34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

Assessment of Videolaryngostroboscopy Images Based on Visible Vessels Of Vocal Folds

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Abstract— **Extraction of vessel structures and the vessel features automatically forms an essential step for computer-aided diagnosis. Visible vessels of vocal folds become a diagnostic aid for vocal fold pathologies by publication of limited number of researches which analyze the effects of vocal fold pathologies on visual characteristics of blood vessels. In this paper we present a novel system that extracts blood vessels centerlines on vocal folds images and detects pathologically altered vocal folds exploiting visual characteristics of vessels.**

Keywords-Blood Vessel Detection, Videolaryngostroboscopy, Vocal Fold Pathologies

I. INTRODUCTION

Organic lesions such as polyp, nodule and Reinke's edema in the vocal folds cause dysphonia and respiratory problems due to vocal fold malfunction.

The clinical diagnosis of the voice pathologies is based on examination of vocal fold vibrations and structural defect of the vocal folds with medical imaging devices such as videolaryngostroboscope and direct laryngoscope. However the subjective diagnoses are error-prone and may vary between different physicians examining the same patient.

Assessment of the blood vessel characteristics is crucial in diagnosing diseases such as diabetic retinopathy, esophageal cancer and heart diseases which affect the anatomic structure of blood vessels [1, 2]. Several systems that segment and analyze the vascularity have been designed so far. Khan at al. divide vessel segmentation algorithms and techniques into six main categories: parallel multiscale, feature extraction and region growing, a hybrid filtering, ridge-based vessel segmentation, artificial intelligence-based approaches, neural network-based approaches, and miscellaneous tube like object detection [3]. However, there is no reported research in the literature that extracts the visible blood vessels on vocal fold.

In this article, we propose a novel system that extracts the vocal folds vessels in the images acquired during routine videolaryngostroboscopy and classifies normal and pathologically altered vocal folds by using vascular defect.

II. METHODOLOGY

Taking into consideration the anatomic structure of vocal fold vessels and the challenges arising from the imaging modalities, a region growing based system was designed to extract the visible vessels of vocal folds. Figure 1 illustrates the block diagram of the proposed vessel centerline detection algorithm.

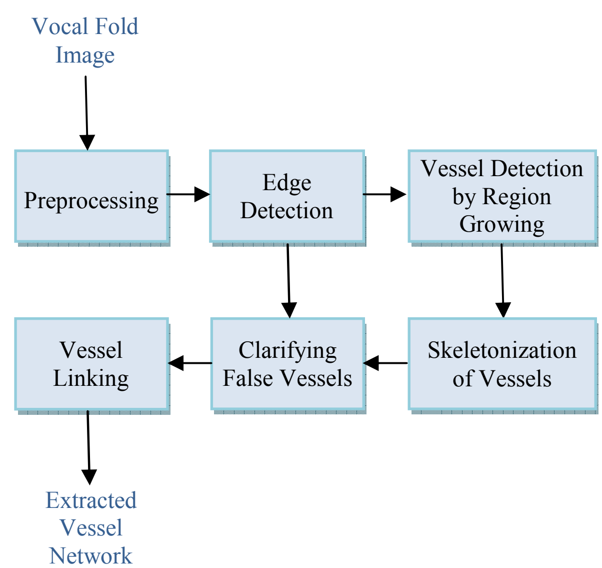

Figure 1: Block diagram of the proposed system

A. *Segmentation Of Glottis*

The first step in the proposed system is segmentation of glottis, the dark area between the vocal folds.

The red, green and blue channels of a vocal fold image are shown in Figure 2. As it can be seen in Figure 2-a, red channel image has the highest contrast between glottis and vocal folds. Therefore, glottis was segmented by applying region growing algorithm on red channel of vocal fold image which was first blurred by Gaussian filter (kernel size=7*7 σ=1.55). Figure 2-d shows the segmentation result.

