Bases de Dados de Grafos

AULA PL08

Hugo Peixoto

2018 – 2019 Universidade do Minho

Conteúdo da UC

http://hpeixoto.github.io/nosql

Agenda

The Graph Database

Components

Advantages

Use Cases

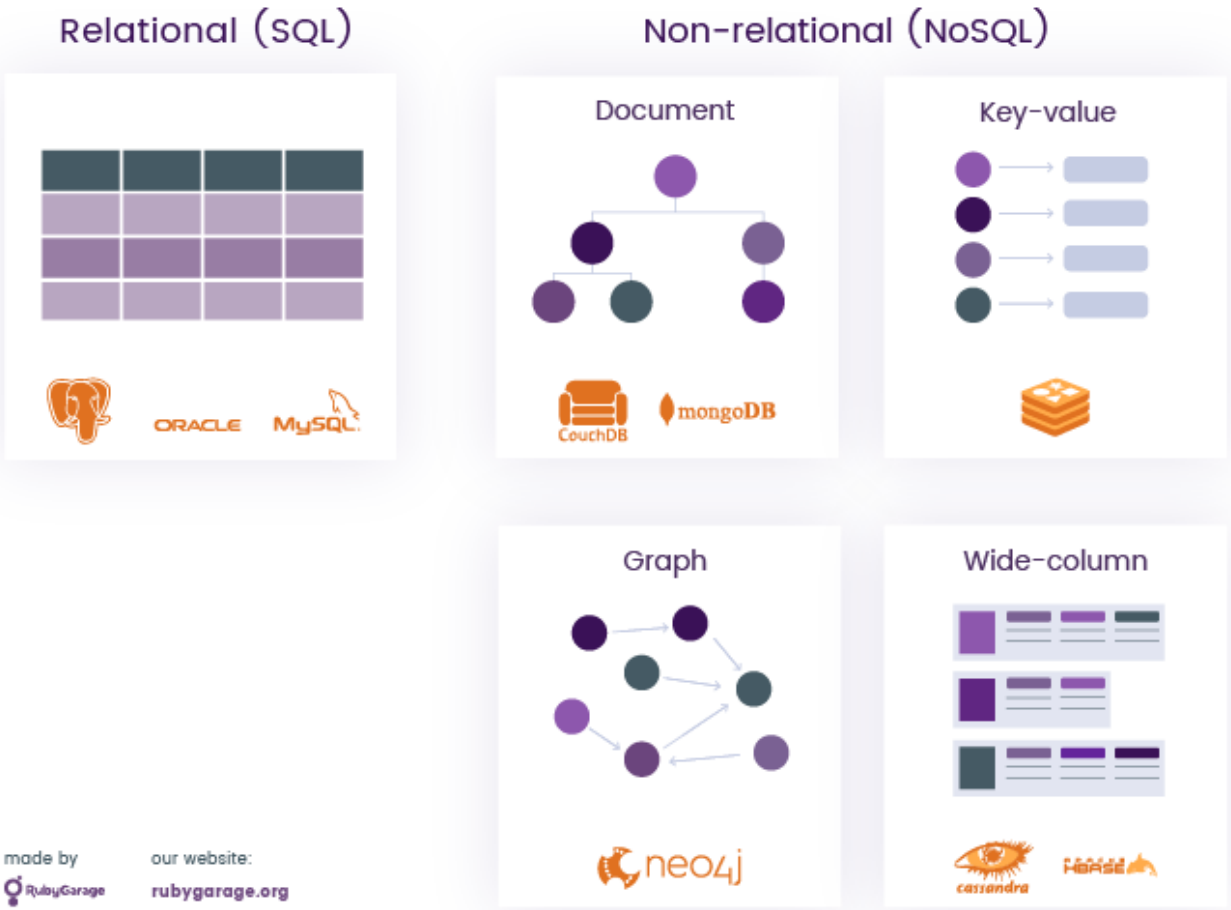
Cypher

Lab

FE07

https://docs.mongodb.com/manual/

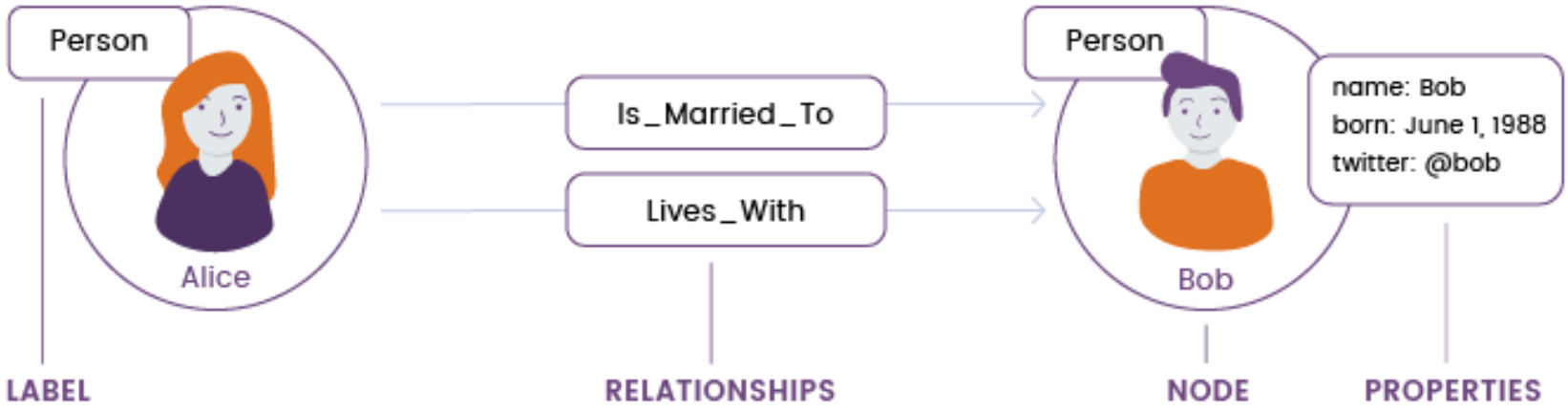
Types of Databases



The Graph Database

Simple Graph

A graph database stores data in a graph, the most generic of data structures, capable of elegantly representing any kind of data in a highly accessible way



Components

- **Nodes** (equivalent to vertices in graph theory). These are the main data elements that are interconnected through relationships. A node can have one or more labels (that describe its role) and properties (i.e. attributes).

- **Relationships** (equivalent to edges in graph theory). A relationship connects two nodes that, in turn, can have multiple relationships. Relationships can have one or more properties.

- **Labels**. These are used to group nodes, and each node can be assigned multiple labels. Labels are indexed to speed up finding nodes in a graph.

