Identifying Radio Neutrinos interaction with Deep Learning

Luan Orion Baraúna, Sjoerd Bouma

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Current (e.g. ARA, ARIANNA, RNO-G) and future (IceCube-Gen2) radio-based in-ice neutrino observatories aim to detect astrophysical neutrinos at ultra-high energies (UHE) of over 10 PeV. However, accurately identifying neutrino-induced events in time series data can be challenging, especially as a significant fraction of recorded events is expected to have a low signal-to-noise ratio (SNR). In recent years, deep learning (DL) has shown great potential in handling such complex data and achieving high classification accuracy [4]. In this proposal, we aim to explore the use of DL techniques, such as recurrent neural networks and convolutional neural networks, for the classification of radio and neutrino interactions in time series data. Our goal is to develop a robust and accurate classification model that optimized in High Performance Computing that can help astrophysicists better understand the behavior of high-energy particles in the universe. This research has the potential to contribute significantly to the field of astrophysics and advance our understanding of the universe's most energetic phenomena.

In order to reconstruct the direction of these neutrinos, both 'standard' [5] and DL based [3] reconstruction algorithms have been or are currently being developed. While better performance may be expected from the latter, the former may help more in terms of identifying current bottlenecks and thus potential areas of improvement. In particular, in [5], it was found that one of the main limiting factors was the reconstruction of the interaction vertex, with the challenge lying in correctly identifying the position of the neutrino pulse at low SNR. This is currently done using template correlation (see Fig.1). One of the aims of this project would be to investigate to what extent this aspect of the reconstruction could be improved by using a neural-network approach.

Another avenue that might be investigated is the classification of neutrino versus non-neutrino events, where the latter could be either thermal-noise-induced events or pulses induced by other phenomena, e.g. triboelectric [1] or anthropogenic sources. This classification has previously been done using e.g. a Fisher discriminant in [2], but here also improvements may be achieved by using a neural network.

References

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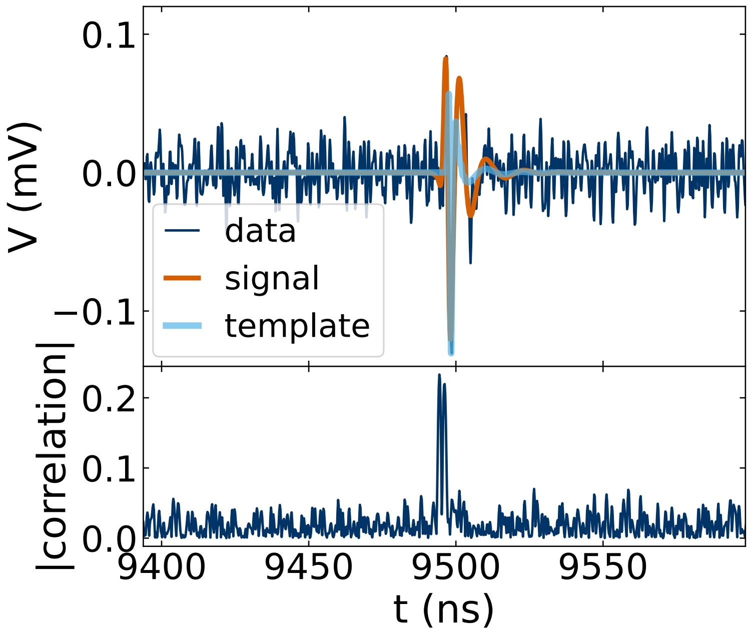

Figure 1: Sketch of current pulse identification using template correlation. While this works well for high-SNR pulses such as the one shown, at low SNR the maximum correlation frequently fails to correctly identify the pulse position.

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