Machine Learning with Graphs (MLG)

GNN Applications

Represent the **relationships of any things** as Graphs

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References

- GNN for Tabular Data
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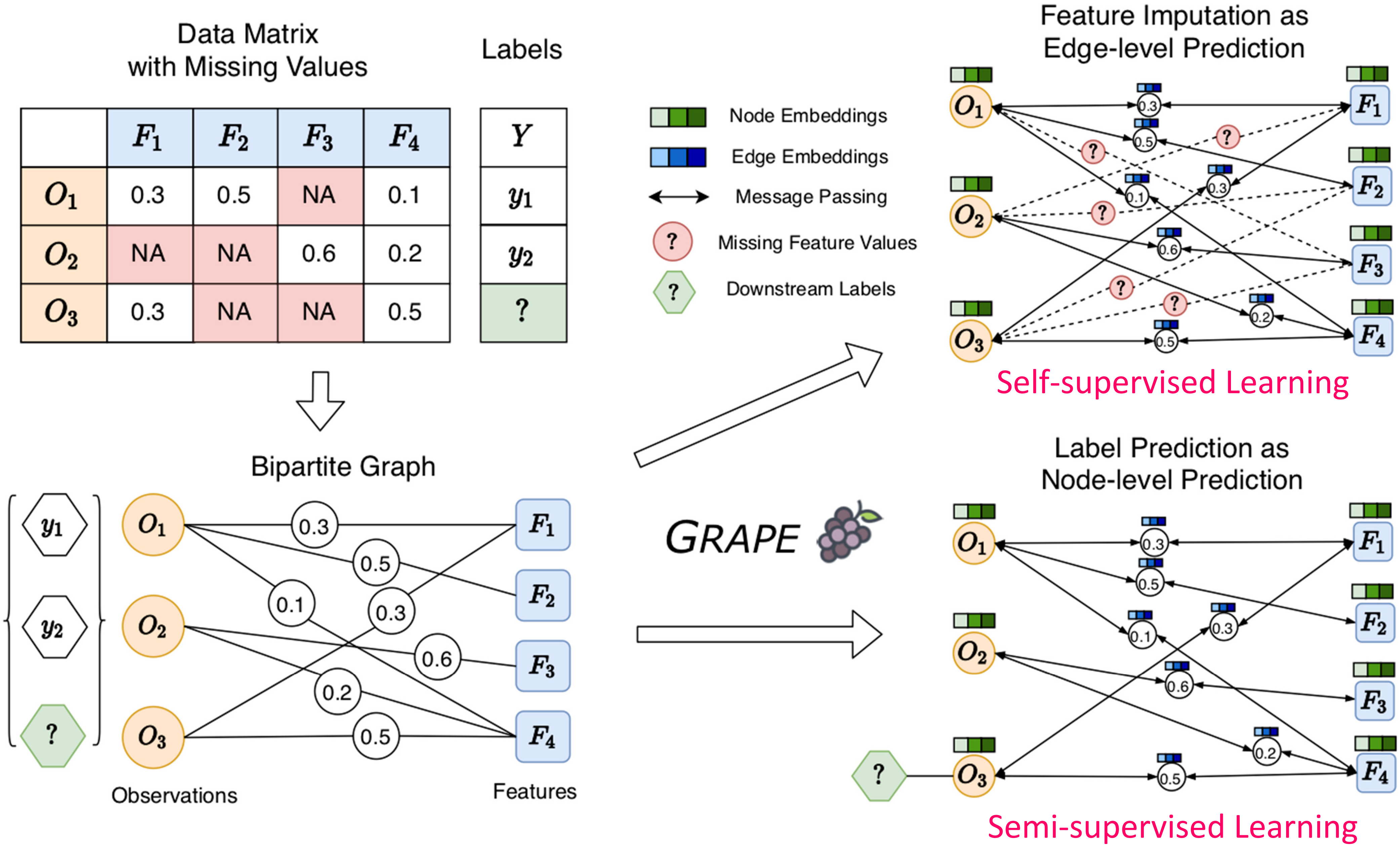
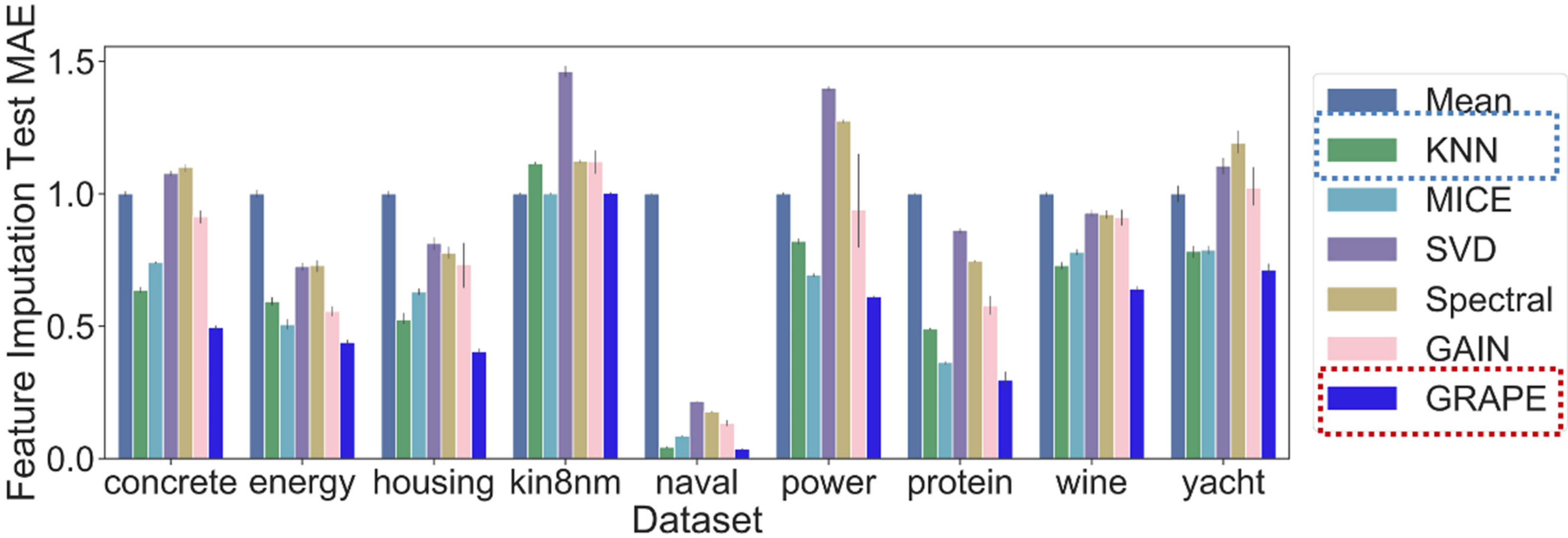
GRAPE: Bipartite GNN

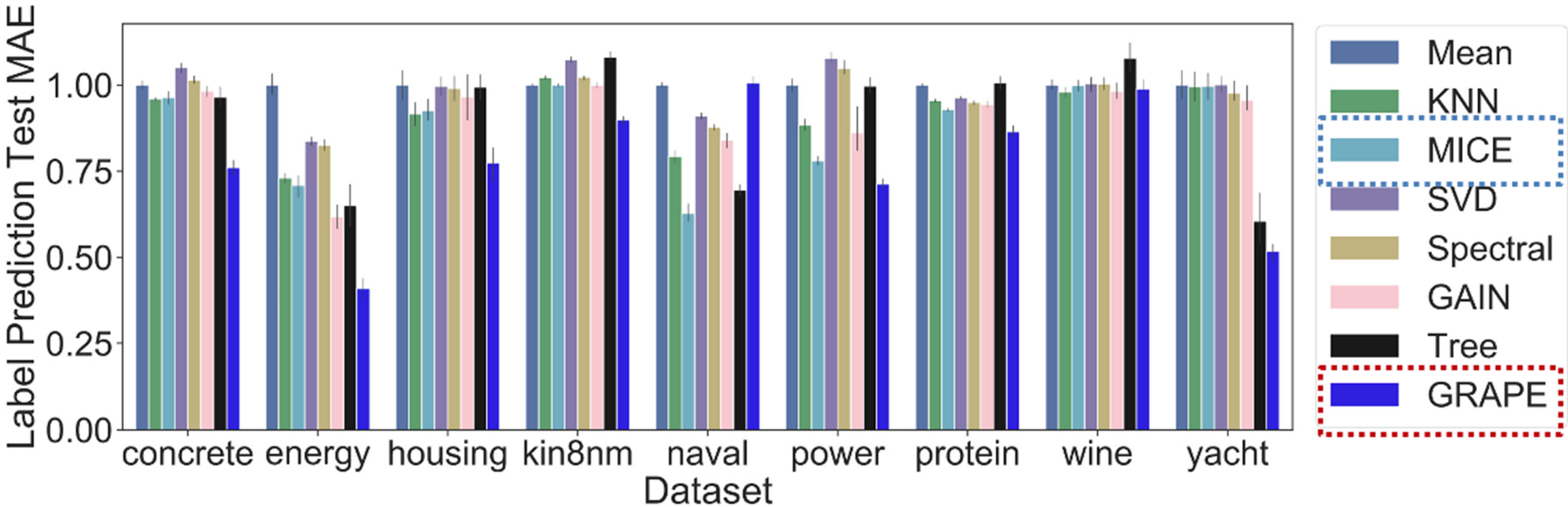


Overall Performance

Experiments on 9 UCI datasets from different domains



Feature imputation: 20% lower MAE than best baseline (KNN)

