

A Remote Access Training System for the Detection of Colorectal Polyps at Computed Tomography Colonography

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Abstract

Computed tomography colonography (CTC) is emerging as a possible alternative to *conventional colonoscopy (CC)* for colorectal cancer screening. A number of recent studies have demonstrated that CTC has sensitivity comparable to that of CC for detecting clinically relevant polyps, however the fact remains that CTC is not yet in widespread use. One of the factors contributing to this is the lack of radiologists that have the relevant CTC training. We have developed a novel remote access system for CTC training. Our system allows radiologists to gain the relevant experience over the Internet without the need for any specialist equipment or software. In this paper we discuss the imaging issues involved in the development of our remote access CTC training system. The evaluation of the system is also discussed and the observations made during this process are used to formulate further research directions.

Keywords: Remote imaging, colonography, colon cancer, Java Servlets.

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1. Introduction

Colorectal cancer is a major cause of cancer related death in developed countries. Statistics published by the National Cancer Registry of Ireland (NCRI) [1] indicate that colon cancer accounted for 9% of all cancer cases diagnosed in 1997, second only to non-melanoma skin cancer (36%). Colorectal cancer can be prevented if precursor polyps are detected early in their course and successfully resected. Regular screening is required in order to detect the presence of colorectal polyps. At present the most sensitive screening technique is *conventional colonoscopy* (CC). This involves an endoscopic examination of the colonic mucosa using an instrument known as a colonoscope. The examination itself is extremely invasive and can lead to complications. The CC examination is embarrassing and uncomfortable for the patient and has achieved limited acceptance among those at risk of developing colorectal cancer.

Computed tomographic colonography (CTC) is a relatively new technique for colorectal cancer screening that was introduced by Vining et al. in 1994 [2]. A CTC examination involves performing an abdominal *computed tomography* (CT) study of a suitably prepared patient. The resulting CT dataset can then be examined, either as a sequence of 2D slices or as a reconstructed 3D model of the colon, for the presence of colorectal polyps. One of the main benefits associated with CTC is that it is potentially more patient friendly than CC due to the fact that it is minimally invasive. Furthermore, there is no need for sedation and the patient can go back to work on the same day as the examination, unlike CC where the patient is required to take a full day off work. Although CTC has been demonstrated to have similar sensitivity to CC for the detection of significant polyps [3, 4] it is not yet in widespread clinical use. This is partly due to the fact that only a limited number of radiologists have the skills required to perform a CTC examination.

The need for CTC training has been highlighted in the literature [5, 6] particularly for problem cases e.g. flat polyps [7]. In order to gain proficiency it is necessary for a radiologist to be trained using a large number of datasets (50-100) containing a mix of polyps, cancers, normal features and pseudo polyps e.g. a protruding ileocecal valve. For this purpose we have developed a novel remote access computer system that allows radiologists to undertake the relevant training. This system allows the trainee to evaluate a CTC dataset by flagging locations that they suspect to be potential polyps. Once the trainee has completed their evaluation the results are sent over the Internet to our server to be compared against the gold standard. In order to maximise accessibility the training system has been developed using Java Servlets. This allows the trainee to access the system remotely from a standard web browser e.g. Mozilla Firefox or Microsoft Internet Explorer. There is no need for any custom software on the client side. This approach provides the highest level of compatibility as it can be used on every operating system. In addition patient confidentiality is maintained as no direct access is provided to patient data. Instead this data is accessed via a Java Servlet which strips all the sensitive patient information leaving only the image data.

This paper describes the results from our initial investigation into remote access training for CTC. This research is ongoing due to the changing needs of our medical collaborators and the constant evolution of the CTC technique. Recent developments in CTC research that will need to be dealt with by any training programme include fecal tagging for improved segmentation and polyp visibility [8, 9] and computer aided detection CAD [10, 11].

2 Background

At present, the most efficient way to develop remote access server side programs is using the Java programming language from Sun Microsystems. A server side Java program is called a Servlet and is an extension to a server that enhances the Server's functionality. Servlets are most

commonly used to process forms and create dynamic content. To develop and test our Servlets, we used the NetBeans software.

The system described in this paper continues on from previous work by the Vision Systems Group in the area of CTC e.g. colon centreline calculation at CTC [12] and *computer aided detection* (CAD) at CTC [13] and also work in the area of medical image interpretation [14]. This previous research provides a solid platform which we are now using to develop our remote access system for CTC training.

