

B4M36DS2, BE4M36DS2: Database Systems 2

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Lecture 12

Graph Databases: Neo4j: Cypher

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Lecture Outline

Graph databases

- Introduction

Neo4j

- Data model: **property graphs**
- **Traversal framework**
- **Cypher** query language
 - Read, write, and general clauses

Neo4j Graph Database



Sample Data

Sample graph with **movies and actors**

```
(m1:MOVIE { id: "vratnelahve", title: "Vratné lahve", year: 2006 })
(m2:MOVIE { id: "samotari", title: "Samotáři", year: 2000 })
(m3:MOVIE { id: "medvidek", title: "Medvídek", year: 2007 })
(m4:MOVIE { id: "stesti", title: "Šťěstí", year: 2005 })

(a1:ACTOR { id: "trojan", name: "Ivan Trojan", year: 1964 })
(a2:ACTOR { id: "machacek", name: "Jiří Macháček", year: 1966 })
(a3:ACTOR { id: "schneiderova", name: "Jitka Schneiderová", year: 1973 })
(a4:ACTOR { id: "sverak", name: "Zdeněk Svěrák", year: 1936 })

(m1)-[c1:PLAY { role: "Robert Landa" }]->(a2)
(m1)-[c2:PLAY { role: "Josef Tkaloun" }]->(a4)
(m2)-[c3:PLAY { role: "Ondřej" }]->(a1)
(m2)-[c4:PLAY { role: "Jakub" }]->(a2)
(m2)-[c5:PLAY { role: "Hanka" }]->(a3)
(m3)-[c6:PLAY { role: "Ivan" }]->(a1)
(m3)-[c7:PLAY { role: "Jirka", award: "Czech Lion" }]->(a2)
```

Cypher

Cypher

Cypher

- Declarative **graph query language**
 - Allows for expressive and efficient querying and updates
 - Inspired by SQL (query clauses) and SPARQL (pattern matching)
- **OpenCypher**
 - Ongoing project aiming at Cypher standardization
 - <http://www.opencypher.org/>

Clauses

- E.g. MATCH, RETURN, CREATE, ...
- Clauses can be (almost arbitrarily) **chained together**
 - Intermediate result of one clause is passed to a subsequent one

Sample Query

Find names of actors who played in *Medvídek* movie

```
MATCH (m:MOVIE)-[r:PLAY]->(a:ACTOR)
  WHERE m.title = "Medvídek"
RETURN a.name, a.year
ORDER BY a.year
```

a.name	a.year
Ivan Trojan	1964
Jiří Macháček	1966

Clauses

Read clauses and their sub-clauses

- MATCH – specifies graph patterns to be searched for
 - WHERE – adds additional filtering constraints
- ...

Write clauses and their sub-clauses

- CREATE – creates new nodes or relationships
- DELETE – deletes nodes or relationships
- SET – updates labels or properties
- REMOVE – removes labels or properties
- ...

Clauses

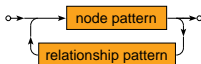
General clauses and their sub-clauses

- RETURN – defines what the query result should contain
 - ORDER BY – describes how the query result should be ordered
 - SKIP – excludes certain number of solutions from the result
 - LIMIT – limits the number of solutions to be included
- WITH – allows query parts to be chained together
- ...

Path Patterns

Path pattern expression

- **Sequence of interleaved node and relationship patterns**
- Describes a single path (not a general subgraph)



- ASCII-Art inspired syntax
 - Circles () for nodes
 - Arrows <-- , -- , --> for relationships

Path Patterns

Node pattern

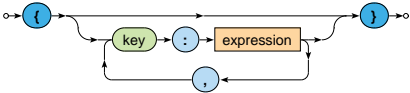
- Matches one data node



- **Variable**
 - Allows us to access a given node later on
- Set of **labels**
 - Data node must have **all the specified labels** to be matched
- **Property map**
 - Data node must have **all the requested properties** (including their values) to be matched (the order is unimportant)