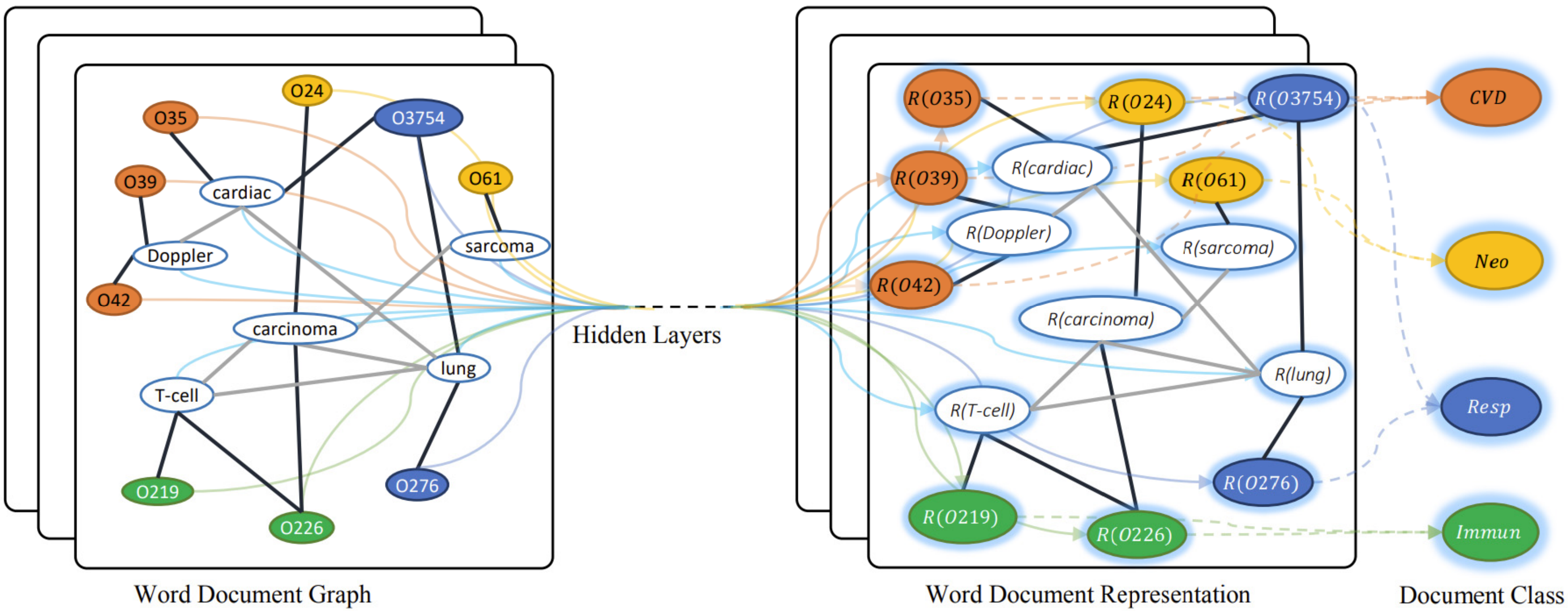


Label prediction: 10% lower MAE than best baseline (MICE)

Text Classification: TextGCN

- Nodes: words and documents
- Edges: co-occurrence (word-word) and TF-IDF (word-doc)
- Model the graph with a Graph Convolutional Network (GCN)
  - Generate document representation
  - Produce the classification outcome

$$A_{ij} = \begin{cases} \mathrm{PMI}(i,j) & i,j \text{ are words, } \mathrm{PMI}(i,j) > 0 \\ \text{TF-IDF}_{ij} & i \text{ is document, } j \text{ is word} \\ 1 & i = j \\ 0 & \text{otherwise} \end{cases}$$

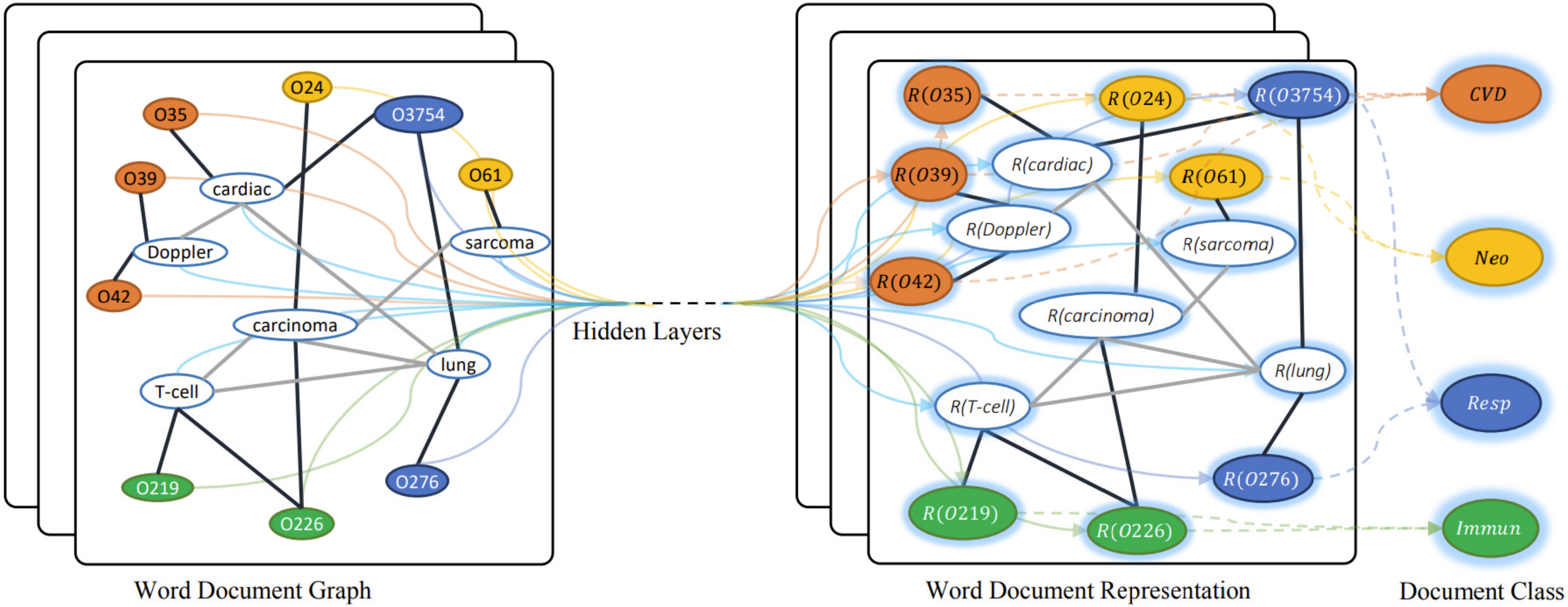


BERT-GCN: Combining BERT & GCN

- Follow the graph construction in TextGCN
- Initialize document node vectors by BERT document embeddings
- Learning doc embedddings and predictions

$$Z_{\text{GCN}} = \text{softmax}(g(X, A)) \qquad Z_{\text{BERT}} = \text{softmax}(WX)$$

- Interpolating BERT and GCN predictions $Z = \lambda Z_{\text{GCN}} + (1 - \lambda) Z_{\text{BERT}}$



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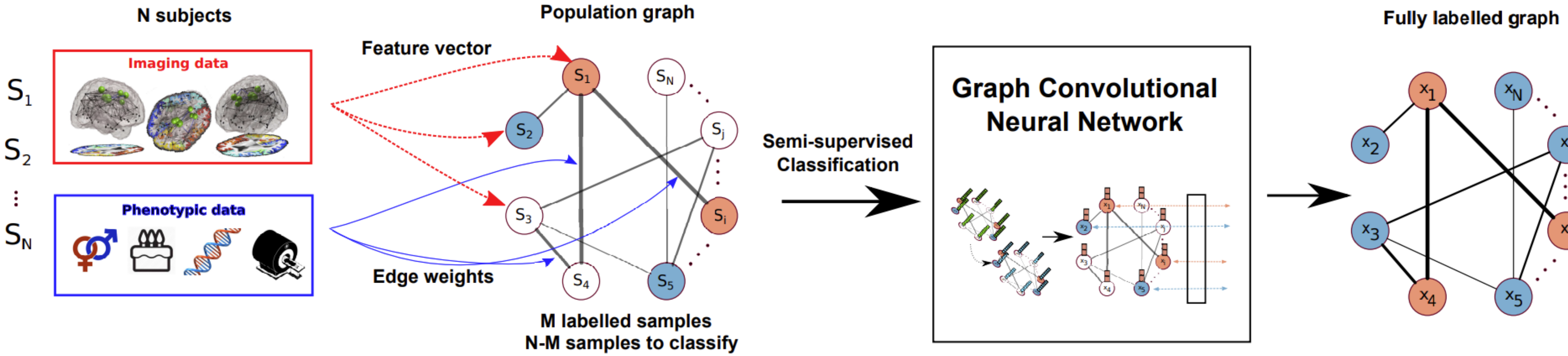
GCN for Autism Spectrum Disorder Prediction (Medical Images)

