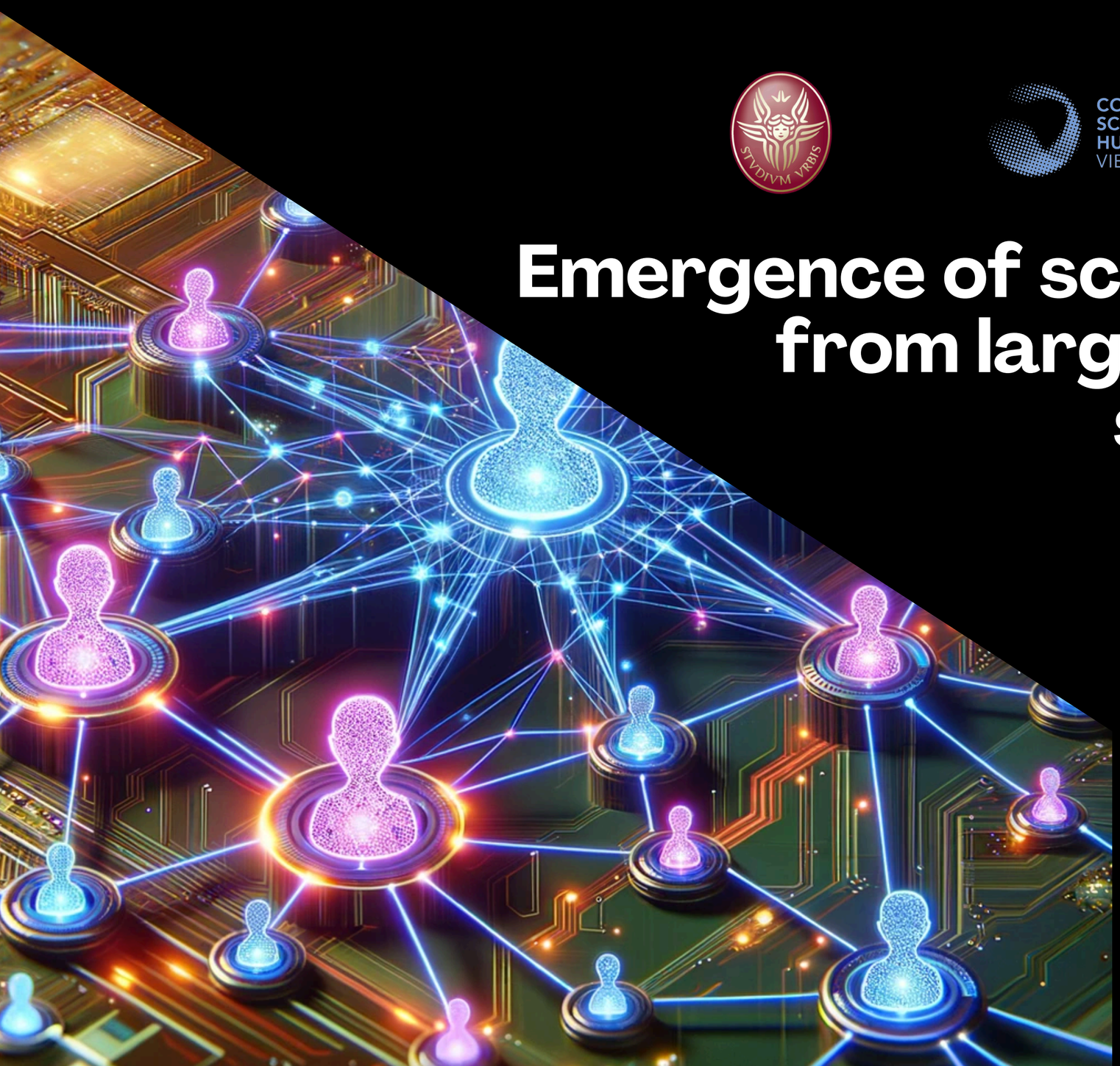


COMPLEXITY SCIENCE HUB VIENNA

CENTRO RICERCHE ENRICO FERMI

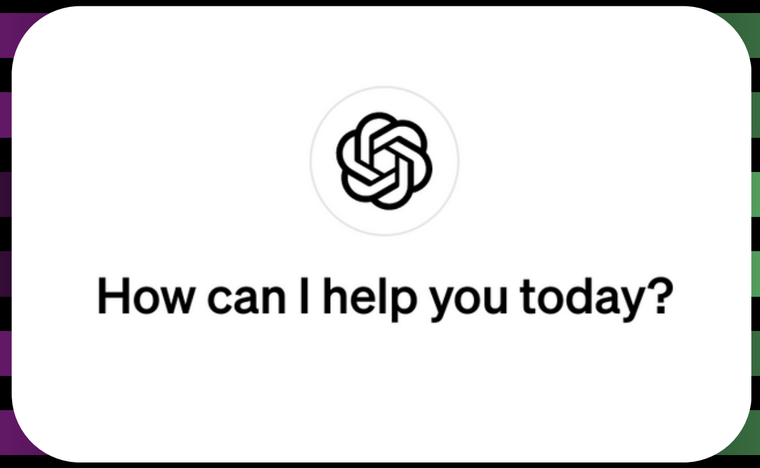
Emergence of scale-free networks from large language models social interactions

Presentation by

Giordano De Marzo

NetSciX 2024

ChatGPT and LLMs



ChatGPT impact has been huge

- One year old
- 180 million users

There are countless applications

- Coding
- Text writing and editing
- Translation

LLMs in Social Science

Surveys

LLMs can be used to generate replies to surveys.

Experiments

LLMs can be used in social experiment without humans.

ABM

LLMs can be exploited as agents in social simulations.

