

Detection of low energy neutrinos via machine learning algorithms for Supernova Pointing at DUNE

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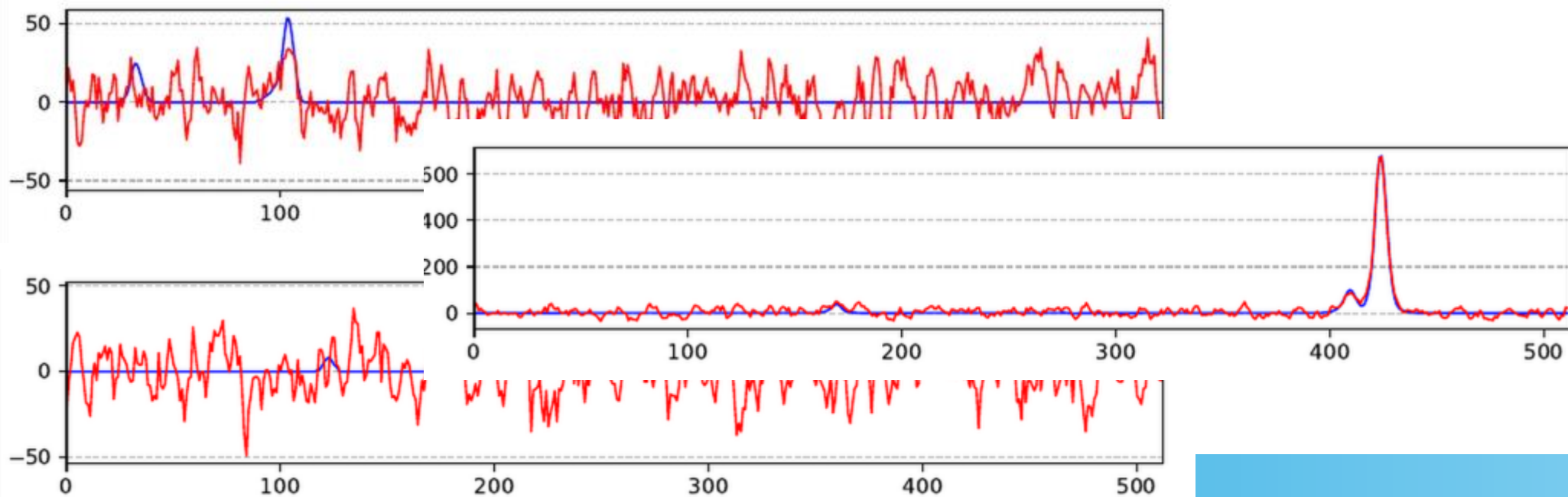
- Supernova pointing at DUNE
- Detecting Low energy neutrinos
- Machine learning implementations
 - Previous: Convolutional Neural Network (CNN)
 - Current: Vector Quantized-Variational Autoencoder (VQ-VAE)
 - Latent Space
- Experimental Implementation
 - FPGA on warm interface board (WIB)

Supernova pointing at DUNE

- Sufficiently large stars experience core collapse supernova
 - These release neutrinos shortly from the center shortly before collapse^{Burrows}
 - These are called core collapse supernovae
- “The determination of the direction of a stellar core collapse via its neutrino emission is crucial for the identification of the progenitor for a multimessenger follow-up”^{Abed}
 - “Historically, the detection of about two dozen neutrinos from SN 1987A inaugurated extragalactic multi-messenger astronomy with the first observation of an astrophysical transient both inside and outside the electromagnetic spectrum.”^{Müller}

Detecting Low energy photons

- Signal processing to reduce noise and eliminate drift field effects, aren't sufficient in all cases to ensure that a detectable signal is exposed <https://larsoft.org/waveform-region/>



Machine learning implementation - 1DCNN

- Was able to discriminate 200-tick waveform snippets into signal containing sections and signal devoid regions ^{Uboldi}
 - This would identify regions of interest via overlapping windows
- This model was able to achieve “AUC=0.97 on the induction plane and AUC=0.99 on the collection plan”^{Uboldi}

