Dynamic Network Classification

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What are Dynamic Networks?

- A system where some **entities share relationships** with each other can be represented as a network
- Network analysis offers useful insights about a system
- Relationships between entities of a dynamic system are **constantly evolving**

Motivation

- The long-term goal of this research is to build a method **to infer the relationships** between entities of a dynamic system, given time-series attribute data of the entities
- The network inferred from said method would need to be **classified** into one of **potential network models** to draw additional insights about the system
- Static network analysis is simpler, and such networks are widely studied, dynamic networks are under-explored

Embedding

- Need to **represent networks in a machine-readable format**
  - Adjacency matrices are one such representation, but they are sparse and become unwieldy for larger networks. They are also not permutation invariant.
- Two widely known whole-graph embedding techniques, **Graph2Vec** (G2V) and **Diffusion Wavelet-based Node Feature Distribution Characterization** (DWB) are leveraged in this study

For dynamic networks, the temporal component needs to be incorporated adequately in the representation as well.

Time Series Representation

One way of representing a dynamic network would be as a time series of its embeddings, obtained by **stitching the embeddings of the individual snapshot networks chronologically**. We would then use sequential models such as LSTMs for the classification task.

Single Point Representation

We can also attempt to **aggregate** the embeddings to a single point in space instead of a time series of points.

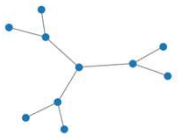
This is obtained by calculating the **weighted average** of the embeddings, with the weights being the difference between current and the previous graph.

Datasets

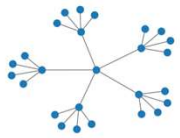
- **Real world**
  - University Email Networks
  - Bitcoin Trust Networks
  - Reddit Networks (originally static)
  - Animal Networks
- **Simulated**
  - Wattz-Strogatz Networks: Growing, Shrinking and Random
  - Stars with Change point
  - Stars and Chains

Experiments

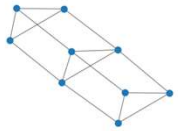
- Each dynamic network is collapsed into a single static network by taking a union of the edges
- Reddit networks: Decompose each static network into dynamic growing/shrinking networks
- Compare classification performances of G2V and DWB embeddings represented as time series and single point for each set of networks



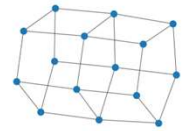
(a) A star graph of degree 3 and level 3



(b) A star graph of degree 5 and level 3



(c) A chain graph of degree 3 and level 3



(d) A chain graph of degree 5 and level 3

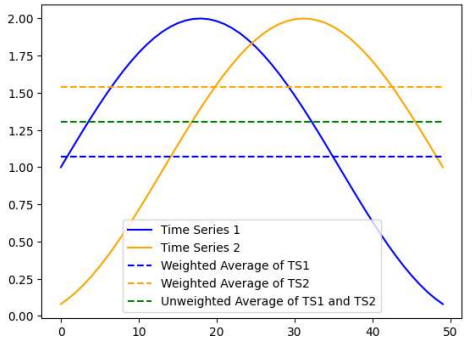


Illustration of why a simple average would not work: the blue and yellow curves are the time series representations of two hypothetical graphs, which happen to be the mirror image of each other. An unweighted average would give us the exact same result for these two graphs

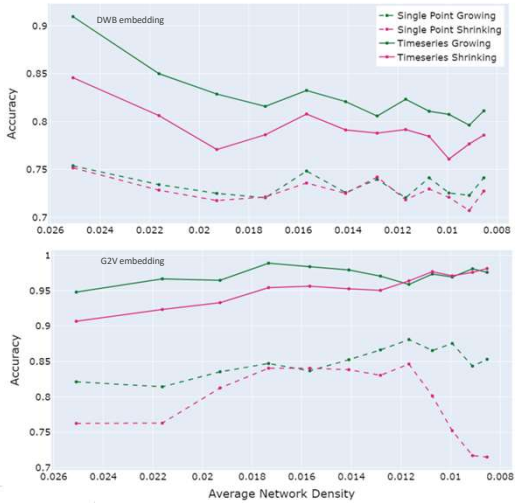


Table 1: Accuracy of Classification on Dynamic Networks

Dataset	Time Series (Dynamic)		Single Point (Dynamic)		Static	
	DWB	Graph2Vec	DWB	Graph2Vec	DWB	Graph2Vec
Email	0.61	0.75	0.61	**0.76**	0.48	0.35
Bitcoin	0.72	0.8	0.74	**0.81**	0.52	0.59
Reddit 4 class	0.79	**0.91**	0.61	0.69	0.79	**1**
Reddit growing 2 class	0.81	**0.96**	0.73	0.87	0.79	**1**
Ants/Birds/Baboons	**1**	0.87	0.98	0.76	**1**	0.85
W-S Growing/Shrinking*	**1**	**1**	**1**	0.79	0.42	0.49
W-S Growing/Shrinking/Random*	**0.85**	0.81	0.67	0.52	0.3	0.39
Stars with Change point	**1**	0.93	0.83	0.95	**1**	0.97
Stars and chains*	**1**	0.89	0.99	0.68	**1**	0.66

Rows marked with (*) denote logistic regression was used as a classifier on these datasets instead of deep neural network

Future Work

- Use embeddings from Graph Neural Network (like GCN) and compare performances
- Examine the effect of 'kind' of networks on the embeddings and study the reason behind variation in embedding obtained from different methods
- Infer networks from time series data

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