Classification of accoustic emission signals in material defectoscopy based on statistics and machine learning

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Signal generation

Zkušební těleso
ÚT AVČR, v.v.i.

Figure: Experimental body

Signal generation

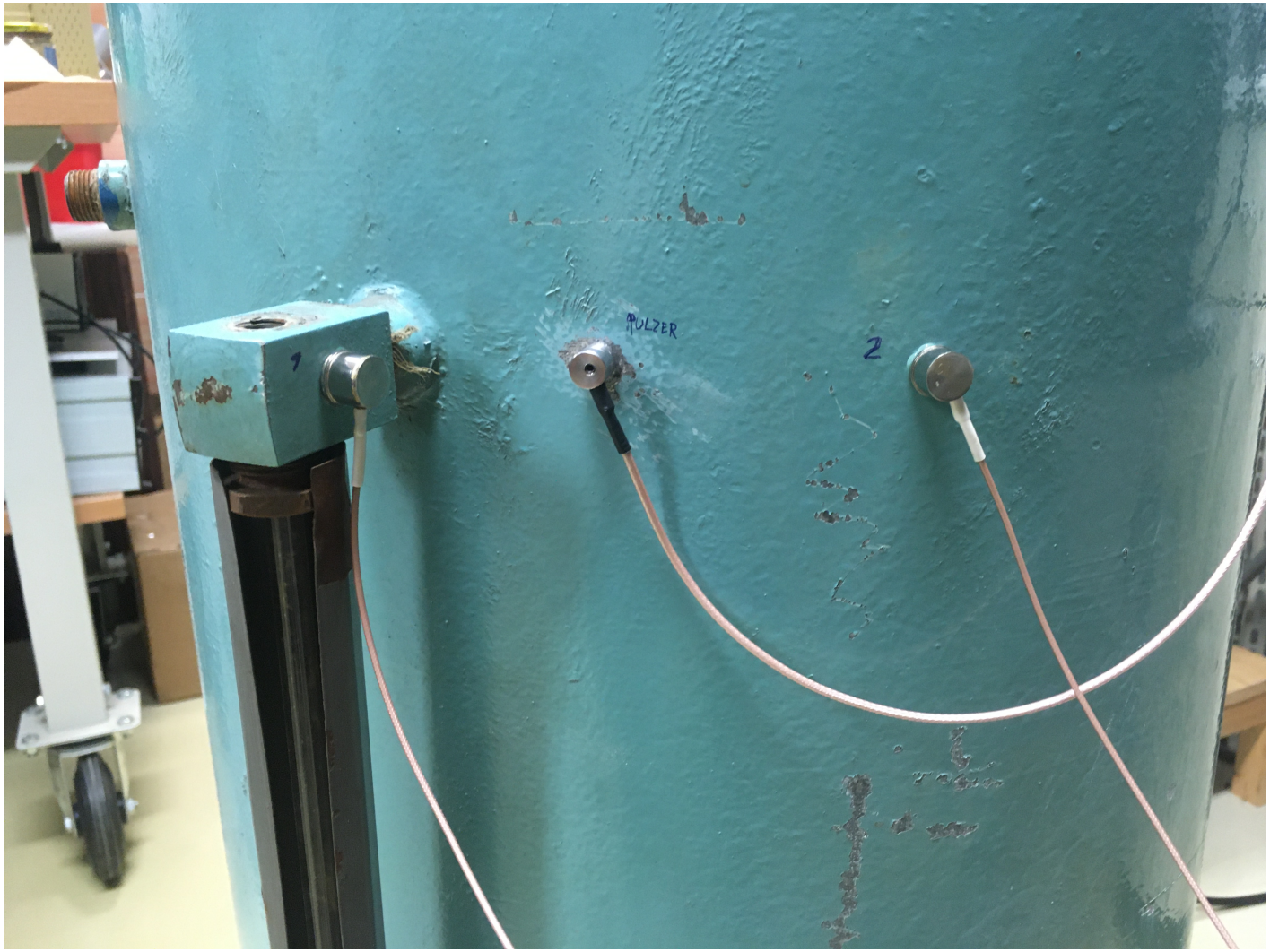


Figure: Experiment configuration

Signal generation

Figure: Signal inducing items

Signal

- Osciloscope + Matlab sampling software
- Different spectral characteristics of sensors

