PGNAA Spectral Classification of Metal with Density Estimations

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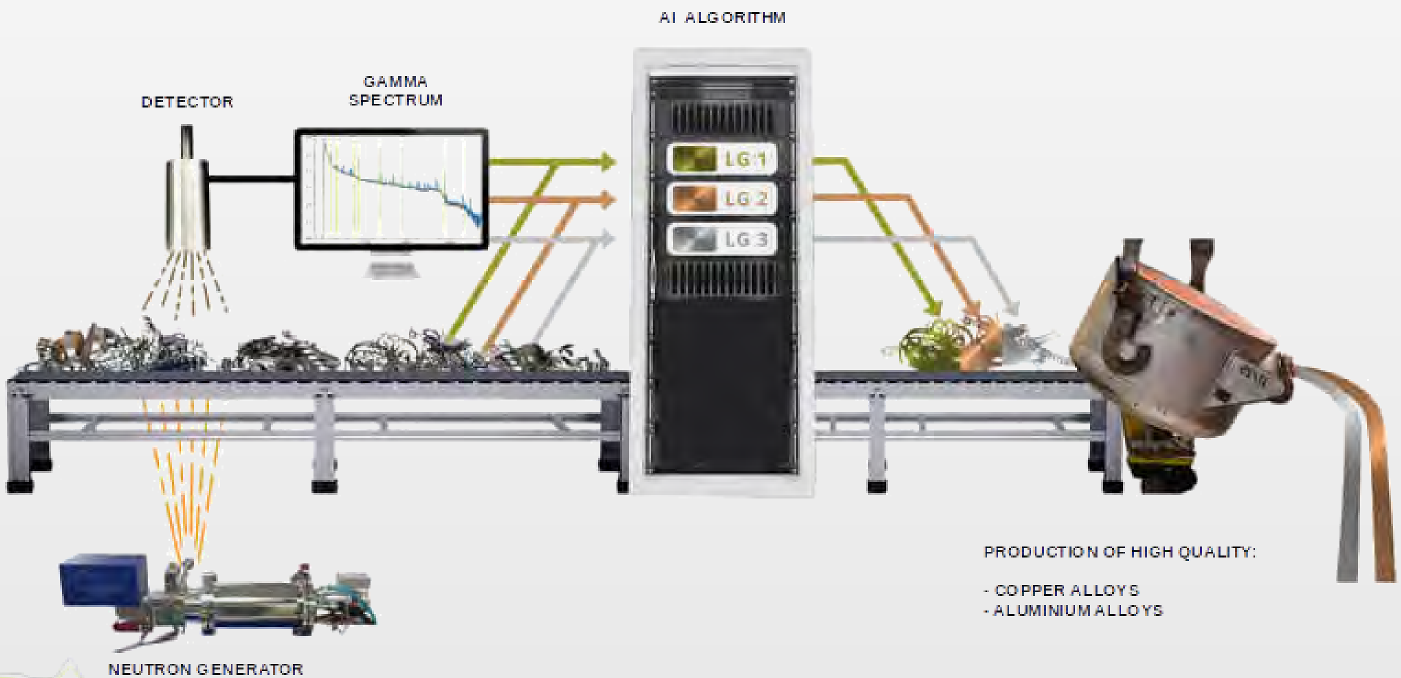
METALCLASS



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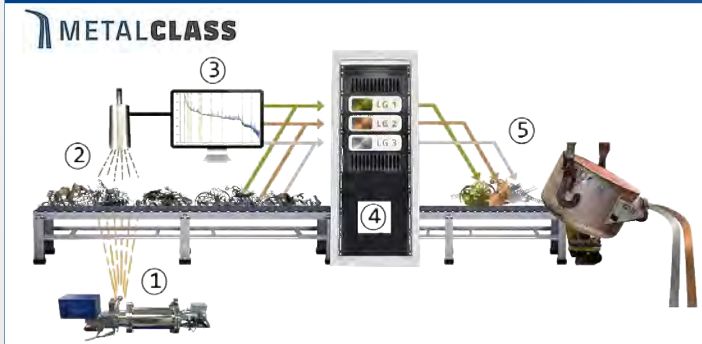
Motivation

- For environmental, sustainable economic and political reasons, recycling processes are becoming increasingly important.
- For the copper and aluminum industries, no method for the non-destructive online analysis of heterogeneous materials are available.
- The Promt Gamma Neutron Activation Analysis (PGNAA) has the potential to overcome this challenge.
- We aim to fill technology gap by presenting the approach of real-time classification of metal alloys by PGNAA as a novelty. This approach has not been used by anyone before.

