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Automated clarity assessment of retinal images using regionally based structural and statistical measures

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ABSTRACT

An automated image analysis system for application in mass medical screening must assess the clarity of the images before analysing their content. This is the case in grading for diabetic retinopathy screening where the failure to assess clarity could result in retinal images of people with retinopathy being erroneously classed as normal. This paper compares methods of clarity assessment based on the degradation of visible structures and based on the deviation of image properties outside expected norms caused by clarity loss. Vessel visibility measures and statistical measures were determined at locations in the image which have high saliency and these were used to obtain an image clarity assessment using supervised classification. The usefulness of the measures as indicators of image clarity was assessed. Tests were performed on 987 disc-centred and macula-centred retinal photographs (347 with inadequate clarity) obtained from the English National Screening Programme. Images with inadequate clarity were detected with 92.6% sensitivity at 90% specificity. In a set of 2000 macula-centred images (200 with inadequate clarity) from the Scottish Screening Programme, inadequate clarity was detected with 96.7% sensitivity at 90% specificity. This study has shown that structural and statistical measures are equally useful for retinal image clarity assessment.

1. Introduction

Digital retinal photography is used across the world for the detection of eye disease such as diabetic retinopathy [1,2]. Computer analysis of retinal images is potentially of value in mass disease screening where a large number of images would be handled more economically by computers than by humans [3]. A proportion of retinal images are ungradable [4] due to loss of quality and hence computer analysis must first check that the quality of images is sufficient for a reliable disease assessment. Patients with inadequate quality photographs may be given repeat photography or recalled for a slit-lamp examination.

Adequate retinal image quality, where a strict photographic protocol is adhered to as in disease screening, depends on adequate field definition (field of view) and image clarity [5]. The current paper deals only with image clarity. The terms clarity and quality are often used interchangeably in other work. Retinal image clarity may be reduced by improper focus or by opacities that adversely affect the contrast and signal to noise ratio as shown in Fig. 1.

Image clarity assessment in disease screening must be performed blind, without reference to an ideal image of the same subject. Outside medical imaging, such blind assessments of image clarity (often referred to as image quality) usually assume that the loss of clarity has been due to blurring [6–9]. The premise is that assessments of image clarity can be made at edge features by making a comparison between the actual and ideal sharp appearance of imaged edges. A similar approach using the sharpness of edges is of value in retinal images and has been used, for example, to enable auto-focussing of a retinal camera [10]. Such edges mainly arise from the vasculature. Therefore, we used vessel detection in an earlier study of image clarity assessment for diabetic retinal screening [5]. Specifically, we used the macular region since it is the most clinically useful part of the image and since the narrow vessels there are obscured even by low levels of image degradation. This method achieved a sensitivity of 100% and a specificity of 89.4% for detection of images with inadequate clarity in a technical evaluation [5] and, a sensitivity and a specificity of 98.4% and 89.7% for a consecutive sequence of macula-centred images from a screening programme [11]. A similar method, but using the entire image, achieved a sensitivity and specificity for detection of ungradable images of 84.3% and 95.0%, respectively [12]. The regional vessel density and colour

Abbreviations: CER, clarity evaluation region; ROC, receiver operator characteristics; AUC, area under curve.

