Neo4j

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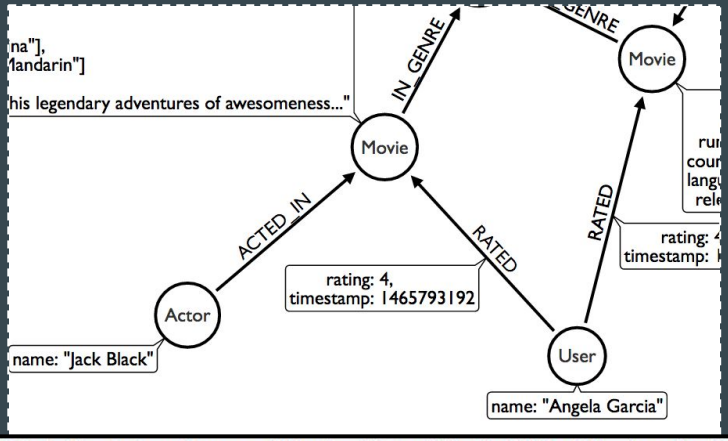
What is Neo4j?

- Neo4j is a “graph database management system”
  - cf. relational database management system
  - Like SQL for graphs
  - Instead of defining tables and columns, we define nodes and relationships
- Uses a SQL-like language called Cypher Query Language to query and update graphs




```
MATCH (nicole:Actor {name: 'Nicole Kidman'})-[:ACTED_IN]->(movie:Movie)
WHERE movie.year < $yearParameter
RETURN movie
```

Background

- Designed to deal with databases of graph-structured data
  - Often more natural representation than relational tables
  - Claims significant speedups over RDBMS
- Relatively new
- Developed by Neo4j, Inc.
  - Founded in 2007
  - Based near San Francisco, Sweden, and elsewhere

Using Neo4j

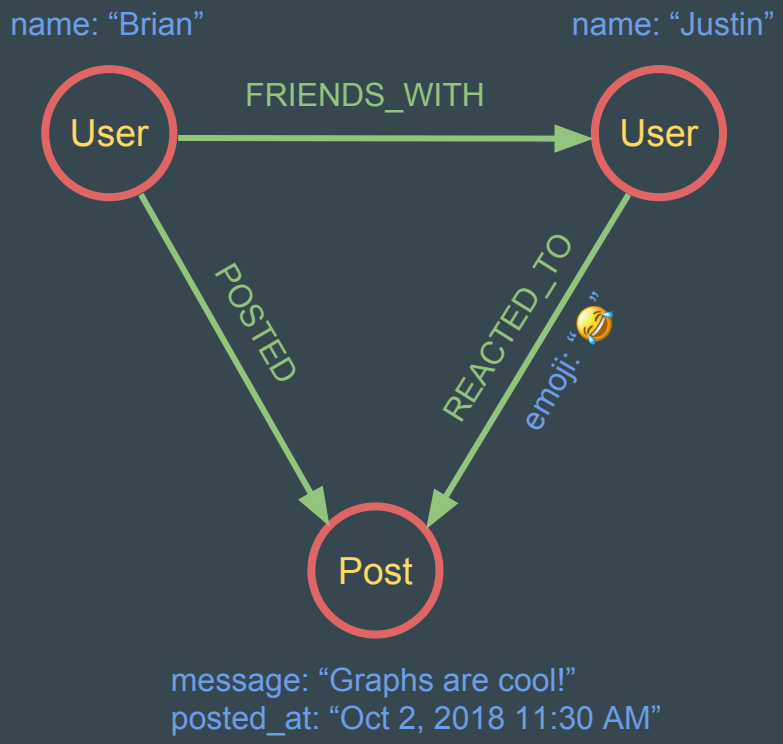
- Open-source community edition and closed-source enterprise edition
- Can be run as a server or embedded in an application
- Implemented in Java
- Drivers exist for major languages (Python, JavaScript, Java, etc.)
- Driver communicates with server via “bolt” protocol
  - HTTP is also an option

```python
# pip install neo4j-driver

from neo4j.v1 import GraphDatabase, basic_auth

driver = GraphDatabase.driver(
    "bolt://54.162.76.69:33079",
    auth=basic_auth("neo4j", "whistles-contract-home"))
session = driver.session()

cypher_query = '''
MATCH (n)
RETURN id(n) AS id
LIMIT $limit
'''

results = session.run(cypher_query,
  parameters={"limit": 10})

for record in results:
  print(record['id'])
```

