Classification of Cardiovascular Age by Single-Particle Tracking Method of Deep Learning

Maximilian Pfundstein

March 23, 2020

Linköpings University

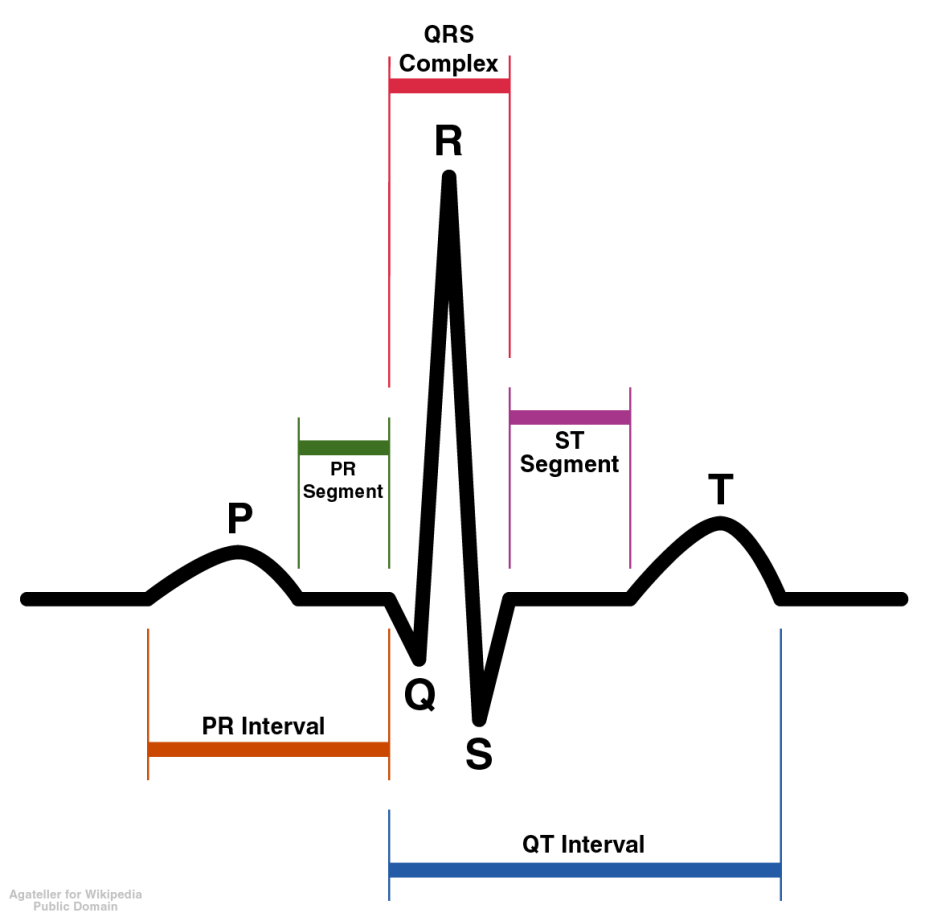
Table of contents

Introduction

Introduction — ECG and HRV

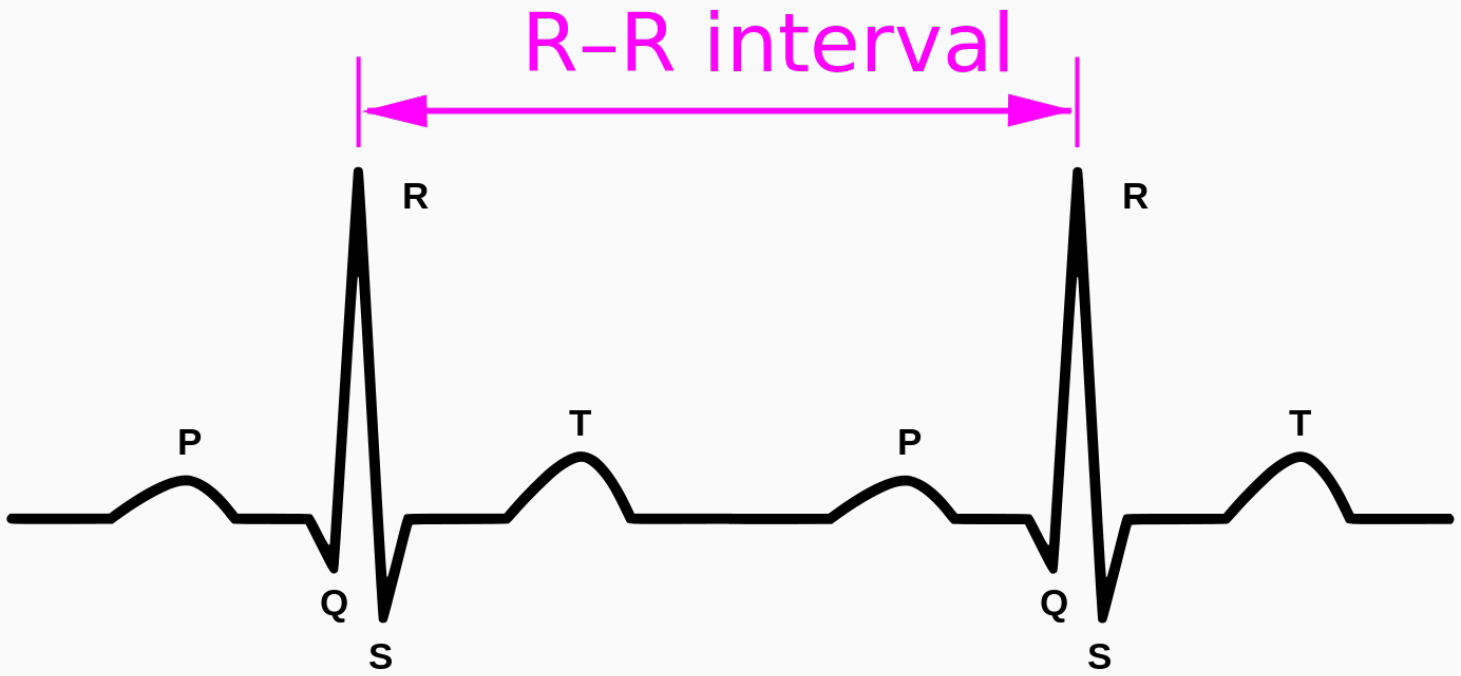
- Electrocardiography (ECG) measures the electrical potential of the heart
- Heart Rate Variability (HRV) is the variation in time

