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SMART VISION CHIP FOR COLON EXPLORATION

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Abstract—In this article, we present our work on our processing chain to realize a Wireless Capsule Endoscopy (WCE) including a Smart Vision Chip (SVC). We obtain a sensitivity of 74.87% and a specificity of 88.31% on a large database, that we have constructed, composed of 18910 images containing 3895 polyps from 20 different video-colonoscopies.

I. INTRODUCTION

Colorectal cancer is the second more common type of cancer and the second death cause by cancer around the world with a death rate of 51.03%, with more incidence in developed countries (60.80%) [5]. It is a real public health problem with 694000 deaths in 2012 [5], [3]. For this type of cancer, an early testing policy with a high degree of compliance is a big part of the solution, it is treatable in 90% of the cases if it is detected earlier before polyp become adenocarcinoma [1].

To perform the detection of polyps, colonoscopy is the gold standard but it is an invasive method where an anesthesia, a specialist and a controlled environment are necessary. It has shortcoming and risks as perforations, infections and not allow the visibility of all the regions near the colon.

To overcome these shortcomings, WCE¹ was introduced by Paul Swain and developed since 2000 [7]. This autonomous medical device has opened up a new world of diagnosis for the gastroenterologists. It is a simple pill that the patient swallows and that transmits images of the gastrointestinal tract via a Radio Frequency communication through the body. But WCE presents some limitations:

- a low image resolution compared to standard colonoscopy, image size in WCE is 320x320 compared to those of colonoscope that are higher than 1920x1080;
- a large amount of unnecessary transmitted images, WCE transmits more than 50000 images with a majority without pathologic pattern;
- a limited energy budget that limits examination around 8 hours only, that is not sufficient to inspect the total intestinal tract because the minimal time required to traverse all the digestive tract is 12 hours.

The goal is to give a WCE the capacity to detect the polyps inside the colon. We need to take into account all non functional constraints of an embedded system : real time execution, energy budget, limited area.

To reduce the time to analyse the images produced by WCE, several automatic recognition algorithms to detect

polyps were introduced [6]. These algorithms are running on an external computer and contribute to help the physician to realize his diagnosis. We can see the performances of the state of the art of these algorithms in table I. We can notice that the most performant results were obtained with small amounts of images in the database. We can also argue, as it is highlighted in [6], that the true sensitivity is difficult to determine due to the lack of an adequate gold standard.

Although these algorithms help the physician and can limit the errors in human interpretation, they are not sufficient to increase the autonomy of the WCE, the resolution of the images and are not designed to be integrated inside a WCE, except the methods in table II.

We propose a new paradigm of WCE. Its originality is to integrate a SVC² inside the WCE[14]. to give it the capability of recognizing a polyp in situ. With this quality, a WCE can transmit only suspicious images in order to reduce their number, increasing its autonomy and providing opportunities to increase the image resolution.

Our method is inspired from the psychovisual two phases methodology used by a physician when doing an colonoscopic examination:

- 1) first phase is the selection of the regions of interest (ROI) is done using shape features.
- 2) second phase is the polyp detection in a ROI and the follow-up of this ROI.

Based on this methodology, we propose a five stages method: pre-processing, ROI selection, ROI follow-up, ROI description and ROI classification, see figure 1.

Stages of our method are:

- 1) **Pre-processing stage:** we prepare the image to be processed, we convert each RGB image model into a brightness model. If any previous ROI was validated as *class1* in the last image, we continue with the stage 3, otherwise we continue with stage 2.
- 2) **ROI selection stage:** we select suspect regions that could contain a polyp. Each region is considered as a ROI, we look for circular/elliptical shapes in the image using the Circle Hough Transform [9], [8], [13], [12]. We continue with the stage 4.
- 3) **ROI follow-up stage:** we follow each ROI that has been validated as *class1* in the last images. Then we integrate a motion estimation method (Matching Block) to determine where this ROI should be. This ROI will be our new selected ROI.
- 4) **ROI description stage:** we extract 26 texture and luminosity descriptors calculating with a co-occurrence

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¹Wireless Capsule Endoscopy

²Smart Vision Chip

TABLE I
STATE OF THE ART OF AUTOMATIC METHODS TO DETECT POLYPS.

