A Knowledge-based System for the Computer Assisted Diagnosis of Endoscopic Images

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Abstract. Due to the actual demographic development the use of Computer-Assisted Diagnosis (CAD) systems becomes a more important part of clinical workflows and clinical decision making. Because changes on the mucosa of the esophagus can indicate the first stage of cancerous developments, there is a large interest to detect and correctly diagnose any such lesion. We present a knowledge-based system which is able to support a physician with the interpretation and diagnosis of endoscopic images of the esophagus. Our system is designed to support the physician directly during the examination of the patient, thus prodving diagnostic assistence at the point of care (POC). Based on an interactively marked region in an endoscopic image of interest, the system provides a diagnostic suggestion, based on an annotated reference image database. Furthermore, using relevant feedback mechanisms, the results can be enhanced interactively.

1 Introduction

1.1 Background

Every year more than 4000 people in Germany are diagnosed with esophageal cancer. Although that is only a small number of all cancers (2%) diagnosed, there is a big interest to detect esophagus cancer at an early stage. The prediction for this cancer shows that more than 80% of all men diagnosed with esophagus cancer will not survive the first five years after the first diagnosis [1]. Thus it can be pointed out that this type of cancer has one of the worst prediction rates. Therefore, it is of the highest importance to detect any change of the esophagus tissue surface as early as possible. The standard diagnosis process for the esophageus is based on an visual examination of the esophagus, cardia and corpus tissues, usually by the use of video tip-chip endoscopes. During the examination the physician interprets the acquired images delivered by the endoscope and shown on a high-resolution monitor. The interpretation is not an easy task, since small variations and changes of the tissue are not unusual. But not all changes are related to a dysplastic or a cancerogenous changes of the mucosa. Therefore we have designed and built a system to support the physician with the interpretation of endoscopic images during the examination process by presenting him a second opinion in an easy and intuitive way at the point of care (POC).

1.2 State of the Art

Computer-Assisted-Diagnosis (CAD) systems support the physician with the interpretation of complex image data acquired from modalities such as CT, MRI, Mammography or Endoscopy. Such CAD systems might become a very important part of clinical workflows and clinical decision making processes for several reasons. First, the use of a CAD system provides an objective second opinion without the need for a second physician. This can save costs as well as time. Secondly, in contrast to physicians, CAD systems will always provide a constant quality for the decision support. Finally, CAD systems can use multimodal knowledge databases which can comprise more information than any physician could ever keep in mind.

Due to the fact that CAD systems for digital endoscopy are currently hardly known in clinical routine, not much literature can be found. Tjoa and Krishnan [2] have suggested an image processing system for the automatic detection and classification of lesions in the colon. Illgner et al [3] presented a method to distinguish between normal and dysplastic taypes of tissue on the vocal folds based on color extended GLCM features. Karkanis et al. [4] as well as Maroulis et al. [5] have proposed methods based on combined color and texture analysis for the the classificaion of polyps in the colon. For that purpose Karkanis et al. have applied color wavelet features. Ji et al [6, 7] have suggested a new set of texture primitives to describe the tissue of the cervix acquired by colposcopy.

2 Material and Methods

The proposed system is based on a knowledge database. This reference database currently contains 482 images of the esophagus, cardia and corpus tissue, obtained from over 60 cases. In these images 482 regions of interest have been marked and classified by clinical experts. All findings and classifictions have been confirmed by a histological biopsy. To compute the features for all marked regions, we use statistical geometrical features [8] and second order textual statistics [9] in color extensions suggested by [10]. These algorithms simultaneously extract spatial (textural) and spectral (colour) information of every region of interest to form a combined feature vector. This feature vector is computed for every annotated region in the image data set, and the complete set of feature vectors is stored in the knowledge database.

The CAD system is designed in such way to enable the physician to interactively mark a region of interest (ROI) on a touch screen while he is examining the patient. After a lesion has been marked as a region of interest, the corresponding feature vector for this ROI is computed automatically. Then the feature vector

Table 1. Confusion matrix and classification rates for the diagnosis of lesions in the eosophagous

true	Corpus	Epithelium	Barett's	$\sum$	%
Corpus	145	2	31	178	81
Epithelium	10	172	0	182	95
Barett's	29	0	94	122	76
$\sum$	184	174	124	482	85

is classified based on the knowledge database, using a kNN classifier. The classifier searches for the k nearest neighbours in the complete database to form a result. The images and lesions related to the k closest neighbours in the database are shown in order of their distance on the screen. The physician has now the possibility to influence the presented results interactively using relevance feedback [11]. From several relevance feedback algorithms available, we have chosen a *Query-Point-Movement* and have used the *Rocchio* formula:

$$q_i = \alpha q_i + \beta v_r \tag{1}$$

where q_i denotes the feature vector of the input image and v_r the avarage sum of all *relevant* reference images. After the physician has assessed the relevance of all reference images, the system re-computes the distances to the reference vectors and re-shows a new result.