Introduction — QRS Complex



Source: `https://en.wikipedia.org/wiki/File:SinusRhythmLabels.png`

Introduction — RR Interval



Source: `https://commons.wikimedia.org/wiki/File:ECG-RRinterval.svg`

Introduction — Research Questions

- Can you infer information about the patients age from RR Intervals?
- How can impurity been handled?
- Can RR Intervals be simulated?

Related Literature

Related Literature

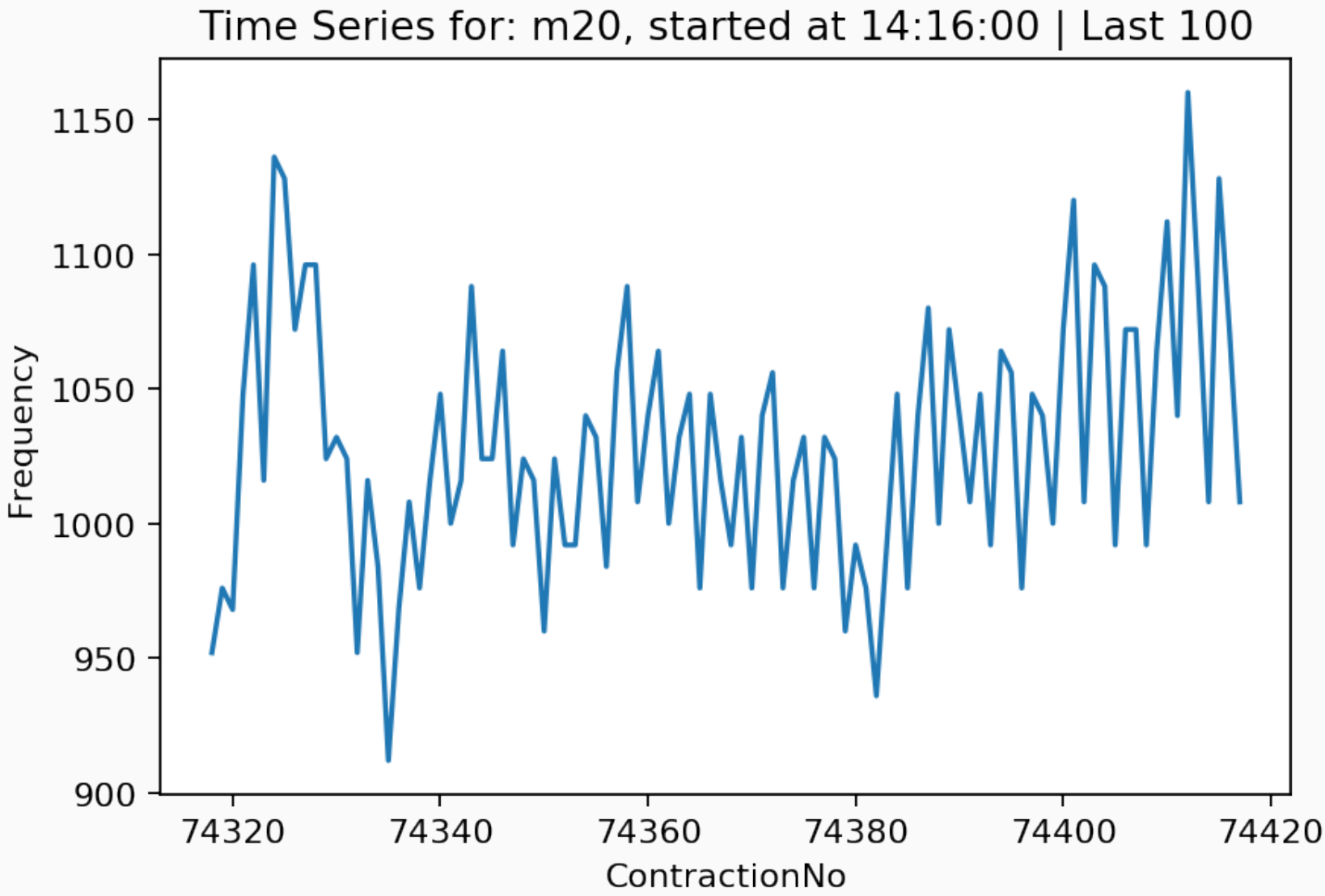
- Patterns of Heart Rate Dynamics in Healthy Aging Population: Insights from Machine Learning Methods [Makowiec and Wdowczyk, 2019]
- Classification of diffusion modes in single particle tracking data: feature based vs. deep learning approach [Kowalek et al., 2019]
- Heart Rate Variability: Analysis and Classification of Healthy Subjects for Different Age Groups [Poddar et al., 2015]

