Computer vision for cancer detection

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Abstract

Approximately five years ago, gastroenterologists 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 triggered a paradigm shift in the research 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 produces these results scans endoscopic images for signs of early esophageal cancer. In particular, esophageal cancers that are in people with the medical condition called Barrett’s esophagus.

Barrett’s esophagus

People suffering from gastro 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 from 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 CAD/CMS technology, allowing endoscopes equipped with High-Definition (HD) cameras. Using HD endoscopy, medical experts have shown a correlation between the endoscopist 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 esophagus is constantly moving during surveillance, attempting to swallow the endoscope. Second, imaging conditions can change rapidly, like --- 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. Therefore, a computer-aided detection system offers a very attractive solution. Such a system can analyze all pixels of every video frame and detect cancer tissue with high accuracy. 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) as a source 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 are represented by slight changes in the 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 other function of the 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 these features, machine learning can be applied to estimate a model for the objects of interest.

What’s next?

With these results, we have shown that supportive automated analysis in endoscopy is feasible and it can match detection rates of experts. We want to bring our system to the clinic, when it can help physicians live during endoscopic screening. 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 project proposal 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 manufacter FUJIFILM and local SME Visonotion.

In order to make the problem 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 analysts and invited other researchers in the field to propose new algorithms for Barrett’s cancer detection. For more information, please visit the challenge website , we are looking forward to your submissions!