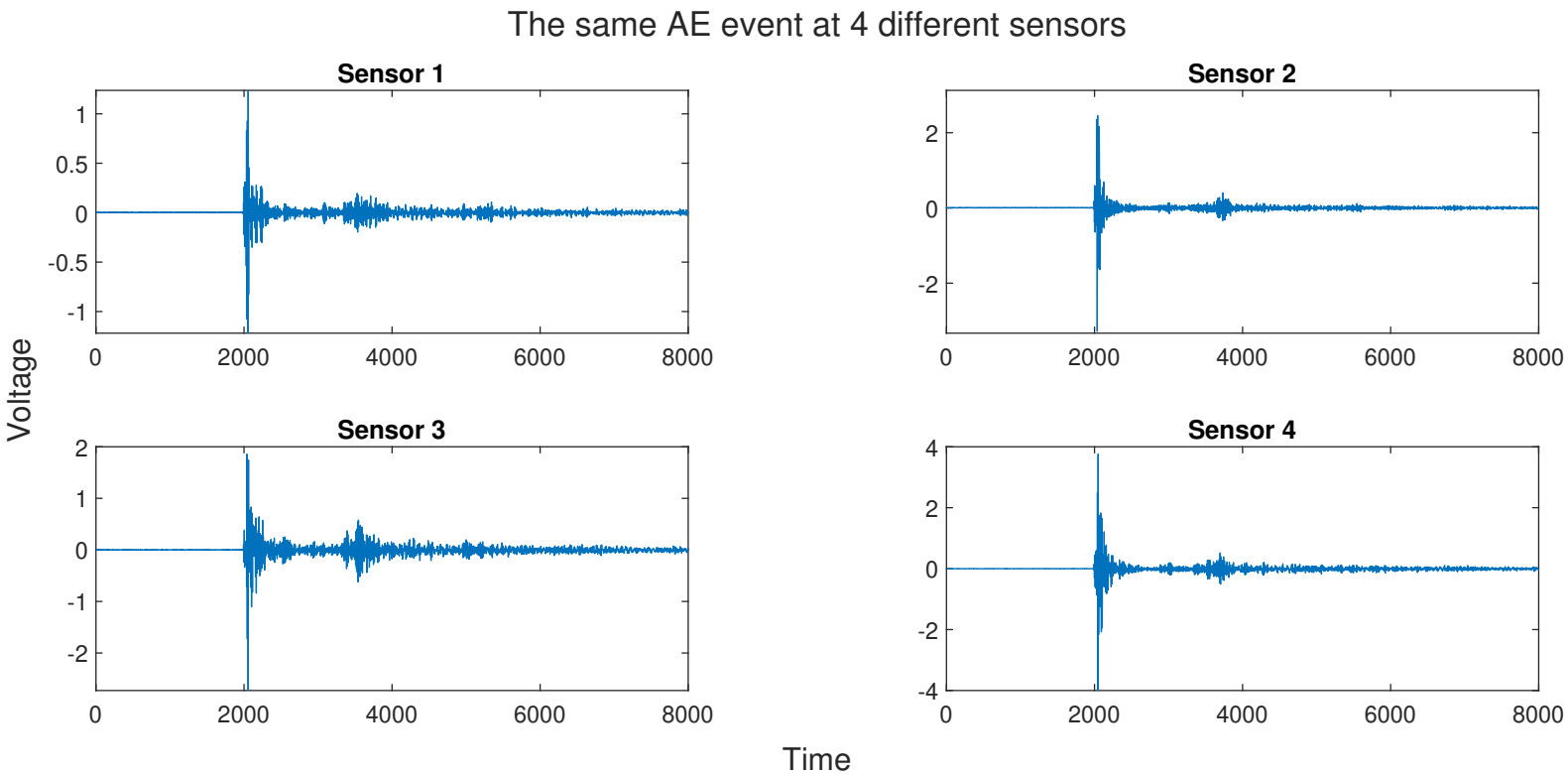


Figure: Signal example

Signal attributes

- Self generated attributes
  - Attribute P: $P = \frac{1}{T}\sum_{f=0}^{T-1} f\, S_f$
  - Attribute Z:

$$Z_c = \sum_{t=\tilde{t}}^{T-1} \delta(x_t), \qquad \delta(x_t) = \begin{cases} 1 & \text{if } (x_t x_{t+1}) = -1, \\ 0 & \text{otherwise.} \end{cases}$$

- Attribute computing package
  - Highly comparative time-series analysis (hctsa)
  - Feature subset Catch22

Fulcher Ben D., Little Max A. and Jones Nick S. 2013Highly comparative time-series analysis: the empirical structure of time series and their methods. J. R. Soc. Interface.1020130048.

Model Based Clustering

- Mixture of normal distributions: $p(x|\theta) = \sum_{j=1}^{M} \alpha_j p_j(x|\theta_j)$, where $\sum_{j=1}^{M} \alpha_j = 1$
- We maximize likelihood

$$L(\theta_k, \tau_k, z_{ik}|x) = \prod_{i=1}^{n} \prod_{k=1}^{M} \tau_k^{z_{ik}} p_k(x_i|\theta_k)^{z_{ik}},$$

$$\text{where } \tau_k \geq 0, \forall k \in \widehat{M} \quad \& \quad \sum_{k=1}^{M} \tau_k = 1$$

