

Co-Registration of Virtual and Optical Colonoscopy Views

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Abstract. While optical colonoscopy (OC) is still considered the gold standard and is necessary for performing polypectomies when required, virtual colonoscopy (VC) systems present certain advantages over the traditional OC, such as increased coverage of the colon wall and the ability to utilize computer-aided detection (CAD) techniques. In order to leverage the abilities provided by both OC and VC, a method for registering the OC and VC views is necessary, such that a suspicious area in the OC can be investigated in the VC, and vice versa. We propose here a method of performing this registration based on the view paths taken by the endoscopes (real and virtual) in traveling through the colon. Given a view location in the OC, this correlation allows for the corresponding view in the VC to be displayed. In this study, virtual colon data is used to simulate the OC.

1 Introduction

Colorectal cancer is the second leading cause of cancer-related mortality in the United States [1]. Early detection of pre-cancerous polyps located on the colon walls is key to the successful treatment of colon cancer. For over a decade, efforts in developing virtual colonoscopy (VC) systems have been ongoing [2], and such systems are clinically available. A VC system can allow a physician to inspect up to 100% of the colon surface, while traditional optical colonoscopy (OC) procedures fall far short, covering an average of approximately 77% of the colon surface [3]. More recently, researchers have focused on using the VC data to perform computer-aided detection (CAD) of the colonic polyps [4]. These CAD results can function as a second reader, helping to further ensure that all suspicious areas of the colon surface are located and rigorously examined.

Our goal is to take this technology to its next logical step, that of being able to register the view from both the VC system and the OC procedure. VC, as mentioned, provides for an increased coverage of the colon surface, as well as the possibility of integrating CAD techniques. OC, on the other hand, provides to the physician the texture of the colon surface, is still currently considered the gold standard, and is of course a necessity when a polypectomy is required. A registration of VC and OC views would allow for the advantages of both methods to be utilized and provide a more robust tool for physicians to use in making diagnoses.

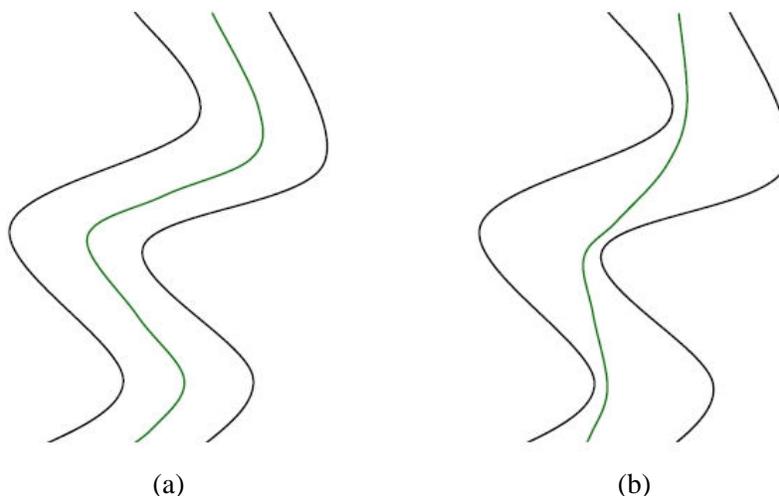


Fig. 1: Illustrated examples of how a centerline (a) and a hugging corner shortest path (b) might appear in a 2D segment.

2 Method

Our method of registering the VC and OC views is based on the correlation of the paths taken by the virtual endoscope in the VC system and the estimated path taken by the physical colonoscope in the OC procedure. The VC path is calculated as the centerline through the colon lumen. The estimated OC path is calculated as a hugging corner shortest path through the colon lumen [3]. Examples of how these two types of paths might appear in a 2D segment are shown in Figure 1. Because the endoscopic lens is not exactly on the edge of the distal end of the colonoscope, this hugging corner shortest path maintains a small distance from the colon wall. Depending on the orientation of the colonoscope, the lens can be anywhere from 2.8 to 10 mm from the wall, and thus we use the average value of 6.4 mm in our calculations.