Science

BACK TO VOL. 380, NO. 6650

PERSPECTIVE | SOCIAL SCIENCE

AI and the transformation of social science research

IGOR GROSSMANN , MATTHEW FEINBERG, DAWN C. PARKER,

NICHOLAS A. CHRISTAKIS, PHILIP E. TETLOCK, AND

WILLIAM A. CUNNINGHAM fewer Authors Info &

Generative Agents

Memory

Agents are endowed with a memory stream that allows them to remember past actions

Autonomous Agents

Agents reflect on what they experience and take decision autonomously

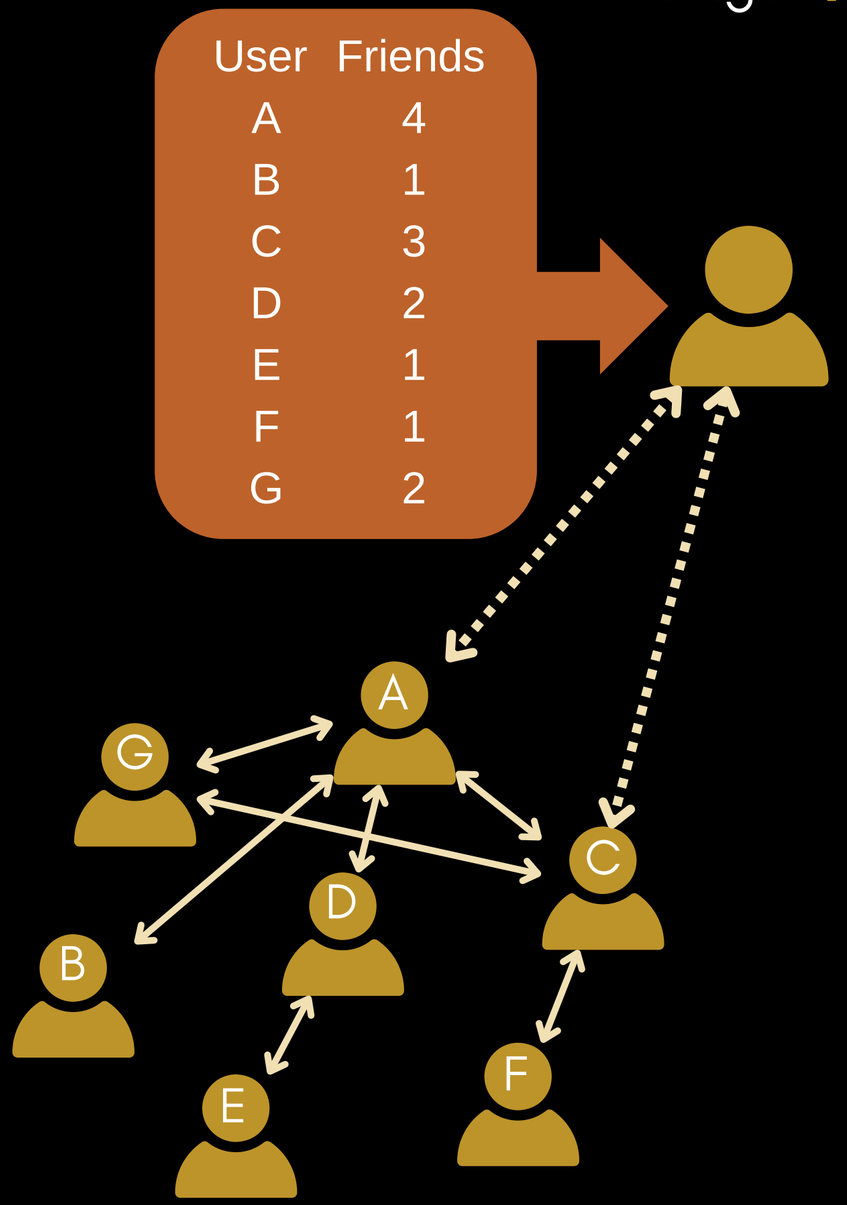
Park, Joon Sung, et al. "Generative agents: Interactive simulacra of human behavior." arXiv preprint arXiv:2304.03442 (2023).

