Lab 8. Story generator

- You're about to develop a program that can read a story and then write a new story in the same style as the original story
- A new story will be based on a random selection of symbols from the original story

Generating random stories

- Input story – old German saying:

What I spent, I had; what I saved, I lost; what I gave, I have.

- Consider each symbol to be the entire word

Current symbol	Possible next symbols (list)
what	I
I	spent, had, saved, lost, gave, have
spent	I
saved	I
lost	what
gave	I
have	-

We can generate a new story:

- Pick symbol at random: **I**
- Pick at random any symbol that can follow I: **lost**
- After lost can be only: **what**
- Then: **I**
- Finally: **have**

I lost what I have

What is the best data structure to store symbol frequencies?

What I spent, I had; what I saved, I lost; what I gave, I have.

Current symbol	Possible next symbols (list)
what	I
I	spent, had, saved, lost, gave, have
spent	I
saved	I
lost	what
gave	I
have	-

We can generate a new story:

- Pick symbol at random: **I**
- Pick at random any symbol that can follow I: **lost**
- After lost can be only: **what**
- Then: **I**
- Finally: **have**

I lost what I have

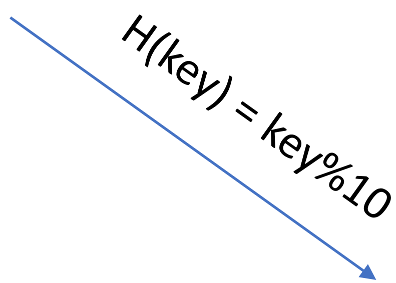
What is the best data structure to store these data?

Current symbol	Possible next symbols
a	b:3, c:4, n:12
b	a:33, o:21
c	a:44, r: 12
d	r: 12, o:23

Lab 8. Implement Hash Map – using Hash Table with separate chaining

- Stores (key, value) pairs
- Collisions are resolved by storing a list

[(11, 5), (21, 3), (33, 1)….]



array index	List of (key, val) pairs
0	
1	(11,5) → (21,3)
2	
3	(33,1)
4	
5	
6	
7	
8	
9	

Lab 8. hash table as a value

- Stores (key, value) pairs, where key is a symbol, and value is another hash table! (list of hash tables for separate chaining)

Key: current symbol

Current symbol	Possible next symbols
a	b:3, c:4, n:12
b	a:33, o:21
c	a:44, r: 12
d	r: 12, o:23

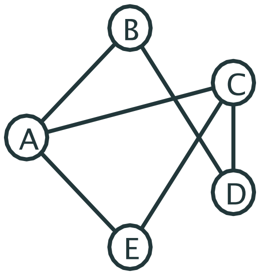
Value: another hash map (next symbol, count)

Graph ADT
Modeling with graphs

Lecture 24

By Marina Barsky

What is a graph?



A graph *G* = (*V*, *E*) is an Abstract Data Type that consists of 2 collections:

- **Set** of objects (*vertices*, nodes)

  V = {A, B, C, D, E}

- **Relation** on set of objects (*edges*)

  E = {(A,B), (A,C), (A,E), (B.D), (C,D), (C,E)}

Running time of Graph algorithms uses **two** numbers:

- n = |V|
- m = |E|

Vertices and edges

- Edge *e* connects vertices *u* and *v*
- Vertices *u* and *v* are end points of edge *e*
- Vertex *u* and edge *e* are incident
- Two edges are also called incident, if they are incident to the same vertex
- *Vertices u* and *v* are adjacent
- *Vertices u* and *v* are neighbors

- This is a vocabulary for undirected graph

The degree of a vertex

- The degree of a vertex is the number of its incident edges.
  I.e., the degree of a vertex is the number of its neighbors

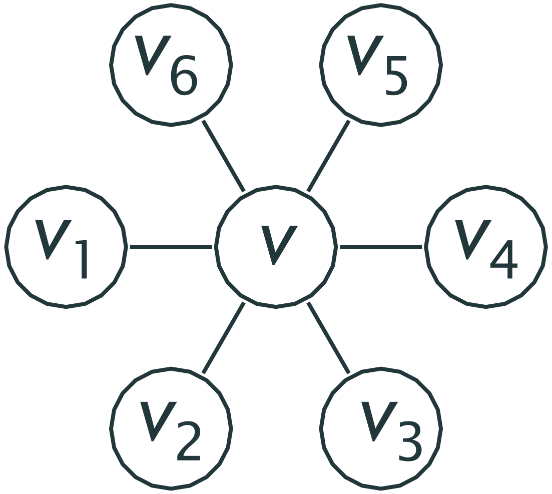
- Let's denote the degree of a vertex v by deg(v)

- The degree of a graph is sum of degree of its vertices.
  The degree of undirected graph with m edges is $2m$

Example

The degree of *v* is 6: deg(v) = 6

The degree of v_6 is 1: deg(v_6) = 1



The degree of *this graph*: deg(G) = 2m = 12

Directed graphs

Nodes: {A,B,C,D}

Edges (ordered pairs):
{(A,C),(D,A),(B,D),(C,B)}

Edges (ordered pairs):
{(C,A),(D,A),(B,D),(C,B)}

These two graphs are different!

Graphs can model many things

Trivial:

- Mobile networks
- Computer networks
- Social networks

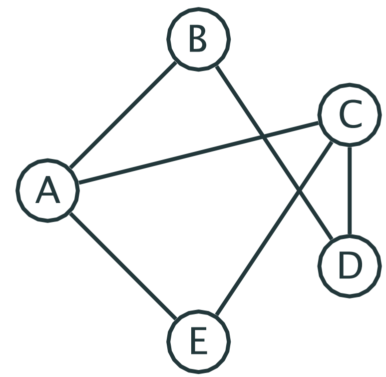
Non-trivial:

- Web pages
- States of the game
- …

Graph: airlines

Graph: airlines

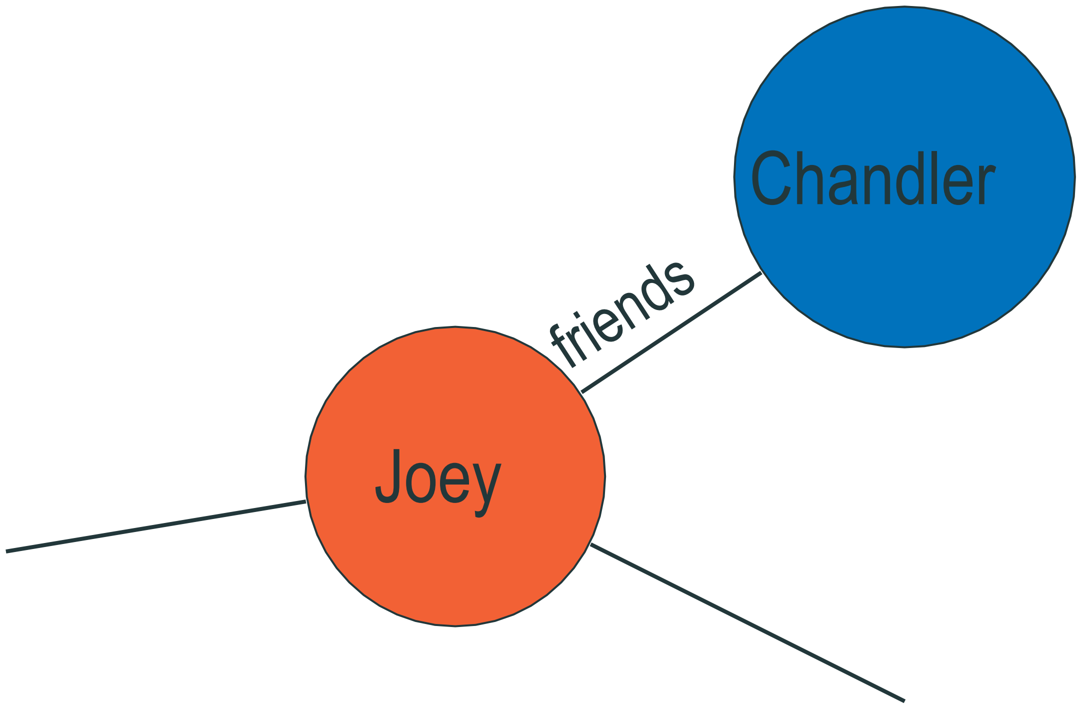
- Is there a direct flight from A to D?
- With one stop?
- With exactly two stops?



