PhD Thesis Title: Computer Aided Assessment of Colon Polyps in CT Colonography using Image Processing Techniques

Author: Manjunath K N, PhD

E-mail: knm_mit@yahoo.com

Institution: Department of Biomedical Engineering, Manipal Institute of Technology, Sir MV Road, Manipala, India 576104

Thesis Supervisor: Gopalakrishna Prabhu K., PhD

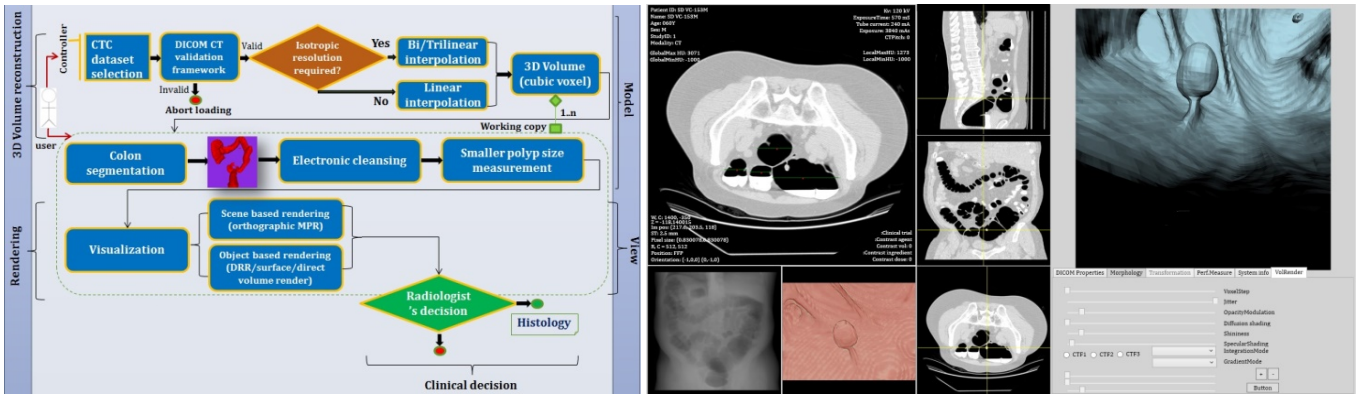
Graduation Date: 17th July 2017

Available Online: http://shodhganga.inflibnet.ac.in/handle/10603/180708

Abstract:

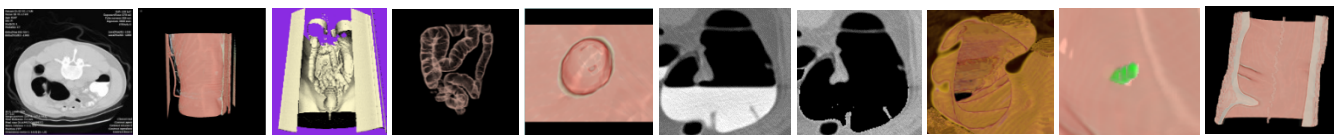
Medical Image Processing (MIP) has a strong footprint in the area of pathology, which has helped doctors for decades. Computed Tomography Colonography (CTC) is a medical imaging and diagnostic procedure for finding the polyps of different shapes and sizes in the large intestine using image processing techniques. Our research focused on the development of an automated computer-aided assessment of polyps using CTC images. The objectives of the study were: a) to segment colon exactly at the colon wall, b) to clean the tagged fecal materials from the segmented colon without loss of colonic structures, and c) to measure the smaller polyps. The new image processing hybrid methods were developed by considering the domain aspects of the colon polyp analysis.

An improved method of boundary-based semi-automatic segmentation was developed, which accurately delineated (accuracy of $\mathbf{94.614 \pm 0.7754}\%$ was achieved) the colon wall. A multistep technique was developed for the virtual cleansing of the colon, which uses the theoretical knowledge of **Housenfield Units**. The key findings were: a) the submerged colonic structures were preserved without soft tissue erosion, b) pseudo enhanced voxels were corrected, and c) the air-contrast layer was removed without losing the adjacent tissues. With the morphological image processing operator (skeletonization) and the domain aspects of deciding the polyp through height and width measurement, an automated method was developed for smaller polyp measurement. Statistically, $\boldsymbol{Sensitivity = 87.5\%}$, $\boldsymbol{Specificity = 82\%}$, $\boldsymbol{Accuracy = 86.27\%}$, $\boldsymbol{PPV = 94.45\%}$, and $\boldsymbol{NPV = 64.28\%}$ were achieved. The method took $\mathbf{1.5 - 2\ min}$ for colon segmentation, $\boldsymbol{five\ min}$ for electronic cleansing, and $\boldsymbol{\sim 4\ min}$ for measuring the polyp from the set of $\mathbf{450 - 500}$ CTC images. The significance of the results was statistically proven by using the qualitative and quantitative validations.



