



Research paper

Imperceptible watermarking for security of fundus images in tele-ophthalmology applications and computer-aided diagnosis of retina diseases



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ABSTRACT

Background and objectives: The authentication and integrity verification of medical images is a critical and growing issue for patients in e-health services. Accurate identification of medical images and patient verification is an essential requirement to prevent error in medical diagnosis. The proposed work presents an imperceptible watermarking system to address the security issue of medical fundus images for tele-ophthalmology applications and computer aided automated diagnosis of retinal diseases.

Methods: In the proposed work, patient identity is embedded in fundus image in singular value decomposition domain with adaptive quantization parameter to maintain perceptual transparency for variety of fundus images like healthy fundus or disease affected image. In the proposed method insertion of watermark in fundus image does not affect the automatic image processing diagnosis of retinal objects & pathologies which ensure uncompromised computer-based diagnosis associated with fundus image. Patient ID is correctly recovered from watermarked fundus image for integrity verification of fundus image at the diagnosis centre.

Results: The proposed watermarking system is tested in a comprehensive database of fundus images and results are convincing.

Experimental: results indicate that proposed watermarking method is imperceptible and it does not affect computer vision based automated diagnosis of retinal diseases.

Conclusions: Correct recovery of patient ID from watermarked fundus image makes the proposed watermarking system applicable for authentication of fundus images for computer aided diagnosis and Tele-ophthalmology applications.

1. Introduction

Transmission of medical images over the network and storage of images in databases is an essential requirement for providing e-health services. [1]. Identification and authentication of medical images is a critical and growing issue for patients in e-health services like Tele-medicine, Tele-diagnosis, Tele-radiology applications [2,3]. Accurate identification of medical images and correct patient verification is an essential requirement to prevent error in medical diagnosis and tele-medicine applications. Hence there is a need to develop methods to address the issue of medical image security for Tele-medicine applications.

1.1. Limitation in the existing systems/techniques for Medical Image Security

The existing research work for security of medical images is based on stenography, cryptography and watermarking techniques. Some

other methods like use of multi-modal biometrics are a recent reliable and vast integrated technology in identification, verification and imperceptible or ensured security of patient's protected health information. The word "multi-modal biometric" means use of two or more biometric data to solve the issue of security. This technique is reliable and accurate but also has some limitations like difficult to access biometric data and requirement of sensors for data acquisitions. In cryptography, the host image is usually scrambled and unreadable which is not very encouraging in the case of medical imaging [4,5]. Steganography techniques generally do not provide strong security against removing or modification of the hidden message, which may not be preferred for medical image security [6]. Digital watermarking is the most popular technique to hide digital information in the host signal with additional requirements like imperceptibility, robustness etc. In the literature, various image watermarking algorithms have been developed for security of medical images. Broadly Medical image watermarking techniques can be categorized into three different types as ROI (region of interest) based watermarking, reversible watermarking and

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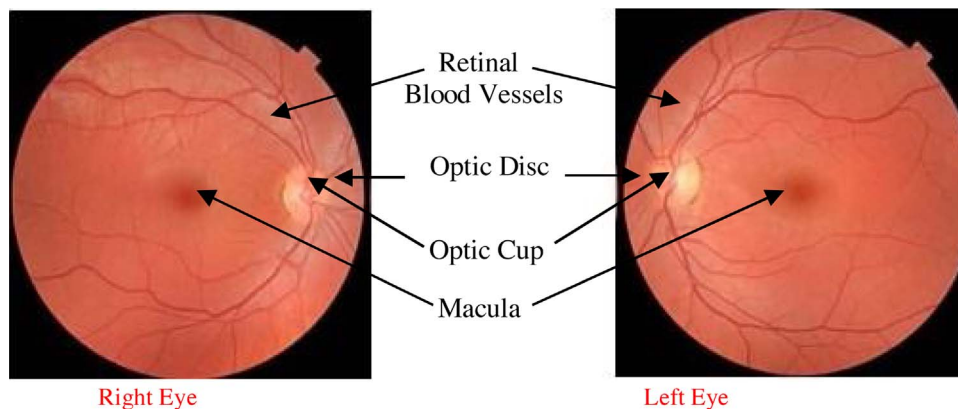


Fig. 1. Digital fundus image with marked important objects: Right and Left eye.