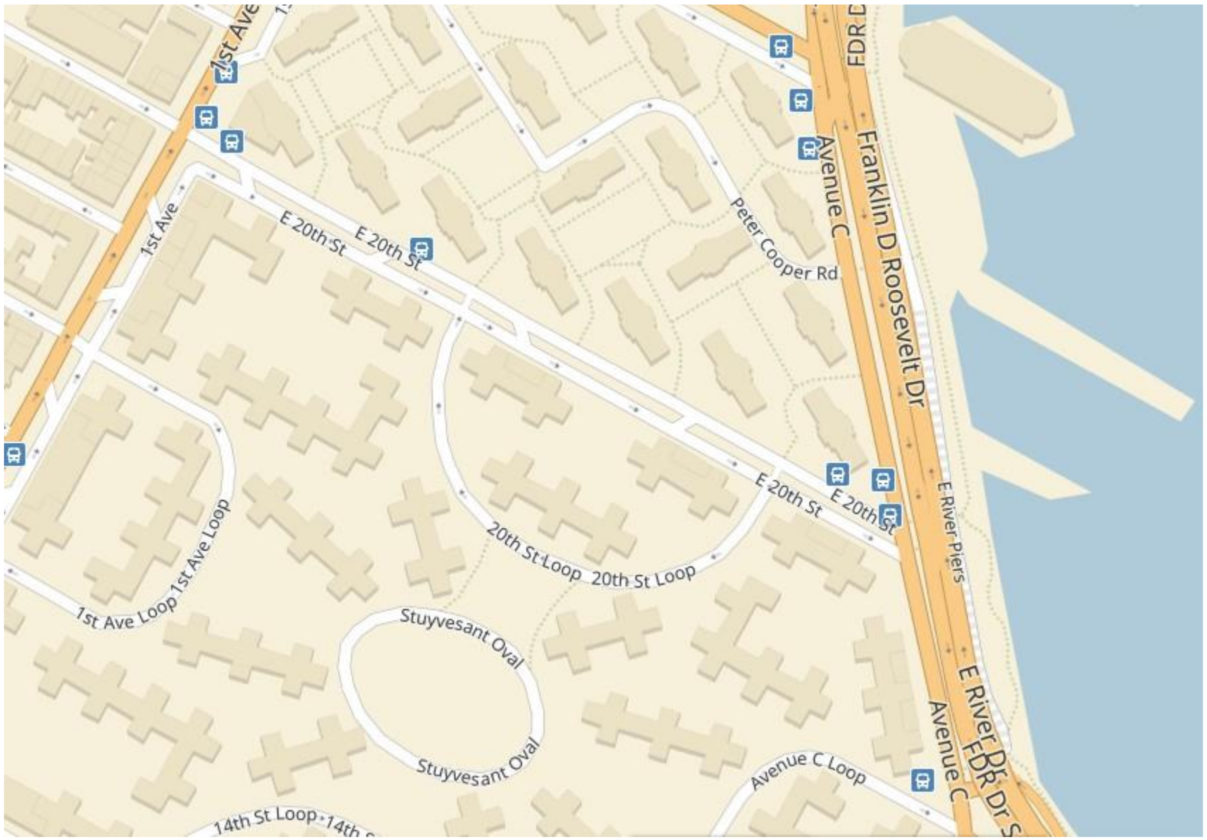
Graph of flights between 5 cities

Facebook graph

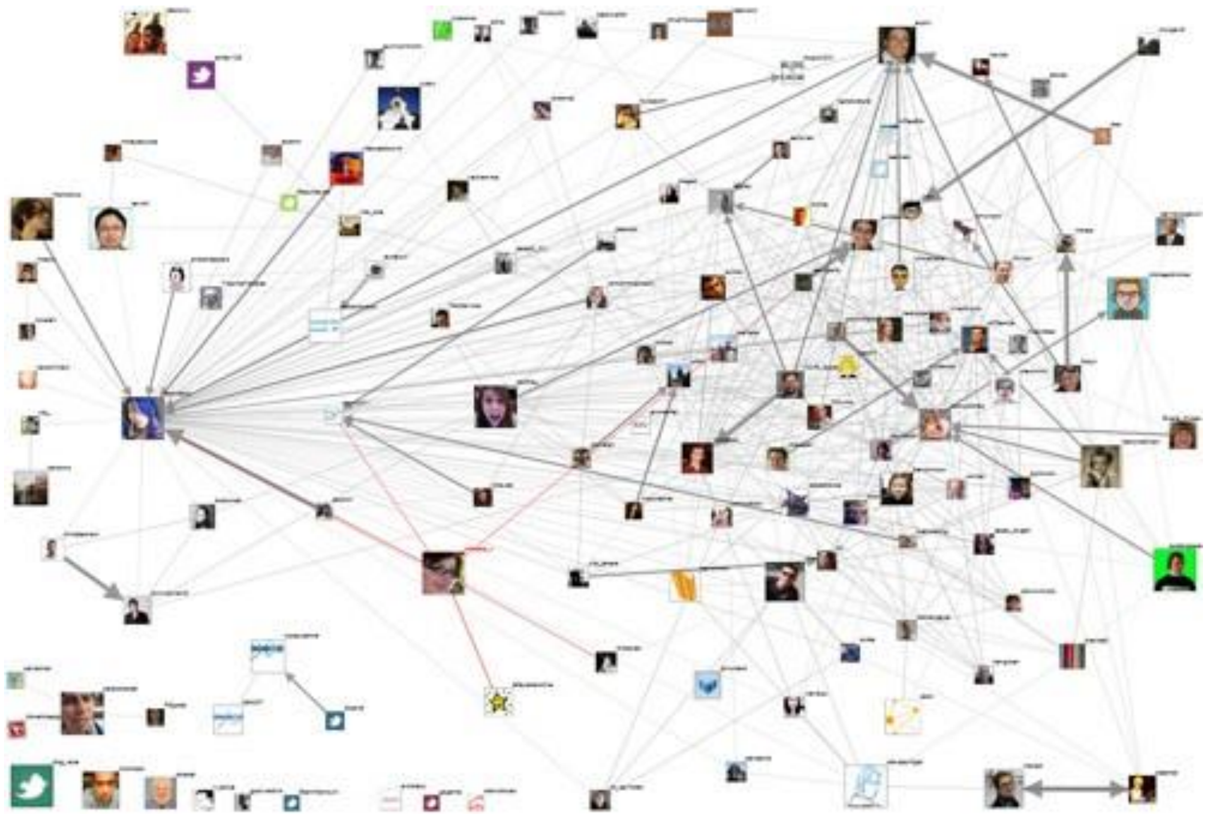
Facebook graph



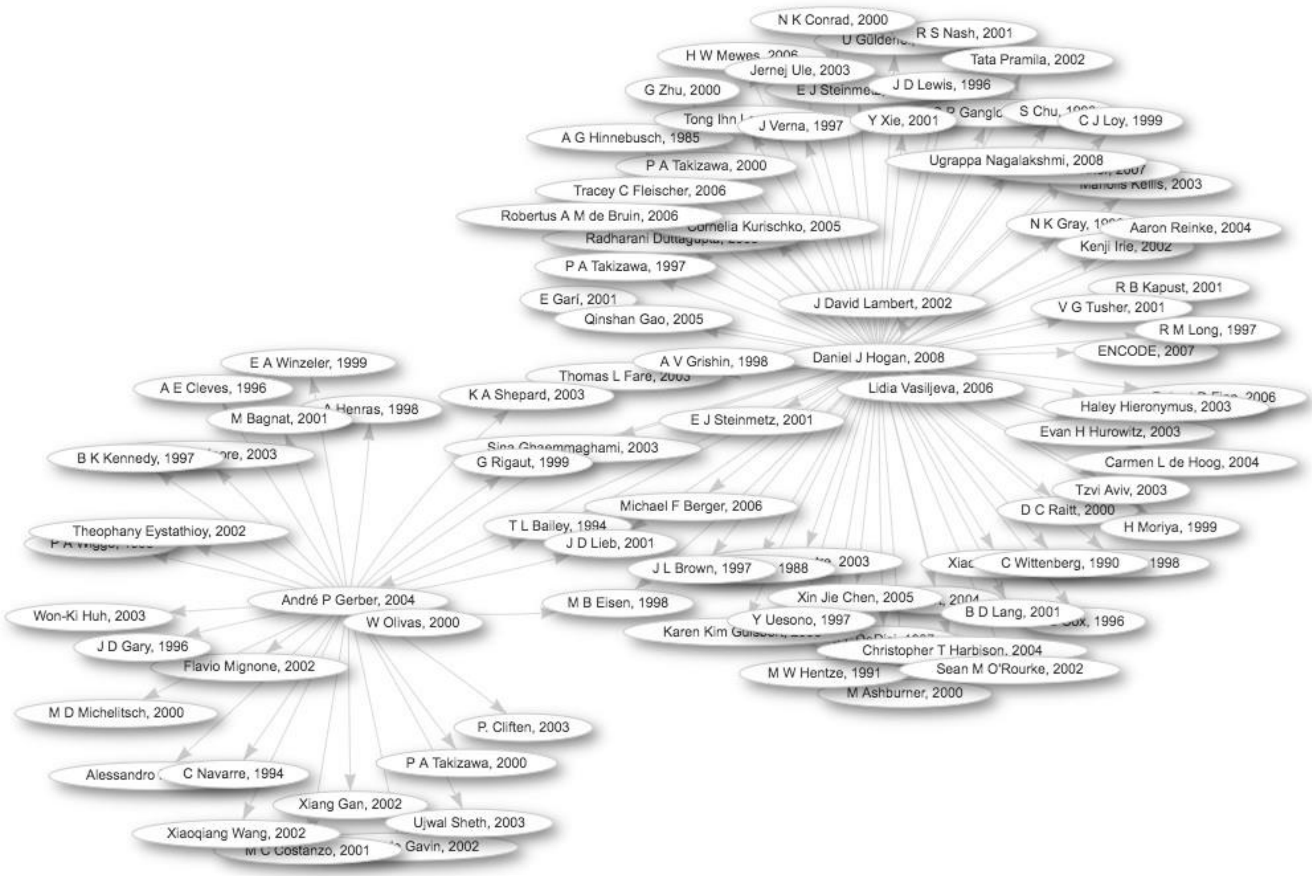
Directed graph: one-way streets



