Neutrino Reconstruction with Graph Neural Networks

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The Ice Cube Neutrino Experiment





The Data

Index		event_no	pulse_no	dom_x	dom_y	dom_z	dom_charge	dom_time	SplitInIcePulses	SRTInicePulses
4930481	4930481	9046736		210.47		309.72				
4930482	4930482	9046736		35.54	-364.83					
4930483	4930483	9046736		195.03	125.59	399.71				
4930484	4930484	9046736	3	326.85	-209.07	464.38	1.325	9757	1	0

Input Features

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The Labels

Index								
0	9846736	2.28352	-75.2582	79.0119	-315.005	0.307499	0.173169	0.935659

Target Features

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Formal Definition:

A graph is a triple (V, E, f) where V is a set (the vertices of the graph), E is a set (the edges of the graph), and $f: E \to V^{<\omega}$ is a function assigning to each edge its set of vertices, where $V^{<\omega}$ means the set of all tuples (finite sequences) from V.



 With every node we associate a list of Node Features



- With every node we associate a list of Node Features
- For every node we define how it's connected to other nodes (edges)



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- For every node we define how it's connected to other nodes (edges)
- Note: This architecture adds a new layer of complexity!



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First approach:

■ Node → *Dom*



First approach:

- Node → *Dom*
- Node Features → Dom Measurement and xyz-position



First approach:

- Node → *Dom*
- Node Features → Dom Measurement and xyz-position
- \blacksquare Edges \longrightarrow A timeseries connection



But this is problematic!

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- Number of nodes in a graph is not constant
- The fact that some doms does not measure anything during an event, is information on it's own!
- Solution: Add all doms to the graphs, and give only the doms that measure something non-zero charge and time.



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How do we now define the edges?

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How do we now define the edges?

😭 Cornell University

arXiv.org > physics > arXiv:1902.07987

Physics > Data Analysis, Statistics and Probability

[Submitted on 21 Feb 2019 (v1), last revised 24 Jul 2019 (this version, v2)]

Learning representations of irregular particle-detector geometry with distance-weighted graph networks

Shah Rukh Qasim, Jan Kieseler, Yutaro liyama, Maurizio Pierini

How do we now define the edges?

Euclidean distance metric was expensive

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How do we now define the edges?

Euclidean distance metric was expensiveCompromise: A conga-line configuration



Library: torch-geometric

Can accept layers from PyTorch library
Supports CUDA (GPU)

class Net(torch.nn.Module): def __init__(self): super(Net, self).__init__() ## HERE LAYERS OF THE MODEL IS DECLARED def forward(self, data): ## HERE GOES LOGIC FOR PASSING data BETWEEN LAYERS return x

We must specify layers in the model such that:

 $[batch_size \cdot N_nodes, input_features] \longrightarrow [batch_size, target_values]$

Our main models became:









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Limitations and Outlook

- graph-sizes and edges
- Could experiment with Data-Class
- Could try to implement more sophisticated models
- Could try different edge configurations

Appendix



Technical Description of Final Project 'Neutrino Reconstruction using Graph Neural Networks' in Big Data course at NBI 2020

Click here for appendix

All Members Contributed Equally