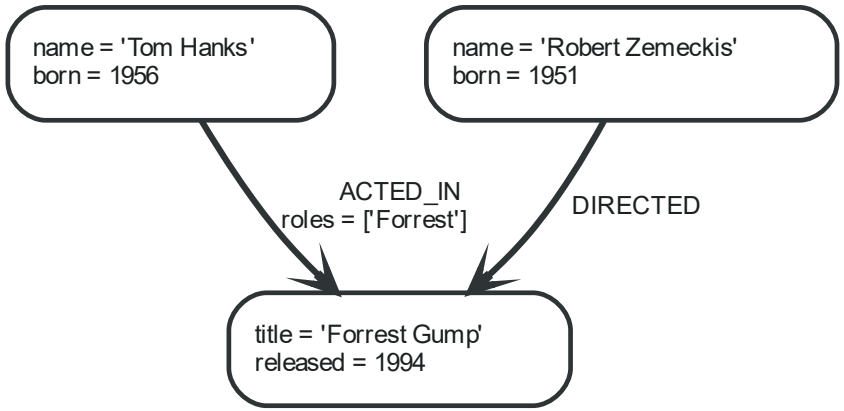
- **Properties**. These are attributes of both nodes and relationships. Neo4j allows for storing data as key-value pairs, which means properties can have any value (string, number, or boolean).

Nodes

A node in Neo4j is a node as described in the property graph model, with properties and labels.

Relationships

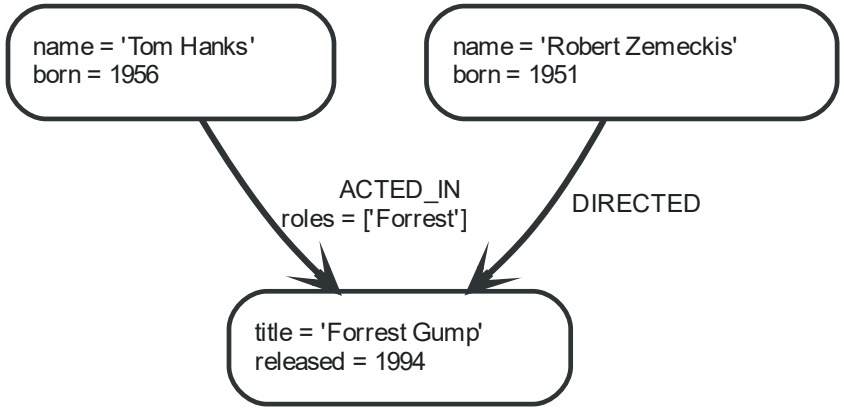
A relationship in Neo4j is a relationship as described in the property graph model, with a relationship type and properties.



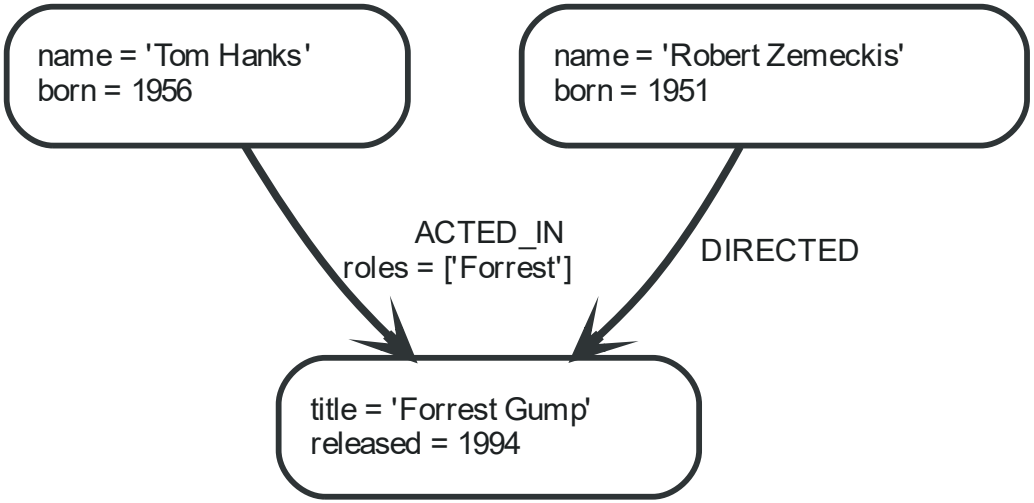
Relationships between nodes are the key feature of graph databases, as they allow for finding related data.

Relationships

ACTED_IN and DIRECTED are relationship types. The roles property on the ACTED_IN relationship has an array value with a single item in it.



Relationships



what can be found by simply following the relationships of a node in the example graph

Properties

A property in Neo4j is a property as described in the property graph model. Both nodes and relationships may have properties.

Types:

Number, an abstract type, which has the following subtypes:

- Integer
- Float

String

Boolean

Spatial types:

- Point

Temporal types:

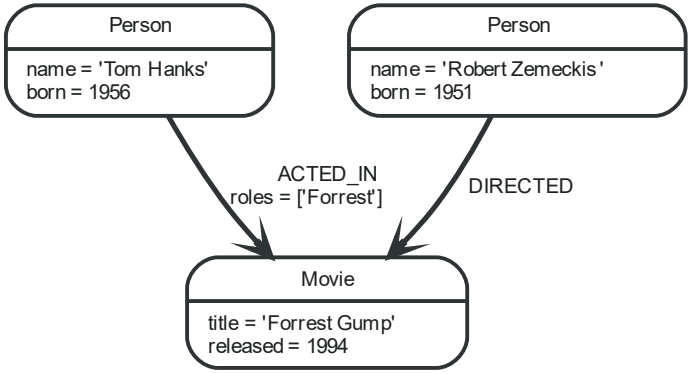
- Date
- Time
- LocalTime
- DateTime
- LocalDateTime
- Duration

null is not a valid property value. Instead of storing it in the database, null can be modeled by the absence of a property key.

Labels

A label in Neo4j is a label as described in the property graph model. Labels assign roles or types to nodes.

A label is a named graph construct that is used to group nodes into sets; all nodes labeled with the same label belongs to the same set.



Comparison

	Neo4j	Relational databases	NoSQL databases
Data storage	Graph storage structure	Fixed, predefined tables with rows and columns	Connected data not supported at the database level
Data modeling	Flexible data model	Database model must be developed from a logical model	Not suitable for enterprise architectures
Query performance	Great performance regardless of number and depth of connections	Data processing speed slows with growing number of joins	Relationships must be created at the application level
Query language	Cypher: native graph query language	SQL: complexity grows as the number of joins increases	Different languages are used but none is tailored to express relationships
Transaction support	Retains ACID transactions	ACID transaction support	BASE transactions prove unreliable for data relationships
Processing at scale	Inherently scalable for pattern-based queries	Scales through replication, but it's costly	Scalable, but data integrity isn't trustworthy

Advantages

- **Performance -** In relational databases, performance suffers as the number and depth of relationships increases. In graph databases like Neo4j, performance remains high even if the amount of data grows significantly.

