

**Title:** Color Coherent Endoscopic/Laparoscopic Image Enhancement with Noise Suppression

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**Structured Abstract:**

**Introduction:** Stereoscopic endoscopes have been used increasingly in minimally invasive surgery to visualize the organ surface and manipulate various surgical tools. However, insufficient and irregular light sources present major challenges for endoscopic surgery. Not only would they hinder computer assisted algorithms, sometimes the surgical tools would be hardly visible when operating within low-light regions. In addition, the low-light regions tend to suffer from low signal to noise ratio and metrication artifacts due to quantization errors. As a result, the traditional image enhancement scheme often leads to heavy noise amplification in low-light region.

**Methods:** In this paper, we propose an effective endoscopic image enhancement scheme to improve the visibility of lowlight region during endoscopic surgery. The algorithm first identifies different illumination regions using thresholds. The image is then further decomposed into illumination and detail layer and the illumination and detail layers are enhanced separately to meet the enhancement design criteria for desired image quality. Finally, the saturation will be corrected based on the saturation information from the endoscopic image from the previous time frame.

**Results:** From our experiments using 200 test endoscopic images, the proposed algorithm yields an average naturalness image quality evaluator (NIQE) of 2.46 and an average illumination index of 0.22, quantitatively demonstrating superior performance than other state-of-the-art algorithms. By visual inspection, the proposed method is able maintain the contrasts and colors in the well-lit image regions, while significantly improving the visibility of the low-light regions.

**Discussion:** Through comparison, we can see visible image artifacts amplified by other algorithms, while our approach yields enhanced images with more natural appearances and higher image quality. All the results confirm that our method has superior performance than the other state-of-the-art algorithms, and can effectively enhance the endoscopic image without amplifying underlying noise/artifact in the low-light regions. In the future we will improve the computational speed of our algorithm and a blinded qualitative rating study will be carried out to learn surgeons' preferences on the enhanced images.