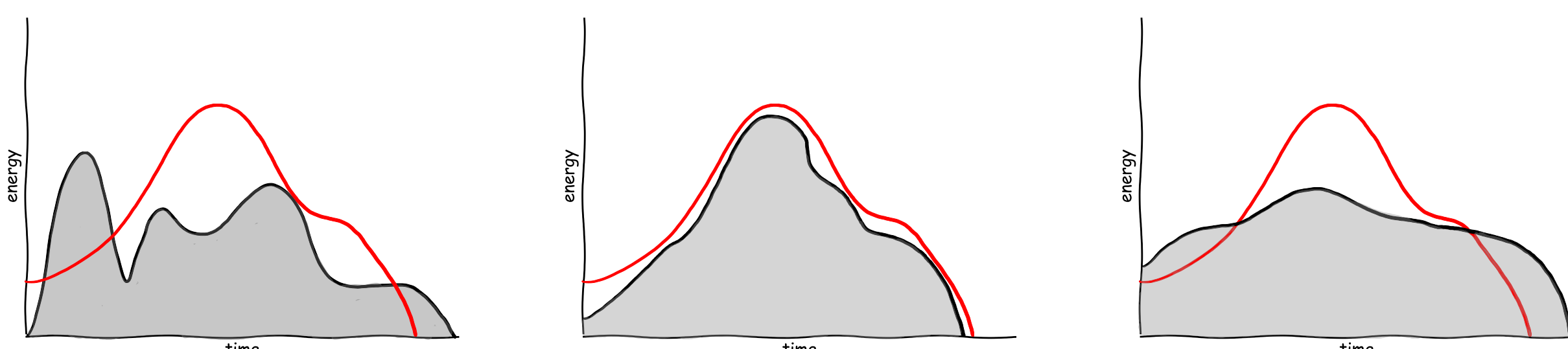


Mining Flexibility Patterns in Energy Time Series from Industrial Processes

Nicole Ludwig, Simon Waczowicz, Ralf Mikut, Veit Hagenmeyer (IAI)

Motivation

Problems due to intermittent generation of renewable energy can be offset by a more flexible consumption.



However: Factories are scaled according to profit while energy consumption is not a concern at the moment

What is Flexibility?

„Flexibility is the amount of energy and the duration of time to which the device energy profile (energy flexibility) and/or activation time (time flexibility) can be changed.“ (Neupane et al. 2014)

- **Energy Flexibility.** Length (duration) and intensity (power) vary, but time of use remains the same.
- **Time Flexibility.** The same pattern occurs in the same form at different e. g. times of day or days of a week
- A combination of the above-mentioned cases.