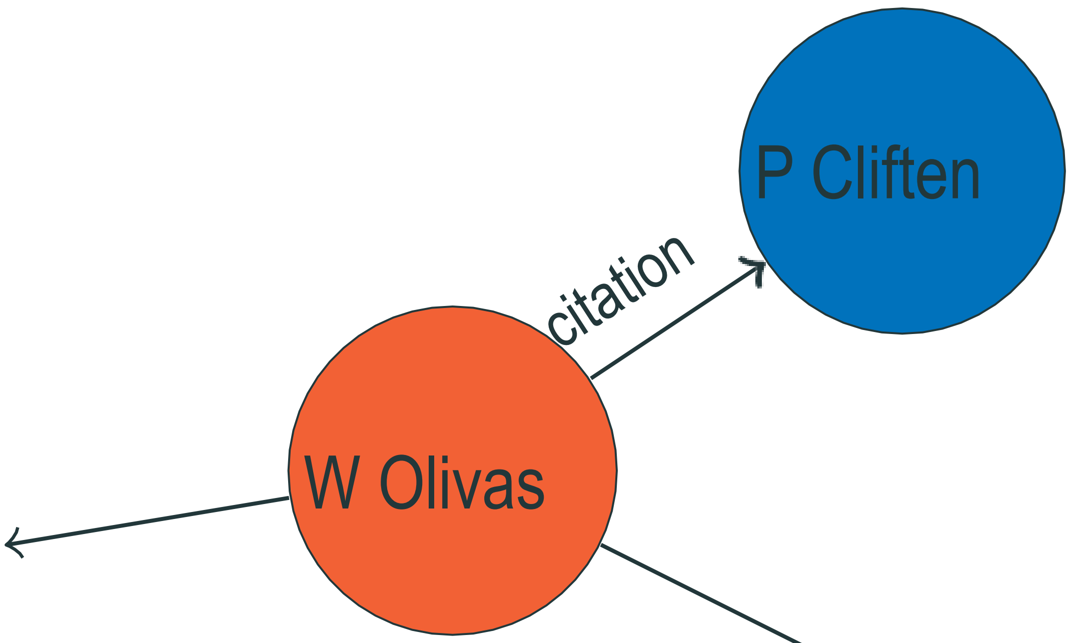
Directed graph: followers



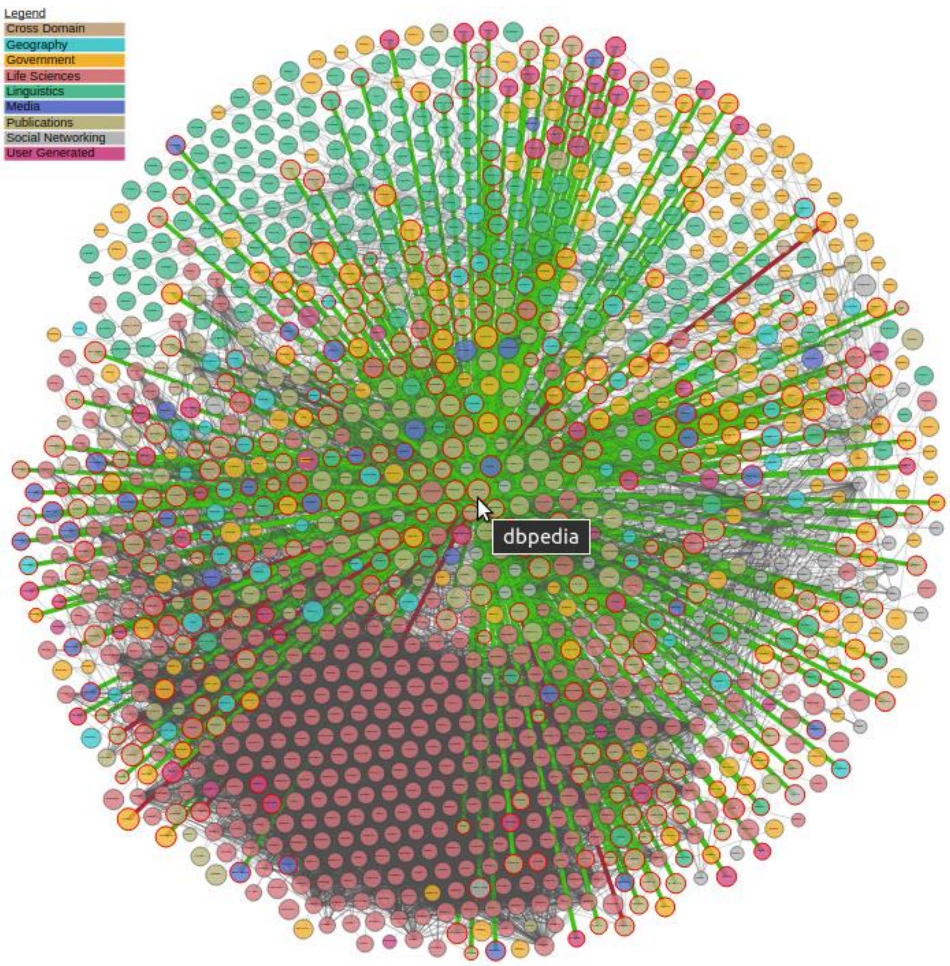
Directed graph: citations



Directed graph: citations

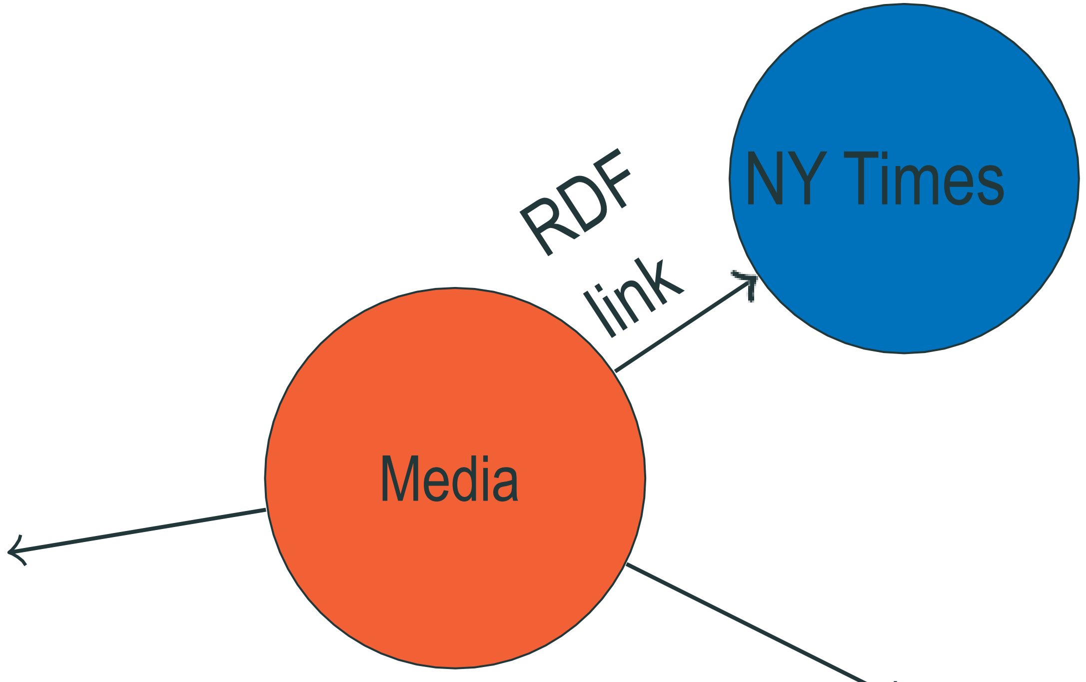