Data

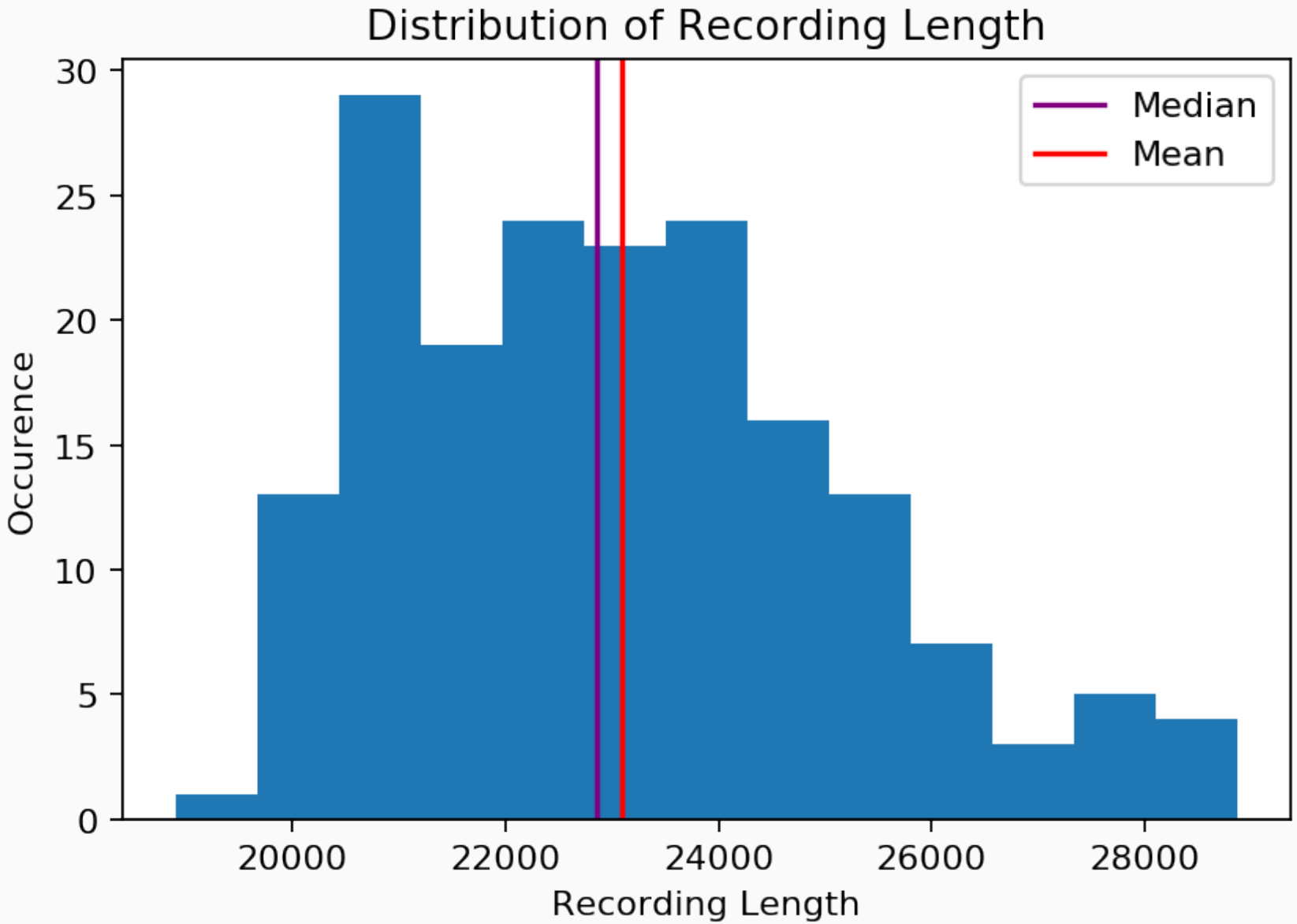
Data — Data Sets

- University of Gdansk
  - 181 Holter recordings of 4 hours
  - Sleep only
  - Healthy patients
  - Missing data points
- PhysioNet: CAST RR Interval Sub-Study Database
  - 1543 recordings of 24 hours
  - Sleep and awake
  - Survivors of myocardial infarction (heart attack)
  - Treated with different medication
  - No missing data points

