Accurate 3D Reconstruction of Underwater Infrastructure using Stereo Vision

Brenton Leighton

Master of Engineering (Research)

Faculty of Engineering and Information Technology

University of Technology Sydney

2019

Certificate of Original Authorship

I, Brenton Leighton, declare that this thesis is submitted in fulfilment of the requirements for the award of Master of Engineering (Research) in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program (RTP), and by the Australian Research Council and Roads and Maritime Services (Linkage Project LP150100935).

Signature:

Production Note:
Signature removed prior to publication.

Date: 05/08/2019

Acknowledgements

I would like to thank my supervisor Associate Professor Shoudong Huang for his guidance of my research work and assistance in the preparation of this thesis. I would also like to thank my co-supervisor Distinguished Professor Dikai Liu and alternate supervisor Dr. Liang Zhao for their support and assistance.

I would like to thank members of the SPIR project Dr. Andrew To, Dr. Khoa Le, and Craig Borrows, for their work in developing the ROV and assistance with data collection.

Finally I would like to thank the staff and students at the Centre for Autonomous Systems, in particular Li Yang Liu, for any advice that helped with my research.

Table of Contents

List of Figures

List of Tables

Acronyms

AGAST adaptive and generic accelerated segment test.
AUV autonomous underwater vehicle.

BRIEF binary robust independent elementary features.
BRISK binary robust invariant scalable keypoints.

CLAHE contrast limited adaptive histogram equalisation.
CMVS clustering views for multi-view stereo.

DSO direct sparse odometry.
DTAM dense tracking and mapping.

ELAS efficient large-scale stereo matching.

FAST features from accelerated segment test.
FREAK fast retina keypoint.

HDR high dynamic range.

IMU inertial measurement unit.

KLT Kanade-Lucas-Tomasi.

LiDAR light detection and ranging.
LSD-SLAM large-scale direct SLAM.

MAPSAC maximum a posterior estimation sample concensus.
MLESAC maximum likelihood sample concensus.
MVE multi-view environment.

ORB oriented FAST and rotated BRIEF.

PMVS patch-based multi-view stereo.
PTAM parallel tracking and mapping.

RANSAC random sample concensus.
ROV remotely operated underwater vehicle.

SfM structure from motion.
SIFT scale-invariant feature transform.
SLAM simultaneous localisation and mapping.
SPIR Submersible Pile Inspection Robot.
SURF speeded-up robust features.
SVO semi-direct visual odometry.

USB universal serial bus.

VIO visual-inertial odometry.
VO visual odometry.

Abstract

Modern vehicle and pedestrian bridges over water are built on concrete piles; foundations that penetrate the soft soil of the bed of the body of water to sit on the solid rock below. Like all built structures these concrete piles require regular inspection to determine if any preventative maintenance is needed. Stereo vision and Structure from Motion techniques offer a cost effective method of creating a 3D reconstructions of a scene, but the underwater environment around a bridge pile has unique challenges. Poor visibility, strong and varying sunlight, and floating material in the water create difficulties for computer vision.

This thesis evaluates exposure control, image enhancement, and feature detection and description algorithms, for the purpose of localising images captured around a bridge pile. Stereo correspondence algorithms are evaluated and used to create a single viewpoint 3D reconstruction of a scene, then a visual SLAM system is used to localise the single viewpoint reconstructions, so that they can be merged together to create a 3D reconstruction of a bridge pile.

Visual odometry, using KAZE with CLAHE image enhancement for feature detection, was successfully performed in the underwater environment. ORB-SLAM2 can also perform well, and 3D reconstructions from a single viewpoint (created with block matching, semi-global matching, or ELAS) were merged to create 3D reconstructions of submerged bridge piles.