- Unknown $z_{ik} \Rightarrow$ EM algorithm, we maximize

$$E_z(l(\theta_k, \tau_k, z_{ik}|x)|\theta_k, \tau_k, x)$$

Model Based Clustering

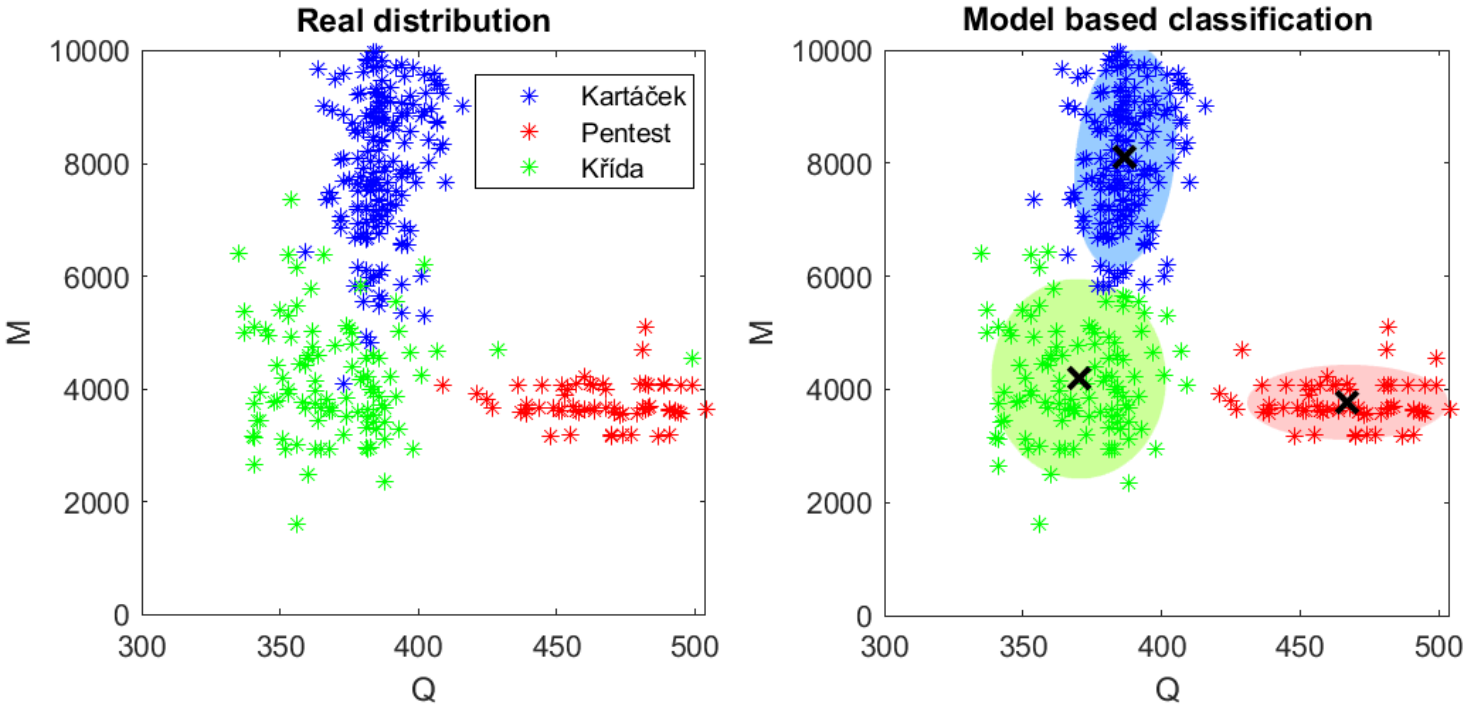


Figure: Caption

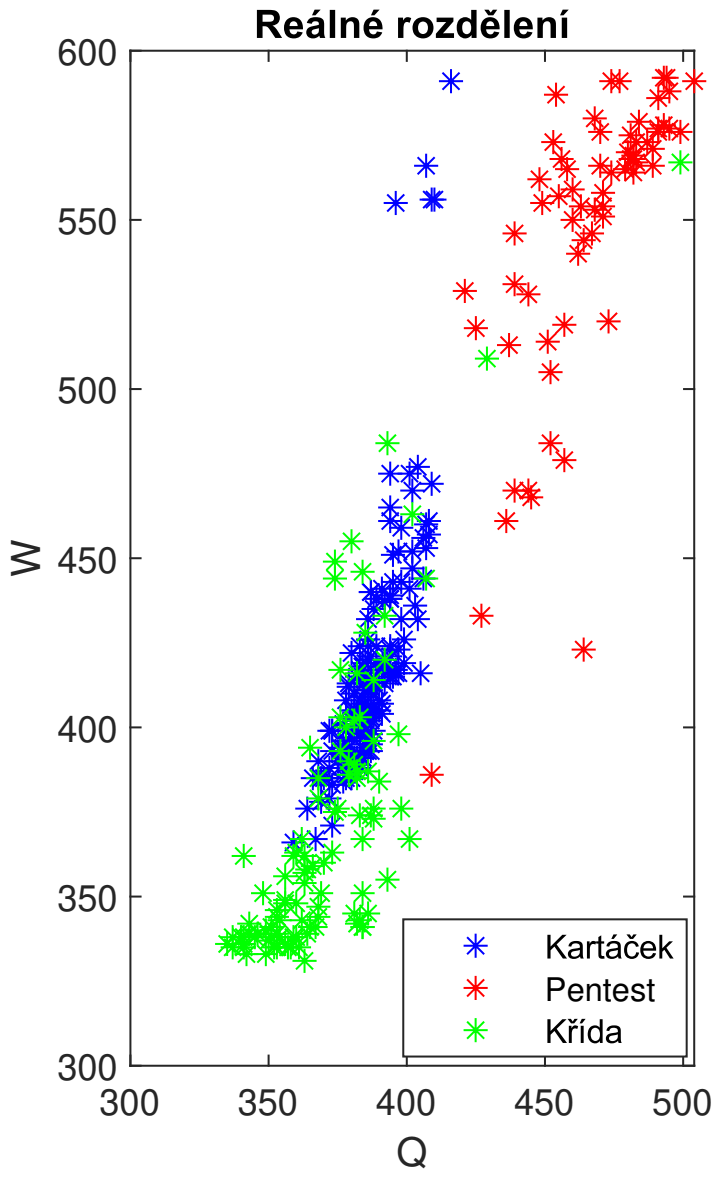
Supervised Kernel Density Estimation Clustering

