Eye Redness Image Processing Techniques

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Abstract. The use of photographs for the assessment of ocular conditions has been suggested to further standardize clinical procedures. The selection of the photographs to be used as scale reference images was subjective. Numerous methods have been proposed to assign eye redness scores by computational methods. Image analysis techniques have been investigated over the last 20 years in an attempt to forgo subjective grading scales. Image segmentation is one of the most important and challenging problems in image processing. This paper briefly outlines the comprehensive of image processing and the implementation of image segmentation in eye redness.

1. Introduction
Eye redness is a common sign of ocular disease which cause an excess of blood in the vessels in conjunctivae and sclera. The interpretation of eye redness is vary such as allergic conjunctivitis, morning eye congestion, dry eye, contact lenses complication, ocular drug-induced allergic reaction, marginal infiltrates of the cornea, bacterial conjunctivitis, severe ocular infection and iritis [1]. The increased diameter of blood vessels which is called as vasodilation are the factor that can cause an excess of blood vessels on the ocular surface. The important features that help the ophthalmologist to diagnose the eye redness are through the location of the vasodilation, the hue (depth of colour) and the intensity of the redness [1,2]. It is valuable in two areas to clinician to diagnose ocular surface characteristics earlier: firstly, it may provide additional diagnostic clues and second, refining the development of validated scales [1].

Image segmentation is one of the basic problems in image analysis. The task of image segmentation is to partition an image into a number of non-overlapping regions with homogeneous characteristics. A process of splitting the image into pixel bands is the image segmentation. As medical imaging contains uncertainties, there are difficulties in classification of images into homogeneous regions [3]. There is a need for segmentation algorithm for removing the noise from the medical image segmentation. Image segmentation is an important and challenging problem and a necessary first-step in image analysis as well as in high-level image interpretation and understanding such as robot vision, object recognition,
and medical imaging. The main aim of the image segmentation is to segment the image into disjoint regions set with uniform and homogenous attributes such as tone, colour, texture, or intensity, etc. Still in many real situations for image segmentation issues such as poor contrast, noise and intensity in-homogeneities variation, limited spatial resolution, overlapping intensities make this segmentation as a difficult task [4].

This paper focuses on overview of image processing and its relation in segmenting eye redness. Previous studies show that image processing has been investigated in an attempt to forgo subjective grading scales. This paper outlines an understanding of how image processing operates to segmenting the eye redness. Since there are very limited numbers of studies on the image processing in eye redness, it can be considered as the contribution of this paper. The objective of this paper is to study the relation of image segmentation as the image analysis.

The remaining sections of this paper are organized as follows: In Section 2, briefly discussed about clinical judgement of eye redness. In Section 3, Digital image processing are described in details. Section 4, shows the image segmentation in eye redness has been applied. Application of image processing in ocular research is mentioned in Section 5. To conclude this paper, the conclusion is presented in Section 6.

2. Clinical Judgement of Eye Redness
The assessment of the ocular surface redness is a routine procedure in clinical practice. The most commonly used method is subjective observation and description [5]. Clinical grading may be judged using at least two general strategies. The first is primarily luminance–chromaticity based. Judgments are made on the basis of the overall redness and brightness (luminance) of the eye. As the redness increases, so the luminance decreases. A second strategy is made on the basis of the appearance of the visible vessels. This could include judgments of the diameter of vessels, vessel tortuosity, and the proportion or number of vessels occupying the area to be graded. The difference between these methods is really one of scale: Luminance judgments would correlate with vessel appearance if the capillary beds giving rise to the conjunctival flush were resolved. Similarly, with a sufficiently low resolution, smaller vessels would not be resolved and would “blend” into the background redness. For any typical clinical observation, however, each type of judgment is possible and could vary (to a large extent) independently of the other. The automated and objective approach proposed is based on the same two criteria: Two features are extracted from each image, one based on redness and the other based on the appearance of blood vessels [6].

The clinical judgment of ocular redness is complex and poorly understood. Typically, the appearance of the eye is judged based on a scale, and the examination of these scales provides a lesson in contemporary views of measurement. Theoretical examination aside, the scales themselves are typically poorly described with few exceptions have been untested. Lack of understanding of the scales themselves, there is no empirical information about how clinicians make judgments of redness [7]. Thus, highly reproducible and fully automated methods of analysis would clearly be of great benefit to many medical staff and patients.

