COMP5338 – Advanced Data Models

Week 8: Neo4j Internal and Data Modeling

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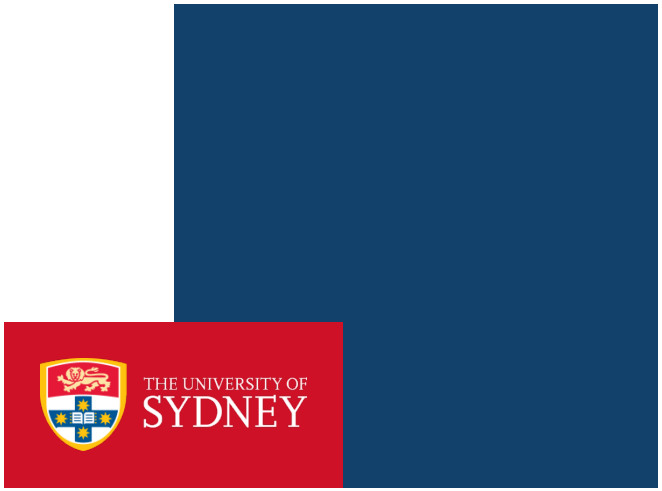

Outline

- **Neo4j Storage**
- Neo4j Query Plan and Indexing
- Neo4j – Data M
- Neo4j – Graph Algorithms

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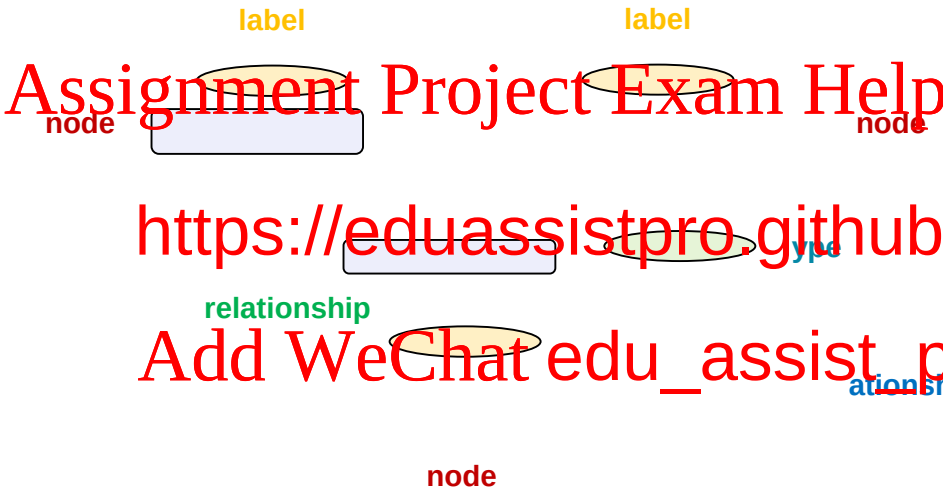
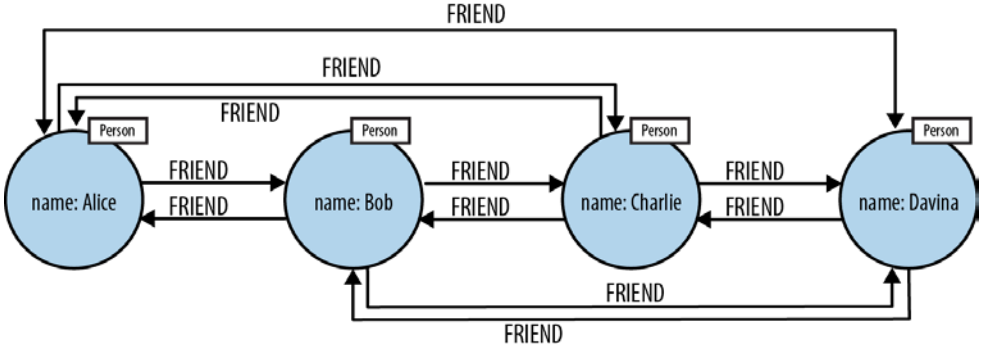
Property Graph Model



Index-free Adjacency

- Native storage of relationships between nodes
  - Effectively a pre-computed bidirectional join
- Traversal is like pointer dereferencing
  - Almost as fast as well
- Index-free Adjac
  - Each node main ent nodes
  - Each node is eff adjacent no
- Cheaper than global indexes
  - Query are faster, do not depends on the total size of the graph



