiple images of the same patient are useful in order to understand the progress by comparing these images either by taking vascular measurements or/and using registration algorithms.

Methods

Diabetes

Hemodynamic features

- Abnormal myogenic response
- Vessel wall thickness
- Blood volume rate
- Blood flow velocity
- Mean circulation time
- Local oxygen perfusion
- Intravascular pressure
- Concentration of hemo-globin

Correlation



Geometric features

- Length-to-diameter ratio
- Branch angles
- Tortuosity index
- Bifurcation optimality
- Junction exponent
- Arteriolar calibre
- Vessel length
- Vessel width

Study of the vascular changes and the dislocation of the vessels between 2 progressed images.

Database of 40 patients who developed diabetic retinopathy during diabetic state.



Figure 1. Same patient image before and after Diabetic retinopathy.

Things that were investigated:

- Position of the vessels in one year before retinopathy and the first year of development of retinopathy
- Measurement of the bifurcations angles and parents-children vessels' width both in veins and arteries

Methods of measurements

- For the measurement of vessel widths and angles a tool developed by Al-Diri *et al.* was used to label bifurcations and take manual measurements of the retina vasculature [1].
- For the comparison between the two images the homography technique was used to relate the pixel co-ordinates in the two images and align them to the same coordinate system.
- Any two images of the same planar surface in space are related by a homography. In mathematical terms homogeneous coordinates are used to represent projective transformations by means of matrix multiplications. With Cartesian coordinates a perspective projection is a non-linear transformation [2].

$$P_a = \begin{bmatrix} xa \\ ya \\ 1 \end{bmatrix}, P_b = \begin{bmatrix} w'xb \\ w'yb \\ w' \end{bmatrix}, H_{ab} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \text{ then } P_b = H_{ab}P_a. \text{ where } H_{ba} = H_{ab}^{-1}. \text{ Also } P_b = P_b' / w' = \begin{bmatrix} xb \\ yb \\ 1 \end{bmatrix}$$

- Optical flow technique [3] for estimating the optical flow field using the classical optical flow objective function in its spatially discrete form as:

$$E(\mathbf{u}, \mathbf{v}) = \sum_{i,j} \{ \rho_D(I_1(i,j) - I_2(i + u_{i,j}, j + v_{i,j})) + \lambda [\rho_S(u_{i,j} - u_{i+1,j}) + \rho_S(u_{i,j} - u_{i,j+1}) + \rho_S(v_{i,j} - v_{i+1,j}) + \rho_S(v_{i,j} - v_{i,j+1})] \},$$

Results

Indications of changes:

- Dislocation of the vessels in the point that we have the development of the first micro-aneurysms (figure 3).
- Changes in the veins width in diabetic retinopathy state. Dilation of the veins was observed (paired t-test two-tailed: $p = 0.04$)
- Changes in the arteries and branches' angles was observed but without being a significant result maybe due to the small sample used (paired t-test two-tailed: $p = 0.09$).



Figure 2. The two images are aligned and registered in order to detect the changes to the retina vasculature. In the highlighted area we can see two areas where there are differences between the two images. In the first case a large vein is dilated which is a sign of diabetic retinopathy since the body tries to regulate the increased blood flow. In the second case an artery has increased curvature.

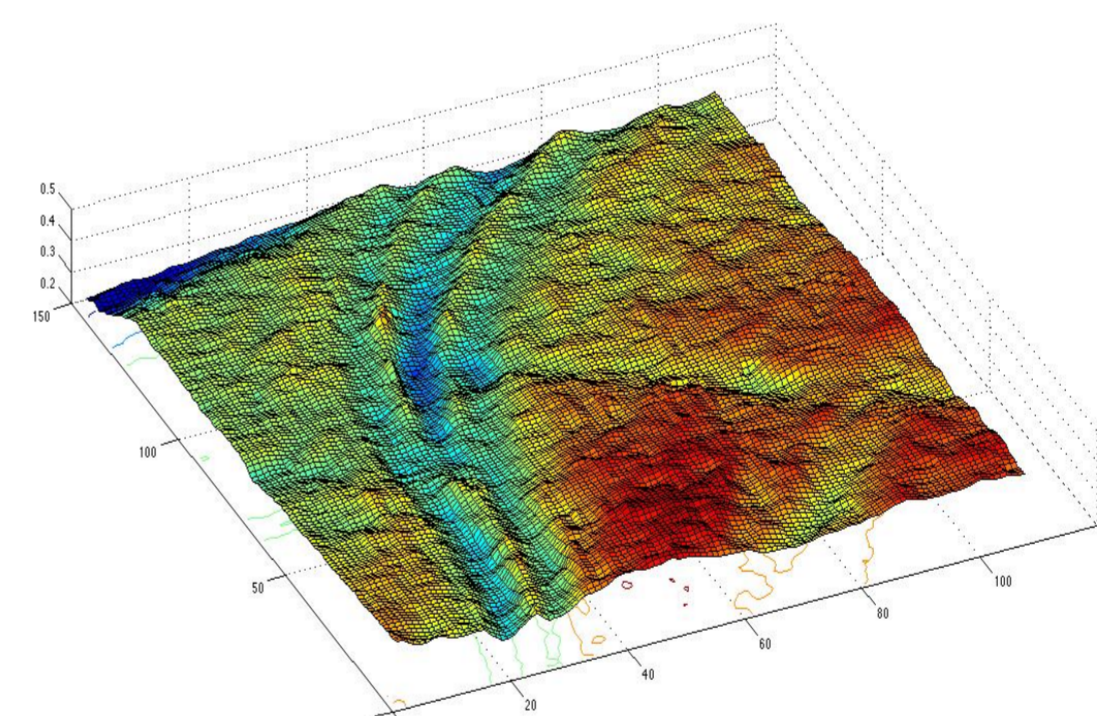


Figure 3. In the left picture we can see the 3-D depiction of the comparison between two vessel segments in two different progress images. In the right picture we can see the optical flow of the comparison between two progress images in order to see the differences through the optical flow.

Conclusion

- Future objective is to correlate the differences in the vasculature with the inherent hemodynamic impairment .
- Robust algorithm for the study and comparison of different images.
- Understanding of the biological and structural changes that precede diabetic retinopathy.
- Concluded in some indications but the sample is not significantly representative, thus it will be extended.

References

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