UMD DATA605 - Big Data Systems

12.2: Neo4j

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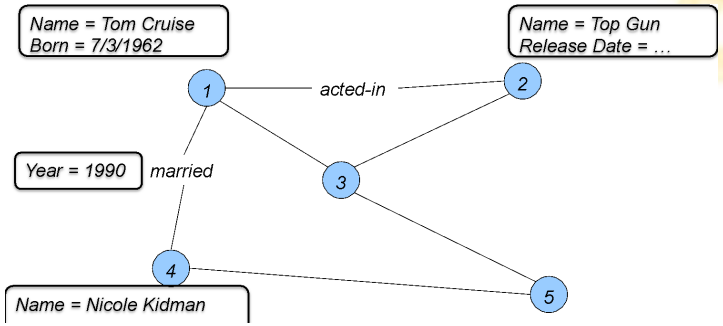
Neo4j

- Graph DB storing data as Property Graph
  - Nodes, edges hold data as key-value pairs
- Graph structure enables flexible schema
  - Focus is on relationships between values
- Two querying languages
  - Cypher
  - Gremlin
- GUI or REST API
- Full ACID-compliant transactions
- High-availability clustering
- Incremental backups
- Run in small application or large server clusters



Graph Data Model in Neo4j: Intuition

- **Nodes**
  - Represent entities or objects
  - Connected via *relationships*
  - Have *properties* (key/value pairs)
- **Relationships**
  - Represent (directional) connections between nodes
  - Relationship types give semantic meaning to edges
  - Multiple relationships per node
  - Have *properties* (key/value pairs)
- **Properties**
  - Store key–value information on nodes and relationships
    - Named values (key is a string)
  - Indexed and constrained
  - Composite indexes from multiple properties
- **Labels**
  - Group nodes into sets with similar roles
  - Nodes may have multiple labels
  - Labels indexed for faster node retrieval
  - Native label indexes optimized for performance

Why Cypher is Powerful

- Direct mapping between query and graph structure
  - Encourages thinking in relationships
  - Reduces impedance mismatch with graph data
- Scales naturally with connected data
- Enables expressive exploratory queries

Basic Cypher Pattern Matching

- Queries describe graph patterns to search for
  - Parentheses `()` represent nodes
  - Brackets `[]` represent relationships
  - Arrows `->` or `<-` show relationship direction
- Example

```
(a)-[:FRIEND_OF]->(b)
```

MATCH Clause

- Used to find patterns in the graph
  - Similar to `FROM ... WHERE` in relational databases
  - Does not modify data
  - Can match multiple patterns in one query
- Example

```
MATCH (p:Person)-[:LIVES_IN]->(c:City)
```

Advanced Matching

- `RETURN` clause specifies what data to output
  - Can return nodes relationships or properties
  - Controls query result shape
  - Example

    ```
    RETURN p.name, c.name
    ```
- Filtering with `WHERE`
  - Adds conditions to pattern matches
  - Works with properties labels and expressions
  - Often combined with `MATCH`
  - Example

    ```
    WHERE p.age > 30
    ```
- Aggregation and Grouping
  - Uses functions like `count`, `avg`, `max`
  - Aggregation happens after `MATCH`
  - `GROUP BY` is implicit in `RETURN`
  - Example

    ```
    RETURN c.name, count(p)
    ```

Creating Data with CREATE

- Used to add new nodes and relationships
- Pattern describes what should be created
- Executes exactly as written
- Example

```
CREATE
  (a:Person {name:"Alice"})
  -[:KNOWS]->
  (b:Person {name:"Bob"})
```

Updating Graph Data

- `SET` modifies properties or labels
- `REMOVE` deletes properties or labels
- Allows incremental graph evolution
- Example

