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Methods for Polyp Detection in Colonoscopy Videos: A Review

Technical Report

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Abstract – Colonoscopy is one of the best methods for screening colon cancer. As the automatic detection of polyps in endoscopic images is a challenging task for image processing, a variety of research groups have proposed methods that try to fulfill this task to develop a system which supports the doctors during examination. However, the problem is still – at least partially – not solved. This paper gives a summary of 16 different polyp detection methods published in the last ten years. We found out that the major drawback of many approaches is the lack of representative video data, which hinders comparison and evaluation of the published methods.

1 Introduction

Colon cancer is one of the leading causes of cancer death worldwide [Wor06]. Colonoscopy is the accepted gold standard for detecting colon cancer or its precursor lesions, colorectal polyps. The removal of adenomatous polyps has been shown to prevent most cancer. Although colonoscopy has become the preferred method of screening colon cancer, several studies showed that it contains an inherent miss rate of up to 25% for the detection of polyps and cancer [Lie05, BPV$^+$04, TAR07].

This alarming statistic emphasizes the demand for computer systems supporting the doctors during examination. Two main causes that lead to misses can be distinguished:

1. The endoscopist does not cover all parts of the colon (parts remain "unseen" by the camera),

2. the polyp appears on the screen but remains undetected by the doctor.

The first error is hard to tackle with computer systems, as it adresses 3D-reconstruction of non-rigid shapes from only one camera. To address the second type of errors, so-called CADx-systems (Computer Assisted Diagnosis) are needed that compare conspicuous structures to a database of structures that yet have a diagnose. Most work has been done on the third problem, the Computer Aided Detection (CADe) or on combined CADx/CADe-systems. Our work focusses on polyp *detection*, on CADe systems.

2 Theory

A general approach in developing a system for automatic detection of colorectal polyps and cancer is as follows: At first colonoscopic images or videos containing normal and abnormal cases are needed. In addition to that, ground truth information that labels the abnormalities is necessary. Extracted feature-data from the images are used to train a classifier which should be tested on a different set of images. Good classification results depend on the selection of appropriate features that characterize polyps and cancer to distinguish between abnormal and healthy areas within an image. Training and testing of classifiers should be based on huge sets of images showing different polyps, due to the high diversity of their appearences.

3 Review of Polyp detection methods

Different approaches have been proposed in literature for computer-aided detection of colon cancer and polyps in endoscopic images. Serveral features were used by these methods analysing shape, texture, and colour of the colon. Besides Support Vector Machines (SVM), Neural Networks (NN) were the most common technique used for classification. In the following we give a review of the methods we found in the literature. This overview is summarized in Table 1.

3.1 Shape-based methods

Krishnan et al. presented a method to detect abnormalities through curvature analysis. Edge detection is performed to extract contours, which are smoothed afterwards to make them suitable for curvature computation [KYC+98].

A similar approach by Hwang et al. is based on the elliptical shape that is common for nearly all small colon polyps. It is observed whether elliptical shapes fit into segmented regions by utilizing a watershed-based image segmentation and ellipse fitting algorithms. New techniques are proposed to distinguish the ellipses of polyp regions from those of non-polyp regions by matching curve direction, curvature, edge distance, and intensity [HOT+07].

The techniques adopted by Dhandra et al. are based on segmentation of colour endoscopic images in HSI colour space followed by morphological watershed segmentation [VS91]. The output of the process indicates whether the endoscopic image is normal or abnormal based on the numberof watershed regions present in the image [DHHM06].

Kang et al. proposed a real-time image processing system for endoscopic applications. After detecting edges using the Canny-operator [Can86], a morphological operation is employed to thicken the edges and connect disjoint edges that are closer together. The emerging segments are classified as either a polyp or a non-polyp by extracting three features: area size, colour and shape [KD03].

3.2 Texture-based methods

Wang et al. developed a method for classification of endoscopic images based on texture and Neural Networks. The Local Binary Pattern [Mäe03] describes the spatial structure of local texture. Combining this pattern with average intensity leads to a two-dimensional histogram. A self-organizing map is applied for the classification process [WKKT01].