- **Flexibility -** Neo4j is flexible, as the structure and schema of a graph model can be easily adjusted to the changes in an application. Also, you can easily upgrade the data structure without damaging existing functionality.

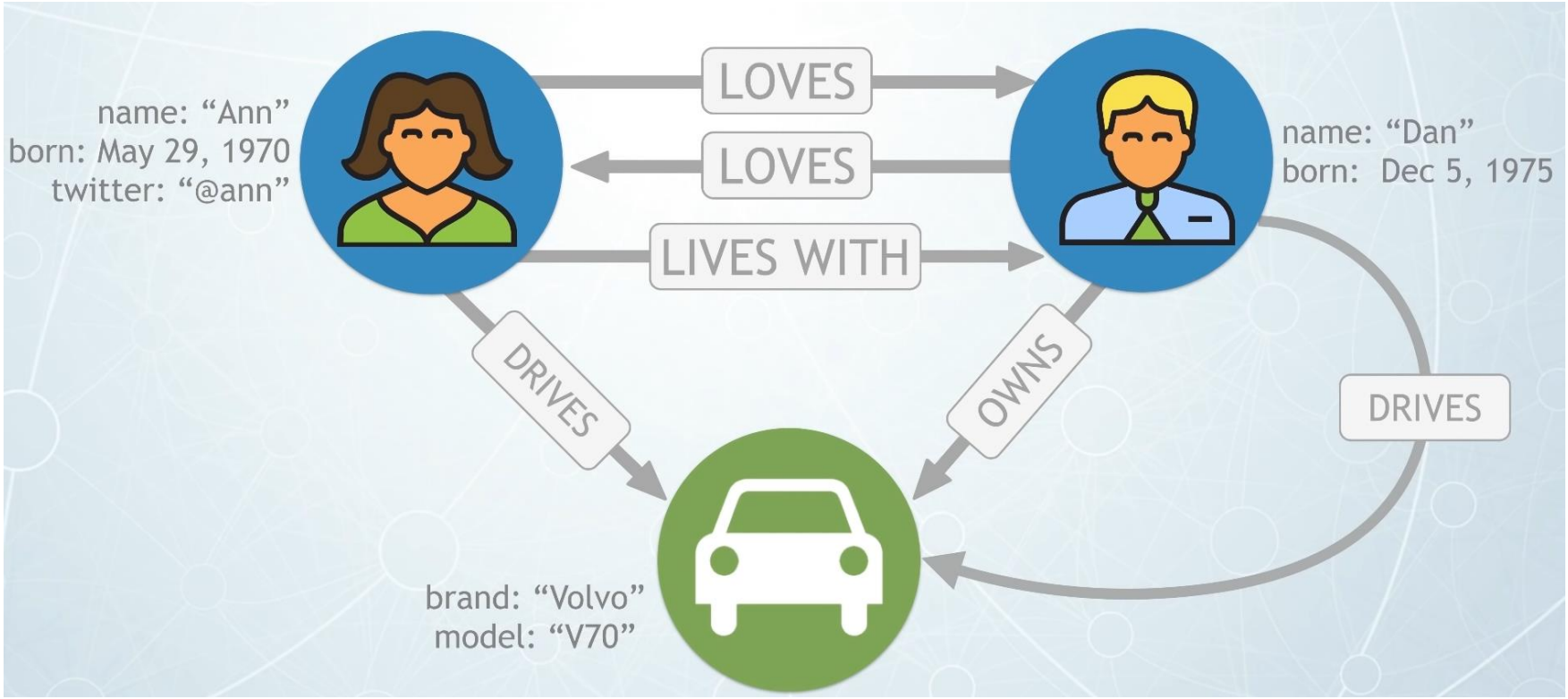
- **Agility -** The structure of a Neo4j database is easy-to-upgrade, so the data store can evolve along with your application.

Use Cases

- Fraud detection and analytics
- Network and database infrastructure monitoring
- Recommendation engines
- Social networks
- Identity and access management

CYPHER, THE GRAPH QUERY LANGUAGE

Detailed Property Graph



Who drives a car owned by a lover?

```
MATCH
    (p1:Person)-[:DRIVES]->(c:Car)-[:OWNED_BY]->(p2:Person)<-
[:Loves]-(p1)
RETURN
   p1
```

Components of a Cypher Query

```
MATCH (p:Person)-[:ACTED_IN]->(:Movie)
RETURN p
```

MATCH and RETURN are Cypher keywords

p is a variable

:Movie is a node label

:ACTED_IN is a relationship

AsciiArt for Nodes

Nodes are surrounded by parenthesis

```
()  or (p)
```

Labels, or tags, start with : and group nodes by roles or types

```
(p:Person:Mammal)
```

Nodes can have properties

```
(p:Person {name : 'Veronica'})
```

AsciiArt for Nodes

```
()
(matrix)
 (:Movie)
(matrix:Movie)
(matrix:Movie {title: "The Matrix"})
(matrix:Movie {title: "The Matrix", released: 1997})
```

() represents an anonymous, uncharacterized node. To refer to the node elsewhere, a variable can be added, for example: (matrix). A variable is restricted to a single statement.

The Movie label (prefixed in use with a colon) declares the node's type. This restricts the pattern, keeping it from matching (say) a structure with an Actor node in this position.

AsciiArt for Relationships

Relationships are wrapped with hyphens or square braquets

```
--> or  - [h:HIRED] ->
```

Direction of the relationship is specified with <>

```
(p1) - [:HIRED] -> (p2)  or (p1) <- [:HIRED] - (p2)
```

Relationships have properties too

```
- [:HIRED {type: 'full-time'}] ->
```

What are those?

