Laryngeal Tumor Classification in Endoscopic Video

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I. INTRODUCTION

Laryngeal carcinoma is one of the most common type of head and neck cancers. Early diagnosis of any carcinoma is the most important factor involved in treatment planning and improves the quality of life of the patient. Moreover, abnormalities that start as benign lesions may develop to malignant tumors in 10% of the cases [6]. The standard diagnosis method is biopsy together with pathological analysis, but this does not represent a risk free procedure. Furthermore, the time needed to obtain the results of the pathological analysis vary from a few days to a few weeks.

Recently, the analysis of endoscopic videos has shown the development of abnormality in the larynx is closely related to an increase in the number of the micro-blood vessels around it. This is an interesting information that can lead to the development of optical biopsy systems. Progress in that direction has started with the development of imaging systems that enhance the visualization of blood vessel, such as the Narrow-Band Imaging (NBI) system patented by Olympus. NBI is based on differences in the penetration depth of different light wavelengths in tissue. Blue light, centred around 415 nm, passes through the mucosa and enhances the superficial blood vessels, while the narrow-band green light, centred around 540 nm, penetrates deeper into the tissue, enhancing the subephitelial vessels. The NBI technology is being increasingly used to locate and characterize lesions in the larynx. However, until present time physicians still do not have access to a statistical measurement system able differentiate between malignant and benign tumors.

The goal of this research is to develop an automatic system to help medical specialists diagnose lesions in the larynx. Similarly to the approach followed by doctors, our method is based on determining the approximate location of the lesion and performing a detailed analysis of the micro-blood vessels network within that region. This finally leads to the classification of the lesion as benign or malignant.

II. MATERIALS AND METHODS

In order to create a computer-aided-diagnosis system, an important step is to remove the specular reflections. In endoscopic imaging, due to the high-illumination, wet and very smooth environment, specular reflections are very common and can be disturbing for the physician. Furthermore, in the task of automatic segmentation and classification of lesions, reflections can cause difficulties. Therefore, removal of specular reflections is the first required step for further image processing.

Specular reflection removal algorithms can be divided according to the number of images used. The first group is based on multiple images, obtained in different conditions (different polarization angles, changing light source direction, etc.). Using any of the techniques in this group is challenging due to the fact that it may not be always possible to meet the required conditions in practice [9]. The second category removes the reflections based on one single image, the method used in this research belonging to this group.

In endoscopic images, specular reflections appear as bright regions in various parts of the image. The size of specular regions do not respect any pattern or size, making the segmentation task very challenging. Large specular regions can also overlap possible malignant tissue. Consequently, we have decided to compute the area of each detected specular region and if it is too large, the area is considered an abnormality and is not removed.

Based on the previous researches [1], [7], [8], in this project an efficient algorithm for reduction of specular reflections using a single image as input has been implemented. The first step is to determine the specular reflection regions based on adaptive thresholding in the HSV color space. The dimension of detected ROI is computed and additional pixels are added to specularities. The last step is to fill the remained ROI by propagation of information from the surrounding non-specular areas.

As stated in [5] the specular reflection have intense brightness and low saturation values, information that can be used in finding the region of interest. Consequently, the HSV color space offers advantages when specular reflections have to be removed. In this case, a region of interest can be defined applying thresholds on the saturation and value channels of the image. An adaptive threshold scheme [5] is used here to obtain accurate results. Based on experiments performed with endoscopic videos of the larynx, thresholds were cho-

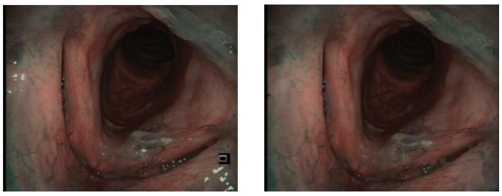
sen as stated in Equation 1 and Equation 2.

$$V = 0.7 \cdot V_{max} \quad (1)$$

$$S = 0.35 \cdot S_{max} \quad (2)$$

In our algorithm, the results obtained with this thresholding scheme are improve based on image gradient information. Reflection regions are small bright spots, so they can be interpreted as high gradient regions in their neighborhood. An experimental threshold was chosen to segment the specular reflection based on the magnitude of the gradient of the gray images. In our case this value was set to 130.

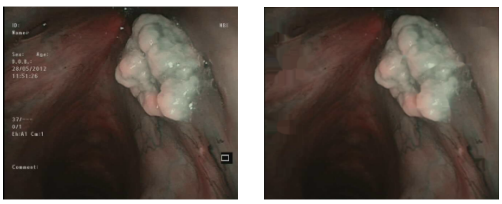
After the regions of reflection were detected, the next step is to reconstruct the affected area. A filling scheme was used for that task considering texture preservation as a key feature to minimize disruption on the results of subsequent image processing. In this research, since specular reflections were assumed to be small, the color behind each reflection was considered constant and similar to the neighboring pixels. The result of this approach presents smooth regions substituting small reflection areas, as can be seen in Figure 1.



(a) Original image (b) Reconstruction

Fig. 1: Specular reflection removal and reconstruction.

Moreover, another important problem is solved with the help of this algorithm: removal of additional information provided by the endoscope equipment. After applying the algorithm proposed previously, both text and specular reflections are removed, due to the similar characteristic, being characterized as bright white areas. Results are presented in the figure 2, where the residual information and the specular reflections are removed, but the lesion is maintained, although it is characterized by a white bright region. As mentioned previous our algorithm is able to differentiate this lesions from specular reflections due to their large areas.



