Computer vision for cancer detection

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Approximately five years ago, gastroenterologist Erik Schoonhoven 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 taking pictures of them, would my endoscopy system also be able to recognize early stage cancer?”

This question (top right) compared to the gold standard, a 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 in part are with 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 esophageal wall in the lower part of the esophagus with an acid-resistant cell type, that is not inherent to the organ, to counteract the acidity. 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 Barrett’s cancer.

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 in theory detect any signs of early stage cancer. 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 “normal” biopsies, 1 cm spaced 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 CAD/CMS technology, allowing endoscopes equipped with High-Definition (HD) cameras. Using HD endoscopy, medical experts have shown a correlation between histology and visual representation 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 endoscope is constantly moving during survey, attempting to swallow the endoscope. Second, imaging conditions can -- such as intestinal juices, 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. Hence, this patient group is closely monitored and periodically receives endoscopic surveillance.

Figures 1 and 2: The patient based detection performance for the system for different fractions of positive training samples (PTF) compared to the performance of experts (left) and the corresponding annotation performance (right).

While all four experts were able to delineate the malignant tissue with similar accuracy as experts on Barrett cancer.

If we compare the exact tissue delineations of the system with those of the four experts, the annotations of the experts show a much closer resemblance to the gold standard. This means that the system can predict whether or not an endoscopic image shows early cancer with similar accuracy as experts on Barrett cancer.

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 who 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 increases, 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 early cancer with similar accuracy as experts on Barrett cancer.