Computer Methods and Programs in Biomedicine (2005) 79, 97—109

Computer Methods and Programs in Biomedicine

www.intl.elsevierhealth.com/journals/cmpb

The reengineering of a software system for glaucoma analysis

Ryan George Fraser [a,*], Jocelyn Armarego [b], Kanagasingam Yogesan [a]

[a] Centre for E-Health, Lions Eye Institute, 2 Verdun Street, Nedlands, WA 6009, Australia
[b] School of Engineering Science, Murdoch University, South Street Murdoch, WA 6150, Australia

Received 29 November 2004; received in revised form 23 December 2004; accepted 3 January 2005

KEYWORDS
Reengineering;
User-centred design;
Software engineering;
Glaucoma

Summary Glaucoma is a destructive eye disease that causes blindness in individuals displaying little or no symptoms. There is no cure as yet though there are treatments that can arrest its effects or slow its development. The earlier the disease is detected, the more likely the treatment will be successful; however early detection of the disease can be difficult. This highlights the importance of ophthalmologists having access to tools that can assist in accurately diagnosing glaucoma and other retinal diseases as early as possible.

The stereo optic disc analyser (SODA) software package is a tool intended to be used by ophthalmologists, to aid in the accurate detection of retinal diseases. SODA will use stereoscopy and three-dimensional image analysis to assist in accurately detecting changes in the retina, caused by diseases such as glaucoma.

This paper will focus on the reengineering and redesign of the SODA software package to overcome the shortcomings inherent in its prototype implementation and develop a package that can be commercialised.

Software Engineering principles and the software development lifecycle, along with principles of object-orientation and usability, have been used to establish a framework for SODA, improve its accuracy, enhance its usability and to redevelop the product into an implementation that can later be commercialised.

1. Introduction

Glaucoma is a destructive eye disease that causes blindness in individuals displaying little or no symptoms [1]. While 300,000 people are affected by glaucoma in Australia alone, this figure grows to approximately 66.8 million worldwide, of which 7.6 million are blind because of the disease [2]. At present there is no cure though there are treatments that can arrest the development of glaucoma: the success of these is largely dependent on how early the disease is detected.

Glaucoma attacks the human retina [2,1]. Ophthalmologists use a combination of techniques to diagnose the disease: in order to do so it is neces-

* Corresponding author.
E-mail address: r_fraser_wa@yahoo.com.au (R.G. Fraser).

0169-2607/$ — see front matter © 2005 Published by Elsevier Ireland Ltd.
doi:10.1016/j.cmpb.2005.01.002

sary for them to have access to realistic views of the patient's eye/retina either by in-person examination or from the traditional method of taking stereo images of the patient's eyes. The former is not always possible and the latter can be expensive, due to the film and camera costs of this method of photography.

These two issues, the value of early detection, and the requirement for realistic views of the eye/retina, highlight the importance of tools that give ophthalmologists the ability to examine patients' eyes realistically in order to diagnose the disease in a timely manner. The stereo optic disc analyser (SODA) [3] addresses these requirements by providing the ophthalmologist with the ability to analyse patient images in a way comparable to examining a patient in person, from stereo images captured by means of a low-cost digital fundus camera.

SODA is a three-dimensional (3D) software package developed at the Lions Eye Institute of Western Australia [3]. By incorporating stereoscopy, which is recognised as a valuable technology for use in diagnosis of eye diseases [4,5], SODA provides a suite of tools to assist ophthalmologists in diagnosing and evaluating retinal diseases and gives them the ability to monitor the disease's progression in their patients' eyes in three-dimensions (3D), based on fundus images. SODAs tools allow the ophthalmologist to objectively support findings gathered from their observations and instrument measures.

This paper describes the reengineering and redesign effort required to transform SODA from prototype form into a product that encompasses a high level of usability, has an ability to evolve, and later to be commercialised.

The intricacies of the glaucoma disease are described and the intent and goals of the software product are detailed in Section 2. The requirements and constraints of this project will then be detailed in Section 3, followed by the description of the methodologies employed to accomplish this project in Section 4. Implementation details and results of the project are then described in Section 5 and a final discussion is made detailing future directions and lessons learnt from the development in Section 6.

2. Background

2.1. Glaucoma and techniques to assist in its diagnosis

Glaucoma is a destructive disease that affects the optic disc [2]. It gradually strips a person of their sight, often without warning and/or symptoms. Glaucoma can be caused by the intraocular pressure (internal pressure) of a patient's eye being too high, which results from internal blockages [1].

At present there is no cure for glaucoma, though it can be treated [2]. Treatment cannot recover lost sight caused by the disease but can arrest or at least slow its development. However, for treatment to be successful the disease must be detected early. This highlights the need for timely and accurate methods of diagnosis.

Several techniques are adopted by ophthalmologists to diagnose whether a patient is suspected of glaucoma, including visual inspection, analysis of the depth of the optic disc, calculation of a ratio such as the vertical cup-to-disc ratio (VCDR) and calculation of the optic disc and cup areas. In particular, the VCDR method is of significant importance to ophthalmologists since it enables the detection of disease progression/development over time. While the size of the disc and cup is genetically determined, a ratio of 0.3 is considered normal, and any variation of this is generally regarded as suspicious. However, some people have small physiological cups with ratios of around 0.2. In these cases analysis of the cup—disc ratio over time is important to detect changes.

Fig. 1 demonstrates the growth of glaucoma in a retina over an elapsed time period. Image ''a'' is of a normal optic disc with a cup—disc ratio of 0.2. Images ''b'' through to ''f'' demonstrates the growth of glaucoma in what was a normal optic disc. The inside cup grows and creates internal blockages which disrupts messages getting through the optic disc and being sent to the brain for interpretation.

One technique to view the human retina for diseases such as glaucoma is fundus photography. Fundus photography is used to image the human retina, which includes the optic disc [6]. Simply, a fundus camera takes the images of the ocular fundus (the retina) by shedding a light through a dilated pupil into the eye and recording the reflection light from the ocular fundus. Fundus images are generally high-resolution (typically above 1728 pixels $\times$ 1152 pixels) and of significant importance to ophthalmologists, who view them to detect changes in the retinal structure, in order to diagnose and to compare them to photographs taken on previous occasions.

Humans can see 3D because their eyes see slightly different perspectives to each other. These differences in perspective are known as the parallax, which gives the brain the information to determine distance or depth [7]. Stereoscopy exploits the parallax principle, where two images of the same object (a stereo pair) are taken at slightly dif-