自閉症類群障礙

- Task: Disease prediction (binary classification)
- Nodes: patients (initial vectors: CNN image features)
- Edges: similarity based on clinical data
  - E.g., k-nearest neighbors
  - E.g., fully-connected weighted graph



GNN for Computer Vision

Semantic Segmentation

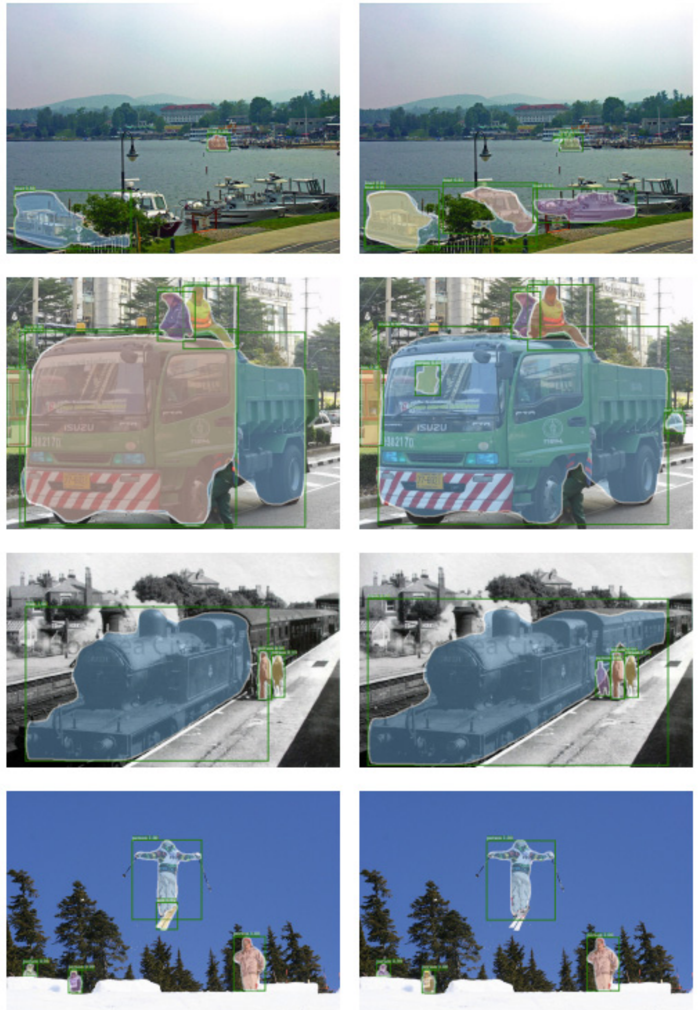
GT

FCN

GCU (ours)

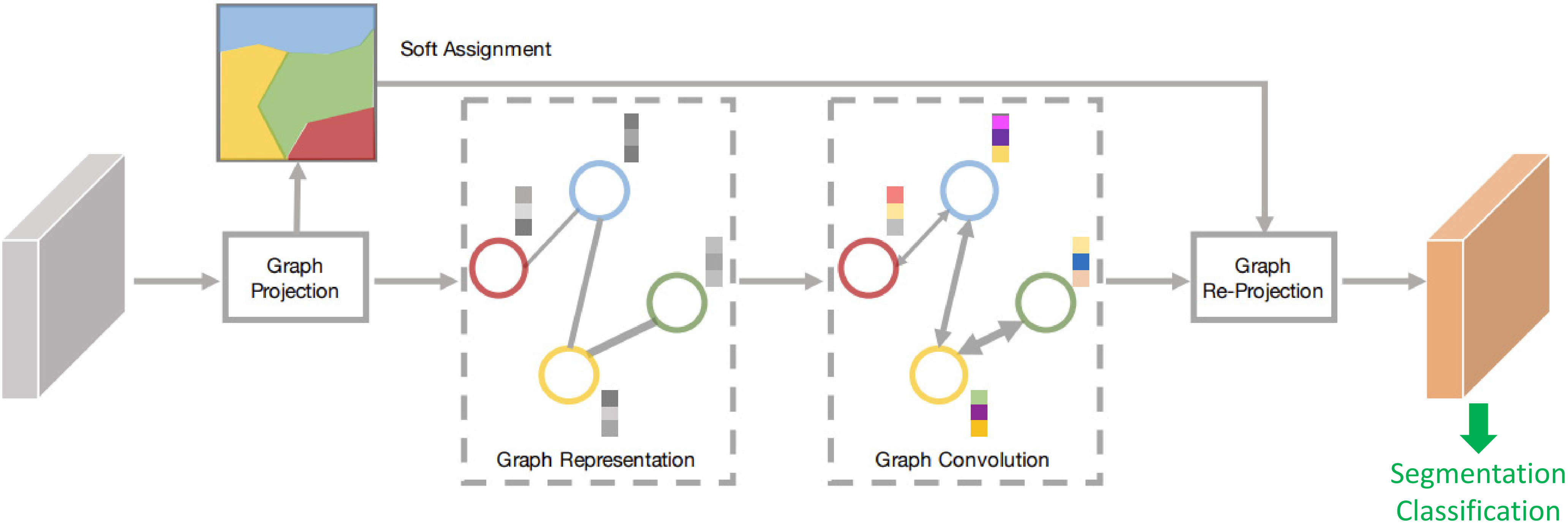
Object Instance Segmentation

Mask RCNN GNN



GNN for Computer Vision

- Learning graph representation from 2D feature maps
  - Capture long range dependencies among regions
  - Facilitate reasoning beyond regular grids
- Nodes: clusters of pixels (e.g., regions)
- Edges: similarity between clusters in feature space



Multi-Label Image Classification

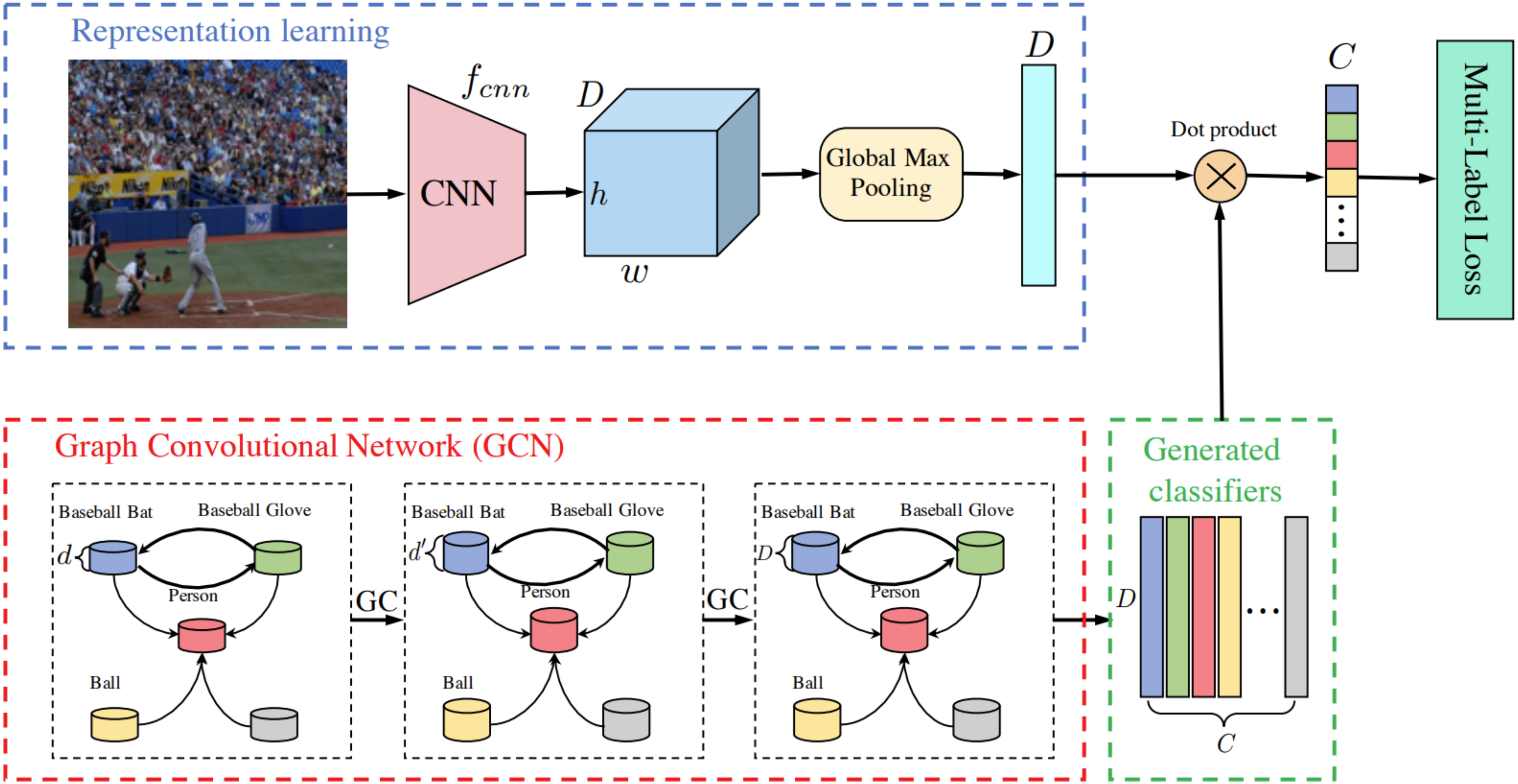
Dog

Traditional image recognition
(Single-label recognition)