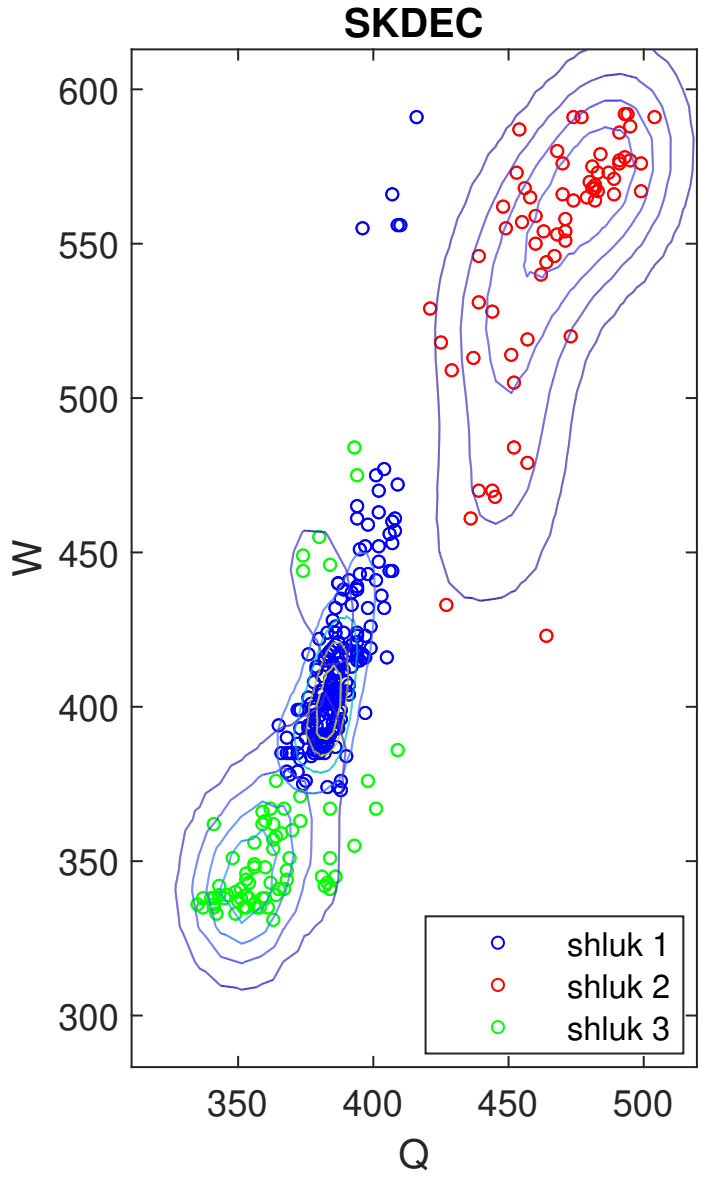
- We estimate kernel densities

$$\widehat{f}_i(t) = \frac{1}{n_i h} \sum_{j=1}^{n_i} K\left(\frac{t - t_j}{h}\right) \quad i \in \widehat{M},$$

  where $t_j \in T_i$, M is # clusters.
- We calculate values $\widehat{f} = \left(\widehat{f}_1(x_j), \ldots, \widehat{f}_M(x_j)\right)$ in each point we classify
- x_j belongs to k-th cluster if $k = \arg\max_{j \in M} \widehat{f}_j(t)$

