Classification and Denoising of Radio Signals using Machine Learning

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ICRC 2021
12-23 July, 2021

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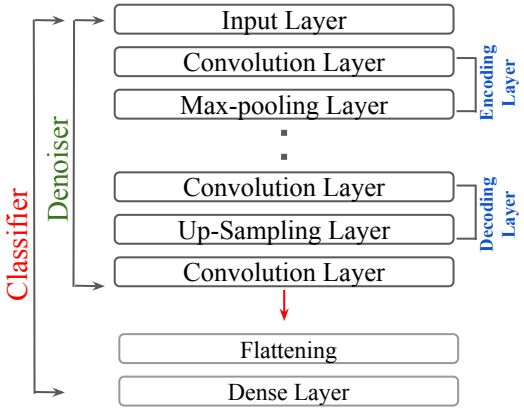
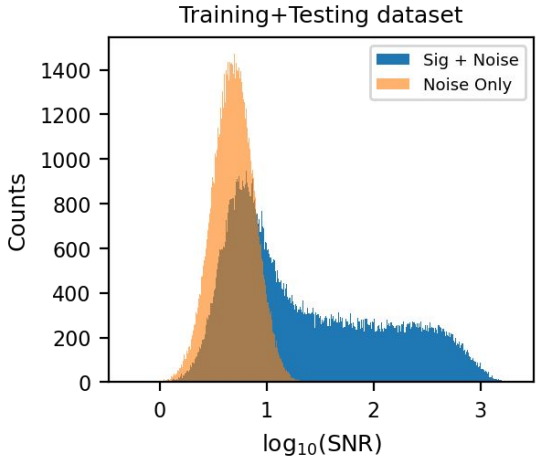
Introduction and Data Set

- **Radio detection of CR air-showers:**
  - Relatively new, Economical, Fully year duty cycle.
  - Has to deal with Continuous, irreducible background.
- **Convolutional Neural Networks →** to mitigate the effect of noise.
  - Classifier : Classify signal traces from noise-only traces.
  - Denoiser : Recover the underlying signals from noisy traces.

- **Dataset:**
  - CoREAS simulation → Radio Signals from air-showers.
  - Cane Model → Galactic, Extra-galactic + Thermal background
  - 103k Signal + 135k noise traces. Filtered band [50-350] MHz.
  - 80% for training, 20% for testing.
- To quantify the signals → $\mathrm{SNR} = \left(\frac{\mathrm{Signal_{Peak}}}{\mathrm{Noise_{RMS}}}\right)^2$



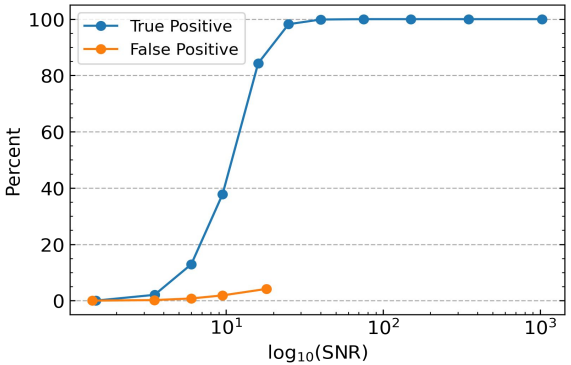
Model Architecture

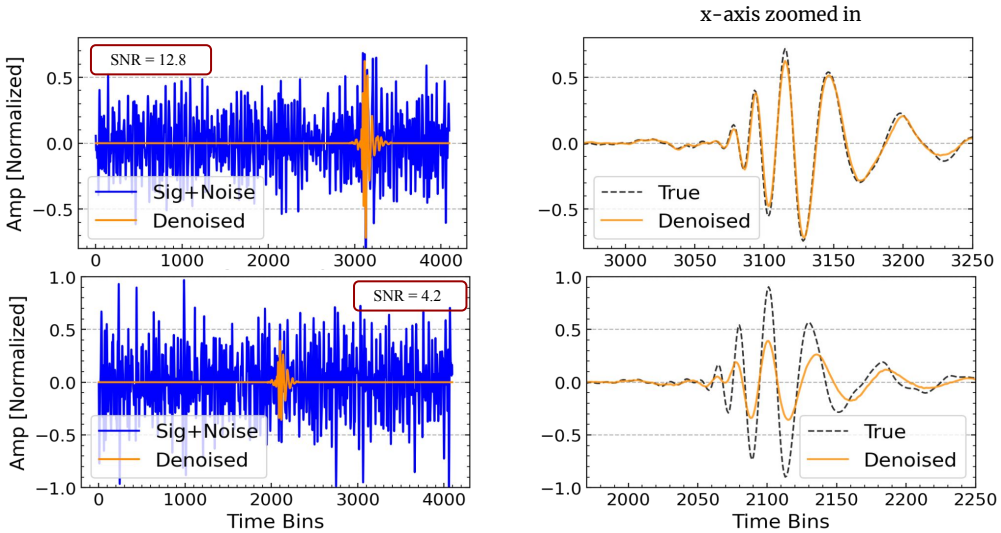


SNR distribution of data set

Results of Classifier and Denoiser

- **Validation set:** 11k signal + 15K background traces.
- Last activation function: **Sigmoid** (output values → [0,1]).
- For signal traces output value should be ≥ **0.6** .
- TP and FP rates (in percent), shown in the right plot.





Examples of the output of Denoiser

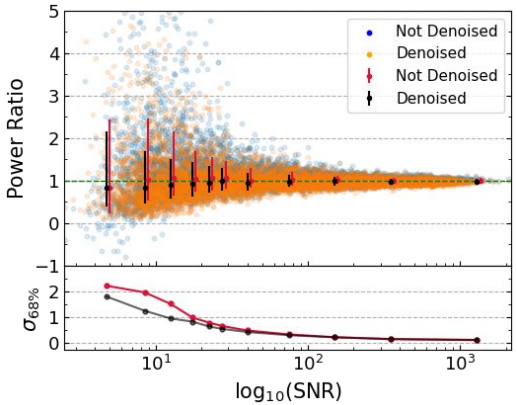
- Classified Signal traces are passed to the Denoiser for cleaning.
- Two examples shown in bottom left.
- 1st row → best case scenario.
- 2nd row → worse case.

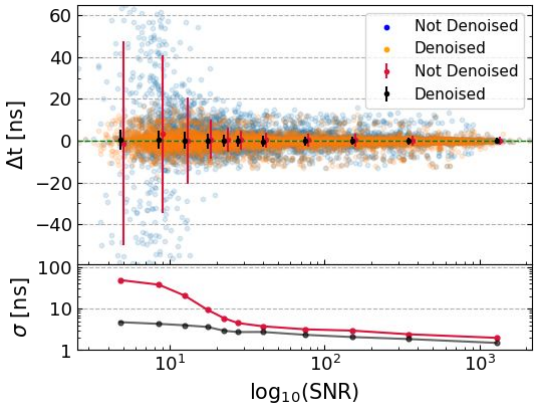
Accuracy Metrics

➢ Left Plot ⟶ Power Ratio $= \dfrac{[P_S - P_N]_{\text{Measured}}}{[P_S - P_N]_{\text{True}}}$.

➢ Right Plot ⟶ $\Delta t = T_{\text{measured}} - T_{\text{true}}$.

P_S , P_N = power in the signal and noise window, respectively.





Summary and Outlook:

- Using CNNs to classify and denoise the radio traces.
- For training, time series information is used. Plan to use freq domain info as well.
- These methods can also be used for real data.