Stanford CS224W: Exam Preparation

CS224W: Machine Learning with Graphs

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http://cs224w.stanford.edu

Exam Information

- **Percentage: 35%** of your course grade
- **Time:** a consecutive, **120-minute** slot from Nov 19, 10:00AM to Nov 20, 09:59AM
  - The make-up exam is 2 days prior
- **Exam Format:** The exam is administered through Gradescope
  - You can typeset your answers in **LaTeX** or handwrite your answers + upload them as **images**
  - The exam should take around 110 minutes, and you have 10 minutes to upload images

Exam Information

- There will be **11** questions
  - Some questions are easy, and some are harder
  - Try to spend **5-15 minutes on each question**
  - If stuck on a particular question for too long, please skip that question and come back later
- Types of questions:
  - **True/False** questions with explanation
  - Give **examples of graphs**
  - Comparison of approaches
  - Mathematical calculations and derivations
- We feel that the exam is **medium difficulty**

General Advice for the Exam

- We suggest that you **read through all lecture slides** carefully
- **Topics** that are **important** for the exam:
  - Node centrality measures, PageRank
  - GNN model and design space (e.g., message, aggregation, update)
  - Knowledge graph embeddings, Query2Box, recommender systems (LightGCN)
- **Lectures** that are **important** for the exam: lectures **2, 4, 6, 7, 8, 10, 11, 13**

General Advice for the Exam

- We suggest that you **read through all lecture slides** carefully

- Lectures that are relatively unimportant for the exam: lectures 1, 3, 5, 9, 12, 14
  - You can spend less time studying these lectures
  - However, you should still read through them and understand the concepts as there may be miscellaneous questions

Stanford CS224W: Homework Review

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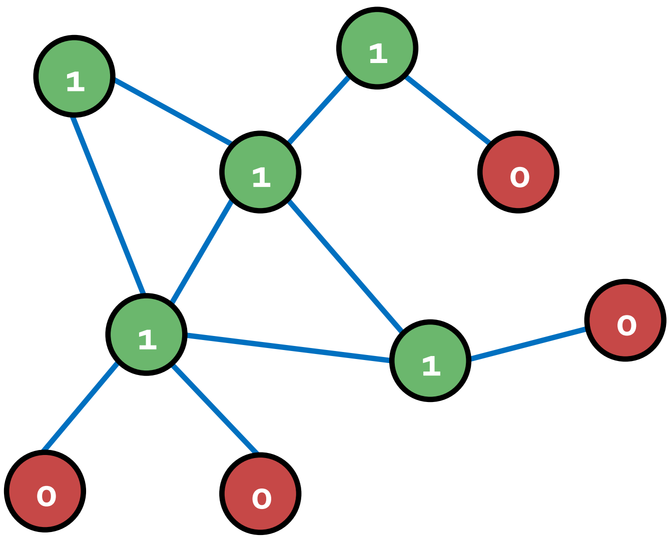
Homework 1, Q4.6

- We use GNNs to execute the BFS algorithm
- Initially, all nodes have input features 0, except a source node with feature 1
- At every step, nodes reached by BFS have embedding 1, and nodes not reached by BFS have embedding 0
- Describe the **message, aggregate, update** functions
  - Advice: Think from the **perspective of nodes** in the graph

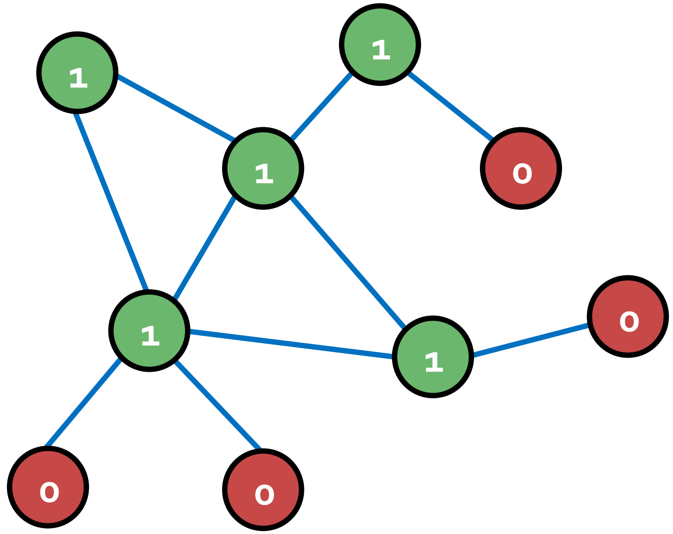


Homework 1, Q4.6

(1) Message passing

- Imagine you are a node in the graph. What information would you tell your neighbors?
  - "I have been visited by the BFS algorithm!" or "I have not been visited!"
  - Simply pass my embedding to my neighbors