Supervise Kernel Density Estimation Clustering





Classification

1. Quality of attributes in classification
2. Comparison of classification methods

Quality of attributes in classification

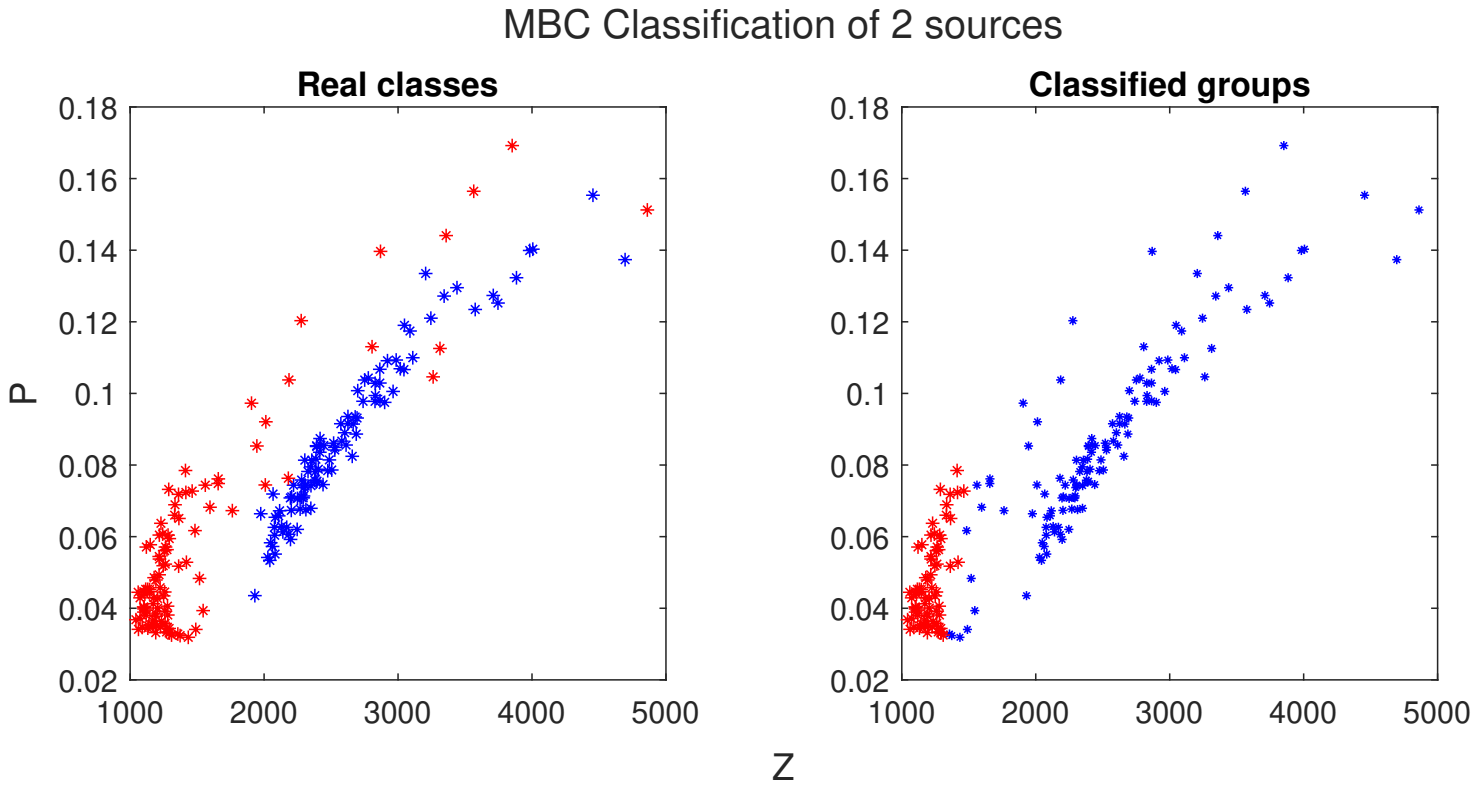


Figure: Classification using MBC on Z-P feature space - 86,5% success rate

Quality of attributes in classification