Simulating Network Growth

Barabasi-Albert like process:

- at each time step a new node is added
- it links to already existing nodes
- a LLM decides which connections to establish

We exploit GPT3.5-Turbo as LLM



Barabási, Albert-László, and Réka Albert. "Emergence of scaling in random networks." science 286.5439 (1999): 509-512.

Prompt

- You've entered a virtual social network.
- You're tasked with connecting to exactly {m} individuals from the list below.
- Each individual is accompanied by their current number of connections.
- Please indicate your choices by replying with their names, separated by commas and enclosed within square brackets.

X7v 5

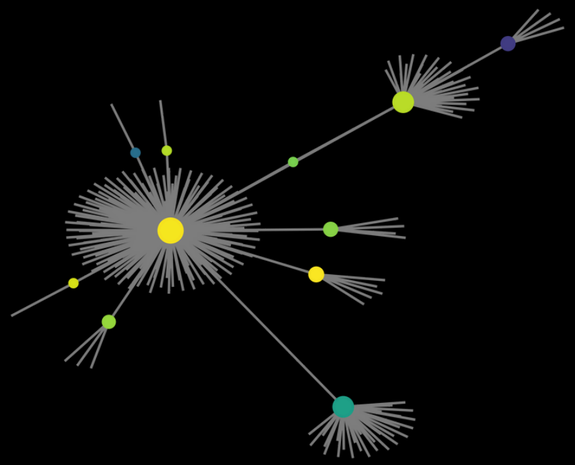
keY 1

91c 17

...