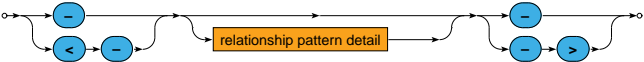
Path Patterns

Property map



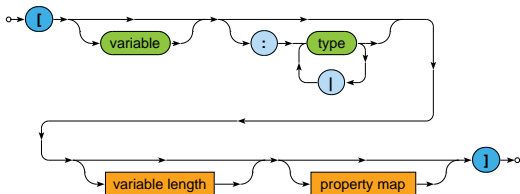
Relationship pattern

- Matches one data relationship



Path Patterns

Relationship pattern

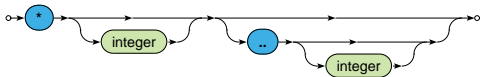


- **Variable**
 - Allows us to access a given node later on
- Set of **types**
 - Data relationship must be of **one of the enumerated types** to be matched

Path Patterns

Relationship pattern (*cont.*)

- **Property map**
 - Data relationship must have **all the requested properties**
- Variable path **length**
 - Allows us to match **paths of arbitrary lengths** (not just exactly one relationship)



- Examples: `*`, `*4`, `*2..6`, `*..6`, `*2..`

Path Patterns

Examples

```
()
```

```
(x)--(y)
```

```
(m:MOVIE)-->(a:ACTOR)
```

```
(:MOVIE)-->(a { name: "Ivan Trojan" })
```

```
()<-[r:PLAY]-()
```

```
(m)-[:PLAY { role: "Ivan" }]->()
```

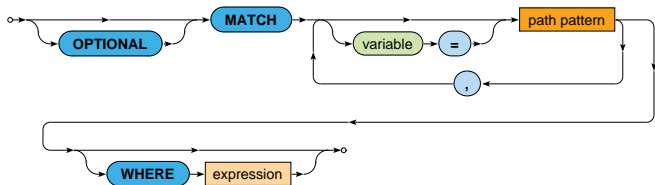
```
(:ACTOR { name: "Ivan Trojan" })-[:KNOW *2]->(:ACTOR)
```

```
()-[:KNOW *5..]->(f)
```

Match Clause

MATCH clause

- Allows to search for **sub-graphs of the data graph** that match the provided path pattern / patterns (all of them)
 - **Query result** (table) = unordered **set of solutions**
 - One solution (row) = set of **variable bindings**
- Each variable has to be bound



Match Clause

WHERE sub-clause may provide additional constraints

- These constraints are **evaluated directly during the matching phase** (i.e. not after it)
- Typical usage
 - Boolean expressions
 - Comparisons
 - Path patterns – true if at least one solution is found
 - ...

Match Clause: Example

Find names of actors who played with *Ivan Trojan* in any movie

```
MATCH (i:ACTOR)-[:PLAY]-(m:MOVIE)-[:PLAY]->(a:ACTOR)
  WHERE (i.name = "Ivan Trojan")
RETURN a.name
```

```
MATCH (i:ACTOR { name: "Ivan Trojan" })
  <-[:PLAY]-(m:MOVIE)-[:PLAY]->
  (a:ACTOR)
RETURN a.name
```

i	m	a		a.name
(a1)	(m2)	(a2)	⇒	Jiří Macháček
(a1)	(m2)	(a3)		Jitka Schneiderová
(a1)	(m3)	(a2)		Jiří Macháček

Match Clause

Uniqueness requirement

- One data node may match several query nodes, but one data relationship may not match several query relationships

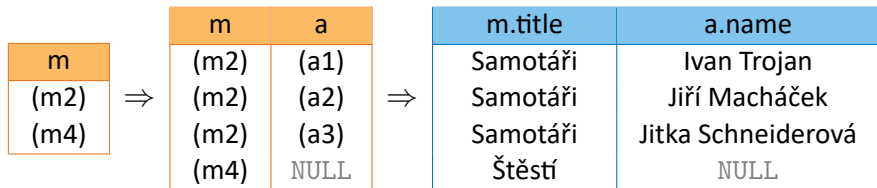
OPTIONAL MATCH

- Attempts to find matching data sub-graphs as usual...
- but **when no solution is found**, one specific solution with **all the variables bound to NULL** is generated
- Note that either the whole pattern is matched, or nothing is matched