Cloud Rainbow Sky

Multi-Label image recognition

Multi-Label GCN (ML-GCN)

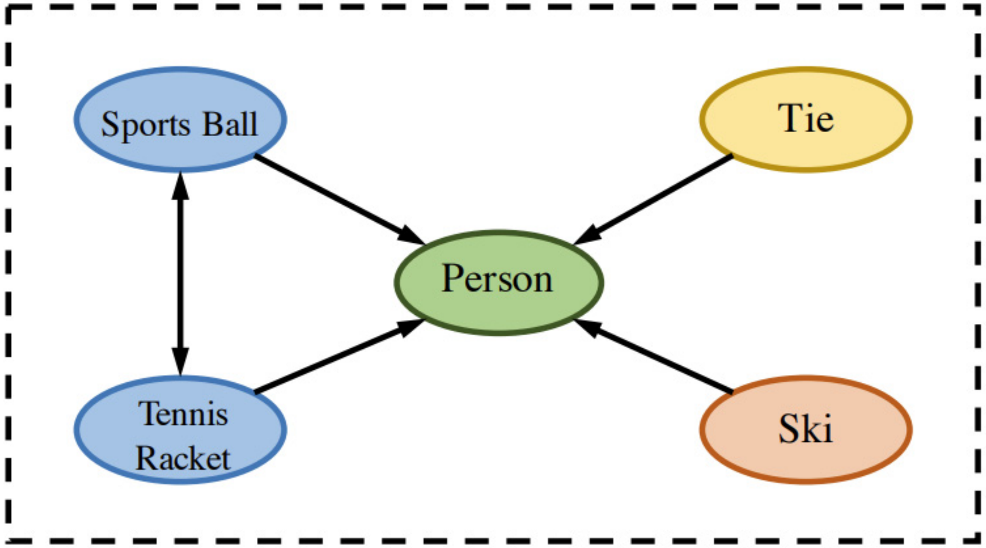


Directed Graph for ML-GCN

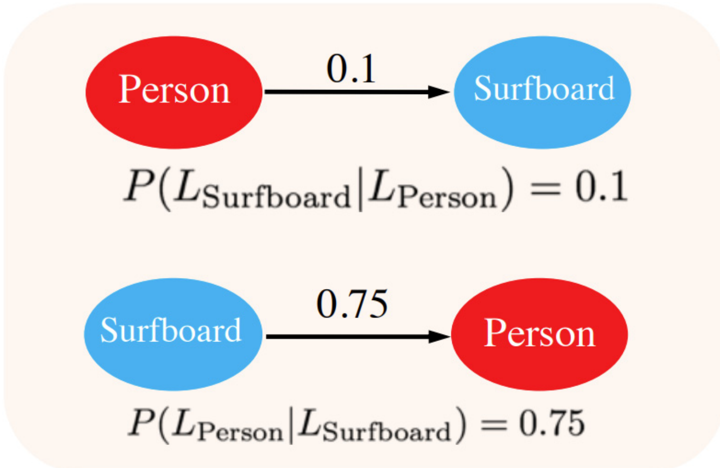
Person, Sports Ball, Tennis Racket

Person, Tie

Person, Ski



Conditional Prob.



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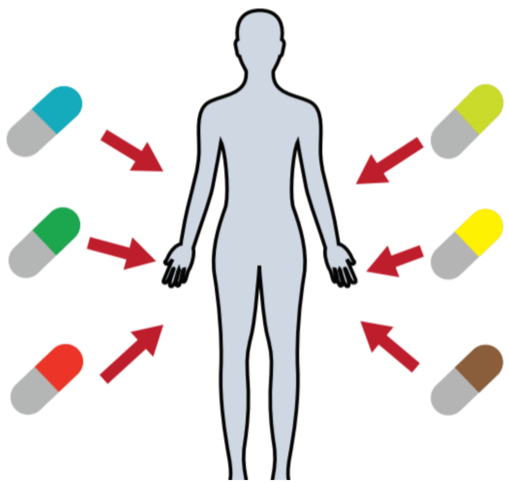
Modeling Polypharmacy with GCN

Why **polypharmacy**?

→ Many patients take multiple drugs to treat complex or co-existing diseases:

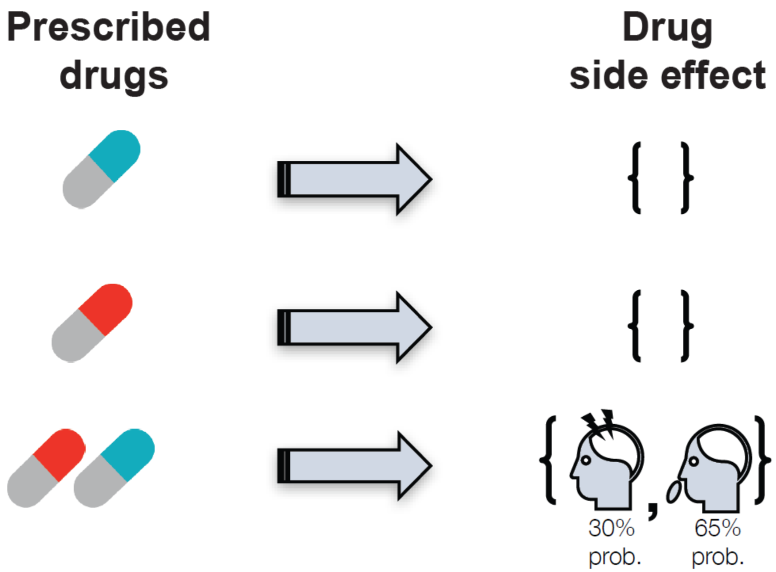
- 25% of people ages 65-69 take more than 5 drugs
- 46% of people ages 70-79 take more than 5 drugs
- Many patients take more than 20 drugs to treat heart disease, depression, insomnia, etc.



[Charlesworth *et al.*, 2015]

Unwanted Side Effects

- Side effects due to drug-drug interactions
- Extremely difficult to identify:
  - Impossible to test all combinations of drugs
  - Side effects not observed in controlled trials
- 15% of the U.S. population affected
- Annual costs exceed $177 billion

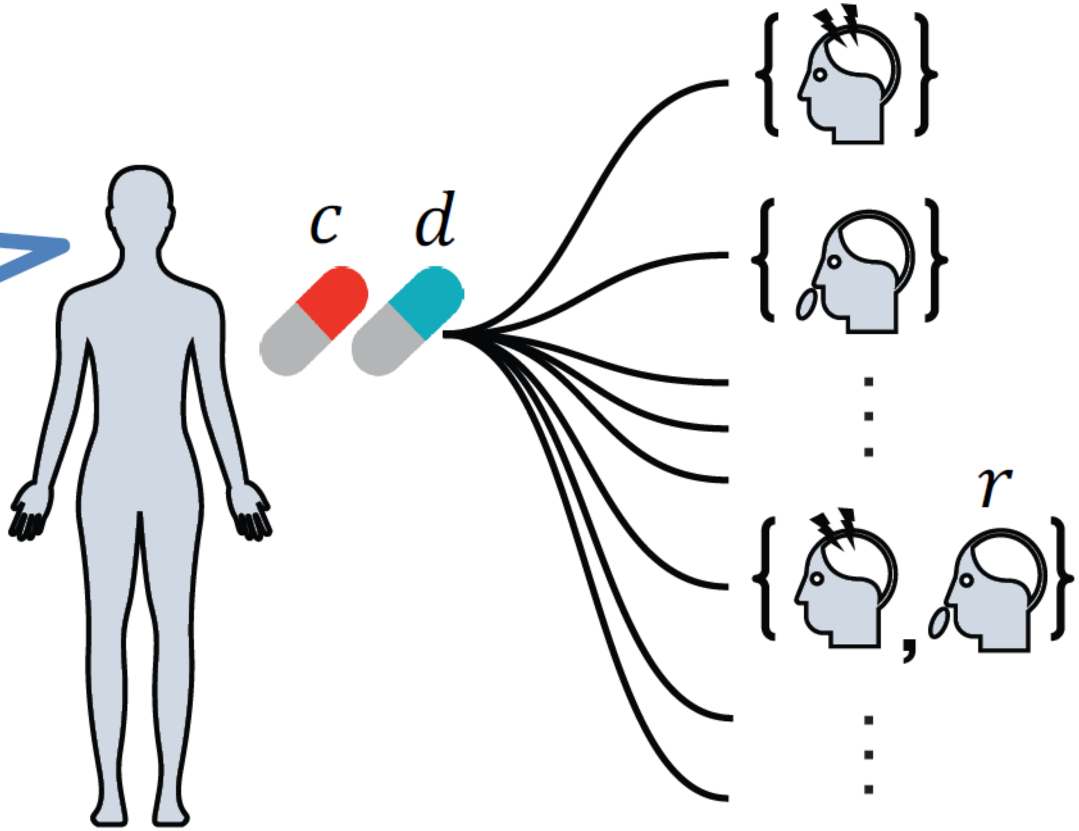


[Kantor et al., 2015]