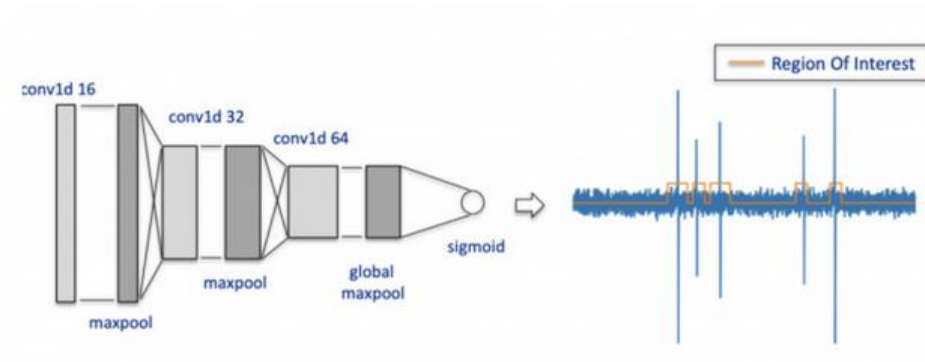
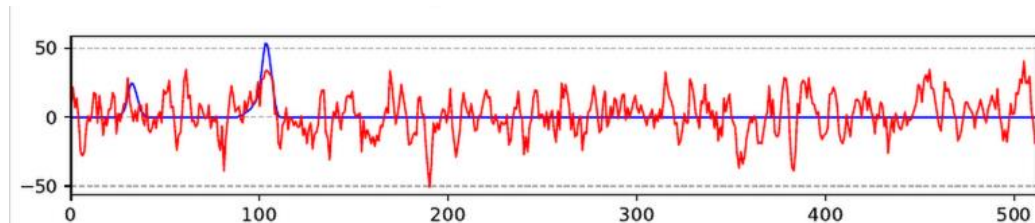
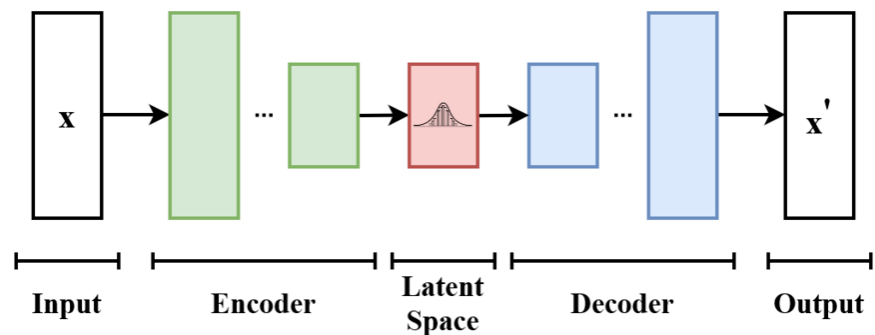


Figure 1: Basic architecture of the 1DCNN (left) used to identify ROIs (in orange) in a raw waveform (right). The spikes in the waveform are simulated signals. See [A machine-learning based raw waveform ROI Finder](#) presentation for more details.

Acciarri

- Machine learning implementation - VQ-VAE

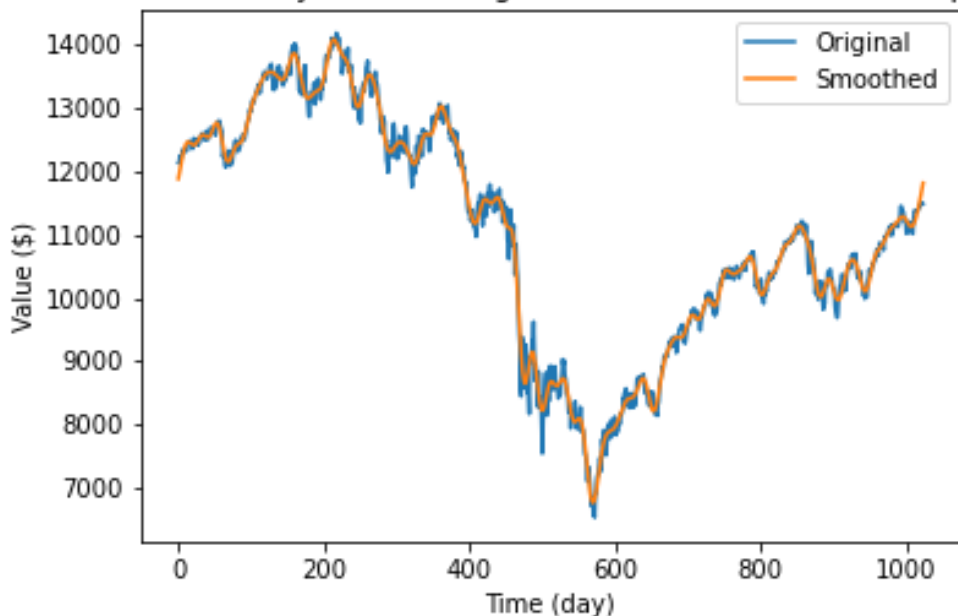
- Normally VAE is an encoder decoder setup like below
- You take the input and encode it in some latent space
- Then you decode that into the target
 - This is common in denoising