In order to meet the needs of our ultimate end users (trainee radiologists in the area of CTC) we are in regular consultation with our medical collaborators from the Gastrointestinal Unit and Department of Radiology at the Mater Misericordiae Hospital in Dublin. Thanks to their feedback we have developed an intuitive interface that implements the usual image processing features that are utilised by radiologists when performing a CTC examination.

3. Method

3.1 Approach

The operation of our system can be divided into 3 parts:

- Firstly, on the home page of the system, the user can choose the CT dataset to train with. This page, as with the entire system, is accessed through an Internet browser (See Fig. 1).

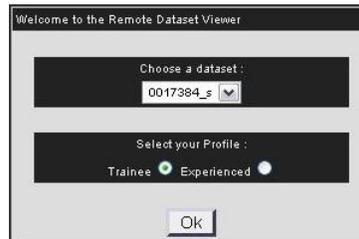


Figure 1. System home page of the system (accessed using any standard Internet Browser)

- Following this first step, the user enters the training interface where it is possible to navigate through the dataset. A new polyp can be highlighted by clicking on its centre and then entering the relevant information using the associated input fields.
- When the trainee has finished the analysis, a result panel displaying the correctly and incorrectly flagged polyps also known as the “true and false positives” is generated. A list of the undetected polyps also known as “false negative” is also displayed.

3.2 Implementation

3.2.1 Home page

The home page of our system consists of a *Java Server Page* (JSP) index and a Java Bean. The user can select the CT dataset required. The Java Bean contains code to read all dataset’s names which are stored on the server’s hard disk. These names are then displayed through the *hyper text mark-up language* (HTML) combo-box of the JSP. Two radio buttons are also added in order to choose a specific profile before launching the servlet. This makes it possible to log on as a trainee

or an experienced radiologist (as illustrated in Fig. 1). When submitted, the servlet reads and displays the first image of the specified dataset.

3.2.2 Layout using CSS

As the entire graphic interface is written in HTML, all style and layout information are gathered into a *Cascading Style Sheets* (CSS) file. Therefore, thanks to the flexibility of CSS, the HTML interface of the system looks more consistent. For example, each of the HTML toolbars have the same appearance and the overall view of the system seems homogeneous.

3.2.3 Extract and display images

The Servlet reads the pixels of an image from a specific dataset using a *RandomAccessFile* object. The datasets are generated from the DICOM [15, 16] images obtained from the original CT scan. This is achieved using the NeatMed API [14]. The user can specify which image is required using a HTML combo-box. The pixels are then stored in a *BufferedImage* object (*TYPE_INT_RGB*) after a colour conversion. This colour conversion is meant to turn the initial pixel's colour range (from -1024 to around 2400) into the standard greyscale colour range (0 to 255). A *Joint Photographic Experts Group* (JPEG) picture is then created from the *BufferedImage*. Finally this JPEG image is displayed through the HTML code of the Servlet using an ** tag.



Figure 2. The trainee's interface with an identified polyp (circle)

3.2.4 Navigation

At the top of the servlet, a navigation toolbar contains a forward and a backward HTML button. These buttons increment or decrement the number of the displayed image. A slide bar is also present on the navigation bar. This bar is a JPEG picture which can be clicked on, in order to instantly access a specific picture on the dataset. This is done using a HTML tag *<input type="image" name="pic">* which gives the coordinates (*pic.x* and *pic.y*) of the user's click position. We only care about the *pic.x* coordinate as the slide bar is horizontal.

3.2.5 Polyp's localisation

We use the HTML tag *<input type="image">* again to select polyp's coordinates which have been located on the current image. X and Y coordinates as well as the current image slice

number, polyp type and size are written to a text file using *FileOutputStream* and *OutputStreamWriter* Java objects.



Figure 3. Trainee’s interface with polyp’s details

3.2.6 Polyp’s marks

When the servlet is launched, the text file containing the polyp coordinates is read using a *RandomAccessFile* object. When an image containing polyp is requested, an oval is drawn around the polyp’s position as illustrated in Fig. 3. This is done by creating the *Graphics2D* object associated with the *BufferedImage* using the *getGraphics()* method. When the user clicks inside a polyp’s oval the click’s coordinates are obtained and compared to the polyps’ positions from the polyp’s text file. Once the specified polyp has been found its type and size are displayed using a HTML table at the bottom of the page.

