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A Comparison of Blood Vessel Features and Local Binary Patterns for Colorectal Polyp Classification

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ABSTRACT

Colorectal cancer is the third leading cause of cancer deaths in the United States of America for both women and men. By means of early detection, the five year survival rate can be up to 90%. Polyps can to be grouped into three different classes: hyperplastic, adenomatous, and carcinomatous polyps. Hyperplastic polyps are benign and are not likely to develop into cancer. Adenomas, on the other hand, are known to grow into cancer (ademoma-carcinoma sequence). Carcinomas are fully developed cancers and can be easily distinguished from adenomas and hyperplastic polyps. A recent narrow band imaging (NBI) study by Tischendorf et al. has shown that hyperplastic polyps and adenomas can be discriminated by their blood vessel structure. We designed a computer-aided system for the differentiation between hyperplastic and adenomatous polyps. Our development aim is to provide the medical practitioner with an additional objective interpretation of the available image data as well as a confidence measure for the classification. We propose classification features calculated on the basis of the extracted blood vessel structure. We use the combined length of the detected blood vessels, the average perimeter of the vessels and their average gray level value. We achieve a successful classification rate of more than 90% on 102 polyps from our polyp data base. The classification results based on these features are compared to the results of Local Binary Patterns (LBP). The results indicate that the implemented features are not inferior to LBP. Further testing will be done to evaluate combinations of the implemented features and LBP.

Keywords: Colon, CAD development, Classifier design, Feature Extraction

1. INTRODUCTION

Colorectal cancer is the third leading cause of cancer deaths in the United States of America for both women (9% of female cancer victims) and men (8% of male cancer victims). The American Cancer Society has published estimations for 2008 indicating that more than 48,000 Americans (24,500 women and 23,500 men) will die of colorectal cancer in 2008. The same study also predicts more than 143,500 new cases of colorectal cancers (69,000 women and 74,500 men) for 2008 in the United States.

The overall five year survival rate for colorectal cancer is 64%. But statistics also show that with an early detection before the cancer has spread (metastasis), the five year survival rate can be increased to 90%. This highlights the importance of early screening and diagnosis. To this end, endoscopic examinations of the colon (colonoscopy) are conducted to locate lessions on the colon surface.

Polyps can be grouped into three different classes: hyperplastic, adenomatous, and carcinomatous polyps. Hyperplastic polyps are benign and are not likely to develop into cancer. They pose no threat to the patient in terms of cancer. Unless they grow in size dramatically and obstruct the digestive process, hyperplastic polyps should not be removed, since a polyp removal (polypectomy) has a 10% risk of causing severe side effects like bleeding or colon perforation.[1] Adenomas, on the other hand, are known to grow into cancer (ademoma-carcinoma sequence). This takes place in the course of about 10 years. Therefore, adenomas are usually removed

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when found during a colonoscopy. Carcinomas are fully developed cancers and might spread cells when removed by polypectomy. Therefore, they are not removed during colonoscopy but documented for a subsequent surgical removal.

A classical approach for the differentiation between hyperplastic polyps and adenomas is Kudo's method.[2] Magnifying endoscopy and chromatic dye are used to visualize the mucosa pit patterns on the polyp surface (chromoendoscopy). The drawbacks of this method are the spraying of dye prior to polyp inspection and the removal of the dye thereafter. A further complication is the possible staining of the lens. It has to be cleaned from dye before the inspection of the colon can continue.

A recent study by Tischendorf et al.[3] has shown that hyperplastic polyps and adenomas can also be discriminated without using dye. Adenomas are active and growing polyps. To support this growth, adenomas develop blood vessels on their surface (angiogenesis). Hyperplastic polyps show little or no blood vessels on the polyp's surficial area. Tischendorf et al. used narrow band imaging (NBI) to enhance the visibility of blood vessels in their endoscopic studies. NBI uses optical band pass filters to narrow the emitted light spectrum to wave lengths strongly absorbed by blood vessels. Therefore, blood vessels can be clearly identified in NBI images. The results of a visual evaluation show that hyperplastic polyps can be distinguished from adenomas by blood vessel characteristics on the polyp surface with a reliability comparable to Kudo's method.