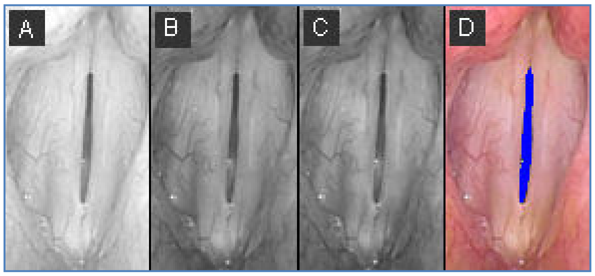

Figure 2: a) red b) green c) blue channels of the vocal fold image d) Segmentation of glottis

B. Vessel Detection By Region Growing

The vessel segments are elongated structures and the area which is a part of the vessels is required to be darker than the background. Brien et. al. proposed a seeded region growing based system that uses these constraints to detect the blood vessels [4]. The center of a d*d sized frame is aligned with a manually determined seed point. The seed point is labeled as a part of vessel in case of the average intensity of the pixels in the frame is greater than the intensity of the seed point. The region is expanded by repeating the test recursively for the neighbors of the seed point.

In this study, Canny Edge Detection [5] method was applied to determine seed points automatically. Blood containing elements such as vessels are best represented and reach higher contrast in the green channel [3]. Thus edge detection applied on green channel of the vocal fold image and edge pixels are used as seed points. Vessels on vocal folds are detected by expanding regions outwards from seed points. The best detection results are achieved where d=29. Edge detection results of Figure 2-b and detected vessels are shown in Figure 3-a and 3-b respectively.

C. Skeletonization and Clarifying False Vessels

Start and end points of blood vessels and calculating vessel direction angles is essential for the assessment of vascular structure.

However the lightening conditions, vocal cord bleeding and pathologies tend to cause false positives in vessel detection. In this study a novel method for eliminating the segments that are not in a fundamental vessel body form is presented. At the first step we obtain vessel skeleton by iterative thinning processes. Then we exploit vessel skeleton and the edges of vocal fold image to clarify the false vessels and to eliminate redundant skeleton branches. Skeleton of detected vessel segment is given in Figure 3-c. False positive vessels and redundant skeleton branches were marked with yellow. False positive elimination procedure was illustrated by the image shown in Figure 4 where black and red lines indicate the skeleton and the vessel edges respectively. Skeleton pixels are labeled as non vessel if one of these conditions is not satisfied;

1) Since the width of the thickest vessels is almost constant for all images taken with same angle and same resolution, we can state that all diameters of vessels in a vocal fold image are less than a parameter maxDiam. The width of the vessel is the distance between the two edges. As illustrated in Figure 4, x and y denote the intersection points of the vessel edges and cross section of the skeleton. Let k and l be the distances of x and y to skeleton respectively, k+l should be less than maxDiam.

2) Two edges of a vessel must always run parallel to each other. Therefore, k and l should be close to each other.

3) The pixels along the cross-section of a vessel have similar intensity values. Let $x_{intensity}$ *and* $y_{intensity}$ *be the green channels of x and y,* $x_{intensity}$ *and* $y_{intensity}$ *should be close to each other.*

Consider two pixels p1 and p2, which lie on skeleton. Pixel p1 is preserved since the three conditions given above are met whereas p2 is eliminated due to condition 1. The result of proposed method and the manually segmented vessel skeletons are given respectively in Figure 3-d and 3-e.

