TES X-ray pulse identification using CNNs

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Abstract

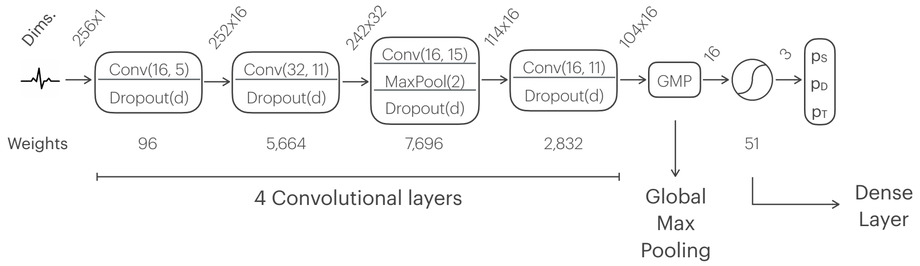
Aims: to detect and to reconstruct the pulses that X-ray photons produce at TES (Transition Edge Sensor) detectors (like the one in the Athena/X-IFU instrument), using Deep Learning techniques. The dataset used contains simulations performed with the Athena official simulator SIXTE.

Methods: We construct and train a Convolution Neural Network (CNN) to differentiate between single, double and triple pulses. We use a hyper-parameter bayesian optimization to select the optimal CNN architecture.

Results: we present the results of our CNN classification over 15,000 simulated pulses achieving excellent performance metrics.

CNN architecture

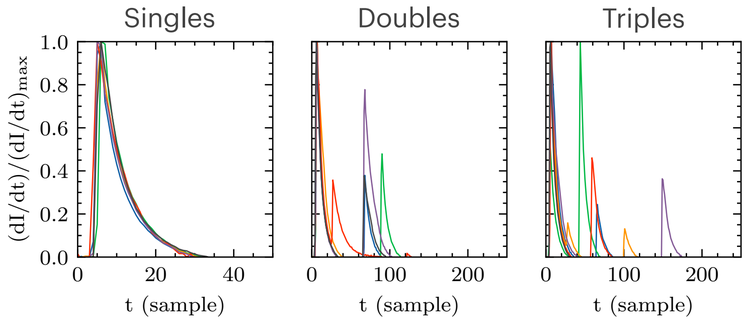
- 3 classes: probability of S, D & T ($p_S + p_D + p_T = 1$)
- Input 256 samples (first derivative norm. to 1)
- 75k training sample + 15k test sample
- Bayesian hyper-parameter optimization (TPE)
- Maximize F1 + minimize FLOPs
- Weights = 16339; FLOPs ~ 6M



SIXTE simulations

(www.sternwarte.uni-erlangen.de/research/sixte/)

- Single, Double & Triple pulses (30k x 3 = 90k)
- Energy range: 0.2 - 12.0 keV (ΔE = 0.1 eV)
- Energy differences: E_{12}, E_{23} ~ U(-11.8, 11.8) keV
- Distance btw. pulses: d_{12}, d_{23} ~ U(1, 100) samples
- Sample rate: 156.25 kHz



Examples of single, double and triple pulses. Vertical axis correspond to the first derivative of the current in the detector normalized by its maximum value. Horizontal axis indicates the time (in sample units)

Results

- Median of 10 CNN models
- **Accuracy = 0.97 and F1 = 0.97**
- FS: D classified as S (**2% of D's**)
- FT: D classified as T (**1% of T's**)
- FD: T classified as D (**5% of T's**)