Li et al. proposed to represent the image regions using multi-size patches simultaneously. The features extracted from these image patches include the means and standard deviations of the absolute value of the approximating and detail coefficients from a two-level Discrete Wavelet Transform decomposition of the image patches in the three channels of *CIE-Lab* colour space. Other features include one-dimensional histograms of luminance L and two-dimensional histograms of the a and b components. An ensemble is constructed based on a set of individual Support Vector Classifiers to categorise patches as normal or abnormal [LCK05].

Tjoa et al. extract different statistical measures from the texture spectra in the chromatic and achromatic domains. Furthermore, colour features for a selected region of interest from each colour component histogram are extracted. The feature vector's dimension is reduced using Principal Component Analysis. For evaluation, Backpropagation Neural Networks are used [TK03].

Alexandre et al. presented a method subdividing each image into small subimages with a fixed size of 40×40 pixels. The used features are RGB-values and coordinates of each pixel. As Support Vector Machines are able to deal with high-dimensional input spaces, learning and classification is performed on this raw data sets [ACN07].

Coimbra et al. are investigating the potential of selected MPEG-7 descriptors for event detection (such as polyps) in colonoscopic images. Some of the used features among others are: color structure, homogenous texture and scalable colour [CC06].

Karkanis et al. proposed a scheme based on features extracted from the Grey-Level Co-occurrence Matrix (GLCM). To distinguish between normal and cancer regions a multilayer feedforward neural network is employed [KMGS99]. The same GLCM-features were used by Magoulas et al. and different learning and classification techniques were investigated [MPV01, MPV04, MPTV04]. An extension proposed by Karkanis et al. based on GLCM-features and discrete wavelet transform [KIKM01] was implemented in CoLD (colorectal lesions detector) [MIKK03]. Another extension by Karkanis et al. utilizes covariances of the GLCM-features calculated over the wavelet frame transformation of different colour bands. This approach using colour wavelet covariance is supported by a linear discriminant analysis (LDA) procedure for the characterization of the image regions [KIM$^+$03].

Iakovidis et al. presented different approaches, all based on features computed from subimages and tested on several colour spaces. The used features include wavelet energy, colour wavelet energy, wavelet correlation signatures, local binary pattern and opponent colour-local binary pattern. Support Vector Machines handle the classification of the feature vectors computed from every single subimage [IMK06].

Maximizing the use of available detection methods, Zheng et al. presented a fusion-based decision support system [ZKT05].

4 Discussion

To provide an overview of all mentioned methods, the main aspects are summarized in table 1. Additionaly, a column *datasets* describes the data used for demonstrating or testing the methods in the corresponding approach.

According to literature, the mentioned methods achieved good classification results. However, the expressiveness of these results can be called into question due to the fact, that the sample sets used for testing and training were relatively small, except for a few cases (cf. results of [SMWM08]). A reliable classification system should be based on a huge set of images containing many different types of abnormalities. Beyond quantity, the quality is an important factor. In future, high definition colonoscopy will be standard. We think that a classifier trained with less than hundred images at VHS-resolution or even lower cannot detect cancer and poylps in a way that meets the requirements of a clinical system.

5 Conclusion

In this paper we presented an overview of colon polyp detection approaches proposed by several research groups. The major problem is the lack of a representative database to evaluate and compare the available methods.

References

[ACN07] Luís A. Alexandre, João Casteleiro, and Nuno Nobre. Polyp detection in endoscopic video using svms. *11th European Conference on Principles and Practice of Knowledge Discovery in Databases*, pages 358–365, 2007.

[BPV+04] Brian Bressler, Lawrence F. Paszat, Christopher Vinden, Cindy Li, Jingsong He, and Linda Rabeneck. Colonoscopic miss rates for right-sided colon cancer: a population-based analysis. *Gastroenterology*, 127(2):452–456, 2004.

[Can86] John Francis Canny. A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 8(6):679–698, 1986.

