# Shape Recovery of Polyp using Blood Vessel Detection and Matching Estimation by U-Net

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***Abstract*—In the medical diagnosis, endoscopic polyps are examined and discrimination between benign and malignant is judged via the visual observation by a medical doctor. Estimating size of the polyp is important because the larger polyp tends to become malignant if the size is more than 1 cm since it is not easy to estimate the size of the polyp except medical doctors who have several years of experience. This paper proposes reliable correspondence between two images with a slight movment of endoscope using ORB features estimating the absolute size of polyp using blood vessel information in the endoscopic images. The effectiveness of the proposed approach is confirmed via experiments.**

***Index Terms*—Shape Recovery, Absolute Size of Polyp, Blood Vessel, U-Net, Endoscope, Corresponding Points**

## I. Introduction

There is a method using a reference object to estimate parameters such as reflectance factor necessary for shape recovery and its polyp size from endoscope image. Ref. [1] uses a medical suture used to connect tissue at a surgical site as a reference object, although the medical suture is suitable as a reference object with a known size. However, it takes costs and effort to insert inside the body. It is a disadvantage that the cost is high. Therefore, ref. [2] proposed a method to use the blood vessel observed in many endoscope images as a reference object. Here, blood vessel is used under the condition that the thickness of the blood vessel is known to some extent in advance. Ref. [2] uses a method to detect blood vessels using the threshold value of HSV color representation from the original RGB color image. In some cases, the unnecessary region except the blood vessel may be detected in some cases of endoscope ennvironment based on the approach.

It became possible to remove unnecessary regions except the blood vessels by ref. [4], which is an extended approach using the Frangi Filter [3]. Frangi Filter is not suitable to detect the blood vessel region in the whole image because Frangi Filter does not have such characteristics.

Approach of ref. [1] uses two images from the movement of endoscope. This approach is sometimes unstable to detect a corresponding blood vessel region by acquiring accurate correspondence points between the images whose final purpose is to estimate the movement of endoscope, reflectance parameters and to recover the absolute shape of polyp. Result of shape recovery of polyp depends on the accuracy of detected blood vessel region.

This paper proposes an approach to obtain more accurate correspondence point between two images which are taken with a slight movement of endoscope image and U-Net [5] is introduced to detect more blood vessel regions. U-Net has an advantage that a large amount of data can be processed and accurate detection can be performed. It is also known that the number of learning images can be reduced in U-Net while a large number of learning in required in machine learning in general.

Ref. [2] uses template matching to determine the corresponding region of blood vessel between two images. However, template matching is sometimes weak to determine the corresponding point and fails to detect correct corresponding region using some threshold values between two endoscope images.

Although template matching uses global features, it may be sometimes better to use local features to find some feature points to correspond to two different images. Ref. [6] extracted Oriented FAST and Rotated BRIEF (ORB) features from endoscope images and proposed the dense matching using optimization. Although the method extracts the feature points extracted from the transition of images including specular points and texture of polyp, the method is available to recover the relative shape not the absolute shape of polyp.

This paper proposes an approach to recover the 3D shape of polyp using the locall feature points based on the blood vessel

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information between two images. Blood vessel information is detected by U-Net and the region segmentation is performed on the blood vessel region. Feature points are extracted for each region and region correspondence and parameter estimation is performed to recover the reliable absolute shape of polyp from two endoscope images.

## II. Metodology

Proposed method detects a blood vessel region by U-Net for an endoscopic image including blood vessel information and two images captured by moving a few frames (about 5 to 8). The segmentation by labeling region is performed. The matching is performed for each region using ORB features. Depth $Z$ is estimated under the condition that the thickness of the corresponding blood vessel is treated as kown with estimating the $\Delta Z$ by taking the difference of the depth Z for each corresponding point. Finally the depth $Z$ is recovered.

### A. Blood Vessel Detection by U-Net

U-Net [5] is a neural network developed to integrate and learn both local features of objects and global position information.

Region extraction requires to identify local features and global position information of an object, but it is also necessary to get the resulting image in the pixel-wise blood vessel detection. Therefore, U-Net is used for blood vessel detection in the proposed method. The position and color of the blood vessel are learned from the created mask image which is the true value to take the blood vessel region as a ground truth. By extracting patches at random from learning images and corresponding mask images, it becomes possible to learn with a small number of images by U-Net. Although the result of blood vessel detection by U-Net is overall dark and it is difficult to recognize the blood vessel region, a binarization process of detecting the blood vessel region and removing the unnecessary noise by taking the intensity difference from the detected image are applied. Proposed method performs the blood vessel detection using the above procedures.

The original image of the image, the mask of the blood vessel, and the mask of the area used for learning are shown in (a), (b), and (c) of Fig. 1, respectively.

The procedure of blood vessel detection by U-Net is shown below.

step1. Create mask image from learning image.

step2. From the image for learning and the mask created in Step 1, create 9500 pathes consisting of 48 $times$48 pixels per patch at random.

step3. The blood vessel region is characterized from the patch of Step 2 and learning is performed.

step4. Detect ORB features of learning data of Step 3 from the original test data.

step5. Remove the detailed noise using the difference of intensity..

### B. Estimating Destination Vessel Region by Corresponding Points between Two Images

Let the original image taken by endoscope be the 1st image and let the following image taken by moving about 5 to 8 frames from the 1st image be the 2nd image. U-Net is applied to detect blood vessel and ORB feature is extracted from two image and the corresponding blood vessel region is estimated. Region is segmented by labeling on two images and the segmented region with the largest area on the 1st image is taken as the region of interest. The region with 1st to 3rd largest area on the 2nd image is compared and the corresponding blood vessel segmented region is detected.

After the corresponding region is detected, the corresponding processing is applied again with ORB features between the 1st region of interest and the detected region to achieve more accurate correspondence.

### C. 3D Shape Recovery

The depth $Z$ is obtained from the thickness of the blood vessel for each of the corresponding feature points, and the movement of $\Delta Z$ of the camera is estimated from the the difference of $Z$ of the corresponding points.

The reflectance factor $C$ is estimated from $\Delta Z$ of the point with the local brightest point of the image. 3D shape of the polyp in the endoscope image is recovered by Fast Marching Method (FMM) based on the Ref.[7].

FMM is a method that solves the eikonal equation representing the propagation of light at high speed without performing convergence calculation. FMM recovers the depth $Z$ by calculating the gradient from the intensity value in the endoscope image. Here, it is assumed that the focal length of the endoscope camera is known in ref. [7].

## III. Experiments

### A. Matching

Experiments were performed using real images and comparison with ref. [2] were investigated to confirm the effectiveness of the proposed approach.

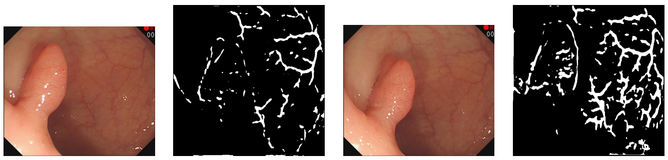
Learning images used in U-Net were 20 images which includes the blood vessel region as shown in Fig. 2(a). Image containing blood vessel region except images used for the learning and the corresponding image taken after several

(a) Original Image (b) True Value of Blood Vessel (c) Objective Region

Fig. 1. Learning Images by U-Net

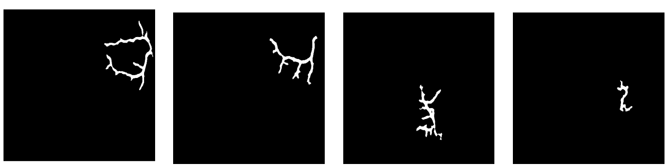
frames are used as a pair of test images which consists of 16 images with 14 white light images and 2 stained images. Blood vessel detection was performed on these prepared images.

Next, matching is performed on the detected image.



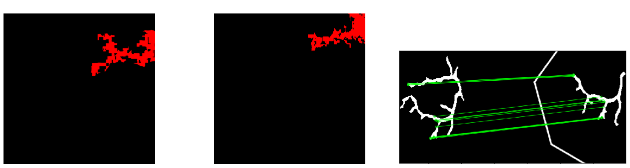
(a)Endoscope Image 1 (b) Blood Vessel Region (c)Endoscope Image 2 (d) Blood Vessel Region

Fig. 2. Images



(a) Region of Interest (b) Candidate Region 1 (c) Candidate Region 2 (d) Candidate Region 3