Hub-and-Spoke topology

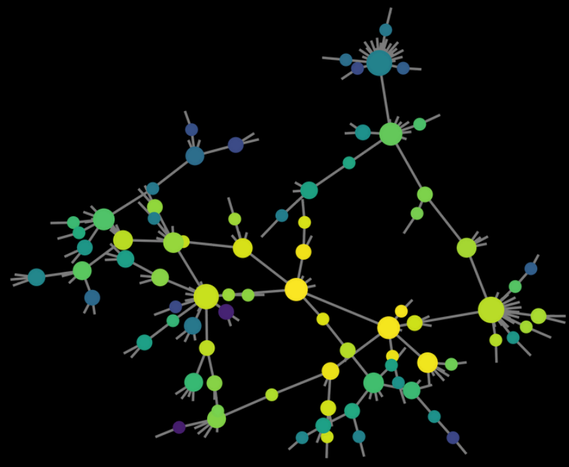
Hub-and-Spoke



Node age

Degrees not shown to agents

Broad



Node age

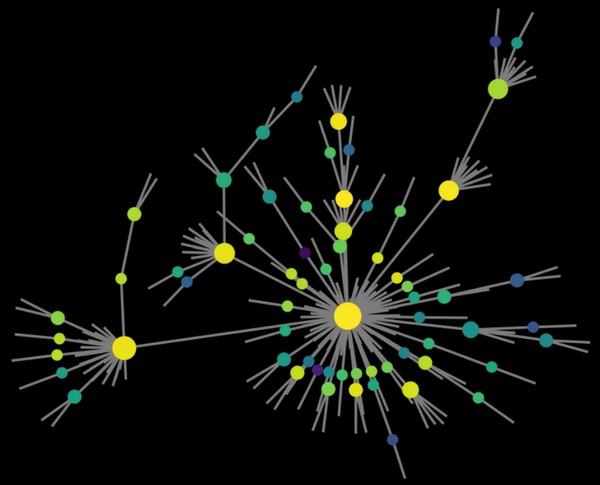
We would expect a random network, but we obtain a more complex structure!

There is a bias!

Broad topology

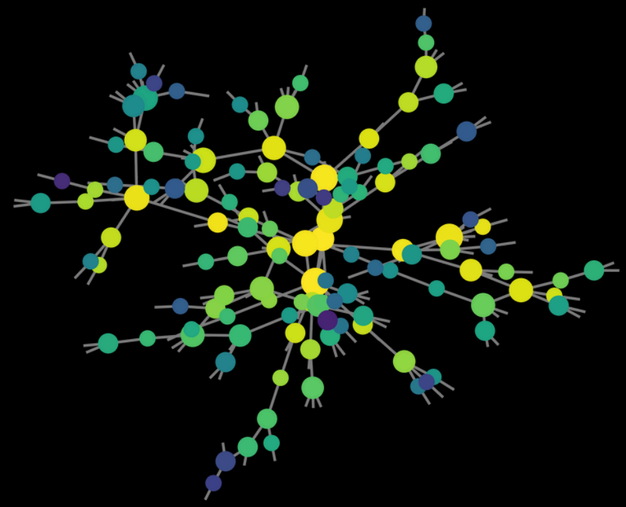
We shuffle nodes names at each iteration to remove the bias due to token prior

Broad



Degrees not shown to agents

Random



Node age

Node age

This is like the Barabasi-Albert model!

