

Automatic segmentation of large bowel obstruction area with Hough transform from erect abdominal radiograph images

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ABSTRACT

Large bowel obstruction is less frequent but often appears acute and needs emergent treatment. Erect abdominal radiograph is usually the first imaging study performed in patients suspected of having large bowel obstruction. However, that modality suffers from operator subjectivity thus a fully automatic computer aided tool is necessary. In this paper, we propose an automatic large bowel feature (air-fluid region) segmentation method based on Canny edge detection and Hough transform. In experiment, the proposed method was successful in finding target region from large bowel obstruction patients' radiographic images in all 30 cases provided. While limited only applicable to the large bowel obstruction cases, the proposed method is practically feasible in application.

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1. INTRODUCTION

Bowel obstruction or intestinal obstruction is a mechanical or functional obstruction of the intestines which prevents the normal movement of the products of digestion. Signs and symptoms include abdominal pain, vomiting, bloating and not passing gas [1]. Large-bowel obstruction (LBO) differs substantially from small bowel obstruction (SBO). LBO constitutes 20% of all mechanical obstruction. Its etiology is age-dependent with colonic cancer being the most common cause in adults [2]. Patients with LBO are usually elderly, and the signs and symptoms of LBO are often insidious in contrast to the abrupt onset of symptoms seen in most SBO [3] and the causes of LBO and SBO differ substantially [4]. While LBO may develop over a protracted period and less frequently occurred than SBO in general, the clinical presentation is often acute and includes abdominal pain, constipation or obstipation, and abdominal distension [5]. Emergency surgery or colonoscopy is usually required to relieve the obstruction [6]. Thus, treating acute LBO is particularly important due to its high morbidity and mortality rates if left untreated [7].

Image analysis plays a vital role in the management of LBO by identifying the location, degree, and cause of obstruction. Abdominal radiography is usually the first imaging study performed in patients suspected of having LBO. While the reported sensitivity of abdominal radiography for the detection of LBO is similar to that for the detection of SBO (84% vs. 82%, respectively), the reported specificity is considerably different (72% vs. 83%, respectively) and as a result, it may be difficult to distinguish between obstruction and colonic pseudo-obstruction in a patient with a distended colon [8, 9]. Furthermore,

radiographic studies showed limited capability in the diagnosis of bowel infections [10-12]. Thus, further evaluation with multidetector computed tomography (MDCT) has become the standard of care to identify the site, severity, and etiology of obstruction [13, 14]. However, this modality is expensive, time consuming, and associated with high radiation exposure that is over 10 times more than the abdominal radiography [15].

In sum, the diagnostic value of abdominal radiographs is limited but continues to be recommended as an important component of the diagnostic imaging pathway of acute abdomen due to above-mentioned trade-off [16]. Normal colonic caliber is variable due to its high distensibility, and for practical purpose cecum >9 cm and rest of the colon >6 cm in diameter is considered as dilated [6]. The presence of colonic air fluid levels usually indicates an acute mechanical obstruction. The absence of distal rectal gas is not a reliable sign of LBO as it can be seen in colonic ileus as well. However, it is difficult to evaluate all the loops or make an etiologic diagnosis with radiographic image analysis alone. Moreover, it is operator dependent and difficult to perform in acute state as well as in obese patient [17].

In this paper, we propose a fully automatic segmentation method for LBO structure detection. Segmentation process is inevitable procedure for making stable diagnosis by medical image analysis but frequently has been a source of operator subjectivity especially using ultrasound or plain radiography [18, 19]. In LBO radiographic image analysis, we may use either supine and erect (or left lateral decubitus). It is reported that erect radiography not only gave slightly better performance in diagnostic accuracy and the intra-rater and inter-rater agreement but also air-fluid levels were only seen on the erect radiograph image [20]. Moreover, for LBO, we can use morphological information such as the discriminative shape of air fluid level from erect radiograph. Still, doctors with less experience may find it difficult to interpret abdominal radiographs that appear to have normal anatomy but have an unusual bowel gas pattern [21]. Thus, automatic segmentation procedure gives less chance of making incorrect decision in diagnosis. Automatic segmentation process includes many image processing steps such as binarization and noise filtering. Our proposed method relies on traditional edge analysis and Hough transform [22] as the main tools to locate the air-fluid area from erect LBO radiographs correctly.

2. METHOD

2.1. Preprocessing and canny edge processing

A typical erect abdominal radiograph having LBO is shown as Figure 1. The lung is shown as relatively low intensity and located in the upper part of the body, and the stomach is in the upper right of the body with low intensity with horizontal flatness. The pelvis exists in the lower part of the body and with relatively high intensity. The intestine which is our region of interest (ROI) is located between the lungs and the pelvis.



