10.1117/2.1200812.1404

Colonography without colon cleansing

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Computed tomography colonography employing partial volume image segmentation improves detection of the colonic mucosa layer and thus of potentially cancerous polyps.

Colonic polyps are the major source of colorectal cancer, which is the second leading cause of cancer-related deaths in the United States. Computed tomographic colonography (CTC) and the current gold-standard optical colonoscopy have shown comparable performance in detecting polyps that are at least 8mm in diameter, but CTC is a less-invasive procedure with less stress on bowel cleansing.[1,2] Further reducing or even eliminating the need for bowel cleansing would widen the use of CTC for screening for colorectal cancer. In addition, better detection of small polyps (<8mm) would improve the capability of CTC as a screening tool. To achieve these two goals, accurate extraction of the colonic mucosa layer from abdominal computed tomography (CT) images is essential.

Removing the need for bowel cleansing helps minimize patient stress from CTC.[3,4] However, because of the similarity in x-ray attenuation among colonic fluid, stool, and the colon wall, in CT images it is almost impossible to find a polyp buried inside colonic materials. The ideal solution would be to decrease the densities of the fluid and stool to yield less x-ray attenuation, similar to air. This would cause the colon lumen to become 'dark' in the CT images, and small polyps protruding into the 'dark' lumen could be detected. In the absence of such an ideal solution, a suboptimal alternative is to increase the densities of the colonic materials to yield enhanced image intensities.[5] This can be achieved by ingesting oral contrast solutions to tag the colonic materials prior to CT scans.[5] However, several drawbacks are associated with this approach, including the photovoltaic (PV) effect at the interface between the colon wall and the colonic materials, nonuniform tagging, and artificially enhanced image intensities of the soft tissues and polyps buried inside the tagged colonic materials (TMs). Segmenting the TMs by threshold-based methods without accurate treatment of the PV effect could obscure small polyps from the image (false negatives) and generate artifacts mimicking polyps (false positives).

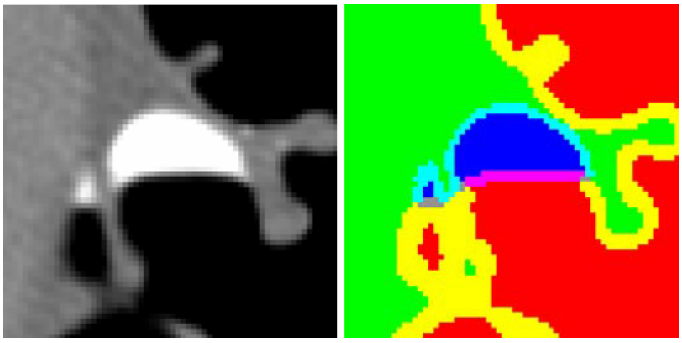

Figure 1. *Resolution of the photovoltaic (PV) effect by our maximum a posteriori expectation-maximization (MAP-EM) mixture segmentation. (left) A zoomed-in view of a small region in a slice of a computed tomography (CT) volume image. (right) A zoomed-in view of the segmentation of the small region, with colors as follows. Red: Pure air space. Blue: Pure tagged colonic materials (TMs). Pink/gray: The mixture space of air and TMs. Yellow: The mixture space of air and colonic tissues. Light blue: The mixture space of TMs and colonic tissues. These interface layers, which indicate the presence of the PV effect, are accurately identified.*

We have been investigating a statistical framework for the expectation-maximization (EM) approach to the maximum a posteriori (MAP) solution for segmenting tissue mixture percentages inside each image voxel.[6,7] In this framework, the observed image intensity in a voxel is modeled as a mixture of K possible tissue types ($K = 4$ for the CTC application: air, soft tissue, muscle, and bone/TM). Each tissue distribution is modeled by a normal function with two parameters, mean and variance. These parameters are fractioned to satisfy the condition that all tissue components add up to the observed image intensity at that voxel. The fractions or percentages of these K tissue types in that voxel and the mean and variance parameters of the tissue distributions are determined from the image data by the MAP so-

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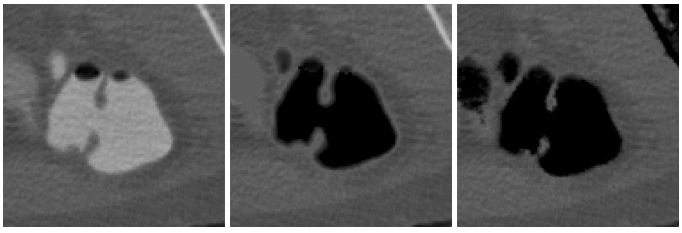

Figure 2. *TM removal to recover buried soft tissues. (left) A zoomed-in view of a small region in a slice of a CT scan. (middle) The result after removal of the TMs. (right) The result of our previous MAP-EM algorithm without the mixture modeling, shown for comparison purposes.*

lution. Because of the incomplete nature of the four-to-one mapping in each voxel, we adapt the EM iterative strategy to compute the MAP solution. The computed tissue percentages in a voxel resolve the PV effect on the mucosa layer where polyps reside.

Figure 1 shows a typical example of the MAP-EM mixture segmentation. The method automatically detects three interfaces at which the PV effect occurs: air and colon wall (yellow), colon wall and TMs (light blue), and air and TMs (pink/gray). Given these segmented interfaces, the TMs are electronically removed while the buried soft tissues and polyps are recovered. Figure 2 shows an example after removal and recovery.

In conclusion, we have developed a statistical framework to accurately detect and extract the colonic mucosa layer in CT images. This electronic colon cleansing provides essential information for removal of colonic materials, discovery of buried polyps, and detection of small polyps that otherwise may be blurred out by the PV effect.

This work was partly supported by NIH grant CA082402 of the National Cancer Institute.

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