Based on this study, we developed a computer-aided system for the differentiation between hyperplastic and adenomatous polyps. Our aim is to provide unexperienced medical practitioners with an additional objective interpretation of the available image data as well as a confidence measure for the classification. This can reduce inter-individual and intra-individual variation in interpretation and, thus, stabilize the quality of the diagnosis. We are examining different features and classifiers to increase the performance of our polyp classification algorithm.

The remainder of the abstract is organized as follows. Chapter 2 introduces the polyp classification algorithm while chapter 3 focuses on the classification features used during the implementation phase. LBP are the topic of chapter 4. The results of the comparison between our implemented features and LBP are given in chapter 5. Chapter 6 provides closing remarks and presents prospects for the future.

2. POLYP CLASSIFICATION ALGORITHM

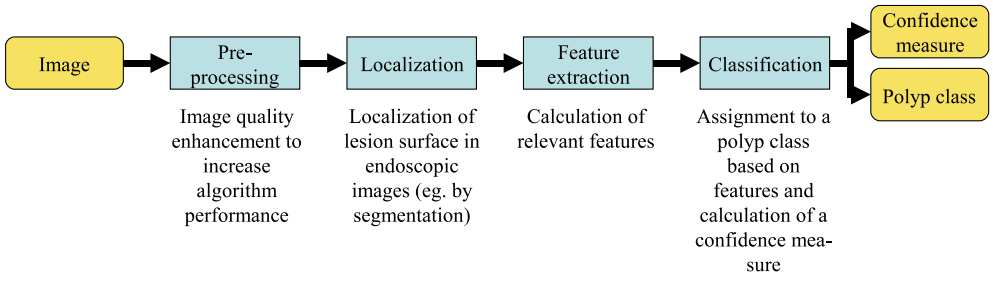

Figure 1. Successive steps of our polyp classification algorithm.

The block diagram of the polyp classification algorithm is shown in fig. 1. The algorithm aims to classify a polyp by analyzing the blood vessels structure on the polyp surface. We choose the green color channel as it exhibits the best contrast for blood vessels.[4] The first step is image preprocessing which includes noise filtering with a 3x3 median filter and contrast enhancement by local background equalization. Also, specular reflections on the wet polyp surface are removed.[5]

Since only parts of the image are showing polyp surface and, therefore, only those are to be included in the feature calculation and classification, the second algorithm step is polyp localization. This is currently done manually, but we are working on a semi- or even fully automatic solution.

Feature extraction is the third step in the polyp classification algorithm. Features are used to reduce the amount of data in the classification process. Characteristic properties of the data are singled out and used for classification instead of the full original data. Blood vessels on the polyp surface are the dominant visual

indication for the differentiation between adenomas and hyperplastic polyps under NBI illumination.[3] Therefore, we expected features extracted from blood vessel segmentation to perform well in colorectal polyp classfication. To this end, we enhance the image contrast and apply Kovesi's features from phase asymmetry[6] to the polyp surface. The detected structures are thinned out by a skeletonization algorithm and used as seed points for the subsequent fast marching algorithm.[7] Three features we developed together with our research group's medical experts in colonoscopy are extracted from the binary outcome of the fast marching. These features will be the focus of sec. 3 and compared to LBP in sec. 5.

The final step in the algorithm is the classification using a k-Nearest-Neighbour classifier. The number of neighbours ranged form 1 to 11.

3. BLOOD VESSEL FEATURES

There are currently three implemented features used in the classification of the algorithm:

- The number of pixels in the skeletonized vessel tree (seeds for fast marching). This is interpreted as the overall length of the detected blood vessels.
- The average perimeter of the vessels located by the fast marching algorithm.
- The average gray level value at the seed points used in the fast marching algorithm. We expect the values to be relatively dark for adenomas and lighter for hyperplastic polyps as blood vessels usually have a high contrast for adenomas.