Relationships are wrapped with hyphens or square braquets

```
--> or  - [h:HIRED] ->
```

Direction of the relationship is specified with <>

```
(p1) - [:HIRED] -> (p2)  or (p1) <- [:HIRED] - (p2)
```

Relationships have properties too

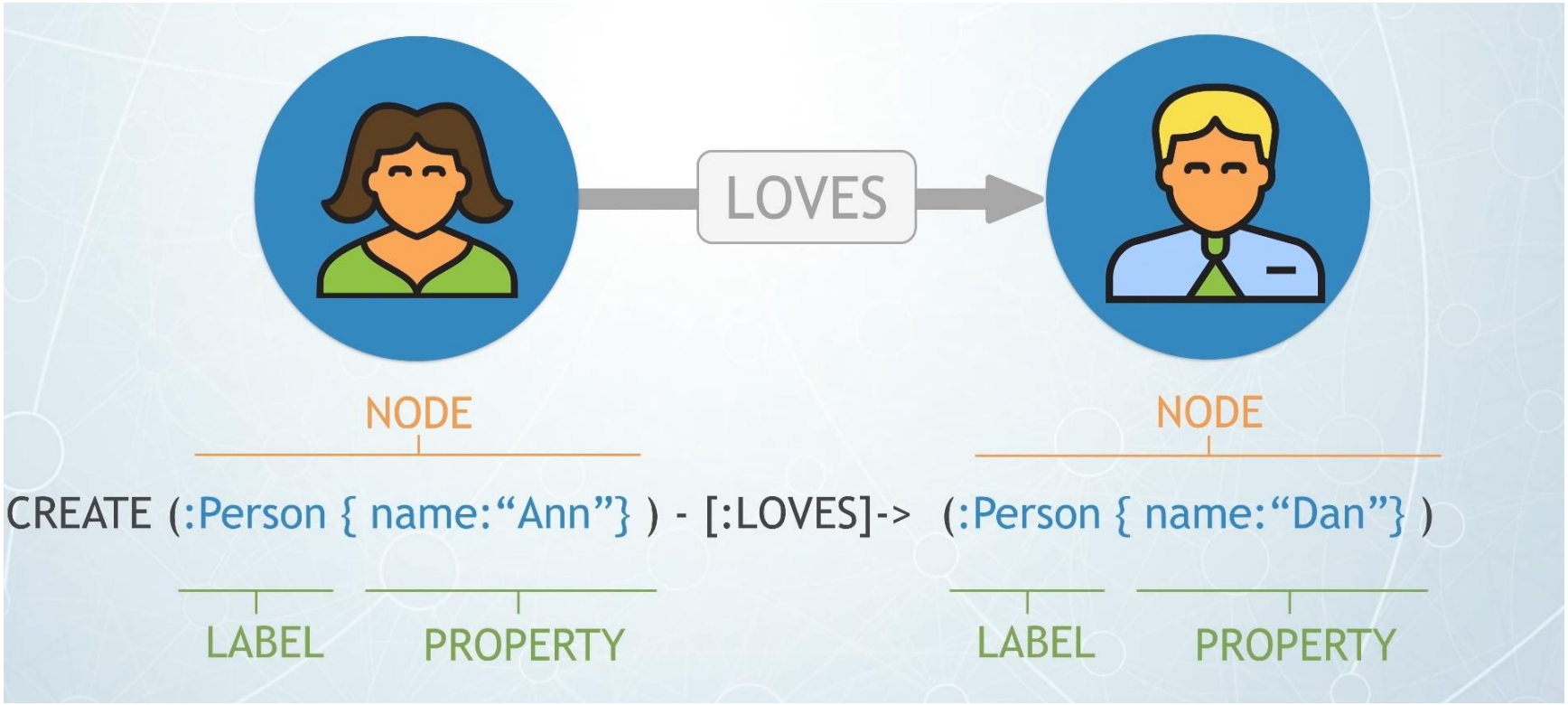
```
- [:HIRED {type: 'full-time'}] ->
```

AsciiArt for Relationships

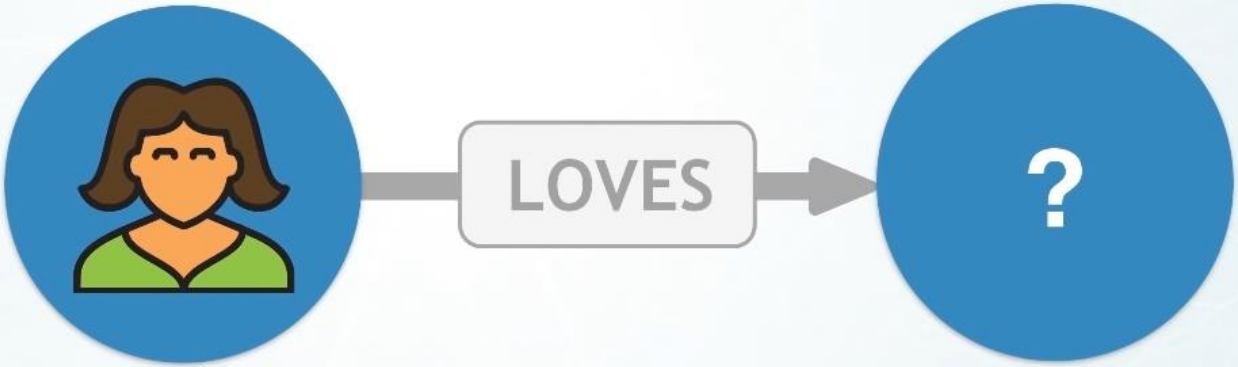
```
-->
-[role]->
-[:ACTED_IN]->
-[role:ACTED_IN]->
-[role:ACTED_IN {roles: ["Neo"]}]->
```

Cypher uses a pair of dashes (--) to represent an undirected relationship. Directed relationships have an arrowhead at one end (<--, -->). Bracketed expressions ([…]) can be used to add details

Creating the Data



Whom does Ann love?




```
MATCH
   (:Person {name:“Ann”})-[:LOVES]->(op:Person)
RETURN
   op
```

How do I find Ann's car?