(a) Original image (b) Reconstruction

Fig. 2: Residual information removal and reconstruction.

After the specular reflections have been eliminated, the design of an automatic system for lesion classification was realized. Analyzing the characteristics of the micro-vascular patterns, abnormality growths can be identified and classified from an early stage. In order to obtain the classification, there is the need of detecting the region of interest and extracting the blood vessels, which represents the main focus of this research.

The presence of abnormality such as tumors, polyps, polypoid lesions results in appearance of rough surface in endoscopic image [4]. Detecting the region of interest is not a straightforward task, the main challenge represents the irregular shape of the tumour or in some cases the non-existence of a tumour. In the case of healthy vocal cords it is a very difficult task to determine which region should be closely analyzed. On the other hand, when abnormalities are present, the extraction of region of interest may assist the physician by suggesting an approximate location of the tumor. The region of interest is detected in most of the cases based on the outer boundaries that describe the lesions. Results from this processing step can be seen in Figure 3. Limitations are encountered when no clear boundaries are present and the characteristics of the abnormality are similar with the surrounding tissue, further research being needed to solve this challenging situations.

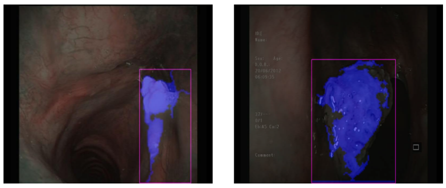


Fig. 3: Region of interest detection.

The next step of the processing algorithm consists in extracting image features from the marked region of interest. Blood vessels vary in shape, length and diameter, so the design of this stage is also challenging. The most important operation performed in this case is edge detection. In this research a number algorithms were merged together in order to detect and segment both very small and large blood vessels. From the problems encountered, the hardest was distinguishing between small vessels and noise. Both present many similarities, tending to produce false positives. Nevertheless, our final algorithm is able distinguish between the two situations, as can be seen in Figure 4. Its final implementation uses Matched Filter based on the First-Order Derivative of Gaussian (MFFODG), as presented in [10]. Moreover, the output of the filter is subsequently thresholded and validated using a Gabor filter and the morphological Black-Top-Hat operation. This combination of algorithms proved to be effective in generating blood vessels maps of the appropriate quality for further processing.

Once segmented, the blood vessels map is used to

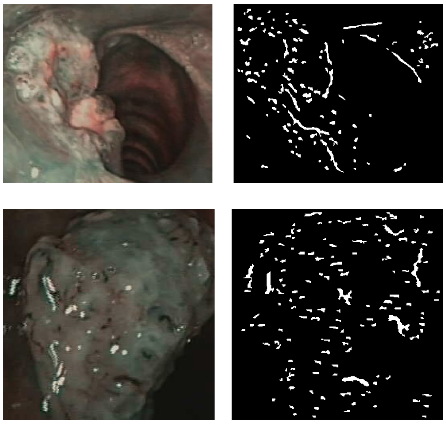


Fig. 4: Micro-blood vessel segmentation.

classify the observed lesion. This is done by quantitative measurements of the blood vessels characteristics, including width and tortuosity, which have been shown correlated to lesion development, i.e., the presence of dilated or highly tortuous blood vessels are signs of lesion development. Here, these measurements are used to classify lesions based on confidence levels, which are computed according to the method proposed in [2]. If the confidence level is over 0.5, the lesions can be considered as malignant. Otherwise, the lesion is considered benign.

III. RESULTS

A collection of narrow-band endoscopic videos of the larynx was provided by the San Martino Hospital of Genoa, including videos acquired from different patients with a wide range of tumors. These videos were used to create a database of 50 images of lesions of vocal cords with both benign and malignant tumors, which were extracted randomly without following any criteria for selecting good frames. Consequently, the dataset contained images far from ideal for processing, some showing only small and distant lesions, some others not perfectly in focus, and others presenting relatively low contrast and motion artefacts. The videos were acquired using rigid endoscopes, the Olympus OTV-S7ProH-HD-10E camera, and the Olympus Visera Elite CLV-S190 video system.

Based on the described database, each part of the developed tumor segmentation and classification system was evaluated. The tumor localization system demonstrated an overall success rate of 78%, and the feature extraction system achieved 87% specificity and 78% accuracy. Finally, the overall accuracy of the tumor classification system was 84.3%.

IV. CONCLUSION

This research proposes a new system for the localization, segmentation and classification of lesions in the larynx based on endoscopic narrow-band imaging video. The developed algorithm starts by detecting the approximate location of the lesion in the vocal cords, which is followed by the segmentation of the blood vessels present in that region. The algorithm continues with the measurement of geometric features of the blood vessels map, based on which an statistical analysis provides the probability of malignancy. To our best knowledge, this is the first system developed for the segmentation and analysis of the blood vessels in the vocal cords.

Considering the experimental results, we can conclude the proposed method is capable of recognizing malignant tumors in the vocal cords with high accuracy. Nevertheless further research is still needed, specially to improve the sensitivity of the blood vessel extraction algorithm. Further development is also needed to create a system useful for medical specialists. Nonetheless, the system developed consists in a promising novel method for cancer detection and classification, representing an innovation in the medical imaging field.

V. ACKNOWLEDGMENT

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