Intelligent Embedded Systems

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Novelty based Driver Identification on RR Intervals from ECG Data

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Motivation

- Improve comfort functions
- Car sharing and car rental companies want to know if an undeclared driver is driving the vehicle

- prevent unknown persons from driving the car (theft protection)

ECG Dataset

Setup

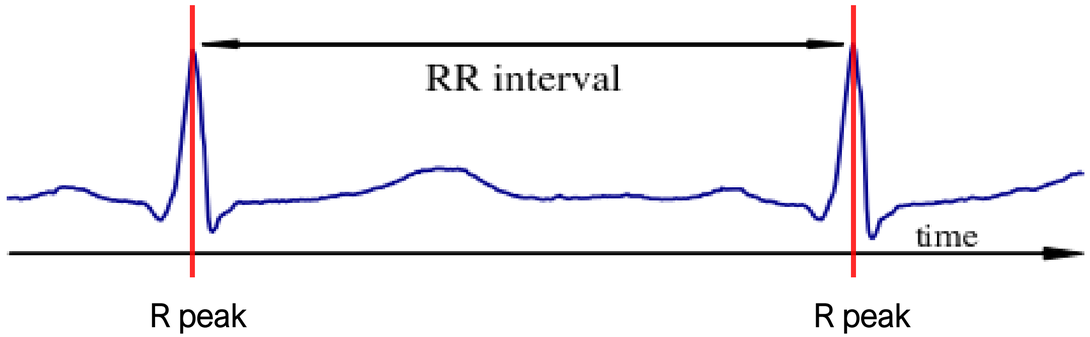
- car driving simulator
- 3D glasses
- shimmer sensors to record the data

Dataset

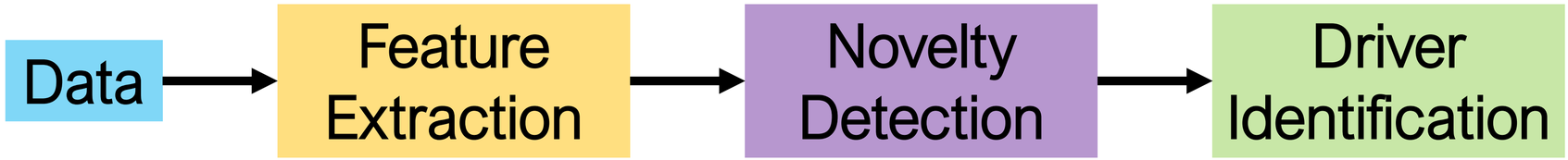
- ECG recordings of 25 persons
- each recording is approx. 90 min

ECG Data

- ECG signal of two successive heartbeats
- RR intervals are not constant they vary over time
- quantification and analysis is called heart rate variability



Overview of Our Approach



Feature Extraction

1. heart rate in beats per minute (HR)
2. standard deviation of the heart rate variability (HRV_{SD})
3. root-mean-squared difference of successive RR intervals (HRV_{RMSSD})
4. ratio of the number of decreasing and increasing RR intervals (HRV_{DI})
5. stress index (SI)*
6. energy of the Fourier transformation (fft_{en})
7. information entropy of the Fourier coefficients ($fft_{inf\text{-}Entr}$)
8. ratio of 33% of the coefficients with the lowest frequency compared to the 33% of the coefficients with the highest frequency (L_{3rd}-H_{3rd}-ratio)

* Baevskii, R.M.: Analysis of Heart Rate Variability in Space Medicine. Human Physiology 28(2), 202-213 (2002)