Figure 1. Typical erect abdominal radiograph with LBO

The target area of our method is the semicircular shape of air-fluid area in the lower boundary of the intestinal obstruction area appearing in the LBO patient's radiographic image as shown in Figure 1. To locate the target area, we apply canny edge detection algorithm [23]. Edge detection is the process of finding sharp separations in an image. The separations are significant changes in pixel intensity which distinguish barriers

of objects in a scene. From the input radiographic image shown as Figure 2(a), we first apply Gaussian Blur mask to filter noises and obtain images like Figure 2(b). The second step is to estimate gradients. Calculation of the gradient is done by the Sobel kernel which is applied to each pixel in the image in both directions. Strength of the edge is determined by gradient magnitude while direction of the gradient is used to determine for each pixel the direction with the largest change in intensity and we obtain the intermediate result as shown in Figure 2(c).

The gradient direction needs to be rounded to nearest 45-degree step. Only the pixel with maximum edge strength will be preserved, otherwise it will be suppressed through a process on nonmaximum suppression for edge thinning. After that, we apply double thresholding technique to remove noises and determine edges from the image. Weak edges are finally preserved or suppressed using edge tracking by hysteresis and finally we obtain edges shown as Figure 2(d). After Canny edge detection, we cut off upper part of the lung and lower part of the pelvis to restrict our ROI as the area having LBO structure to make our method more efficient in computation.

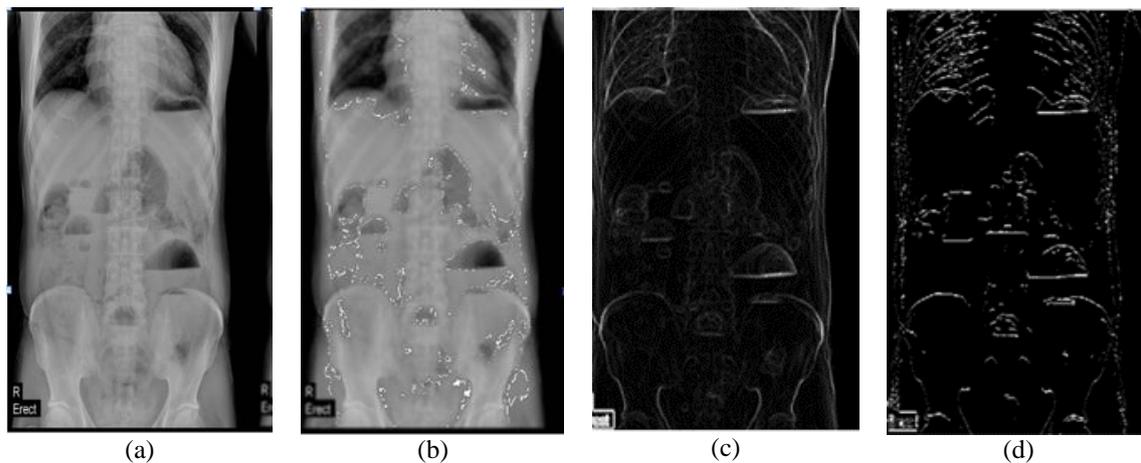


Figure 2. Canny edge application, (a) input, (b) after Gaussian blur, (c) after gradient, (d) extracted edges

2.2. Extracting LBO features by Hough transform

The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing [23-27]. The purpose of the technique is to find imperfect instances of objects within a certain class of shapes by a voting procedure for the possible geometric shapes of edges. The Hough transform can be defined as the transformation of a point in Cartesian space into the parameter space defined by the shape of the object of the interest. For any point (x, y) on a straight line (edge) can be transformed to (r, θ) space called as Hough space by (1).

$$r = x \cdot \cos(\theta) + y \cdot \sin(\theta) \quad (1)$$

One way of interpreting this is to drop a perpendicular from the origin to the line. θ is the angle that the perpendicular makes with the x-axis and r is the length of the perpendicular. θ is bounded by $[0, 2\pi]$ and r is bounded by the diagonal of the image. In this paper θ is limited to $[87, 93]$ in degree.

To detect an accurate straight line, in this paper, the average of the extracted edge lengths is set as the threshold and the number of sine curves passing through a point appearing on the Hough space is compared with the threshold, The point with the most intersection in that process is chosen to be transformed into a straight line of (x, y) plane by applying (2). The result is shown as Figure 3(b).

$$\sum_{y=0}^H x = \frac{(r-y \cdot \sin(\theta))}{\cos(\theta)}$$

$$\sum_{x=0}^W y = \frac{(r-x \cdot \cos(\theta))}{\sin(\theta)} \quad (2)$$

where H and W denote the height and width of the given image respectively.