Linked Open Data Diagram

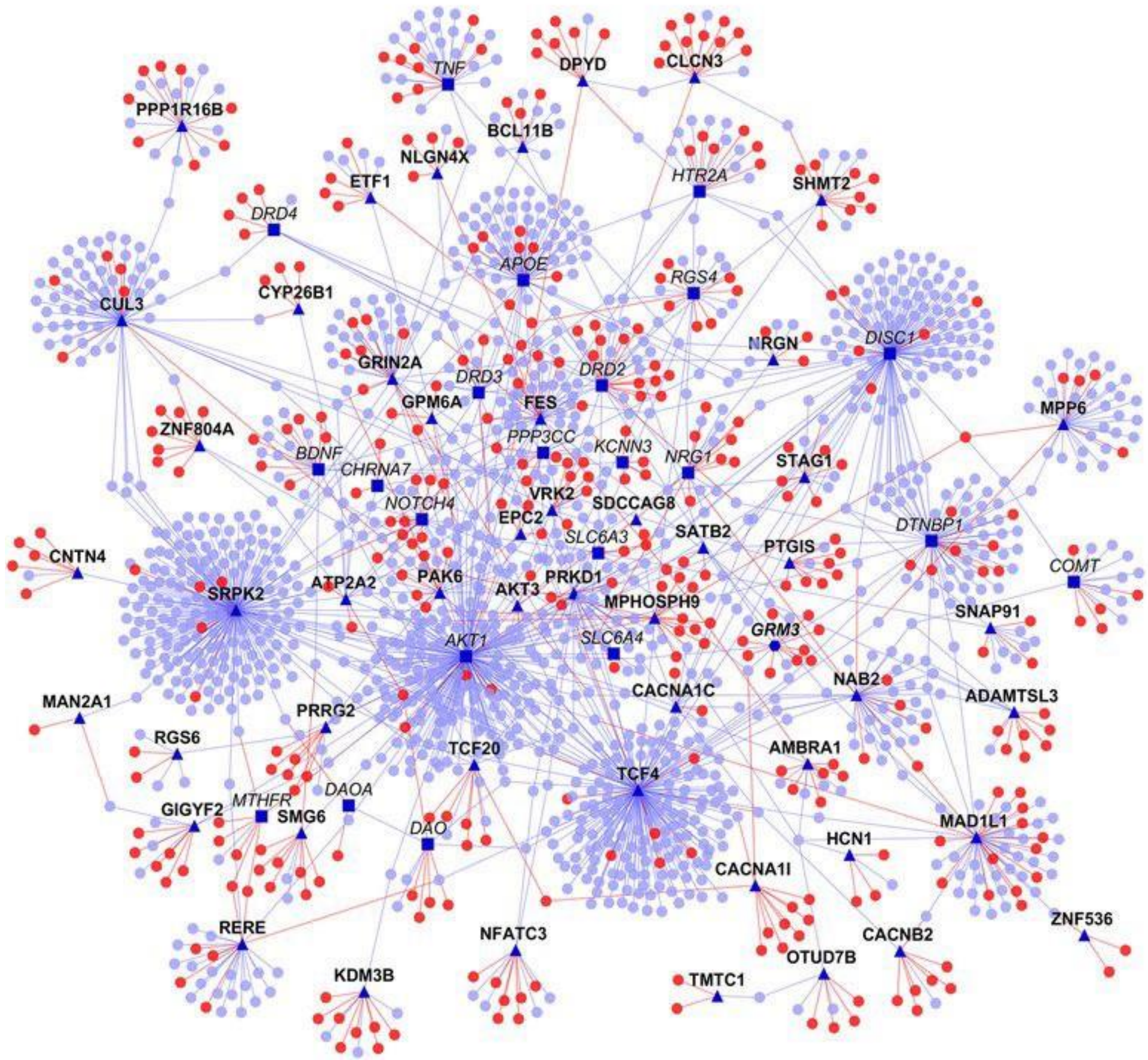


DBpedia: structured cross-domain knowledge

Linked Open Data Diagram



Schizophrenia Protein-Protein Interaction (PPI)



