Graph Neural Network-based Fraud Detection -- from Research to Application

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Graph Neural Network-based Fraud Detection
from Research to Application

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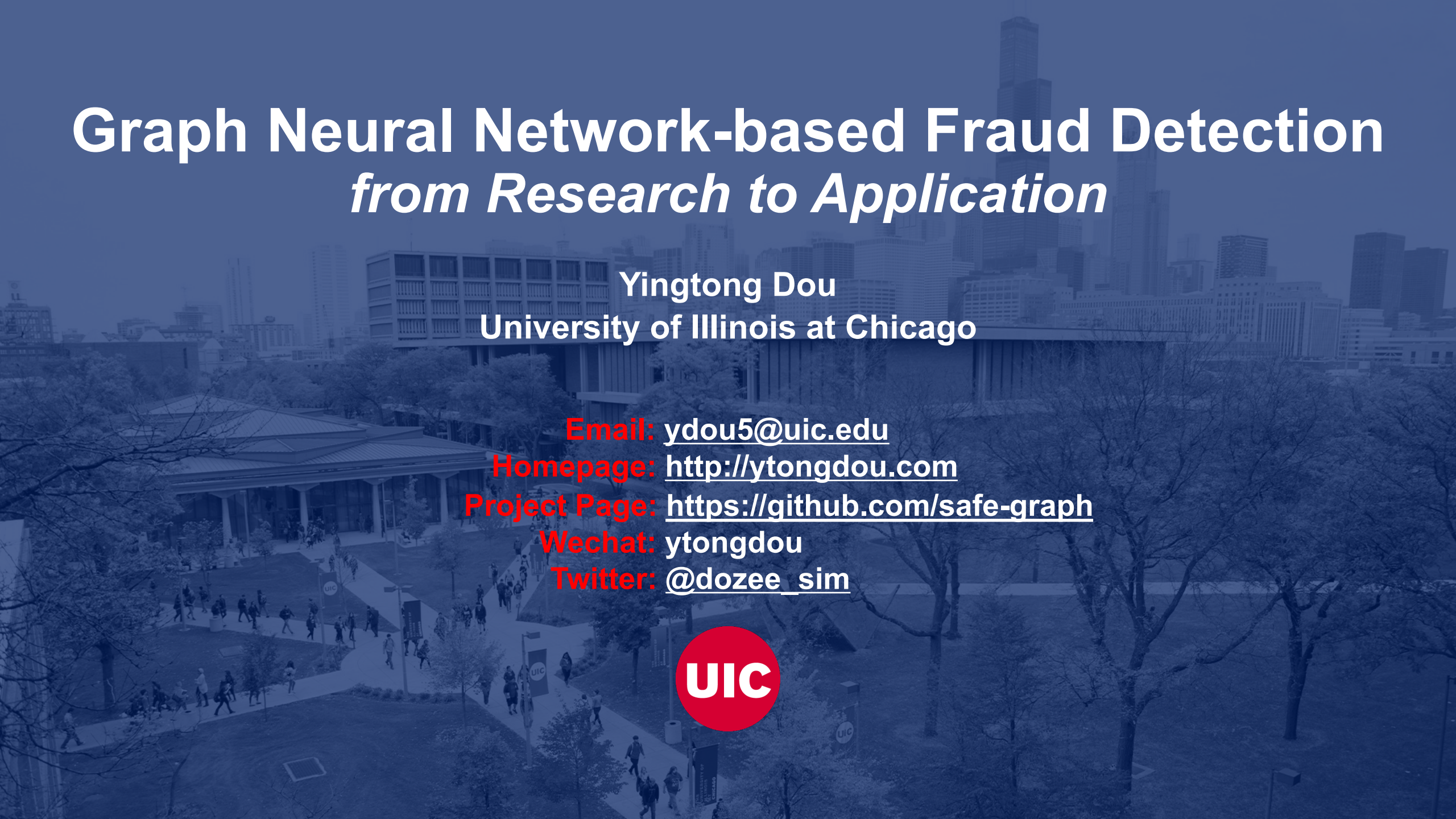

Outline

- **Background:** Graph Neural Network & Fraud Detection.
- **Research:** A History (w/ Highlights) of GNN-based Fraud Detection Research.
- **Application:** The Guideline for Applying GNNs to Fraud Detection.
- **Resources:** Dataset, Toolbox, Paper List, etc..
- **Q&A**

