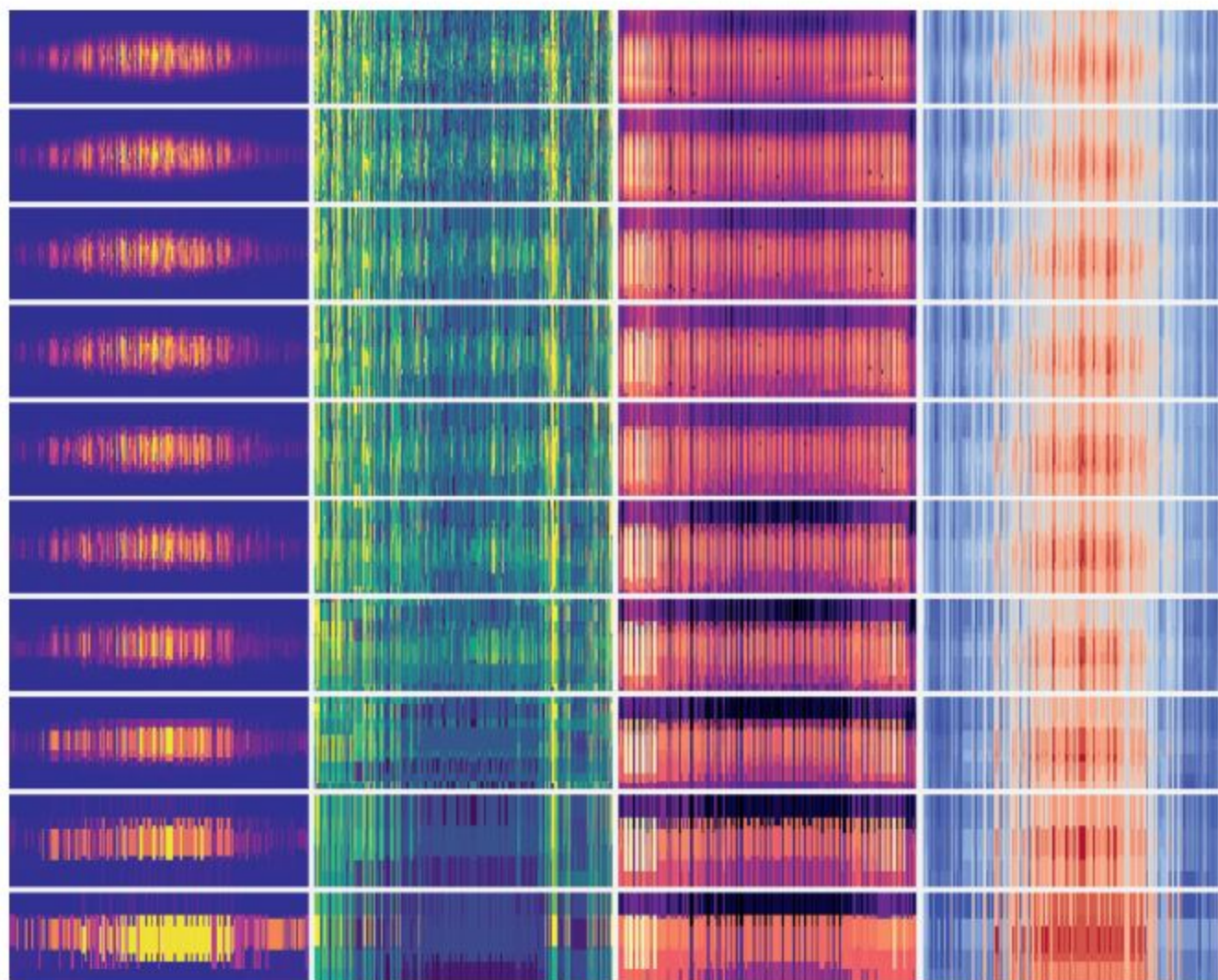




Temporal Aggregation Methods for Energy System Modeling

Maximilian Alexander Camillo Hoffmann

Energie & Umwelt / Energy & Environment

Band / Volume 605

ISBN 978-3-95806-683-0

Forschungszentrum Jülich GmbH
Institut für Energie- und Klimaforschung (IEK)
Techno-ökonomische Systemanalyse (IEK-3)

Temporal Aggregation Methods for Energy System Modeling

Maximilian Alexander Camillo Hoffmann

Schriften des Forschungszentrums Jülich
Reihe Energie & Umwelt / Energy & Environment