The purpose of our method is to create a registration between the two paths, whereby a point on one path is directly correlated to a point on the other path. The paths are represented as spline curves, though they are discretized into a given number of points for display and visualization. These discretized points are what we use as the basis for our path correlation. The calculations to identify the correlated discrete points are performed as a pre-processing step. Thus, only a table look-up is required during rendering to obtain the necessary view point.

In our thinking, the two points which would yield the most similar view inside the colon are the two points within the same cross section of the colon lumen. Although for each discretized point the closest point on the other path might be a close approximation, it is not guaranteed to be within the same cross section. Being that the centerline path closely follows the curvature of the colon lumen, we use it as the basis for our calculations. For each point x on the centerline, we calculate its corresponding point y on the shortest path as follows:

1. Obtain normalized direction vector v for point x .

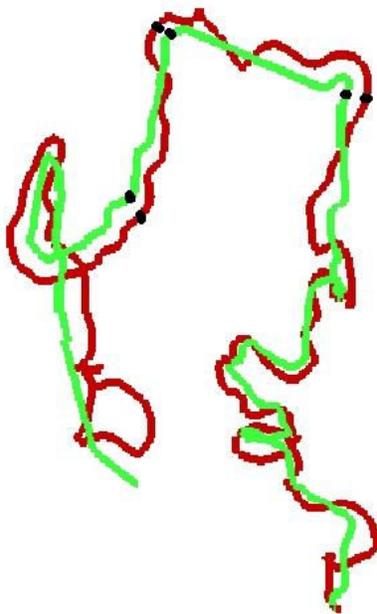


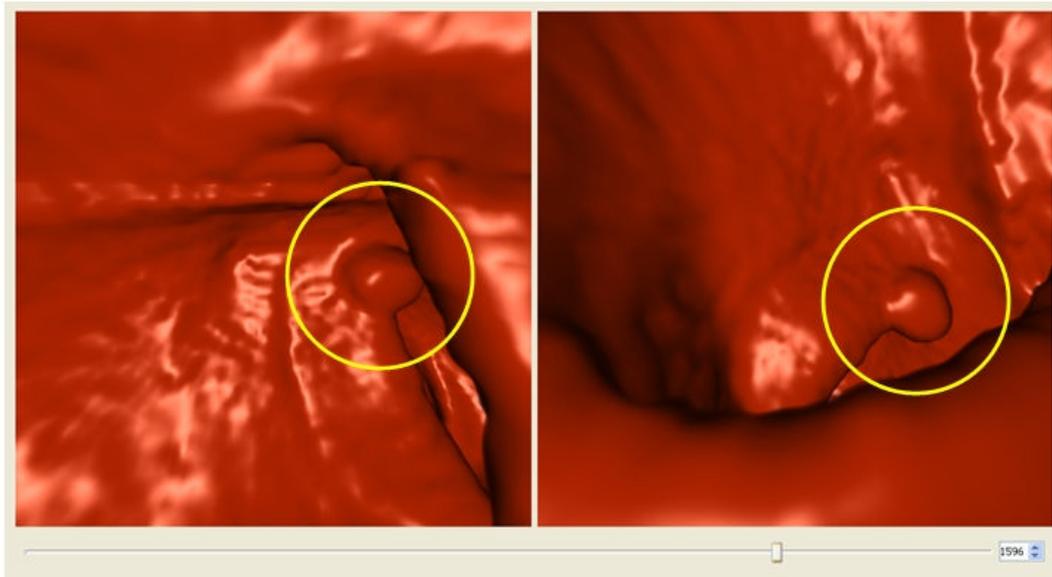
Fig. 2: An example of the correlation between the centerline (dark red) and the hugging corner shortest path (light green). Calculated corresponding points are illustrated by a black dot on each line.

2. Take v as the normal of a plane p which intersects point x . Since the centerline, of which x belongs to, closely follows the curvature of the colon, plane p can also be taken to be the cross section of the colon lumen at point x .
3. Find the point y on the shortest path which intersects plane p . If multiple points intersect the plane (due to the shape of the colon), take the point which is closest in distance to x .