Research Group	*Method / Features*	*Feature Class*	*Classifier*	*Datasets (# images, resolution)*	*Literature*
Krishnan et al.	curvature analysis	shape	-	2 normal and 4 abnormal images	[KYC+98]
Hwang et al.	curve direction, curvature, edge distance, intensity	shape, colour	-	27 polyp shots	[HOT+07]
Dhandra et al.	number of regions after morphological watershed segmentation	shape, colour	-	50 normal and 50 abnormal images	[DHHM06]
Kang et al.	area, colour and shape of segments	shape, colour	-	-	[KD03]
Wang et al.	Local Binary Pattern, intensity	texture, colour	NN	3 images	[WKKT01]
Li et al.	Wavelet coefficients, Lab histograms	texture, colour	SVM	12 normal and 46 abnormal images, 256 × 256 pixels	[LCK05]
Tjoa et al.	texture spectrum, colour histograms	texture, colour	NN	12 normal and 54 abnormal images	[TK03]
Karkanis et al.	GLCM-features	texture	NN	2, 10, 4, 2	[KMGS99] [MPV01] [MPV04] [MPTV04]
Karkanis et al.	GLCM-features, Wavelets	texture	NN	8 images containing a polyp, 512 × 512 pixels	[KIKM01]
Karkanis et al.	Colour Wavelet Covariance	texture, colour	LDA, SVM	1380, 15000 images, 320 × 240 pixels	[KIM+03] [IMK06]
Iakovidis et al.	Wavelet Energy	texture	SVM	15000 images, 320 × 240 pixels	[IMK06]
Iakovidis et al.	Colour Wavelet Energy	texture, colour	SVM	15000 images, 320 × 240 pixels	[IMK06]
Iakovidis et al.	Wavelet Correlation Signatures	texture, colour	SVM	15000 images, 320 × 240 pixels	[IMK06]
Iakovidis et al.	Local Binary Pattern	texture	SVM	15000 images, 320 × 240 pixels	[IMK06]
Iakovidis et al.	Opponent Colour–Local Binary Pattern	texture, colour	SVM	15000 images, 320 × 240 pixels	[IMK06]
Alexandre et al.	RGB-values and coordinates of each pixel	-	SVM	35 images, 514 × 469 pixels	[ACN07]
Coimbra et al.	MPEG-7 descriptors	texture, colour	-	899 images	[CC06]

Table 1: Overview of different polyp detection approaches. Meanings of the abbreviations in column 'Classifier' are: NN = Neural Network, SVM = Support Vector Machine, LDA = Linear Discriminant Analysis

[CC06] M.T. Coimbra and J.P.S. Cunha. Mpeg-7 visual descriptors contributions for automated feature extraction in capsule endoscopy. *IEEE Transactions on Circuits and Systems for Video Technology*, 16(5):628–637, 2006.

[DHHM06] B. V. Dhandra, Ravindra Hegadi, Mallikarjun Hangarge, and V. S. Malemath. Analysis of abnormality in endoscopic images using combined hsi color space and watershed segmentation. *Proceedings of the 18th International Conference on Pattern Recognition*, 4:695–698, 2006.

[HOT+07] Sae Hwang, JungHwan Oh, Wallapak Tavanapong, Johnny Wong, and Piet C. de Groen. Polyp detection in colonoscopy video using elliptical shape feature. *International Conference on Image Processing*, (2):465–468, 2007.

[IMK06] D.K. Iakovidis, D.E. Maroulis, and S. A. Karkanis. An intelligent system for automatic detection of gastrointestinal adenomas in video endoscopy. *Computers in Biology and Medicine*, 36(10):1084–1103, 2006.

[KD03] J. Kang and R. Doraiswami. Real-time image processing system for endoscopic applications. *IEEE Canadian Conference on Electrical and Computer Engineering*, 3:1469–1472, 2003.

[KIKM01] S. A. Karkanis, D. K. Iakovidis, D. A. Karras, and D. E. Maroulis. Detection of lesions in endoscopic video using textural descriptors on wavelet domain supported by artificial neural network architectures. *IEEE International Conference on Image Processing*, pages 833–836, 2001.