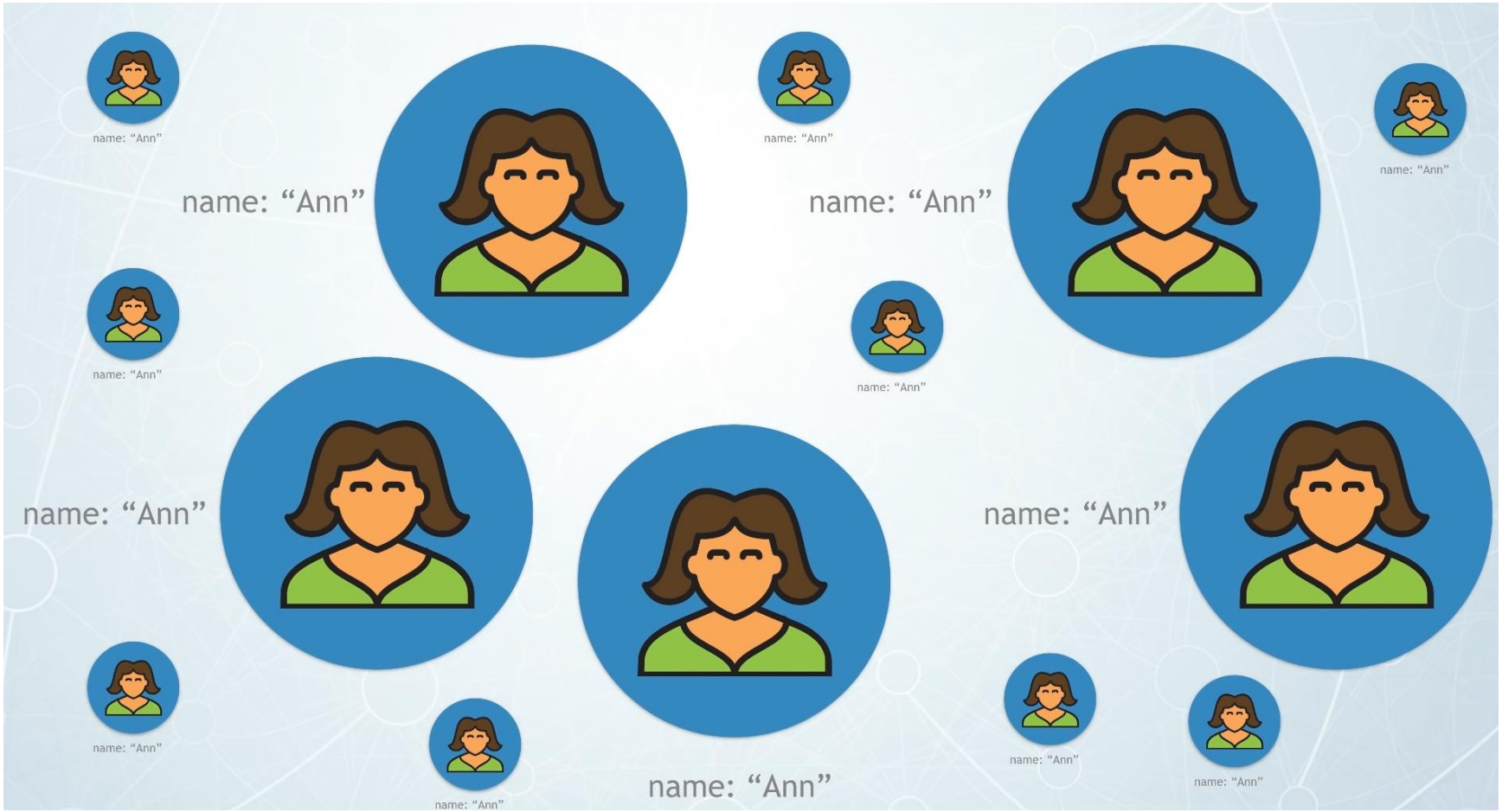
```
MATCH
  (:Person {name: 'Ann'})-[:DRIVES]->(c:Car)
RETURN
  c
```

How do I find Ann's car?

Another way:

```
MATCH
  (a:Person)-[:DRIVES]->(c:Car)
WHERE
  a.name='Ann'
RETURN
  c
```

Uniqueness

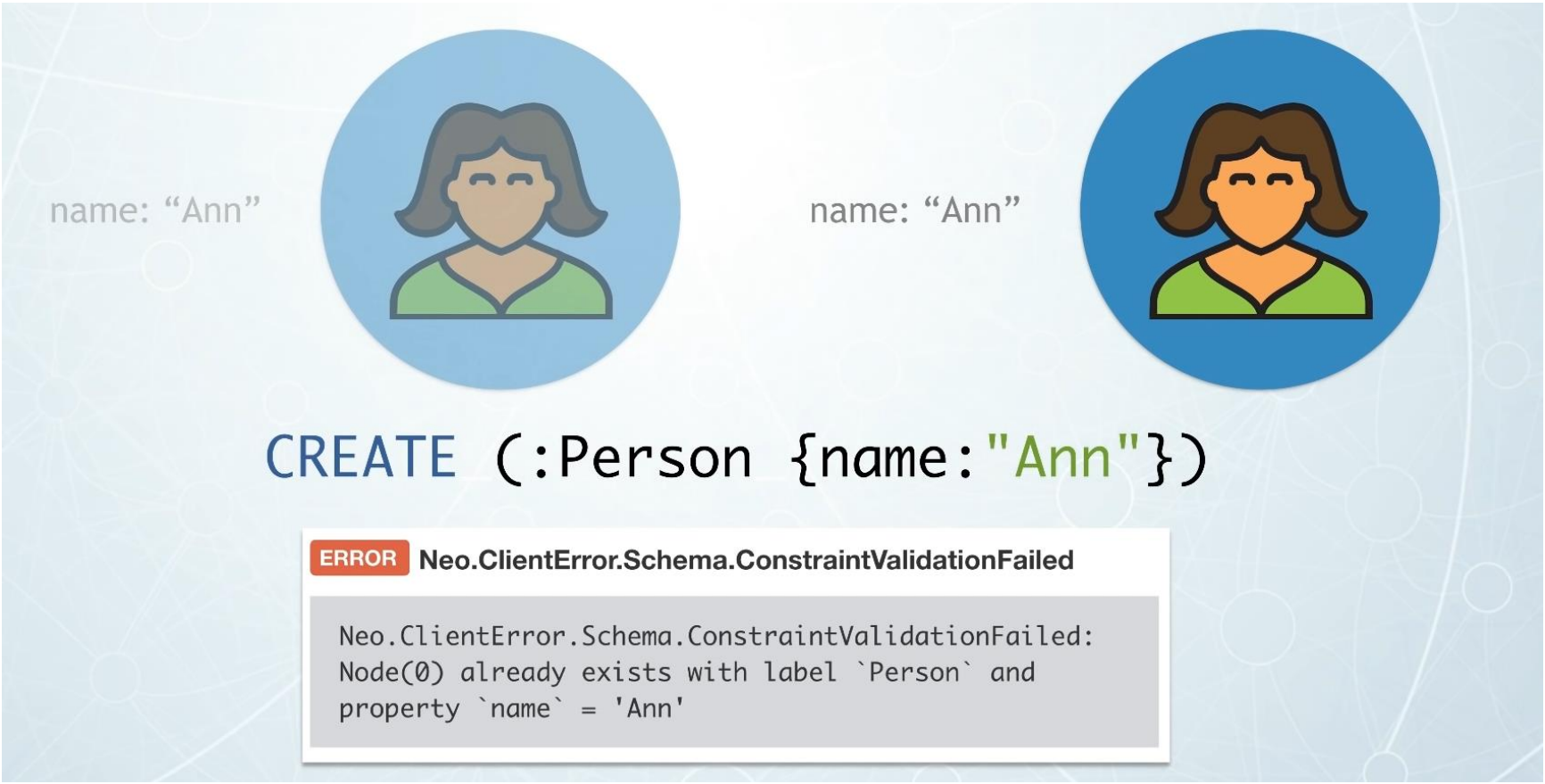

name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”
name: “Ann”

There can only be only One!

name: “Ann”

```
CREATE CONSTRAINT ON (p:Person)
ASSERT p.name IS UNIQUE
```

I want another Ann!