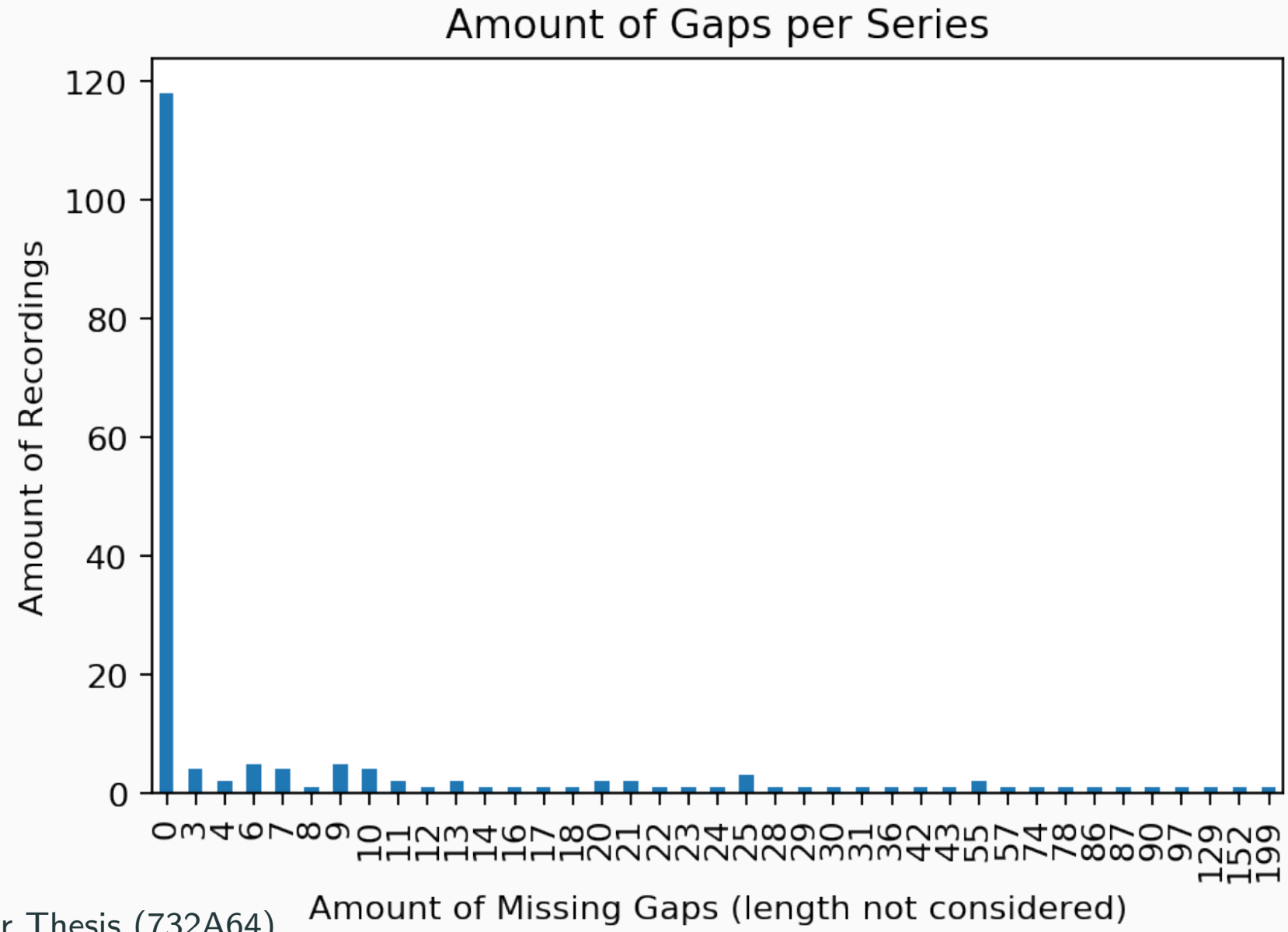
Data — Plots


Time Series for: m20, started at 14:16:00 | Last 100
Frequency
1150
1100
1050
1000
950
900
74320
74340
74360
74380
74400
74420
ContractionNo

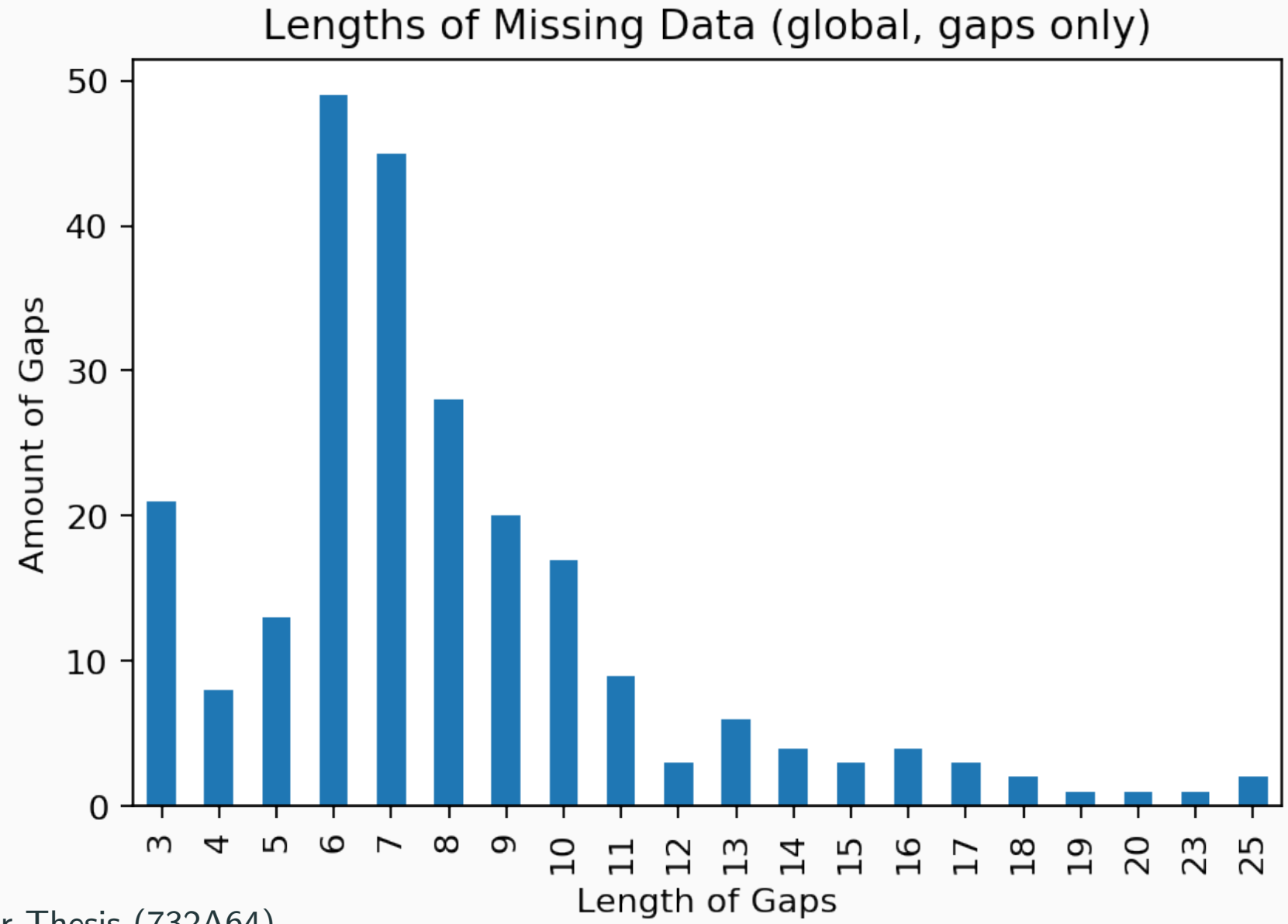
Data — Plots


Distribution of Recording Length
Median
Mean
Occurence
Recording Length
0
5
10
15
20
25
30
20000
22000
24000
26000
28000