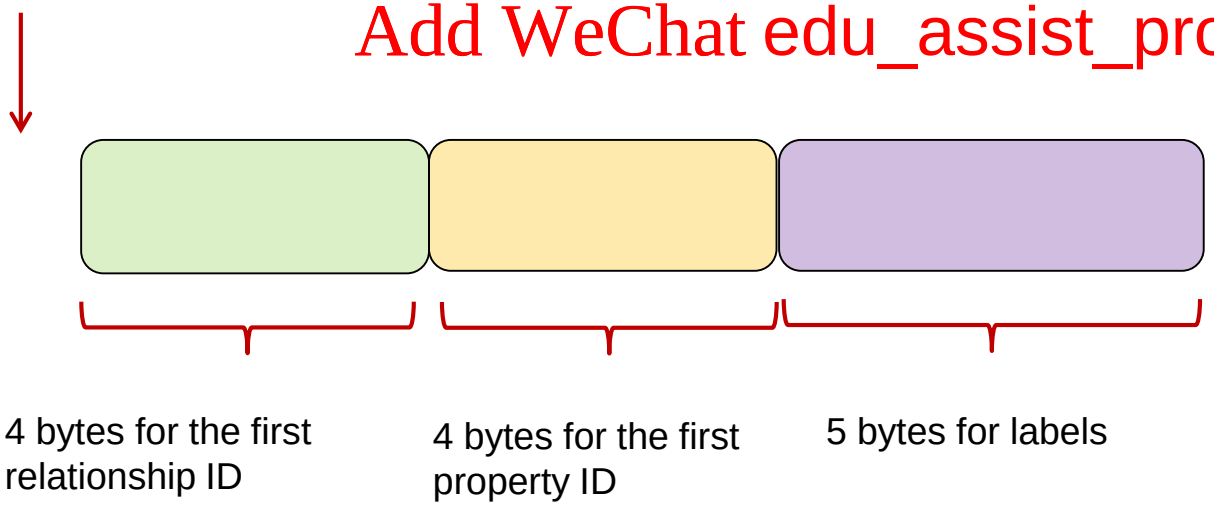
Slides 3-10 are based on Graph Database chapter 6.1 and 6.2

Neo4j Architecture

- Graph data is stored in *store files* on disk
  - Nodes, relationships, properties and labels all have their own store files.
  - Separating graph and property data promotes fast traversal
- user's view of their graph and the actual records on disk are structurally dissimilar

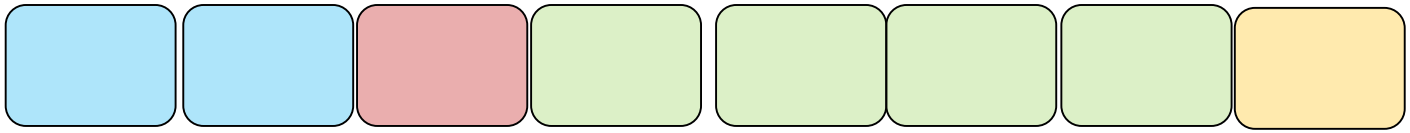
Node store file

- All node data is stored in one node store file
- Physically stored in file named *neostore.nodestore.db*
- Each record is of a **fixed size** – 15 bytes (*was 9 bytes in earlier version*)
- Offset of stored node = node id * 15 (node id = 100, offset = 1500)
- Deleted IDs in *.id* file and can be reused



Relationship store file

- All relationship data is stored in one relationship store file
- Physically stored in file named *neostore.relationshipstore.db*
- Each record is of a fixed size – 34 bytes
- Offset of stored relationship = relationship id * 34
  - So, relationship



Other Files

- **Property store** contains fixed size records to store properties for nodes and relationships
  - Simple properties are stored inline
  - Complex ones such as long string or array property are stored else where
- Node label in no ata in **label store**
- Relationship typ eferences data in **relationship type store**
- Both Node ID and Property ID are of 4 bytes
  - The maximum ID value is $2^{32}-1$
  - ID is assigned and managed by the system
    - The corresponding record will be stored in the computed offset
  - The IDs of deleted nodes/relationships will be reused