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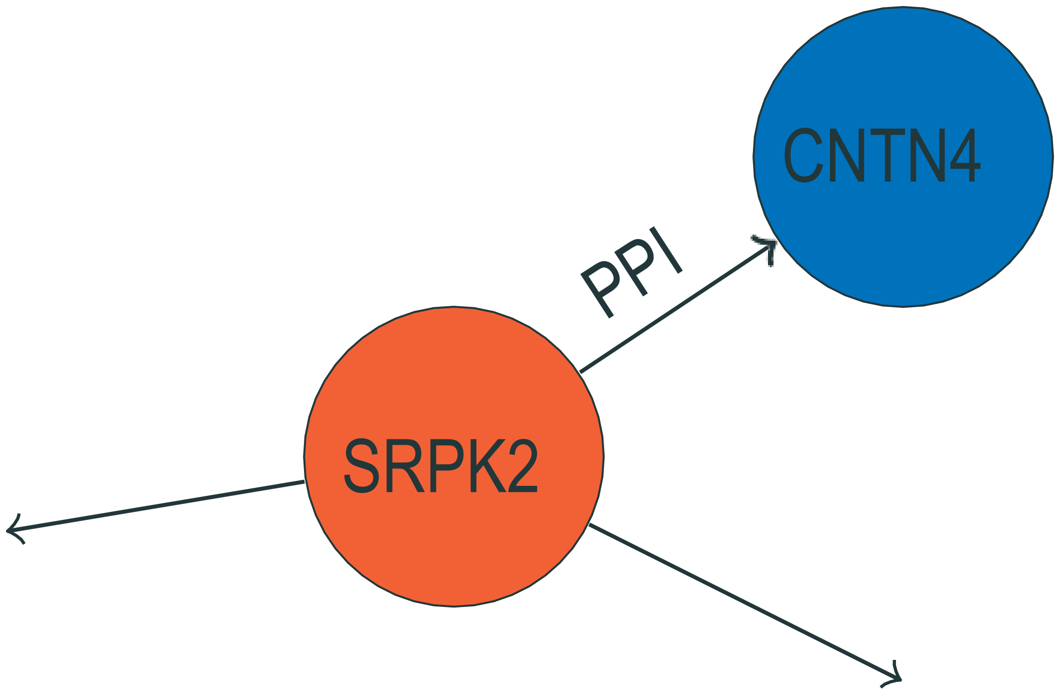
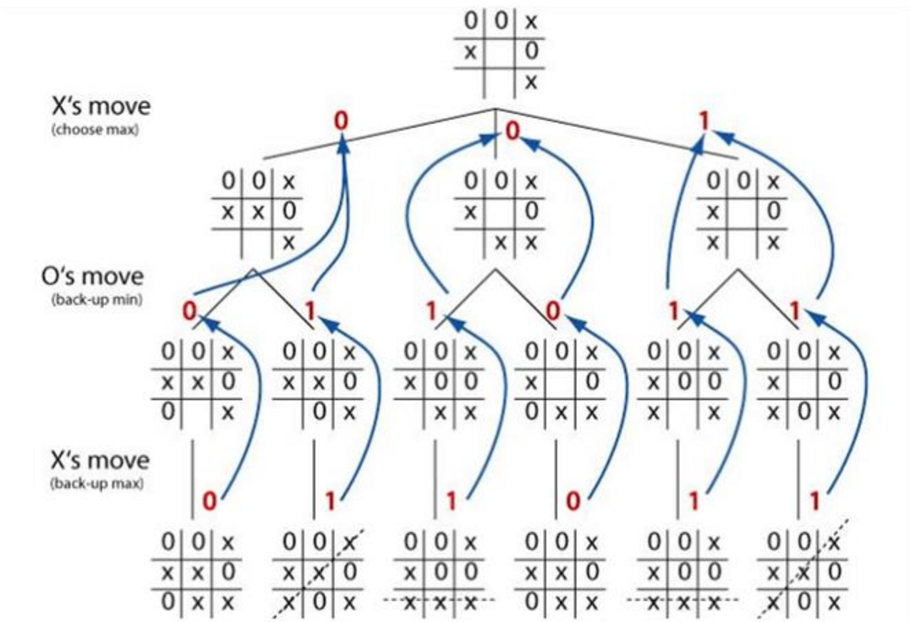
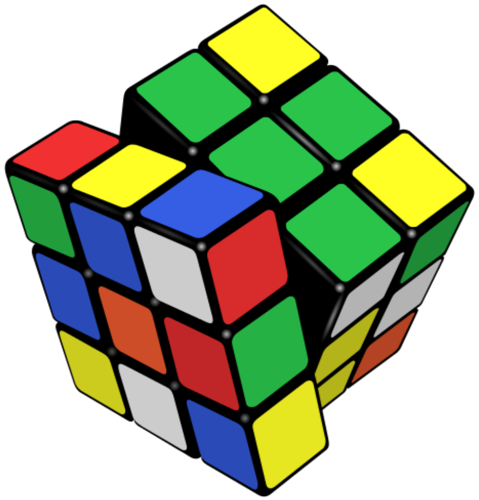


Graph of states: explicit vs Implicit

- A graph is *explicit* if all its vertices and edges are stored.
- Often we work with an *implicit graph* which is conceptual or unexplored.



There are only 3^9 = 19,683 different states in Tic-Tac-Toe. We can store the entire graph and compute the optimal strategy as a path through this graph



The Rubik's Cube has 43 quintillion states.
It can be solved without explicitly listing all vertices (states)

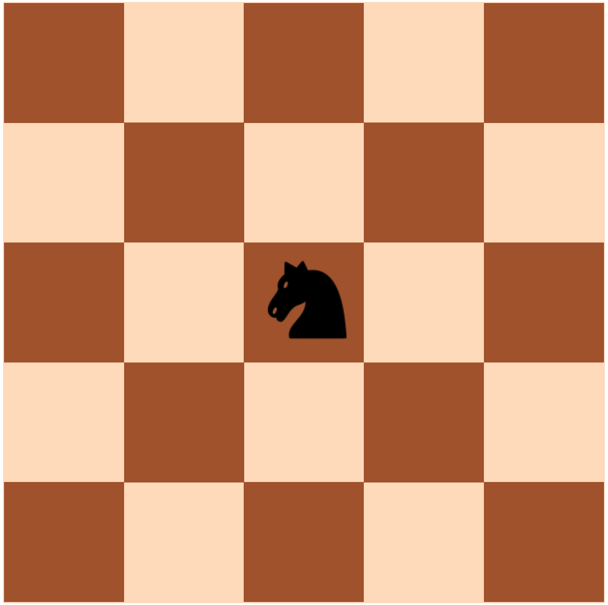
Paolo Guarini di Forli, Italy
15th - 16th Century

