Improved Fluorescence Imaging in Medical Applications

Background

Dyes, such as Indocyanine Green (ICG), are used in several medical applications including visualization of blood flow, identification of critical anatomy, and highlighting regions of interest, all when visible light is not ideal for doing so. These dyes have well-defined absorption and emission spectra. Visualization is typically accomplished by injecting the dye into the bloodstream or region of interest, illuminating the scene with a laser source tuned to the absorption wavelength of the dye, and capturing the scene with a camera system that filters out the illuminant's wavelength but is sensitive to the emission wavelength. The fluorescence image is typically overlaid on a background consisting of a visible light image of the scene for context.

Problem

Dye fluorescence is very useful but, since it depends on light penetrating tissue and being absorbed and re-emitted and passing back through the tissue before finally being sensed, occurs at much lower brightness levels than those at which visible light images are typically captured. Just like visible light, though, the dye excitation light is subject to specular and diffuse reflections when it reaches tissue, which can alter the wavelength of the light enough that it is not filtered by the camera system, meaning these reflections can be mistaken for dye fluorescence. The optics of the camera systems used in these applications, especially in minimally invasive surgeries, are additionally subject to light falloff farther from the center of the image, which means only fluorescence near the center of the field of view is reliably detected. Finally, combined with these two problems, noise inherent in the system becomes even more problematic in fluorescence imaging than in the visible light case.

Project

Detecting and correcting for different varieties of reflections could be very beneficial for fluorescence imaging. Artusi et al survey multiple potentially applicable methods for detecting, distinguishing, and mitigating the effects of these different types of reflections[1]. Eliminating the effects of light falloff would enable a more consistent fluorescence image across the entire visible scene, and Zheng et al discuss a

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[1] A Survey of Specularity Removal Methods. Alessandro Artusi, Francesco Banterle, and Dmitry Chetverikov. COMPUTER GRAPHICS forum Volume 30 (2011), number 8 pp. 2208–2230. DOI: 10.1111/j.1467-8659.2011.01971.x

method of correcting for this vignetting using gradient distributions[2]. Regarding noise from the system, Qu, Zhang, and Jia suggest an efficient method for denoising images like this[3]. Combining these approaches with some knowledge about the color content of the illuminant should result in a much more consistent and useable fluorescent image when some post-processing is applied.

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[2] Yuanjie Zheng, Stephen Lin, Sing Bing Kang, Rui Xiao, James C. Gee, Chandra Kambhamettu. Single-Image Vignetting Correction from Gradient Distribution Symmetries. IEEE Transactions on Pattern Analysis and Machine Intelligence, Volume 35 Issue 6.

[3] Xiujie Qu, Fu Zhang, and Huan Jia, “An Efficient Adaptive Denoising Algorithm for Remote Sensing Images,” Mathematical Problems in Engineering, vol. 2013, Article ID 207461, 5 pages, 2013. doi:10.1155/2013/207461