Novelty Detection

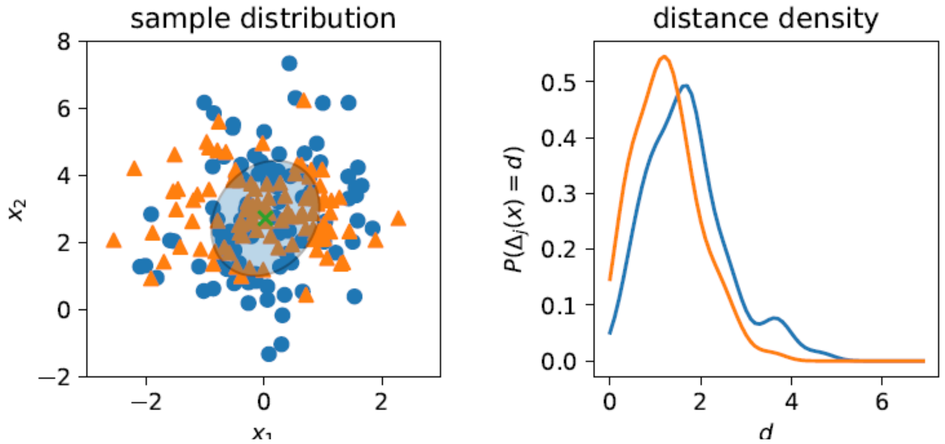
- The sample data from the known driver is used to learn a probabilistic model = expected model (Gaussian Mixture Models)

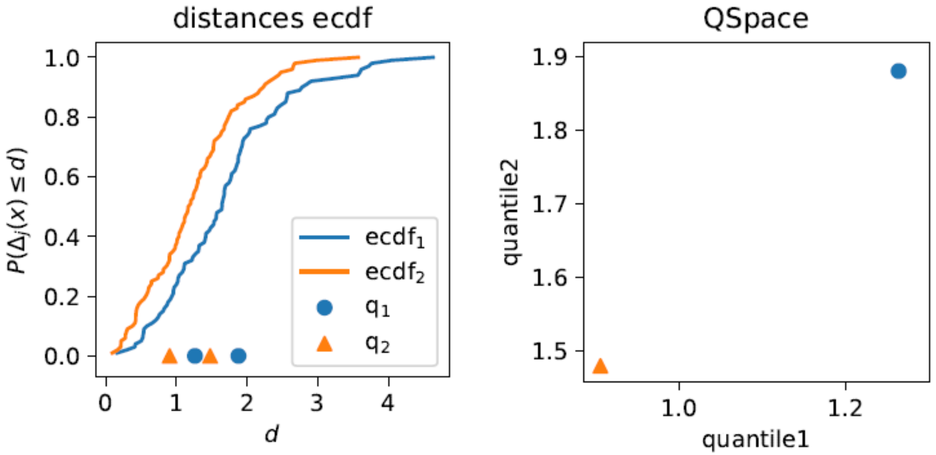
- CANDIES is able to detect novelties in the Low-Density Region (LDR) and High-Density Regions (HDR)
- A user-selected threshold decides whether a sample is within HDR or LDR.
- To measure the distance, we use the Mahalanobis distance.

Gruhl, C., Sick, B.: Novelty detection with CANDIES: A holistic technique based on probabilistic models. Int. J. Mach. Learn. Cyber. 9(6), 927-945 (2018)