Node structure

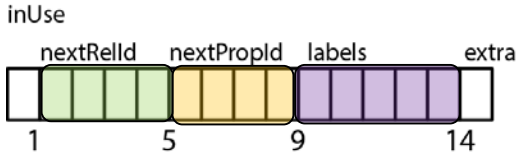
- Bob LIKES Alice

4 bytes pointer to the first relationship in relationship store

5 bytes pointer to the first label in label store

4 bytes pointer to the first property in property store

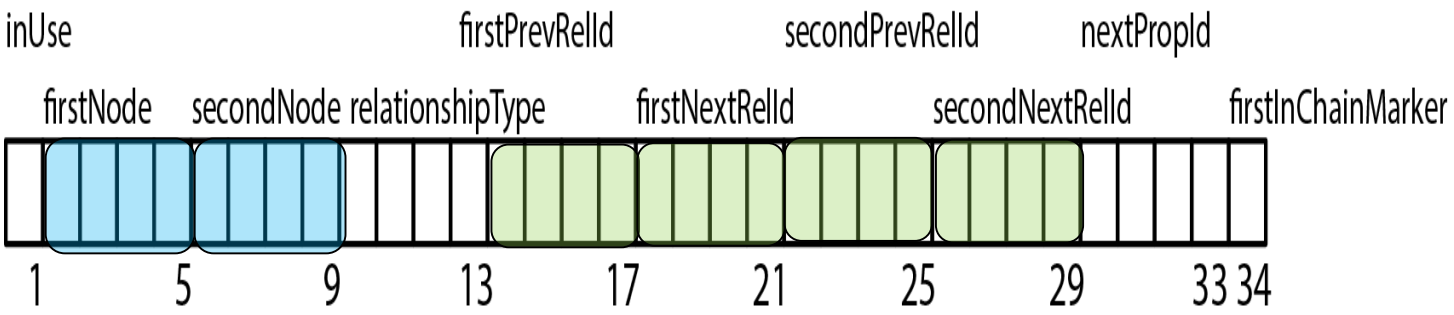
The record representing Node 1 contains 3 pointers plus one inUse byte and one extra byte



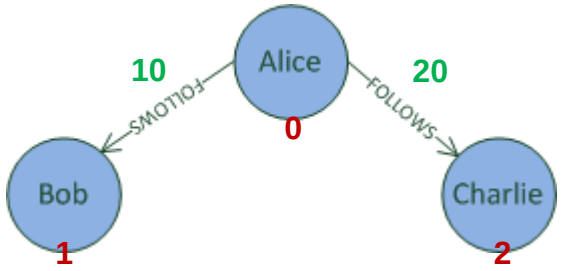
Relationship structure

- Bob LIKES Alice

vious and next is
determined by relationship
creation time in the database

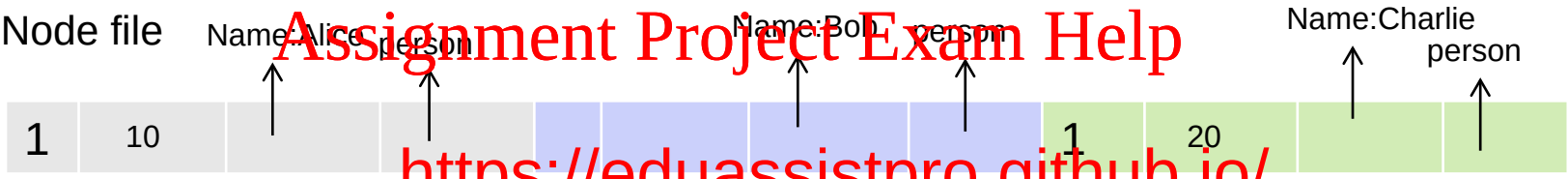


Doubly linked list



Creation order:
- node Alice
- node Bob
- node Charlie
- relationship Alice --> Bob
- relationship Alice --> Charlie