The Task

Goal: Modeling and predicting side effects of drug pairs

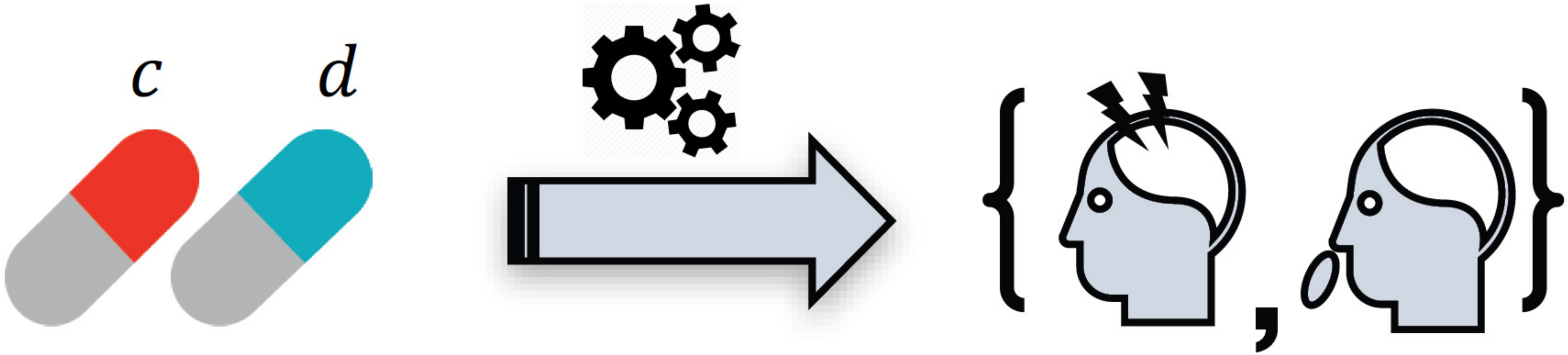
How likely with a pair of drugs c, d lead to side effect r?



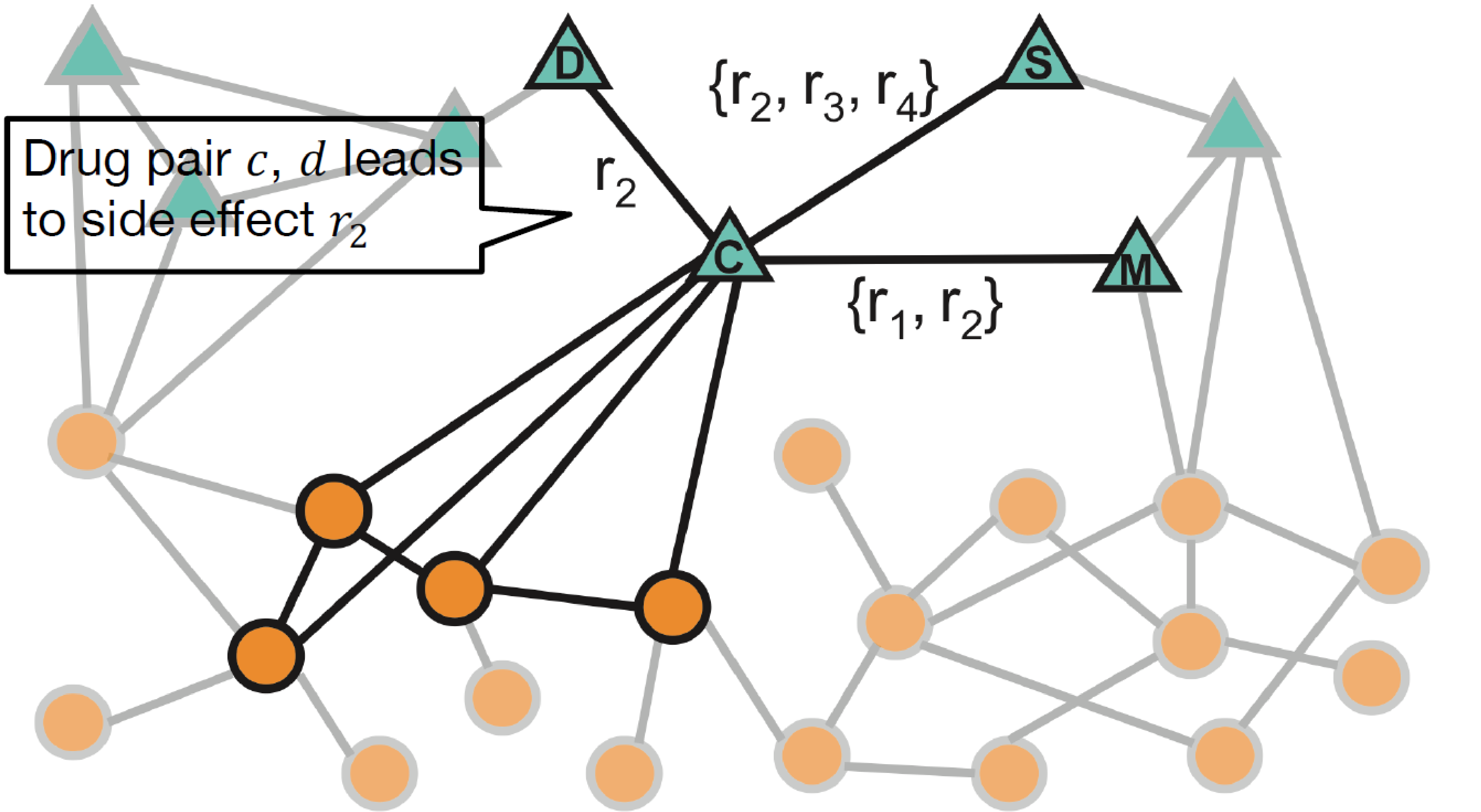
The Approach

In silico screening of drug combinations

- Use molecular, drug, and patient data
- Task: Given a drug pair c, d,
- Goal: predict side effects of that drug pair