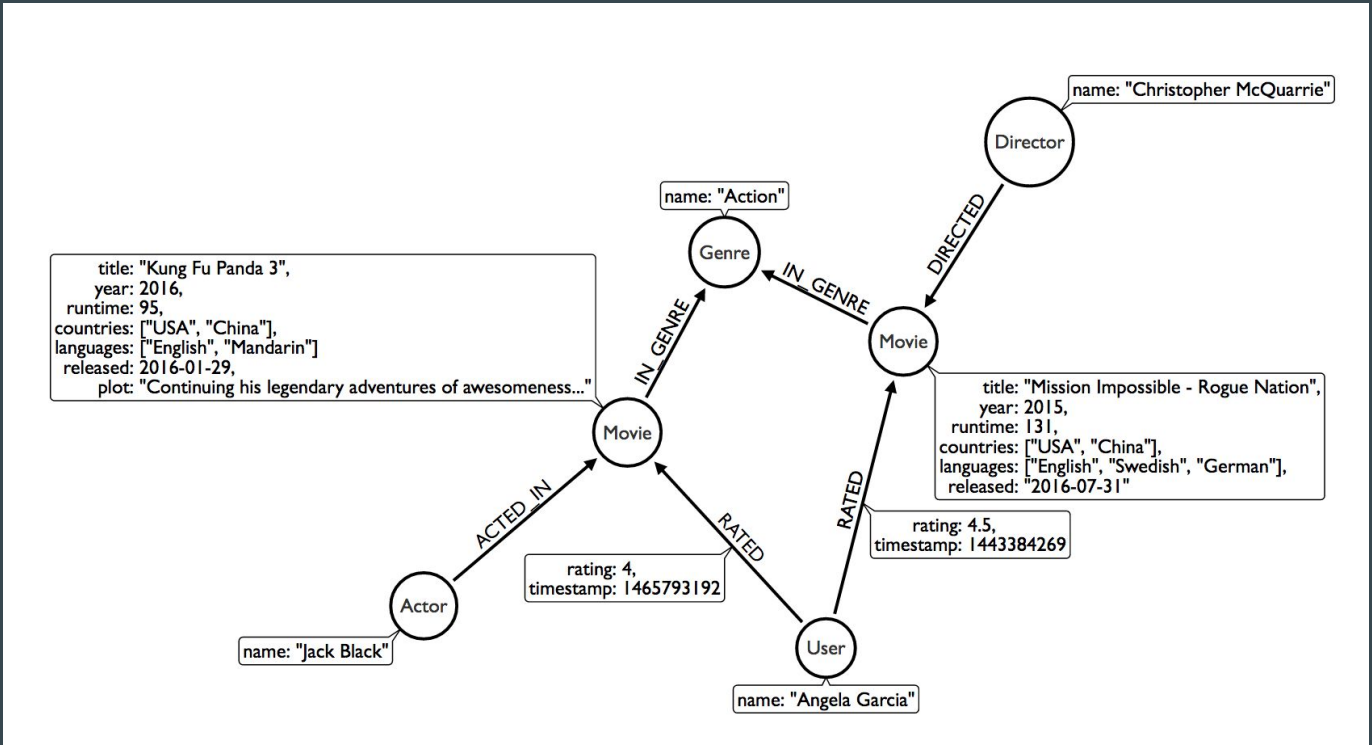
Using Neo4j with Python

Property Graph Model

- Nodes: graph vertices
  - Nodes have one or more labels that specify node type
- Relationships: directed edges between nodes
  - Each one has exactly one relationship type
  - Can have multiple edges between same nodes
- Properties: key-value pairs that can be attached to both nodes and relationships
  - Values have their own type system with ints, floats, strings, etc.