Modeling with graphs

Solving puzzles

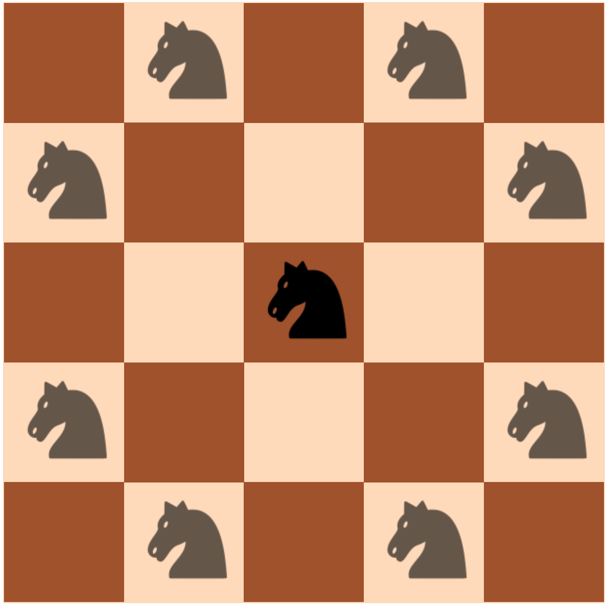
Chess Knight

A chess knight can move in an **L** shape in any direction

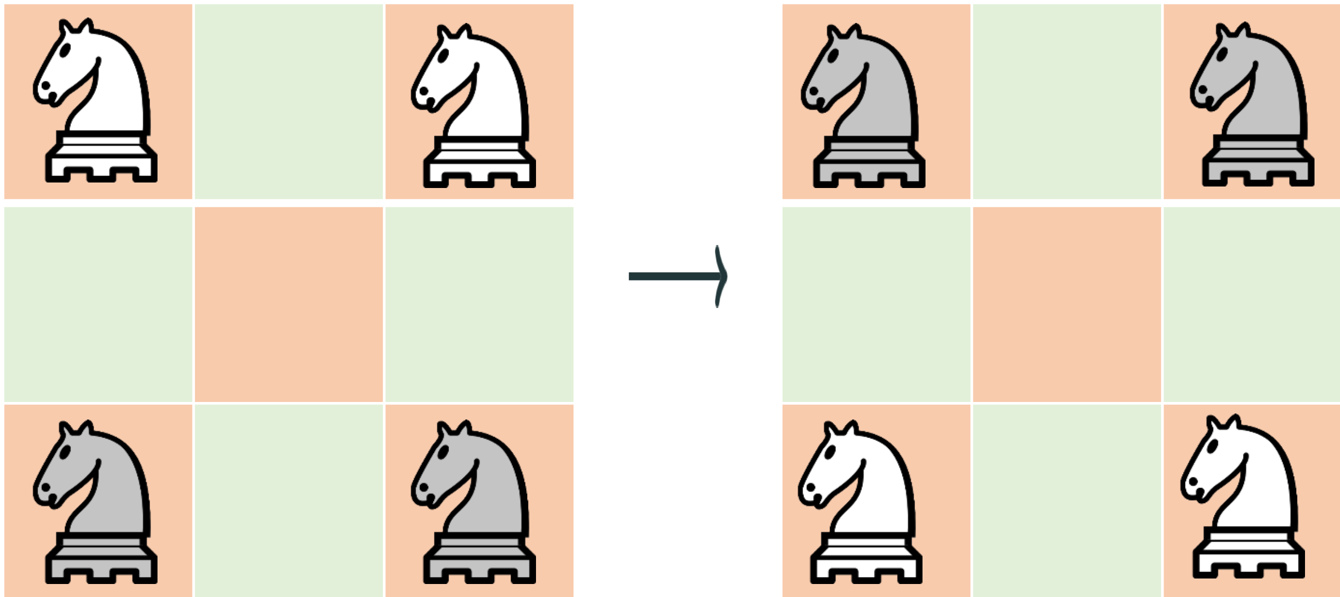


Chess Knight

A chess knight can move in an **L** shape in any direction



Guarini's Puzzle

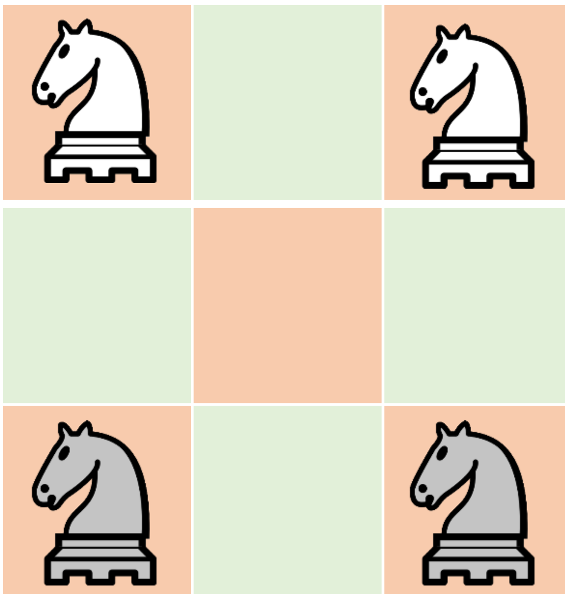


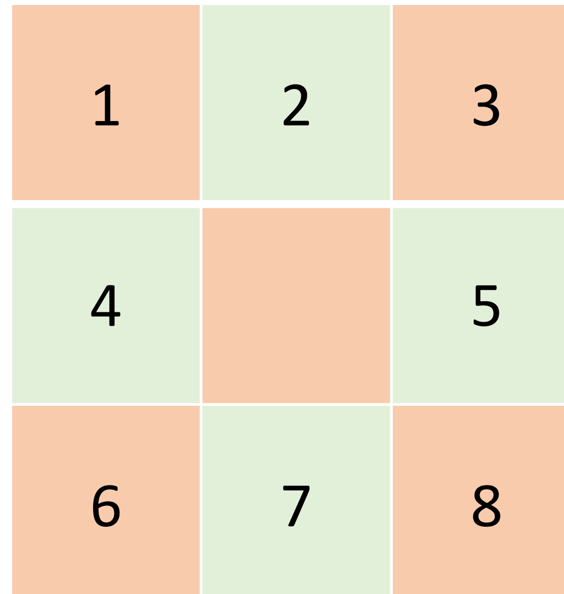
There are four knights on the 3×3 chessboard: the two white knights are at the two upper corners, and the two black knights are at the two bottom corners of the board.

The goal is to switch the knights in the minimum number of moves so that the white knights are at the bottom corners and the black knights are at the upper corners.