Research Questions

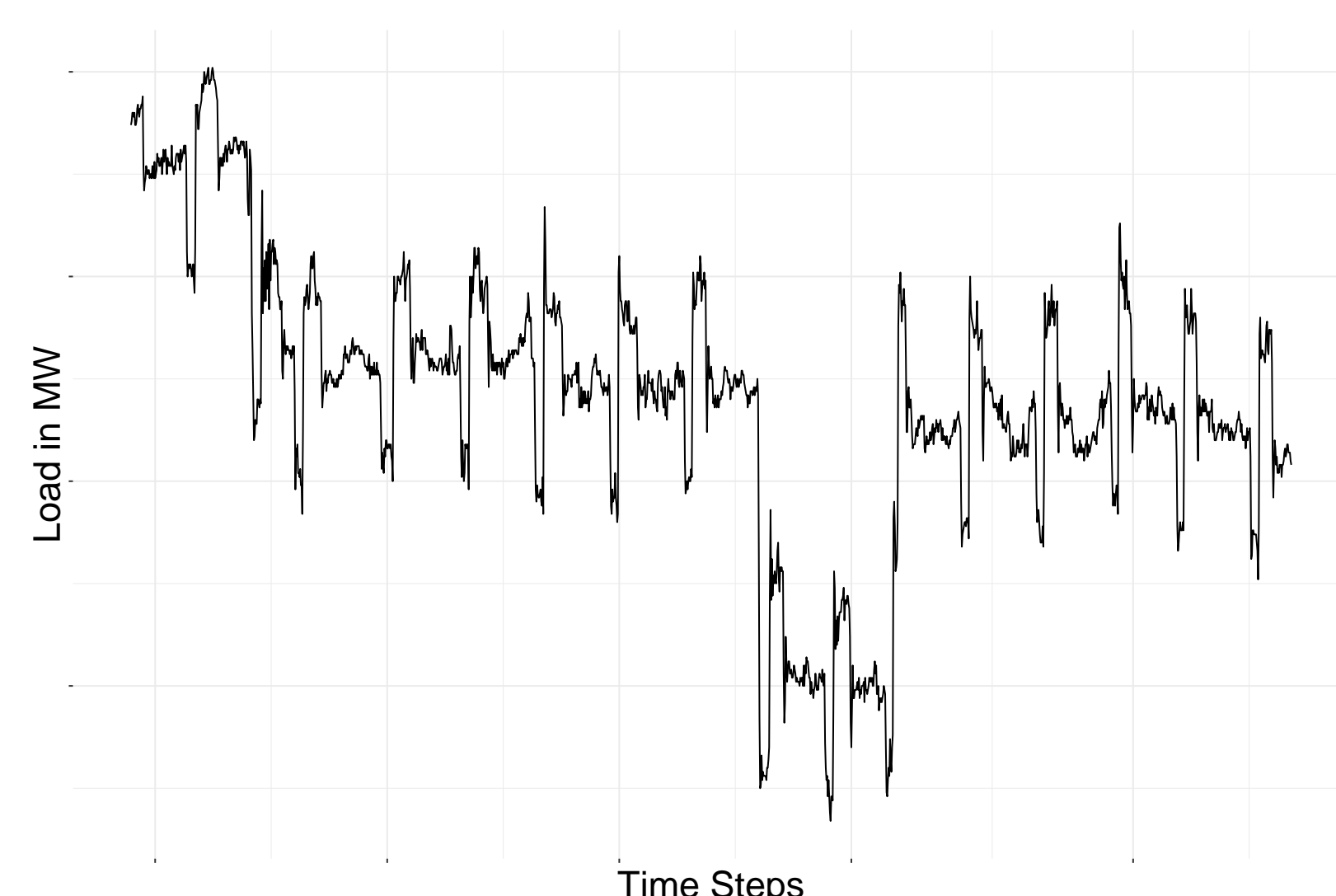
Can we determine the flexibility of a process from the historical consumption data?

- Can we extract information about the processes *normal shape* unsupervised?
- To what extent can we induce flexibility from the deviations of that normal shape?

