Volumetric CPR as an Enhancement to Virtual Colonoscopy Systems

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Abstract. Volumetric CPR is a new visualisation technique for curved tubular structures within the body. It works by splitting a structure lengthwise and presenting it to the user as two or more halves, each containing a detailed volume rendering of the inside of the structure and a greyscale rendering providing context information. In this work we look at the integration of the Volumetric CPR with an existing virtual colonoscopy system and the advantages which it can bring.
We demonstrate that the Volumetric CPR is a useful tool for displaying additional information not typically available during a flythrough, such as real-time surface coverage data or translucency rendering. We also show that, because the Volumetric CPR provides and alternative view on the colon, it increases surface coverage from 86.8% (for a flythrough in each direction) to 99.2%; significantly improving the chances of detecting abnormalities.

Keywords: virtual colonoscopy; visualization

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1. Purpose

Volumetric Curved Planar Reformation (Volumetric CPR) [1] is a new approach to the examination of curved tubular structures inside the body. Compared to traditional visualisation approaches [2, 3] it has numerous advantages in terms of image clarity, surface coverage, and examination time. Our previous work described the technical implementation of the technique but did not give details of its application. The purpose of this work, therefore, is to explore the benefits it can bring to one particular domain – namely that of virtual colonoscopy.

While it is widely acknowledged that virtual colonoscopy presents a much more pleasant experience for the patient (compared to optical colonoscopy), concerns remain about the effectiveness of the technique [4, 5]. Many of these concerns relate to the surface coverage of a flythrough [6, 7]; if polyps are missed then this can have potentially serious consequences. Other problems include the contrast enhanced fluid (typically taken to aid the electronic segmentation) obscuring polyps or creating false positives.

We intend to demonstrate that Volumetric CPR can help address these issues when integrated with more traditional approaches.

2. Method

A Volumetric CPR works by splitting the colon lengthwise and presenting it to the user as two halves. This is shown in Figure 1; the Volumetric CPRs at the bottom are synchronised with the other views such that, as the camera moves through the colon, the Volumetric CPR images scroll from right to left.

There are a number of benefits to this setup. Firstly, the Volumetric CPR allows the user to see much further ahead than they are able to by using the flythrough alone. They are

also able to see behind them – if they are concerned that something of interest may have been missed then it is possible to glance at the Volumetric CPR to check without needing to interrupt the flythrough. Because each piece of the colon surface is visible to the user for a longer period of time there is also a greater chance that any abnormalities will be noticed. Secondly, the Volumetric CPR can be used as a navigational tool. Clicking any point on it will cause the other views to jump to that point in the colon allowing a more detailed analysis.

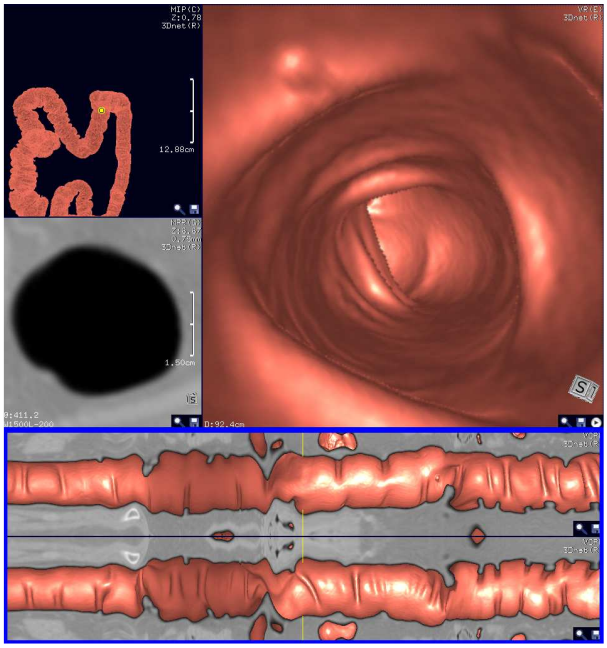


Fig. 1. The layout of the colonoscopy system including an overview (top-left), flythrough (top-right), and MPR (center-left). The two Volumetric CPRs (one looking up, one looking down) are at the bottom marked in the blue rectangle. The current position in the flythrough corresponds to the yellow marking in the centre of the Volumetric CPR. The area marked in purple on the Volumetric CPRs corresponds to what can currently be seen in the flythrough.

Further benefits are provided by the greyscale part of the Volumetric CPR. This shows what is beyond the surface and can provide useful context information. For example, when contrast enhanced fluid is present it is possible for a thin layer of fluid to stick to part of the colon surface – potentially hiding polyps underneath. This is difficult to detect in a flythrough because the fluid just shows up as part of the surface. In the Volumetric CPR, however, it shows up as a bright white boundary where the color rendering meets the greyscale image.

In addition to the basic uses of the Volumetric CPR illustrated so far, it is also possible to add overlays to convey further information. Actually, this capability has already been seen in Figure 1 where it was used to indicate what the flythrough is currently seeing. More generally, it can keep track of all parts of the surface seen so far (see Figure 2). Once the flythrough is complete the user can determine whether any regions have been missed and, if so, simply clicking the region on the Volumetric CPR will cause all views to jump to that location.

As well as monitoring the surface coverage of the flythrough, the Volumetric CPR actually increases coverage by providing an alternative viewing direction. It is often the case that polyps are occluded by folds in the colon but the Volumetric CPR is able to display many regions which would otherwise be missed.