$$\text{message}_{v \to u}\left(h_v^{(k-1)}, e_{v,u}\right) = h_v^{(k-1)}$$

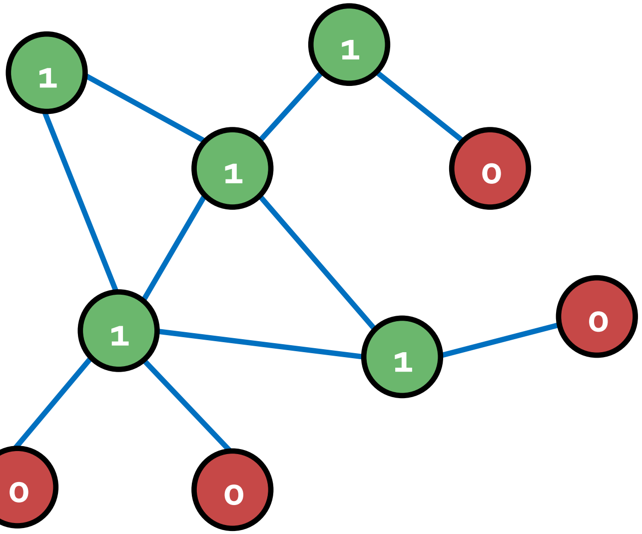


Homework 1, Q4.6

(2) Aggregation

- What information should you get from your neighbors?
  - I want to know whether any of my neighbors have been visited
- Node *u* aggregates neighbors' information via:

$$\text{aggregate}\left(\{\text{message}_{v \to u},\ \forall v \in \mathcal{N}(u)\}\right) = \max_{v \in \mathcal{N}(u)} \text{message}_{v \to u}$$

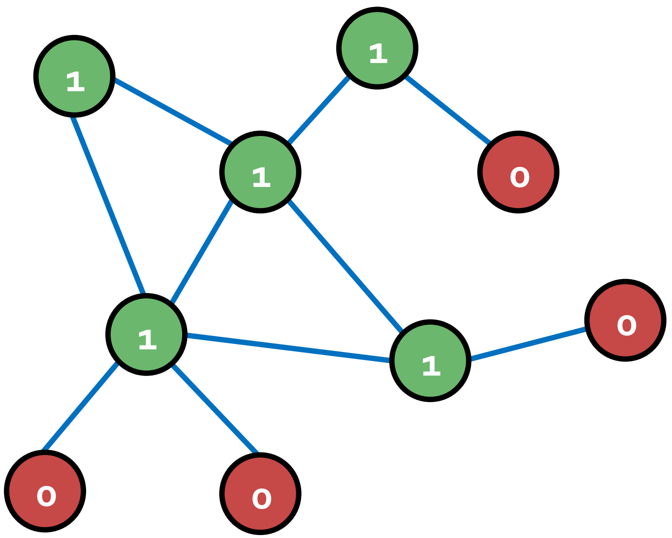


Homework 1, Q4.6

(3) Update

- Don’t forget the **self-link** to the previous embedding for node u
  - BFS: I am visited if (1) I have been visited, or (2) any of my neighbors has been visited

$$\text{update}\left(h_u^{(k-1)}, \text{aggregate}(\cdots)\right) = \max\left(h_u^{(k-1)}, \text{aggregate}(\cdots)\right)$$



- This is one solution to Q4.6, there are alternatives

Homework 2, Q3.1

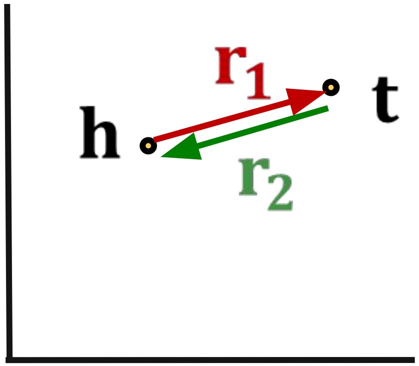
- There are **common patterns** in knowledge graph embeddings
  - **Symmetry**: A is married to B, and B is married to A
  - **Inverse**: A is teacher of B, and B is student of A
  - **Composition**: A is son of B, and C is sister of B, then C is aunt of A
- **KG method:** TransE
  - Given a triplet (h, l, t), TransE trains entity and relation embeddings to follow the equation $h + l \approx t$
- Can we use TransE to model each of the relation patterns?

Homework 2, Q3.1

- Given *(h, l, t)*, TransE equation is: $\boldsymbol{h} + \boldsymbol{l} \approx \boldsymbol{t}$
- **Key question:** For the given relation pattern, what equations should hold true?
- **Symmetry**: A is married to B, and B is married to A
- Can we use TransE to model *symmetry*? **No**
  - For two triplets *(h, l, t)* and *(t, l, h)* to both hold true, we will have: $\boldsymbol{h} + \boldsymbol{l} \approx \boldsymbol{t}$ and $\boldsymbol{t} + \boldsymbol{l} \approx \boldsymbol{h}$
  - The only possibility for both equations to be true is if $\mathbf{l} = 0$ and $\mathbf{h} = \mathbf{t}$, which is a problem since two different entities should have different embeddings