Match Clause: Example

Find movies filmed in 2005 or earlier and names of their actors (if any)

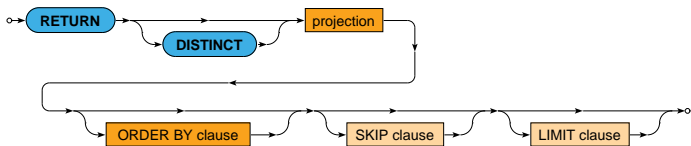
```
MATCH (m:MOVIE)
  WHERE (m.year <= 2005)
OPTIONAL MATCH (m)-[:PLAY]->(a:ACTOR)
RETURN m.title, a.name
```



Return Clause

RETURN clause

- Defines what to include in the query result
 - Projection of variables, properties of nodes or relationships (via dot notation), aggregation functions, ...
- Optional ORDER BY, SKIP and LIMIT sub-clauses



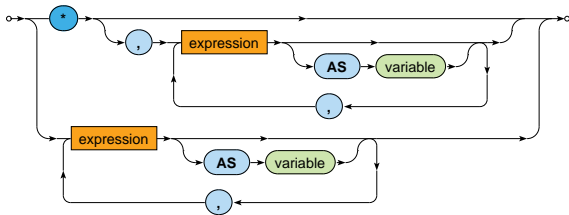
RETURN DISTINCT

- Duplicate solutions (rows) are removed

Return Clause

Projection

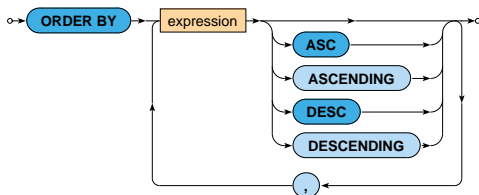
- * = **all the variables**
 - Can only be specified as the very first item
- AS allows to **explicitly (re)name** output records



Return Clause

ORDER BY sub-clause

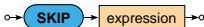
- Defines the **order of solutions** within the query result
 - Multiple criteria can be specified
 - Default direction is ASC
- The order is undefined unless explicitly defined
- Nodes and relationships as such cannot be used as criteria



Return Clause

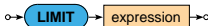
SKIP sub-clause

- Determines the **number of solutions to be skipped** in the query result



LIMIT sub-clause

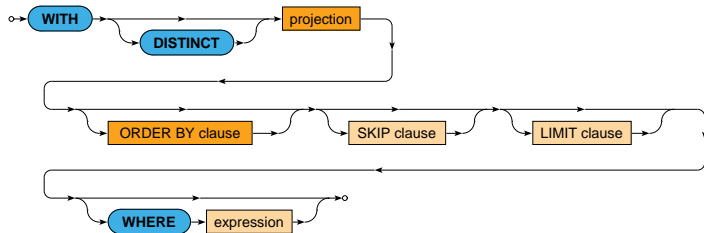
- Determines the **number of solutions to be included** in the query result



With Clause

WITH clause

- **Constructs intermediate result**
 - Analogous behavior to the RETURN clause
 - Does not output anything to the user, just **forwards the current result to the subsequent clause**
- Optional WHERE sub-clause can also be provided