Property Graph Model - Movie Database Example



Cypher Query Language

- Declarative language inspired by SQL
- Intentionally similar to SQL and best learned by example
- Unlike SQL, the language includes data types for lists, maps, and paths
- Standardization attempt via openCypher

PATTERN SYNTAX

```
MATCH (m:Movie)<-[:RATED]-(u:User)
WHERE m.title CONTAINS "Matrix"
WITH m.title AS movie, COUNT(*) AS reviews
RETURN movie, reviews
ORDER BY reviews DESC
LIMIT 5;
```

“How many reviews does each Matrix movie have?”

Pattern Syntax

- Describes patterns of nodes, relationships, and attributes in graphs with ASCII art
- Nodes are in (parentheses), relationships are in [brackets], properties are like {key: value}
- Arrows can be written in either direction or omitted
- Binds data to variable names like `n`
- Names `$likeThis` are named parameters
- Same syntax used for both matching and creating data

```
CREATE (n {name: $value})
```
Create a node with the given properties.

```
CREATE (n $map)
```
Create a node with the given properties.

```
UNWIND $listOfMaps AS properties
CREATE (n) SET n = properties
```
Create nodes with the given properties.

```
CREATE (n)-[r:KNOWS]->(m)
```
Create a relationship with the given type and direction; bind a variable to it.

```
CREATE (n)-[:LOVES {since: $value}]->(m)
```
Create a relationship with the given type, direction, and properties.

`(n:Person)`
Node with `Person` label.

`(n:Person:Swedish)`
Node with both `Person` and `Swedish` labels.

`(n:Person {name: $value})`
Node with the declared properties.

`()-[r {name: $value}]-()`
Matches relationships with the declared properties.

`(n)-->(m)`
Relationship from `n` to `m`.

`(n)--(m)`
Relationship in any direction between `n` and `m`.

`(n:Person)-->(m)`
Node `n` labeled `Person` with relationship to `m`.

`(m)<-[:KNOWS]-(n)`
Relationship of type `KNOWS` from `n` to `m`.

`(n)-[:KNOWS|:LOVES]->(m)`
Relationship of type `KNOWS` or of type `LOVES` from `n` to `m`.

`(n)-[r]->(m)`
Bind the relationship to variable `r`.

`(n)-[*1..5]->(m)`
Variable length path of between 1 and 5 relationships from `n` to `m`.

`(n)-[*]->(m)`
Variable length path of any number of relationships from `n` to `m`. (See Performance section.)

`(n)-[:KNOWS]->(m {property: $value})`
A relationship of type `KNOWS` from a node `n` to a node `m` with the declared property.

`shortestPath((n1:Person)-[*..6]-(n2:Person))`
Find a single shortest path.

`allShortestPaths((n1:Person)-[*..6]->(n2:Person))`
Find all shortest paths.

`size((n)-->()-->())`
Count the paths matching the pattern.

Basic Query Syntax

`MATCH` a pattern and bind variable names

`WHERE` filters results using a Boolean expression

`WITH` (1) assigns values to variable names, and (2) computes aggregate functions like `COUNT`; explicitly separates query parts

```
MATCH (m:Movie)<-[:RATED]-(u:User)
WHERE m.title CONTAINS "Matrix"
WITH m.title AS movie, COUNT(*) AS reviews
RETURN movie, reviews
ORDER BY reviews DESC
LIMIT 5;
```

"How many reviews does each Matrix movie have?"

