

# Contents

|          |                                                                               |           |
|----------|-------------------------------------------------------------------------------|-----------|
| <b>1</b> | <b>Introduction</b>                                                           | <b>1</b>  |
| 1.1      | Motivation                                                                    | 1         |
| 1.2      | Structure of the Thesis                                                       | 3         |
| <b>2</b> | <b>Related Work</b>                                                           | <b>5</b>  |
| 2.1      | Pattern Discovery in Time Series                                              | 5         |
| 2.1.1    | Terminology                                                                   | 8         |
| 2.1.2    | Matrix Profile                                                                | 11        |
| 2.1.3    | Discretization-based Approaches                                               | 17        |
| 2.1.4    | Other Approaches                                                              | 21        |
| 2.2      | Representative Cycles                                                         | 24        |
| 2.2.1    | Possible Applications                                                         | 25        |
| 2.2.2    | Representativeness                                                            | 26        |
| 2.2.3    | Existing Construction Methods                                                 | 27        |
| 2.3      | The Idea of Pattern-based Cycles                                              | 34        |
| <b>3</b> | <b>Development of Pattern Discovery Algorithms for Automotive Time Series</b> | <b>37</b> |
| 3.1      | Suitability of Approaches                                                     | 38        |
| 3.1.1    | Special Requirements in Automotive Time Series                                | 38        |
| 3.1.2    | Discussion of Suitability                                                     | 40        |
| 3.2      | Framework Introduction                                                        | 42        |
| 3.3      | Preprocessing—Reduction of Complexity                                         | 43        |
| 3.3.1    | Problem of Symbolic Toggling                                                  | 44        |
| 3.3.2    | Problem of Multidimensionality                                                | 47        |
| 3.3.3    | Problem of Time Warping                                                       | 49        |

---

|          |                                                               |            |
|----------|---------------------------------------------------------------|------------|
| 3.4      | Creating a Dictionary .....                                   | 52         |
| 3.4.1    | Adapted Sequitur Compression Algorithm .....                  | 52         |
| 3.4.2    | Pattern Enumeration Algorithm .....                           | 55         |
| 3.5      | Postprocessing—Selection of Relevant Patterns .....           | 56         |
| 3.5.1    | Filtering of Irrelevant Patterns .....                        | 57         |
| 3.5.2    | Selection of Representative Patterns .....                    | 58         |
| <b>4</b> | <b>Pattern-based Representative Cycles .....</b>              | <b>67</b>  |
| 4.1      | Pattern-based Statistics .....                                | 68         |
| 4.1.1    | Characteristic Parameters .....                               | 68         |
| 4.1.2    | Use Case Differentiation .....                                | 69         |
| 4.1.3    | Pattern-based Distance Measure .....                          | 73         |
| 4.1.4    | Influence of Pattern Discovery .....                          | 77         |
| 4.2      | Identification of Full Trip RDC .....                         | 79         |
| 4.2.1    | Trips and Pattern Sets .....                                  | 80         |
| 4.2.2    | Selection of RDC .....                                        | 81         |
| 4.3      | Construction of RDC .....                                     | 83         |
| 4.3.1    | Selection of Absolute Pattern Frequency .....                 | 83         |
| 4.3.2    | Solving a Directed Graph Problem .....                        | 84         |
| 4.3.3    | Design of Transitions between Patterns .....                  | 90         |
| <b>5</b> | <b>Evaluation .....</b>                                       | <b>95</b>  |
| 5.1      | Experimental Evaluation of Unsupervised Pattern Discovery ... | 95         |
| 5.1.1    | Synthetic Randomized Data Set .....                           | 96         |
| 5.1.2    | Real-Life Data Set .....                                      | 103        |
| 5.1.3    | Dimensionality .....                                          | 107        |
| 5.1.4    | Postprocessing .....                                          | 108        |
| 5.2      | Representativeness of Driving Cycles .....                    | 114        |
| 5.2.1    | Basics .....                                                  | 114        |
| 5.2.2    | Identification of Full Trip RDC .....                         | 120        |
| 5.2.3    | Construction of RDC .....                                     | 126        |
| 5.2.4    | Evenly Distributed Pattern Frequency RDCs .....               | 131        |
| <b>6</b> | <b>Conclusion .....</b>                                       | <b>135</b> |
|          | <b>References .....</b>                                       | <b>141</b> |