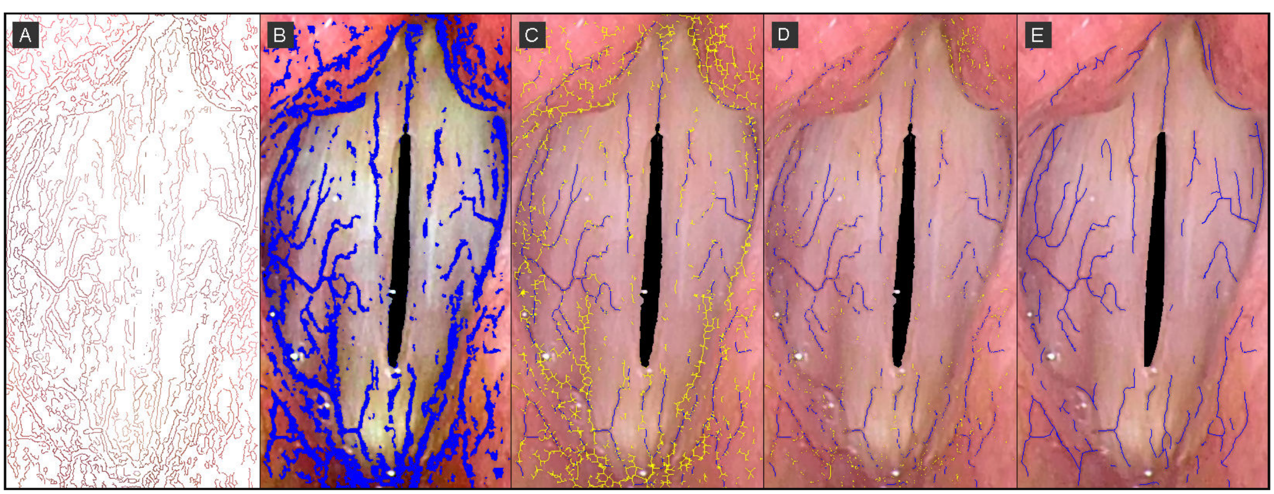

Figure3: a)Detected edges b) Vessel structures c) Skeleton segments d) Result of false positive elimination process e) Manually labeled vessel skeleton segments

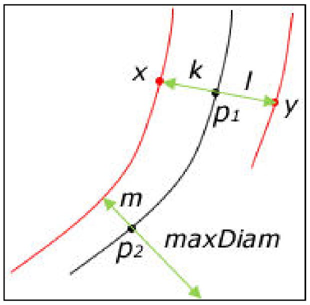

Figure 4: False positive elimination

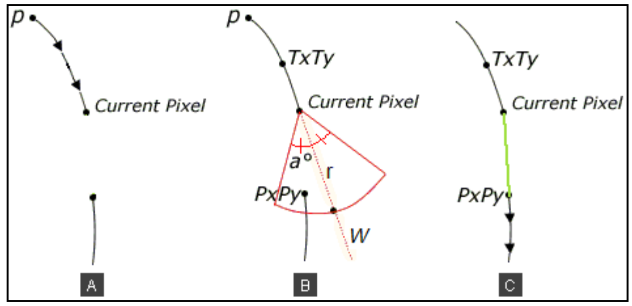

Figure 5: Vessel linking steps

D. Vessel Linking

Since each pixel is classified independently in region growing phase, gaps may occur in the segmented vessels which cause breaks in vessel network. False positive elimination process also may results small gaps on the skeletons of thin vessels. To fix these problems we propose a vessel linking method.

In the proposed system, each unconnected skeleton segment is traced end to end. Let p and CurrentPixel are the starting and ending pixels of a skeleton segment shown in Figure 5-a respectively. The following steps were executed to link the segments that belong to the same blood vessel;

1) We approximate TxTy point on the skeleton by following the path from CurrentPixel to p for n pixels. The strength line passing through point CurrentPixel and TxTy is denoted by W.

2) Let S be a circle sector that denoted by a 4-tuple (CurrentPixel, r, W, 2a), where CurrentPixel is the center, r is the radius, W is the angle bisector and 2a is the central angle, the pixels covered by S are scanned (Figure 5-b). The point PxPy and CurrentPixel were connected and the tracking was continued from PxPy where PxPy is the closest point to the CurrentPixel within S (Figure 5-c).

To be able to fill the gaps with several sizes the vessel linking process was executed with different parameter values iteratively.