Novelty Detection

QSpace



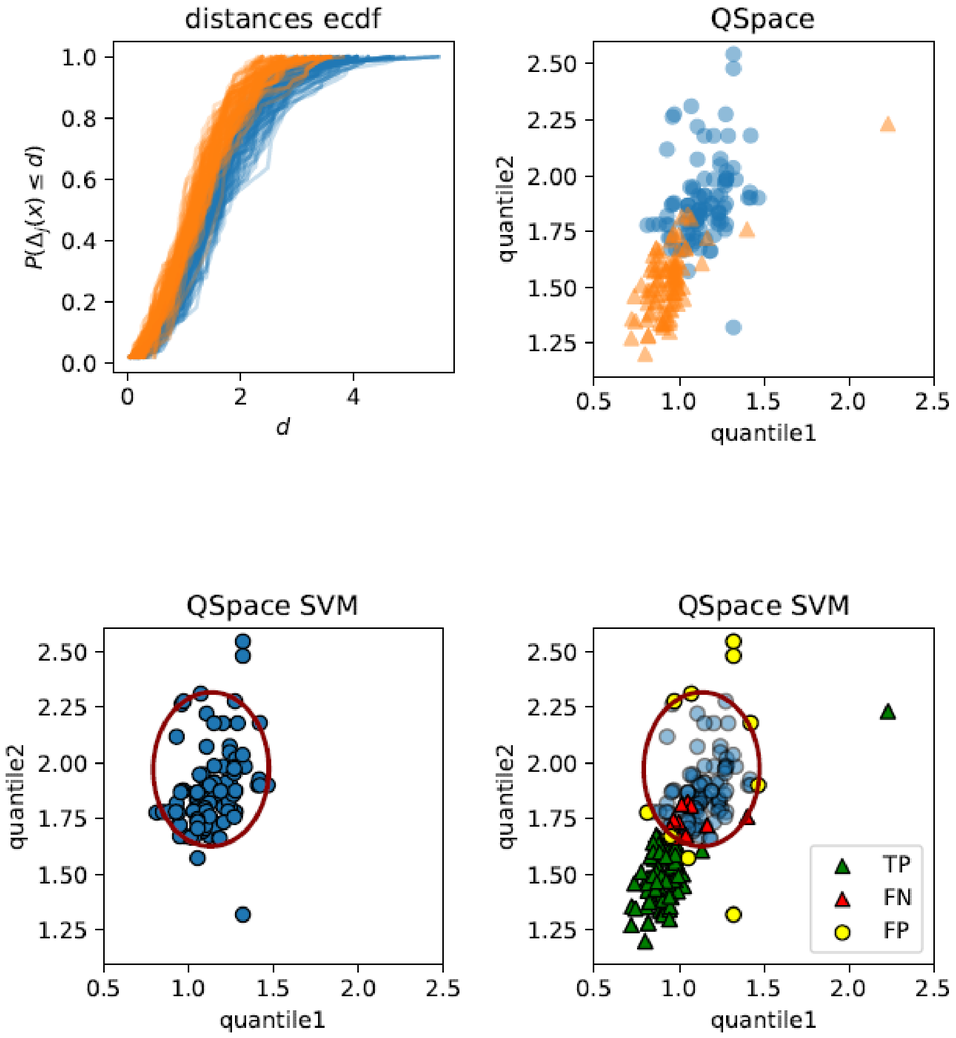


ecdf:
(empirical cumulative density function)

Q-Space is an approximation of the ecdf.