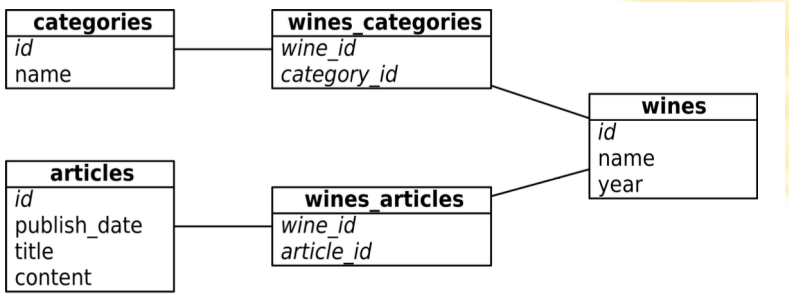
```
SET p.age = p.age + 1
```

Wine Suggestion Engine: Example 1/2

- **Create a wine suggestion engine**
  - Wines categorized by:
    - Varieties (e.g., Chardonnay, Pinot Noir)
    - Regions (e.g., Bordeaux, Napa, Tuscany)
    - Vintage (year grapes harvested)
  - Track articles describing wines by authors
  - Users track favorite wines
  - ...

Wine Suggestion Engine: Example 2/2

- **Relational approach**
- Create various tables
  - `wines`: (id, name, year)
  - `wines_categories` (wine_id, category_id)
  - `category` table (id, name)
  - `wines_articles` (wine_id, article_id)
  - `articles` (id, publish_date, title, content)
- Relationships are
  - `produced`
  - `reported_on`
  - `grape_type`



- **Problem with relational approach**
  - There isn't much of a schema
  - Lots of incomplete data
  - An old saying in relational DB world: *"On a long enough timeline all fields become optional"*

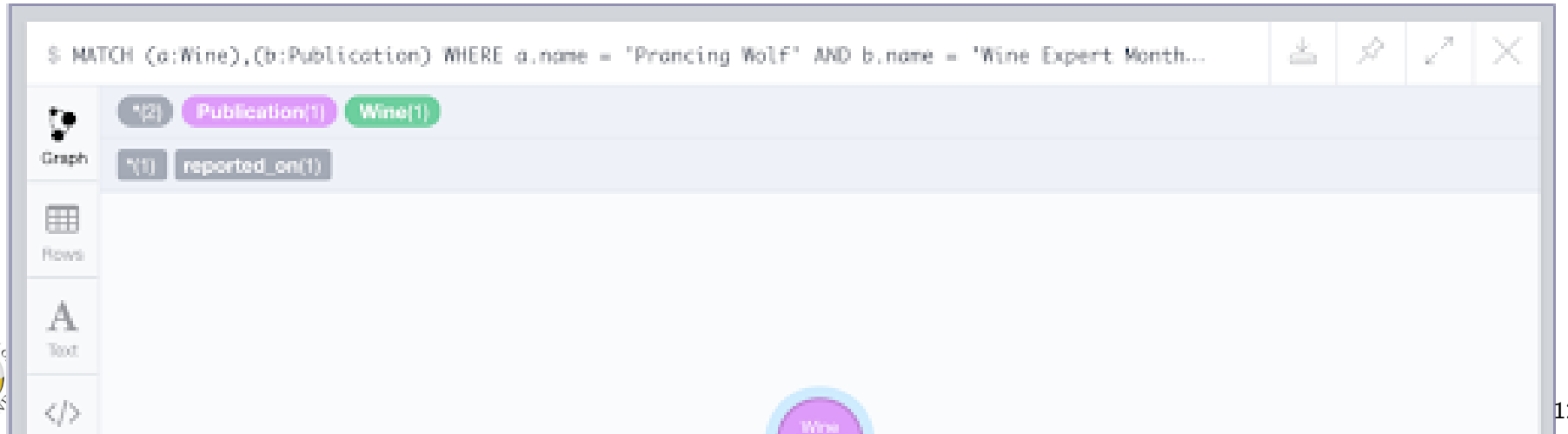
Cypher Example

- **Graph DB approach**: provide values and structure only where necessary

```
CREATE (w:Wine
    {name: "Prancing Wolf",
      style: "ice wine",
      vintage: 2015})

CREATE (p:Publication
    {name: "Wine Expert Monthly"})

MATCH (p:Publication
    {name: "Wine Expert Monthly"}),
    (w:Wine {name: "Prancing Wolf",
    vintage: 2015})
    CREATE (p)-[r:reported_on]->(w)
```

