Learning from deep sea light with KM3NeT

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Motivations

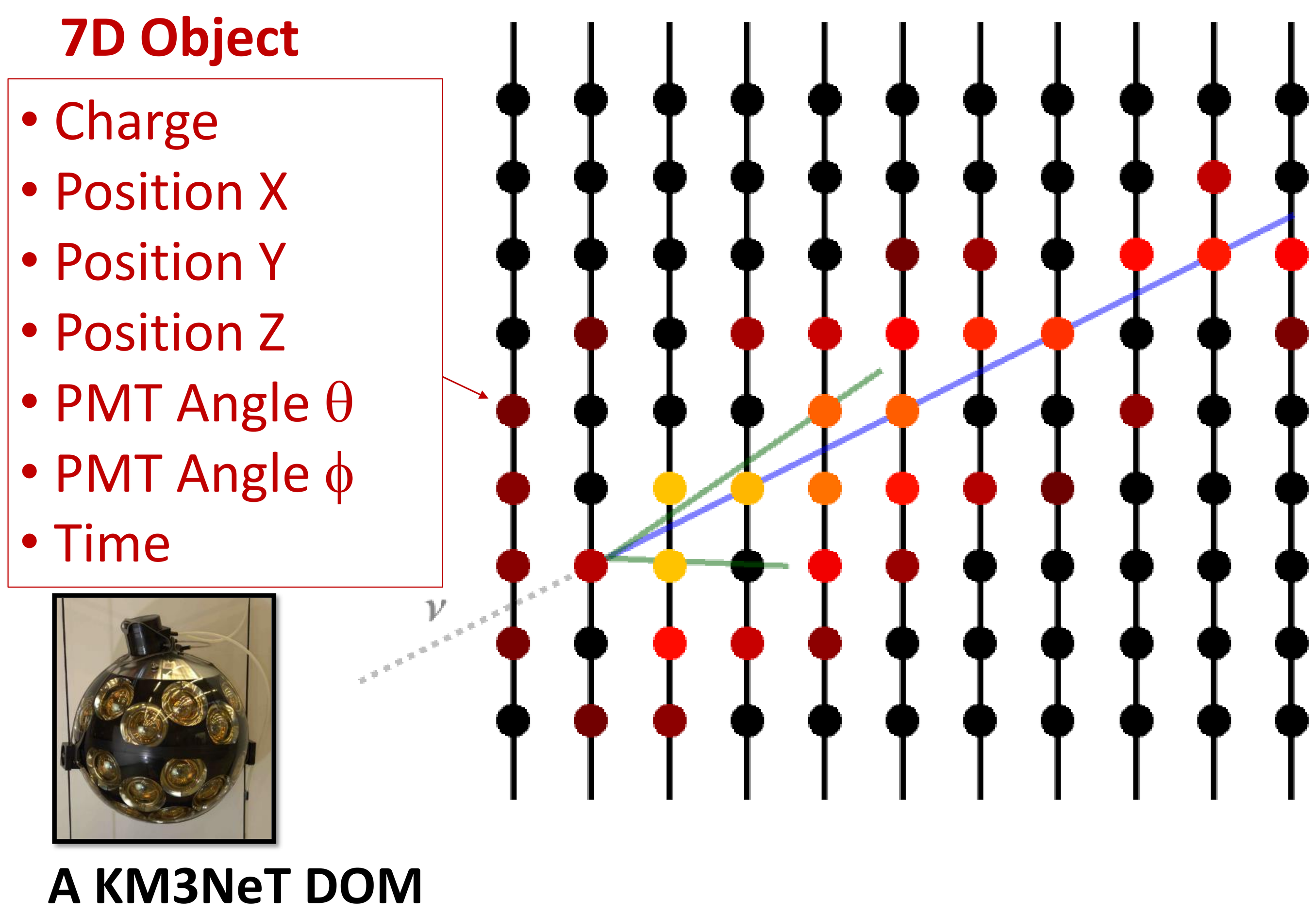
KM3NeT is a next-generation neutrino telescope currently under construction in the Mediterranean Sea [1]. The detectors are aimed at studying neutrino physics and astrophysics, but the construction of these large networks of sensors in the deep sea has also strong interdisciplinary potential for studies of marine life, and geophysics. With this proposal we aim to exploit the potential of data coming out of the KM3NeT detectors including these multidisciplinary efforts.

Proposed solution

This scenario motivates the use of deep neural networks for full event reconstruction in KM3NeT from lower-level features. The hierarchical nature of such networks may be able to tease apart the sub-components of a multi-particle event, and therefore extract additional information that is missed in traditional approaches.

Dataset Description

The KM3NeT data consists of photons hitting the PMTs (hits), forming points in a 7D space describing 3 space coordinates, 2 pointing angles, time and charge.



References

[1] KM3NeT, J. Phys. G 43.8 (2016), 084001
[2] A. Aurisano *et al.*, JINST 11.09 (2016), P09001
[3] KM3NeT, JINST 15.10 (2020), P10005
[4] S. Reck *et al.*, JINST 16.10 (2021), C10011
[5] KM3NeT, Eur. Phys. J. C 81.5 (2021), 445

Problem statement

When neutrinos interact inside or near the KM3NeT detectors, multiple charged particles are created which in turn produce light as they travel through the seawater. By observing the pattern that these light signals leave in the detector, KM3NeT is able to reconstruct basic properties of the neutrino interactions such as energy, momentum, and inelasticity.

Traditional techniques make simplifying assumptions on the interaction structure. The main difficulty lies in designing features in complex topologies containing multiple particles

Related Work

The use of deep learning for neutrino event reconstruction was pioneered by NOvA [2] and has flourished with many applications in the last 5 years. Within KM3NeT, approaches with Convolutional Neural Networks [3] have been pursued and work on Graph Neural Networks (GNN) is ongoing and well advanced [4].

#NEUTRINO
#DEEPLEARNING
#GNN

Results & Prospects

Current results from GNNs in KM3NeT show improved performance in all reconstruction aspects in comparison with traditional techniques. However, little focus has been given to reconstruction of substructures of neutrino events, a task that is practically impossible with traditional techniques. Additionally, current GNNs are trained for individual tasks. A multitask approach may benefit from transferred learning between tasks that exploit similar event structures.

Beyond the archetypical application to high energy neutrinos described here, recent studies have shown the potential for KM3NeT to measure much lower energy events that comprise a single Digital Optical Module (DOM) [5]. The exploitation of these events would significantly expand the scientific reach of KM3NeT. Novel techniques are needed to learn the spatial structure of energy deposits in a single DOM while exploiting the surrounding activity to filter out background noise.

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