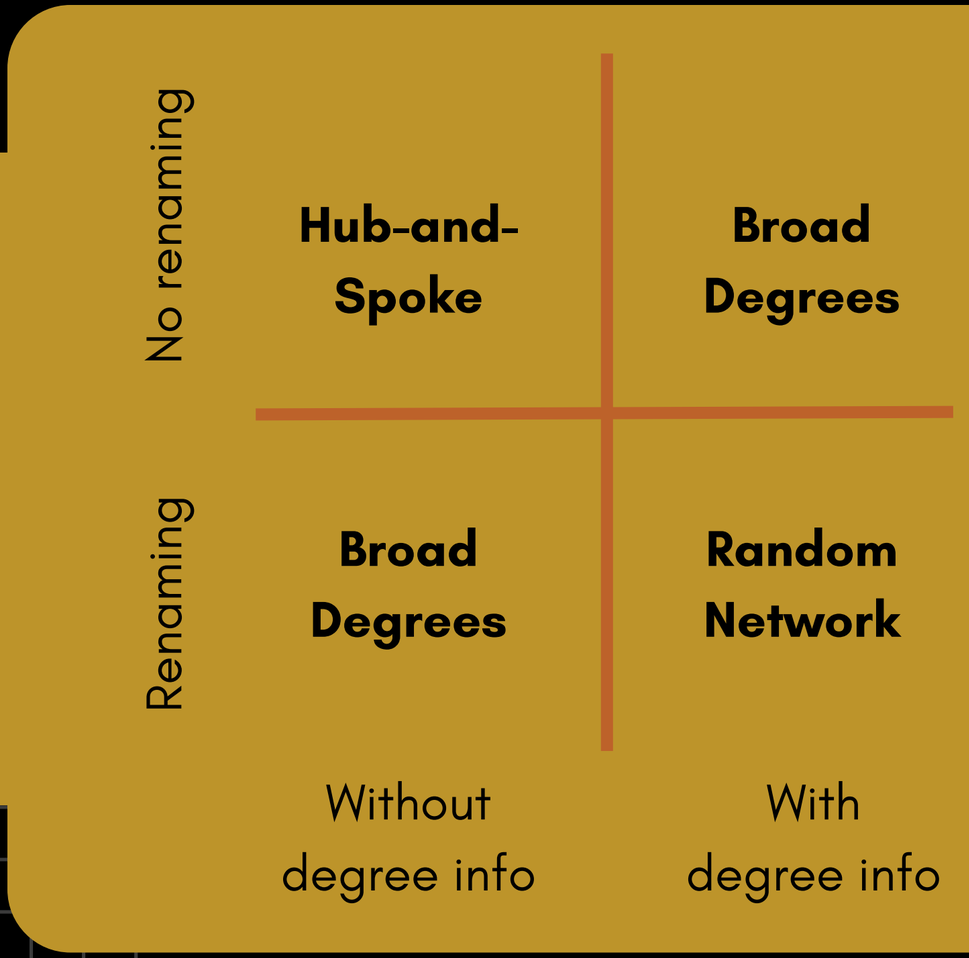
Network Structures

Power Law Bias

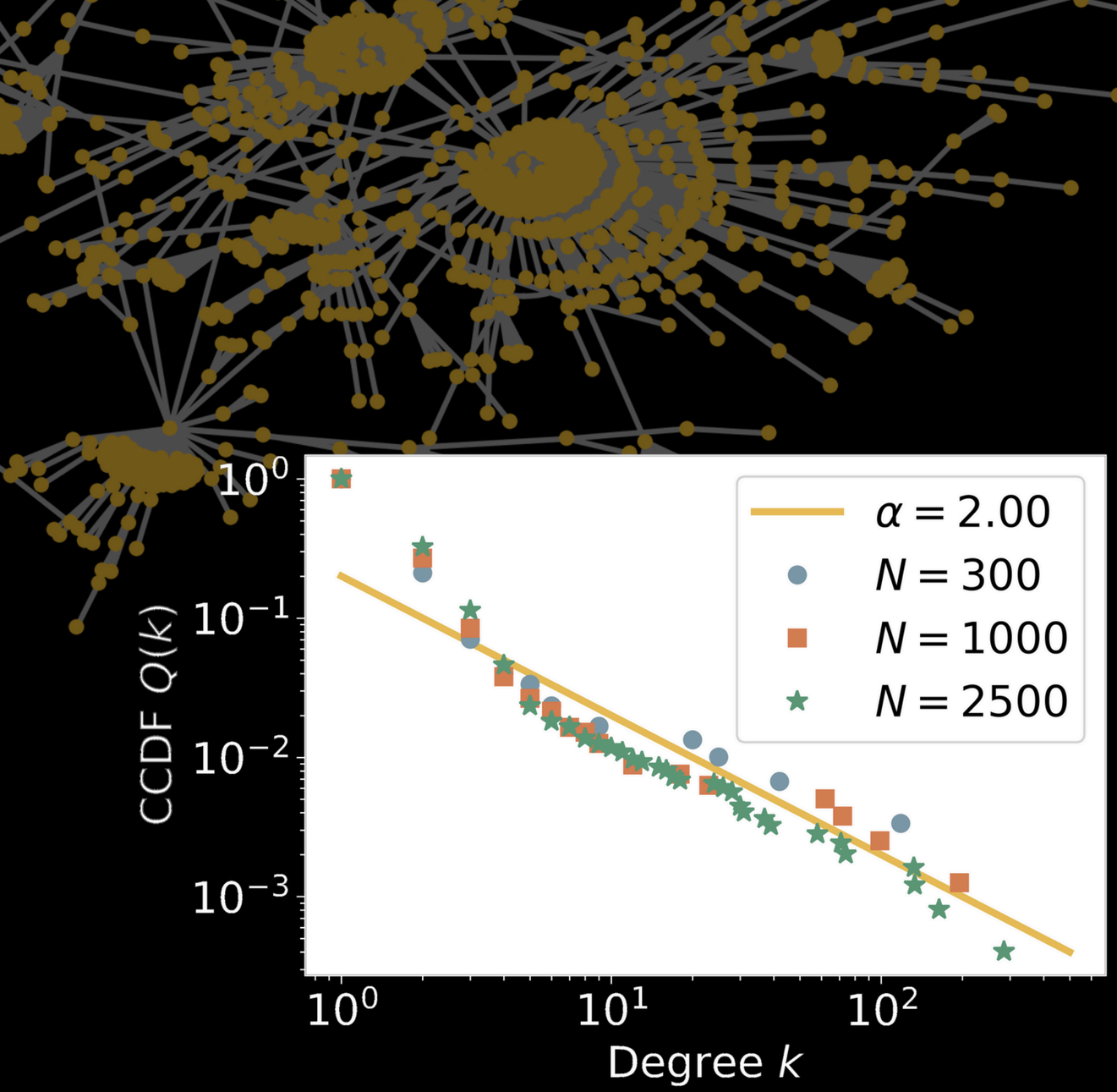
ChatGPT shows a power law like bias in token generation.

