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FACULTY OF ENGINEERING

Electronics and Electrical Communications Engineering

Retinal Image Analysis using Image Processing Techniques

A Thesis submitted in partial fulfillment of the requirements of the
degree of

Doctor of Philosophy in Electrical Engineering
(Electronics and Electrical Communications Engineering)

By

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Statement

This thesis is submitted in partial fulfillment of Doctor of Philosophy in Electrical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

Automatic retinal screening systems (ARSS) facilitate wide and periodic screening of the huge numbers of candidate ocular patients, recommending professional treatment only when early disease symptoms are detected. Early detection and proper treatment of silent retinal diseases, such as diabetic retinopathy, can prevent or delay severe visual impairments that result from advanced disease progressions. However, the reliability of these systems was found greatly dependent on the quality of the processed retinal images. In this thesis, a no-reference comprehensive wavelet-based retinal image quality assessment (RIQA) algorithm is introduced that is intended for early diabetic retinopathy diagnosis using ARSS.

Initially, RIQA was performed based on the intuition that good quality retinal images have sharp retinal structures. Wavelet decomposition has the advantage of separating an image's sharpness information equivalent to high frequency components within its detail subbands. Moreover, multiresolution analysis brings out the finer image details related to the different retinal structures within the various wavelet levels. Consequently, retinal image sharpness features were calculated from the detail subbands of five level wavelet decompositions. The sharpness features were tested on two datasets of different resolutions and degree of blur resulting in an area under the receiver operating characteristic curve (AUC) of 1.000 and 0.985 for the low resolution severely blurred and the high resolution slightly blurred retinal datasets, respectively. For the high resolution dataset, the introduced features achieved an AUC that is between ~10-20% higher than other RIQA algorithms from literature while requiring 5-10 times less computation time.

Next, the effect of image resolution on the introduced wavelet-based features as well as on several RIQA algorithms was studied.

Specifically two cases were considered, the case when both training and testing image resolutions were similarly varied and the case at which the training and testing dataset images had different resolutions. This study showed that the performance of RIQA algorithms can be significantly affected in the latter case. For the proposed wavelet-based RIQA algorithm, two methods were introduced and validated that permit maintaining high classification performance in cases of different training and testing image resolutions. In cases of large resolution differences, the wavelet-based algorithm's performance was improved by up to a 100% by the suggested methods.

Finally, a comprehensive framework was developed that considers five common quality issues for retinal image quality evaluation. Wavelet-based features were implemented for image sharpness, illumination, homogeneity, and field definition assessment whereas color information was used to separate retinal and non-retinal images. Furthermore, a new proposed saturation channel was created specifically for retinal image homogeneity evaluation. Classification performance for each of the five quality feature sets resulted in AUCs higher than 0.99. The overall RIQA algorithm, combining the five quality feature sets, achieved an AUC of 0.927 which is between 2.0-4.5% higher than several other algorithms from literature.

Wavelet-based RIQA algorithms are being recently adopted for RIQA. However, existing RIQA algorithms do not take full advantage of the wavelet transform's multiresolution capabilities or the relation between the retinal structures and the various levels. Moreover, these algorithms utilize wavelet-based features only for retinal image sharpness assessment. In this thesis, multilevel wavelet decomposition was exploited to evaluate several quality issues within retinal images. The introduced wavelet-based RIQA algorithm overcomes limitations within other more commonly implemented RIQA methods by comprehensively evaluating retinal image quality,

considering structural information for quality assessment, requiring small processing time, in addition to achieving reliable performance for different image resolutions and quality grades. Consequently, the introduced wavelet-based RIQA algorithm is highly suitable for integration within real-time ARSS.

Keywords Retinal image quality assessment, wavelet transform, retinal image resolution, automated retinal screening systems, biomedical imaging

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*“But I have discovered the secret,
that after climbing a great hill,
one only finds that there are
many more hills to climb.”*

– Nelson Mandela, Long Walk to Freedom

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