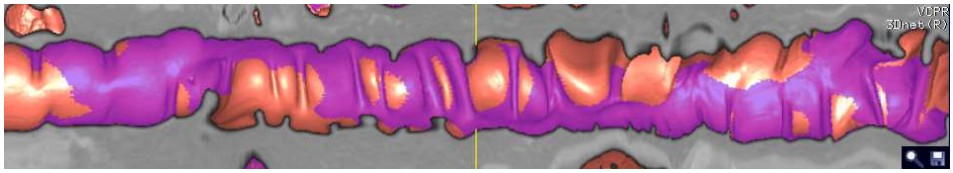
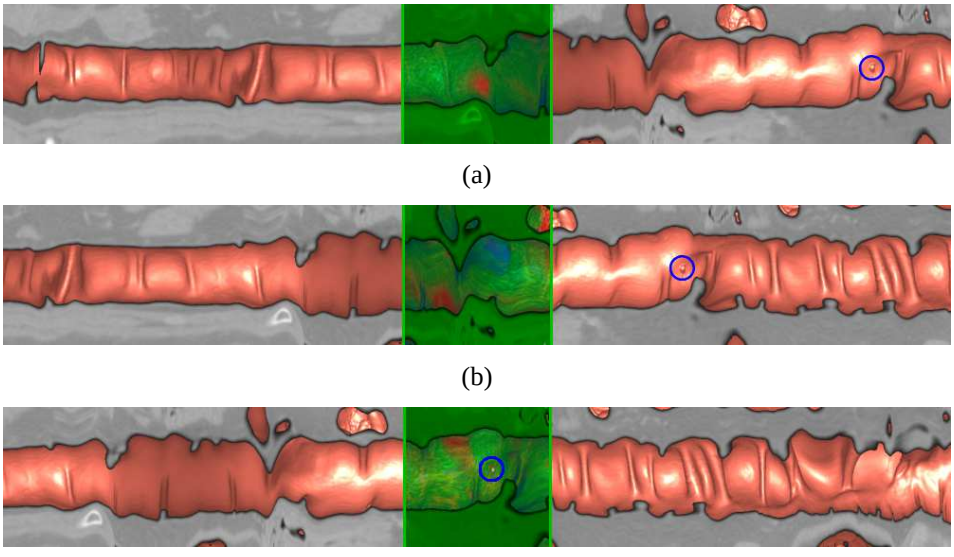


Fig 2. The Volumetric CPR can be used to visualise what regions have been seen by the flythrough. In this case a flythrough has been completed in one direction and it can be seen that large areas have been missed. Repeating the flythrough in the reverse direction will reduce the problem but not solve it completely.

A further problem caused by contrast enhanced fluid is the possibility of false positives due to tagged material in the colon. For example, Figure 3(a) shows what appears to be a polyp on the surface of the colon. In [8] a technique is described for performing 'translucent rendering' which allows the user to determine the density of material just behind the surface; tissue shows up red or green while fluid shows up white. Unfortunately this interrupts the workflow when applied to a flythrough because the user is required to stop, switch on translucent rendering to examine the structure, switch back to normal rendering, and resume the flythrough. It integrates much more elegantly with the Volumetric CPR because we simply provide a 'translucency band' which all of the surface passes through at some point. Applying this to the regions around the 'polyp' reveals that it is actually just a deposit of fluid (Figure 3(c)).



(a)

(b)

(c)

Fig 3. A suspicious structure is identified in the colon (marked by a blue ring in (a)). As the flythrough proceeds, the Volumetric CPR moves from right to left (b). As it passes under the translucency band the inside of the structure can be seen to have a high density (c) and it is therefore a deposit of fluid rather than a polyp.

3. Results

The technique was demonstrated to the gastrointestinal department of University College London Hospital and has received positive comments and feedback. The early stage trial has proven that Volumetric CPR is a viable technique and, when combined with other approaches such as a flythrough, can help provide more of the information required when assessing a patient's condition. We are planning to conduct a larger scale

clinical trial with the group based on this and similar techniques for the analysis of gastrointestinal diseases.

We have also obtained quantitative results relating to the surface area which is seen by the flythroughs and the Volumetric CPRs. A flythrough was performed in each direction and sets of 2 (up and down) and 4 (up, down, left and right) Volumetric CPRs were generated for each of 3 colon datasets. The results are shown in Table 1.

Table 1
The percentage of the surface seen by the flythroughs and the Volumetric CPRs in various combinations.

	Dataset 1	Dataset 2	Dataset 3	Average
Flythrough (Antegrade)	62.2%	69.6%	65.1%	65.6%
Flythrough (Retrograde)	61.9%	66.1%	64.5%	64.2%
Flythrough (Both Directions)	84.8%	89.8%	85.9%	86.8%
Volumetric CPR (Up + Down)	76.1%	82.8%	74.1%	77.6%
Volumetric CPR (Left + Right)	76.3%	84.3%	74.8%	78.5%
Volumetric CPR (All Directions)	97.9%	98.8%	96.5%	97.7%
Flythrough (Both) + Volumetric CPR (All)	99.3%	99.6%	98.8%	99.2%

4. Conclusion

Even without overlays, the Volumetric CPR is a valuable extension to the traditional virtual colonoscopy package. It can be used to allow more of the colon to be seen at once, to provide a navigational aid, and to increase surface area which is seen. It the latter case it increases the surface coverage from 86.8% to 99.2% on average. This significantly improves the chance that polyps are detected.

The addition of overlays allows the Volumetric CPR to become a powerful tool for monitoring surface coverage or for analysing the composition of a surface. This adds significant diagnostic value to the technique and allows a more streamlined workflow. Future work will likely focus on the development of further overlays such as curvature information or a display of the results of computer aided polyp detection.

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