Creating and Querying Nodes

```
CREATE (me:Person {name: "My Name" })
RETURN me

MATCH (me:Person )
WHERE me.name="My Name"
RETURN me.name
```

or in a short-hand syntax:

```
MATCH (me:Person {name:"My Name"})
RETURN me.name
```

The All Nodes Query

Return **all nodes** in the graph:

```
MATCH (n)
RETURN n
```

(In a larger graph this will return A LOT of data, usually you add a LIMIT 100 or such.)

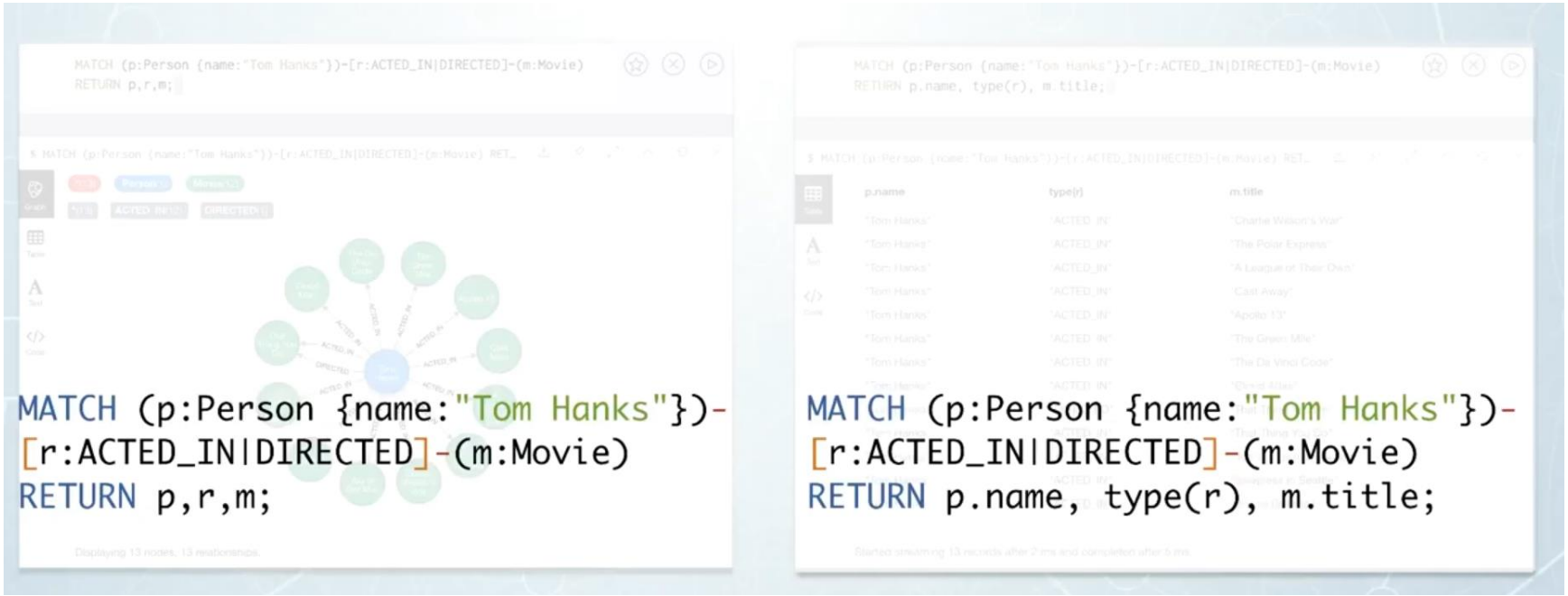
Full graph search.

Visits every single node to see whether it matches the pattern of (n). In this concrete case

The pattern is simply a node that may or may not have a label or relationships, so it will match every single node in the graph.

The RETURN clause then returns all of the information about each of those nodes, including all of their properties.

Query Data


MATCH (p:Person {name:"Tom Hanks"})-[r:ACTED_IN|DIRECTED]-(m:Movie)
RETURN p,r,m;
MATCH (p:Person {name:"Tom Hanks"})-[r:ACTED_IN|DIRECTED]-(m:Movie)
RETURN p.name, type(r), m.title;

Where clause

```
MATCH (p:Person)-[r:ACTED_IN]->(m:Movie)
WHERE m.released >= 2000
RETURN m.released, a.name
```

Filtering Results

```
MATCH (m:Movie { title: "The Matrix" })
RETURN m
```

```
MATCH (m:Movie)
WHERE m.title = "The Matrix"
RETURN m
```

Filtering Results

Filter by comparing properties of different nodes. For example, we could RETURN all of the actors who acted with Tom Hanks and are older than him:

```
MATCH (tom:Person)-[:ACTED_IN]->()<-[:ACTED_IN]-(actor:Person)
WHERE tom.name = "Tom Hanks"
AND actor.born < tom.born
RETURN actor.name AS Name
```

Operators

```
=, <>, <, >, <=, >=, IS NULL, IS NOT NULL
```

Regular expressions

```
MATCH (p:Person)-[r:ACTED_IN]->(m:Movie)
WHERE p.name =~ "K.+" OR m.released > 2000
RETURN p,r,m
```

Adding Properties

Add a tagline to the "Mystic River" :Movie node we've just added. First, locate the single movie again by its title, then SET the tagline property. The query:

```
MATCH (movie:Movie)
WHERE movie.title = "Mystic River"
SET movie.tagline = "We bury our sins here, Dave. We wash them clean."
RETURN movie.title AS title, movie.tagline AS tagline
```

Update Property

```
MATCH (movie:Movie)
WHERE movie.title = "Mystic River"
SET movie.released = 2003
RETURN movie.title AS title, movie.released AS released
```

The syntax is the same for updating or adding a property. You SET a property. If the property exists, SET will update it. If the property doesn't exist, SET will add it.