3 Results

We evaluated the effectiveness of our correlation in two ways. The first evaluation is based on a visual inspection of the two paths with a correlated point on each path illustrated. In this inspection, each point on one of the paths is visited, and the corresponding point on the other path is illustrated. A visual inspection of these paths shows them to be well aligned, and an example of this view is shown in Figure 2.

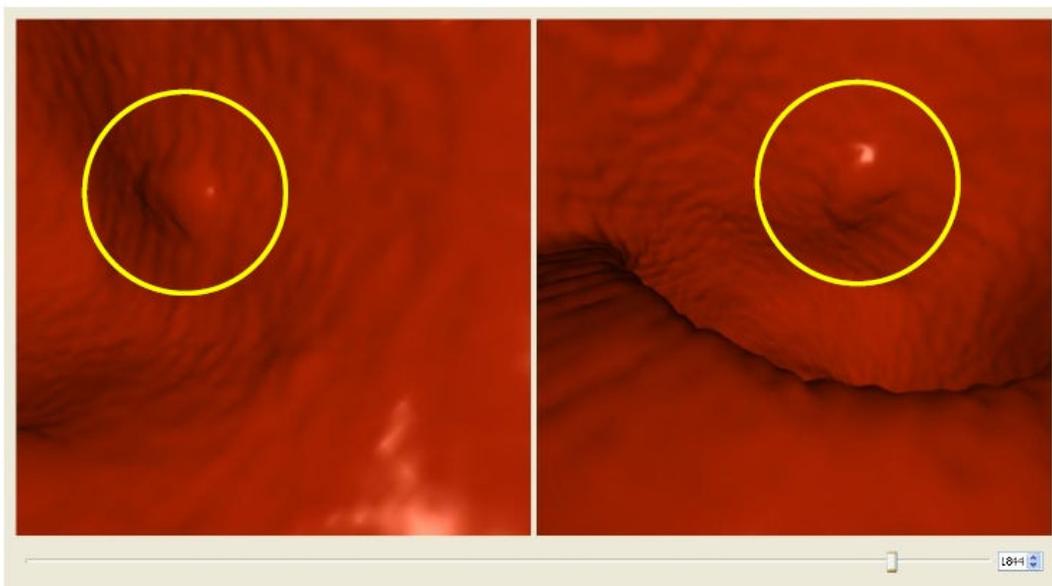
The second method of evaluation for our correlation is to volume render the views for both the VC and the simulated OC for each pair of corresponding points. Again, one path is taken as the driver, and adjusting the current view location on that path results in the view from the other path also being adjusted. Examples of these correlated views can be seen in Figure 3. A visual inspection of these rendered views shows them to be well correlated.



Exam ple 1:

(a) View from the centerline

(b) View from the shortest path



Exam ple 2:

(c) View from the centerline

(d) View from the shortest path

Fig. 3: Screenshots of our program showing the correlation between the two views.

4 Discussion

We have presented a method for registering VC and OC views through the correlation of their corresponding view paths. Since the correlation is done offline and entirely using

the CT data, the necessary calculations can be performed before the OC is started. In this way, given the location with which the OC view is on the simulated path, only a simple table look-up is necessary to acquire the point from which the VC view should be rendered.

To transfer this method from simulation to practice, it will be necessary to obtain from the OC colonoscope the distance into the colon with which it has been inserted. Using the CT data, this distance can be transformed into a position along the simulated path. From this point, it would then be possible to obtain the corresponding point on the VC centerline, allowing for the VC volume rendered view to then match that from the OC camera. The OC image features radial distortion, due to the fisheye lens used in the colonoscope. Radial undistortion of this view (or, to the contrary, radial distortion of the VC image) could allow for a better matching correspondence [5].

At the present time, all work has been done in simulation, using CT datasets. For future work, we hope to test and refine our method in a real-world clinical setting. Work on refining the registration, such that the orientation of the endoscope is also taken into account, is an item that also deserves further attention. The use of computer vision techniques to further improve the registration can also be investigated, as well as the integration of CAD results.

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