(a) (b)

Figure 1: The research and development of image processing framework. a) The design of research and development, and b) The prototype user interface with 2D MPR and 3D visualization.



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

Figure 2*:* Features supported. a) The axial CT slice, b) Direct volume rendering of patient scan data, c) Surface rendering, d) Volume rendering after segmentation, e) The tumor mass, f) The submerged tissues in contrast agent, g) Contrast removed from colon without losing the tissue details, h) volume render after contrast removal, i) The smaller polyp of size less than 10mm, j) The clipping plane shows the colon interior.

By considering the requirements of the Radiologist from medical imaging application, the research results were translated to a prototype software (Figure 1a, 1b) which has the features like, loading of CTC images (Figure 2a), performing various image

processing methods (2b, 2c and 2j) and automated methods for colon segmentation (2d), electronic cleansing (2f – 2h), and smaller polyp measurement (2e and 2i). The prototype includes object-oriented design, multithreading, GPU programming, following the standard coding guidelines and integrating volume rendering frameworks for 3D visualization. This prototype can be used as a low-cost software after the necessary verification and validation as per the IEC 62304 medical device development standards. This can be used as a basic image processing framework for different medical imaging modalities like, CT, MRI, and PET.

References to author publications that relate specifically to the dissertation:

1. **KN Manjunath**, PC Siddalingaswamy, GK Prabhu, "Measurement of smaller colon polyp in CT colonography images using morphological image processing," International Journal of Computer Assisted Radiology and Surgery, 12(11):1845(2017). DOI:10.1007/s11548-017-1615-4

2. **KN Manjunath**, PC Siddalingaswamy, K. Gopalakrishna Prabhu, "An Improved Method of Colon Segmentation in Computed Tomography Colonography Images Using Domain Knowledge," Journal of Medical Imaging and Health Informatics, 6(4):916-24(2016). DOI:10.1166/jmihi.2016.1786

3. **KN Manjunath**, PC Siddalingaswamy, GK Prabhu, "Automatic Electronic Cleansing in Computed Tomography Colonography Images using Domain Knowledge," Asian Pacific Journal of Cancer Prevention, 16(18):8351-8(2015). DOI:10.7314/APJCP.2015.16.18.8351

4. **Kanabagatte Nanjundappa Manjunath**, Prabhu Karkala Gopalakrishna, Puttappa Chandrappa Siddalingaswamy, "Feasibility of Computed Tomography Colonography as a Diagnostic Procedure in Colon Cancer Screening in India," Asian Pacific Journal of Cancer Prevention, 15(13):5111-6(2014). DOI:10.7314/APJCP.2014.15.13.5111

References to author publications related to the thesis:

5. **KN Manjunath**, GK Prabhu, PC Siddalingaswamy, "A quantitative validation of segmented colon in virtual colonoscopy using image moments," Biomed Journal, 43(1):74-82(2020). DOI:10.1016/j.bj.2019.07.006

6. **Manjunath KN**, Siddalingaswamy PC, GK Prabhu, "Domain-Based Analysis of Colon Polyp in CT Colonography Using Image-Processing Techniques," Asian Pacific Journal of Cancer Prevention, 20(2):629-637(2019). DOI:10.31557/APJCP.2019.20.2.629

Conference proceedings

1. **Manjunath KN**, GK Prabhu, PC Siddalingaswamy, “Developing a low-cost medical imaging software product from research prototype in Radiology,” 3rd International Clinical Engineering And Health Technology Management Congress, Rome Italy, Oct 20-23, 2019, Abstract appears in Global Clinical Engineering Journal, DOI:10.31354/globalce.v2iSpecial%20Is

2. **Manjunath KN**, GK Prabhu, PC Siddalingaswamy, “Poster presented in Image Science,” Gordon Research Conferences. Boston, USA, 17-22 June 2018 (Carl Storm underrepresented minority fellowship from NIH, USA).

3. **Manjunath KN**, GK Prabhu, PC Siddalingaswamy, “Quantitative analysis of segmented colon in CT Colonography using geometrical features,“ Computer Assisted Radiology and Surgery Congress, Berlin, 20-23 June 2018, DOI:10.1007/s11548-018-1766-y

4. **Manjunath KN**, GK Prabhu, PC Siddalingaswamy, “Analysis of Colon Polyps in CT Colonography using image processing techniques,” Research Colloquium by Alexander Von Humboldt Stiftung (Germany), Nov 23-25, in Bengaluru

5. **Manjunath KN,** GK Prabhu, PC Siddalingaswamy, “An improved method of polyp size measurement in CTC Images,” International Conference on Graphics and Signal Processing, Nanyang Technological University, Singapore, June 24-27, DOI:10.1145/3121360.3121380