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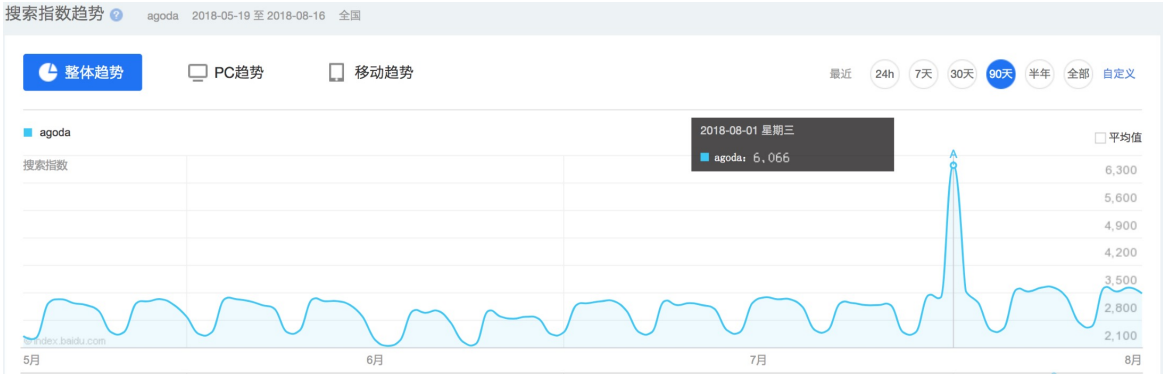
What is Fraud?

- **Fraud definition according to U.S. Law:**
  - a misrepresentation of a fact, made from one person to another, with knowledge of its falsity and for the purpose of inducing the other to act.

- **Fraudster vs. Hacker**
  - Most fraudsters are NOT hackers.
  - Only few hackers are fraudsters.

- **Fraud vs. Anomaly**
  - Not all frauds are anomalies.
  - Not all anomalies are frauds.



Fraud Types in 2021

Social Network

- Fake Reviews
- Social Bots
- Misinformation
- Disinformation
- Fake Accounts
- Social Sybils
- Link Advertising

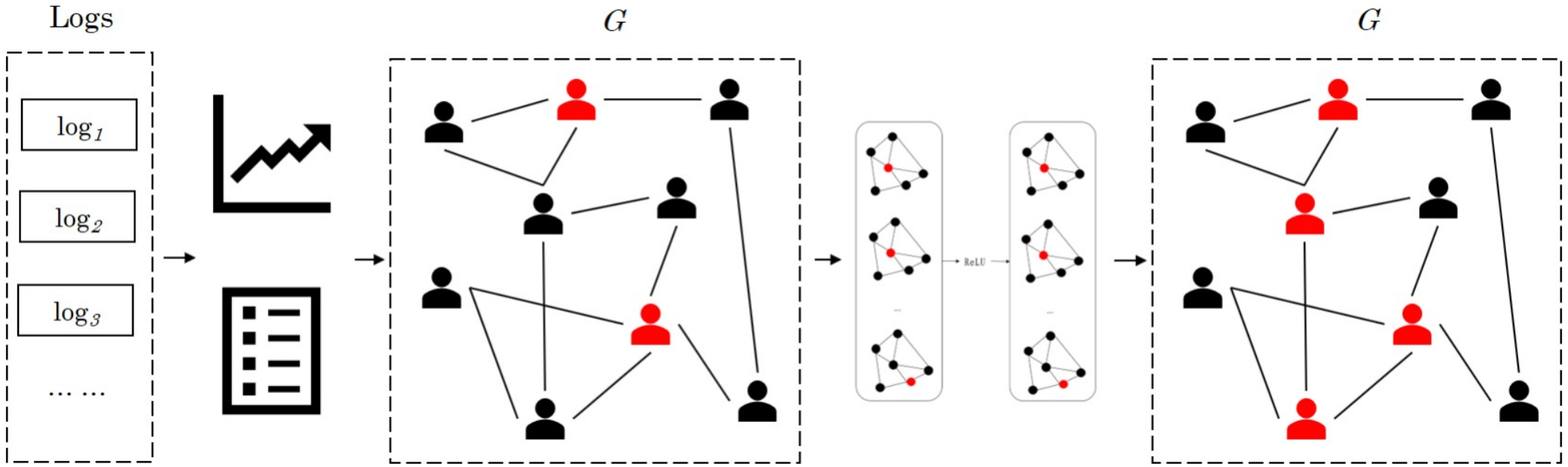
Finance

- Insurance Fraud
- Loan Defaulter
- Money Laundering
- Malicious Account
- Transaction Fraud
- Cash-out User
- Bitcoin Fraud