Band / Volume 605

ISSN 1866-1793

ISBN 978-3-95806-683-0

Table of Contents

Abstract	VI
Kurzfassung	VII
Introductory Remark	VIII
Table of Contents	IX
List of Figures	XIII
List of Tables	XXVI
List of Symbols	XXVIII
List of Abbreviations	XXX
1. Motivation	2
1.1. Drivers of Model Complexity	2
1.2. Motivation and Scope of the Thesis	4
1.3. Structure of the Thesis	6
2. State of the Art	8
2.1. Methodology and Structure of Chapter 2	8
2.1.1. Methodology of the Literature Research	8
2.1.2. Structure of the Review	9
2.2. Time Series Aggregation	11
2.2.1. Resolution Variation	15
2.2.2. Typical Periods	19
2.2.3. Random Sampling	35
2.2.4. Miscellaneous Methods	37
2.2.5. Trends in Time Series Aggregation	39
2.3. Preserving Additional Information	42
2.3.1. A Priori Methods	42
2.3.2. A Posteriori Methods	50
2.3.3. Trends in the Integration of Additional Information	55
2.4. Review Summary	57
3. Methodology	59
3.1. The Process of Time Series Aggregation	60
3.1.1. Period Clustering	60

Table of Contents

3.1.2. Segmentation	61
3.1.3. Combination of Period Clustering and Segmentation	64
3.2. Representation Methods	65
3.2.1. Centroids	66
3.2.2. Medoids	67
3.2.3. Maxoids	69
3.2.4. Maximum- and Minimum Representation	72
3.2.5. Distribution Preserving Representation	74
3.2.6. Summary of Representation Methods	80
3.3. Error and Complexity Indicators	82
3.3.1. A Priori Indicators	84
3.3.2. A Posteriori Indicators	88
3.3.3. Quantifying the Quality of A Priori Indicators	89
3.3.4. Optimal Aggregation Based on A Priori Indicators	91
3.4. Methods for Systematic Over- and Underestimations	98
3.4.1. Upper and Lower Bounds for LPs and MILPs	99
3.4.2. Upper and Lower Bounds for MILPs	101
4. Validation and Results	104
4.1. Model Overview and Data Resources	107
4.1.1. The Island System	107
4.1.2. The Self-Sufficient Building Model	108
4.1.3. The European Model	110
4.1.4. The Electricity Dispatch Model	113
4.1.5. Model Summary	116
4.2. The Optimal Aggregation: A Sensitivity Analysis	118
4.2.1. Analyses of the Island System Model	119
4.2.2. Analyses of the Self-Sufficient Building	135
4.2.3. Analyses of the European Model	142
4.2.4. Adaption of the Distribution-Preserving Algorithm	166
4.2.5. Summary	175
4.3. Typical Days or Typical Time Steps	177

4.3.1. Input-Data Driven Analysis	179
4.3.2. Output-Data Driven Analysis	181
4.3.3. In-depth Analysis of Computational Resources	186
4.3.4. Summary	190
4.4. Error Bounding Methods	193
4.4.1. Bounds Based on Over- and Underestimation	193
4.4.2. Model-Specific Bounds for MILPs without Cost Time Series	198
4.4.3. Summary	201
4.5. Discussion	202
4.5.1. Discussion of the Main Results	202
4.5.2. Temporal Aggregation in the Context of Other Simplifications	206
5. Summary	213
5.1. Scope and Objective	213
5.2. General Approach and State of the Art	214
5.3. Methodology	215
5.4. Results and Main Conclusions	217
Appendix	220
A. Glossary Used For Literature Research	220
B. Table of Methods	222
C. Customer and Unit Partitioning	239
D. An Example for Time Series Normalization	241
E. Clustering Algorithms Applied in the Literature	242
F. Modified Feature-Based Merging	247
G. Proofs and Lemmata for Section 3.2	249
H. Classification of Optimization Problems	256
H.1. Linear Programs (LPs)	256
H.2. Mixed-Integer Linear Programs (MILPs)	260
H.3. Quadratic Programs (QPs)	264
H.4. Summary	269

Table of Contents

I. Matrix Aggregation and Error Bounding	270
I.1. Matrix Aggregation	270
I.2. Error Bounding	280
I.2.1. A General Workflow to Determine Bounds	281
I.2.2. Upper bounds	291
I.2.3. Lower Bounds	299
J. Techno-Economic Model Assumptions	315
J.1. Model Assumptions for the Island System Model	315
J.2. Model Assumptions for the Self-Sufficient Building Model	317
J.3. Model Assumptions for the Electricity Dispatch Model	318
Bibliography	320

Energie & Umwelt / Energy & Environment
Band / Volume 605
ISBN 978-3-95806-683-0