Towards a Color Space for Automated Lesion Segmentation in Robotic Capsule Endoscopy

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***Abstract*— Image segmentation plays an important role for the assessment of endoscopy images, e.g., for lesion detection and measurement. This paper presents a method for superpixel-based segmentation of various gastrointestinal lesions using a novel color space constructed by Kernel Principal Component Analysis. The advantageous results obtained with a publicly available dataset are promising for the development of future robotic capsule endoscopy systems with enhanced diagnostic capabilities.**

I. Introduction

Passive wireless capsule endoscopes (WCE) are evolving into active robotic devices with capabilities for locomotion, and enhanced diagnostics [1]. In this context, image segmentation is important for automated lesion detection and size measurement [2]. A pioneering approach for color image segmentation was based on principal component analysis (PCA) [3]. In the latter, the red, green and blue components of the RGB color space are linearly transformed into three décorrelated components forming the $I_1I_2I_3$ color space. These components are ordered by their variance, i.e., I_1 represents the component with the highest variance and corresponds to luminance, with I_2 and I_3 represent lower variance components. In a later study [4], an improved performance over PCA for color space construction was indicated with the use of independent component analysis (ICA). However, this was only qualitatively assessed, whereas ICA has the drawback of being dependent on initialization. In WCE, PCA has been utilized only for segmentation of reddish lesions [5]. Image segmentation was based on thresholding schemes.

In this paper, a novel method for segmentation of various lesions (not only reddish) is proposed. It is based on non-linear kernel PCA for the color space construction and a modified simple linear iterative clustering (SLIC) superpixel segmentation [6].

II. Methodology

Each RGB channel of a given image is represented as a vector. The three vectors obtained, form a data matrix X_{3xn}. A kernel matrix $K_{ij} = k(X_i, X_j)$ is applied on each RGB pixel of the dataset X_i, $i=1,...,n$, where k is the kernel function. Subsequently, the eigenvectors of K (that correspond to the matrix transformation) are calculated. Each eigenvector component contributes to the linear transformation from the RGB color space to the new one, called $K_1K_2K_3$. The RGB to $K_1K_2K_3$ transformation matrix is obtained by

$$M = \begin{bmatrix} 0.77773 & -0.17356 & -0.60417 \\ 0.24861 & -0.79784 & 0.54923 \\ -0.57735 & -0.57735 & -0.57735 \end{bmatrix}$$

Subsequently, Welch's t-test is utilized to capture the most discriminative chromatic components. A modified SLIC superpixel segmentation algorithm is applied for WCE image segmentation, where only K_2 and K_3 are used for the estimation of color distances instead of all the CIE-Lab components considered in the original algorithm.

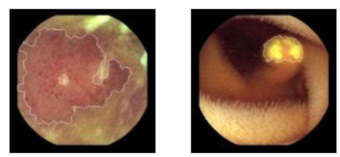

Figure 1. Indicative segmentation results of an aphthae (left) and a lymphanigiectasia (right).

III. Results

We used the dataset described in [7] for the segmentation of angioectasias, polypoid lesions, lymphangiectasias, stenoses, ulcers, aphthae, and chylous cysts. This dataset is publicly available via the KID database [2]. A 40% sample of these images was used to apply KPCA using third order polynomial kernel function. The rest, non-overlapping, samples were used for testing. The average performance of the proposed method was higher (94%) than the one obtained by using CIE-Lab (92%). Indicative results are illustrated in Fig. 1.

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*Research supported by the special account for research grants of the Technological Educational Institute of Central Greece.

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