Creating Relationships

```
CREATE (movie:Movie {title: "Mistic River", released:1993 })
```

find the actor "Kevin Bacon" and the movie "Mystic River" and add the relationship between the movie and the actor to the dataset:

```
MATCH (kevin:Person) WHERE kevin.name = "Kevin Bacon"
MATCH (mystic:Movie) WHERE mystic.title = "Mystic River"
CREATE (kevin)-[r:ACTED_IN {roles:["Sean"]}]->(mystic)
RETURN mystic, r, kevin
```

Creating Relationships

Create ourselves first in the database:

```
CREATE (me:Person {name:"My Name"}) RETURN me.name
```

Rate the movie "Mystic River":

```
MATCH (kevin:Person), (movie:Movie)
WHERE me.name="My Name" AND movie.title="Mystic River"
CREATE (me)-[r:REVIEWED {rating:80, summary:"tragic character movie"}]->(movie)
RETURN me, r, movie
```

Deleting Nodes

```
CREATE (me:Person {name:"My Name"}) RETURN me.name
```

Let's then run the following query to make sure you have been added successfully to the graph.

```
MATCH (p:Person {name:"My Name"})
RETURN p.name
```

To remove both yourself and any relationships you may or may not have, you need to run:

```
MATCH (p:Person {name:"My Name"})
OPTIONAL MATCH (me)-[r]-()
DELETE me,r
```

Deleting Nodes

As this is a frequent task, `DETACH DELETE` was added to Cypher, which deletes a node with all its relationships.

```
MATCH (emil:Person {name:"Emil Eifrem"})
DETACH DELETE emil
```

Order by, Skip and Limit

In Cypher it's easy to order results using an ORDER BY command.

Display the oldest people in the database. We could use the following query:

```
MATCH (person:Person)
RETURN person.name, person.born
ORDER BY person.born
```

```
MATCH (actor:Person) -[:ACTED_IN]->(movie:Movie)
RETURN actor.name AS Actor, movie.title AS Movie
SKIP 10 LIMIT 10
```

Case Sensitivity

Case sensitive:

- Node Labels
- Relationship types
- Porperty keys

Case insensitive:

- Cypher keywords

Note on null

`null` is not `null`

null represents missing or undefined values.

You do not store a null value in a property. It just doesn't exist on that particular node.

Indexing and Labels

To increase search speed:

```
CREATE INDEX ON :Movie(title)
```

Drop the index created:

```
DROP INDEX ON :Movie(title)
```

LAB

Lab - Building an email targeting system with Neo4j

Step #1: Installing Neo4j

Download and install Neo4j community edition

Step #2: Launching the Neo4j Browser

Create new graph > “Play” > open Neo4J browser

Step #3: Data modeling

Offer the most relevant products or services to customers

Lab - Building an email targeting system with Neo4j

Our email targeting system is going to have the following entities (with attributes in parentheses):

Category (title)
Product (title, description, price, availability, shippability)
Customer (name, email, registration date)
Promotional Offer (type, content)

So here's what we've got:

Product is_in **Category**
Customer added_to_wish_list **Product**
Customer bought **Product**
Customer viewed (clicks_count) **Product**

Lab - Building an email targeting system with Neo4j

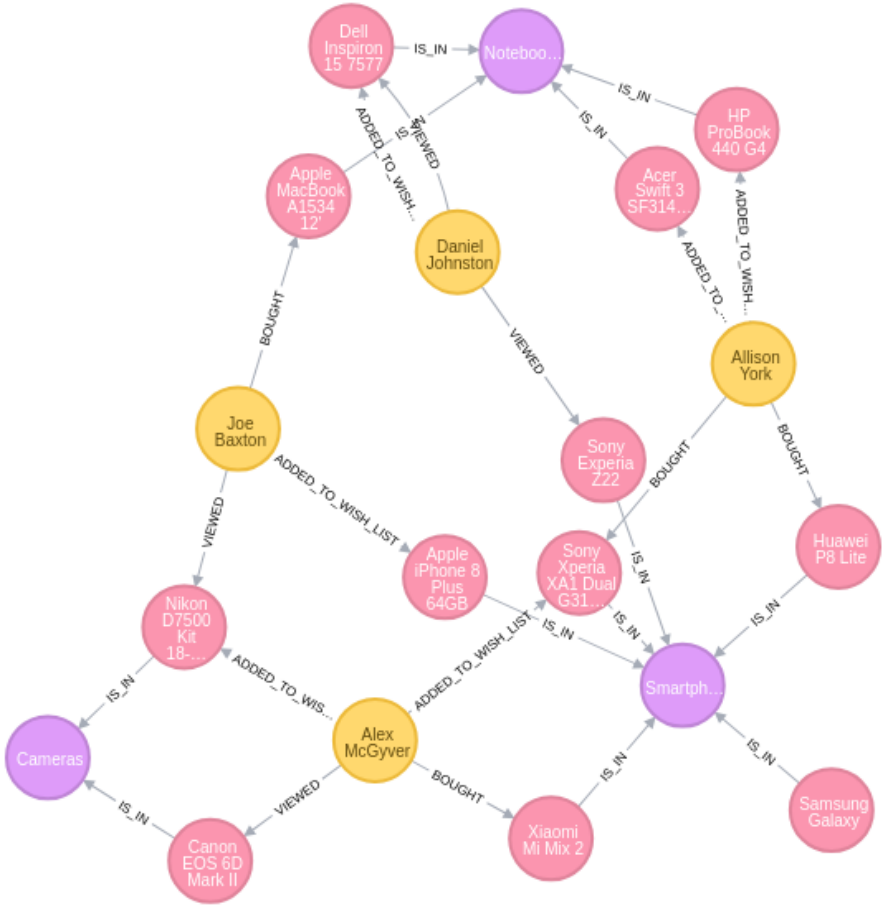
Step #4: Import the database

Copy contents of email_neo4j.txt to browser and run it

Try out query:

```
MATCH (n)
RETURN n
```

Lab - Building an email targeting system with Neo4j



Lab - Building an email targeting system with Neo4j

Example #1: Using Neo4j to determine customer preferences

Suppose we need to learn preferences of our customers to create a promotional offer for a specific product category, such as **notebooks**.