Problem Formulation: Graphs



r_1 Gastrointestinal bleed side effect

r_2 Bradycardia side effect

r_3 Nausea side effect

r_4 Mumps side effect

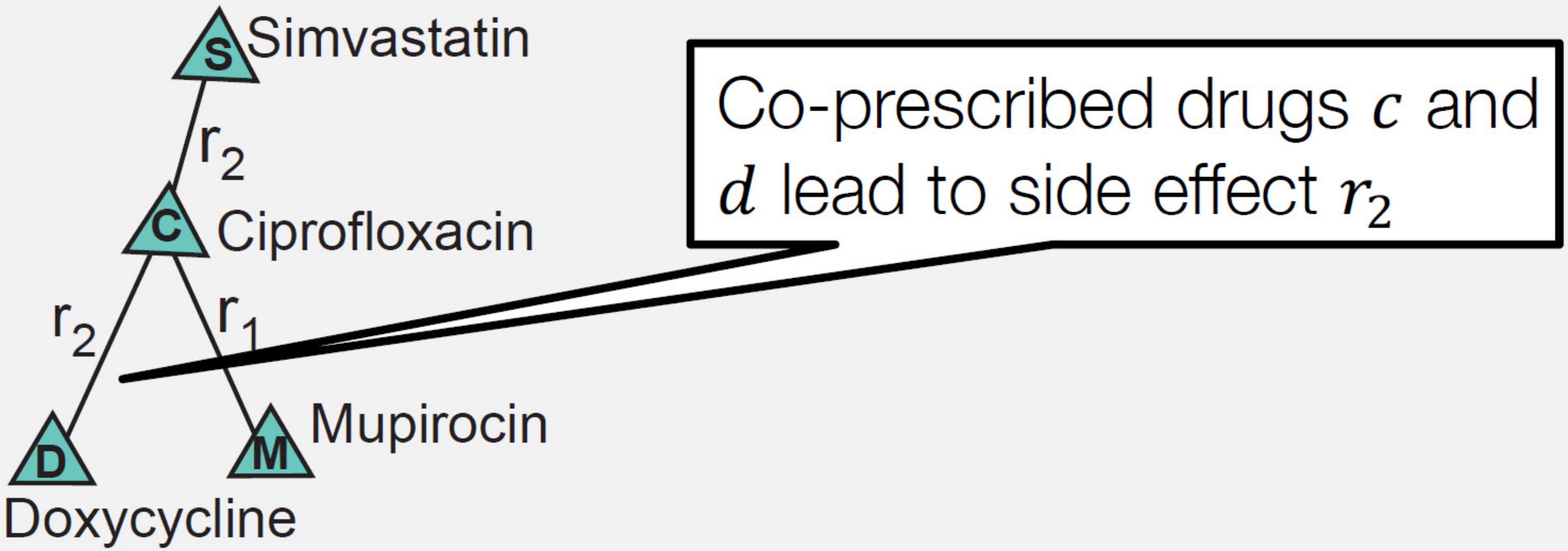
Drug-protein interaction

Protein-protein interaction

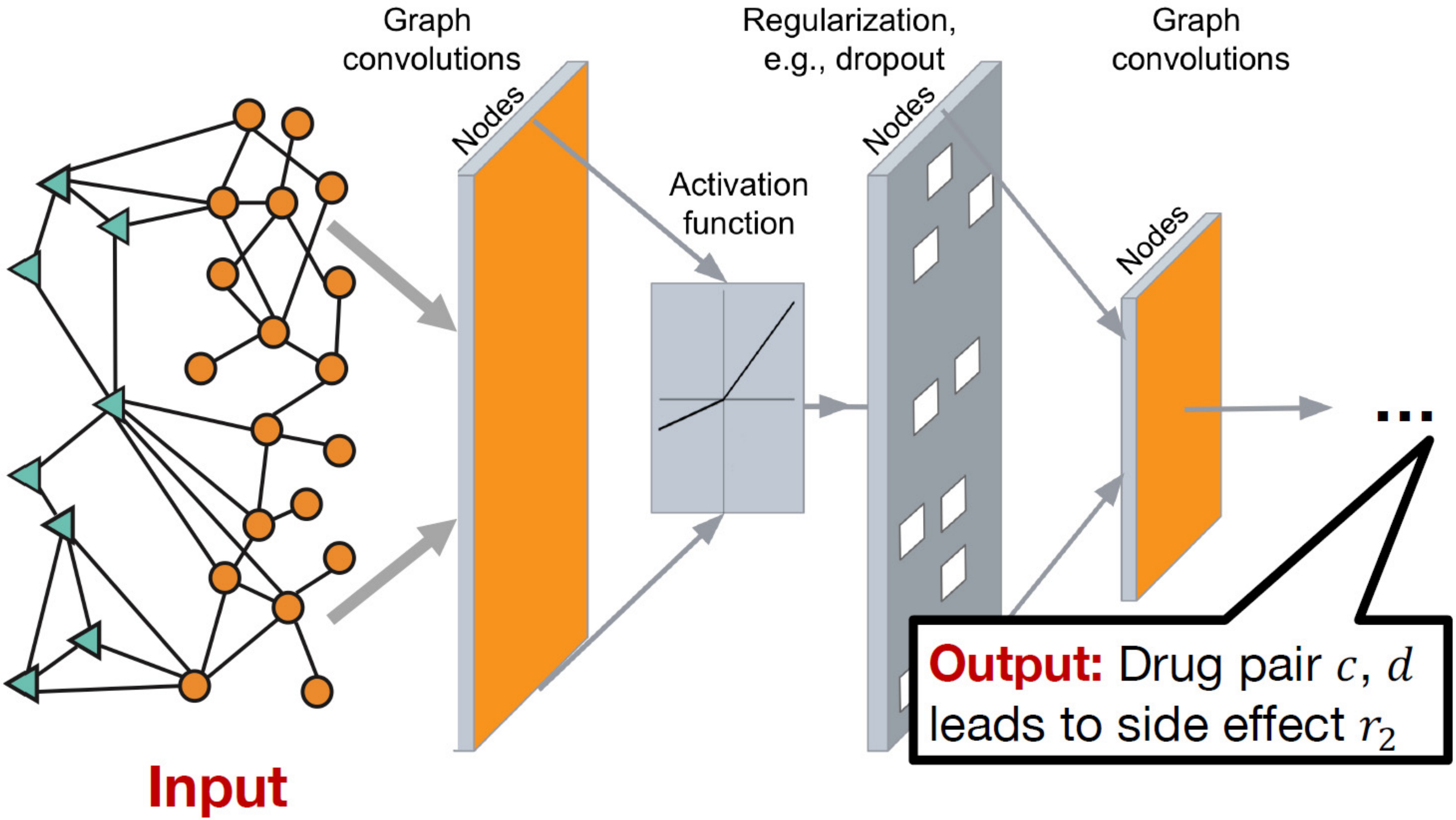
Problem Formulation: Predict

Goal: Given a partially observed graph, predict labeled edges between drug nodes

Query: Given a drug pair c, d, how likely does an edge (c, r_2, d) exist?