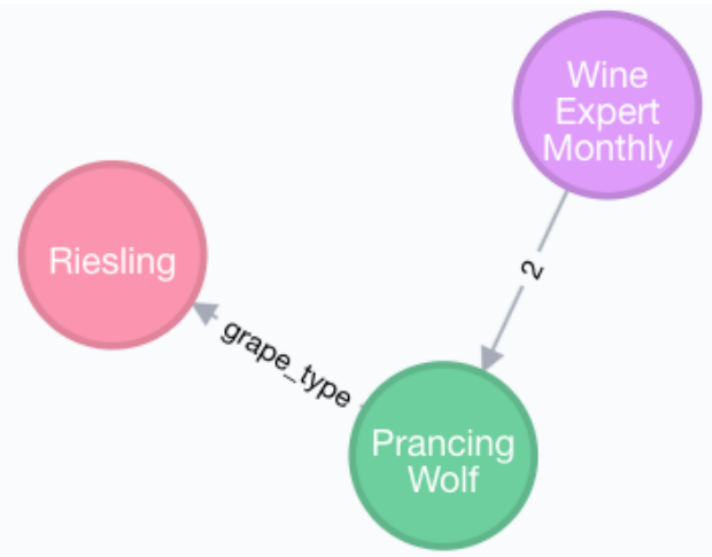


Cypher Example

```
MATCH (p:Publication {name: "Wine Expert Monthly"}),
    (w:Wine {name: "Prancing Wolf"})
    CREATE (p)-[r:reported_on {rating: 2}]->(w)

CREATE (g:GrapeType {name: "Riesling"})

MATCH (w:Wine {name: "Prancing Wolf"}),
  (g:GrapeType {name: "Riesling"})
  CREATE (w)-[r:grape_type]->(g)
```



Cypher Example

```
CREATE (wr:Winery {name: "Prancing Wolf Winery"})
MATCH (w:Wine {name: "Prancing Wolf"}),
    (wr:Winery {name: "Prancing Wolf Winery"})
    CREATE (wr)-[r:produced]->(w)
CREATE (w:Wine
    {name:"Prancing Wolf", style: "Kabinett", vintage: 2002})
CREATE (w:Wine
    {name: "Prancing Wolf", style: "Spätlese", vintage: 2010})
MATCH (wr:Winery
    {name: "Prancing Wolf Winery"}),(w:Wine {name: "Prancing Wolf"})
    CREATE (wr)-[r:produced]->(w)
MATCH (w:Wine), (g:GrapeType {name: "Riesling"})
    CREATE (w)-[r:grape_type]->(g)
```

Cypher Example

- Add a social component to the wine graph
  - People preference for wine
  - Relationships with one another
- The changes were made “superimposing” new relationships without changing the previous data :::columns ::::{.column width=50%}

```
CREATE (p:Person {name: "Alice"})

MATCH (p:Person {name: "Alice"}),
    (w:Wine {name: "Prancing Wolf",
    style: "ice wine"})
    CREATE (p)-[r:likes]->(w)

CREATE (p:Person {name: "Patty"})

MATCH (p1:Person {name: "Patty"}),
    (p2:Person {name: "Tom"})
    CREATE (p1)-[r:friends]->(p2)
```

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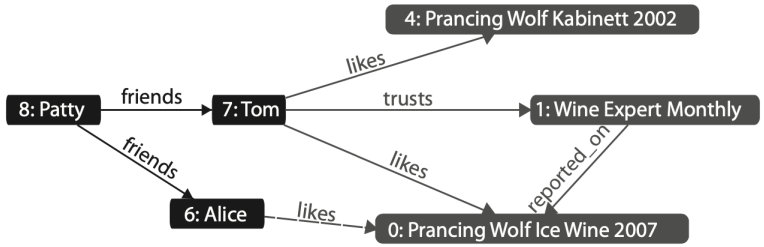
Cypher: Query Structure

```
MATCH [Nodes and relationships]
  WHERE [Boolean filter statement]
  RETURN [DISTINCT] [statements [AS alias]]
  ORDER BY [Properties] [ASC or DESC]
  SKIP [Number] LIMIT [Number]
```

