Topic 2: Computer Vision and Medicine

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At what point does the human diagnostician's eye no longer remain the "gold standard"?

A diagnostician acquires the art of understanding the science of human body, its functioning and the abnormalities developed in it. Medical diagnosis is about collecting symptoms from the patient. The knack of interpreting medical images is developed with years of training and practice. The eyes of a diagnostician are aided with their knowledge, previous experience and environment of the reading room [4]. But with best efforts and knowledge, the human diagnosis has its own sets of limitations. It is very subjective because of their subtle nature and detection depends on the perception of the diagnostician. Computer applications are trying to replace the cognitive aspect of the clinician's mind.

As per a study more than 50% of lung cancers missed initially by radiologists on chest radiographs were identified by a commercially available computer-aided detection (CAD) system [6]. CAD is a technology combining elements of computer vision with radiological information. They help in delineation of conspicuous structures and their quantification, which is often the goal of the radiological examinations. Initial round lesions of 5-10 mm [7] are easily overlooked by radiologists and are also very difficult to detect such a lesion through X- rays but with commercially available CAD systems average size of lesions detected with CAD was 1.73 cm [6]. Early detection of lungs cancer is lifesaving. The routine application of CAD Chest Systems may help to detect lungs cancer in its initial stages. Lung cancer takes more life than breast cancer, prostate cancer and colon cancer put together. This is due to the asymptotic growth of this cancer. In the majority of cases it is too late for a successful therapy as the patients develops first symptoms like chronic crankiness or hemoptysis at a very later stage. The CAD in CT scan (computed tomography scan) with special three-dimensional CAD systems are established and considered gold standard in case of diagnosis of lungs cancer.

There are other areas of clinical application where CAD systems have shown promise. The colon cancer develops from precursor adenomatous polyps. The polyps if discovered early can be prevented from becoming cancerous. The CT colonography (CTC) helps to provide their mass screening. The CT images required high-level expertise on the part of the radiologist to interpret the polyps and hence the was variable diagnostics performance but with introduction of the CAD, radiologists can detect small polyps. The performance of the CAD when compared with that of unaided human detection, was found to be superior. The per-polyp detection sensitivity of unaided human CTC reading was 70% for lesions $\geq$ 6 mm, 69% for lesions $\geq$ 8mm and 69% for lesions = 10mm, whereas those of CAD where 76%, 88% and 90% respectively [8].

A large number of CAD applications are being developed for detection and characterization of other types of cancer. Breast Cancer is found to be the most fatal and common cancer among women in USA [1]. According to National Cancer Institute, more than 40,000 have women died due to this disease and with every 3 minutes passed a new diseased is added to this list [1]. Mammography is used for the diagnosis, where low intensity x- rays are passed and viewing done by radiologist.

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Radiologists visually examine mammograms to search for signs of abnormal regions. They usually look for clusters of micro calcifications, architectural distortions, or masses. CAD has enhanced the detection power of the radiologists tremendously. But CAD has faced various challenges in these areas. CAD algorithms have failed to mark areas of cancer which radiologists consider cancer. In case of breast cancer detection CAD is considered a second reader only; the final decision is still left to the experts eyes. There are various reasons why computers have not replaced human eyes. First, the imaging system may have imperfections and work needs to be done to improve the imaging techniques. Second, the image analysis task is further complicated by the large variability in the appearance of abnormal regions. Finally, abnormal regions are often hidden in dense breast tissue. The goal of the detection stage is to assist radiologists in locating abnormal tissues. It is an extremely challenging task, to develop algorithms that analyze medical images with a performance level comparable, if not better, to that of human experts. Still is found by a study of United Kingdom National Breast Screening Program that CAD had 6.5% more chances of cancer detection than twice viewing by a radiologist [2].

Clinician makes a diagnosis by taking into account multiple clinical parameters. Diagnosis, in many areas, is still almost exclusively the work of humans. This is expected to change in the future. Many of the recent advances in diagnostic methods use advanced imaging techniques as an indispensable part in making the analysis. We see many developments in computer software that can assist the clinician in detecting abnormalities that are present. Computer programs can be trained to locate abnormalities that are usually picked up by radiologists, but which may be overlooked in a busy environment. Sometimes in complex scenarios, e.g. differential diagnosis of interstitial lung diseases, it is difficult for a clinician to distinguish accurately between many interstitial lung diseases because they can produce similar or even identical radiographic patterns. An advanced technology like artificial neural networks (ANN) in this scenario is an ideal model for integration of many clinical parameters and complex radiographic features [5].

The area of computer vision seeks to develop algorithms which infer properties of the external world purely by acquiring, processing, analyzing, and understanding images. Computer vision has now extended its area of application to interventional radiology, replacing classical surgical interventions by minimally invasive alternatives. These alternatives help in various ways like reducing hospitalization, faster recovery and minimizing surgical trauma. Radio frequency Ablation (RFA) of liver tumors and Trans jugular Intrahepatic Porto systemic Shunt creation (TIPS), are two representative percutaneous intervention procedures. The minimally invasive nature of the intervention makes it challenging for the clinician. There is no direct eyesight to the target and conventional interventional imaging modalities have limited capabilities. Hence the clinician is visually blinded when he is performing the intervention. Computer-assisted surgery (CAS), also known as image-guided surgery, is a computer vision based procedure that uses technologies such as 3D imaging and real-time sensing in the planning, execution and follow-up of surgical procedures. CAS allows for better visualization and targeting of sites as well as improved diagnostic capabilities, giving it a significant advantage over conventional techniques in preoperative planning.

The diagnostic errors are induced in scenarios where the disease remains dormant, mimics something more common, symptoms are unidentified or may stem from negligent or careless act by a diagnostician. These errors creep in because diagnostic tests are not always perfect, patients are sometimes non-compliant and often the physician invariably chooses the most likely diagnosis over the correct one, depicting the probabilistic nature of choosing a diagnosis. The point at which judgmental error becomes misdiagnosis is not very clear. Misdiagnosis from faulty data collection or interpretation, flawed reasoning or incomplete knowledge guaranty that diagnostic errors would persist [3]. Misdiagnosis or delayed diagnosis happens, when the treating doctor did (or didn't do) to how a reasonably skillful and competent doctor under the same circumstances would not have made the diagnostic error. These malpractices can be regulated by several factors: new imaging techniques, innovations in the processing of medical images, new standards published by scientific societies, as well as clinical guidelines issued by medical professional organizations.

Error in judgment may lead to malpractice lawsuits. These lawsuits often have adverse effects on a physician, creating an atmosphere of distrust between the patient and the physician. Litigation for alleged malpractice is often associated with feelings of guilt and isolation. Medical professionals who have committed errors are open to a reduction in quality of life and an increase in the frequency of burnout. Perceived stress is associated with an increase in the number of errors committed in the subsequent period, thus creating a vicious cycle whereby errors lead to stress, which in turn leads to new errors. Physicians may feel a sense of guilt resulting from the error and may fear suffering professional and economic consequences and being isolated by their own colleagues and clients [4].

In the longer term, if diagnostic errors are to be reduced, authorities should invest in better training of clinicians. Clinicians should obtain as much information as possible with conscious attempt to explore other diagnostic possibilities. Consulting with colleagues and referring them before concluding and rendering the final report would help the cause. Authorities should encourage a "blame-free" culture within the hospital where, open discussion of errors is encouraged in a sensitive and constructive fashion. With technological advancement the clinician's eye is expected to be better equipped. They will have deeper insight into their findings and become more productive.

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