Clinical evaluation of conjunctival hyperemia is subjective, and relies on grading scales such as the McMonnies/Chapman-Davies scale [8], the Institute for Eye Research scale, the Efron scale [9], and a validated bulbar redness scale [10]. The grades generally range from zero to four or five. The scoring scales in these systems increment in single units. A clinician grading an eye with bulbar hyperemia halfway between grade 0 and grade 1 on the Efron scale will give a grade of 0.5. Thus, a weakness of this method is that it cannot provide a continuous linear quantitative evaluation.

In the past 10 years, numerous methods have been proposed to assign redness scores by computational methods. The question then might be, how does the procedure developed here advance these methods? There are a number of reasons why this experiment describes methods and results that actually make it feasible to use this technique as a replacement for grading the redness of images. First, the technology is readily available and expensive. Whereas some previous studies have used
rather exotic hardware and software combinations, the algorithms are available to anyone using a computer running almost every operating system that may be encountered. Second, a minimum amount of operator intervention is required. This removes some of the subjectivity in some previous techniques and further lends itself to automation. And finally, it has shown that both accuracy and much less variability are present in the automated technique than in the subjective technique [11,12]. These factors, provide a strong rationale for the adoption of emerging image processing technique to replace clinical grading of bulbar redness. Because anterior segment assessment is much more than just redness evaluation, how to implement this technique more generally to replace in vivo grading is yet to be determined [13,14].

There is an advanced technology called the OCULUS Keratograph® 5M. It helps Ophthalmologist and Optometrists in accurately diagnosing eye redness and documenting the findings. The Keratograph® 5M can classify the eye and limbal redness using the R-Scan. The R-Scan detects vessels in the conjunctiva and evaluates the degree of redness. This eliminates the need for time-consuming comparisons and provides greater reliability during evaluation. Figure 1 shows the OCULUS Keratograph® 5M machine.

![OCULUS Keratograph® 5M](image)

Figure 1. OCULUS Keratograph® 5M

R-scan software is automatic prediction of the eye redness. Conjunctival redness used to be an assessed subjectively and depended on the examiner. The R-Scan is the first module that automatically and objectively documents and classifies the eye and limbal degree of redness. The R-Scan detects the blood vessels in the conjunctiva and evaluates the degree of redness. This automatic assessment reduces time consuming and expertise of having to make manual comparisons using classification sheets.

3. Digital Image Processing

Digital image processing and image analysis have been used to derive physical attributes that describe bulbar redness chromatically and spatially. The Fundamental step in Digital Image processing is shown in Figure 2. The goal of image processing is to transform or enhance an image by Owen et al [15]:-
Figure 2. Fundamental step in Digital Image Processing

i) **Image acquisition**
   - Acquire a digital image.

ii) **Image pre-processing**
   - To improve the low image quality due to low dose usage [23]. Image enhancement techniques give a better result of the original image which is often presented as dark, low in contrast and noisy [24].

iii) **Image segmentation**
    - To partition an input image into its constituent objects.

iv) **Representation and description (Feature selection and Feature extractions)**
    - Representation: To convert the input data to a form suitable for computer processing.
    - Description: To extract features that result in some qualitative information of features that are basic for differentiating one class of objects from another.

v) **Recognition and interpretation**
    - Recognition: To assign a label to an object based on the information provided by its descriptors.
    - Interpretation: To assign meaning to an ensemble of recognized objects.

4. **Image Segmentation**
   Image segmentation is performed by a set of techniques and its aim is to divide the image into a shape that is more conducive for analysis. Any technique should preserve the essential properties of the images; otherwise, there could be serious errors of analysis [13]. Image analysis techniques have been investigated over the last 20 years in an attempt to forgo subjective grading scales. Thresholding, edge detection, smoothing, color extraction, morphometry, and densiometry have all been used to measure eye redness [5]. We highlighted the two most important of image segmentation used in segmenting eye redness.
i) Threshold
Thresholding is the easiest way of segmentation. Segmentation through thresholding has fewer computations compared to other techniques [8]. **Threshold segmentation** techniques grouped in classes [4]:

- **Local** techniques are based on the local properties of the pixels and their neighbourhoods.
- **Global** techniques segment an image on the basis of information obtain globally (e.g. by using image histogram; global texture properties).
- **Split, merge and growing** techniques use both the notions of homogeneity and geometrical proximity in order to obtain good segmentation results [8].

ii) Edge based
In this edge based segmentation, there is no need for the detected edges to be closed. Edges are detected to identify the discontinuities in the image. Edges on the region are traced by identifying the pixel value and it is compared with the neighbouring pixels. There are various edge detectors that are used to segment the image such as canny detection, roberts detection, prewitt detection, and sobel detection.

