



UNIVERSITÀ  
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INFORMATION ENGINEERING DEPARTMENT  
MASTER'S DEGREE IN COMPUTER ENGINEERING

**APEROL from Networks:  
Analyzing Pipeline and Embedding Representations  
for Optimized Learning (from Networks)**

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# 1 Datasets

Before proceeding to a discussion of the preprocessing of the datasets, it is necessary to inform readers that changes have been made to the Pennsylvania dataset in the proposal. The dataset from [1] has been used instead. The decision to change the dataset was made to have a directed graph, instead of an undirected one, so to have more uniformity among road networks.

Due to concerns about the large number of edges of the Twitch dataset during the first experiments, it has been replaced with a smaller Deezer dataset from [2].

We also want to provide more information about the two "Mus Musculus" and "Saccharomyces cerevisiae" datasets. Both of them have been downloaded from the STRING Database [3], filtered with the following options:  $> 0.4$  confidence score for Mus Musculus,  $> 0.7$  for Saccharomyces cerevisiae; only AB pairs (undirected).

What follows is the complete updated table (changes highlighted):

Network	$ V $	$ E $	Type
Pennsylvania [4]	1,088,092	3,083,796	Directed
Padua (province) [5]	122,680	304,184	Directed
Hong Kong (city) [6]	43,620	91,542	Directed
Italian Covid-19 Retweet Network [7]	221,574	800,000	Directed
Deezer [2]	143,884	846,915	Undirected
GitHub Developers [8]	37,700	289,003	Undirected
Mus Musculus Protein Interactions [3]	20,969	800,000	Undirected
Saccharomyces cerevisiae Protein Interactions [3]	5,786	100,000	Undirected
Bio-grid-fission-yeast [9]	2,000	25,300	Undirected

Table 1: Datasets used in the project

A preprocessing pipeline is employed where all datasets are converted into CSV files and only useful features are kept, if present. Undirected edges  $(u, v)$  are represented using a pair of directed edges  $(u, v)$  and  $(v, u)$ . Unweighted datasets are represented as having a uniform weight of 1.0 for all edges. Finally, if the node IDs are not numeric, they are mapped to numeric consecutive IDs starting from 0. The Python script that performs this preprocessing step is available in the project's Github repository.

## 2 Experiments

We provide additional details on the train-validation-test split in our pipeline. Consider graph  $G = (V, E)$ , where  $V$  denotes the set of vertices and  $E$  is the set of edges. A first split of the set of edges  $E$  is needed for the embedding algorithms, creating  $E_{\text{embed}}$  and  $E_{\text{class}}$ .  $E_{\text{embed}}$  is used for the subgraph  $G_{\text{embed}} = (V, E_{\text{embed}})$  given as input to the embedding methods: the shallow embedding methods will use it to learn a lookup table  $Z$  of node embeddings, whereas the deep embedding methods aim to learn a function  $f$  that can generalize well. The remaining edges in  $E_{\text{class}}$  are instead reserved for the classification task, where the second split occurs: from  $E_{\text{class}}$  the sets  $E_{\text{train}}$ ,  $E_{\text{val}}$ ,  $E_{\text{test}}$  are created for the training, validation and test of the classification model.

To train and evaluate the classification models, labeled *negative* edges are added to each of the three splits. A negative edge in this setting is defined to be an edge  $(a, b) \notin E$  with  $a, b \in V$ . Furthermore, in order to avoid data leakage, the sampled negative edges must be distinct from those used internally by the embedding algorithms during training.

For each edge  $(u, v)$  belonging to any of these splits of  $E_{\text{class}}$ , its corresponding embedded representation is constructed by combining the embeddings  $z_u$ ,  $z_v$  of its incident nodes, using an operator such as the average, the dot product, or concatenation. These edge embeddings are the

ones used as input to the classification models.

A feasible split for a large graph could be: (from E) 80% for  $E_{\text{embed}}$  and 20% for  $E_{\text{class}}$ ; (from  $E_{\text{class}}$ ) 60% for  $E_{\text{train}}$ , 20% for  $E_{\text{val}}$  and 20% for  $E_{\text{test}}$ .

We revised the implementations that will be adopted for our experiments: [10] for Node2Vec, [11] for LINE, [12] for DVNE, [13] for GraphSage. Depending on our specific needs, some of these could be modified or used as an inspiration for our own implementations. In particular, DVNE was not evaluated on directed graphs in the original work [14], meaning it may be necessary to explore adaptations for this setting. If no satisfactory solution is found, DVNE will be restricted only for undirected graphs to maintain a fair comparison.

Following some initial experiments, we decided to use the DEI cluster "Blade" as hardware for the computation of the larger graphs. The specifications for the nodes of the cluster are available in the open documentation [15]. More information about the project's memory usage and runtime will be available in the final report.

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## Contribution of Authors and AI Usage

The contributions for this project are:

- Datasets preprocessing: Silvia Mondin (implementation, writing);

The following AI tools were used:

- Copilot was used to suggest code and report snippets.
- DeepL was used to correct the grammar and syntax of the text.