Authors	No. Images / (polyps)	Source of images	Segmentation Method	Sensitivity %	Specificity %	Accuracy %
Kodogiannis, 2007[10]	140 / (70)	WCE	Local Binary Pattern	97.1	94.3	NA
Karargyris & Bourbakis, 2011[9]	50 / (10)	WCE	Log Gabor Filters	96.2	70.2	NA
Li & Meng, 2011[11]	1200 / (600)	WCE	Uniform LBP	NA	NA	91.6
Bernal, 2012[2]	300 / (300)	colonoscopy	Watersheds	89.0	98.0	97.0
David et al., 2013[4]	30540 / (540)	colonoscopy	Color Based	80.0	65.0	NA
Mamonov & Figueiredo, 2014[12]	18968 / (230)	colonoscopy	Geometrical Processing	81.0	90.0	NA

TABLE II
STATE OF THE ART OF AUTOMATIC METHODS TO DETECT POLYPS .

Authors	No. Images / (polyps)	Source of images	Segmentation Method	Sensitivity %	Specificity %	Accuracy %
Romain, Aymeric, Silva, Granado et Pinna, 2013[13]	1500 / (300)	colonoscopy	Hough Transform	91.0	95.2	NA
Graba, kolar et Ayoub, 2013[4]	100 / (100)	Prototypes de polypes	Color Based	95.0	96.0	NA

matrix for each ROI. The texture and luminosity are the important descriptors to recognize and discriminate polyps [13].

- 5) **ROI classification stage:** a fuzzy-forest using Zadeh operators is used to classify and validate each ROI as one containing a polyp or not. We restart from the stage 1 for the next image.

Our method has two important approaches:

- With ROI follow-up stage, we can follow a ROI containing a polyp once it is detected, that reduce the number of ROI processed per image and reduce the number of false positives.
- With a fuzzy logic classification, we can aggregate the response of multiple classifiers (as a fuzzy-forest) and have a robust response. Also we can use many classes which allows us to construct specialized classifiers for each type of polyp.

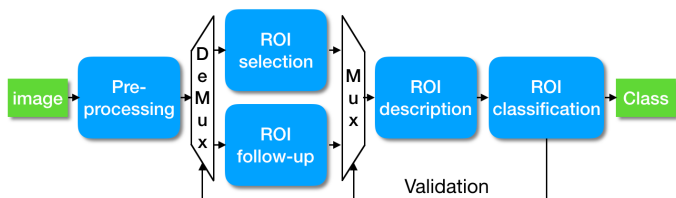


Fig. 1. Proposed system scheme of polyps detection.

II. RESULTS

We test our algorithm on one set of 20 video-colonoscopy frames of which 10 containing a polyp [15], in total 9894 frames with 8010 containing a polyp validated, each frame with a resolution of 1920x1080 pixels. From the 20 video-colonoscopy frames we have obtained a dataset composed by 131038 ROI (3856 ROI containing a polyp). We have

built 50 learning datasets composed by 4628 ROI where 50% containing a polyp. A test dataset was built. In total 50 fuzzy trees are constructed from these learning datasets.

The results of the selection performance and classification performance are shown in table III. In these results, we call selection the selection of a suspicious region and we call classification the recognition of a polyp inside a suspicious region.

TABLE III
PERFORMANCE OF POLYPS DETECTION.

Metric	Dataset 1
Number of frames	18910
Number of frames with a polyp	5391
Resolution of frames [pixels]	1920x1080
Sensitivity of selection [%]	56.93
Precision of selection [%]	4.77
Number of ROI selected per image	11
Sensitivity of classification [%]	74.87
Specificity of classification [%]	88.31
Precision of classification [%]	29.92
Accuracy of classification [%]	87.47
F1-score of classification [%]	42.75

III. CONCLUSIONS

We have proposed a processing chain to detect polyp inside the colon with a sensitivity of 74.87% and a specificity of 88.31%. Now we need to integrate it in an integrated system inside a WCE, we need to conceive a SVC that integrates the proposed processing chain taking into account all the non-functional constraints related to the application in real time, limited energy and surface, in a first time we developed our image processing method to arrive at a good detection performance.

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