[KIM+03] S. A. Karkanis, Dimitrios K. Iakovidis, Dimitrios E. Maroulis, Dimitris A. Karras, and M. Tzivras. Computer-aided tumor detection in endoscopic video using color wavelet features. *IEEE Transactions on Information Technology in Biomedicine*, 7(3):141–152, 2003.

[KMGS99] S. A. Karkanis, G. D. Magoulas, M. Grigoriadou, and M. Schurr. Detecting abnormalities in colonoscopic images by textural description and neural networks. *Proceesings of Workshop on Machine Learning in Medical Applications, Advance Course in Artificial Intelligence*, pages 59–62, 1999.

[KYC+98] S. M. Krishnan, X. Yang, K. L. Chan, S. Kumar, and P. M. Y. Goh. Intestinal abnormality detection from endoscopic images. *Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2:895–898, 1998.

[LCK05] P. Li, KL Chan, and SM Krishnan. Learning a multi-size patch-based hybrid kernel machine ensemble for abnormal region detection in colonoscopic images. *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2, 2005.

[Lie05] David Lieberman. Quality and colonoscopy: a new imperative. *Gastrointestinal Endoscopy*, 61(3):392–394, 2005.

[MIKK03] D. E. Maroulis, D. K. Iakovidis, S. A. Karkanis, and D. A. Karras. Cold: a versatile detection system for colorectal lesions in endoscopy video-frames. *Computer Methods and Programs in Biomedicine*, 70(2):151–166, 2003.

[MPTV04] G. D. Magoulas, V. P. Plagianakos, D. K. Tasoulis, and M. N. Vrahatis. Tumor detection in colonoscopy using the unsupervised k-windows clustering algorithm and neural networks. *Fourth European Symposium on Biomedical Engineering*, 2004.

[MPV01] George D. Magoulas, Vassilis P. Plagianakos, and Michael N. Vrahatis. Improved neural networkbased interpretation of colonoscopy images through on-line learning and evolution. *European Network of Excellence on Intelligent Technologies for Smart Adaptive Systems*, pages 38–43, 2001.

[MPV04] George D. Magoulas, Vassilis P. Plagianakos, and Michael N. Vrahatis. Neural network-based colonoscopic diagnosis using on- line learning and differential evolution. *Applied Soft Computing*, 4(4):369–379, 2004.

[Mäe03] T. Mäenpää. The local binary pattern approach to texture analysis–extensions and applications. 2003. Dissertation, University of Oulu.

[SMWM08] N. Shevchenko, S. Mühldorfer, T. Wittenberg, and C. Münzenmayer. Untersuchung von Texturanalysemethoden zur automatischen Polypenerkennung. In *7. Jahrestagung der Deutschen Gesellschaft für Computer- und Roboterassistierte Chirugie e. V., Tagungsband*, pages 205–206, 2008.

[TAR07] Alan Thomson, Dennis Ahnen, and John Riopelle. Intestinal polypoid adenomas. *eMedicine, The Continually Updated Clinical Reference*, 2007.

[TK03] Marta Tjoa and Shankar Krishnan. Feature extraction for the analysis of colon status from the endoscopic images. *BioMedical Engineering OnLine*, 2(1):9, 2003.

[VS91] Luc Vincent and Pierre Soille. Watersheds in digital spaces: An efficient algorithm based on immersion simulations. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 13(6), 1991.

[WKKT01] P. Wang, S. M. Krishnan, C. Kugean, and M. P. Tjoa. Classification of endoscopic images based on texture and neural network. *Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 4:3691–3695, 2001.

[Wor06] World Health Organization. Fact sheet no 297: cancer. *WHO Media Centre Fact Sheets*, 2006.

[ZKT05] M. M. Zheng, S. M. Krishnan, and M. P. Tjoa. A fusion-based clinical decision support for disease diagnosis from endoscopic images. *Computers in Biology and Medicine*, 35(3):259–274, 2005.

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