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Computer vision for cancer detection

By: Fons van der Sommen

Approximately five years ago, gastroenterologist Erik Schoon from the Catharina Hospital in Eindhoven called Eindhoven University of Technology with a simple question: “If my new phone can recognize the faces of my children when they take pictures of them, would my endoscopy system also be able to recognize early stage cancer?”

This question (top right) compared to the gold standard group of the Electrical Engineering department, headed by prof. Peter de With, who has extensive experience with video content analysis and computer vision. Together with dr. Svetla Zinger he visited the hospital to assess the image quality and complexity of the task at hand and concluded that the problem was definitely worth investigating. Five years later, the breakthrough results of the research that followed are published in medical journal Endoscopy. The developed image analysis algorithm that produced these results scans endoscopic images for signs of early esophageal cancer. In particular, esophageal cancers that arise in people with a medical condition called Barrett’s esophagus.

Barrett’s esophagus

People suffering from gastric reflux over a prolonged period of time, can develop a so-called Barrett’s Esophagus (BE). This is a condition in which the body has replaced the cells of the esophagus wall in the lower part of the esophagus with an acid-resistant cell type, that is not inherent to the organ, tocounteract the acidic nature of the stomach. This defense mechanism, however, comes at a cost: an over thirty-fold increased chance of developing esophageal cancer. Hence, this patient group is closely monitored and periodically receives endoscopic surveillance.

The incidence of Barrett’s cancer has increased dramatically over the past decades. Especially in the Western world, the number of cases per year is rising rapidly. This growth is predominantly explained by Western lifestyle and diet, as overweight is a major risk factor for the development of cancer. At an early stage, Barrett’s cancer can be treated endoscopically, showing cure rates approaching 100%. However, it is not halted early in its development, only 15% of the patients survive the first five years after diagnosis. Therefore, early detection is of crucial importance.

A new biopsy protocol

Until recently, medical protocol dictated to take “four-quadrant, 1-cm endoscopic biopsies performed at closely timed intervals”, in order to detect the presence of developing cancer cells in BE. However, recent studies have shown that early cancers are regularly missed when this biopsy protocol is employed. Therefore, experts on Barrett’s cancer have called for a paradigm shift, moving from blind biopsies to targeted biopsies, based on visual inspection of the tissue. This change in biopsy protocol has been enabled by the developments in CCI/CMS technology, allowing endoscopes equipped with High-Definition (HD) cameras. Using HD endoscopy, medical experts have shown a correlation between abnormalities in endoscopic and histological images of the tissue, where generally, deviating color and texture patterns in the tissue are associated with developing cancer.

The need for computer-aided detection

Finding early cancer in BE endoscopically is a very challenging task. First of all, the esophagus is constantly moving during surveillance, attempting to swallow the endoscope. Second, imaging conditions change -- such as intestinal juice, poor lighting and specular reflections -- impede the visual detection even further. On top of that, most gastroenterologists typically encounter these early cancers only a couple of times a year, severely steepening the learning curve for recognition. As a result, a considerable portion of developing cancers is overlooked during endoscopic screening and is detected only at an advanced stage, when local endoscopic treatment is no longer an option.

Given the above-mentioned issues, a computer-aided detection system offers a very attractive solution. Such a system can analyze all pixels of every video frame and highlight relevant regions. Furthermore, the involved machine learning methods allow for training a model based on expert knowledge, very fast and efficiently. The advantage of a computer-aided detection system that helps the gastroenterologist during endoscopic surveillance works in two ways: (1) serving as an extra pair of expert eyes, more cancers will be detected at an early stage and (2) providing live feedback to endoscopists, this improves the learning rate for recognition of these early cancers.

Endoscopic image analysis

In computer vision, the problem of segmentation deals with dividing a certain image into meaningful regions. The definition of a meaningful region all depends on the goal of the segmentation algorithm. For example, for autonomous vehicles objects such as cars, pedestrians and traffic signs can be meaningful objects in an image. Typically, objects in an image can be segmented based on properties such as shape, color or texture. These qualitative properties are quantified using image features, which can be histograms of the color, output of specific filters or basically any measurable property of a region in an image and produces a vector. As the variation in objects is usually too large to capture them with a set of heuristic rules based on those features, machine learning can be applied to estimate a model for the objects of interest.

Given the clinical context of Barrett cancer detection, the region in an endoscopic image that displays cancersous tissue is of interest. At the SPS-VCA research group, we have developed a unique method to find and tune a system for segmenting this cancerous image region. Based on medical literature and expert knowledge, we have devised image features that are capable of capturing the deviating color and texture patterns of early cancer in BE. Fig. 1 shows an example of specifically tuned filters that we employ to quantify the texture properties of the tissue. These filters are a modification of well-known Gabor filters, which have been shown to correlate with spatial firing patterns of neurons in the visual cortex of the mammalian brain. In addition we have shown the benefit of including color information, as it quantifies the red hue associated with neo-angions and not tissue that is more white due to necrosis.

After investigating the most discriminative features, we have developed a framework that uses those image features for endoscopic image analysis. The first step in our framework extracts patches of the image that is suitable for analysis, i.e. the Region Of Interest (ROI). Next, the image features are computed and a machine learning model is trained based on examples of expert annotations. Once trained, the model can predict, for every position in the image, whether or not cancerous tissue is present.

Clinical validation

For validation of the proposed detection system, we have invited four experts on Barrett’s cancer to delineate the malignant tissue in a set of 100 images. Pathological data was available for all the images, including delineations of the gastroenterologist that treated these patients, serving as a gold standard. We compared both the detection results of the four medical experts as well as the detection performance of our system to the gold standard. The leftmost graph in Fig. 2 shows the detection performance of the system for several training options. The sensitivity of the system increases with the fraction of the training examples that contain cancer (PTF). However, as it finds more cancers, the number of false positives also increase, resulting in a lower specificity. The figure shows that once a good trade-off is established, expert detection performance can be matched. This means that the system can predict whether or not an endoscopic image shows cancer with similar accuracy as experts on Barrett cancer.

What’s next?

With these results, we have shown that a supervised automated analysis in endoscopy is feasible and it can match detection rates of experts. We want to bring our system to the clinic, where it can help physicians live during endoscopic surveillance. However, the current algorithm is designed for still images and not suitable for video yet. The step to analysis of real-time endoscopic video offers a lot of challenges, but also a number of interesting options to investigate, such as the availability of several frames of the same tissue and temporal consistency of detections.

To make the next steps necessary to prepare the system for clinical practice, Dutch cancer society KWF and technology foundation STW have awarded funding to a recently submitted proposal project of our group. This project, called ARGOS (Automatic Recognition of iRregularities in the esOPhagus), is a joint effort in collaboration with the Catharina Hospital Eindhoven, the Academic Medical Center (AMC) Amsterdam, endoscope manufac-turer FUJIFILM and local SME Vionotion.

In order to make the project more accessible, our group has organized a Grand Challenge at the MICCAI 2015 conference in Munich. For this ongoing challenge, we have shared our data with the image analysis community and invited other researchers in the field to propose new algorithms for Barrett’s cancer detection. For more information on this challenge, please visit the challenge website, we are looking forward to your submissions!