Others

- Advertisement
- Mobile Apps
- Ecommerce
- Crowdturfing
- Fake Clicks
- Game
- Account Takeover

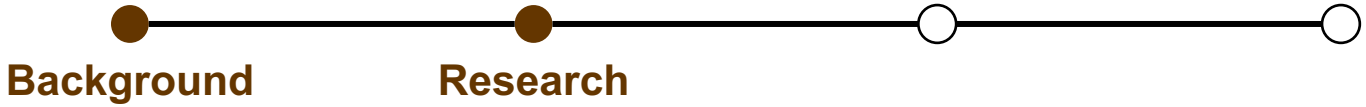
GNN-based Fraud Detection



(1) Graph Construction. (2) Training GNN on the Graph. (3) Classifying Unlabeled Nodes.

Key idea: the connected nodes are similar (homophily assumption)

Image from Jianyu Wang et. al. 2019. FdGars: Fraudster Detection via Graph Convolutional Networks in Online App Review System. WWW 2019.



A History of GNN Fraud Detection (75+Papers)

GraphRAD
MLG@KDD'18

GeniePath
AAAI'19

BitGCN
ADF@KDD'19

GEM
CIKM'18

InsurGNN
SIGIR'19

GAS
CIKM'19

CARE-GNN
CIKM'20

GraphRfi
SIGIR'20

SemiGNN
ICDM'19

GraphConsis
SIGIR'20

Bi-GCN
AAAI'20

Player2Vec
CIKM'19

GAL
CIKM'20

APAN
SIGMOD'21

IHGAT
KDD'21

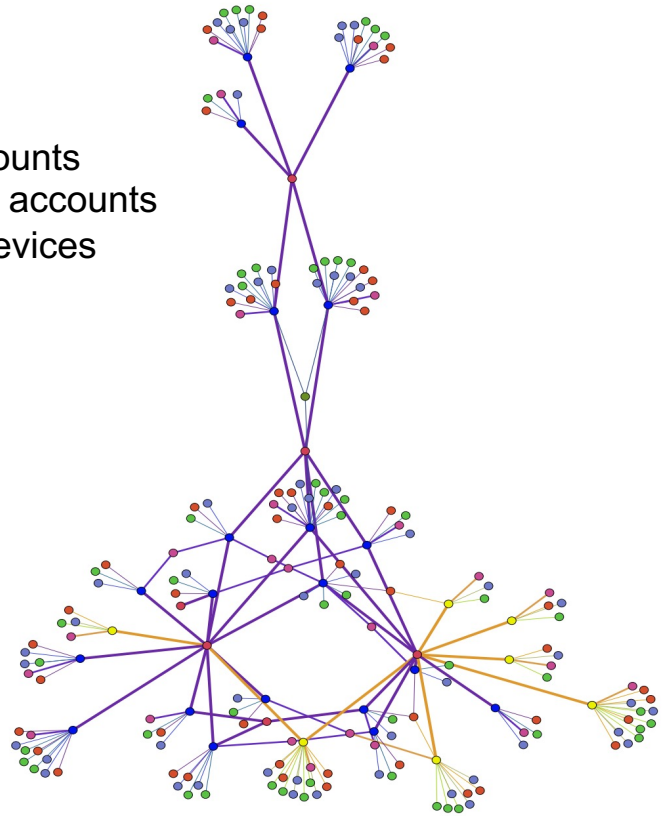
MvMoE
WSDM'21

DCI
SIGIR'21

FD-NAG
arXiv'21

GEM (CIKM'18)