Data — Plots


Amount of Gaps per Series
Amount of Recordings
120
100
80
60
40
20
0
0 3 4 6 7 8 9 10 11 12 13 14 16 17 18 20 21 22 23 24 25 28 29 30 31 36 42 43 55 57 74 78 86 87 90 97 129 152 199
Amount of Missing Gaps (length not considered)

Data — Plots

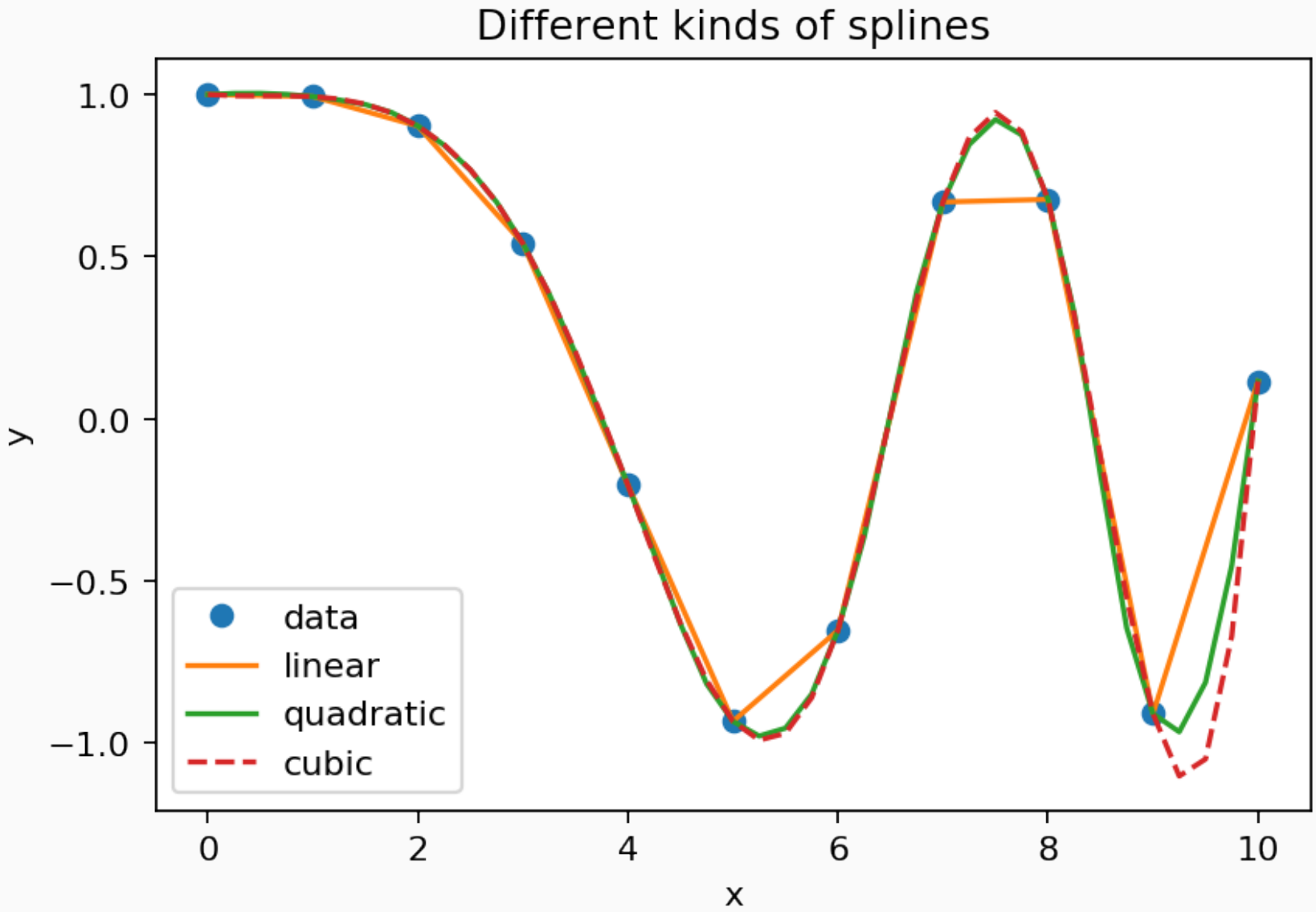

Lengths of Missing Data (global, gaps only)
Amount of Gaps
0
10
20
30
40
50
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
23
25
Length of Gaps