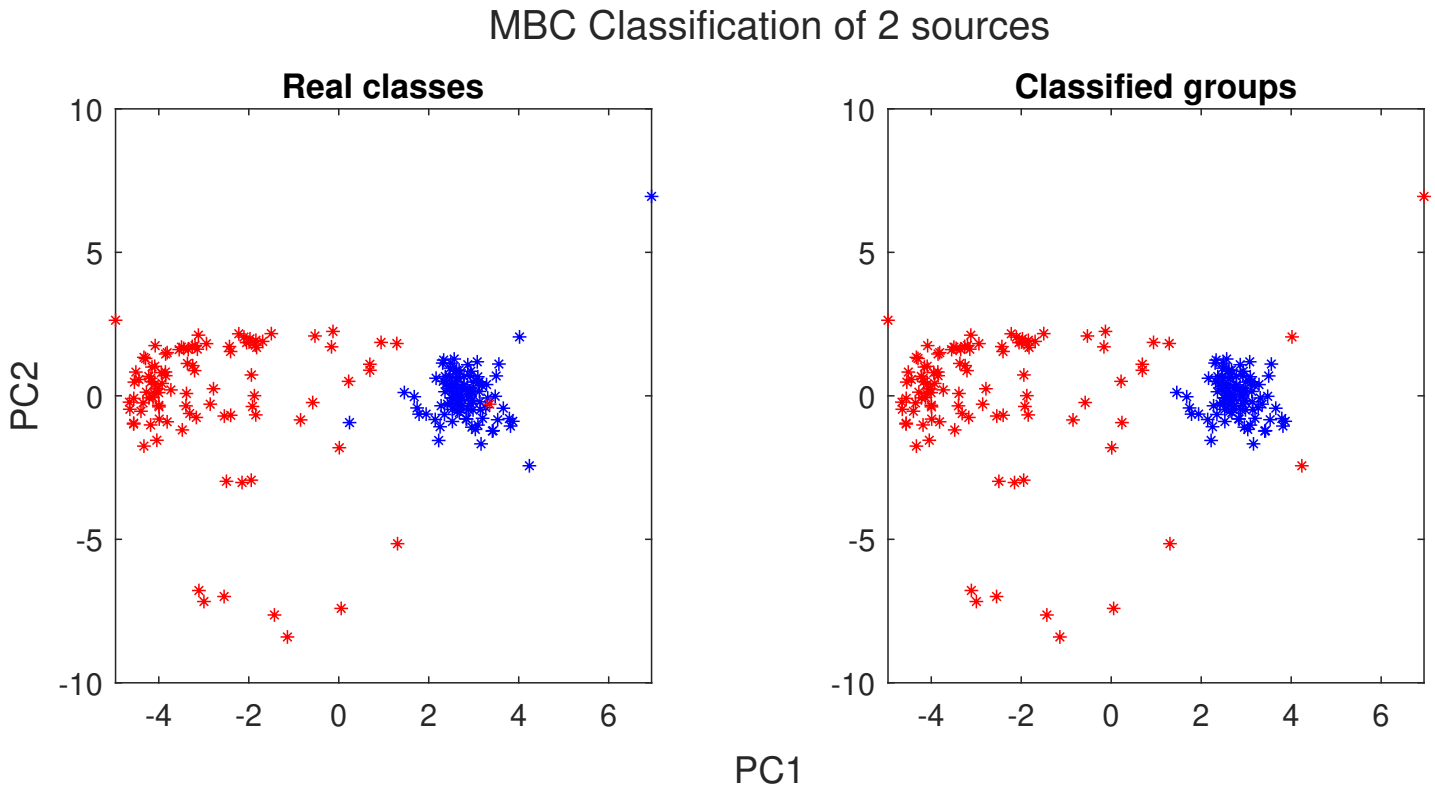


Figure: Classification using MBC on first two principle components of catch22 attributes - 97,5% success rate

Comparison of classification methods

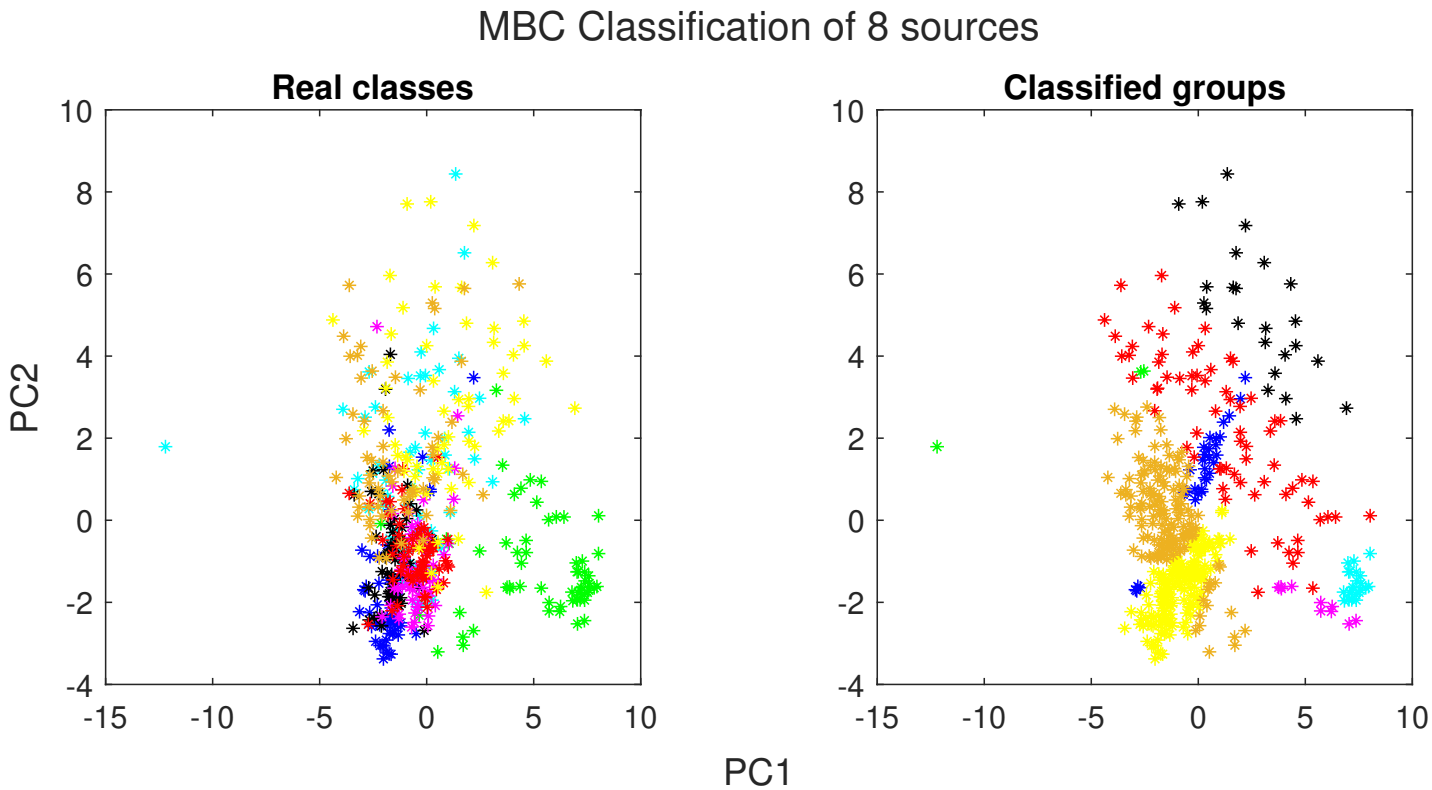


Figure: Classification using MBC on the first two principle components of catch22 attributes - 28,5% success rate