Basic Query Syntax

Additional `MATCH-WHERE` clauses can be inserted here to further filter results

`RETURN` determines what the query returns much like SQL `SELECT`

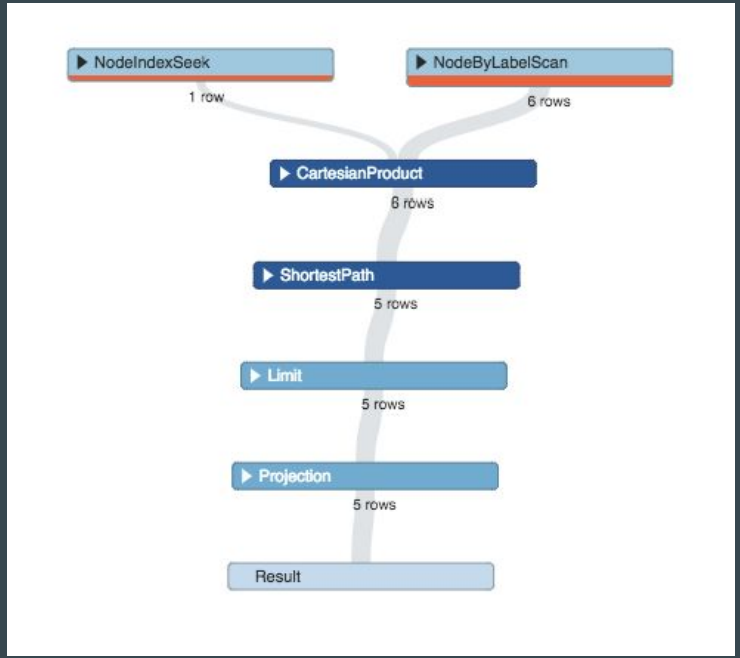
Fully analogous to SQL

```
MATCH (m:Movie)<-[:RATED]-(u:User)
WHERE m.title CONTAINS "Matrix"
WITH m.title AS movie, COUNT(*) AS reviews
RETURN movie, reviews
ORDER BY reviews DESC
LIMIT 5;
```

“How many reviews does each Matrix movie have?”

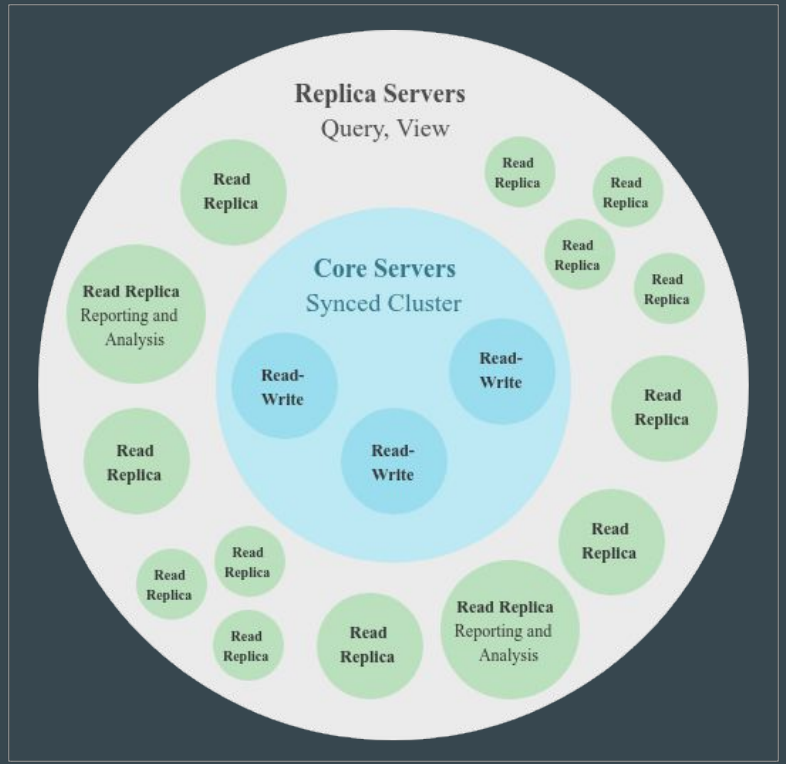
Execution Model

- Supports ACID transactions
- Queries are analyzed and decomposed into an execution plan AST
  - Vertices are low-level operations like “filter rows” or “sort”
  - Operations input and output sets of rows and pipe into each other
  - Some support lazy evaluation
  - Leaves extract data from the database
- Indexes can speed up queries
- Cypher query planner optimizes execution plans using four pre-computed statistics including
  - Number of nodes with label X
  - Number of relationships by type



