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Anomaly Detection in Complex Networks

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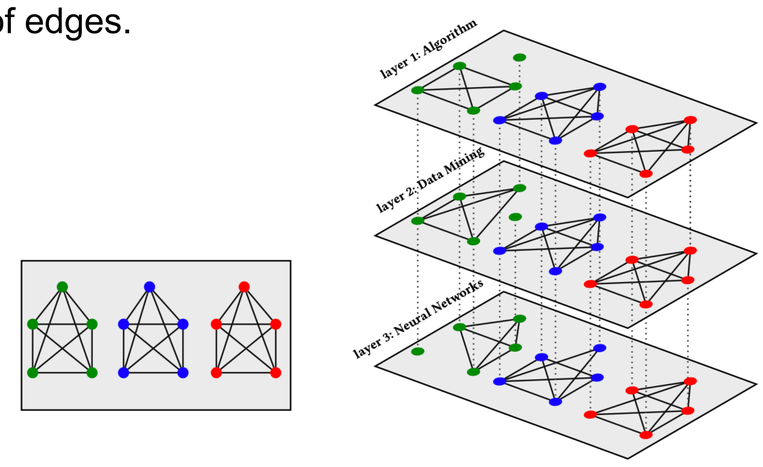
Problem

How do you detect anomalies in graphs with different types of edges?

Multiplex Networks:
Multiplex networks are graphs with different types of edges.



(a) Single-layer perspective (b) Multiplex perspective

Applications

Abnormal activity detection in the human brain:
- A fundamental task in neuroscience.
- Detecting brain disease or disorders.

- **Brain Networks:**
  Nodes: regions of interest (ROIs),
  Edges: high functional correlations between ROIs.

Fraud Detection in Multiple Blockchains:
- Cryptocurrency criminals make cross-cryptocurrency trades to hide their identity.
- Detecting suspicious transactions and identifying criminal activities across several blockchain transaction networks.

Challenges

1. Anomalies are **complex** and do **not** follow a **single pattern**.
2. **Interactions** between objects are complex and of **different types**.
3. The **importance** of each relation-type can varies among objects.
4. Object characteristics **change** over time.
5. **Lack** of high-quality **labeled data** for training.

ANOMULY is **the first edge anomaly detection** framework for **multiplex dynamic networks.**

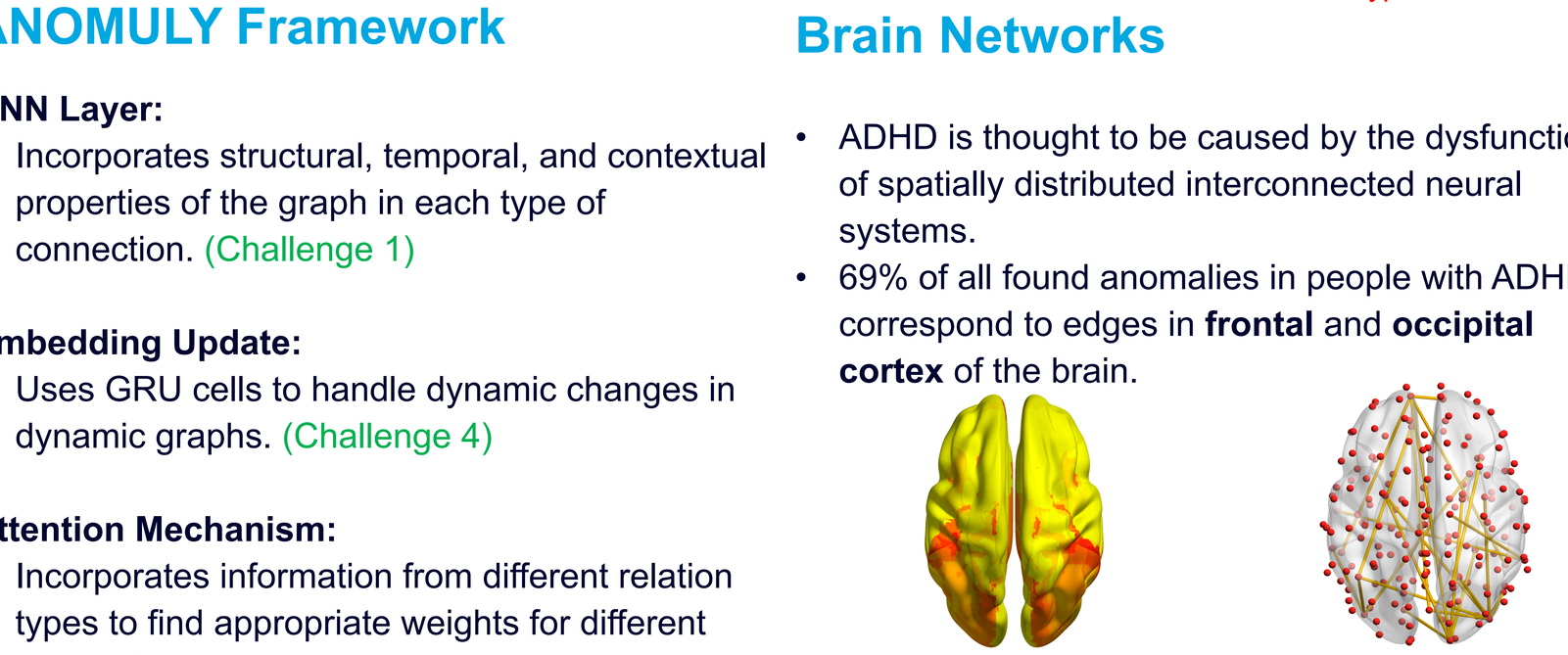


Figure 1. Framework and design of ANOMULY model

ANOMULY Framework

GNN Layer:
- Incorporates structural, temporal, and contextual properties of the graph in each type of connection. (Challenge 1)

