

Universität Stuttgart

User Behaviour Prediction Using Graph Neural Network

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Temporal Networks:

- Found in domains like **e-commerce**, **social networks**, **finance**, and **education**.
- Nodes represent **entities** (users, items), and edges represent **interactions** (clicks, purchases, messages).

How Is Behaviour Predicted ?

User behavior prediction can encompass a wide range of tasks, such as:

- Node-Level Prediction :

Predicting attributes or states of users (e.g., whether a user will churn, their preferences, or engagement levels).

- Edge-Level Prediction :

Predicting interactions between users and items (e.g., whether a user will interact with an item, click on content, or purchase a product). This is typically framed as a link prediction problem.

- Temporal Behavior Prediction :

Predicting how user behavior evolves over time (e.g., next interaction, future state transitions). This often involves sequential models like RNNs, Temporal Graph Networks (TGNs), or attention-based models.

Overview

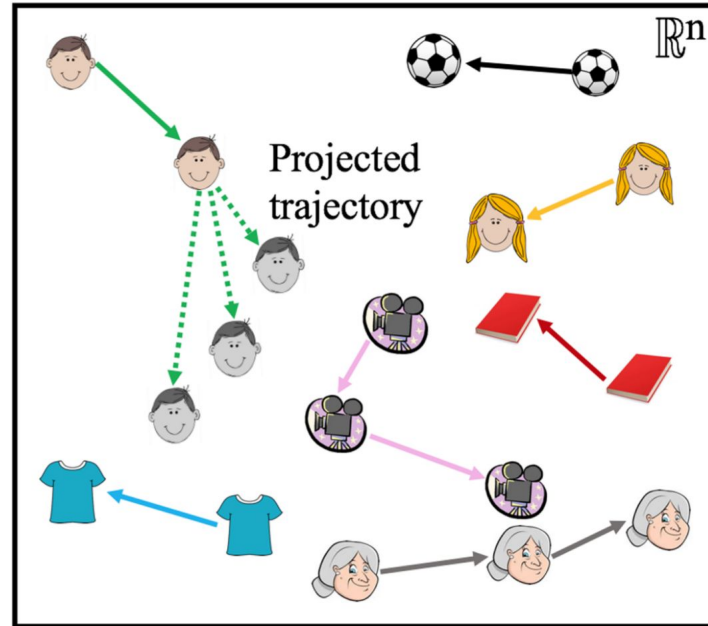
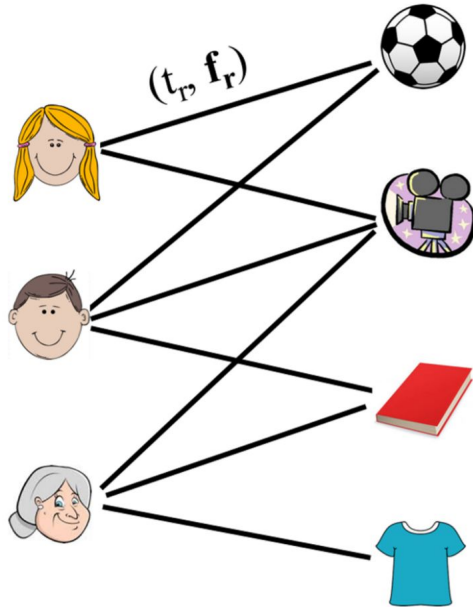
JODIE Overview:

- **Dynamic Embedding:** Learns time-evolving trajectories for nodes instead of static embeddings.
- **Key Benefits:**
 - Fast and accurate predictions.
 - Supports tasks like link prediction, node classification, and anomaly detection.

Applications:

1. Temporal Link Prediction: Which two nodes will interact next? Example applications are recommender systems and modeling network evolution.
2. Temporal Node Classification: When does the state of a node change from normal to abnormal? Example applications are anomaly detection, ban prediction, dropout and churn prediction, and fraud and account compromise.

Overview



Datasets

Structure:

- Each file <network>.csv represents a temporal network.
- Each line corresponds to one interaction (edge) between a user and an item.

Datasets Used:

- Reddit
- Wikipedia
- LastFM
- MOOC

Table with dataset information.

Data	Users	Items	Interactions	State Changes	Action Repetition
Reddit	10,000	984	672,447	366	79%
Wikipedia	8,227	1,000	157,474	217	61%
LastFM	980	1,000	1,293,103	-	8.6%
MOOC	7,047	97	411,749	4,066	-

Limitations Of JODIE

- RNNs struggle with complex dependencies and long-term patterns.
- Jodie's dynamic embedding approach is limited by sequential modeling constraints.
- Need for a more expressive model to capture temporal dependencies.

JODIE vs GNN

Feature	JODIE(RNN)	GNN
Model Type	Recurrent Neural Network	Graph Neural Network
Data Representation	Sequence of user-item pairs	Graph structure of interactions
Handling of Time	Uses timestamps directly	Uses temporal attention
Long-Term Dependencies	Struggles with long-term dependencies	Captures dependencies via graph connectivity
Scalability	Slow for larger datasets	More efficient graph processing
Prediction Capability	Limited by sequence modeling	Models complex interactions effectively

Solution

Enhance user behavior prediction by transitioning from traditional Recurrent Neural Networks (RNNs) to advanced Graph Neural Networks (GNNs)

Why ?