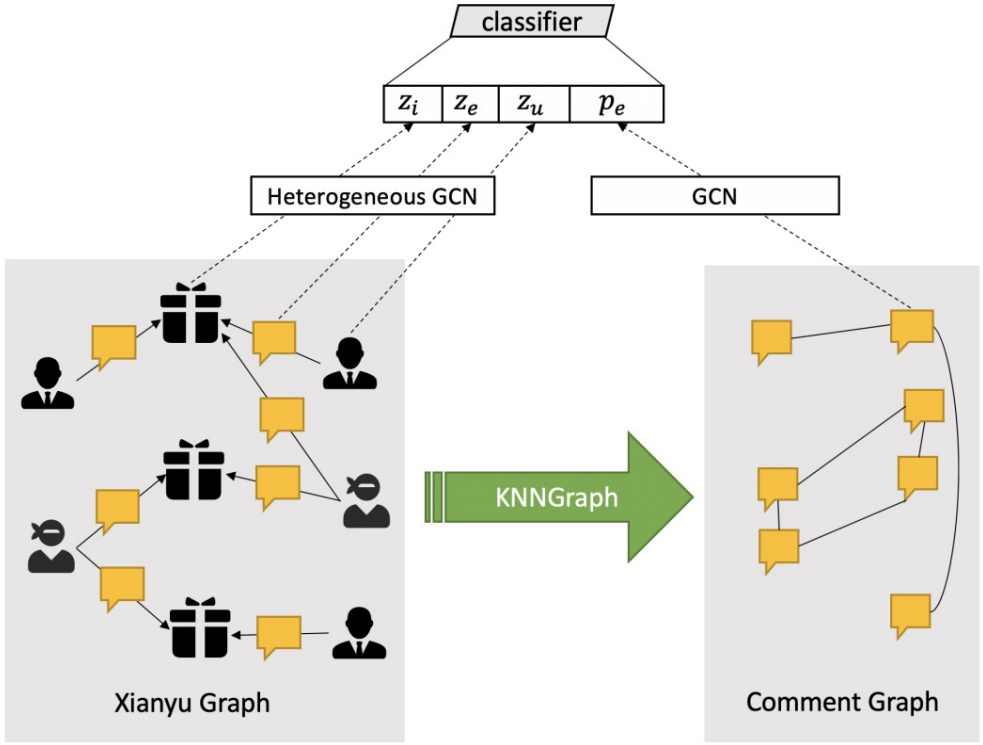
Blue: normal accounts
Yellow: malicious accounts
Other: different devices



Account-Device Heterogeneous Graph

- Task: malicious accounts detection in Alipay.
- **The first paper leveraging the heterogeneous graph for fraud detection.**
- Device types include UMID, MAC address, IMSI, APDID (Alipay Fingerprint).
- Using attention mechanism to learn importance of different sub-graphs.
- Code is available.

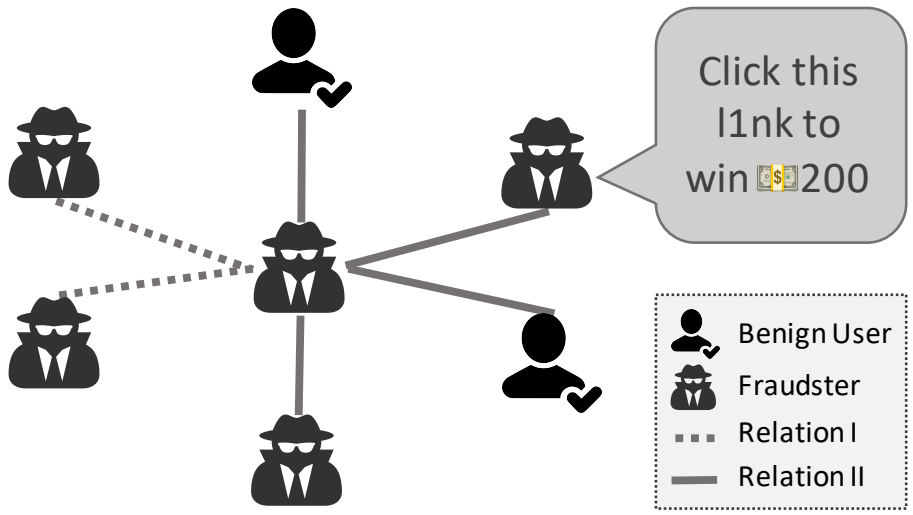
GAS (CIKM'19)



User-Comment-Product Graph
+
Comment-Comment Graph

- Task: spam review detection on the Xianyu Platform.
- CIKM'19 Industrial Track Best Paper.
- **Novel graph construction approach. Encoding each heterogeneous entity separately.**
- Verifying a sampling approach for graph construction.
- Code is available.