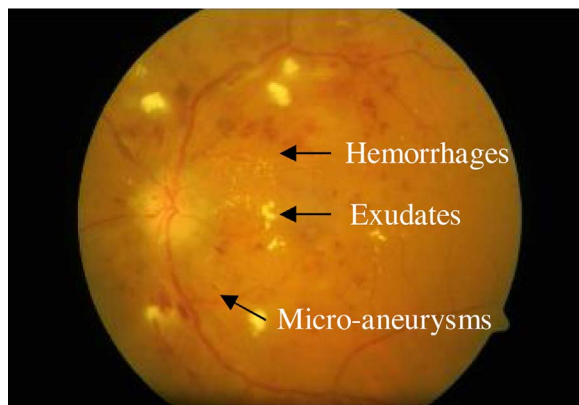


Fig. 2. Digital fundus image with marked Retinal pathologies.

imperceptible watermarking [7].

In the ROI based watermarking, medical image is divided into clinically informative and non informative regions where clinically non informative regions are chosen for watermark embedding [8–10]. Since segmentation of medical images into informative and non informative

regions may requires interaction and/or approval of medical consultant or a professional doctor which is sometimes very difficult and expensive. In addition, dividing of medical images into clinically informative and non informative regions may not be possible for all medical images. Hence ROI based watermarking may not be a good choice for watermarking of medical image.

Reversible watermarking technique ensures that original image is correctly recovered from watermarked image with no loss of patient's health information [11–15]. Development of reversible watermarking method for medical images is promising because of the requirement to recover host image without any compromise of the diagnostic accuracy. Additionally in reversible watermarking, watermark is extracted from image before the diagnosis which creates unsecure environment as once the watermark is removed; the image loses its security.

In the imperceptible watermarking techniques, digital watermark is physically embedded in the original image which means that original and watermarked image is visually similar but computationally different. Since watermark embedding makes slight computational changes in watermarked image, there may be a possibility that computer-based diagnosis maybe affected. Hence there is need to develop methods to make sure that watermark embedding should be done in an imperceptible manner i.e. it would affect image quality to an extent where the patient's health information is maintained [16–19] without any loss of information.

Imperceptible watermarking for security of medical images can be a

Table 1
Important Objects/Pathologies for Computer Aided Diagnosis of Retinal Health.

S. No.	Name	Object/ Pathology	Inferences
1.	Macula	Object	Macula is darker/red-brown color object of human retina which is important for color and central vision. Any harm in macula or presence of any retinal abnormalities (Bright/Red Lesions) near to macular region leads to loss of color vision. The damage in the macular region or presence of bright lesions near to macula is a serious retinal disease called as Diabetic Macular Edema (DME) .
2.	Optic Disc	Object	Optic disc (OD) is the brighter object of fundus image. It is approximately circular or elliptical shaped object. Glaucoma is a very common retinal disease which damages the optic disc which results to loss of vision. Some important features of optic disc like cup to disc ratio (CDR), neuro retinal rim (NRR), segmented blood vessels in the ISNT quadrants of optic disc are used for diagnosis of glaucoma.
3.	Blood Vessels	Object	Retinal blood vessels play an important role in revealing various eye diseases like Diabetic Retinopathy, Glaucoma etc. Blood vessels segmentation and removal are considered to detect other artifacts like red lesions, macula, optic disc and optic cup for diagnosis of various retinal diseases.
4.	Red Lesions	Pathology	Red Lesions are the main symptoms of diabetic retinopathy which includes Micro-aneurysms and Hemorrhages. Microaneurysm is a small area of blood bulging out from veins which results to blood leakage in the eye. When Microaneurysm rupture and blood is collected in the nearby tissues, it leads to hemorrhages. Detection of red lesions is used for diagnosis and grading of DR in different stages.
5.	Bright Lesions	Pathology	Bright lesions (Exudates) are yellow lipid sediments because of serous leakage from damaged capillaries. Presence of bright lesion in the fundus image marks the beginning of loss of vision. Detection of hard exudates is considered for screening of Diabetic retinopathy. Presence of bright lesions near to macula is recognized as serious eye diseases Diabetic Macular Edema.

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