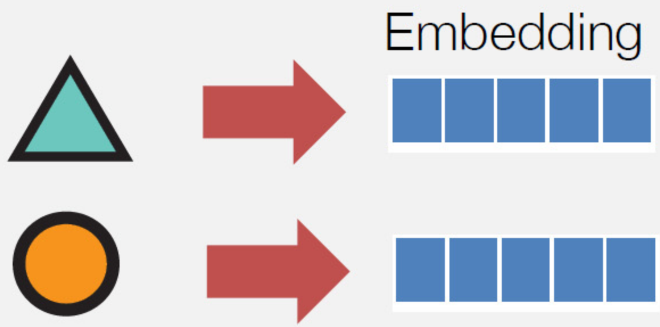


Graph Neural Network

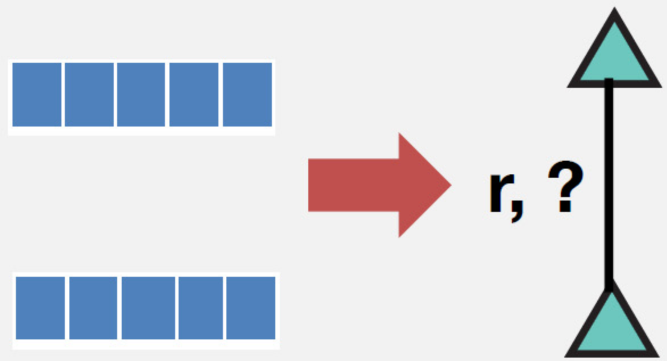


Graph Neural Network

1. Encoder: Take the graph and learn an *embedding* for every node

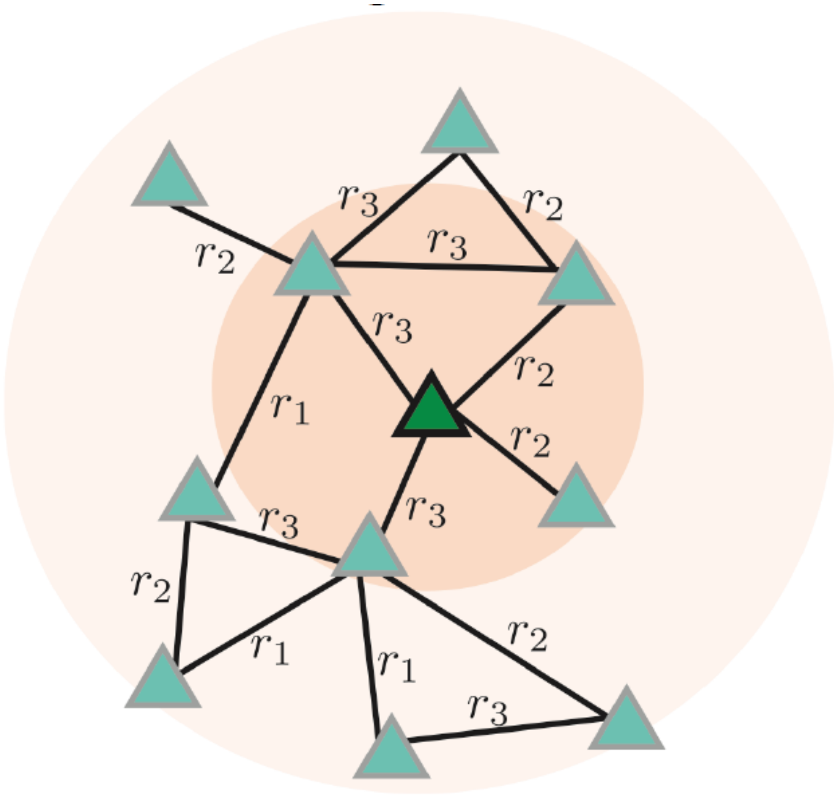


2. Decoder: Use the learned embeddings to predict side effects

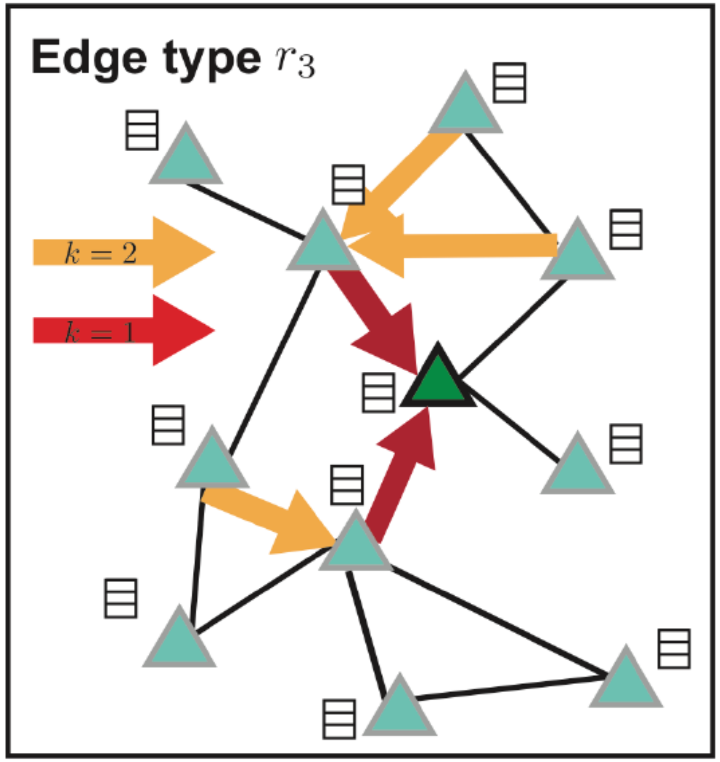


Encoder: Principle

- **Key idea:** Generate node embeddings based on local network neighborhoods
- Each edge type is modeled separately

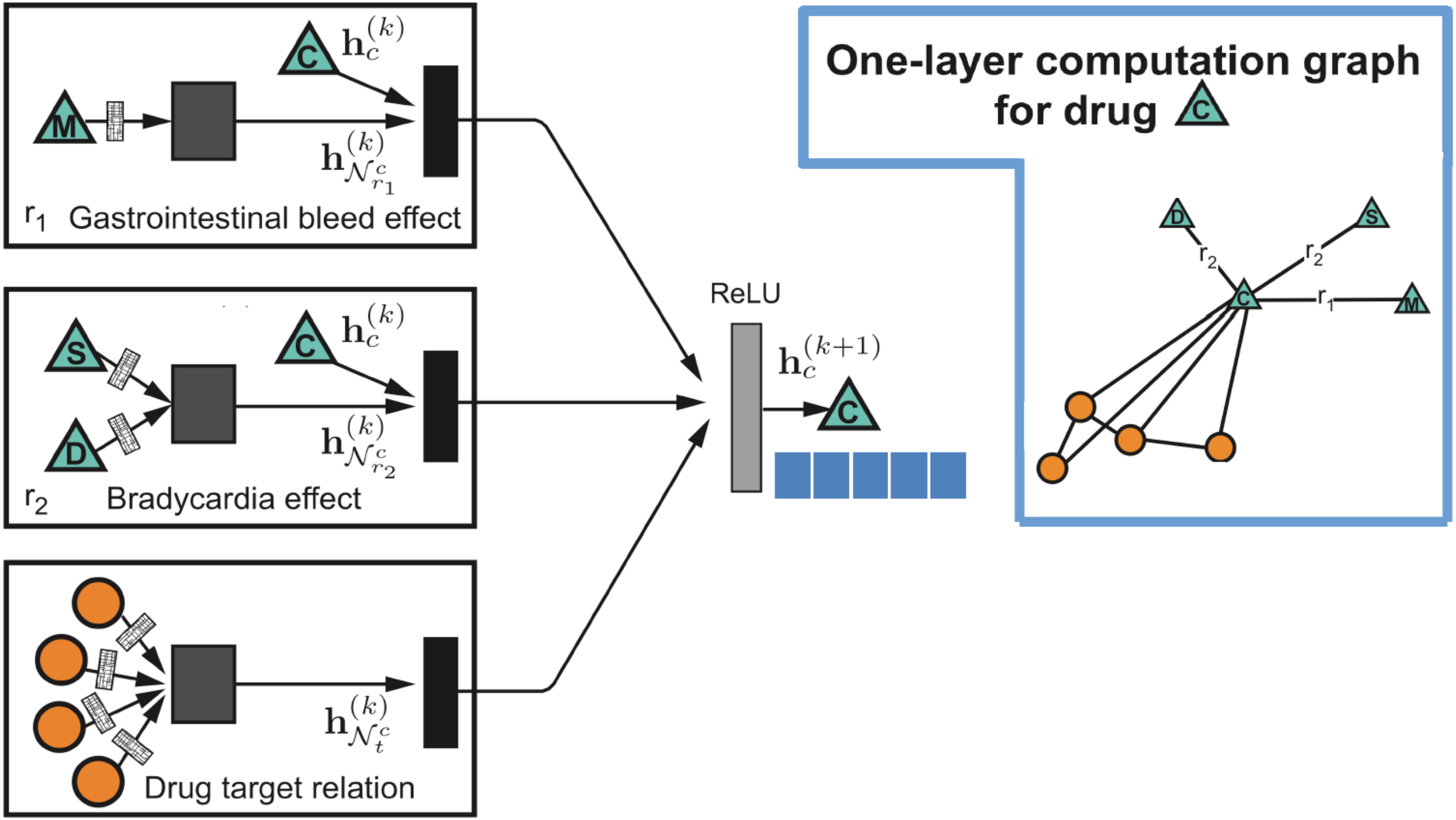


Determine a node's computation graph

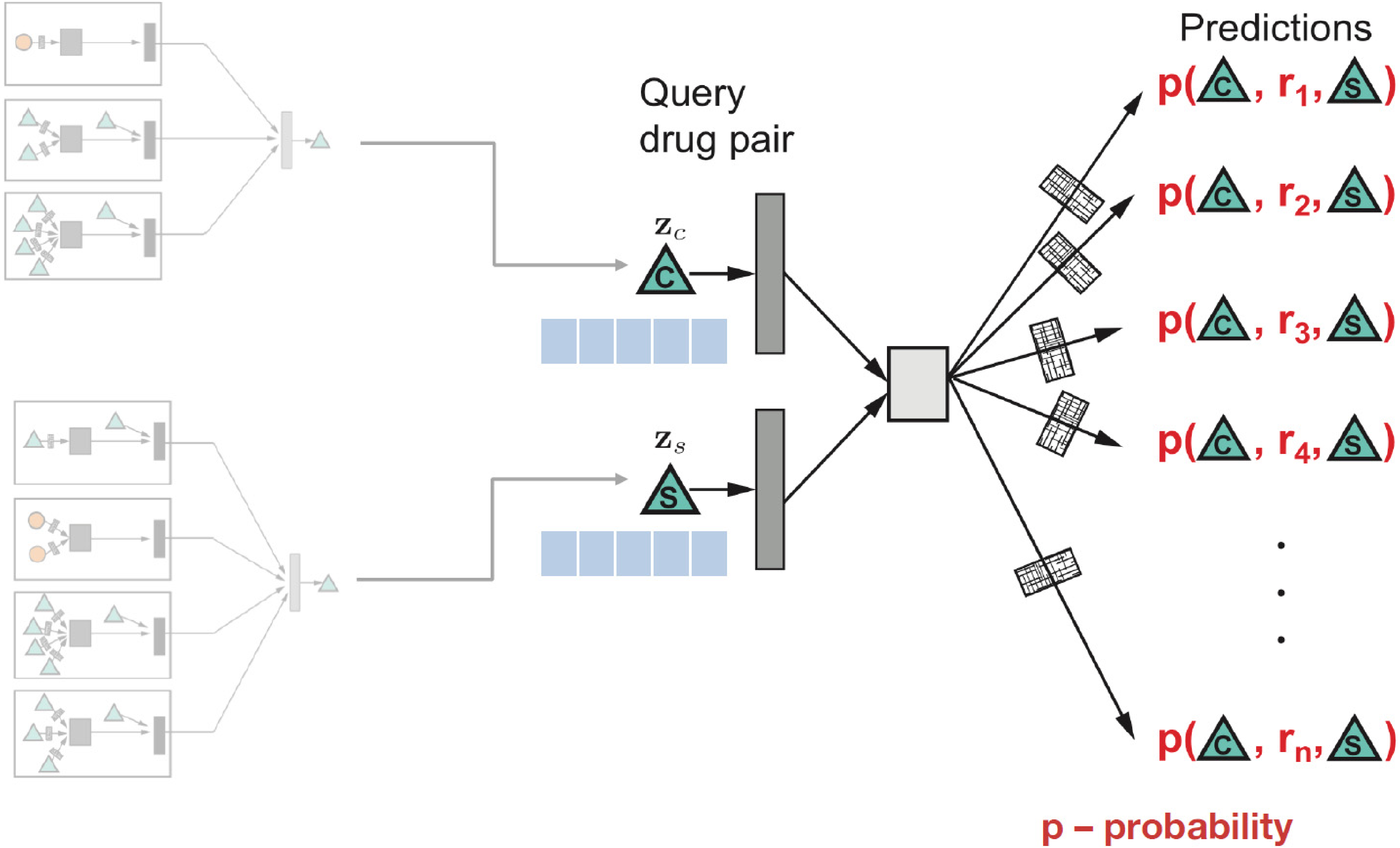


Learn how to transform and propagate information across the graph

Encoder: Embeddings



Decoder: Link Prediction

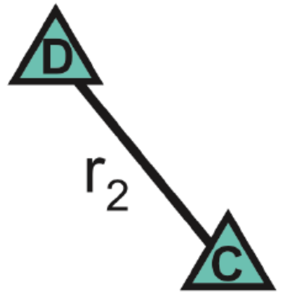


Data: Molecular, Drug & Patient

- Protein-protein interactions: Physical interactions in humans **[720K edges]**

- Drug-target relationships **[19K edges]**

- Side effects of drug pairs: National adverse event reporting system **[4.6M edges]**



