Depth Estimation and 3D Reconstruction of Ex-vivo Tissue and Probe Tracking Marked with DRS Information

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Abstract

Robotic surgery has made great progress in the field of minimally invasive surgery, due to its advantages in flexibility, precision, and 3D vision. Meanwhile, integrated augmented reality (AR) systems are becoming more and more significant in robotic surgery systems, which allows information from multiple modalities to be incorporated into real-time surgery procedure. Scene depth estimation is an essential part and a prerequisite. This project aims to design a benchtop stereo-vision system, acquire dataset and ground truth, apply deep learning networks to the system, and evaluate the reconstruction results.

Introduction

3D reconstruction based on depth information is crucial for image-guided intervention in MIS, which helps localize the tissue and control the endoscope movement at the same time.

DRS

Diffuse reflectance spectroscopy (DRS) is a fast, convenient and mature optical measurement technology based on light absorption and scattering to measure composition and morphology [1]. DRS system allows surgeons to determine the lesions and healthy tissues accurately according to different optical characteristics.

Objective

Combine the 3D reconstruction and DRS information. The area in *ex-vivo* tissue marked with DRS information can be visualized in the 3D reconstruction model, which is useful in AR technology.

Method

ZED-Mini system depth accuracy test [2]

- 2D image processing: acquire depth value of each pixel
- 3D processing: register real and ideal point clouds, and find the corresponding rigid matrix [R|t]
- RMS error estimation and curve fitting

Stereo-vision setup

- Setup stereo-vision system using two Logitech cameras
- Find best baseline according to reprojection error using OpenCV in Python

System reliability evaluation

- Use traditional stereo-matching methods to test the reliability of the system

Deep-learning network to estimate depth

- Based on MICCAI dataset [3], find the networks has the best depth estimation results

Transfer learning

- Acquire ground truth using ZED-Mini system [4], and acquire raw images using stereo-vision system
- Apply the chosen network on the acquired dataset.
- Evaluate the depth and reconstruction results.

(a)

(b)

***Figure 1 -** (a) ZED-Mini camera system; (b) Logitech camera stereo-vision system*

Preliminary Results

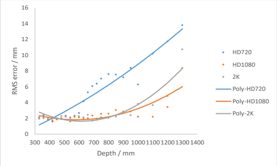
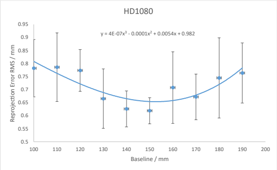
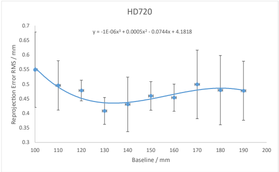


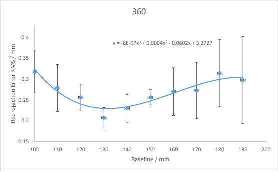
***Figure 2 – ZED-Mini depth accuracy. Depth RMS error v.s. depth/distance from ZED to objects.** After polynomial fitting, trends are different for the 3 resolution (2K, HD1080, HD720)*



(a)



(b)

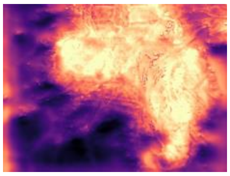


(c)

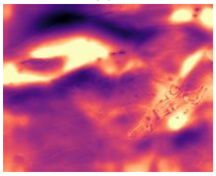
***Figure 3 – Reprojection error v.s. baseline using different resolution** (a) HD1080 fitting curve with the best baseline = 150mm; (b) HD720 fitting curve with the best baseline = 130mm; (c) 360 fitting curve with best baseline = 130mm.*

(a)

(b)



(c)



(d)

***Figure 4 – MonoDepth2 [5] pretraining results** (a)-(c) ex-vivo tissue and its corresponding disparity map; (b)-(d) in-vivo tissue from MICCAI dataset and its corresponding disparity map.*

Future Plan

Deep learning methods comparison

- Train MICCAI dataset [3] on two deep learning networks, including Monodepth2 [5] and PSMNet [6]
- Compare the results and choose the better one

Data collection

- ZED-Mini takes the ground truth images on *ex-vivo* tissues
- Logitech cameras stereo system takes the raw images

Transfer learning

- Apply the better network on the preprocessed images
- Evaluate the depth and reconstruction results

Application

- Combine 3D reconstruction with probe tracking

References

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[4]"Stereolabs Docs: API Reference, Tutorials, and Integration | Stereolabs", Stereolabs.com, 2021. [Online]. Available: https://www.stereolabs.com/docs/
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