The idea of overall process (schematically)



① The scrap is irradiated with a beam of neutrons.

② Through nuclear reaction, the material emits prompt gamma rays, which are measured with a gamma ray spectrometer.

③ The data of measured gamma spectra can be saved/visualized and

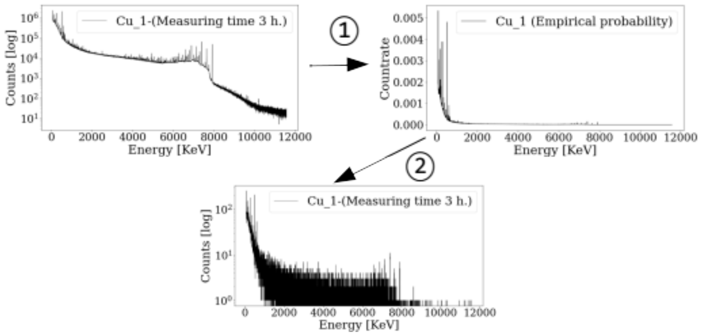
④ classified using an algorithm.

⑤ After classification, the material can be recycled purposefully.

We deal with point ③ (Data generation) and point ④ (Data classification).

Method

Data generation



① From a thoroughly (3 hours) measured copper alloy, obtain the empirical probability.

② Sample short-time measurements (e.g.\ 1 s) from this distribution.

Data classification

- First, for each of completely measured materials' spectra we obtain the distribution using the kernel density estimator.
- To assign an unknown short time measurement to a material, we use the maximum (log-)likelihood method.
- The maximum (log-)likelihood method assigns the short time measurement to the most fitting distribution of a fully measured spectrum:

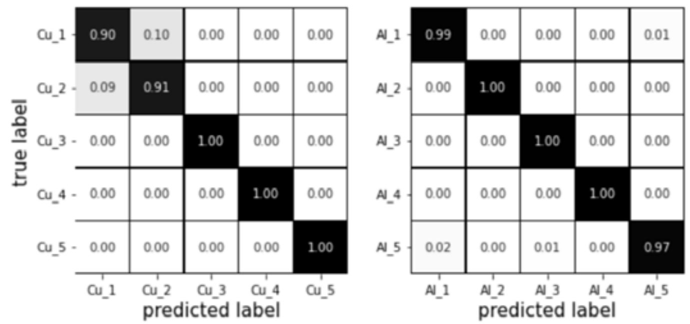
$$\max_i \log(p(s|S_i)),$$

where s stands for the unknown short time measurement and S_i for a completely measured spectra.

- The classification uses the whole information of the spectrum and not only estimated peaks.

Results

- Five different standard aluminum and copper alloy were measured in a demonstrator measurement system.
- The following confusion matrices show the classification results of copper (Cu_1, ..., Cu_5) and aluminum (Al_1, ..., Al_5) alloys with measurement time of 0.5 s. and 0.25 s respectively.



- Different materials (E-scrap, cement, stucco, aluminum, melamine, ASILIKOS, PVC, soil, batteries, ore, copper) can be classified to 100 % by a measurement time of 0.0625 s.
- CNN need about 10 times longer for similar results.

Summary

- The goal of online classification can be achieved for recycling processes using the kernel density estimator and the maximum likelihood method.
- We can classify faster than a CNN and only need a single fully measured spectrum of the material as training data.
- We don't need data preprocessing and additional training data.
- We have introduced a simple and fast method for simulating an unlimited number of different short- and long-term spectra.