With Clause: Example

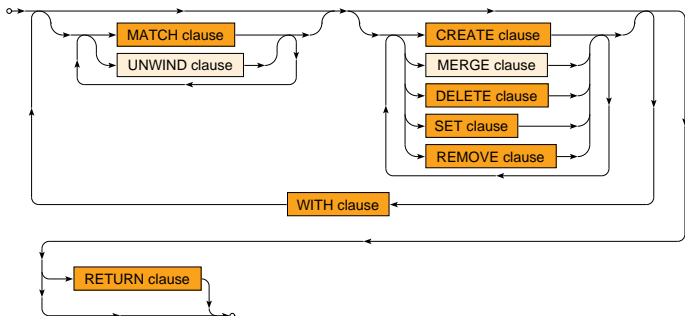
Numbers of movies in which actors born in 1965 or later played

```
MATCH (a:ACTOR)
  WHERE (a.year >= 1965)
WITH a, SIZE( (a)-[:PLAY]-(m:MOVIE) ) AS movies
RETURN a.name, movies
ORDER BY movies ASC
```

a		a	movies		a.name	movies
(a2)	⇒	(a2)	3	⇒	Jitka Schneiderová	1
(a3)		(a3)	1		Jiří Macháček	3

Query Structure

Chaining of Cypher clauses (*simplified*)



- **Read** clauses: MATCH, ...
- **Write** clauses: CREATE, DELETE, SET, REMOVE, ...

Query Structure

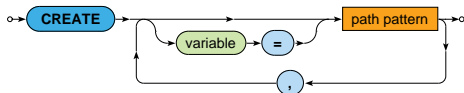
Query parts

- **WITH clauses split the whole query into query parts**
- Certain restrictions apply...
 - **Read clauses (if any) must precede write clauses (if any)** in every query part
 - **The last query part must be terminated by a RETURN clause**
 - Unless this part contains at least one write clause
 - I.e. **read-only queries must return data**
 - ...

Write Clauses

CREATE clause

- Inserts new nodes or relationships into the data graph



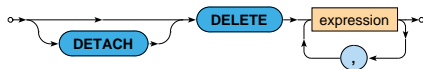
Example

```
MATCH (m:MOVIE { id: "stesti"})
CREATE
  (a:ACTOR { id: "vilhelmova", name: "Tatiana Vilhelmová", year: 1978}),
  (m)-[:PLAY]->(a)
```

Write Clauses

DELETE clause

- **Removes nodes, relationships or paths** from the data graph
- Relationships must always be removed before the nodes they are associated with
 - Unless the DETACH modifier is specified



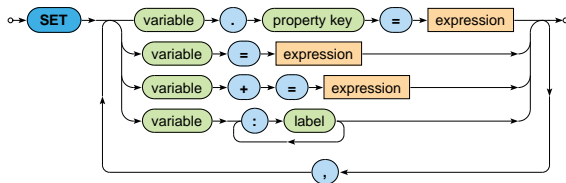
Example

```
MATCH (:MOVIE { id: "stesti"})-[r:PLAY]->(a:ACTOR)
DELETE r
```

Write Clauses

SET clause

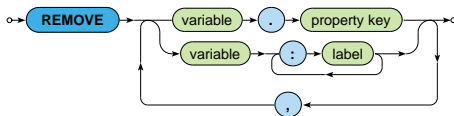
- Allows to...
 - **set a value of a particular property**
 - or remove a property when NULL is assigned
 - **replace properties** (all of them) with new ones
 - **add new properties** to the existing ones
 - **add labels** to nodes
- Cannot be used to set relationship types



Write Clauses

REMOVE clause

- Allows to...
 - **remove a particular property**
 - **remove labels** from nodes
- Cannot be used to remove relationship types



Expressions

Literal expressions

- Integers: decimal, octal, hexadecimal
- Floating-point numbers
- Strings
 - Enclosed in double or single quotes
 - Standard escape sequences
- Boolean values: `true`, `false`
- NULL value (cannot be stored in data graphs)

Other expressions

- Collections, variables, property accessors, function calls, path patterns, boolean expressions, arithmetic expressions, comparisons, regular expressions, predicates, ...

Lecture Conclusion

Neo4j = graph database

- **Property graphs**
- **Traversal framework**
 - Path expanders, uniqueness, evaluators, traverser

Cypher = graph query language

- Read (sub-)clauses: MATCH, WHERE, ...
- Write (sub-)clauses: CREATE, DELETE, SET, REMOVE, ...
- General (sub-)clauses: RETURN, WITH, ORDER BY, LIMIT, ...