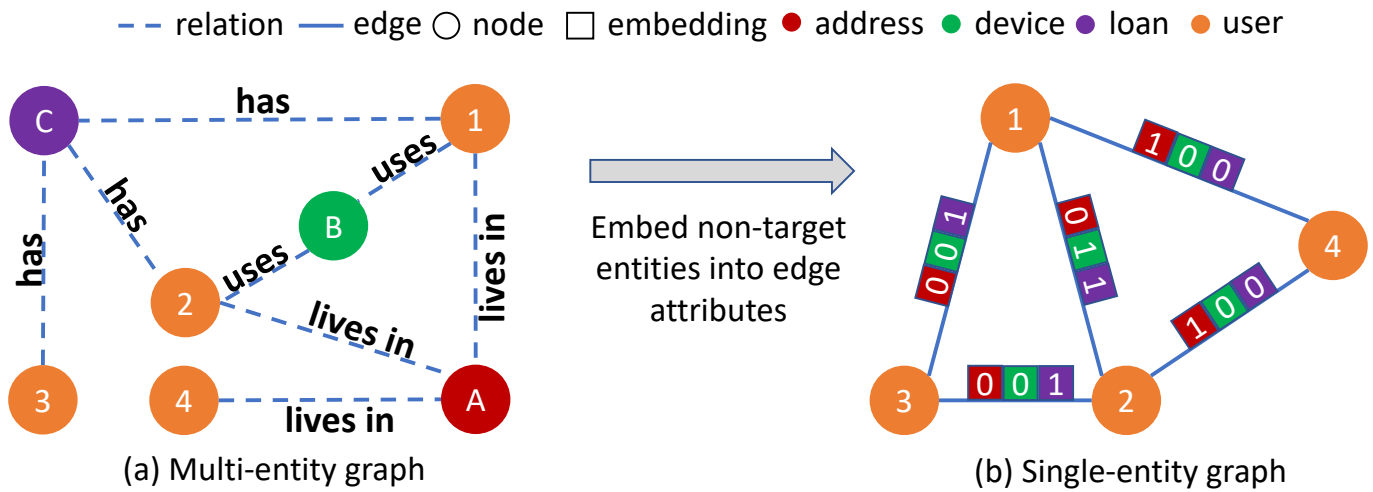
CARE-GNN (CIKM'20)



Fraudster Camouflage

- Task: spam review detection on Yelp; malicious reviewer detection on Amazon.
- Top 15 influential papers in CIKM'20.
- **Addressing the fraudster camouflage and class-imbalance problems in fraud detection.**
- Using reinforcement learning to select the most informative neighbors for GNNs.
- Integrated with DGL, introduce two **public datasets**.
- Extended TOIS version with more applications.
- Code is available.

FD-NAG (arXiv'21)



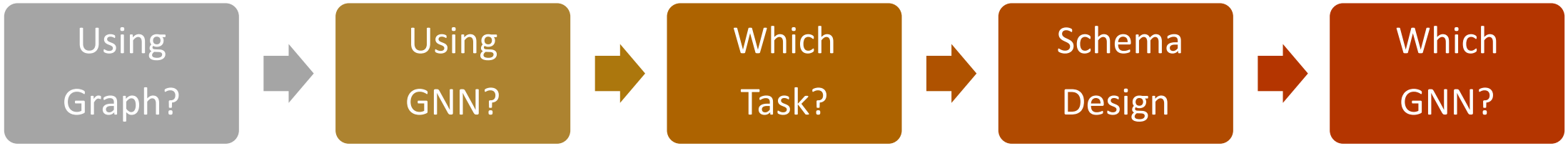
Transferring a heterogeneous non-attributed graph to an edge-attributed homogeneous graph

- Task: fraudsters detection in ride sharing services.
- Designing node and edge features for non-attributed graphs.
- **Empirically verified the effectiveness of contrastive learning in fraud detection.**

