# CONTENTS

APPROVAL PAGE ..... i
SELF DECLARATION AGAINST PLAGIARISM ..... ii
ABSTRACT ..... iii
CONTENTS ..... iv
LIST OF FIGURES ..... vi
LIST OF TABLES ..... vii
LIST OF ABBREVIATIONS ..... viii
LIST OF SYMBOLS ..... ix
CHAPTER 1 INTRODUCTION ..... 1
1.1 Background ..... 1
1.2 Problem Identification ..... 3
1.3 Object ..... 3
1.4 Scope Limitation ..... 4
1.5 Methodology ..... 4
CHAPTER 2 BASIC CONCEPTS ..... 6
2.1 The Fundamentals of Camera Vision ..... 6
2.1.1. Basic Perspective Projection ..... 6
2.1.2. The Intrinsic Matrix ..... 8
2.1.3. The Euclidean Transformation ..... 9
2.1.4. The Pinhole Camera Model ..... 10
2.2 Pose Vector ..... 11
2.3 The Fundamentals of Convolutional Neural Networks ..... 12
2.3.1. ResNet-18 ..... 13
2.3.2. Batch Normalization ..... 14
2.3.3. Feature Pyramid Networks ..... 15
2.3.4. Freeze Layer ..... 17
2.4 Data Set ..... 18
CHAPTER 3 SYSTEM AND MODEL DESIGN ..... 20
3.1. Data Preparation ..... 20
3.1.1. Read LiDAR files (bin) ..... 20
3.1.2. Filter out points that are behind the LiDAR ..... 21

3.1.3. Transform Point Cloud to Camera Coordinates ..... 22
3.1.4. Transform Camera Coordinates to Pixel Coordinates ..... 23
3.2. Model CNN Architecture ..... 24
3.2.1 Original CNN ..... 24
3.2.2 CNN with The Addition of BatchNorm ..... 25
3.2.3 CNN with The Addition of FPN ..... 26
3.2.4 CNN with The Freeze Layer ..... 27
3.3. System Flowchart ..... 28
3.4. Accuracy and Average Error ..... 28
CHAPTER 4 PERFORMANCE EVALUATIONS ..... 31
4.1 Experiment Preparation ..... 31
4.2 Original CNN Analysis ..... 31
4.3 CNN with The Addition of BatchNorm Analysis ..... 33
4.4 CNN with The Addition of FPN Analysis ..... 34
4.5 CNN with The Addition of Freeze Layer Analysis ..... 35
4.6 Comparison All Modifications Model ..... 36
4.7 Comparison Best Model with Other Model ..... 38
CHAPTER 5 CONCLUSIONS AND FUTURE WORKS ..... 39
5.1 Conclusions ..... 39
5.2 Future Works ..... 39
REFERENCES ..... x