Embedding Update:
- Uses GRU cells to handle dynamic changes in dynamic graphs. (Challenge 4)

Attention Mechanism:
- Incorporates information from different relation types to find appropriate weights for different types of connections. (Challenge 3)

Negative Sampling:
- Uses negative samples to train the model in an unsupervised manner. (Challenge 5)

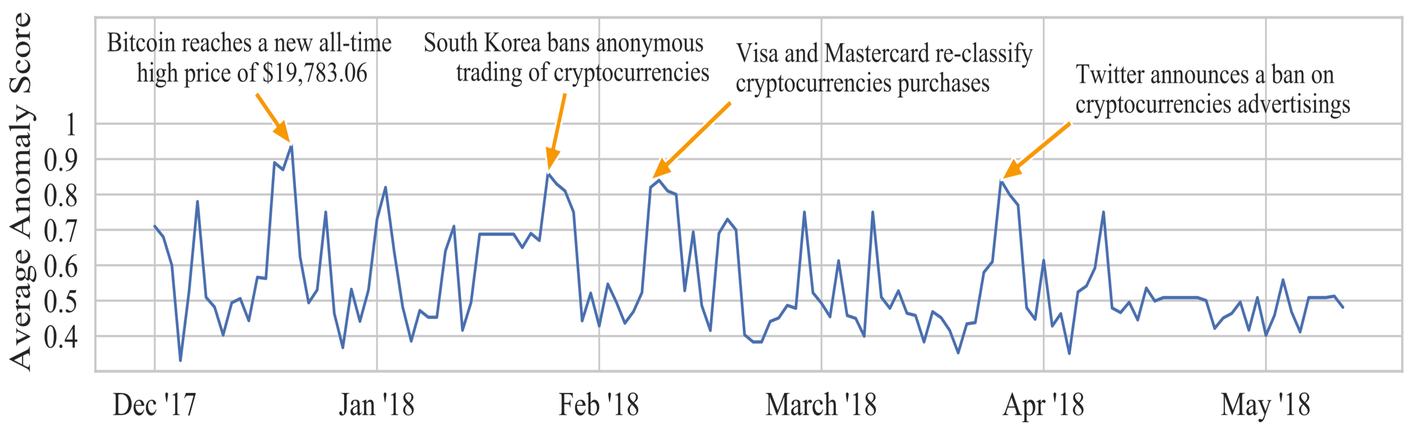
Detection Rate

Datasets: 9 datasets from social, co-authorship, blockchain, and co-purchasing networks domains.

- **Single-layer Networks:** ANOMULY outperforms single-layer methods by **5.94% to 9.98%**.
- **Multiplex Networks:** ANOMULY outperforms multiplex methods by **8% to 17.36%**.

Event Detection

- The top-4 local maximums all coincide with **major events** annotated in the figure.



Paper

Brain Networks

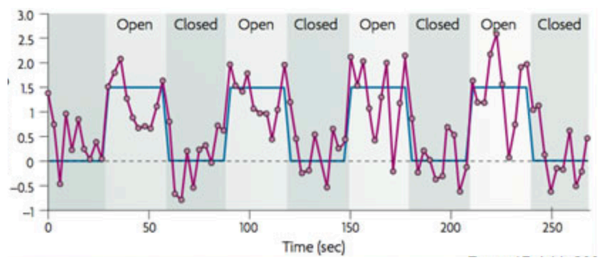
- ADHD is thought to be caused by the dysfunction of spatially distributed interconnected neural systems.
- 69% of all found anomalies in people with ADHD correspond to edges in **frontal** and **occipital cortex** of the brain.

(a) Distribution of anomalous edges

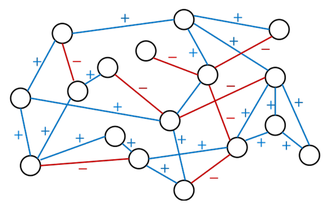
(b) Anomalous edges

Future Work

- **Task-based fMRI:** resting fMRIs cannot fully take advantage of temporal properties.
  In Task-based fMRI, each activity can be viewed as a snapshot of a temporal network.



- **Signed Network Anomaly Detection:**
  Relationships between two nodes can be positive or negative.
  E.g., blockchain, social media, and brain networks.



- **Hypergraphs Anomaly Detection:** Hyperedges can connect more than two nodes, capturing more complex relationships.
  E.g., Authors of a paper, users buying the same products, higher-order correlations in the brain.