

# **CONTENTS**

## **APPROVAL PAGE**

## **SELF DECLARATION AGAINST PLAGIARISM**

<b>ABSTRACT</b>	<b>iv</b>
<b>ACKNOWLEDGEMENTS</b>	<b>v</b>
<b>PREFACE</b>	<b>vi</b>
<b>CONTENTS</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>x</b>
<b>LIST OF TABLES</b>	<b>xii</b>
<b>LIST OF ABBREVIATION</b>	<b>xiii</b>
<b>LIST OF SYMBOL</b>	<b>xiv</b>
<b>1 INTRODUCTION</b>	<b>1</b>
1.1 Background . . . . .	1
1.2 Problem Identification . . . . .	2
1.3 Objectives . . . . .	3
1.4 Scope of Work . . . . .	3
1.5 Research Methodology . . . . .	4
1.6 Structure of this Thesis . . . . .	5
<b>2 BASIC CONCEPT</b>	<b>7</b>
2.1 Semantic Mapping . . . . .	7
2.2 Camera and Light Detection and Ranging (LiDAR) . . . . .	8
2.2.1 Camera . . . . .	9
2.2.2 LiDAR . . . . .	9
2.3 Robot Operating System (ROS) . . . . .	10
2.4 SLAM (Simultaneous Localization and Mapping) . . . . .	11
2.5 Object Detection in Robotics . . . . .	13

2.5.1	How Convolutional Neural Networks (CNNs) Work . . . . .	14
2.5.1.1	Convolution Operation . . . . .	14
2.5.1.2	ReLU Activation . . . . .	15
2.5.1.3	Pooling . . . . .	15
2.5.2	YOLOv3 Framework . . . . .	15
2.5.3	YOLOv3 Loss Function . . . . .	16
2.5.4	Localization Loss in YOLOv3 . . . . .	16
2.5.5	Confidence Loss and Intersection Over Union (IOU) . . . . .	16
2.6	Camera and LiDAR Fusion in Robotics . . . . .	17
<b>3</b>	<b>METHODOLOGY AND TECHNIQUE</b>	<b>19</b>
3.1	Block Diagram of the Proposed Method . . . . .	19
3.2	System Design . . . . .	19
3.2.1	Arduino Schematic Design . . . . .	20
3.2.2	ROS Setup . . . . .	21
3.3	System Architecture . . . . .	22
3.4	Robot Model . . . . .	22
3.5	Simultaneous Localization and Mapping (SLAM) Technique . . . . .	24
3.5.1	Gmapping Overview . . . . .	24
3.5.2	Gmapping Configuration . . . . .	25
3.5.3	Sensor Integration . . . . .	26
3.5.3.1	LiDAR Sensor Integration . . . . .	26
3.5.3.2	Odometry Integration . . . . .	26
3.5.4	Implementation in ROS . . . . .	26
3.6	Object Detection Using YOLOv3 . . . . .	27
3.6.1	Dataset Labeling and Augmentation . . . . .	27
3.6.2	YOLOv3 Training Process . . . . .	28
3.6.3	Bounding Box Prediction and ROS Integration . . . . .	29
3.7	Object Marker Algorithm . . . . .	29
3.7.1	Object Detection Integration . . . . .	29
3.7.2	LiDAR Data Integration . . . . .	31
3.7.3	Calculating Object Width Using Cosine Rule . . . . .	31
3.7.4	Transforming to Global Coordinates . . . . .	32
3.7.5	Publishing Object Markers . . . . .	32
3.8	Semantic Map Generation . . . . .	32
3.8.1	Core Components of Semantic Mapping . . . . .	33
3.8.2	Process of Generating the Semantic Map . . . . .	33
3.8.3	Steps for Building the Semantic Map . . . . .	34

<b>4</b>	<b>EXPERIMENTAL RESULTS AND ANALYSIS</b>	<b>36</b>
4.1	Map Construction using SLAM . . . . .	36
4.2	Object Detection using YOLOv3 . . . . .	37
4.3	Real-Time Semantic Mapping . . . . .	38
4.3.1	Object Detection Data Acquisition . . . . .	38
4.3.2	Handling of Object Dimensions . . . . .	38
4.3.3	Saving Object and Grid Data in CSV Format . . . . .	39
4.4	Analysis of Object Detection Errors . . . . .	42
4.4.1	Actual Object Dimensions . . . . .	42
4.4.2	Error Calculation Methodology . . . . .	42
4.5	Error Analysis . . . . .	43
4.6	Offline Semantic Map Visualization . . . . .	44
<b>5</b>	<b>CONCLUSION</b>	<b>46</b>
5.1	Conclusions . . . . .	46
5.2	Future Works . . . . .	46
<b>REFERENCES</b>		<b>48</b>