Cypher: Query Example

```
MATCH (p:Person
  {name: "Alice"})-->(n)
  RETURN n;
```




```
MATCH (p:Person
  {name: "Alice"})-->(other: Person)
  RETURN other.name;
```

```
MATCH (fof:Person)-[:friends]-(f:Person)-[:friends]-(p:Person {name: "Alice"})
  RETURN fof.name;
```

Matching nodes and relationships

- Nodes
  - (a), (), (:Ntype), (a:Ntype),
  - (a { prop:'value' }) ,
  - (a:Ntype { prop:'value' })
- Relationships
  - (a)–(b)
  - (a)–>(b), (a)<–(b),
  - (a)–>(), (a)-[r]->(b),
  - (a)-[:Rtype]->(b), (a)-[:R1|:R2]->(b),
  - (a)-[r:Rtype]->(b)
- May have more than 2 nodes
  - (a)–>(b)<–(c), (a)–>(b)–>(c)
- Path
  - p = (a)–>(b)

More options

- Relationship distance:
  - `(a)-[:Rtype*2]->(b)`: 2 hops of type Rtype
  - `(a)-[:Rtype*]->(b)`: any number of hops of type Rtype
  - `(a)-[:Rtype*2..10]->(b)`: 2-10 hops of Rtype
  - `(a)-[:Rtype*..10]->(b)`: 1-10 hops of Rtype
  - `(a)-[:Rtype*2..]->(b)`: at least 2 hops of Rtype
- Could be used also as:
  - `(a)-[r*2]->(b)` r gets a sequence of relationships
  - `(a)-[*{prop:val}]->(b)`

Operators

- Mathematical
  - +, -, *, /,%, ^ (power, not XOR)
- Comparison
  - =,<>,<,>,>=,<=, =~ (Regex), IS NULL, IS NOT NULL
- Boolean
  - AND, OR, XOR, NOT
- String
  - Concatenation through +
- Collection
  - Concatenation through +
  - IN to check if an element exists in a collection

More WHERE options

- WHERE others.name IN [‘Andres’, ‘Peter’]
- WHERE user.age IN range (18,30)
- WHERE n.name =~ ’Tob.*‘
- WHERE n.name =~ ’(?i)ANDR.*‘ - (case insensitive)
- WHERE (tobias)–>()
- WHERE NOT (tobias)–>()
- WHERE has(b.name)
- WHERE b.name? = ‘Bob’ (Returns all nodes where name = ‘Bob’ plus all nodes without a name property)

Functions

- On paths:
  - MATCH shortestPath((a)-[*]-(b))
  - MATCH allShorestPath((a)-[*]-(b))
  - Length(path) – The path length or 0 if not exists.
  - RETURN relationships(p) - Returns all relationships in a path.
- On collections:
  - RETURN a.array, filter(x IN a.array WHERE length(x)= 3) FILTER - returns the elements in a collection that comply to a predicate.
  - WHERE ANY (x IN a.array WHERE x = “one”) – at least one
  - WHERE ALL (x IN nodes(p) WHERE x.age $>$ 30) – all elements
  - WHERE SINGLE (x IN nodes(p) WHERE var.eyes = “blue”) – Only one
- nodes(p) – nodes of the path p

With

- Manipulate result sequence before passing to following query parts
- Usage of WITH:
  - Limit entries passed to other MATCH clauses
  - Introduce aggregates for predicates in WHERE
  - Separate reading from updating the graph. Each query part must be read-only or write-only

Data access is programmatic

- REST API
- Through the Java APIs
  - JVM languages have bindings to the same APIs
    - JRuby, Jython, Clojure, Scala...
- Managing nodes and relationships
- Indexing
- Traversing
- Path finding
- Pattern matching