Node file

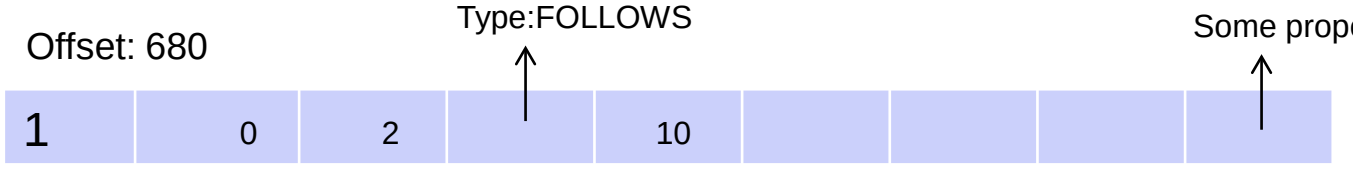


Relationship file

Offset: 340

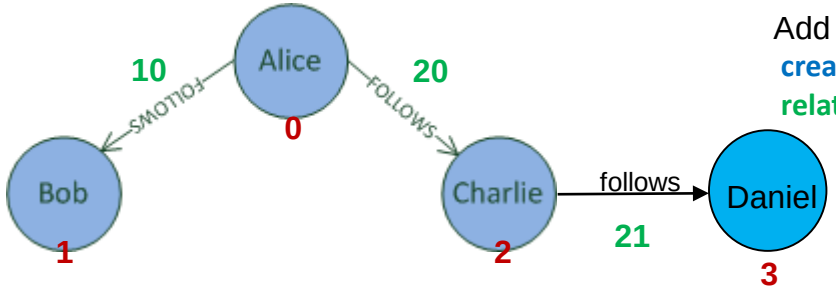
Alice's next relation

Offset: 680



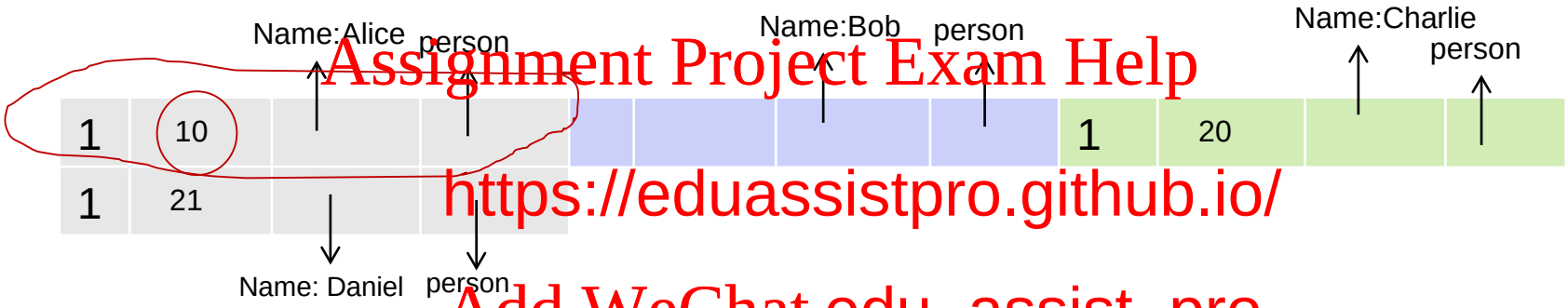
Alice's previous relation

Doubly linked list (cont'd)



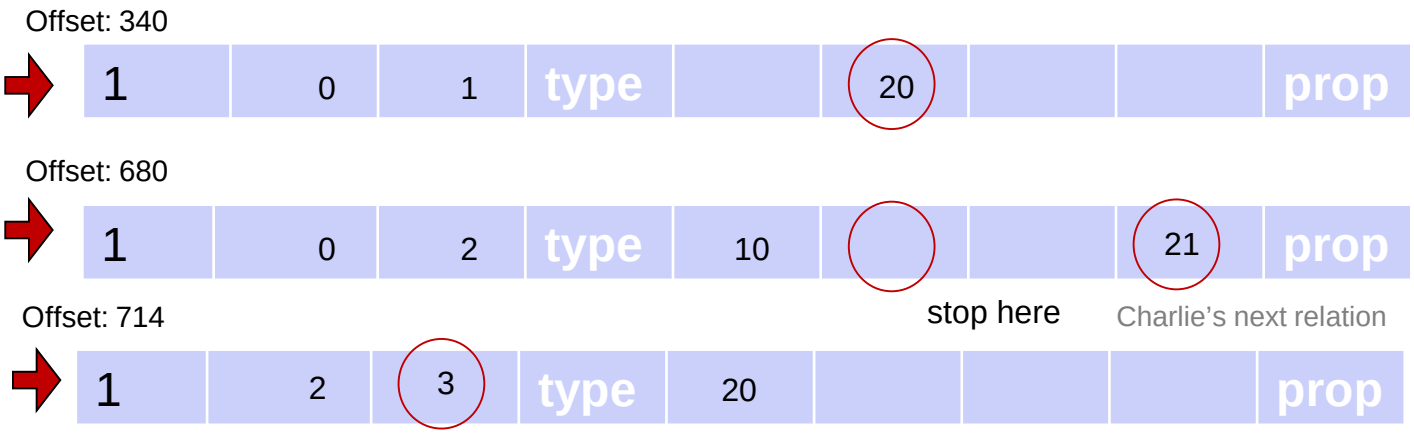
Add another node and relationship
create node Daniel
relationship Charlie --> Daniel