Comparison of classification methods

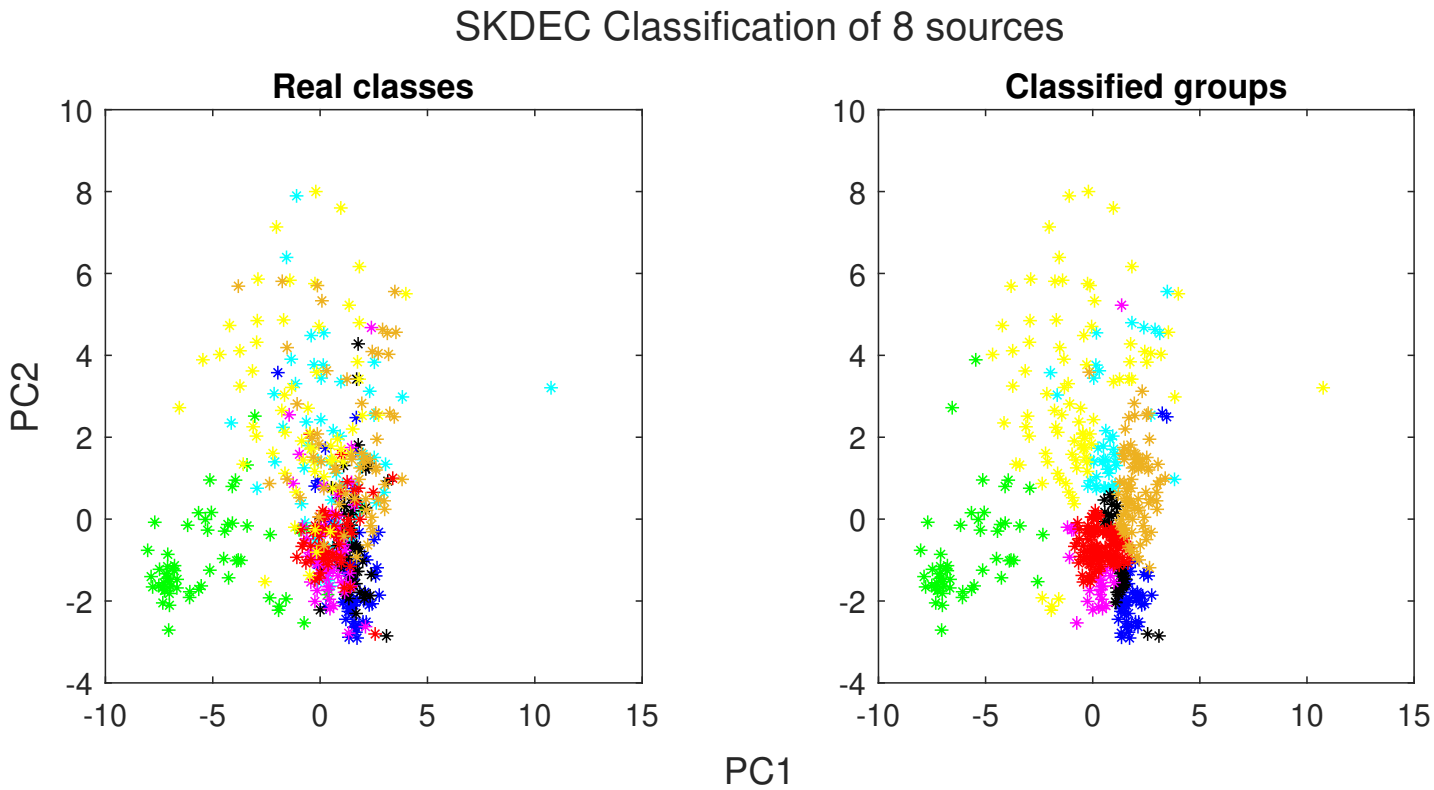


Figure: Classification using SKDEC on the first two principle components of catch22 attributes - 43,9% success rate

