

Contents

Nomenclature	xiii
1 Motivation and Objectives	1
1.1 Motivation	1
1.2 Main Objectives	3
2 State of the Art and Introduction of Novel Approach	5
2.1 Previous Studies in Route Optimization for Ships	5
2.2 Previous Studies in Energy Management System Optimization for Hybrid Vehicles	6
2.3 Novel Approach applied in this Thesis	8
2.4 Foundations of Machine Learning	10
2.4.1 Neural Networks	12
2.4.2 Reinforcement Learning	14
3 Methodology	23
3.1 Scientific Procedure	23
3.2 Fuel Consumption Modeling	25
3.2.1 Basic Modeling Approach	25
3.2.2 Characteristics of the Case Study Engine	25
3.2.3 Artificial Neural Network for Fuel Consumption Prediction	28
3.2.4 Neural Network Architecture and Performance	31
3.3 Wind Propulsion Systems	32
3.3.1 Flettner Rotor	33
3.3.2 Wingsail	36
3.4 Modeling of Controllable Pitch Propeller	38
3.5 Hybrid Powertrain Configuration	42
3.5.1 Battery Model	44
3.5.2 Gensets Model	49
3.5.3 Route Optimization	51
3.6 Structure of the Reinforcement Learning Concept	52
4 Results and Discussion	55
4.1 Comparison of different Reinforcement Learning-Methods	55
4.2 Route Optimization under Consideration of Wind Propulsion Systems	56
4.3 Route Optimization under Consideration of Pitch and Engine Parameters	65
4.4 Route Optimization under Consideration of Energy Management System	80
4.5 Reinforcement Learning vs Conventional Optimization Techniques	91

4.6 Summary of the Results	95
5 Conclusion and Outlook	99
5.1 Conclusion	99
5.2 Outlook	100
List of Figures	101
List of Tables	105
Bibliography	107
Appendix	115