Graph Databases

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Graph Databases

A (native) graph database:

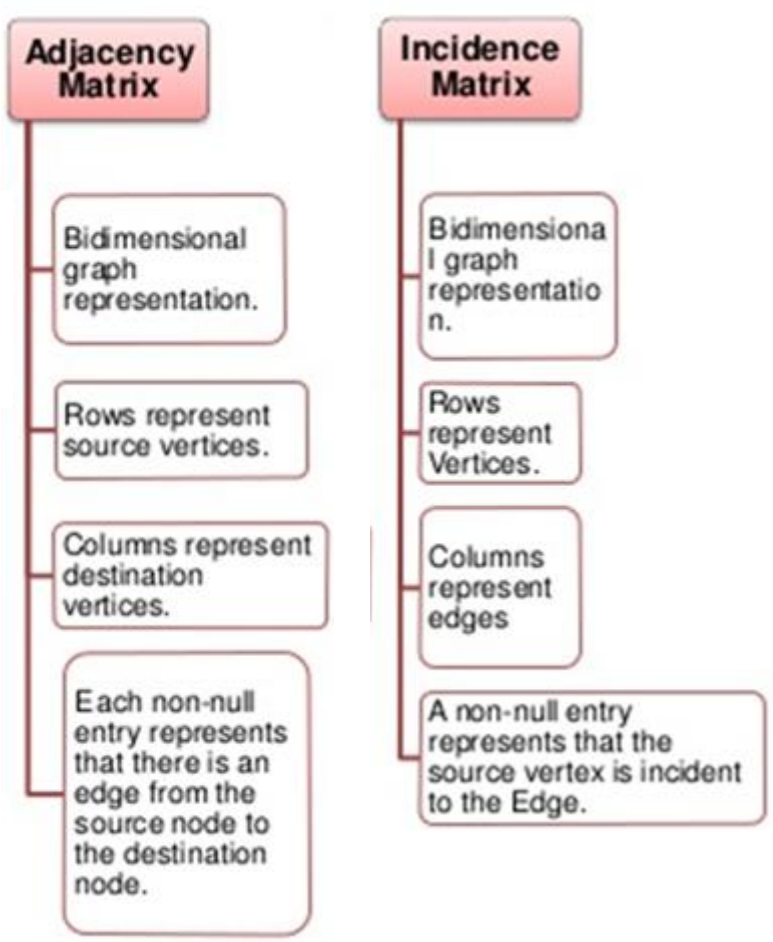
- Provides means to efficiently **process** graph data
  - **Index-free adjacency**
- Provides means to **store** graph data
  - Each having potentially different physical graph data models
- Examples: Neo4j, Titan

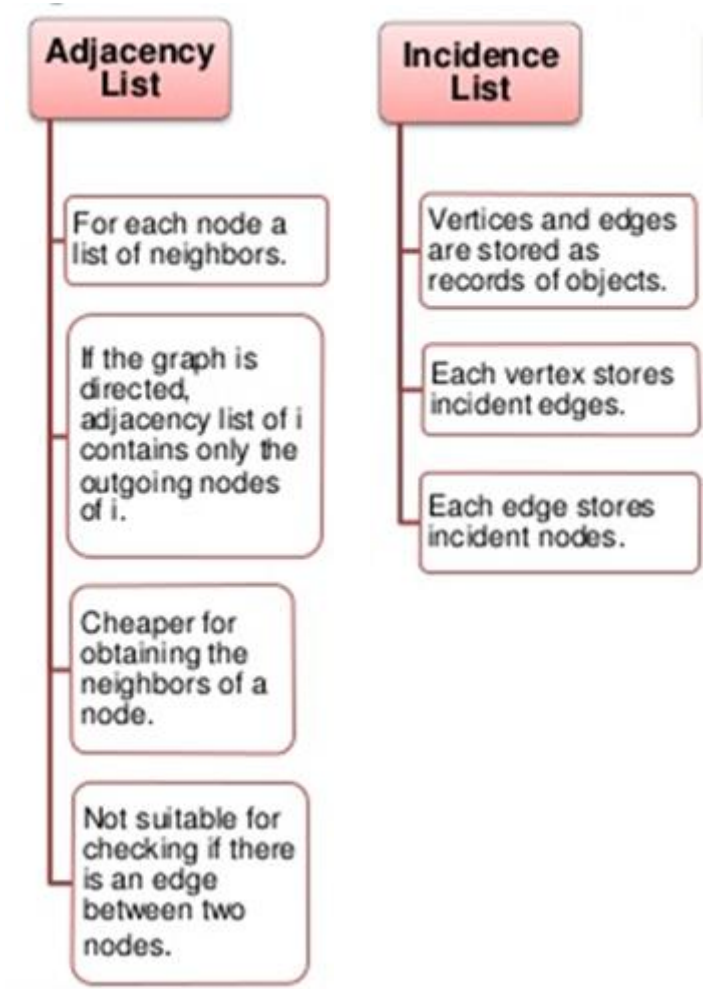
(Distributed) Graph frameworks:

Next lecture!

- Efficiently **process** graph data
  - Like MapReduce or Spark, provide means to extract data from databases **BUT DO NOT STORE GRAPHS**
- Examples: Pregel (Google), Giraph (MapReduce), GraphX (Spark), …

Implementation of Graphs

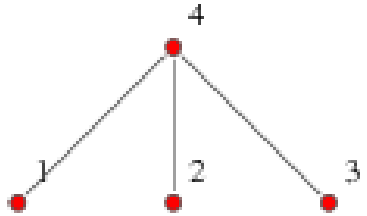


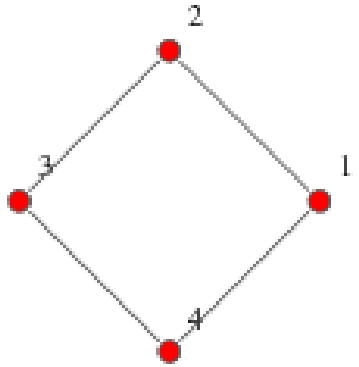


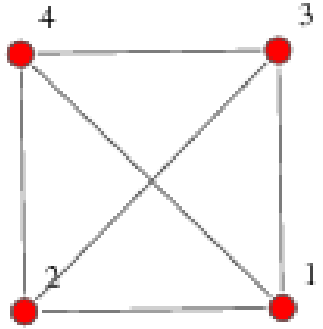
https://www.slideshare.net/maribelacosta/se-35384177

Implementation of Graphs

Adjacency matrix (baseline)







$$\begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix} \qquad \begin{pmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{pmatrix} \qquad \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix}$$

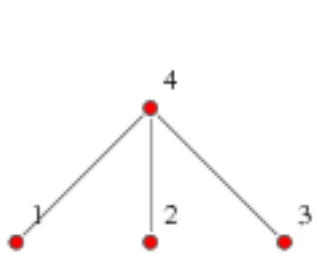
Pros?
Cons?

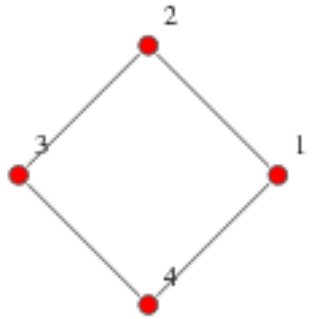
What about an incidence matrix?

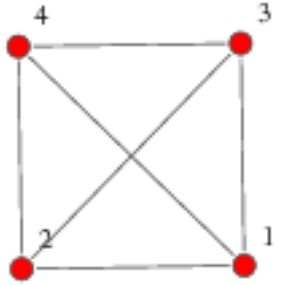
Activity

Objective: Understand the different structures needed to implement graphs following the main graph implementation strategies

- *Implement the following graphs as an adjacency list **AND** as an incidence list*







$$\begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix} \qquad \begin{pmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{pmatrix} \qquad \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix}$$