GNNs generalize neural networks to graph-structured data.

Key advantage: Ability to model complex interactions between nodes.

Types of GNNs considered for replacement:

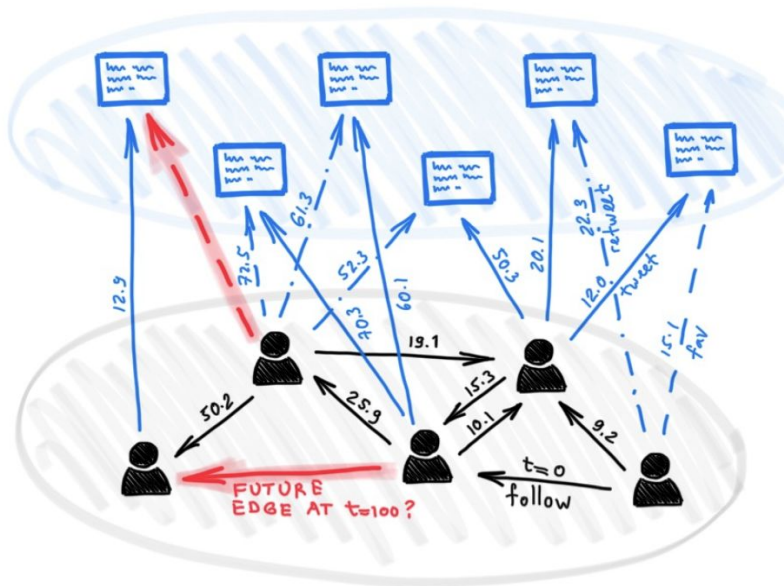
GCN vs. GAT vs. TGAT

Feature	GCN	GAT	TGN
Graph Type	Static Graphs	Static Graphs	Temporal Graph
Node Attention	No attention mechanism	Uses attention per edge	Uses temporal attention
Temporal Awareness	None	None	Explicit time modeling
Computation	Faster, but less expressive	More expressive, but slower	Computationally complex
Use Case	General Graph Learning	Adaptive Edge Weights	Time-Aware Predictions

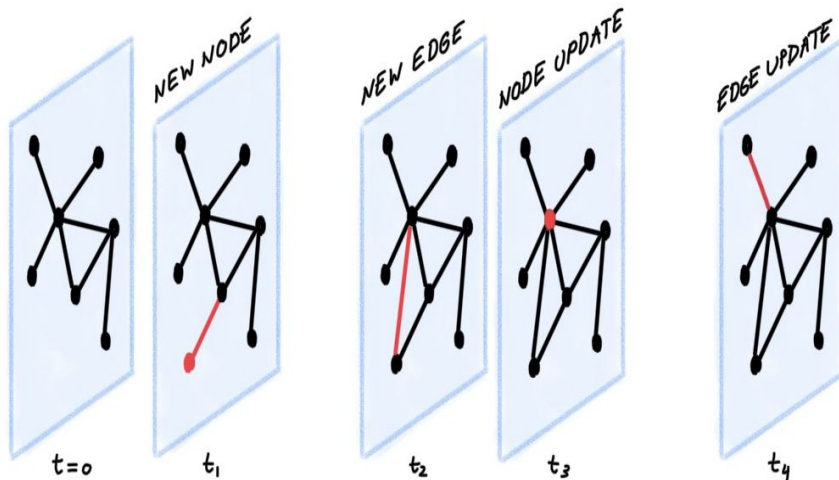
TGN is a framework tailored for deep learning on dynamic graphs, effectively modeling the temporal aspects of interactions to enhance predictive accuracy.

TGN effectively model the temporal dynamics of complex systems, enabling accurate predictions in applications like social network analysis and recommendation systems.

TGN



How TGN works on Twitter Dataset to Predict future user-interactions



Node and edge creation
in a Graph Neural
Network

Core Components

- Memory Module:

Maintains a dynamic state for each node, encapsulating its historical interactions over time.

- Message Function:

Generates messages based on interactions between nodes, which are then utilized to update the nodes' memory states.

- Memory Updater:

Incorporates incoming messages to refresh the memory states of nodes.

- Embedding Module:

Generates time-dependent embeddings for nodes, applicable to various predictive tasks.

Implementation Plan

Reproduce Jodie's results as a baseline.

Modify preprocessing to accommodate GNN-based approaches.

Replace RNN with GCN, GAT, and TGAT for improved user behavior prediction.

Compare performance metrics (AUC in our case).

Expected Benefits of GNNs over Jodie

Better Temporal Awareness: TGN models evolving interactions over time.

Improved Prediction Accuracy: GNNs learn richer representations of user interactions.

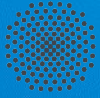
Scalability: More efficient training compared to sequence-based models.

Evaluation Metrics ROC AUC %

Model	Wikipedia	Reddit
JODIE	94.62	97.11
TGAT	95.34	98.12
TGN	98.56	97.70

Feedback and Questions

Do you have and valuable feedback to give us ?



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Vielen Dank!

**Muhammad Rizwan
Parth Patwardhan**