Lab - Building an email targeting system with Neo4j

Query for all the notebooks that users have viewed or added to their list:

```
MATCH (:Customer)-[:ADDED_TO_WISH_LIST|:VIEWED]->(notebook:Product)-[:IS_IN]->(:Category {title: 'Notebooks'})
RETURN notebook;
```

OR

```
MATCH (:Customer)-[:ADDED_TO_WISH_LIST|:VIEWED]->(notebook:Product)-[:IS_IN]->(cat:Category)
WHERE cat.title = 'Notebooks'
RETURN notebook;
```

Lab - Building an email targeting system with Neo4j

Include these Notebooks in a promotional offer:

```
CREATE(offer:PromotionalOffer {type: 'discount_offer',
content: 'Notebooks discount offer...'})
WITH offer
MATCH (:Customer)-[:ADDED_TO_WISH_LIST|:VIEWED]-
>(notebook:Product)-[:IS_IN]->(:Category {title:
'Notebooks'})
MERGE(offer)-[:USED_TO_PROMOTE]->(notebook);
```

Lab - Building an email targeting system with Neo4j

Check Notebooks with the promotional offer:

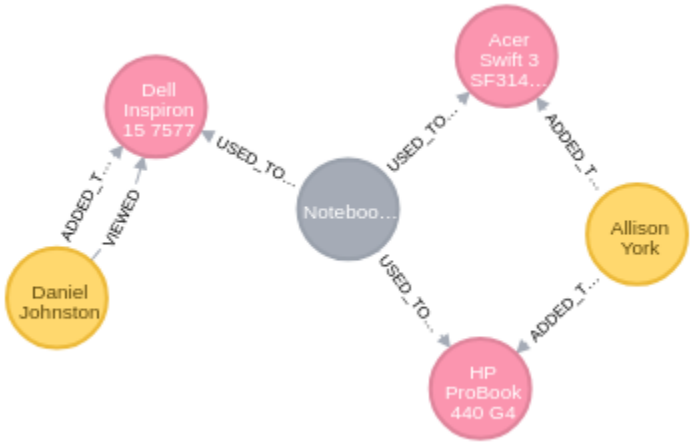
```
MATCH (offer:PromotionalOffer)-[:USED_TO_PROMOTE]->(product:Product)
RETURN offer, product;
```

Lab - Building an email targeting system with Neo4j

When building the promotional offer it is important to check which customers viewed or added those notebooks to their list:

```
MATCH (offer:PromotionalOffer {type: 'discount_offer'})-
[:USED_TO_PROMOTE]->(product:Product)<-
[:ADDED_TO_WISH_LIST|:VIEWED]-(customer:Customer)
RETURN offer, product, customer;
```

Lab - Building an email targeting system with Neo4j



Lab - Building an email targeting system with Neo4j

Example #2

Now let's imagine that we need to develop a more efficient promotional campaign. To increase conversion rates, we should offer alternative products to our customers. For example, if a customer shows interest in a certain product but doesn't buy it, we can create a promotional offer that contains alternative products.

Lab - Building an email targeting system with Neo4j

All products that don't have either:

`ADDED_TO_WISH_LIST`,
`VIEWED`,
`BOUGHT` relationships with a client named Alex McGyver.

Opposite query that finds all products that Alex McGyver has

`ADDED_TO_WISH_LIST`,
`VIEWED`,
`BOUGHT`.

Two queries select products in the same categories.

Only products that cost 20 percent more or less than a specific item should be recommended to the customer.

Lab - Building an email targeting system with Neo4j

```
MATCH (alex:Customer {name: 'Alex McGyver'})
MATCH (free_product:Product)
WHERE NOT ((alex)-->(free_product))
MATCH (product:Product)
WHERE ((alex)-->(product))

MATCH (free_product)-[:IS_IN]->()<-[:IS_IN]-(product)
WHERE  ((product.price-product.price*0.20)  >=  free_product.price
<= (product.price+product.price*0.20))

RETURN free_product;
```

Lab - Building an email targeting system with Neo4j

The **product** variable is supposed to contain the following items:

- **Xiaomi Mi Mix 2** (price: $420.87): Price range for recommendations: from $336.70 to $505.04.
- **Sony Xperia XA1 Dual G3112** (price: $229.50): Price range for recommendations: from $183.60 to $275.40.

The **free_product** variable is expected to have these items:

- Apple iPhone 8 Plus 64GB (price: $874.20)
- Huawei P8 Lite (price: $191.00)
- Samsung Galaxy S8 (price: $784.00)
- Sony Xperia Z22 (price: $765.00)

Lab - Building an email targeting system with Neo4j

The **product** variable is supposed to contain the following items:

- Xiaomi Mi Mix 2 (price: $420.87): Price range for recommendations: from $336.70 to $505.04.
- Sony Xperia XA1 Dual G3112 (price: $229.50): Price range for recommendations: from $183.60 to $275.40.

The **free_product** variable is expected to have these items:

- Apple iPhone 8 Plus 64GB (price: $874.20)
- **Huawei P8 Lite (price: $191.00)**
- Samsung Galaxy S8 (price: $784.00)
- Sony Xperia Z22 (price: $765.00)

Lab - Building an email targeting system with Neo4j

```
MATCH (alex:Customer {name: 'Alex McGyver'})
MATCH (free_product:Product)
WHERE NOT ((alex)-->(free_product))
MATCH (product:Product)
WHERE ((alex)-->(product))

MATCH (free_product)-[:IS_IN]->()<-[:IS_IN]-(product)
WHERE  ((product.price-product.price*0.20)  >=  free_product.price
<= (product.price+product.price*0.20))

CREATE(offer:PromotionalOffer{type:'personal_replacement_offer',
content: 'Personal replacement offer for ' + alex.name})
WITH offer, free_product, alex
MERGE(offer)-[rel:USED_TO_PROMOTE{email:alex.email}]-
>(free_product)
RETURN offer, free_product, rel;
```

FE07

FE07

Create new graph, “Play”, open Neo4J browser.

Import “movies” database:

- :play movies > 2ª page > click the code > press play

FE07

Try out query:

```
MATCH (n) WITH COUNT(n) AS numVertices
MATCH (a)-[e]->(b)
RETURN numVertices, COUNT(e) AS numEdges
```

Try out query:

```
MATCH (n)
RETURN n
```

FE07

1) RETURN a list of all the characters in the movie The Matrix.

Movies have the label Movie and a title property you want to compare to.

We're looking for the characters—the roles which are a property of the ACTED_IN relationships—not the names of the actors.

2) Find all of the movies that Tom Hanks acted in?

3) Limit that to movies which were released after 2000? Note that there is a released property on Movie.

FE07

4) Find directors acting in their movies?

5) Find all movies in which Keanu Reeves played the role Neo.

You need an variable for the relationship.

The **ACTED_IN** relationship has a **roles** property (which is an array).

The syntax for seeing whether an element is in an array is **{element} IN r.roles**.

Generally check for the existence of the value of **{expression} IN {collection}**

6) Return the names of all the directors each actor has worked with.

FE07

7) Return the count of movies in which each actor has acted.

8) Return the count of movies in which an actor and director have jointly worked.

9) Write a query that will display the five (5) busiest actors, i.e. the ones who have been in the most movies.

Bases de Dados de Grafos

AULA PL08

Hugo Peixoto

2018 – 2019 Universidade do Minho