New Application of Graph Neural Network in the Cosmic Web

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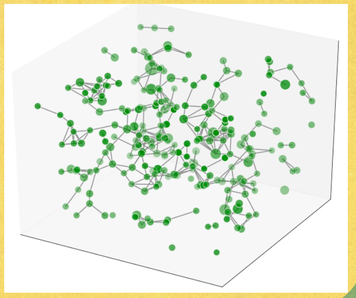
Motivation:

- For Euclid like surveys, many Dark Energy (DE) and Modified Gravity models have to be explored.
- The need of extracting row information of Dark Matter (DM) field to exploit all the encoded features.
- Standard cosmological analyses based on abundances, two-point and higher-order statistics have been widely used up and can only exploit a sub-set of the whole information content available.

Simulation and Data set:

- DM halo catalogue from **Quijote** simulation, 360 realisations for the training, 40 validation and 100 test set from each model. The DE parameter, **w0**, changes in the range of **[-1.05, -1, -0.95]**.
- We have applied mass cut of 7×10^{14} for each catalogue.
- Only **mass and coordinates** of halos are give to the network as features.



Network Architecture:

Graph Neural Network (GNN), using *Spektral* package, in Tensorflow

1 Block of **EdgeGNN** which consists of 1 message passing layer and MLP.

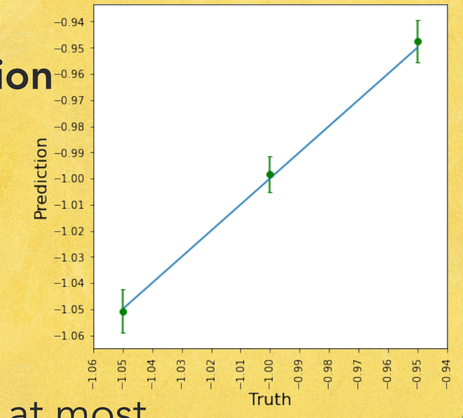
2 Blocks of **GeneralConv** which consists of 1 message passing layer and convolutional layer.

ReLU as the activation function and Adam as optimiser.

Results:

Graph-level analysis is done for the DM catalogue and the built GNN model succeed in all the different tests:

- **99%** of accuracy in the case of **Binary-classification** to distinguish between w0 = -1.05 & w0 = -0.95.
- In the case of **Multi class-classification**, **97%** of accuracy to distinguish between all the three values of w0.
- In the case of **Regression**, the network is able to predict the value w0 correctly with only **2%** error at most.



1. https://quijote-simulations.readthedocs.io
2. https://graphneural.network