

Modification of Method for Drusen Detection in Eye Fundus Images

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Introduction

Drusen are white or yellow spots in eye fundus that consist of extracellular material. They are a sign of age-related macular degeneration – the main cause of blindness in the developed countries and a third main cause of blindness in the whole world.

In most cases various digital filters are used to find drusen [1–3], although other methods, including thresholding by Otsu method is also used [4], Markov random fields [3] or cellular neural networks [5] have also been tried. However, none of those methods have achieved highly accurate results. For example, in case of semi-automatic method using thresholding sensitivity between 0.42 and 0.86 and specificity between 0.53 and 0.98 has been reported [4].

While drusen are similar to the spots and blobs in other images, many of blob detection methods are not applicable. For example, the method utilising radial basis function neural networks [6], or the method utilising Ant Colony Optimisation [7] cannot be used without modifications as they require the spots to be close to circular, while the drusen can be elliptical.

Previously a drusen detection method based on optimized colour combinations has been proposed [8], but it has only been investigated empirically. Thus the goal of this work is to investigate such method using one-dimensional and two-dimensional models of drusen, its properties are found and improvements suggested.

Eye fundus images

Twenty eye fundus images used in this study (size – 3072×2048 px) were produced in the screening program organised in Kaunas University of Medicine [8].

An expert ophthalmologist has marked drusen in each of those images. On average, each of the images has about 207 drusen (minimal amount – 50, maximal amount – 477)

that took 0.764 % of the area of the image (minimal amount – 0.038 %, maximal amount 2.695 %).

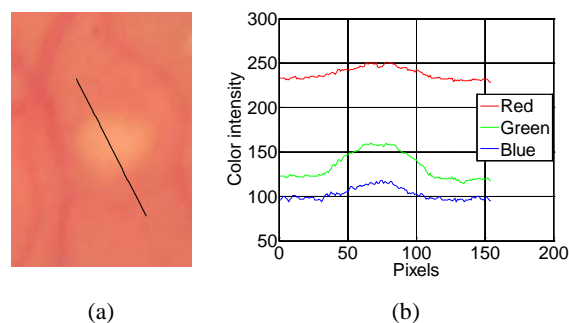


Fig. 1. Image fragment with a druse (a) and its profile along the direction marked as a black line on the image (b)

The shape of a typical profile of a druse (Fig. 1) can be seen to be similar to a hill. In the method used the image is inverted so that the profile of a druse would have the shape of a pit instead of a hill, thus this is the shape to be modelled.

Druse models

Several different one-dimensional models were used. The first model was a function

$$f(x) = |x|, \quad (1)$$

where x – the coordinate of the pixel. The second and third one-dimensional models were a piecewise polynomial function and a cubic spline.

Two-dimensional models were produced from the one-dimensional models by rotation around the start of the coordinates (here f and g are functions describing 1D and 2D models, x and y are coordinates):

$$g(x, y) = f\left(\sqrt{x^2 + y^2}\right). \quad (2)$$

In each case white Gaussian noise was introduced into the image to simulate the unevenness of actual drusen profile. Then the resulting image was quantised.

Drusen detection algorithm

The proposed method (“Fountain algorithm”) utilises optimised colour combinations, found using the method, analogous to the one described in [9]. The simplified flowchart of this algorithm is shown in Fig. 2 and Fig. 3.

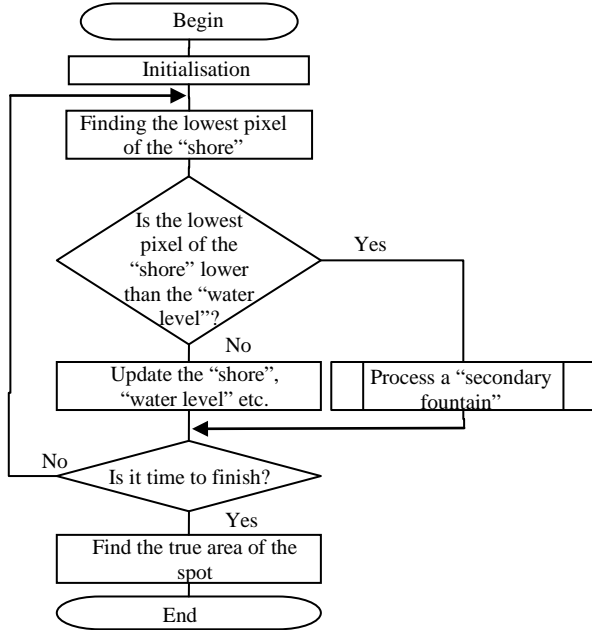


Fig. 2. Simplified flowchart of the “Fountain algorithm”