3.2.7 Density setting

On the left of Fig. 3, another toolbar gives the end user the possibility to focus on a specific density. It works on two image characteristics which are commonly used by radiologists, these are the window width and the window centre. Images from a dataset have a density value between -1024 to around 2400. This means that each picture can have on of approximately 3424 greyscales. The window centre specifies the density value that we want to focus on. It is then possible to use this parameter in order to highlight information associated with the bones or lungs. The window width is the amount of other density values that we want to display around our chosen window centre.

3.2.8 Zoom setting

A zoom feature is available on the main menu of the servlet. Three radio buttons let the user choose from the appropriate zoom scale. Then, the user can click on a + or – button in order to zoom in or zoom out. These buttons are HTML submit buttons which simply increase or decrease the zoom factor in accordance to the chosen zoom scale. The image width and height are multiplied by this zoom factor and results are passed as parameters to a *getScaledInstance()* method. In order to navigate into the zoomed picture, there are 4 submit buttons named Left, Right, Up and Down. As we draw the zoomed Image to the *BufferedImage*, x and y values are given as parameters to the *drawImage()* function in order to apply the required translation.



Figure 4. The result panel

3.2.9 Result panel

The results of the evaluation are displayed in a dedicated result panel's interface (Fig. 4). The user can instantly see the results by looking at the navigation bar at the top of the screen. On this bar, white lines indicate correctly flagged polyps (true positives), yellow lines indicate incorrectly flagged polyps (false positives) and red lines indicate unflagged polyps (false negative). Images containing polyps flagged by the trainee that match with the gold standard are displayed side by side under the navigation bar. The user can then click on one of these pictures to switch it to full screen mode. Two HTML combo boxes are located under these images. On the first one, the trainee can choose to display a picture on which he identified wrong polyps. On the second list, the user can choose to display a picture with a polyp which he didn't find and which is in the gold standard. For each correctly flagged polyp (true positive), a score is calculated for the type and size accuracy. A HTML button is associated with each true positive. When pressed this button displays side by side, images with the matching trainee's selection with the gold standard. Ultimately, a final score is calculated for the type and size accuracy for each flagged polyps and the result is divided by the number of unflagged polyps to yield the final result.

Tasks	Time for server with CPU: P4 1.6GHz RAM: 512Mo	Time for server with CPU: P4 2.8GHz RAM: 512Mo
1.Creation of the BufferedImage	250ms	100ms
2.Reading polyp's info from text file	<1ms	<1ms
3.Adding polyp's marks and zooming	1875ms	750ms
4.Creation of the JPG picture	75ms	40ms
5.Transferring and display interface	700ms	700ms
<i>Total time to display a new Image</i>	2900ms	1590ms

Table 1. Overview of the time required for the different tasks.

4. Results

Upon completion of the system, a demonstration was organised in order to obtain suggestions from end users. Two radiologists were present from the Mater Misericordiae Hospital in Dublin. These specialists were satisfied with the interface and the different features of the system but they also found some issues that will have to be taken in consideration for the next version of the system.

- The main issue clearly appeared to be the latency of the system. In other words, the Servlet takes too much time to perform the requested tasks and transfer pictures through the Internet. An overview of the length of time related to each step of the program is displayed in Tab. 1. The times on rows 1 to 4 were locally calculated on the servlet and the time on row 5 was obtained while requesting a new image from a remote computer.
- It would be useful to be able to use the mouse wheel to navigate through the images of a dataset. This feature will also have to be added to the next version.
- A few requests were made about the “evaluation” mode. First, each trainee should have the possibility to login with a specific name and password in order to train with several datasets and then send the results of their attempts to be evaluated.
- Finally, the results should be formatted so that all the images containing false positives should be visible together on the same screen and all the images containing false negatives (i.e. unflagged polyps) should be visible together on another screen.

5. Conclusion

This paper has introduced a remote access training system for CTC. This system has been developed based on the requirements of our medical collaborators and allows a trainee radiologist to gain proficiency in an emerging colorectal cancer screening technique. This research has yielded an operational system that meets the main requirements of our medical collaborators however further work will be required to address the issues of usability and speed associated with our current implementation.

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