Node file



ame: 'Alice') –[*2]->(other) RETURN other

Relationship file



"The node and relationship stores are concerned **only** *with the* ***structure*** *of the graph, not its property data. Both stores use fixed-sized records so that any individual record's location within a store file can be rapidly computed given its ID. Th ons that underline Neo4j rmance traversals."*

-- Chapter 6, Graph Databases

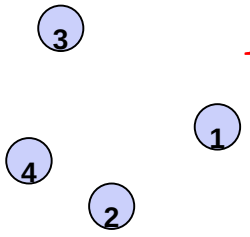
Outline

- Neo4j Storage
- **Neo4j Query Plan and Indexing**
- Neo4j – Data M
- Neo4j – Graph Algorithms

Neo4j Query Execution

- Each Neo4j Query is turned into an execution plan by a **execution planner**
  - **Rule** Strategy Planner
    - Consider available indexes but does not use statistical information
  - **Cost** Strategy Planner (default and in development)
    - Use statistic information to evaluate a few alternative plans
    - E.g. If there are es, a query involving both may get better perfor f Movie nodes
      - See example in lab
- Query plan stages
  - Starting point
  - Expansion by matching given path in the query statement
  - Row filtering, skipping, sorting, projection, etc…
  - Combining operations
  - Updating

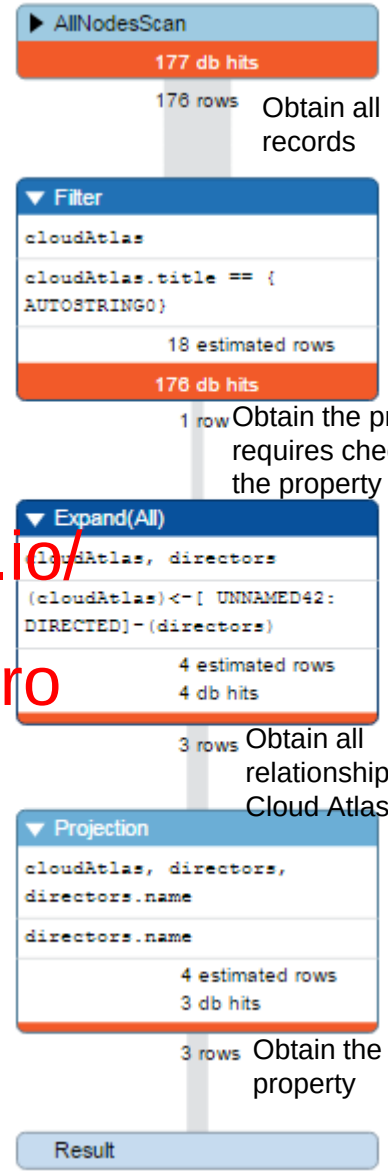
Query Plan: an example



Query:

MATCH
(cloudAtlas {title: "Cloud Atlas"})<-[:DIRECTED]-(directors)
RETURN directors.name

explain



profile

Query Starting Points

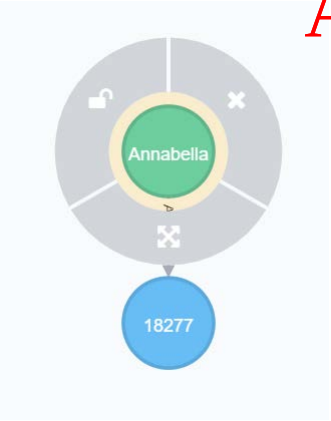
- Most queries start with one or a set of **nodes** except if a relationship ID is specified
  - **MATCH (n1)-[r]->() WHERE id(r)= 0 RETURN r, n1**
  - This query will start from locating the first record in the relationship file
- Query may start
  - **MATCH(n) RETURN**
  - **MATCH (cloudAtlas {title: "Cloud Atlas"})-(directors) RETURN directors.name**
- Query may start by scanning all nodes belonging to a given label
  - **MATCH (p:Person{name:"Tom Hanks"}) return p**
  - Labels are implicitly indexed
- Query may start by using index

