Interactive OCT Annotation and Visualization for Vitreoretinal Surgery

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Abstract. Vitreoretinal surgery is an extremely challenging surgical discipline requiring surgeons to use limited visualization to locate and safely operate on particularly delicate eye structures. Intraocular image guidance can potentially aid in localizing retinal targets, such as Epiretinal Membranes. This paper describes a system and methods for localizing difficult to identify anatomical features in the retina using video stereo-microscopy and intraocular OCT. We visually track the retina motion and relative position of a hand-held OCT probe to assemble an $M$-Scan, the cross-sectional image of the anatomy corresponding to a trajectory of the probe across the retina. The surgeon is then able to interrogate the OCT image during the procedure by pointing a surgical instrument at the M-Scan trajectory superimposed on the retina and displayed in 3D. The system is designed to provide relevant intraoperative imaging to increase surgical precision, and minimize the surgeon’s cognitive load. We describe our system and quantify its performance in a phantom eye.

Keywords: vitreoretinal surgery, image guided interventions, stereo microscopy, anatomical annotations, visualization, OCT, smart instruments.

1 Introduction

Vitreoretinal surgery treats many sight-threatening conditions, the incidences of which are increasing due to the diabetes epidemic and an aging population. It is one of the most challenging surgical disciplines due to its inherent micro-scale, and to many technical and human physiological limitations such as intraocular constraints, poor visualization, hand tremor, lack of force sensing, and surgeon fatigue. Epiretinal Membrane (ERM) is a common condition where 10 - 80 μm thick scar tissue grows over the retina and causes blurred or distorted vision [1]. Surgical removal of an ERM involves identifying or creating an “edge” that is then grasped and
peeled. In a typical procedure, the surgeon uses a stereo-microscope, a vitrectomy system and an intraocular light guide to completely remove the vitreous from the eye to access to the retina. Then, to locate the transparent ERM and identify a potential target edge, the surgeon relies on a combination of pre-operative fundus and Optical Coherence Tomography (OCT) images, direct visualization often enhanced by coloring dyes, as well as mechanical perturbation in a trial-and-error technique [2]. Once an edge is located, various tools can be employed, such as forceps or a pick, to engage and delaminate the membrane from the retina while avoiding damage to the retina itself. It is imperative that all of the ERM is removed, which can be millimeters in diameter, often requiring a number of peels in a single procedure.

The localization of the candidate peeling edges is difficult. Surgeons rely on inconsistent and inadequate preoperative imaging due to developing pathology, visual occlusion, and tissue swelling and other direct effects of the surgical intervention. Furthermore, precision membrane peeling is performed under very high magnification, visualizing only a small area of the retina (~5-15%) at any one time. This requires the surgeon to mentally register sparse visual anatomical landmarks with information from pre-operative images, and also consider any changes in retinal architecture due to the operation itself.

To address this problem we developed a system for intraoperative imaging of retinal anatomy. It combines intraocular OCT with video microscopy and an intuitive visualization interface to allow a vitreoretinal surgeon to directly image sections of the retina using a single-fiber OCT probe and then to inspect these tomographic scans interactively, at any time, using a surgical tool as a pointer. The location of these “M-Scans” is registered and superimposed on a 3D view of the retina. We demonstrate how this system is used in a simulated ERM imaging and navigation task.

![Fig. 2. Components of the Imaging and Visualization System](image-url)