Implementation of Graph Databases

NEO4J

Neo4J native graph storage

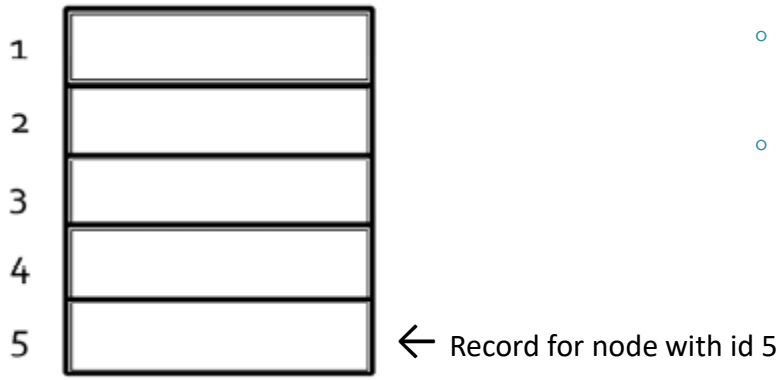
Based on **incidence lists**

- Implemented by means of singly and doubly linked list structures

Separate files for each different part of the graph

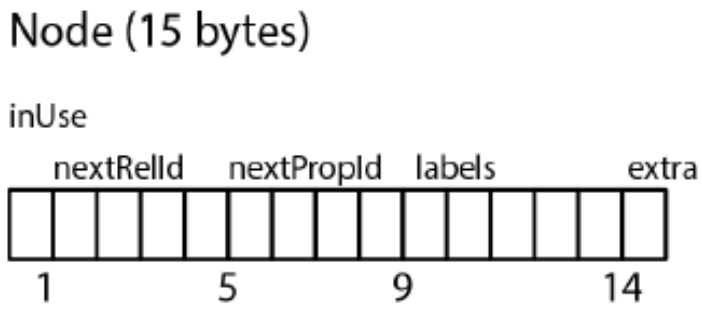
- Nodes
- Relationships
- Properties
- Labels
- Values

Incidence Lists – Neo4J



Nodes

- One physical file to store all nodes (in-memory, *Least Frequently Used* cache policy)
- **Fixed-size** record: 15 bytes in length
  - Fast look-up: O(1)



- Each record is as follows:
  - Byte 1 (metadata; e.g., in-use?)
  - Bytes 2-5: id first relationship
  - Bytes 6-9: id first property
  - Bytes 10-14: labels
  - Byte 15: extra information

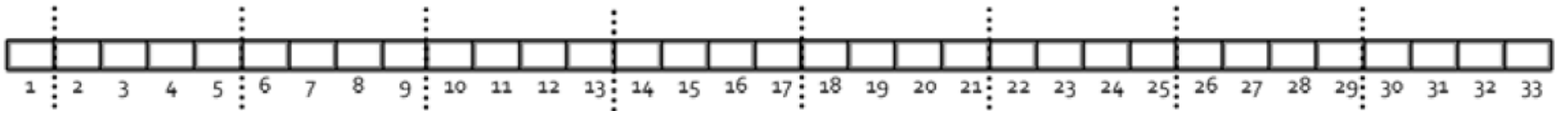
Incidence Lists – Neo4J

Relationship file

- Records of **fixed size**
- Cache with *Least Frequently Used* policy

- Contents of each record:
  - Metadata
  - id starting node, id end node
  - id label
  - ids of the **previous and following relationship** of the starting node and of the ending node
  - id first property
- Doubly linked list

Only stores the structure of the graph, not values -> fixed size + saves space



Incidence Lists – Neo4J

Property file

- Records of **fixed size**
- Cache with *Least Frequently Used* policy
- A single file for all properties, regardless if they belong to nodes or to edges.

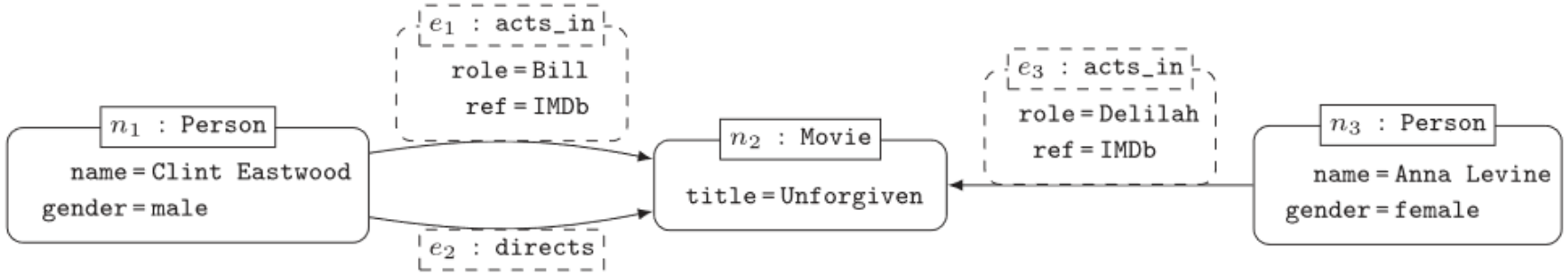
- Contents of each record:
  - Metadata (incl. a bit determining whether it belongs to an edge or node)
  - id node / edge
  - id of the **following property** of the node / edge
  - id property name
  - id property value
- Singly linked list