To support the clinical workflow, the CAD- system consists additionally of a touchscreen and a footbutton to enable the physician to use the system while examining the patient.

3 Results

We have created a knowledge-based system for the Computer-Assisted-Diagnosis of endoscopic images of the oesophagus. Classification results for the 3-class problem (epithelum, corpus and cardia, Barett's mucosa) are presented in Table 1. Using a leaving-one-out analysis (n-fold-cross-validation) [12] a combined classification rate of 85% could be achieved. The individual classification rates for the corpus and cardia class was 81%, for the epithelium 96% and for the Barett's mucosa 76%. Furthermore, using the relevance feedback for that image data set and simulating the input of the physician, the classification rate could be increased up to over 90% after 2 iterations. A screenshot of the graphical user interface (GUI) is presented in Figure 1.

4 Discussion

The use of CAD systems becomes a more important part of clinical workflows today. These systems can provide a second opinion without the need of a second physician and thus might save cost and time.

We have presented a system for the interpretation of endoscopic images of the esophagus which is able support the physician while he is examining the patient using a gastroscopic video tip-chip endoscope. That makes it possible to integrate the system easily into the existing workflows to provide the physician a second opinion at the point of care (POC) immediately. The diagnosis assistance we provide is based on a validated knowledge database. The database we use contains 482 annotated image regions. The database includes cases of all usual changes of the surface tissue. Therefore the system is able to handle all these changes.

The feature extraction algorithms have also a big influence on the performance of the complete system. We use the algorithms which are presented in [10] and which seem to fit the requirements of our task. The use of other feature extraction algorithms can surely increase the accuracy and will be tested in the future.

The statistics for esophageal cancer show that there are several additional factors which can influence the risk. Such known factors include the weight, the age, the consumption of tobacco and alcohol and the existence of similar cancers

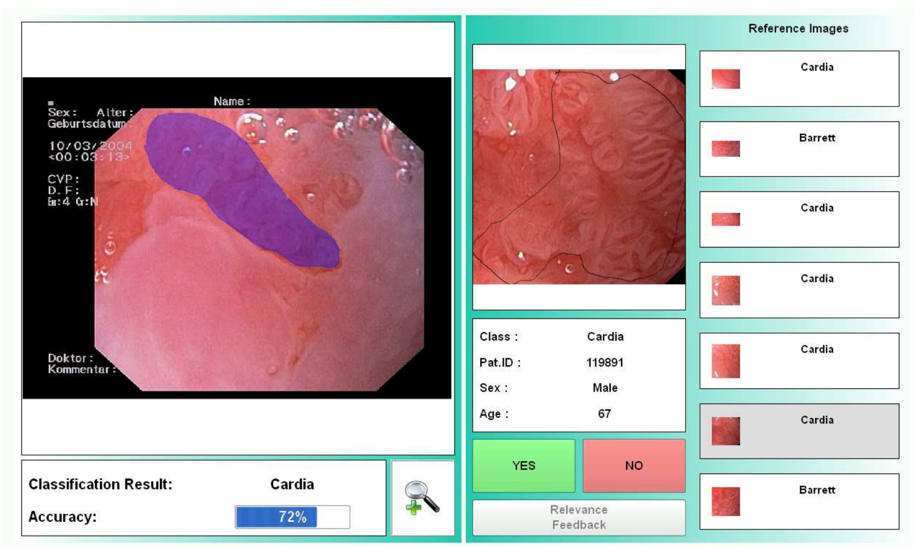

Fig. 1. Screenshot of the GUI of the proposed system. On the left pane the actual endoscopic *live* image is depicted. The user has the possibility to capture and freeze the current live image by pushing a foot-button. Then a region of interest can be interactively marked in the acquired image as shown in the screenshot. Within the next instant, the system computes a classification result and presents it to the user immediately. On the right hand side a list of all database entries which have been used to create the result is presented. All of these reference images can be reviewed by the user and marked as *relevant* or *not relevant*. After doing that the system uses this feedback to compute a new refined result

in the patient's family. The inclusion of these anamnestic parameters as well as the inclusion of the patients demographic data is likely to further increase the accuracy of the diagnosis assistance and will be part of our future work.

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