Edge detection contains Filtering, Enhancement and Detection [26]:
- **Filtering** is used to eliminate the images that often corrupted by unnecessary information which is called as noise.
- **Enhancement** it is essential to determine changes in intensities in the neighbourhood pixel.
- **Detection** determines which points of pixel are edge points because it may vary each particular point in each image.

5. Application in Ocular Research
Image processing and analysis have been used for the objective quantification of redness. In general, these studies analyzed sample images using image processing techniques, and compared the physical attributes to subjective estimates using grading. The image processing operations that were commonly applied to enhance the photographs of eye redness aimed at the removal of noise from the images and at separating the vessels from the background so that spatial attributes of the vessels could be quantified [16,17]. In general, noise reduction was achieved by filtering operations that are typically applied locally. The advantage of using localized filtering operations is that small capillaries, which may have very similar grey level intensities as the scleral background, are not removed from the image [18,19] investigated whether subjective grading estimates obtained using the Efron and IER grading scales could be predicted by image analysis techniques (edge detection and relative colour extraction). In agreement with [21] they found that a combination of morphometric and colour-based information was best suitable to predict subjective redness estimates.

Wang [20] identified surrounding ocular surface vessels in four zones around the cornea and directly calculate the vessel parameters to assess the degree of hyperaemia. They found a new method that directly calculated the parameters of ocular surface vessels around the limbus to assess the degree of regional bulbar redness. It offers advantages for objective observation of ocular surface redness, especially for the follow-up of disease treatment in individual patients.

Sanchez [14] proposed an automatic methodology to measure the redness level of the conjunctiva. The methodology proposed gave a good agreement for the transformation from the extracted features to grading scales, using artificial neural networks.

Park [22] established a new clinical grading scale and objective measurement for eye redness. The image segmentation which is using k-means and contrast-limited adaptive histogram equalization [CLAHE] algorithm showed the best correlation and reproducibility with subjective grading scale.
Downie [25] compared whether quantification of ocular eye redness using image processing of relative Red-channel (Red-value) can be applied to subjective grading scale and automated eye redness grading technique (Oculus Keratograph 5M, R-Scan). It revealed that Red-value calculations can be implemented to produce reliable estimates of ocular redness.

6. Conclusion
In this study, the image is segmented using a series of decision and there is no universal segmentation method for eye redness images and also an image can be segmented by using different segmentation methods. Objective image analysis of the anterior eye is applicable as being substantially more sensitive and reliable than subjective grading. It may therefore offer a new gold standard in the anterior ocular examination and could be developed further as a tool for use in research, to allow more highly powered analysis without bias, and in clinical practice to enhance the monitoring of anterior eye disease.