Activity

Objective: Understand how to use incidence lists to implement graphs

Consider the graph below. What would be the resulting data structures if you create such graph in Neo4J?

- Node records: First edge, First property, Label
- Relationship records: Start node, End node, Label, Next edge start node, Previous edge start node, Next edge end node, Previous edge end node, First property
- Property records: Edge or node?, Edge/node, Next property, Name, Value

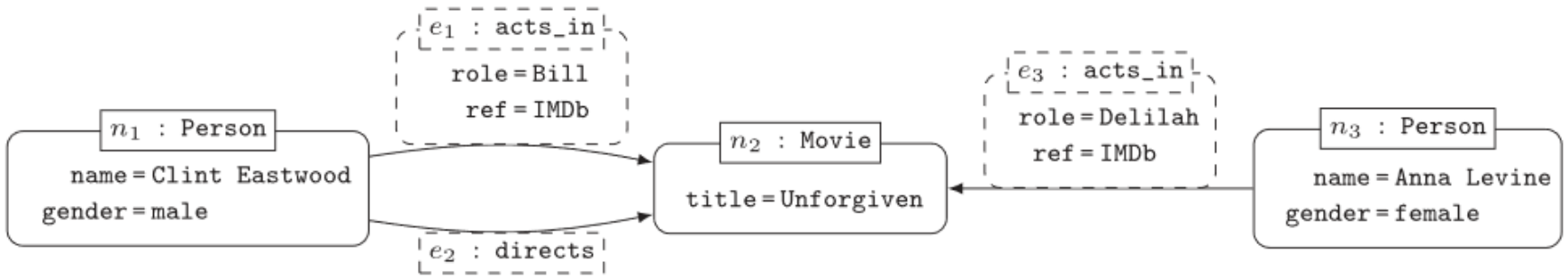


Activity

Objective: Understand how to implement graph operations with incidence lists

Consider the graph below, and its implementation with an incidence list (simplified version). How can you solve the following operations?

- Adjacency of n2
- Reachability from n1 to n3
- Pattern matching: (p1: Person)--> (m: Movie) <-- (p2: Person)



Types of graph databases

Types of Graph Databases

Some graph databases / processing frameworks are based on strong assumptions that are not explicit

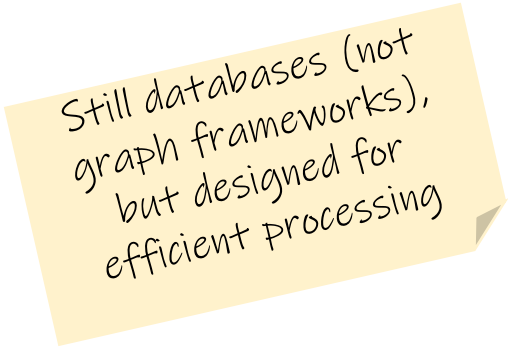
- As a consequence of how they implement internal structures

Operational graphs:

- Map to the concept of a CRUD database
  - Nodes, edges can be deleted, updated, inserted and read
  - Example: Neo4j, Titan, OrientDB, Amazon Neptune, ...

Analytical graphs

- They are *snapshots* that cannot be modified by the final user
  - Equivalent to a data warehouse for graphs
  - Example: Sparksee, Giraph, GraphX, etc.



Summary

All graph databases follow the same principles, but the way they are implemented really affects graph processing

When choosing a graph database, consider:

- Operational vs. Analytical graph database
- Internal data structures
- Impact of the internal data structures on the required graph processing for your project