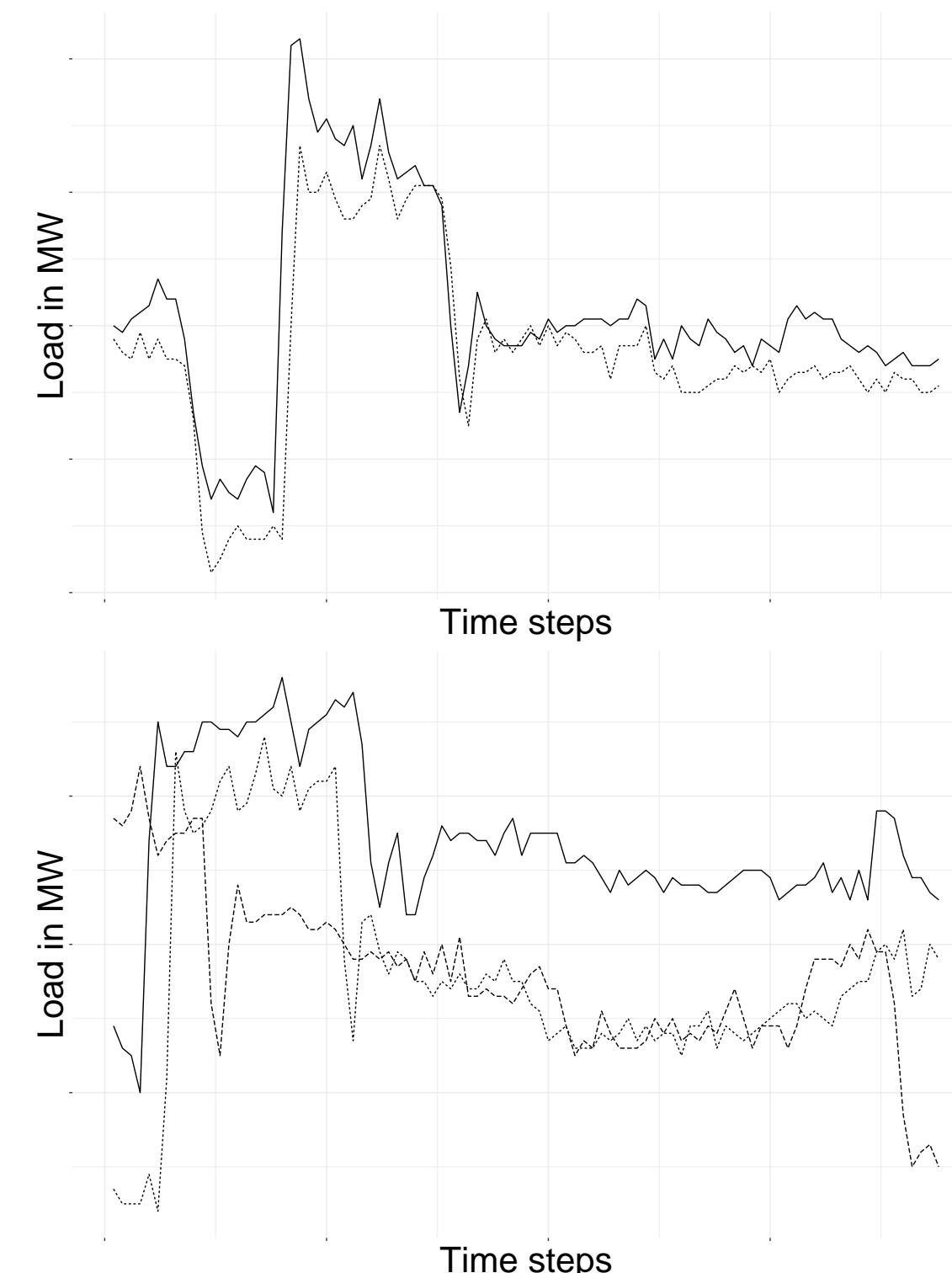
Methodology

1. Event Search (Sequences)
2. Univariate Motif Discovery via SAX transformation (Motifs)
3. Comparison of Sequences and Motifs
4. Categorization according to flexibility potential