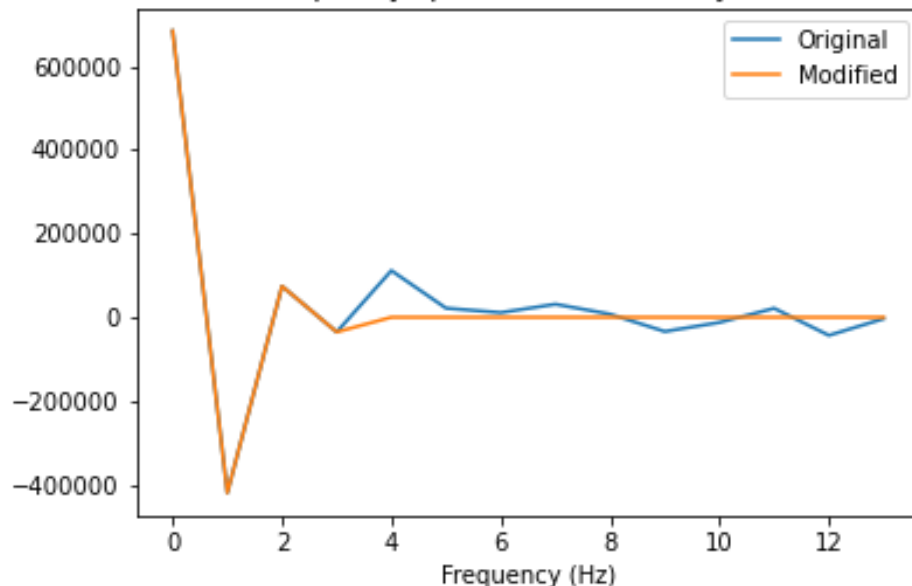
Why Vector Quantized

- The encoder network outputs discrete, rather than continuous, codes
- Also these discrete codes learnt rather than static

Value of Dow Jones, starting in late 2006, With smoothed plot



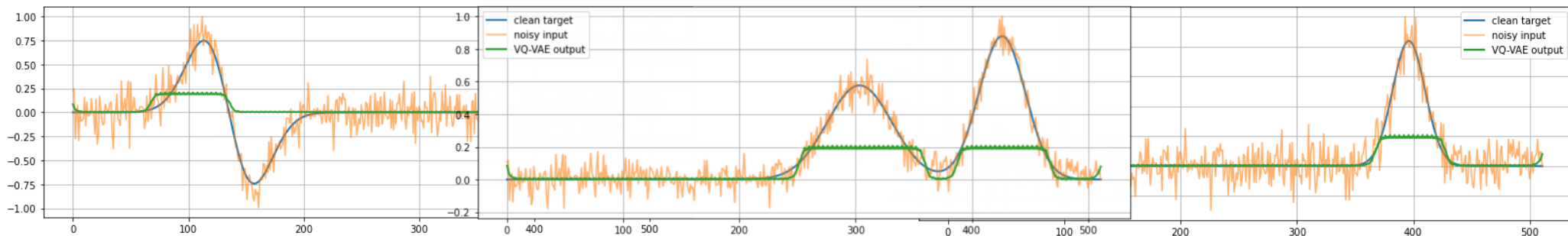
Frequency spectrum of the Dow Jones



With guest the Dow Jones!

Current Status:

- Currently The VQ-VAE is not fully recreating pulses but only up to middling value
- It will correctly indicate multiple pulses down to a Signal to Noise Ratio (SNR) of 5 where the data generation fails
- It also fails at pulses of negative value
 - Appears to be over training



Next Steps

- Moving from a Simple data model of Gaussian pulses with Gaussian noise to real data
- Further fine tuning with better run tracking to identify the best hyper parameters for the data
- Implement a progressive learning schema towards lower SNRs to improve performance

FPGA and WIB

- FPGA
 - Field Programmable Gate Array
 - Programmable circuit board
 - Hard to program but very fast
 - Hls4ml allows for the running of trained models on FPGAs
- Warm interface board
 - The detector needs to be cold
 - The warm interface board interfaces between those electronics and our warm ones

References

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