Query starting from labelled node

```
MATCH (n:Person) -[r]-(something)
with n, count(something) as degree
order by degree
limit 1
return n
```

Obtain all 133 Person nodes records

Obtain 133 nodes + 256 relationships



Memory processing

Query Plan With Index

- Neo4j supports index on properties of labelled node
- Index has similar behaviour as those in relational systems
- It can be built on composite prope
- Create Index
  - **CREATE INDEX ON :Person(name)**
- Drop Index
  - **DROP INDEX ON :Person(name)**

Query:

MATCH **(bacon:Person {name:"Kevin Bacon"})-[*1..4]-(hollywood)**
RETURN DISTINCT hollywood

A relatively complex query and plan

```
MATCH  (n:Person{name:  "Tom  Hanks"})
WITH n.phone as phones, n
UNWIND phones as phone
MATCH (m:Person)
WHERE phone in m.phone and n<>m
RETURN m.name
```


Apply works by performing a nested loop. Every row being produced on the left-hand side of the Apply operator will be fed to the leaf operator on the right-hand side, and then Apply will yield the combined results

Obtain all 133 Person nodes records twice!

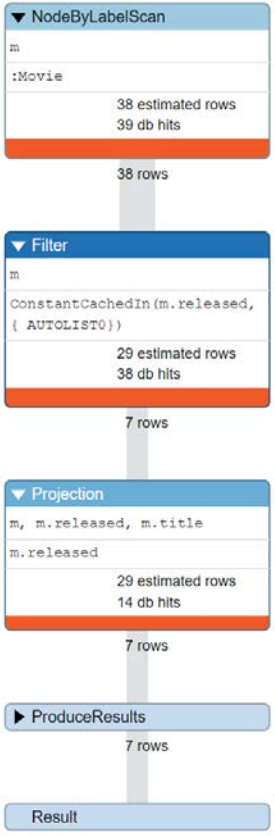
Obtain 132 Person nodes's phone property twice!

Obtain the matching node's name property

Comparing Execution Plans

```
MATCH (m: Movie)
WHERE m.released IN [1999,2003]
RETURN m.title, m.released
```

```
UNWIND [1999,2003] as year
MATCH (m: Movie)
WHERE m.released = year
RETURN m.title, m.released
```



Earlier version

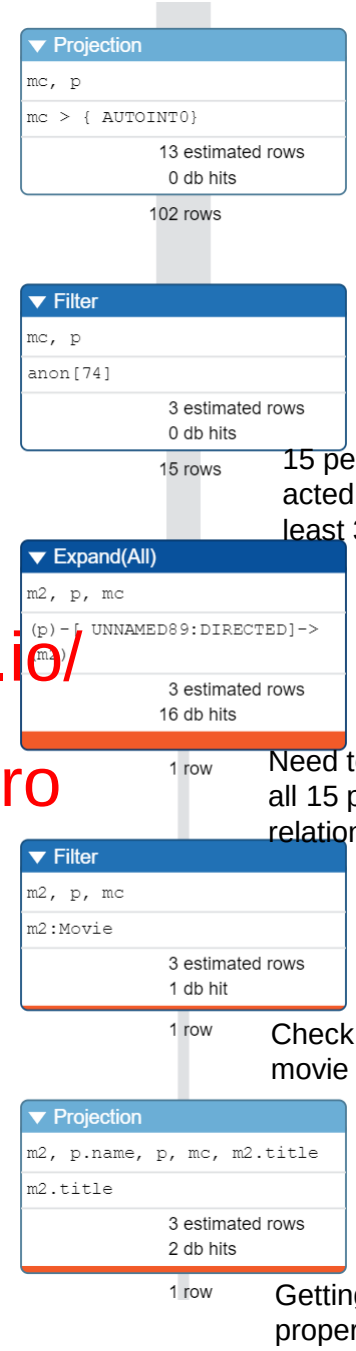
version 3.2

Another example of comparison

- Question: Find out a list of person who has acted in at least three movies and also directed at least one movie
- Cypher is powerful and flexible
  - It is possible to write very different queries that produce the same results
  - The performanc
  - The DB engine ge to rewrite the queries as those in SQL
    - Not based on relational algebra