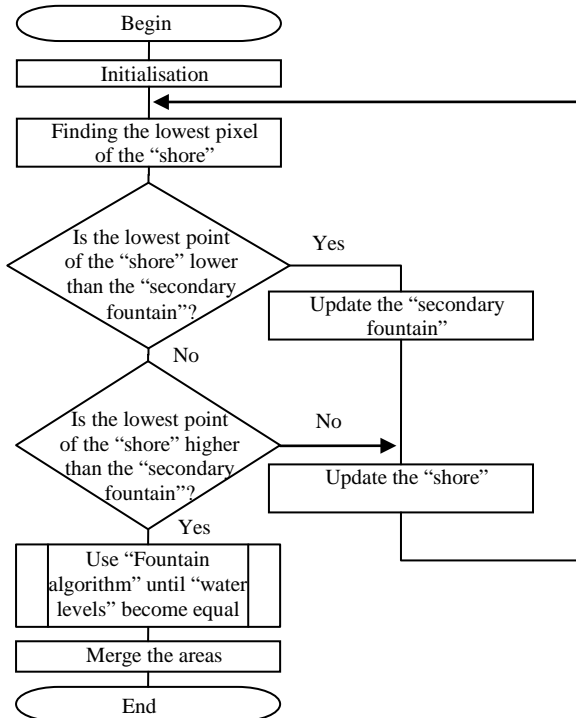


Fig. 3. Simplified flowchart of the “Fountain algorithm”: processing of “secondary fountain”

The result of this algorithm is a series of masks, corresponding to different “water levels”. Thus it is necessary to find the mask that corresponds to the true area of the druse. Model-based analysis was used to find the way to find such an area.

The results achieved by this method have been compared with results achieved by other drusen detection methods [4] and with watershed transform based method with and without markers.

The performance of those methods was estimated by sensitivity (proportion of correctly identified drusen pixels), specificity (proportion of correctly identified non-drusen pixels) and Matthews correlation coefficient (considered useful when classes are of very different sizes). The centres of the drusen marked by an expert were used as starting points in each case.

Results

The first one-dimensional model was investigated analytically. As 1D model is equivalent to 2D model with one of dimensions being equal to 1, “flooded area” (S) can be expressed in terms of “water level” (h):

$$S = 2h \cdot 1 = 2h. \quad (3)$$

Similarly, “water volume” (V) can also be expressed in terms of h :

$$V = 2 \cdot \frac{h \cdot h}{2} \cdot 1 = h^2. \quad (4)$$

By taking into account (3) and (4), S is related with V :

$$S = 2\sqrt{V}. \quad (5)$$

The relationships stay similar in case of the piecewise-linear one dimensional model (Fig. 4). It can be seen that the level when “water” reaches “the top of the pit” is indicated by a fast increase of “flooded area” (S) for a small increase of “water level” (h) or “volume” (V).

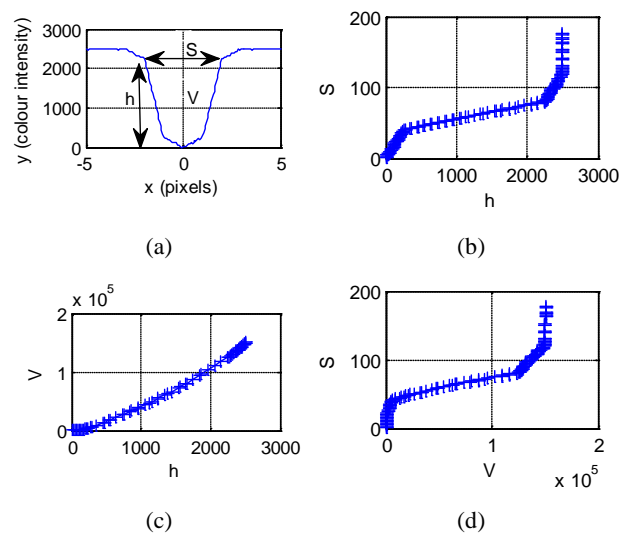


Fig. 4. Analysis of piecewise-linear 1D inverted druse profile model: 2D representation (a), the relationship $S(h)$ (b), the relationship $V(h)$ (c) and the relationship $S(V)$ (d)

The same increase of S indicates “the top of the pit” in case of spline-based one-dimensional model (Fig. 5).