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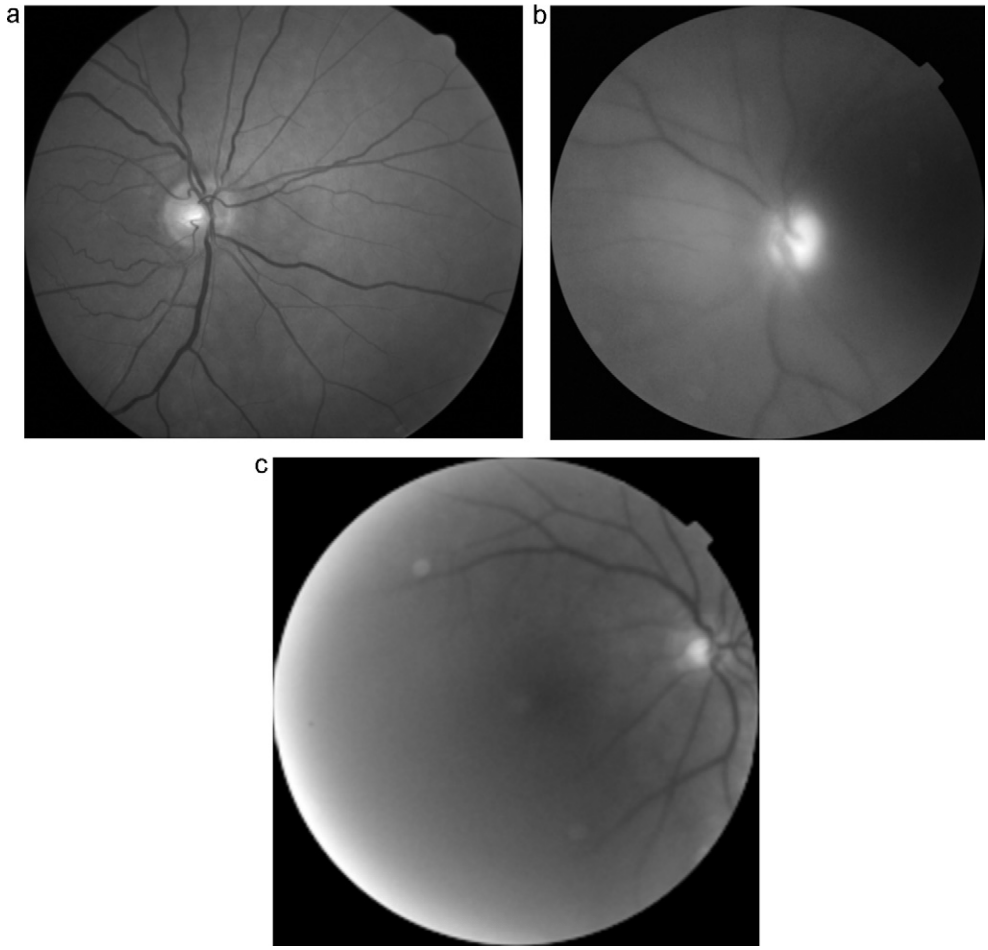

Fig. 1. A good clarity disc-centred retinal image (a). The macula is mainly off the photograph to the left. An inadequate clarity disc-centred image (b). The macula is mainly off photograph to the right. An inadequate clarity macula-centred photograph (c). All cases show the green plane of colour photographs.

histograms have been used as inputs to a classifier to determine image quality [13].

An alternative premise is that blind clarity assessment of images is possible where a constrained environment, imaging protocol and modality produces images with consistent appearance. A reduction in image clarity is then associated with certain textural or statistical properties having values which are outside normal limits. This approach has been used for clarity assessment of medical images, such as three-dimensional MRI brain scans [14], microscopic cytometry images [15], optical coherence tomography images of the back of the eye [16] and retinal photographs [17–22]. In an approach named Image Structure Clustering, textural classes were derived empirically in order to optimise the assessment of retinal image quality (which included clarity and possibly field definition) [24]. One of the optimal textural classes approximates the vasculature, while another corresponds to the optic disc. This technique attained an accuracy of 97.4% with a test set containing equal quantities of normal and low quality images.

This study makes use of both of the above premises. A comparison between structural methods based on the vasculature and statistical methods is made, thus providing previously unavailable information on the relative abilities of these indicators of image quality. It demonstrates a new technique that makes a clarity assessment using only selected portions of the image. The study also explicitly demonstrates that a fast algorithm can perform well regardless of the retinal field of view.

2. Material

2.1. Image sets

Two fully anonymised image sets were used during development and two were used for testing. Approval for use of this data in research was obtained from Scotland's National Caldicott Guardian. The study complied with the principles laid down in the Declaration of Helsinki.

2.1.1. Training

Training set A was used for evaluation of feature distributions. It consisted of 98 colour retinal photographs with 2160 × 1440 pixels obtained using non-mydriatic 45° fixed Canon CR5-45NM cameras (Canon Inc. Medical Equipment Business Group, Kanagawa, Japan) attached to Canon D30 digital colour cameras. A clinician had graded 39 of these images as being of inadequate clarity.

Training set B was used for optimisation of the method. The images were red-free (greyscale), 50° fundus images with 1024 × 1024 pixels obtained with a Topcon TRC-50XT fundus camera (Topcon UK, Newbury, Berkshire, UK). They were classified as having adequate or inadequate clarity for disease grading by an ophthalmologist. This set contained 552 images of which 281 were macula-centred and 271 showed retina mainly on the nasal side of the optic disc. There were 92 inadequate clarity images of which 49 were macula-centred and 43 were nasal views.