- Additional side information

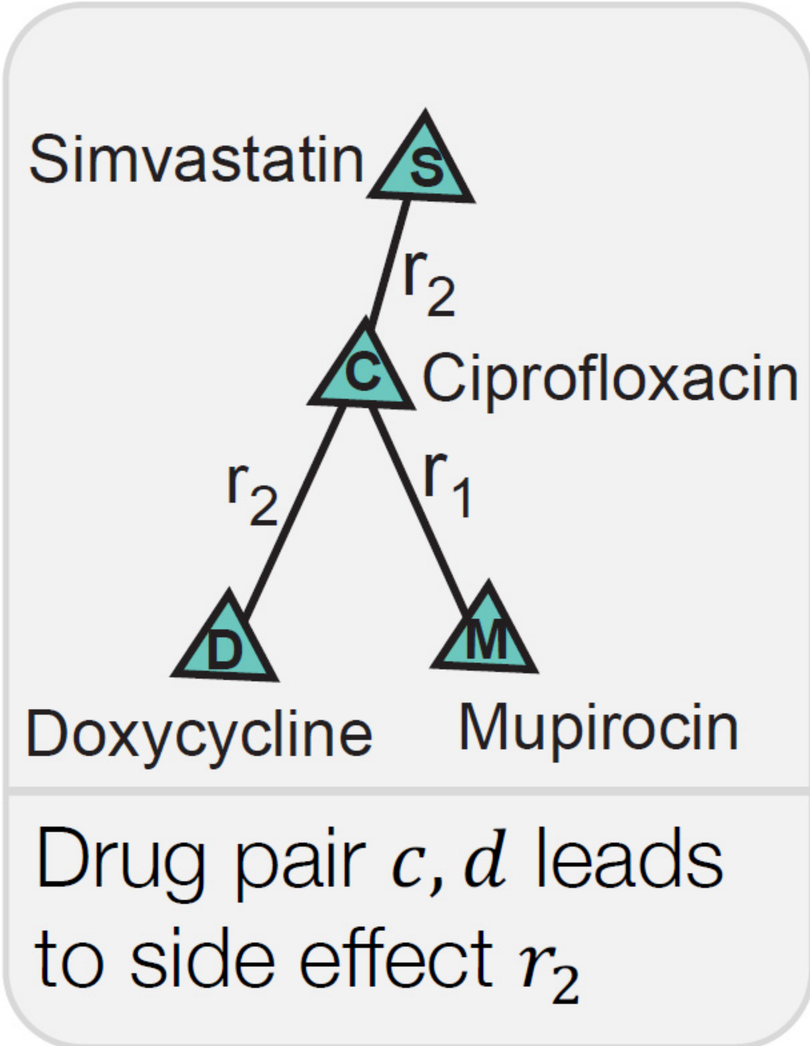
Final graph has **966 different edge types**

Experimental Setup

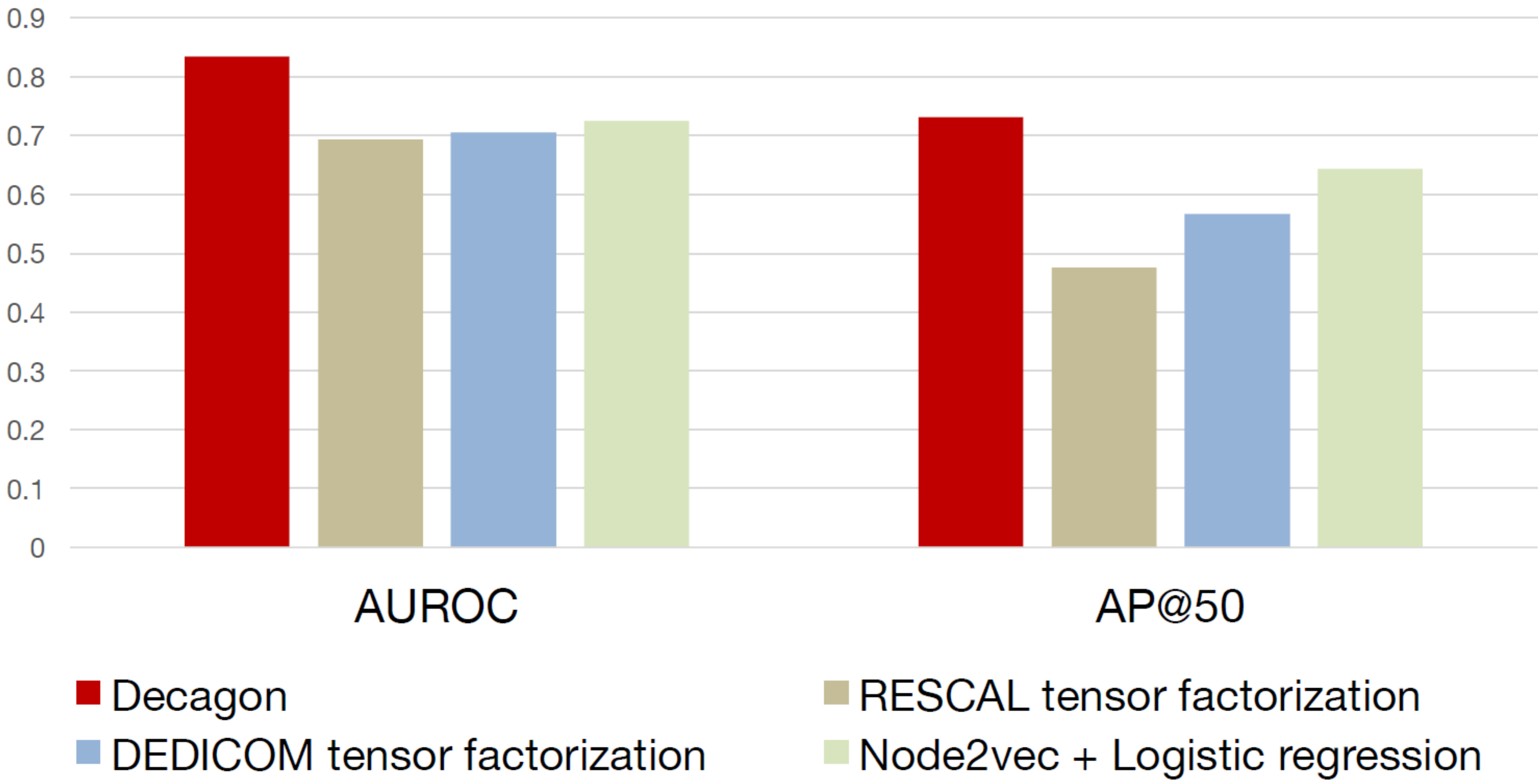
Construct a heterogeneous graph of all the data

Side-effect centric evaluation:

- **Train:** Fit a model on known side effects of drug pairs
- **Test:** Given a query drug pair, predict all types of side effects



Results: Side Effect Prediction



36% average in AP@50 improvement over baselines

De novo Predictions

Rank	Drug c	Drug d	Side effect r	Evidence found
1	Pyrimethamine	Aliskiren	Sarcoma	Stage *et al.* 2015
2	Tigecycline	Bimatoprost	Autonomic neuropathy	
3	Omeprazole	Dacarbazine	Telangiectases	
4	Tolcapone	Pyrimethamine	Breast disorder	Bicker *et al.* 2017
5	Minoxidil	Paricalcitol	Cluster headache	
6	Omeprazole	Amoxicillin	Renal tubular acidosis	Russo *et al.* 2016
7	Anagrelide	Azelaic acid	Cerebral thrombosis	
8	Atorvastatin	Amlodipine	Muscle inflammation	Banakh *et al.* 2017
9	Aliskiren	Tioconazole	Breast inflammation	Parving *et al.* 2012
10	Estradiol	Nadolol	Endometriosis	

Case Report

Severe Rhabdomyolysis due to Presumed Drug Interactions between Atorvastatin with Amlodipine and Ticagrelor

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