Objectives

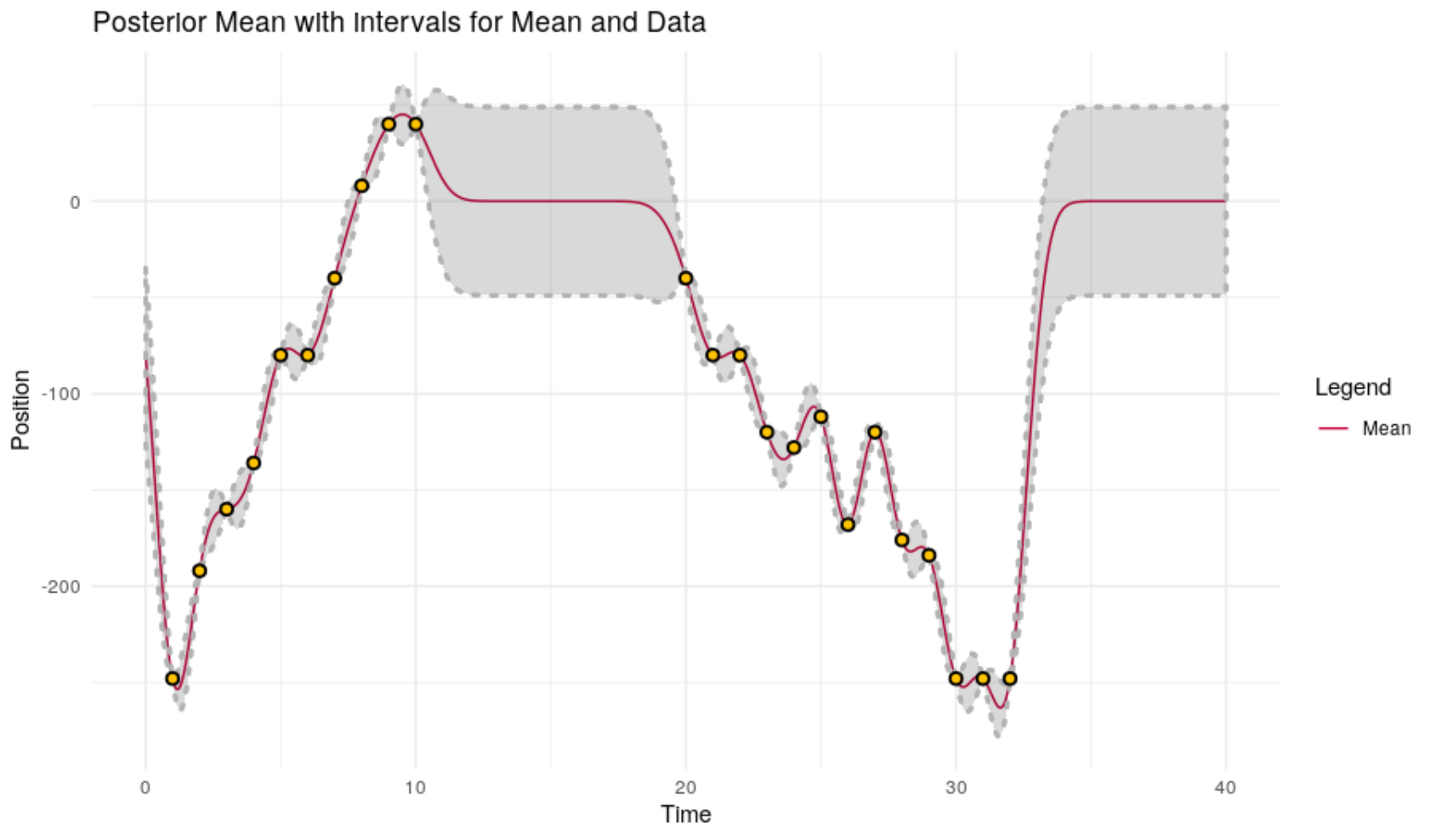
Objectives — Impurity

- Splines
- Gaussian Processes (GPs)

Objectives — Impurity — Splines



Objectives — Impurity — GPs



Objectives — Classification

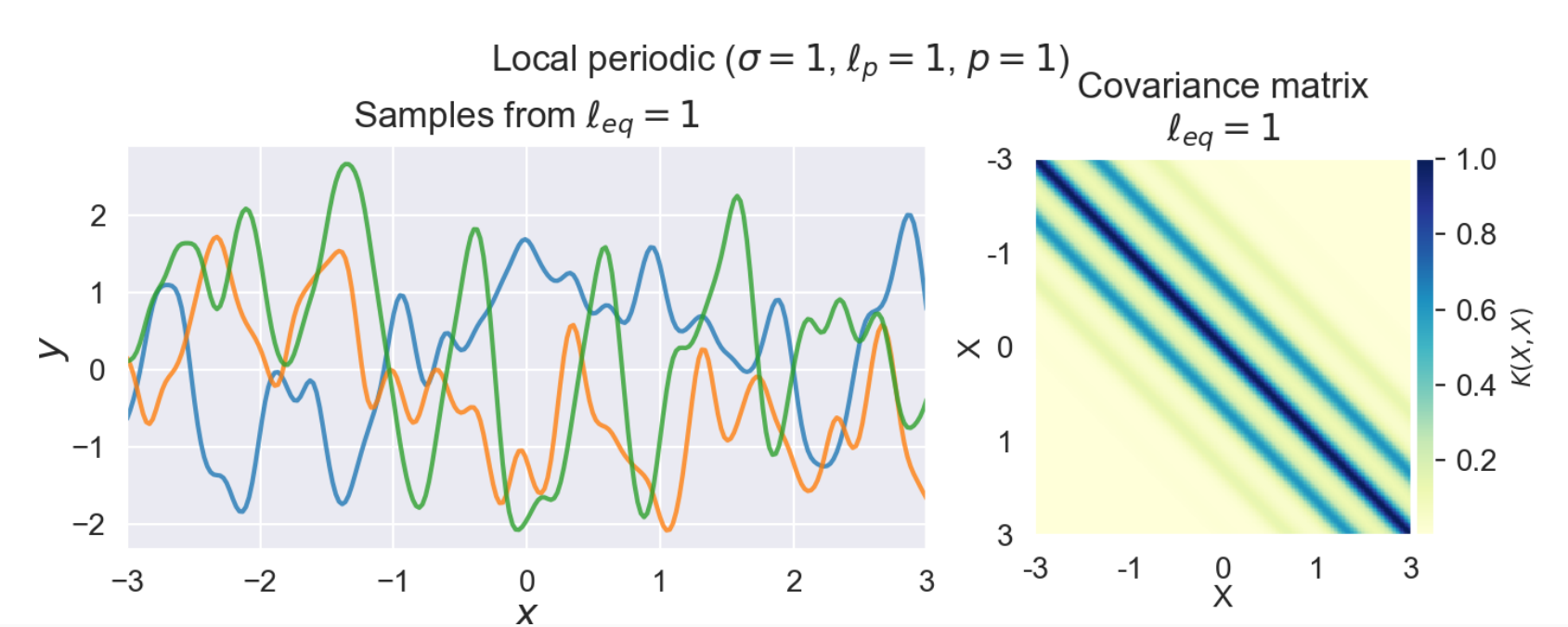
- Feature based Machine Learning Methods*
- Deep Learning - Convolutional Neural Networks (CNNs)