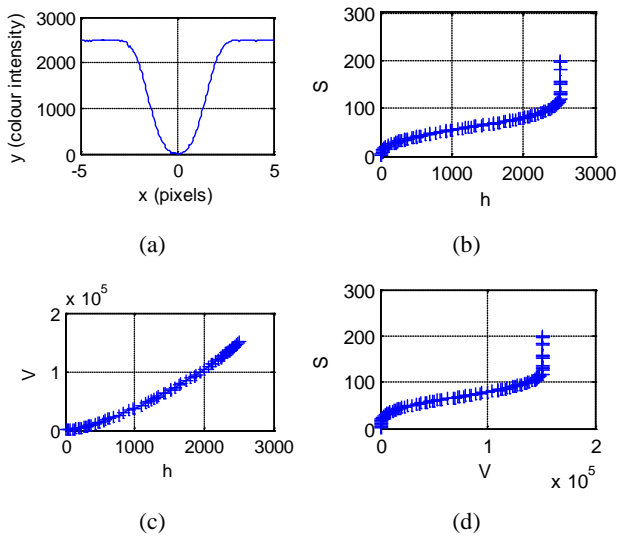


Fig. 5. Analysis of spline-based 1D inverted druse profile model: 2D representation (a), the relationship $S(h)$ (b), the relationship $V(h)$ (c) and the relationship $S(V)$ (d)

Both relations ($S(V)$ and $S(h)$) can also be seen to indicate the limits of the druse in two-dimensional case (Fig. 6).

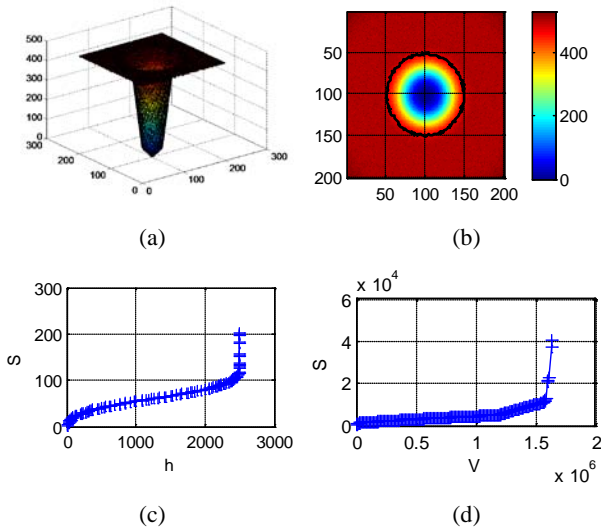


Fig. 6. Analysis of piecewise-linear 2D inverted druse image model: 3D representation (a), 2D representation with a marked limits found by the described algorithm (b), the relationship $S(h)$ (c) and the relationship $S(V)$ (d)

However, in case of spline-based two-dimensional model (Fig. 7), the relationship $S(V)$ seems to be more suitable for detection of the limits of the druse than $S(h)$, because the range of values of V on the right side of the feature to be detected is relatively higher than the range of the values of h .

Given that the curve $S = S(V)$ is “S” shaped, its second derivative tends to be positive until the edge of the druse is reached and negative afterwards.

Thus the edge of a druse can be found by applying the pattern matching filter with coefficients (1 1 -1 -1) to

the second derivative of the function $S = S(V)$. Then the correct edge should correspond to the maximum of the filter response. However, such estimation is highly sensitive to noise. Thus the fact that drusen tend to be elliptical is exploited: the area detected (D) is approximated by an ellipse (E) and a condition is checked:

$$\frac{|D \cup E| - \min(8, 2 \cdot r_a + 2 \cdot r_b)}{|D \cap E|} \leq 1.15, \quad (6)$$

where r_a and r_b are the semiaxes of the ellipse.

If it is fulfilled, the estimated edge is accepted, otherwise the former maximum is suppressed and a new maximum is found.

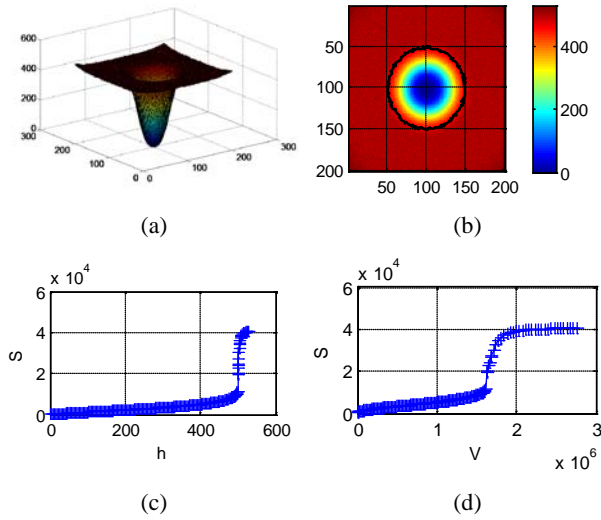


Fig. 7. Analysis of spline-based 2D inverted druse image model: 3D representation (a), 2D representation with a marked limits found by the described algorithm (b), the relationship $S(h)$ (c) and the relationship $S(V)$ (d)

