Proposal for Mathematical structure and complex system
Mathematical modeling and Hierarchical Hyper-graphs
in social system for recommendation applications.

1.   Abstract / Introduction

In social system, like social media Apps or e-commerce website, existing many data can reflect meaningful states and trends which can be mined or constructed as mathematical network. And then we can treat these constructed mathematical network model as hierarchical hyper-graphs. And most of these graph network are evolving and dynamic, some of them even have stochastic properties. Therefore we can use both graph theory and data mining techniques to analyze these hyper-graphs to get meaningful results which can be applied for recommendation in the field of social media or e-commerce field.

2.   Existing literature/significant prior research.

· 《Graph embedding techniques, applications, and performance》
  In this paper, authors demonstrated several quite import embedding techniques based on graph, which can be applied to our project.

· 《Learning Tree-based Deep Model for Recommender Systems》
  In this paper, authors used the data from e-commerce field and them constructed them into the hierarchical graph (might be bipartite tree). After that we can get the node embedding and items embedding based on the achieved hierarchical tree. Finally just using these embeddings as inputs of neural network and we can get the final model for recommendation system.
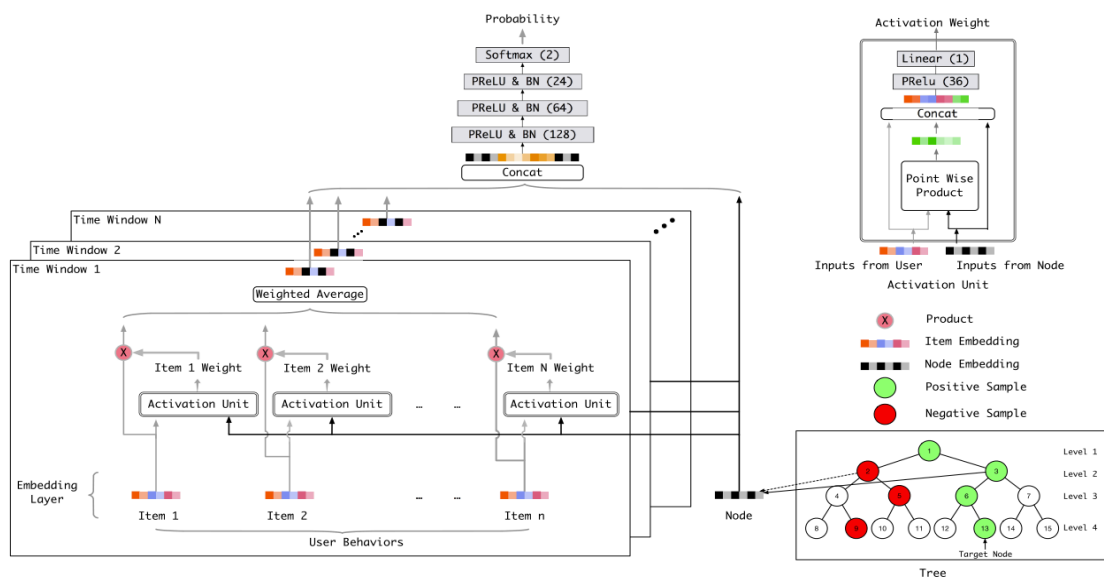

Figure 2: The tree-based deep model architecture. User behaviors are divided into different time windows according to the timestamp. In each time window, item embeddings are weighted averaged, and the weights come from activation units. Each time window's output along with the candidate node's embedding are concatenated as the neural network input. After three fully connected layers with PReLU [33] activation and batch normalization [14], a binary softmax is used to yield the probability whether the user is interested in the candidate node. Each item and its corresponding leaf node share the same embedding. All embeddings are randomly initialized.

- 《Graph-based Recommendation Systems/ Comparison Analysis between Traditional Clustering Techniques and Neural Embedding.》
This paper introduce several embedding methods based on graph traversal techniques on bipartite graph. And made comparison between traditional clustering methods and neural network method, which we can analyze which method is more suitable for us.

3. Project details / steps

· **Step1.**

Graph / Network construction.

At first, for the mathematical modeling for social system, we should use the traditional graph theory to build the corresponding social network based on social media or e-commerce data.

· **Step2.**

Basic graph theory analysis.

Then, we should apply some graph theory method on achieved network. To explore various properties of it, such as degree distribution, directions, growths, etc.

· **Step3**.

Cluster & Graph algorithms.

After that, we can apply some clustering techniques to explore more meaningful properties of the network, to see whether the network is evolved or whether it has some preferential attachments, small world hubs, communities. And then we can get the clusters of network which can do further analysis regarding to the network. Also we can apply some graph algorithms, like Dijkstra algorithm, random walk, etc. to get more property of the network.

· **Step4**.

Data embedding based on achieved tree / graph (network) properties.

Since we get the clusters properties of this social system network, then we can construct a meaningful hierarchical hyper-graph which has some hierarchical properties. For instance, each hierarchies has different elements with different properties, also importance. Then we can use the hierarchical graph property to embedding the data, which already has been explored in some prior research paper, we can cite and go further.

· **Step5**.

Deploy the recommendation or forecasting methods based on the embedded data.

Finally after we get the embedding vector based on the hierarchical graph, we can deploy some neural network algorithms for recommendation or social system trend forecasting.

4.   Proposed Approaches

- Graph theory method and analysis, such as degree distribution, growth, preferential attachment, small world, hub, community, etc.

- Graph algorithms, such as dijkstra algorithm, BFS & DFS, random walk, etc.

- Clustering algorithms, especially hierarchical clustering.

- Data embedding based on the hierarchical graph or network.

- Recommendation or social network trend forecasting based on machine learning or neural network approaches.

5.   Potential outcomes

- From Step1. Mathematical model (complex network) based on used social media or e-commerce data.

- From Step2. Network properties of constructed hyper-graph.

- From Step3. Clusters or hubs in used social system or corresponding network.

- From Step4 & 5. Predicted recommendation result or social network predicted trend.

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