Comparison of classification methods

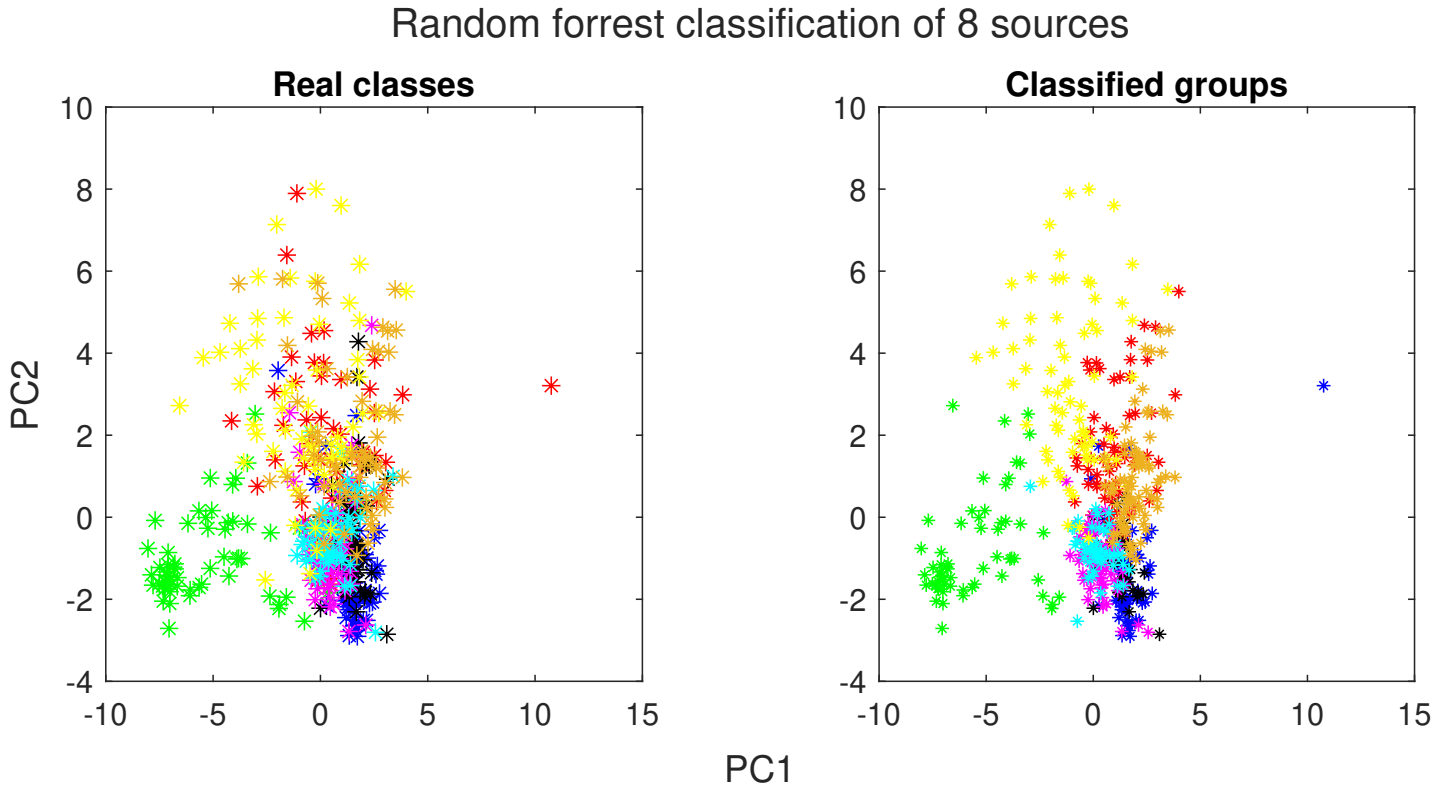
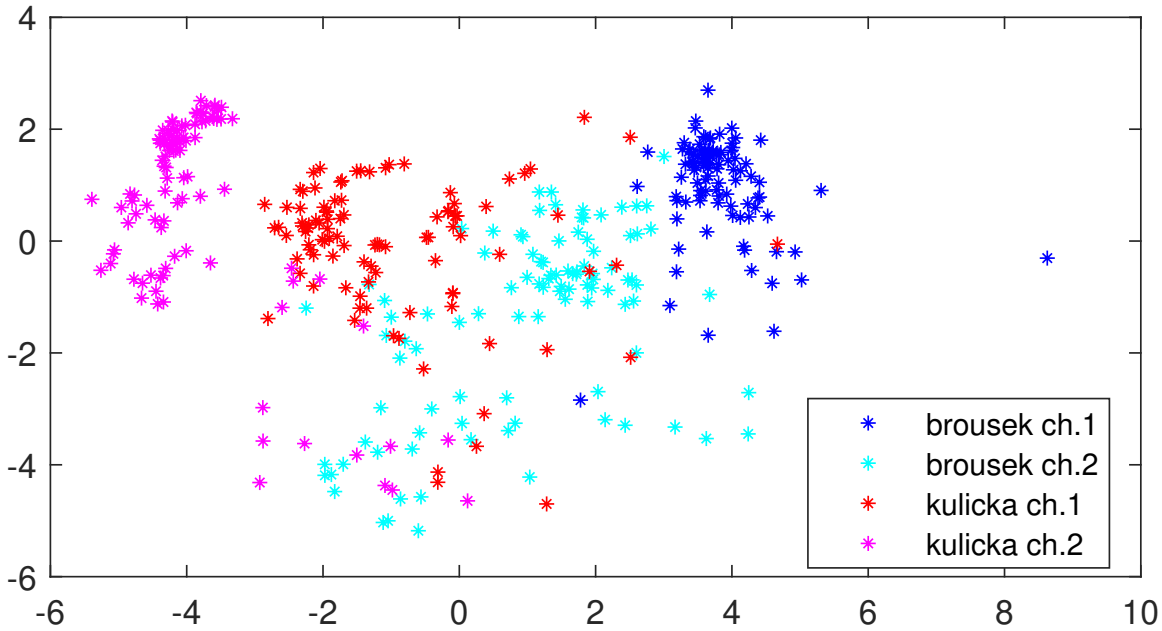


Figure: Classification using Random forrest on catch22 attributes - 65,8% success rate

Future plans

- FRESH algorithm
- Transformation of signal into image
- Classification of entire signals
- Using more channels



Thank you for your attention