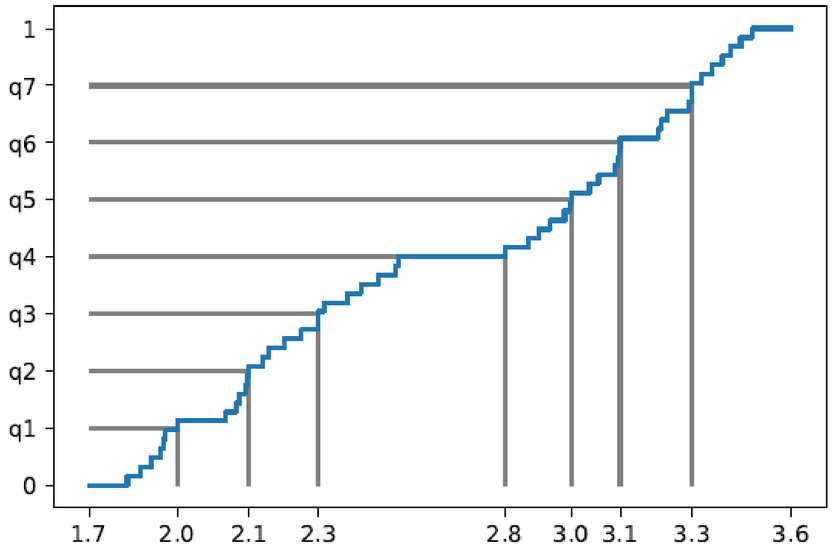
Novelty Detection

QSpace

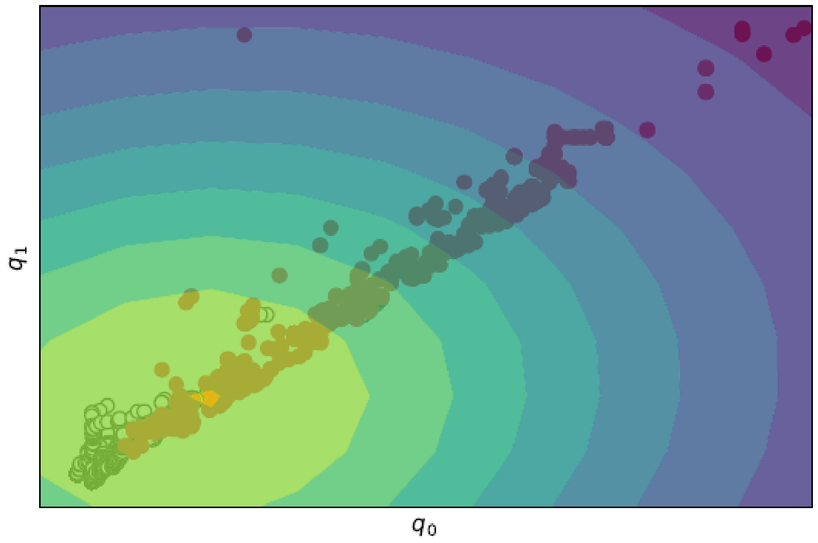


Novelty Detection

QSpace



ecdf of one component



QSpace of the component

Driver Identification

Single well-known Driver

- Model output is stored in the ring buffer.
- If the relative frequency is above a threshold, the driver is marked as well-known.

Multiple well-known Driver

- One ring buffer for each well-known driver.
- The driver is marked as known, if the relative frequency is above a threshold.
- By how much the relative frequency is greater than the threshold, determines which driver it is.

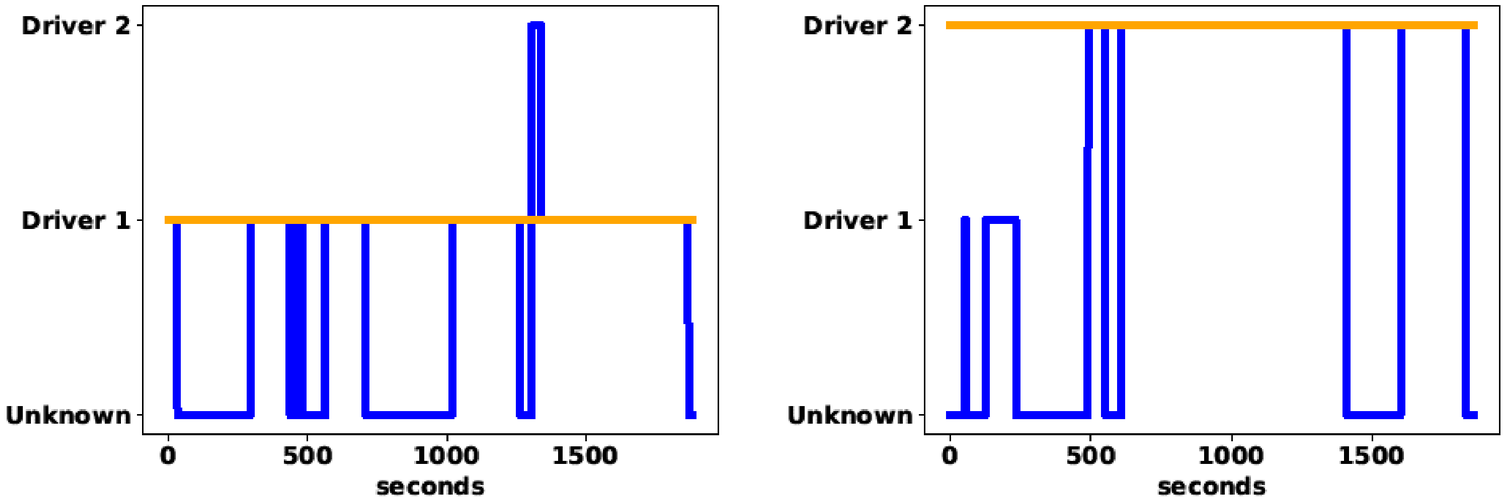
In both cases the threshold value is calculated with the help of the well-known driver data.

