Computer Aided Detection of Potential Colorectal Neoplasia at CT Colonography

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1. Introduction

Computed tomography colonography (CTC), also known as *virtual colonoscopy* (VC), is a minimally invasive alternative to *conventional colonoscopy* (CC) for imaging the interior of the colon. This technique, which was first described by Vining et al. in 1994 [1], involves performing an abdominal *computed tomography* (CT) study of a suitably prepared patient. The resulting CTC dataset can then be inspected using one of several visualisation techniques. Colorectal cancer screening is one of the most important applications of CTC. Results from a major study comparing CC and CTC [2] indicate that both techniques have similar efficiencies for the detection of significant colorectal polyps.

CTC has several major benefits over CC. It is a minimally invasive examination, thus making it more attractive to screening candidates and reducing the potential for complications (e.g. colonic perforation). CTC can be used to image the entire colon from rectum to caecum, even in the presence of large obstructions which cannot be traversed endoscopically [3]. A CTC examination is not limited to the interior of the colon. In fact, the entire abdomen can be examined. This may result in the discovery of extracolonic findings which would be have been overlooked at CC [4]. Finally, a CTC dataset can be analysed using custom software. One of the most important examples of this is *Computer aided diagnosis at CTC* (CAD-CTC), a recent development which facilitates the automated detection of colorectal polyps prior to radiologist review.

CAD-CTC has the potential to increase the sensitivity of CTC by detecting colorectal polyps more reliably and facilitating the detection of problematic polyps. CAD-CTC will reduce review time by automatically reporting the location of potential colorectal neoplasia, thus removing the need to examine obviously healthy

segments of the colon. Recently published results [5, 6] indicate that CAD-CTC is indeed feasible and high levels of sensitivity can be achieved. We introduce a novel CAD-CTC approach, describe some of the problems that effect CTC and present results from an initial evaluation of our technique.

2. Technique

2.1 Segmentation

Voxels which represent the colon lumen must be identified from the CTC dataset prior to analysis. This process is known as segmentation. A wide range of segmentation techniques are described in the literature. Some early approaches utilised seeded region growing to identify contiguous colon lumen voxels. More recent approaches use *a priori* knowledge of abdominal anatomy to obtained better results. A good segmentation is essential as it forms the basis for all further processing. A CTC dataset is illustrated in Fig. 2.1 both before (a) and after (b) segmentation.

2.2 Centreline Calculation

Bitter et al. [7] define the centreline of the colon as "the shortest path between the two most distant points inside the colon that includes heavy penalties for coming close to the colon wall". The centreline was originally used for automating intraluminal navigation. However, it is not restricted to navigation and can be used to facilitate high level analysis of the colon (e.g. colon lumen sub-segmentation [8] a technique for identifying the five main anatomical regions of the colon). The centreline is suitable for high level analysis as it provides a compact representation of the colon which retains much of the shape information from the original segmented lumen. The task of centreline calculation is generally regarded as being extremely time consuming and many techniques are described in the literature which address the

issue of centreline calculation. We employ an efficient centreline calculation algorithm [9] which utilises an optimised version of 3D topological thinning [10] to generate fast and accurate results, see Fig. 2.1 (c).

2.3 Analysis

The purpose of the analysis stage is to flag potential colorectal neoplasia for radiologist review. This is achieved by analysing the CTC dataset in conjunction with the segmentation and centreline information in order to identify projections into the colon lumen. These projections are subsequently classified based on quantifiable characteristics such as size, morphology and density and ultimately flagged as naturally occurring colonic features or potential colorectal neoplasia, see Fig. 2.2 (a) & (b).

Projections into the colon lumen are identified using 2D image analysis techniques. The axial images which make up the CTC dataset intersect the colon lumen at various arbitrary angles. As a result the axial images are not ideal for direct analysis. An alternative approach involves extracting a sequence of reformatted planes which are perpendicular to the centreline of the colon. This process is illustrated in Fig 2.2 (c). These reformatted planes intersect the colon at know angles and provide a much more suitable representation of the original dataset for analysis. The reformatted planes can be generated in real-time from the original dataset and the entire process requires no user interaction.

The reformatted dataset retains the density information of voxels surrounding the segmented colon lumen and as a result two types of analysis can be performed, i.e. identification of projections into the lumen (as described earlier) and an inspection of the surrounding tissue. Inspecting the surrounding tissue facilitates the computer aided detection of flat or depressed neoplasia. These types of lesions cannot be

reliably detected using CAD-CTC techniques that are restricted to an analysis of the surface curvature of the colon lumen. Analysis of the reformatted dataset provides a unified technique for detecting flat, depressed and polypoid colonic lesions.

3. Problems

CAD-CTC suffers from many of the same problems as standard CTC. Residual material in the colon can occlude regions of the colon and in extreme cases blockages may occur, see Fig 3.1 (a) & (b). There are two main types of residue which may be found in the colon at CTC. These are residual faecal material which may be present due to poor bowel preparation and retained intraluminal fluid, which can be present where a wet bowel preparation is used. In some cases residual faecal material can resemble polyps as illustrated in Fig 3.1 (c). Dual positioning can help to overcome the problem of residual material in the colon [11]. This is particularly useful in differentiating between mobile stool and fixed lesions. Dual positioning is not an ideal solution for dealing with residue as it increases both the radiation does and the exam time. An alternative technique known as digital subtraction bowel cleansing [12] can be used to eliminate residual material in the colon as well as removing the need for rigorous bowel preparation. This is achieved by administering an orally ingested, high density contrast agent before performing abdominal CT. The high density residual material is subsequently subtracted from the CTC dataset. This has the effect of digitally removing any residual material. Collapsed segments may be present in CTC datasets due to inadequate colonic distension, see Fig 3.2. Collapsed segments cannot be examined at either CTC or CAD-CTC as there is no air-tissue interface. The presence of either excess residual material or collapsed segments hinder the segmentation process. Other problems at CAD-CTC include pseudo-polyps, the detection of flat or depressed colonic neoplasia and image artefacts. All of these

problems must be addressed before CTC and CAD-CTC can be accepted as a primary colorectal cancer screening technique.

4. Results

CTC dataset are currently being collated from a large cohort of patient (~100) for a clinical trail comparing the sensitivities of CC and CTC for colorectal cancer screening. This database has been made available to the Vision Systems Laboratory at Dublin City University for the development and testing of a CAD-CTC system. Initial tests have been carried out using 4 CTC datasets. 65% of polyps were detected with 34% false positive detections. Examples of automatically detected polyps are presented in Fig. 4.1. The CAD-CTC system was implemented using the Java programming language from Sun Microsystems and the average time required to analyse a complete dataset was approximately 13 minutes. Further validation of this CAD-CTC system is currently underway.

5. Conclusion

We have demonstrated that CAD-CTC is feasible and can be used to flag potential colorectal neoplasia at CTC. This technology will ultimately increase the sensitivity of CTC while reducing the time required to perform the examination. There are several problem associated with both CTC and CAD-CTC, some of which have already been dealt with and others still required attention. CAD-CTC has the potential to significantly increase the performance of standard CTC, however it will only be useful in a clinical environment when maximum sensitivity can be achieved in the presence of a small number of false positives.

6. References

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Figures: