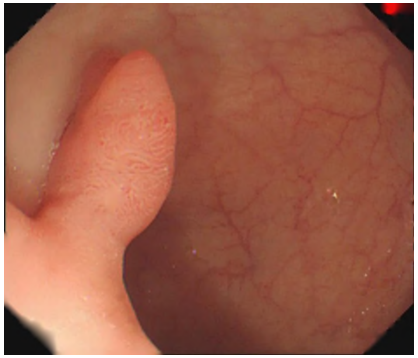
PATTERNS 2021

Recovering Shape from Endoscope Image Using Eikonal Equation

Yuji Iwahori (Chubu University)
Hiroyasu Usami (Chubu University)
M. K. Bhuyan (Indian Institute of Technology)
Aili Wang (Harbin University of Science and Technology)
Naotaka Ogasawara (Aichi Medical University)
Kunio Kasugai (Aichi Medical University)

Introduction

- Endoscope is used to detect polyps and the examinations of abnormal parts in the stomach and intestines.
  - ✓ Polyps have a variety of sizes and shapes.
  - ✓ Medical doctors estimate the size and shape of polyp empirically.



Endoscope image

This paper proposes a new approach for a polyp shape and size recovery by solving Eikonal Equation under the condition of point light source and perspective projection for a supporting system of medical diagnosis.

Preprocessing: Removal of Specular Reflectance Component and Generation of Lambertian Image [3]

Step 1: Classification using histogram of H

Step 2: Calculate the V ratio between interest color points and those neighboring points whose color is most frequent color.

Step 3: Equation of reflectance using V ratio calculated in Step 2 using the points which are not used in Step 2 of interest color.

Step 4: Equalization of reflectance for all color groups by repeat Step 2 and Step 3.

[3] N. Ikeda et al. "Generating Lambertian Image by Removing Specular Reflection Component and Difference of Reflectance Factor Using HSV, Proc, of ITC-CSCC 2016, pp.5470550, 2016.

Experiment using actual image

Endoscope images


Image1

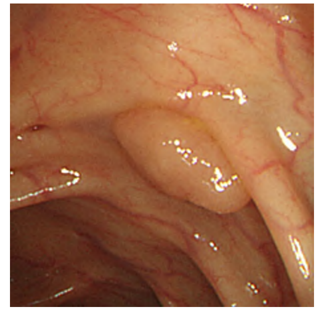


Image2


Image3

Grayscale images

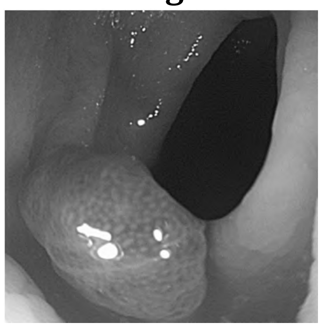


Image1

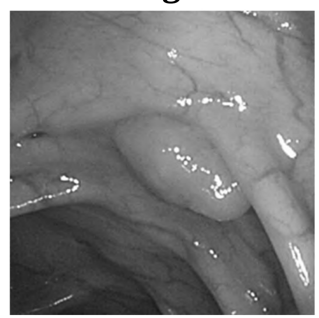


Image2

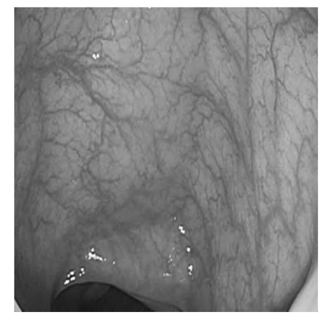


Image3

Result images

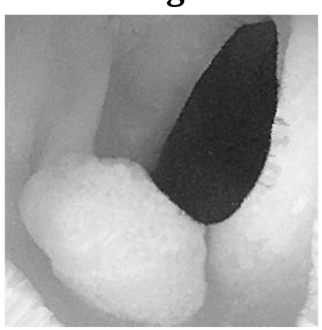


Image1


Image2

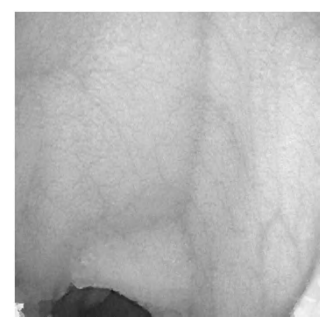


Image3

Proposed Method

Photometric Constraint Equation and Geometric Constraint Equation should become the same depth value of Z for both.

Photometric Equation | **Geometric Equation**

$$\sqrt{\frac{CV(-px-qy+f)}{E(p^2+q^2+1)^{\frac{1}{2}}}} = \frac{Z_k(f-p_kx_k-q_ky_k)}{f-p_kx_t-q_ky_t}$$

Eikonal Equation Eq.(4)

$$\sqrt{p^2+q^2} = \sqrt{\left(\frac{C}{E}\right)^2 A - 1} \quad A = \frac{V^2(f-p_kx_t-q_ky_t)^6}{Z_k^4(f-p_kx_k-q_ky_k)^4}$$

C : Reflectance Factor
f : Focal Length
E : Image Intensity
(p,q) : Gradient Parameters
(x,y) : Image Coordinate
(x_k,y_k) (x,y) at known point
(p_k,q_k) (p,q) at known point
(x_t,y_t) (x,y) at trial point
Z_k Depth at known point

Fast Marching Method

$$Z_{ij} = \begin{cases} \dfrac{Z_a+Z_b+\sqrt{2f_{ij}^2-(Z_a-Z_b)^2}}{2} & (|Z_a-Z_b|<f_{ij}) \\ \min(Z_a,Z_b)+f_{ij} & (|Z_a-Z_b|\geq f_{ij}) \end{cases}$$

$Z_a = \min(Z_{i-1,j}, Z_{i+1,j})$
$Z_b = \min(Z_{i,j-1}, Z_{i,j+1})$
(i,j) specified pixel
f ij corresponds to the inverse of right term of Eq.(4)

Estimating C and Absolute Size

- Step1. SIFT (in Ref.[6]) or ORB (in Ref.[7]) feature points extracted from blood vessels using two images and movement ΔZ of endoscope camera is estimated.
- Step2. Parameter C is estimated using ΔZ (See Ref.[6]).
- Step3. Shape recovery is applied for each uniform Lambertian image generated by Ref.[3].

[6] Y. Iwahori et al. "Estimating Reflectance Parameter of Polyp Using Medical Suture Information in Endoscope Image", Proc. of ICPRAM 2016, pp.503-509, 2016.

Absolute size of polyp using two images with slight movement of ΔZ

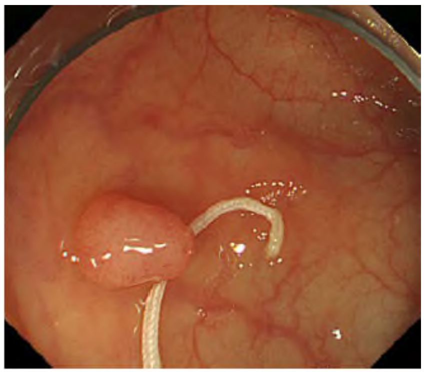


Figure 3: Input Image 1 (Experiment 1)

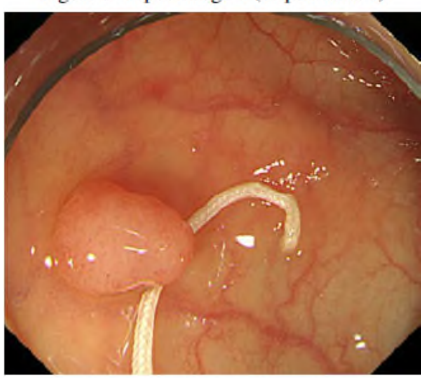


Figure 4: Input Image 2 (Experiment 1)

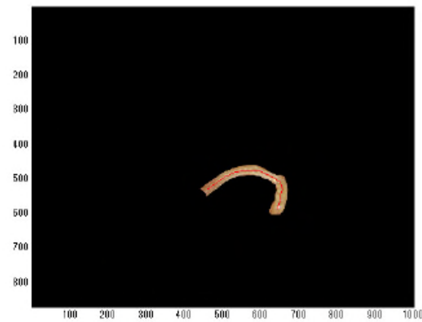


Figure 5: Medical Suture Region of Image 1 (Experiment 1)

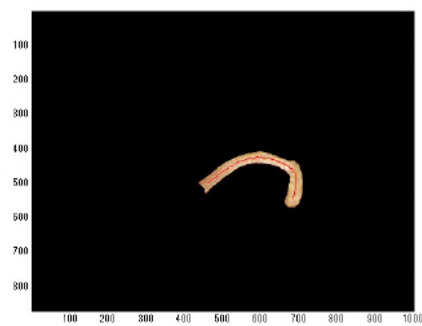


Figure 6: Medical Suture Region of Image 2 (Experiment 1)

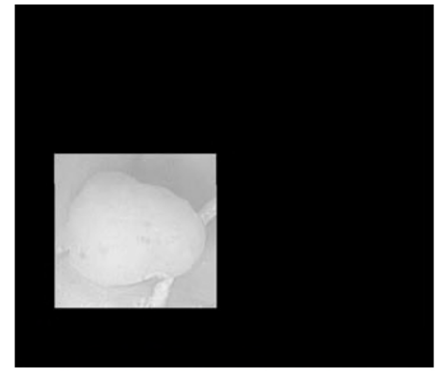
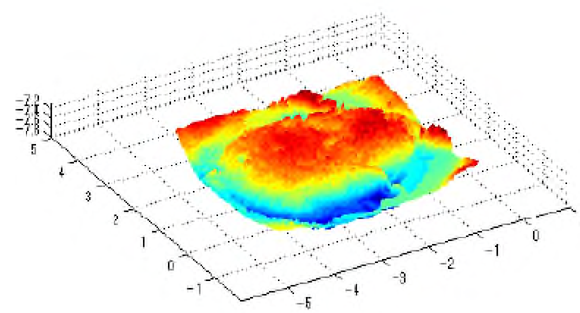


Figure 7: Test Object (Experiment 1)



These results are obtained from Ref.[6] and recovering algorithm is different one.

[6] Y. Iwahori et al. “Estimating Reflectance Parameter of Polyp Using Medical Suture Information in Endoscope Image”, Proc. of ICPRAM 2016, pp.503-509, 2016.