Experimental Evaluation

Well-known Drivers	1	2	3
Classes	unknown, driver 1	unknown, driver 1/2	unknown, driver 1/2/3
Precision	0.568	0.435	0.378
Recall	0.766	0.640	0.561
F1 Score	0.598	0.477	0.423
F1majority	0.333	0.167	0.100

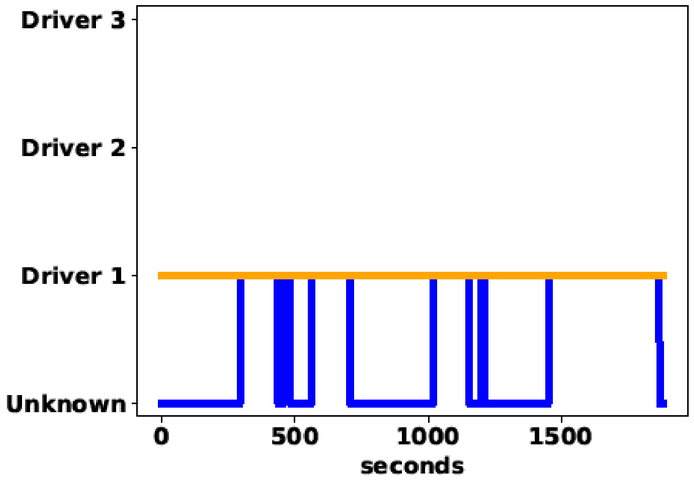
Experimental Evaluation

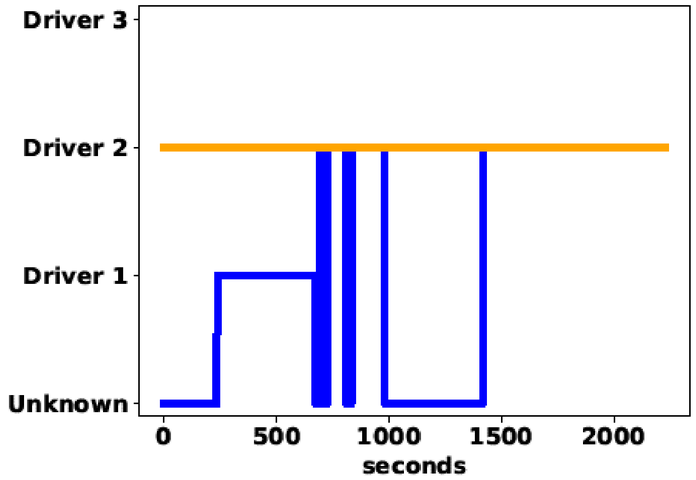
Result from two well-known drivers

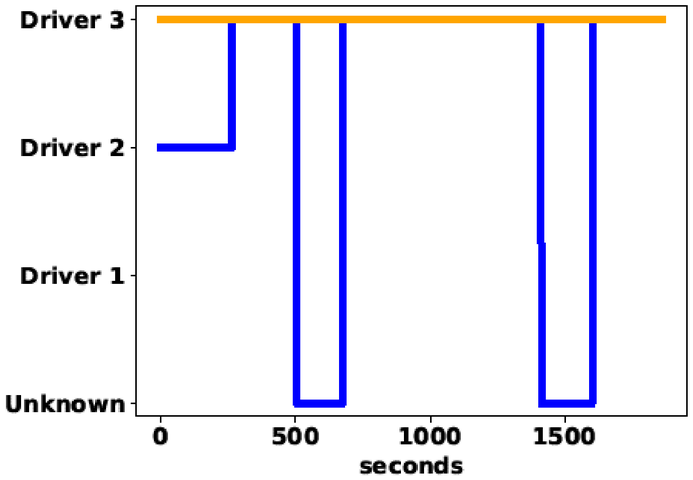


Experimental Evaluation

Result from three well-known drivers

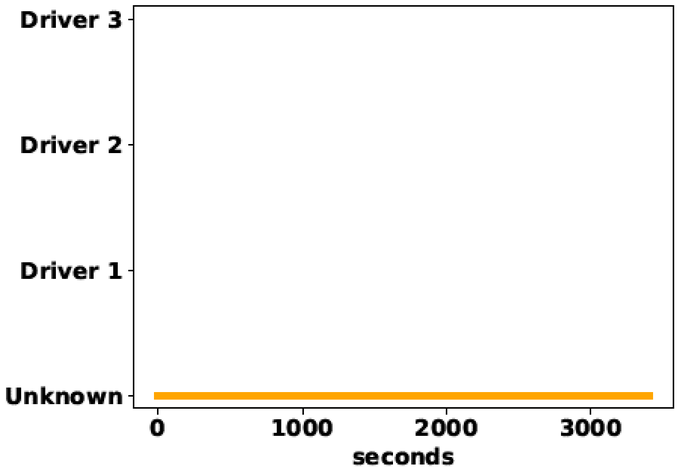


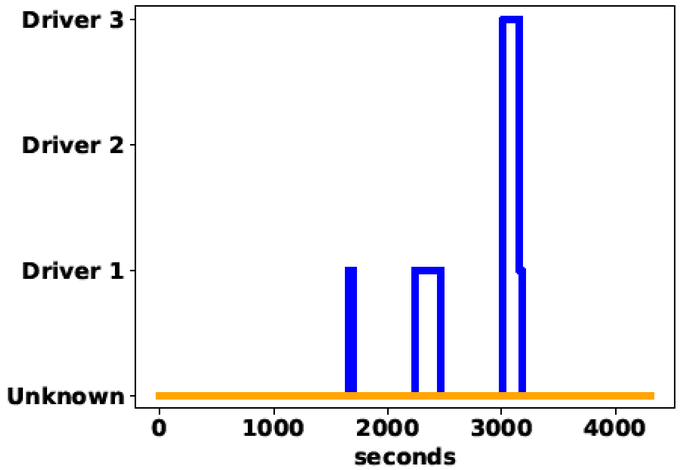


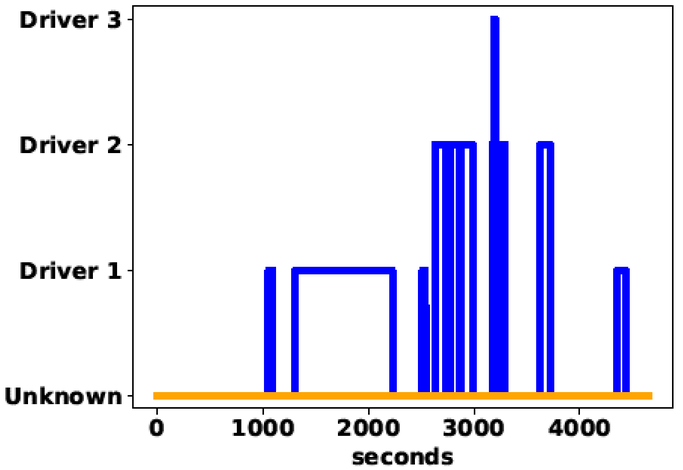


Experimental Evaluation

Results from unknown drivers







Outlook and Future Work

- Optimization of the novelty detectors, by implementing a calibration method to automatically determine various thresholds and parameters to make a computationally expensive grid search obsolete.
- Replace the one-class SVM with a regular multiclass SVM.
- Improvement to differentiate between larger groups of well-known drivers.
- Expand our dataset.

Thanks for your attention.