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References
[1] Prabu C, Bavithiraja S V M G and Narayanamoorthy S 2016 A novel brain image segmentation using intuitionistic fuzzy C means algorithm. *International Journal of Imaging Systems and Technology*, 26(1), 24-28.
[2] Wang X Y, Wu Z F, Chen L, Zheng H L and Yang H Y 2016 Pixel classification based color image segmentation using quaternion exponent moments. *Neural Networks*, 74, 1-13.
[3] Abelson M B, Lane K and Maffei C 2010 Code red: The key features of hyperemia. *Rev Ophthalmol*, 17(4), 92-94.
[4] Zaitoun N M and Aqel M J 2015 Survey on image segmentation techniques. *Procedia Computer Science*, 65, 797-806.
[5] Rodriguez J D, Johnston P R, Ousler III G W, Smith L M and Abelson M B 2013 Automated grading system for evaluation of ocular redness associated with dry eye. *Clinical Ophthalmology*, 7, 1197-1204.
[6] Sağ T and Çunkaş M 2015 Color image segmentation based on multiobjective artificial bee colony optimization. *Applied Soft Computing*, 34, 389-401.
[7] Zhao W J, Duan F, Li Z T, Yang H J, Huang Q and Wu K L 2014 Evaluation of regional bulbar redness using an image-based objective method. *International journal of ophthalmology*, 7(1), 71-76.
[8] Mcmonnies C W and Chapman-davies A 1987 Assessment of conjunctival hyperemia in contact lens wearers. Part II. *Optometry and Vision Science*, 64(4), 251-255.
[9] Efron N 1997 Clinical application of grading scales for contact lens complications. *Optician*, 213(5604), 26-34.
[10] Schulze M M, Jones D A and Simpson T L 2007 The development of validated bulbar redness grading scales. *Optometry & Vision Science*, 84(10), 976-983.
[11] Yogamangalam R and Karthikeyan B 2013 Segmentation techniques comparison in image processing. *International Journal of Engineering and Technology (IJET)*, 5(1), 307-313.
[12] Peterson R C and Wolffsohn J S 2007 Sensitivity and reliability of objective image analysis
compared to subjective grading of bulbar hyperaemia. British Journal of Ophthalmology, 91(11), 1464-1466.

[13] Shahverdi R, Tavana M, Ebrahimnejad A, Zahedi K and Omranpour H 2016 An improved method for edge detection and image segmentation using fuzzy cellular automata. Cybernetics and Systems, 47(3), 161-179.

[14] Sánchez L, Barreira N, Pena-Verdeal H and Yebra-Pimentel E 2015 A novel framework for hyperemia grading based on artificial neural networks. In International Work-Conference on Artificial Neural Networks, 263-275.

[15] Owen C G, Ellis T J, Rudnicka A R and Woodward E G 2002 Optimal green (red- free) digital imaging of conjunctival vasculature. Ophthalmic and Physiological Optics, 22(3), 234-243.

[16] Wu S, Hong J, Tian L, Cui X, Sun X and Xu J 2015 Assessment of bulbar redness with a newly developed keratograph. Optometry & Vision Science, 92(8), 892-899.

[17] Derakhshani R, Saripalle S K and Doynov P 2012 Computational methods for objective assessment of conjunctival vascularity. In Engineering in Medicine and Biology Society (EMBC),1490-1493.

[18] Ciesielski K C, Herman G T and Kong T Y 2016 General theory of fuzzy connectedness segmentations. Journal of Mathematical Imaging and Vision, 55(3), 304-342.

[19] Xu Z, Jiang H, Tao A, Wu S, Yan W, Yuan J, Liu C, DeBuc D C and Wang J 2015 Measurement variability of the bulbar conjunctival microvasculature in healthy subjects using functional slit lamp biomicroscopy (FSLB). Microvascular research, 101, 15-19.

[20] Wang X Y, Wu Z F, Chen L, Zheng H L and Yang H Y 2016 Pixel classification based color image segmentation using quaternion exponent moments. Neural Networks, 74, 1-13.

[21] Baudouin C, Barton K, Cucherat M and Traverso C 2015 The measurement of bulbar hyperemia: challenges and pitfalls. European journal of ophthalmology, 25(4), 273-279.

[22] Park I K, Chun Y S, Kim K G, Yang H K and Hwang J M 2013 New Clinical Grading Scales and Objective Measurement for Conjunctival Injection New Clinical Grading Scales. Investigative ophthalmology & visual science, 54(8), 5249-5257.

[23] Ahmad S A, Taib M N, Khalid N E A and Taib H 2012 An analysis of image enhancement techniques for dental X-ray image interpretation. International Journal of Machine Learning and Computing, 2(3), 292-297.

[24] Ahmad S A, Taib M N, Khalid N E A and Taib H 2012 Correlation between Quantitative and Qualitative Analysis on Image Quality of Digital Dental X-ray Images. Journal of Computer Science & Computational Mathematics, 2, 43-51.

[25] Downie L E, Keller P R and Vingrys A J 2016 Assessing ocular bulbar redness: a comparison of methods. Ophthalmic and Physiological Optics, 36(2), 132-139.

[26] Senthilkumaran N and Rajesh R 2009 Edge detection techniques for image segmentation—a survey of soft computing approaches. International journal of recent trends in engineering, 1(2), 250-254.