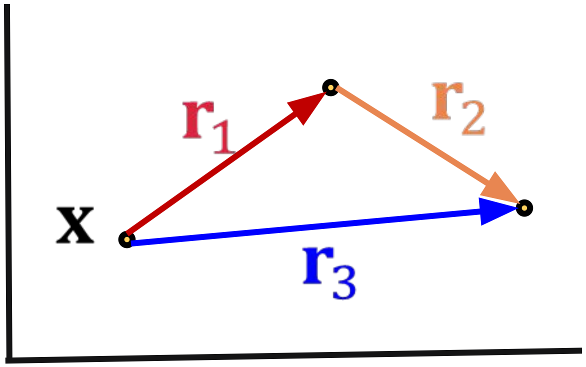
Homework 2, Q3.1

- Given *(h, l, t)*, TransE equation is: $\boldsymbol{h + l \approx t}$
- **Inverse:** A is teacher to B, and B is student to A
- Can we use TransE to model *inverse*? **Yes**
  - For two triplets *(h, r1, t)* and *(t, r2, h)* to both hold true, we will have: $h + r1 \approx t$ and $t + r2 \approx h$
  - It suffices to set the inverse relation $r2 = -r1$



Homework 2, Q3.1

- Given *(h, l, t)*, TransE equation is: $\boldsymbol{h} + \boldsymbol{l} \approx \boldsymbol{t}$
- **Composition:** A is son of B, and C is sister of B, then C is aunt of A
- Can we use TransE to model *composition*? **Yes**
  - Given three triplets, *(a, r1, b), (b, r2, c), (a, r3, c)*, where *r3* is the composition of *r2* and *r1*
  - For all triplets to be true, we will have: $a + r1 \approx b$, $b + r2 \approx c$, $a + r3 \approx c$
  - Set $r3 = r1 + r2$ for composition



Stanford CS224W: Miscellaneous Topics

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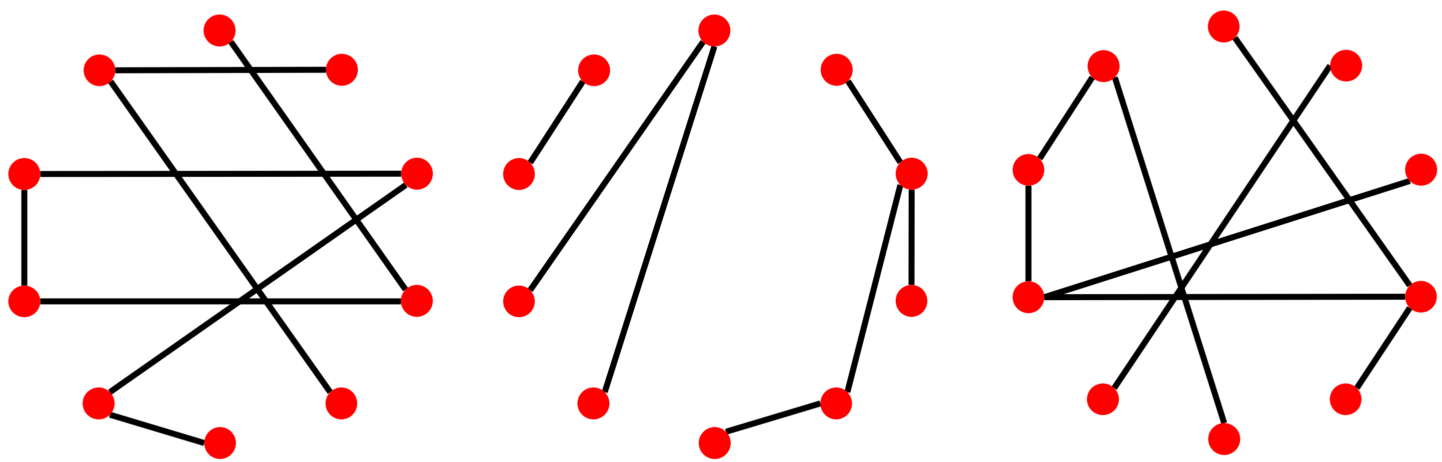
Erdös-Rényi Random Graph

- To produce an undirected graph *G = (V, E)*, the ER model uses a fixed likelihood to generate edges connecting any pair of nodes:

$$\mathbb{P}\left[(u,v) \in E\right] = r, \quad \forall u, v \in V, u \neq v$$



n = 10
r= 1/6

Erdös-Rényi Random Graph

What is the expected average node degree, **E[*d*]**, of a graph generated by ER?

- **Key idea**: summing the edge connectivity over nodes to compute the expected node degree

$$|E| = \frac{1}{2}\sum_{u\in V}\sum_{v\in V\setminus\{u\}} 1\cdot\mathbb{1}[(u,v)\in E]$$

$$\mathbb{E}[|E|] = \frac{1}{2}\sum_{u\in V}\sum_{v\in V\setminus\{u\}} 1\cdot\mathbb{E}[\mathbb{1}[(u,v)\in E]]$$

$$= \frac{1}{2}\sum_{u\in V}\sum_{v\in V\setminus\{u\}} 1\cdot r$$

$$= \frac{|V|(|V|-1)}{2}r$$

$$= \binom{|V|}{2}r$$

$$d = \frac{2|E|}{|V|}$$ ⇦ total degree in G

$$\mathbb{E}[d] = \frac{2\mathbb{E}[|E|]}{|V|}$$

$$= (|V|-1)r$$

All the Best

- All the best with your exam preparation!