The centered circle angle is decreased and radius r is increased for each iteration until no new connections are available. Each skeleton segment is tracked bidirectionally. As a final step, connected component labeling is applied to remove the small skeleton segments. Results of several iterations are shown in Figure 6. The new established connections are shown in green.

E. Results and Observations

We have constructed a database of manually labeled images for evaluation of our proposed method. The database consists of 20 color vocal fold images obtained using electronic videolaryngostroboscopy. 14 of the images belong to patients with sulcus vocalis, scar and polyp. The remaining 6 images belong to control group. 20 manually segmented vessel skeleton images were used as ground truth to evaluate segmentation results. Average sensitivity, accuracy and false positive rate were measured as 0.83, 0.99 and 0.005 respectively. Source images and ground truth images are illustrated in column a and vessel segmentation results are illustrated in column b of Figure 7.

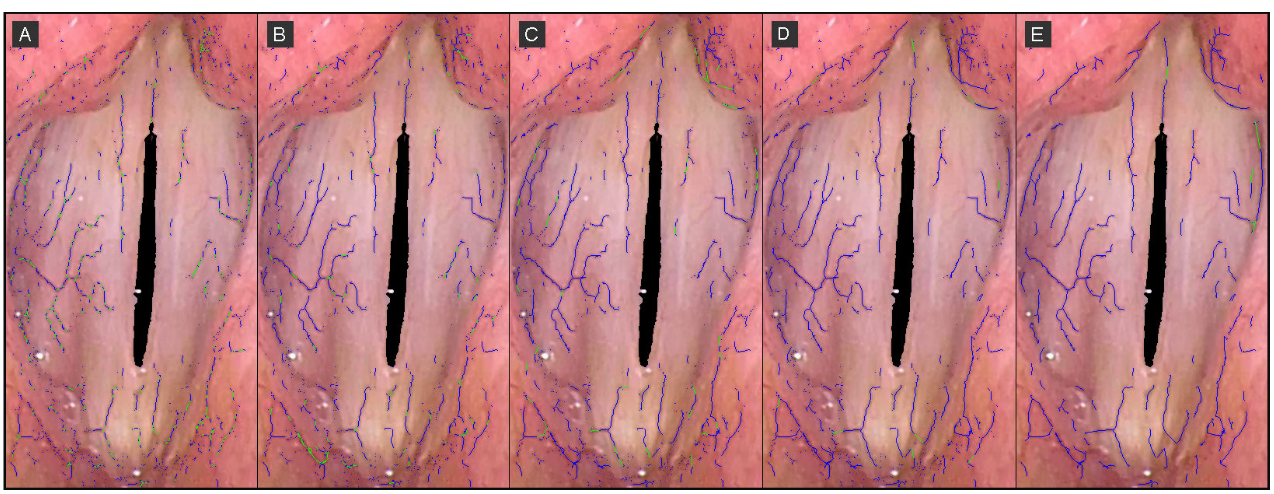

Figure 6: Vessel linking results a) iter. 1: r=5 n=2 a=30 b) iter. 2: r=7 n=3 a=25 c) iter. 3: r=10 n=5 a=20 d) iter. 4: r=15 n=7 a=10 e) iter. 5: r=20 n=15 a=5

In healty vocal folds, blood vessels run parallel to the vibratory margin and are somewhat tortuous. The incidence of transverse vessels was significantly higher in the alterations of vocal folds such as epidermoid cysts and vocal sulci than in the control groups [6].