Applying GNN into Fraud Detection

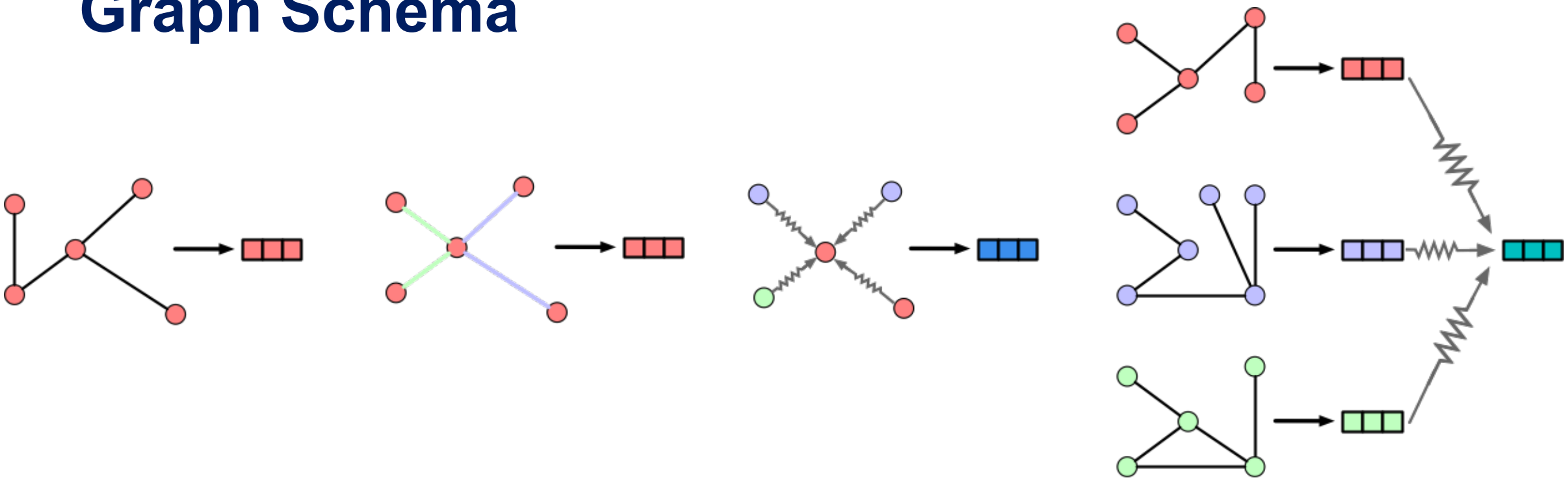
- **Problem Formulation**
  - Whether using Graph&GNNs?
  - Which task to choose?
  - What graph schema is suitable?
- **Key Issues and Solutions**
  - Camouflage, Scalability, Class imbalance
  - Label scarcity, Label fidelity, Data-scarcity
- **Novel Practices**
  - Novel methods
  - Industrial cases

Problem Formulation



- **Using Graph?**
  - The fraudsters share common entities.
  - The fraudsters have clustering behavior.
  - The trade off between cost and effectiveness.
- **Using GNN?**
  - The infrastructure.
  - The feature availability and feature types.
  - Integrating with other modules and tasks.
- **Which Task?**
  - Node/edge/graph/subgraph classification.
  - Community detection; anomaly detection.
- **Schema Design**
  - Node/edge type and node/edge feature.
  - Graph schema, node sampling.
  - Graph structure is flexible: SIGIR'19, ICDM'20.
- **Which GNN?**
  - GNN is chosen based on task and schema.
  - Simple GNN model is enough.
  - GAT and Graph-SAGE are commonly used.

Graph Schema



Homogeneous

BitGCN
FdGars
GeniePath
FD-NAG

Multi-relation

GraphConsis
CARE-GNN
PC-GNN

Heterogeneous

GAS
mHGNN
IHGAT

Hierarchical

GEM
SemiGNN
Player2Vec
AA-HGNN

Key Issues and Solutions

- **Camouflage**
  - Neighboring filtering: SIGIR'20, CIKM'20, WWW'21.
  - Aware of adversarial behavior: IJCAI'20, WWW'20.
  - Active generative learning: ACL'20.
  - Bayesian edge weight inference: ACL'21.
- **Scalability**
  - GNN scalability: MLF@KDD'20.
  - Shallow graph models are more scalable: MLG@KDD'18, WWW'20.
- **Class imbalance**
  - Under-sampling: CIKM'20.
  - Neighbor selection: WWW'21.
  - Data augmentation: CIKM'20.