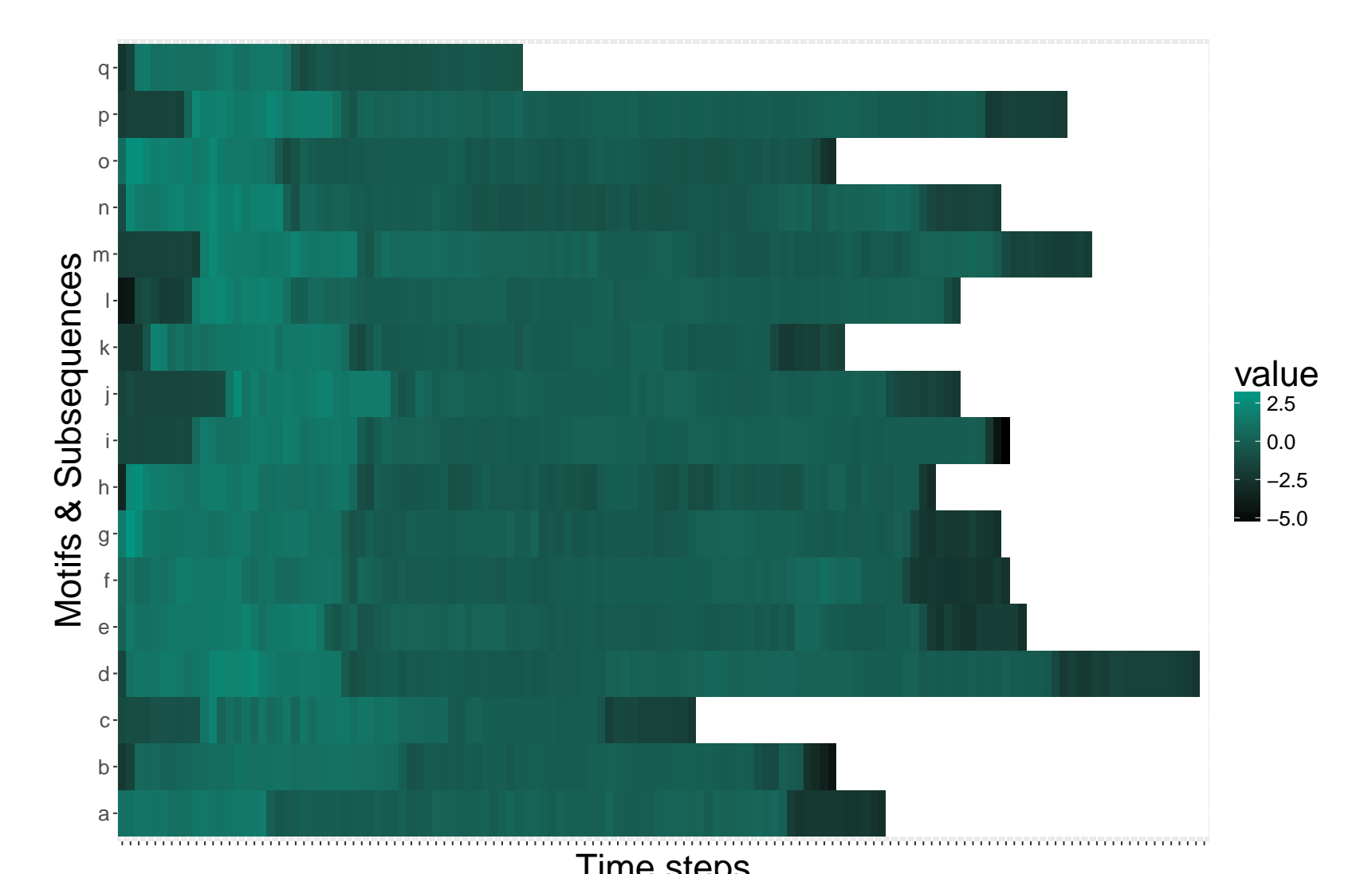
Load Time Series



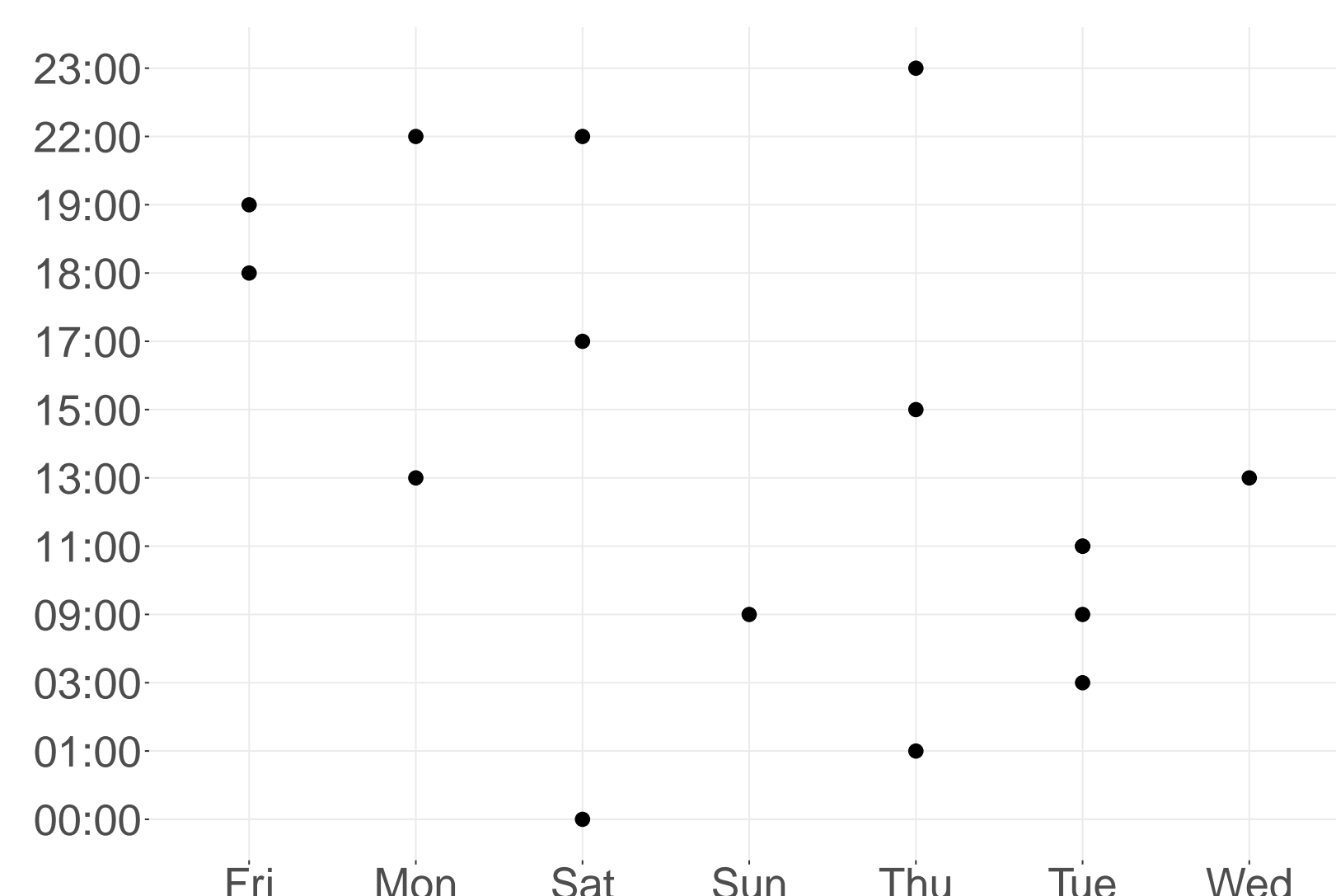
Motif



Similarity of Sequences



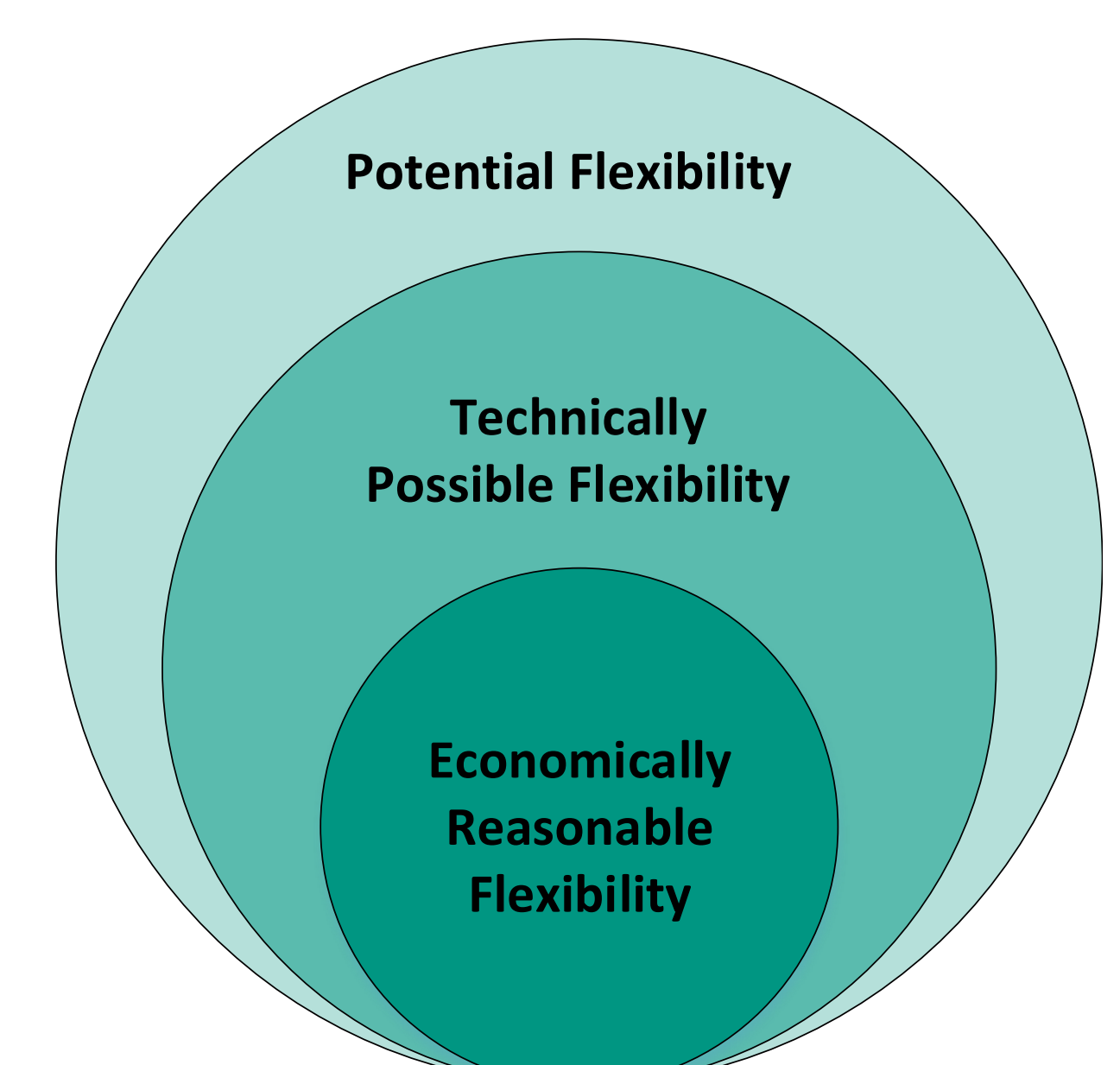
Time Flexibility



Energy Flexibility

Characteristic	Min	Median	Max	StdDev
Length	49.00	102.00	131.00	19.13
Intensity	293.94	294.37	310.97	7.31
Ramping Time	2.00	12.50	90.00	21.68

Problems



Based on: Ludwig, Nicole; Waczowicz, Simon; Mikut, Ralf; Hagenmeyer, Veit (2017): Mining Flexibility Patterns in Energy Time Series from Industrial Processes. In Frank Hoffmann, E. Hüllermeier, Ralf Mikut (Eds.): Proceedings. 27. Workshop Computational Intelligence, Dortmund, 23. – 24. November 2017: KIT Scientific Publishing, pp. 13–32.