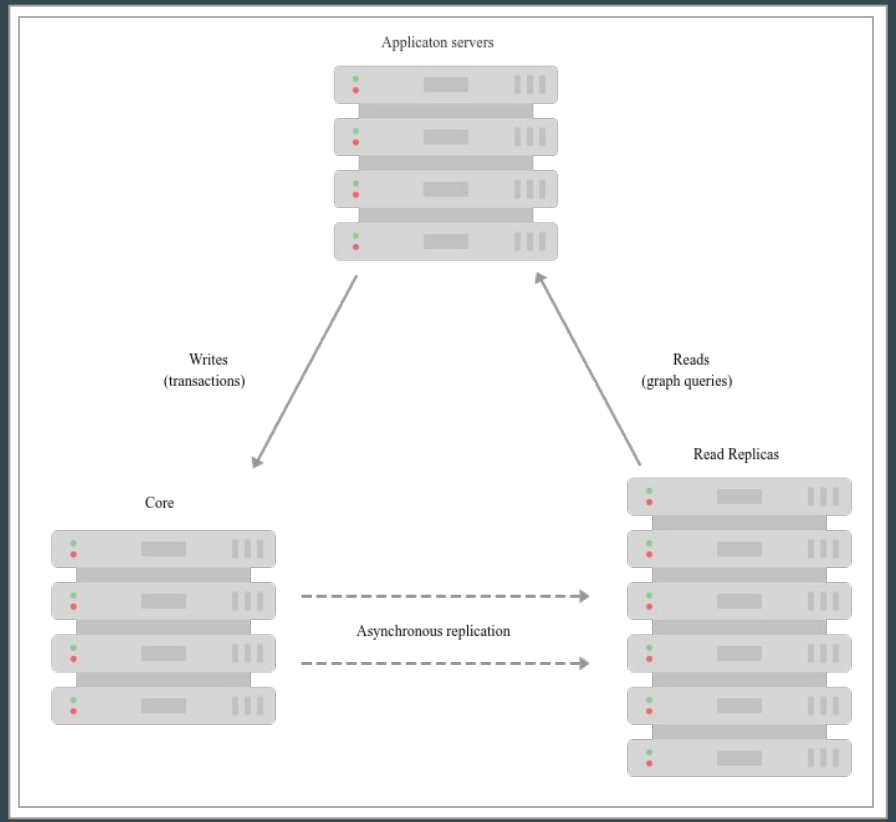
Parallelism

- Declarative API decouples query from execution model
- Only Enterprise Edition of Neo4j supports multi-machine clustering (“Causal Clustering”) and “Massively Parallel Graph Algorithms” library
- Clusters consist of Core Servers and Read Replicas
- Read replicas allow large-scale graph queries to be widely distributed



Parallelism

- Core Servers maintain synchronized version of data
- Applications communicate only with Core Servers
- Only Core Servers handle writes
- Data is asynchronously copied to Read Replicas
- Read-only queries can be processed in parallel among Read Replicas



Movie Database Jaccard Example

What movies are most similar to Inception based on Jaccard similarity of genres?

```
MATCH (m:Movie {title: "Inception"})-[:IN_GENRE]->(g:Genre)<-[:IN_GENRE]-(other:Movie)
WITH m, other, COUNT(g) AS intersection, COLLECT(g.name) AS i
MATCH (m)-[:IN_GENRE]->(mg:Genre)
WITH m,other, intersection,i, COLLECT(mg.name) AS s1
MATCH (other)-[:IN_GENRE]->(og:Genre)
WITH m,other,intersection,i, s1, COLLECT(og.name) AS s2
WITH m,other,intersection,s1,s2
WITH m,other,intersection,s1+filter(x IN s2 WHERE NOT x IN s1) AS union, s1, s2
RETURN m.title, other.title, s1,s2,((1.0*intersection)/SIZE(union)) AS jaccard ORDER BY jaccard DESC LIMIT 100
```

m.title	other.title	s1	s2	jaccard
"Inception"	"Strange Days"	["Crime", "Drama", "Mystery", "Sci-Fi", "Thriller", "IMAX", "Action"]	["Crime", "Action", "Thriller", "Sci-Fi", "Mystery", "Drama"]	0.857142857142857
"Inception"	"Watchmen"	["Crime", "Drama", "Mystery", "Sci-Fi", "Thriller", "IMAX", "Action"]	["Drama", "Action", "Sci-Fi", "Mystery", "IMAX", "Thriller"]	0.857142857142857
"Inception"	"Insomnia"	["Crime", "Drama", "Mystery", "Sci-Fi", "Thriller", "IMAX", "Action"]	["Crime", "Action", "Mystery", "Drama", "Thriller"]	0.714285714285714

Matrix = Table