Try it out http://barsky.ca/knights/

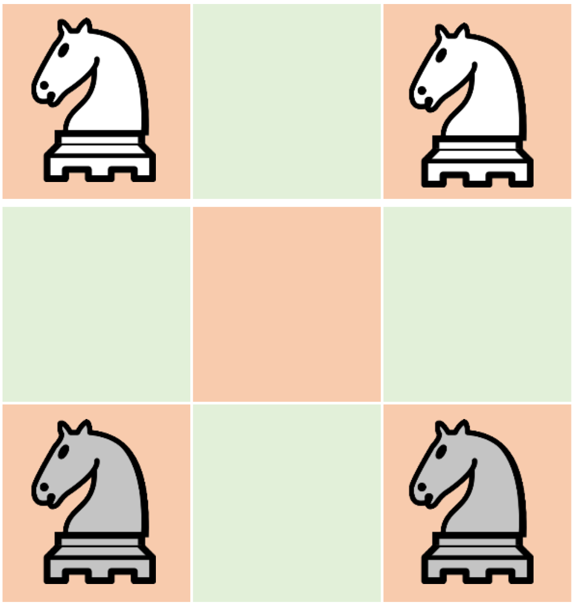
Graph: nodes

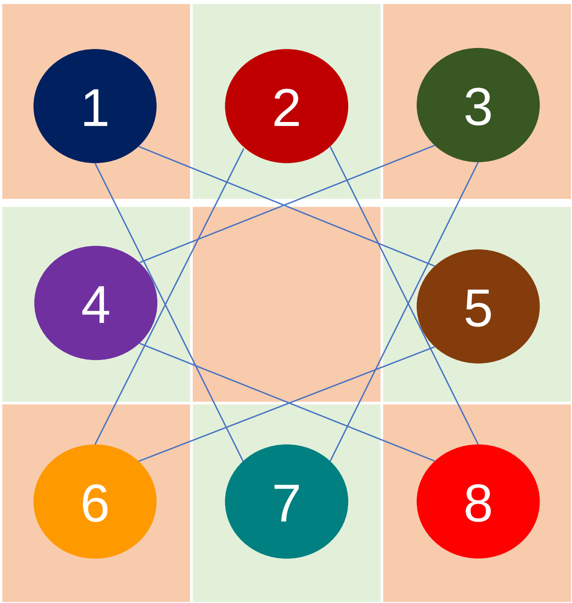




Each position is a node in a graph

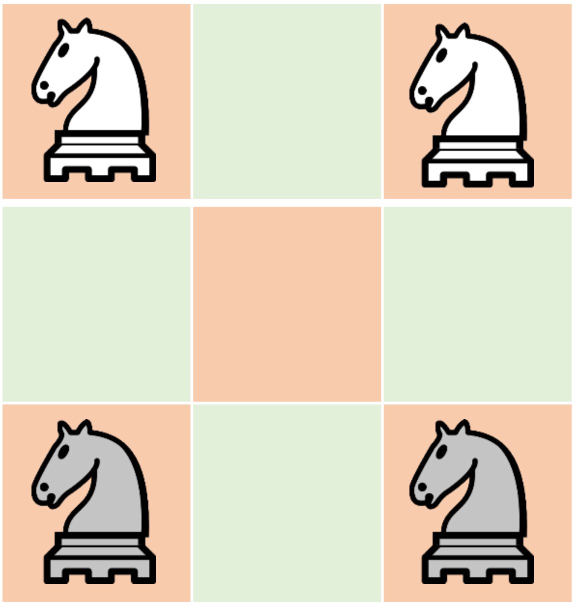
Graph: edges

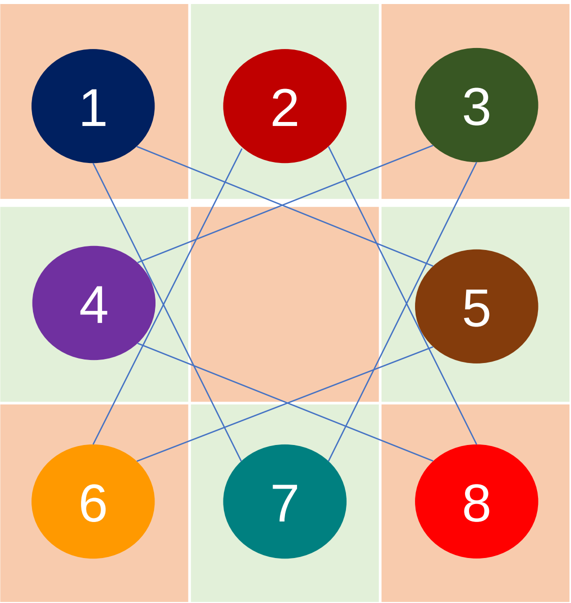




There is an edge between the nodes if you can go from one node to another by 1 knight move

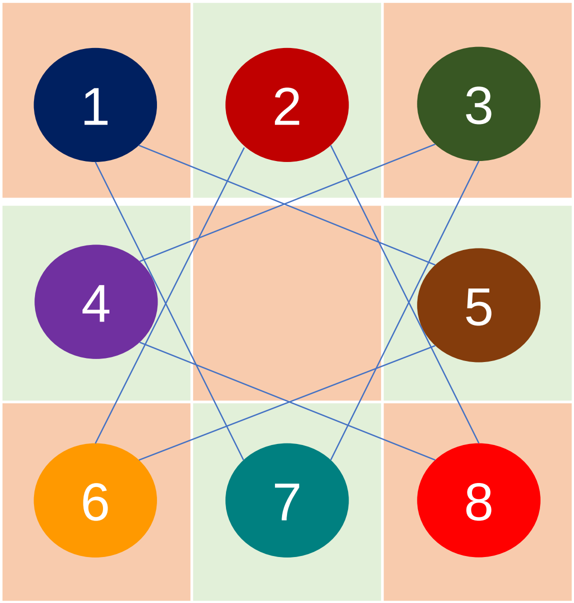
Graph: edges

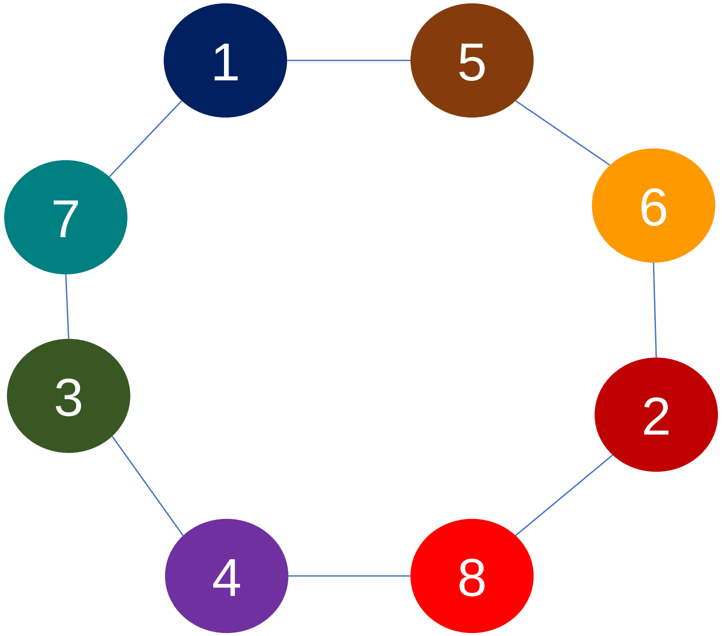




Does it help to solve the puzzle?

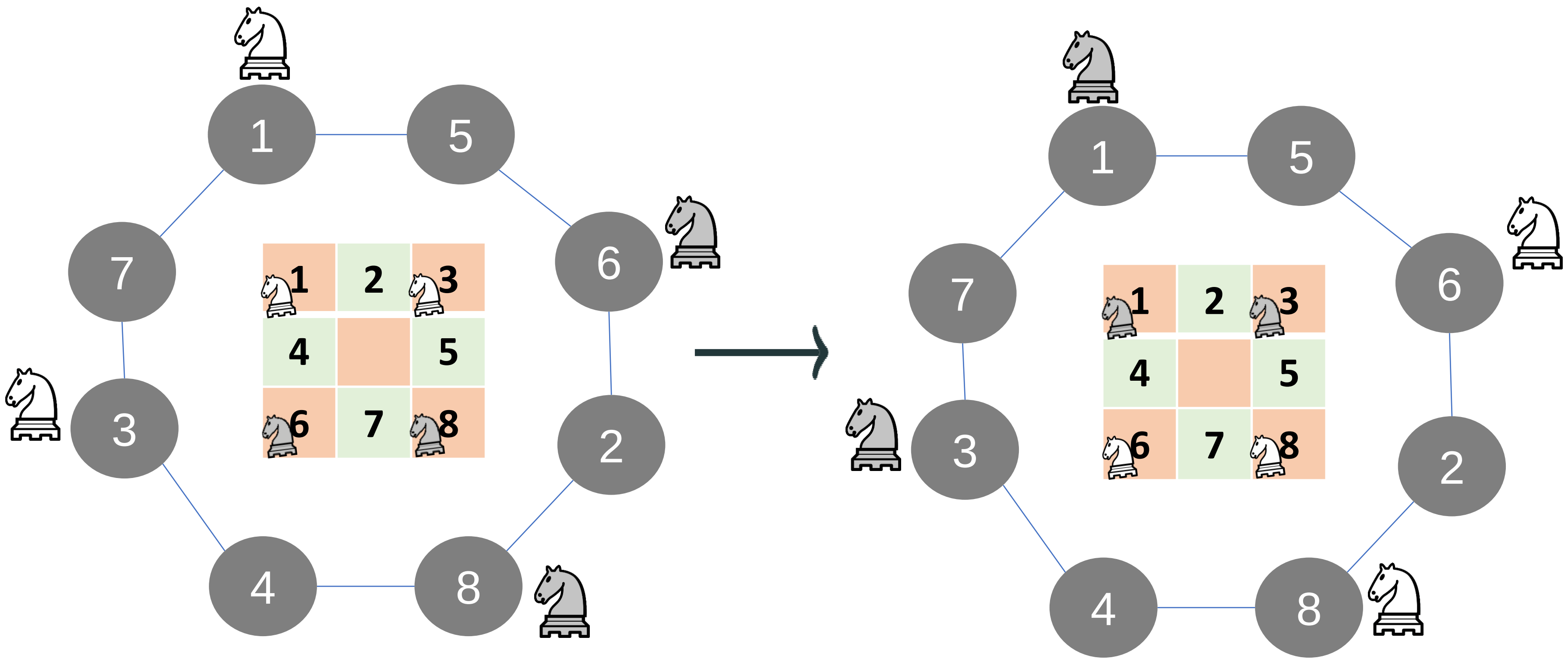
Unfold the graph!