Popularity

Disclosing the number of connections of users strongly influences the network structure.



Scale-Free Networks



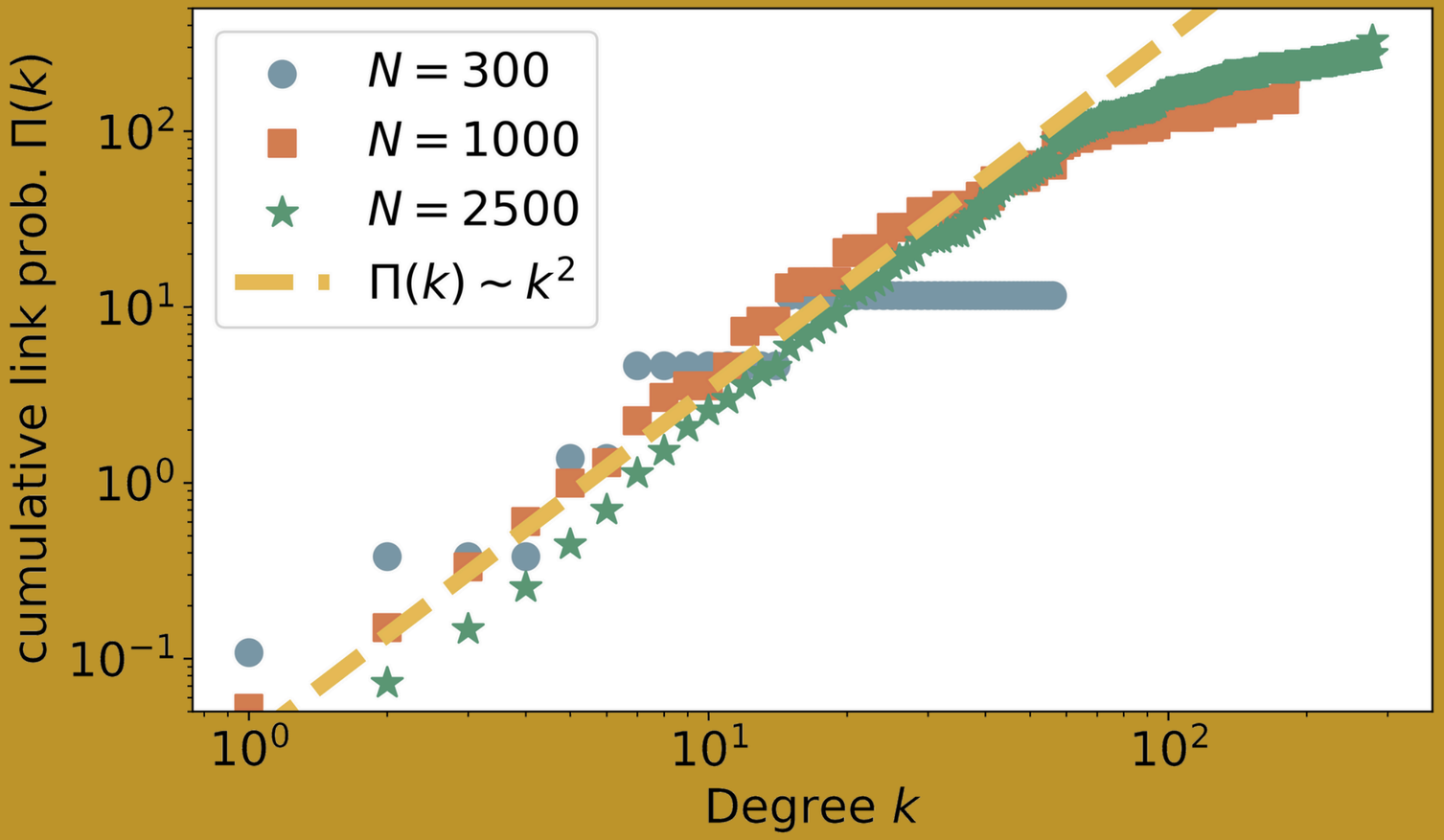
We focus on the **renaming-degree** scenario:

