CS5284 : Graph Machine Learning

Administrative (Week 3)

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QR Attendance

Please, scan the new below QR image for attendance.

A new state-of-the-art image generative model was released yesterday (Aug 26) https://developers.googleblog.com/en/introducing-gemini-2-5-flash-image

The model is in preview via the Gemini API (US$0.039/image): https://ai.google.dev/gemini-api/docs/image-generation

```python
from google import genai
from PIL import Image
from io import BytesIO

client = genai.Client()

prompt = "Create a picture of my cat eating a nano-banana in a fancy restaurant under t

image = Image.open('/path/to/image.png')

response = client.models.generate_content(
    model="gemini-2.5-flash-image-preview",
    contents=[prompt, image],
)

for part in response.candidates[0].content.parts:
  if part.text is not None:
    print(part.text)
  elif part.inline_data is not None:
    image = Image.open(BytesIO(part.inline_data.data))
    image.save("generated_image.png")
```

Admin

Tutorials

- Venue and TA in charge of your tutorial group :
  - TUT 1 : COM03-01-20, Mr. Ryoji Kubo, e1583584@u.nus.edu
  - TUT 2 : COM03-01-22, Mr. Wang Jiaming, e0942816@u.nus.edu
  - TUT 3 : COM03-01-25, Mr. Liu Nian, e1154528@u.nus.edu

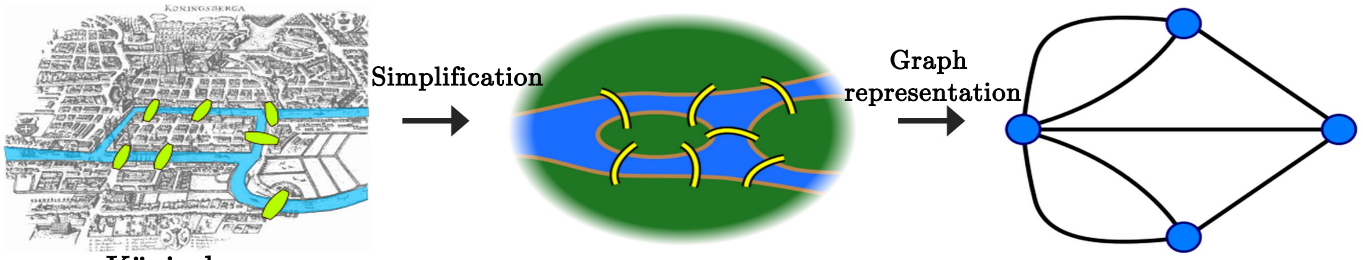


- Attendance :
  - Attendance will be recorded via QR code during tutorials.
  - It will count toward your attendance grade.
- Please, contact your TA if you have any questions or need clarification about the module !

In-lecture questions

In-lecture question [Answer]

- Can we find a path through the city (starting from any place) that crosses each bridge once and only once? Justify your response.



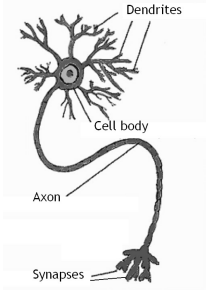
Königsberg
City

Source: Wikipedia.

- Answer : Mathematician Leonhard Euler (1707-1783) proved that it is not possible (it is only feasible if the graph has even degree that allows cycles).

In-lecture question [Answer]

- In the human brain, some 86 billion neurons form 100 trillion axon connections to each other. Can we model the human brain as a sparse graph?
  - n = ?
  - |E| = ?



One neuron
Input is a dentrite
Output is a synapse
Connection is an axon

Human biological neural network

- Answer : $n = 86.10^9 \Rightarrow n \approx 10^{11} \Rightarrow n^2 \approx 10^{22}$ (if fully connected graph)

$|E| = 100.10^{12} = 10^{14} \ll 10^{22} \Rightarrow$ Sparse graph with the % of non-zero elements is $10^{14} / 10^{22} = 10^{-8}$ or 0.000001%.

Student questions

Student question

Would you consider a class of graphs with |E| = θ(n log n), or more generally, |E| = O(n polylog(n)) to be a sparse graph? What about the cases where |E| = θ(n^1.25), |E| = θ(n^1.5) and |E| = θ(n^1.75)?

- Any graph with complexity less than O(n^2) is mathematically sparse.
- What is important is not the complexity but the sparsity pattern like human/artifical brain network, transportation network, molecules, etc.
- This is the data property that we want to capture to train our network, such that it can generalize to new data sampled from the same (complex) distribution.

Student question

1. When the graph is huge (billions of nodes and edges like facebook network), how are we storing them in real life? I assume the adjacency matrix is super huge and probably cannot fit in a single machine. And computational wise, are we doing anything to address this challenge?

- A graph with billions of nodes and edges can be stored efficiently as an edge list (start_node, end_node) rather than a full adjacency matrix.
- Although the matrix would be huge, it is very sparse!
- Modern libraries such as NVIDIA SparseCUDA, DGL, and PyG exploit sparse linear algebra to handle large-scale graphs efficiently.

Student question

2. For edge connection, do we have situation that 2 nodes are connected with multiple edges? For example, 2 people in real life can be both friend, colleague, landlord etc, how do we model such kind of diverse connection in graph?

- If you allow multiple distinct edges between the same two nodes (Alice and Bob: friend edge, colleague edge, landlord-tenant edge), that structure is called a multi-graph.
- Each edge can carry a label or type describing the relationship. In practice, this is often modeled as a heterogeneous graph, where edges belong to different categories.

Questions?