By taking the most intersected edges with Hough transformed lines from Figure 3(a) are chosen as candidates of the LBO segmentation features as shown in Figure 4(a). Then, we consider the morphological characteristic of LBO to locate the delated air fluid region as shown in Figure 4(b).

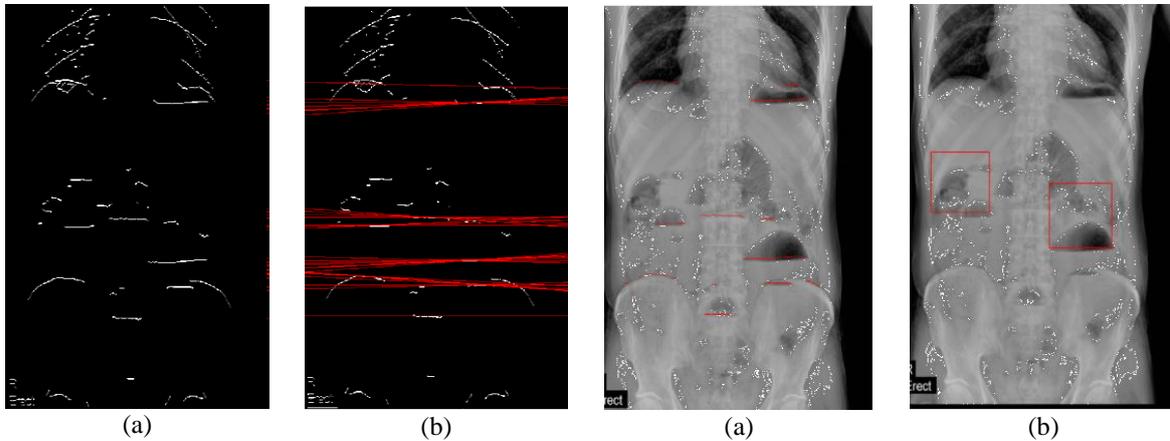


Figure 3. Effect of Hough transform, (a) canny edge result, (b) after Hough transform

Figure 4. Extracting LBO features example, (a) LBO feature candidates, (b) LBO features

3. RESULTS

The implementation of the proposed method is written by C# under Visual Studio2015 environment on IBM compatible PC with Intel(R) Core (TM) i7-7500 CPU @ 1.80GHz and 16 GB RAM. An experiment is designed to verify of the proposed method finds LBO features from the erect radiograph image photographed by DK Medical Accuray-650R diagnostic radiation generator. Total 30 LBO patients' images are obtained from Baik Hospital, Busan, Korea. In this experiment, the proposed method was successful to locate the LBO features in all 30 input images. The performance of the implemented software was verified by the pathologists from Baik Hospital. An example of real-world LBO feature segmentation result is demonstrated in Figure 5.

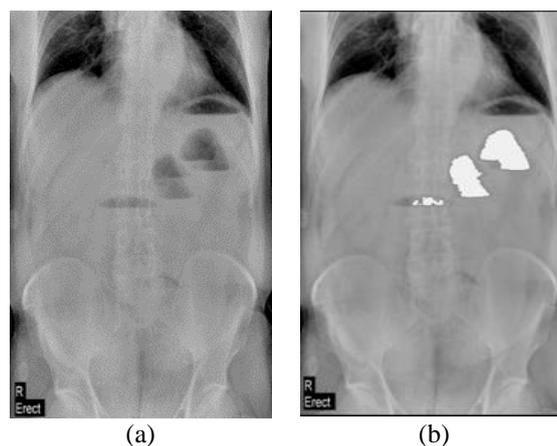


Figure 5. Examples of successful LBO feature extractions, (a) input, (b) successful extraction

4. CONCLUSION

In this paper, we propose a method to extract LBO feature (air-fluid area) automatically from Erect radiograph images. Erect abdominal radiography is better than supine abdominal radiography in inter- and intra-operator agreement but still this plain radiographic modality has operator subjectivity problem. Thus, we provide a fully automatic segmentation tool for doctors having objective evidences in diagnosis. The proposed method consists of many image processing procedures but the main engines for automatic

segmentation are Canny edge detector and Hough transform to locate air-fluid area from the input radiographic image. In experiment, the proposed method is perfect in automatic segmentation of target LBO feature when the image actually contains that feature (air-fluid region of sufficient size). There was no failed case among given 30 patients' images. However, this method has some limitations. Firstly, we test only real LBO patient cases. Thus, the 100% performance of this experiment should be read as true positive rate (TPR) only. Secondly, since we use morphological knowledge of LBO (edge length) in segmentation, the same procedure does not work properly in SBO segmentation. The main advantage of this approach is simple but strong objective tool for real-world pathologist in very specific limited usage.

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