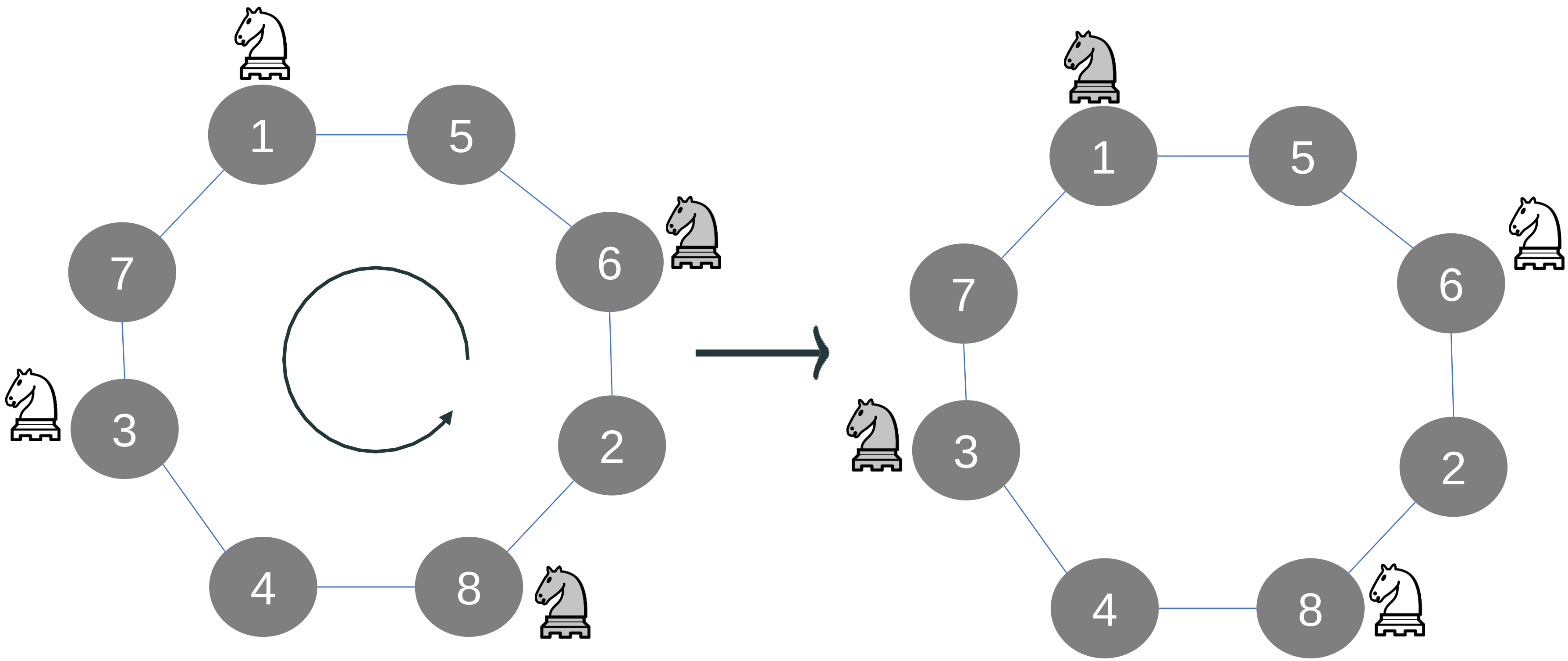
All the nodes are on a circle

Solution



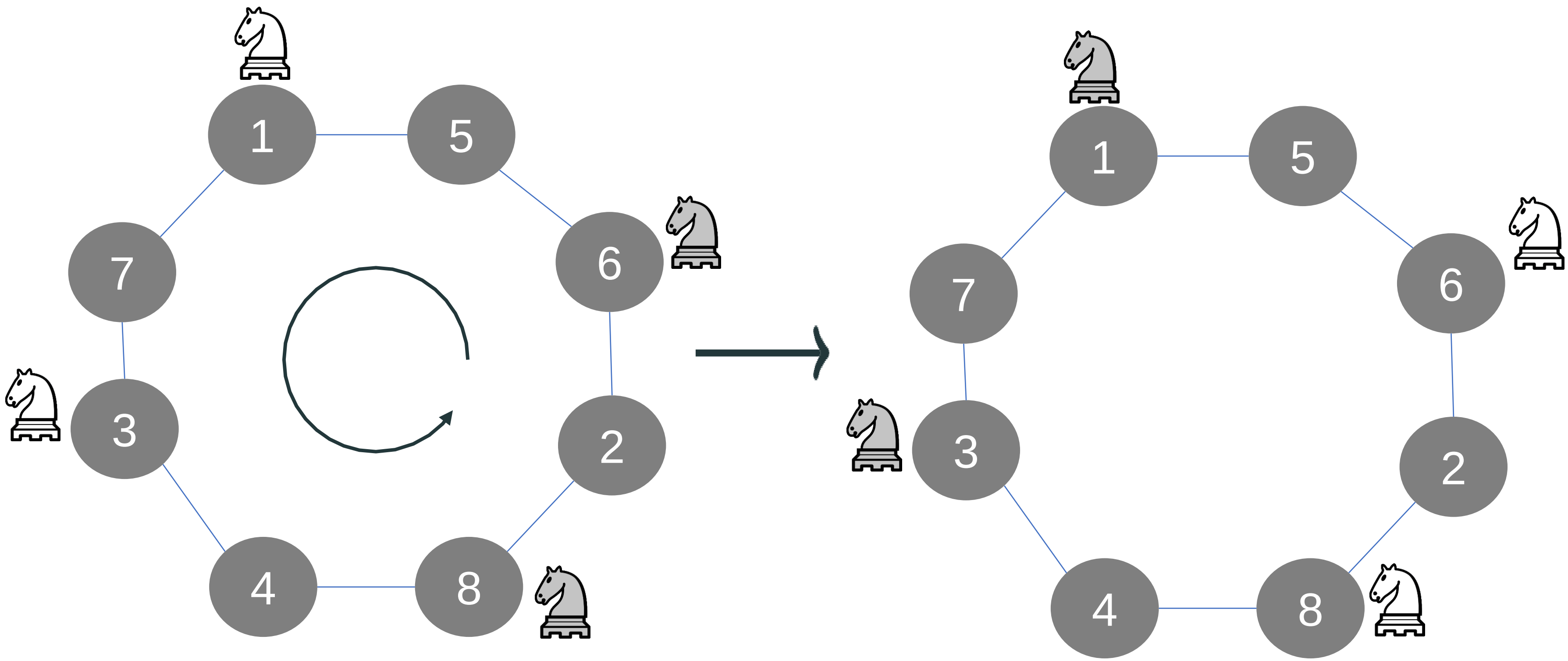
Do you see it now?

Solution



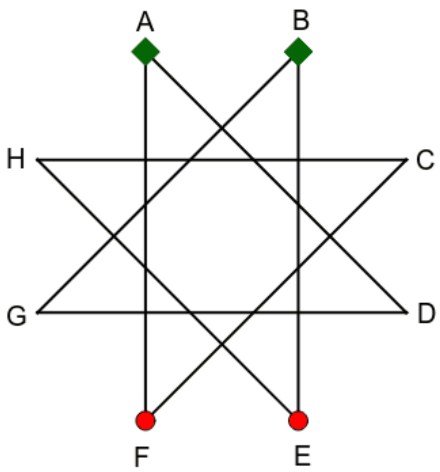
Move around the circle following legal edges

Solution



Until knights are in desired positions

Group activity
Graphs and puzzles



Consider the following puzzle:

- You can move each of the green or red pieces along the lines.
- The goal is to interchange the positions of the colored pieces in the minimum number of moves.

Draw a graph model which would help you to solve this puzzle

What is the minimum number of moves? _______________