

TABLE OF CONTENTS

PREFACE	iii
TABLE OF CONTENTS	iv
LIST OF TABLE	vi
TABLE OF FIGURES	vii
ABSTRACT	viii
CHAPTER I INTRODUCTION.....	1
1.1 Research Background.....	1
1.2 Research Problem.....	4
1.3 Research Boundary/Scope	5
1.4 Research Objective.....	5
1.5 Research Advantage	6
CHAPTER II LITERATURE REVIEW	7
CHAPTER III BASIC THEORY	17
3.1 Catfish (Clarias gariepinus).....	17
3.1.1 Cultivation Method	17
3.1.2 SNI 6484.5:2011	18
3.2 IoT-based Aquaponic System.....	18
3.2.1 Architecture of IoT.....	19
3.3 Early Warning System.....	19
3.4 Water Quality Parameters	19
3.4.1 Temperature.....	20
3.4.2 pH.....	20
3.4.3 Dissolved Oxygen (DO).....	21
3.4.4 Ammonia (NH ₃).....	21
3.5 Neural Network.....	22
3.6 Recurrent Neural Network (RNN)	22
3.7 Bidirectional Long Short-Term Memory (Bi-LSTM).....	23
3.7.1 Forget Gate.....	24
3.7.2 New Memory Cell.....	25
3.7.3 Input Gate.....	26
3.7.4 Output Gate	26
3.8 Bidirectional Gated Recurrent Unit (Bi-GRU)	27
3.8.1 Reset Gate	28
3.8.2 Update Gate.....	29
3.8.3 New Memory Cell.....	29
3.8.4 Final Memory (Hidden State)	30
3.9 Evaluation Model.....	30
3.9.1 Symmetric Mean Absolute Percentage Error.....	30
3.9.2 Root Mean Squared Error	31
CHAPTER IV RESEARCH METHODOLOGY	32
4.1 Research Description	32

4.2	Research Plan	32
4.2.1	Research Activities Plan/Layout	33
4.2.2	Research Dataset	33
4.2.3	Research Model Layout	34
4.2.4	Research Evaluation.....	35
CHAPTER V IMPLEMENTATIONS.....		36
5.1	Importing Libraries	36
5.2	Importing Dataset.....	36
5.3	Data Preprocessing.....	37
5.3.1	Normalization.....	37
5.3.2	Interquartile Range (IQR)	39
5.4	Data Visualization	41
5.5	Window Generator	42
5.6	Gated Recurrent Unit Model.....	45
5.7	Bidirectional Long Short-Term Memory Model.....	46
5.8	Denormalization	48
5.9	Evaluation Metrics	48
5.9.1	Symmetric Mean Absolute Percentage Error	49
5.9.2	Root Mean Square Error	49
CHAPTER VI RESULT ANALYSIS.....		50
6.1	Model Training Result	50
6.1.1	Bidirectional Gated Recurrent Unit	50
6.1.2	Bidirectional Long Short-Term Memory	52
6.2	Test Dataset Result	53
6.2.1	Bidirectional Gated Recurrent Unit	54
6.2.2	Bidirectional Long Short-Term Memory	56
6.3	Comparison Between Bi-GRU and Bi-LSTM.....	58
6.3.1	Comparison on Training Dataset.....	59
6.3.2	Comparison on Validation Dataset.....	59
6.3.3	Comparison on Test Dataset.....	60
CHAPTER VII CONCLUSION AND RECOMMENDATION		63
7.1	Conclusion	63
7.2	Recommendation for Future Research.....	63
BIBLIOGRAPHY		64