- as the system grows, the degree CCDF's shows a power law tail
- this indicates a scale-free topology.

Linear Preferential Attachment

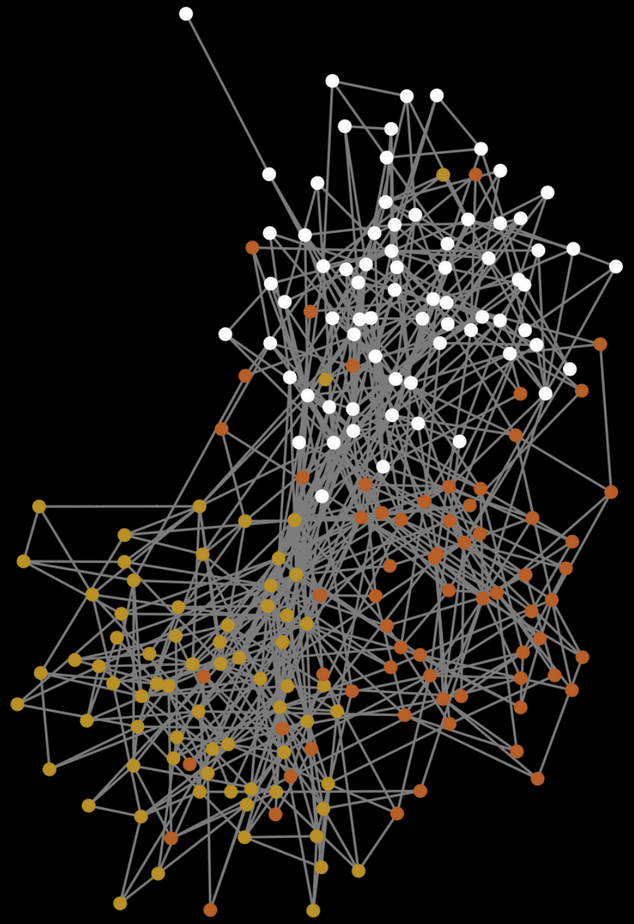
We reconstruct the cumulative linking probability.

Generative agents show linear preferential attachment!



Newman, Mark EJ. "Clustering and preferential attachment in growing networks." Physical review E 64.2 (2001): 025102.

Homophily



Instead of specifying the number of connection we can show agents other features.

When ethnicity, gender or political leaning are shown, communities get formed.

Conclusions

01 LLMs can be used in agent based simulations

02 Biases and priors must be carefully studies

03 LLMs spontaneously form scale free networks

04 LLMs show linear preferential attachment

Thank you for your attention!

De Marzo, Giordano, Luciano Pietronero, and David Garcia. "Emergence of Scale-Free Networks in Social Interactions among Large Language Models." arXiv preprint arXiv:2312.06619 (2023).