Objectives — Simulation — GP

Sampling from the Posterior of the GP

- $f(x) \sim \mathcal{GP}(m(x), k(x, x'))$
- $m(x)$ is the mean function, $k(x, x')$ the kernel function
- $K_{OU}(x, x') = \exp\left(- \frac{|d|}{\ell} \right)$
- $K_{LP} = \sigma^2 \exp\left(- \frac{2}{\ell^2} \sin\left(\pi \frac{|x - x'|}{p} \right) \right) \exp\left(- \frac{(x - x')^2}{2\ell^2} \right)$

Objectives — Simulation — GP



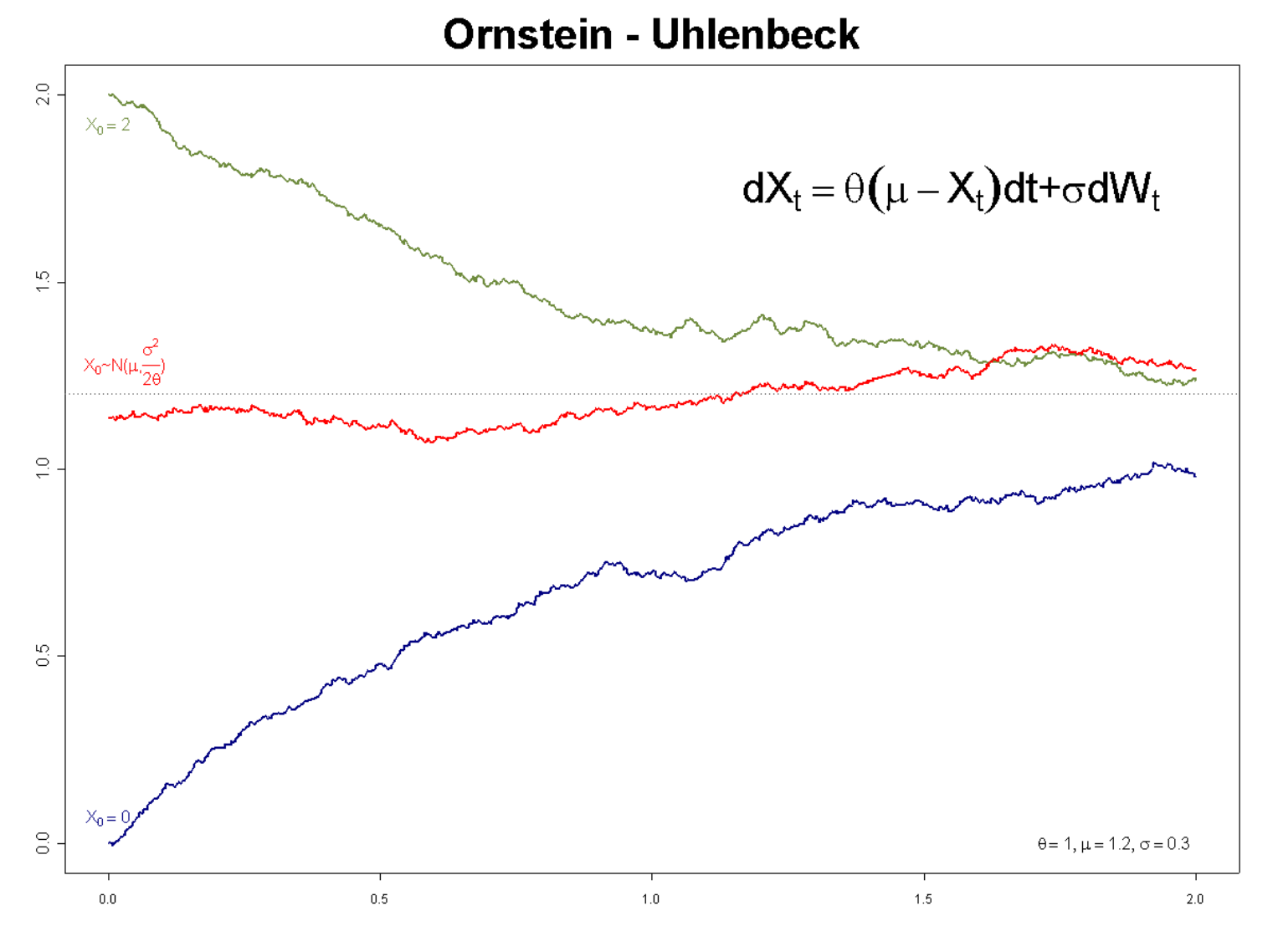
Source: `https://peterroelants.github.io/posts/gaussian-process-kernels/`

Objectives — Simulation — OU

Fitting an Ornstein–Uhlenbeck (OU) process

- Stochastic Differential Equation (SDE)
- $dx_t = \theta(\mu - x_t)d_t + \sigma dW_t$
- μ is the long-term mean
- θ defines the speed of mean reversion
- σ defines the randomness
- W_t is the *Wiener process*
- $\Rightarrow$ Using a trigonometric function as the optimum function