We conducted our initial tests with these features, but are now moving to improve the performance of the classification algorithm. In sec. 4 we will introduce LBP as an alternative to our features. Our comparison results will be presented in sec. 5.

4. LOCAL BINARY PATTERNS

LBP[8] present a very simple, yet powerful way of texture analysis. The aim is to approximate the joint propability of neighborhood greylevel distributions. To this end, the neighborhood of each pixel in the texture is analyzed. Possible neighborhoods consist of 8, 16, or 24 pixels, but during our explanation we focus on the 8 pixel neighborhood. The value of the center pixel is subtracted from the values of the surrounding pixels. The result is eight values between -255 and 255 stored in a vector. Now a thresholding operation quantizes all negative values to 0 and all positive values to 1. The resulting eight-dimensional vector can be interpreted as a binary code. A histogram composed of all codes extracted from an image patch can be used to characterize its texture.

One of the available extensions to LBP yields rotation invariance. This is achieved by bit-shifting the LBP codes, which are essentially binary numbers. Each code is shifted until the resulting number is the lowest possible. This ensures that every code without regard for its (quantized) rotation is interpreted equally. The number of bins in the histogram from reduced from 256 (8 bit) to 36.

A second extension is used to further decrease the number of bins by combining similar patterns in a single bin. There are patterns with similar appearances but binary codes that vary even after the rotation invariance has been applied. Therefore, the histogram bins of these patterns can be added up to further reduce the amount of data to be handled. The rotation invariant and uniform LBP approach results in a 10 bin histogram. Rotation invariance and uniformity extensions can be combined in a single lookup table for a fast implementation.

5. RESULTS

We took 102 polyp images from our polyp data base, which is regularly extended and combined with histological ground truth data by our research team's clinical experts. These 102 images were masked to remove all pixels not part of the polyp surface. The resulting images were enhanced and preprocessed as described above. We applied the phase symmetry filter, the skeletonization and the fast marching algorithm to obtain the segmented blood vessel lumen.

The LBP approach generated a histogram for each of the 102 polyps. All LBP histograms have to be normalized as the size of the polyp surface on the images varies. We ignored the bin containing the empty patterns (00000000_2), as they carry no information on the blood vessels, and normalized the remaining bins.

Table 1. Classification results for blood vessel features and LBP. (ri - rotation invariant LBP, riu - rotation invariant uniform LBP, 8 - information from eight pixel neighbourhood, 16 - information from sixteen pixel neighbourhood, 8+16 - combined information from eight and sixteen pixel neighbourhoods, k - number of closest results interpreted for kNN classifier)

	Proposed features	ri 8	ri 16	ri 8+16	riu 8	riu 16	riu 8+16
k = 1	0.82 %	0.77 %	0.87 %	0.88 %	0.80 %	0.86 %	0.86 %
k = 3	0.84 %	0.84 %	0.87 %	0.87 %	0.85 %	0.88 %	0.87 %
k = 5	0.89 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %
k = 7	0.89 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %
k = 9	0.90 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %
k = 11	0.90 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %	0.87 %

The resulting feature vectors are used in a one-against-all scenario using a nearest-neighbor (k-NN) classifier. We tested LBP with 8, 16, and 8+16 neighborhood in combination with rotation invariant and rotation invariant uniform patterns. The results in tab. 1 show, that our proposed features outperform the LBP with a rising number of neighbors regarded in the nearest-neighbor classifier. For a small number of neighbors, LBP seem to perform superior to our features.

6. CONCLUSION

The performance of the blood vessel feature matches the previous test with 56 polyps. We achieved 90% correct classification rate. The results indicate that LBP are no straight replacement for our implemented features. In the final version of the paper, we will investigate combinations of features created from LBP and our features. Moreover, we will further increase the number of polyps in the tests.

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