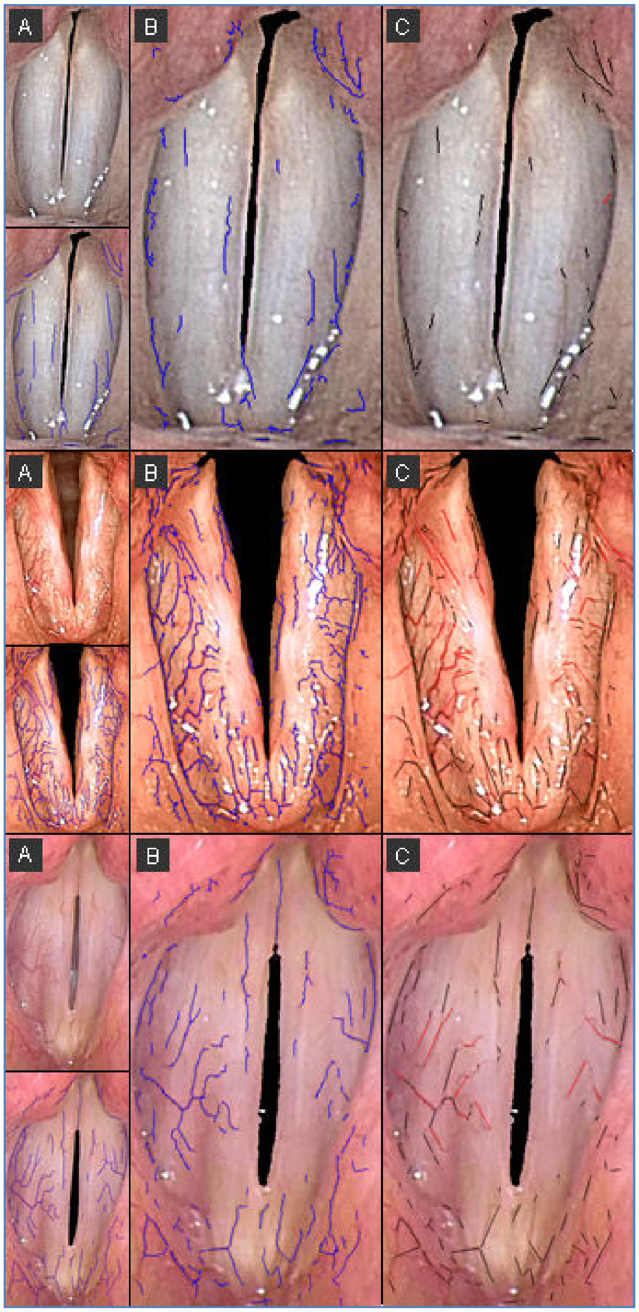

Figure 7: a) Source and ground truth images b) Vessel segmentation results c) Presentation of transverse components by line segments

Vocal fold alterations observed predominantly at middle two-third of the vocal fold, where the mechanical force of vibration is most intense. Therefore, transverse blood vessels which are localized in that part of vocal fold are examined. To express the transverse portion of blood vessels, each vessels skeleton component (each branch of a skeleton segment is defined as a component) is presented by line segment that is bounded by rightmost and leftmost points of it.

The presentation of components by line segments is given in column c of Figure 7 where the red lines indicate the components with lower slope which were localized in middle two-third of the vocal fold. First row of Figure 7 shows a normal vocal fold image while second and third row shows representative examples of scar and sulcus vocalis respectively. Number of components with lower slope is used to determine whether or not there is a vocal fold alteration. Exceeding an experimentally defined threshold refers an abnormal vocal fold. The classification accuracy is measured as 90% for the healthy and altered vocal fold classes.

F. Conclusion

In this article, we propose a novel approach to detect blood vessels on the superior surface of vocal folds and examine vocal fold alterations in conjunction with the blood vessel defects. Studies on vocal fold disorders presented that the incidence of transverse vessels is significantly higher in the alterations of vocal folds. Therefore, changes in horizontal alignment of blood vessels are used for healthy-pathologically altered vocal fold classification. We believe that our system could help the physicians to reveal a direct connection between blood vessels and vocal fold pathologies objectively and aid in the diagnosis of pathologies, which may be difficult to differentiate.

Acknowledgment

This research has been supported by Yildiz Technical University Scientific Research Projects Coordination Department under the grant number 2011-04-01-DOP02.

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