Option 1

```
MATCH (p:Person)-[:ACTED_IN]->(m:Movie)
WITH p, count(m) AS mc
WHERE mc > 2
MATCH (p)-[:DIRECTED]->(m2:Movie)
RETURN p.name, m2.title
```

Option 2

```
MATCH (m1:Movie)<-[a:ACTED_IN]-(p:Person)-[:DIRECTED]->(m2:Movie)
WITH p, count(distinct m1) as ac, m2
WHERE ac > 2
RETURN p.name, m2.title
```

Obtain the 18 Movie nodes from the 18 relationships as m1

Memory processing

38 nod relationships

44 Person nodes

Among 62 relationships only 18 are of DIRECTED type

Transactions

- Neo4j supports full ACID transactions
  - Similar to those in RDBMS
- Uses locking to ensure consistency
  - Lock Manager manages locks held by a transaction
- Logging
  - Write Ahead Logging (WAL)
- Transaction Commi
  - Acquire locks (Ato
  - Write Undo and Redo records to the
    - for each node, relationship, property n to the log
  - Write commit record to the log and flush to disk (Durability)
  - Release locks
- Recovery – if the database server/machine crashes
  - Apply log records to replay changes made by the transactions

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- **Neo4j – Data M**
- Neo4j – Graph Algorithms

Graph Data Modelling

- Graph data modelling is very closely related with domain modelling
- You need to decide
  - Node or Relationship
  - Node or Property
  - Label/Type or P
- Decisions are ba
  - Features of entities in application
  - Your typical queries
  - Features and constraints of the underlying storage system

Slides 35-39 are based on Chapter 4 of Graph Databases book

Node vs. Relationship

- Nodes for Things, Relationship for Structures
  - **AS A** reader who likes a book, **I WANT** to know which books other readers who like the same book have liked, **SO THAT** I can find other books to read.


```
MATCH (:Reader {name:'Alice'})-[:LIKES]->(:Book {title:'Dune'})
<-[:LIKES]-(:Reader)-[:LIKES]->(books:Book)
RETURN books.title
```

Node vs. Relationship

- Model Facts as Nodes

Node or Property

- Represent Complex Value Types as Nodes

Relationship Property or Relationship Type

- E.g. The relationship between user node and address node can be:
  - typed as **HOME_ADDRESS**, **BILLING_ADDRESS** or
  - typed as generic **ADDRESS** and differentiated using a type property {type:'home'}, {type:'billing'}
- We use fine-grai ever we have a closed set of rel
  - Eg. there are only a finite set of a
  - If traversal would like to follow ge DRESS, we may have to use redundant relationships
    - MATCH (user)-[:HOME_ADDRESS|WORK_ADDRESS|DELIVERY_ADDRESS]->(address)
    - MATCH (user)-[:ADDRESS]->(address)
    - MATCH (user:User)-[r]->(address:Address)

Outline

- Neo4j Storage
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- **Neo4j –** Graph Algorithms

Graph Algorithm

- In addition to graph query and traversal, a rich set of graph algorithms are provided by Neo4j
  - Used to be part of the Neo4j server
  - It is now moved out as a separate project
- The graph algorithms are implemented as Cypher **procedures** and parately
- Procedure is a o4j
  - Take arguments, perform databa nd return result
  - Written in Java and compiled to jar files
  - Once installed, it can be called directly from Cypher

https://neo4j.com/docs/graph-algorithms/3.4/

https://neo4j.com/docs/developer-manual/current/extending-neo4j/procedures/

References

- Ian Robinson, Jim Webber and Emil Eifrem, *Graph Databases*, Second Edition, O'Reilly Media Inc.,
  - You can download this book from the Neo4j site, https://neo4j.com/graph-databases-book/?ref=home
    - Chapter 4, Chapter 6
- Neo4j – Refer
  - https://neo4j.com/docs/developer-