

Contents

Nomenclature	v
1 Introduction	1
1.1 Motivation	1
1.1.1 Acoustic design	1
1.1.2 Surrogate modeling	3
1.2 State of the art	5
1.2.1 Multi-fidelity modeling	6
1.2.2 Acoustic design	8
1.3 Scope and structure of the thesis	9
1.3.1 Framework and objective	10
1.3.2 Organization and structure	12
2 Theory	13
2.1 Acoustics	13
2.1.1 Basic acoustic equations	13
2.1.2 Numerical acoustics	17
2.2 Multi-fidelity surrogate modeling	23
2.2.1 General surrogate modeling	23
2.2.2 Multi-fidelity modeling	24
2.3 Gaussian process regression	28
2.3.1 Gaussian process	29
2.3.2 Gaussian process model construction	32
2.3.3 Model training	34
2.3.4 Hyperparameter optimization and bounds	38
2.3.5 Multi-level Gaussian process regression	39
2.4 Model selection and assessment	45
2.4.1 Surrogate prediction error	46
2.4.2 Loss functions	47
2.4.3 Prediction error estimators	49
2.4.4 Error frequency sweep	53

2.5	Design of experiments	54
2.5.1	Single-fidelity design of experiments	55
2.5.2	Multi-fidelity design of experiments	56
3	Test scenarios and -methodology	63
3.1	Test case	63
3.1.1	Finite element model	64
3.1.2	Model parameterization	67
3.1.3	Quantity of interest	69
3.1.4	Design of experiment setup	71
3.2	Surrogate setup	73
3.3	Model selection	75
3.4	Model assessment and test methodologies	76
3.4.1	Academic test scenario	79
3.4.2	Realistic test scenario	80
4	Academic test scenario	83
4.1	General data analysis	83
4.2	Model selection	85
4.2.1	Low-fidelity model selection	86
4.2.2	Multi-fidelity model selection	89
4.3	Cost-accuracy-analysis	94
4.3.1	Comparison of single- and multi-fidelity results	94
4.3.2	Comparison of different FE formulations	100
5	Realistically limited data scenario	107
5.1	Model selection based on cross-validation	108
5.2	Multi-fidelity cross-validation performance	110
5.3	Sequential model construction based on cross-validation	116
5.3.1	Design procedure setup	118
5.3.2	Sequential design results	120
5.4	Cost comparison for high- and multi-fidelity models	125
5.4.1	Cost estimates based on computational complexities	125
5.4.2	Cost comparison for the test case	128
6	Dispersion error correction	133
6.1	Dispersion-reducing data scaling	134
6.2	Data scaling function	139
6.3	Multi-fidelity surrogate results based on scaled data	141

7 Conclusion and outlook	145
7.1 Conclusion	145
7.2 Outlook	148
Bibliography	149