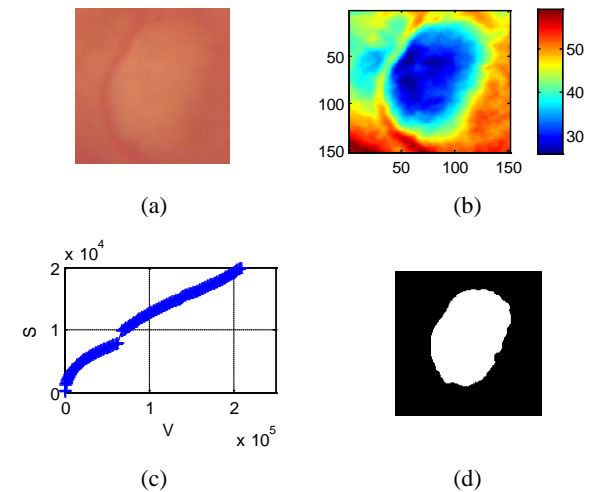


Fig. 8. Image fragment with a druse (a), the preprocessed image (b), function $S=S(V)$ (c), the binary mask showing the druse as detected by the proposed algorithm (d)

Fig. 8 shows a sample druse being detected using the proposed method.

Table 1 compares average sensitivity, specificity and Matthews correlation coefficient (MCC) for the proposed

method and two variants of watershed transform.

Table 1. Average performance indexes for different drusen detection methods

Method	Sensitivity	Specificity	MCC
“Fountain algorithm”	0.3498	0.9972	0.3979
Watershed transform without markers	0.2388	0.9996	0.3863
Watershed transform with markers	0.5668	0.9928	0.4035

It has been found that the difference of means of MCC achieved by proposed method and by two variants of watershed transform is not statistically significant (for all pairs $p > 0.6$ using paired t-test), with different methods achieving best results for different images. The results achieved by proposed method are also arguably better than achieved by method described in [4].

Conclusions

The proposed method shows results similar to the ones achieved by other methods, indicating the need for larger sample and possibility to improve the results by combining the methods. It also seems useful to repeat the investigation using the markings provided by multiple experts to take the inter-expert variability into account.

The discussed methods can be used not only for detection of drusen, but also of other spots in images.

Acknowledgment

The work was partially supported by EU project SM-BIO-POWER (grant agreement FP-201119) and project E!4297 NICDIT under EUROSTARS programme.

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Received 2010 02 15

M. Patašius, V. Marozas, D. Jegelevičius, A. Lukoševičius, M. Špečkauskas. Modification of Method for Drusen Detection in Eye Fundus Images // *Electronics and Electrical Engineering*. – Kaunas: Technologija, 2010. – No. 5(101). – P. 115–118.

Drusen are white or yellow spots in eye fundus that consist of extracellular material. They are a sign of age-related macular degeneration (AMD) – the main cause of blindness in the developed countries and a third main cause of blindness in the whole world. Previously a drusen detection method based on optimized colour combinations has been proposed, but it has only been investigated empirically. Thus here this method is investigated using one-dimensional and two-dimensional models of drusen, its properties are found and improvements suggested. III. 8, bibl. 9, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

М. Паташюс, В. Марозас, Д. Егелявичюс, А. Лукошявичус, В. Шпечкаускас. Модификация метода детекции друз в изображениях очного дна // *Электроника и электротехника*. – Каунас: Технология, 2010. – № 5(101). – С. 115–118.

Друзы – это белые и жёлтые пятна на очном дне. Они являются симптомом возрастной макулопатии – главной причиной слепоты в развитых странах и третьей во всём мире. Ранее предложенный метод детекции друз был исследован только эмпирически. Здесь этот метод исследуется при помощи одномерных и двумерных моделей друз с целью найти его свойства и предложить усовершенствование. III. 8, библи. 9, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

M. Patašius, V. Marozas, D. Jegelevičius, A. Lukoševičius, M. Špečkauskas. Metodo drūzoms aptikti akies dugno vaizduose modifikavimas // *Elektronika ir elektrotechnika*. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 115–118.

Drūzos – tai baltos ar geltonos dėmės akies dugne, susidedančios iš tarpląstelinės medžiagos. Jos yra vienas iš amžinės makulos degeneracijos (AMD) simptomų. AMD yra dažniausia akluomo priežastis išsivysčiusiose šalyse ir trečia pagal dažnumą pasauliniu mastu. Anksčiau pasiūlytas drūzų paieškos metodas rėmėsi optimizuotomis spalvų kombinacijomis. Tačiau tada jis buvo tiriamas tik empiriškai. Šiame straipsnyje minėtas metodas iširtas naudojant vienmačius ir dvimačius drūzų modelius, nustatytos metodo savybės ir pasiūlyta patobulinimų. II. 8, bibl. 9, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).