Key Issues and Solutions (Cont'd)

- **Label scarcity**
  - Active learning: ICDM'20, TNNLS'21.
  - Ensemble learning: CIKM'20.
  - Meta learning: WSDM'21.
- **Label fidelity**
  - Active learning: TNNLS'21.
  - Human-in-the-loop: AAAI'20.
- **Data scarcity**
  - Data augmentation: CIKM'20, CIKM'21, ACL'20.

Novel Practices

- **Graph Pretraining (Contrastive Learning)**
  - Fraudster is distinguishable from its structural pattern.
  - TNNLS'21, SIGIR'21, arXiv'21(1), arXiv'21(2).
- **Dynamic/Temporal/Streaming Graph**
  - The historical information is useful for identifying fraudsters.
  - The efficiency and cost are bottlenecks.
  - CIKM'21, KDD'21(1), KDD'21(2), SIGMOD'21.
  - arXiv'21, SDM'21, ICDM'20, KDD'20.
  - ROLAND.

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Novel Practices (Cont'd)

- **Multi-task Learning**
  - Credit limit forecasting and credit risk predicting: WSDM'21.
  - Fraud detection and recommender system: SIGIR'20.
- **Explainable Fraud Detection**
  - Explainable fraud transaction detection: arXiv'20, KDD'21.
  - Explainable fake news detection: ACL'20.
- **Recent Surveys**
  - A Comprehensive Survey on Graph Anomaly Detection with Deep Learning.
  - Anomaly Mining - Past, Present and Future.
  - Graph Computing for Financial Crime and Fraud Detection: Trends, Challenges and Outlook.

Industrial Cases

- **Facebook**
  - WWW'20, KDD'20, Security'21.
- **Amazon**
  - MLG@KDD'18, KDD'21.
- **Tencent**
  - WWW'19, WWW'20, KDD'21.
- **Alibaba & Ant Group**
  - CIKM'18, AAAI'19, SIGIR'19, CIKM'19, ICDM'19, IJCAI'20, ACL'20, CIKM'20(1).
  - CIKM'20(2), SIGMOD'21, WSDM'21, WWW'21, AAAI'21, KDD'21(1), KDD'21(2).
- **eBay**
  - Workshop@AAAI'21, arXiv'20, MLF@KDD'20.
- **Others**
  - App Market, Money Laundering, Fake Invitation (iQIYI), Bitcoin, Grab.

SafeGraph (https://github.com/safe-graph)

- **DGFraud**: a GNN-based fraud detection toolbox implemented TensorFlow 1.X.
  - 360 stars, ten GNN models.
- **DGFraud-TF2**: a GNN-based fraud detection toolbox implemented TensorFlow 2.X.
  - 31 stars, nine GNN models.
- **UGFraud**: an unsupervised graph-based fraud detection toolbox.
  - 71 stars, six classic models, deployed on Pypi.
- **GNN-FakeNews**: a collection of GNN-based fake news detection models.
  - 80 stars, benchmarking GNN-based fake news detection, integrated with DGL and PyG.
- **Graph-based Fraud Detection Paper List (frequently updated).**
  - 466 stars, more than 100 papers listed plus code, datasets, surveys, and other resources.
- **Graph Adversarial Learning Literature (frequently updated).**
  - 455 stars, more than 200 papers surveyed.

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Other Toolboxes

- PyOD: Python Outlier Detection
  - https://github.com/yzhao062/pyod.
- PyODD: An End-to-end Outlier Detection System
  - https://github.com/datamllab/pyodds.
- DGL Fraud Detection Pipeline
  - https://github.com/awslabs/realtime-fraud-detection-with-gnn-on-dgl.
- PyG 2.0: A PyTorch-based GNN Library
  - https://github.com/pyg-team/pytorch_geometric.

Other Resources

- KDD Machine Learning in Finance Workshop
  - https://sites.google.com/view/kdd-mlf-2021.
- KDD Machine Learning on Graph Workshop
  - http://www.mlgworkshop.org/.
- KDD'20 Deep Anomaly Detection Tutorial
  - https://sites.google.com/view/kdd2020deepeye/home.
- Awesome Fraud Detection Papers
  - https://github.com/benedekrozemberczki/awesome-fraud-detection-papers.

Thanks!

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