Objectives — Simulation — OU



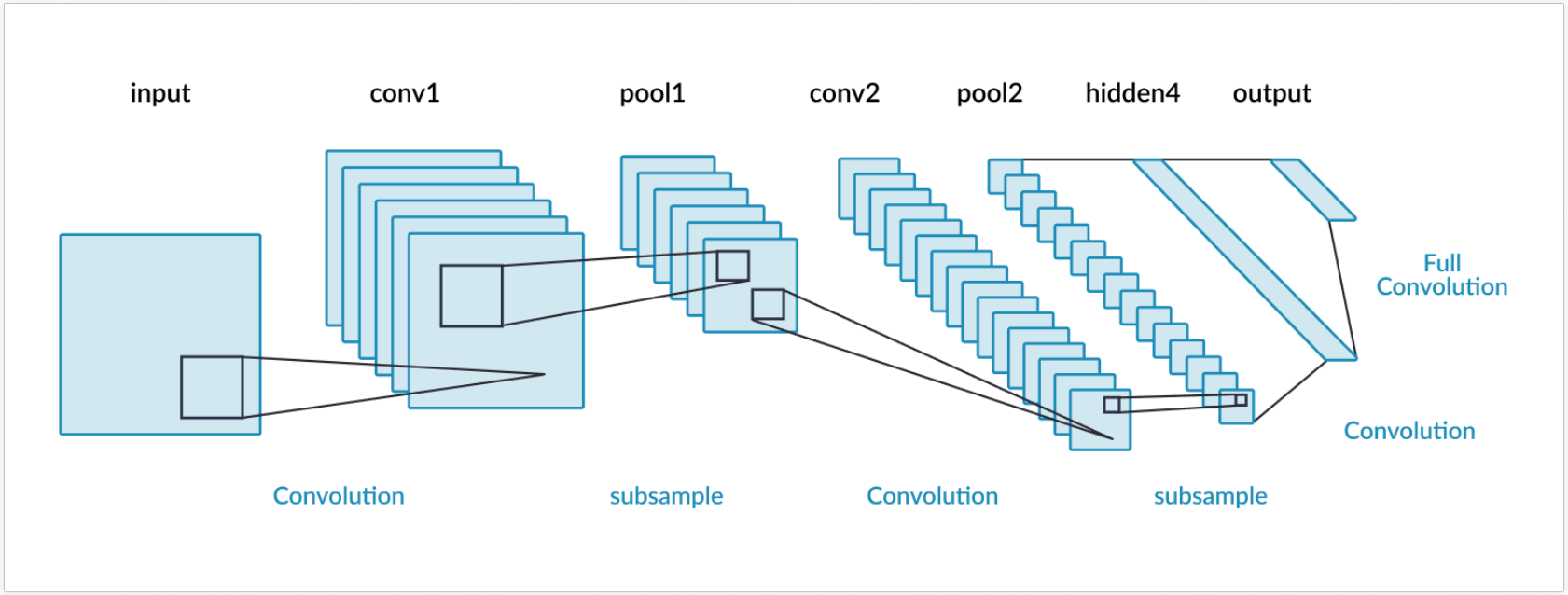
Status and Outlook

Status and Outlook

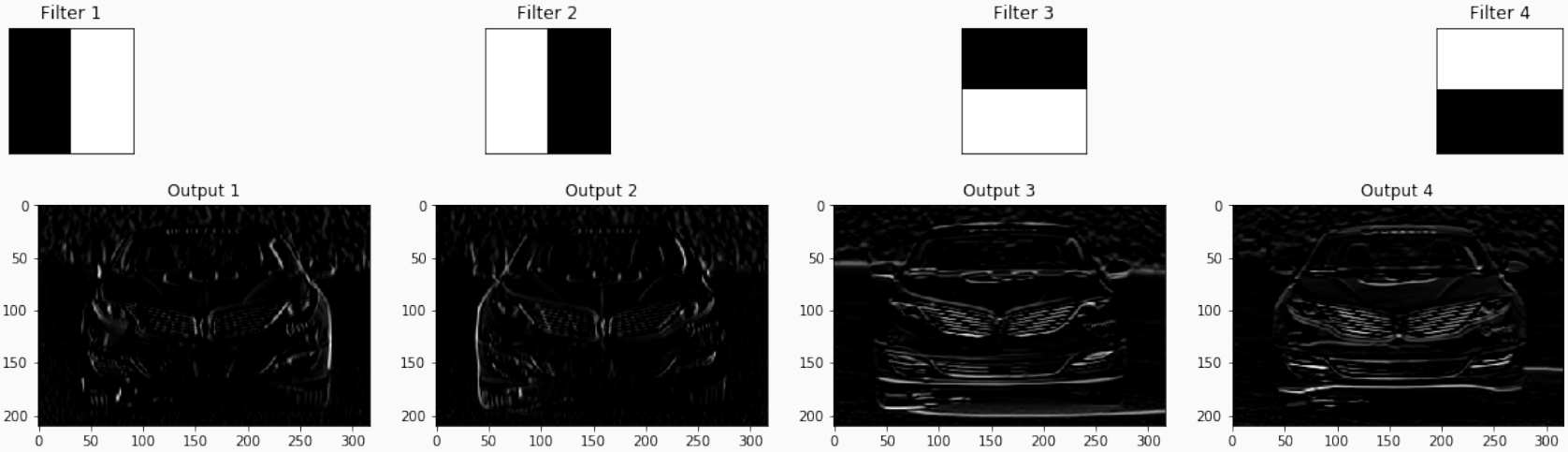
- Impurity
  - (done) Splines (linear, quadratic, cubic)
  - (open) GP, possibly in TensorFlow Probability (TFP), **very large** covariance matrix
- Classification
  - (done) Simply CNN yields in very bad results
  - (open) More advanced CNN, maybe combine with Recurrent Neural Networks (RNNs)
  - Utilise Long Short-Term Memory Cells (LSTMs)
- Simulation
  - (open) Sampling from GP
  - (open) Fitting OU process
- Evaluation

Appendix

Objectives — Classification — CNN



Objectives — Classification — CNN



References i

- Kowalek, P., Loch-Olszewska, H., and Szwabiński, J. (2019). **Classification of diffusion modes in single particle tracking data: feature based vs. deep learning approach.**
- Makowiec, D. and Wdowczyk, J. (2019). **Patterns of heart rate dynamics in healthy aging population: Insights from machine learning methods.** *Entropy*, 21:1206.
- Poddar, M., Kumar, V., and Sharma, Y. (2015). **Heart rate variability: Analysis and classification of healthy subjects for different age groups.**