Fig. 3. Region of Interest and Candidate Region after Movement



(a) Ref. [2](1) (b) Ref. [2](2) (c) Proposed

Fig. 4. Results of Estimating Movement

TABLE I
EVALUATION OF GENERALIZATION

| | Detected | Not Detected | Success Ratio(%) |
|---|---|---|---|
| Ref. [2] | 8 | 8 | 50 |
| Proposed Method | 14 | 2 | 87.5 |

### B. Absolute Shape Recovery

Three-dimensional shape recovery is performed using the obtained parameters and result is compared with ref. [2]. Parameters obtained from blood vessel information are shown

TABLE II
文献 [2]

| Parameter | Endoscope Image 1 | Endoscope Image 2 |
|---|---|---|
| $\Delta Z$ | 3.7019 | 2.8672 |
| $C$ | 76.1 | 78.6 |
| Height of Polyp (mm) | 6.21 | 6.8 |

in Table II, Target polyp is shown in Fig.6 and result is shown in Fig.7.

In the ref. [2], the red parts in Fig.4(a)(b) are the detected results for the region of interest in the 1st image and the destination in the 2nd image. Two regions in Fig.4(c) are the detection results of the corresponding blood vessel regions. It is shown that both can be detected correctly.

In the case of ref. [2], SIFT features are extracted for the detected region and the movement $\Delta Z$ of the camera is estimated to determine the reflectance factor $C$. In the proposed method, matching of regions is performed at feature points. Using the matched points among the feature points by ORB can estimate the parameters similarly as that in ref. [2].

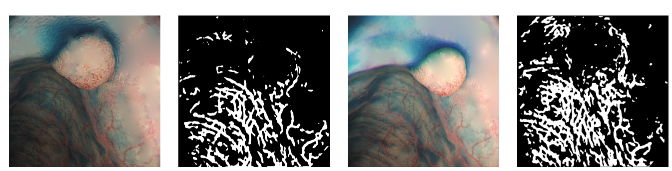
It is also confirmed that the proposed method can detect the corresponding point in the 2nd image but the method of **??** failes in detecting that after the movement. The proposed method could estimate the moving destination acurately including 14 images except the stained images.

The reason why the matching could not applied well in the stained images may include the situations that in

As the reason for not being able to perform matching in the stained image, the stained images includes more non-blood vessel detection as shown in b and c in Fig.5 in comparison with the result of white light images as shown in b and d in Fig.2 by U-Net. As a result, segmentation is not done well and parameters could not be estimated well.

Since the stained image is considered to be suitable for obtaining blood vessel information originally since it emphasizes edges such as blood vessels in the endoscopic image, the region segmentation should be improved with the goal of getting more robust results.

When parameters cannot estimated, 3D shape recovery also cannot be provided. It can be seen from Table II that the values



(a)Endoscope Image 1 (b) Blood Vessel Region (c)Endoscope Image 2 (d) Blood Vessel Region

Fig. 5. Failure Example of Region Segmentation

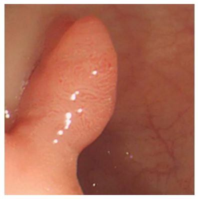
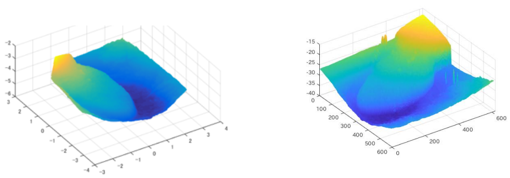


Fig. 6. Target Polyp



(a) Ref. [2] (b) Proposed

Fig. 7. Recovered Results of 3D Shape

of the parameters are obtained with ref. [2] and the heights are also recovered In ref. [2], 3D shape recovery can not be performed when parameters can not be obtained if the mapping of the regions between the images fails.

In the proposed method, matching was successfully performed on images except the stained images used in the experiment. 3D absolute shapes for all the images for which parameters could be obtained. It is confirmed that the effectiveness of the proposed method works for the original purpose of the paper.

## IV. Conclusion

This paper proposed a method to estimate the correspondence of the blood vessel region using ORB features of the blood vessel region for the detection image by U-Net for the endoscope image where the blood vessel is observed.

The paper shows that it makes it possible to apply the method to a variety of the endscope scenes by using ORB features which are the local feature from the conventional global feature under the endoscope environment.

Future topics of research include region segmentation and correspondence methods except white light images and consideration of point cloud-based shape recovery using extracted feature points to get more robust results.

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