



Universiteit
Leiden

The Netherlands

Model-assisted optimal control framework for industrial system coupling problems

Wei, X.

Citation

Wei, X. (2026, July 7). *Model-assisted optimal control framework for industrial system coupling problems*. Retrieved from <https://hdl.handle.net/1887/4307775>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/4307775>

Note: To cite this publication please use the final published version (if applicable).

Contents

Abstract	i
Contents	iii
Acronyms	vii
1 Introduction	1
1.1 Background.....	1
1.2 Research Questions.....	3
1.3 Outline.....	5
1.4 Contributions of this Thesis.....	6
2 Industrial System Coupling and Model-assisted Optimization Control	9
2.1 Coupling in Industrial Systems and Their Impact on Optimal Control.....	9
2.1.1 Coupling Between Industrial Systems and the Environment.....	10
2.1.2 Coupling Among Components Within Industrial Systems.....	13
2.1.3 Coupling Between Industrial Systems and Working Media.....	16
2.2 Model-assisted Optimal Control.....	17
2.3 Optimal Control Framework Design for Industrial Coupling Problems.....	20
3 Case Study on Optimal Control Problems under System - Environment Coupling Conditions	25
3.1 Background.....	25
3.2 Previous Research and Main Issue.....	28
3.3 Hierarchical POMDP Framework.....	31

3.4	Methodology.....	37
3.4.1	Formulation of TBM Trajectory Navigation	37
3.4.2	PCDM TBM Model.....	40
3.4.3	Structure of the End-to-end TBM Trajectory Navigation Approach	44
3.4.4	TBM Trajectory Navigation Approach Design.....	45
3.5	Experiments.....	46
3.5.1	Path Planning Based on DDPG	47
3.5.2	Thrust Force Prediction and Transfer Learning with Real-world Data	52
3.6	Summary.....	58
4	Case Study on Optimization Problems under Coupling Among Components within Industrial Systems Conditions.....	61
4.1	Background.....	61
4.2	Previous Research and Main Issue	64
4.3	Modelling and Description of the Parameter Optimization Problem.....	66
4.3.1	Digital Twin Modeling of Reflow Oven.....	66
4.3.2	Real-time Parameter Identification for Digital Twin Model.....	69
4.3.3	Reflow Oven Control Parameter Optimization Problem.....	70
4.4	Methodology.....	73
4.4.1	Overview of the SMADT Framework.....	73
4.4.2	Real-time Parameter Identification of Digital Twin Model.....	75
4.4.3	Rationale and Architecture of the Surrogate Model	77
4.4.4	Detailed Implementation of the Surrogate Model	79
4.5	Experiments.....	84
4.5.1	Parameter Identification Experiment for the Digital Twin Model.....	85
4.5.2	Control Parameter Prediction Experiment by the Surrogate Model	89
4.5.3	Comparative Experiments Against Baseline Optimization Methods.....	100
4.6	Summary.....	104
5	Case Study of Optimization Problems under System-Working Medium Coupling	

Conditions.....	107
5.1 Background.....	107
5.2 Previous Research and Main Issue.....	111
5.3 Methodology.....	113
5.3.1 Centrifugal Compressor Modeling.....	114
5.3.2 Coordinated Controller Design.....	116
5.3.3 CMA-ES-based Controller Parameter Optimization.....	118
5.4 Experiments.....	120
5.4.1 Constant Outlet Pressure Adjustment Experiment.....	122
5.4.2 Constant Mass Flow Rate Adjustment Experiment.....	124
5.4.3 Coordinated Mass Flow and Outlet Pressure Adjustment Experiment.....	126
5.5 Summary.....	129
6 Conclusion and Future Work.....	131
6.1 Summary.....	131
6.2 Future Work.....	136
Bibliography.....	139
List of publications.....	161
Summary.....	163
Samenvatting.....	165
Acknowledgements.....	167
Curriculum vitae.....	169

Acronyms

MAO	Model-assisted optimization
ODE	Ordinary differential equations
PDE	Partial differential equations
DAE	Differential-algebraic equations
TBM	Tunnel boring machine
MDP	Markov decision process
POMDP	Partially observable Markov decision process
CNN	Convolutional neural networks
GRU	Gated recurrent unit
LSTM	Long short-term memory
RNN	Recurrent neural network
PCB	Printed circuit board
SMADT	Surrogate model-assisted digital twin
FEA	Finite element analysis
CFD	Computational fluid dynamics
GA	Genetic algorithms
PSO	Particle swarm optimization
BO	Bayesian optimization

ACRONYMS

CMA-ES	Covariance matrix adaptation evolution strategy
MPC	Model predictive control
Z-N	Ziegler-Nichols
PID	Proportional-integral-derivative