B4M36DS2, BE4M36DS2: **Database Systems 2**

https://cw.fel.cvut.cz/wiki/courses/b4m36ds2/

Lecture 10

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

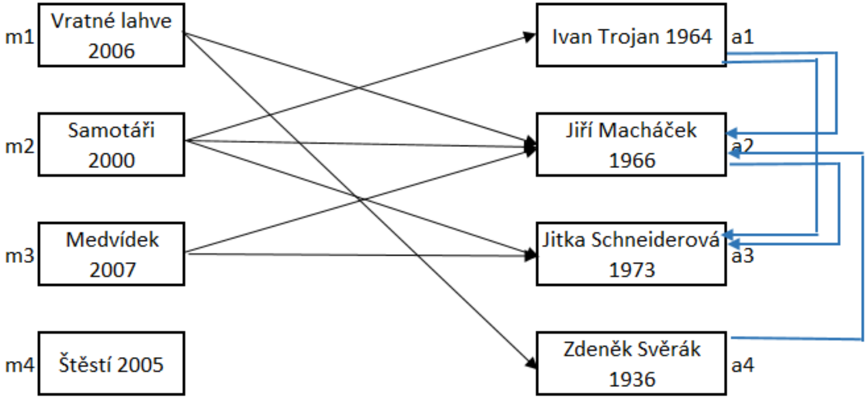
Sample Data

Sample graph with **movies and actors**

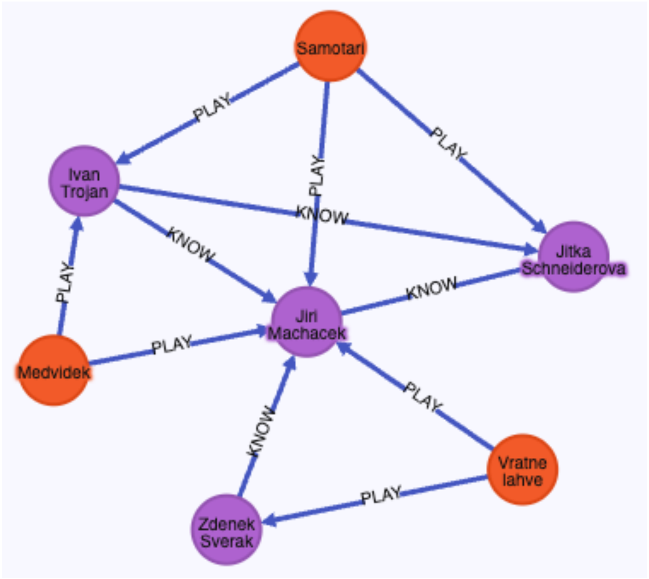
```
(m1:MOVIE { id: "vratnelahve", title: "Vratné lahve", year: 2006 })
(m2:MOVIE { id: "samotari", title: "Samotáři", year: 2000 })
(m3:MOVIE { id: "medvidek", title: "Medvídek", year: 2007 })
(m4:MOVIE { id: "stesti", title: "Štěstí", year: 2005 })

(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)
(a1)-[f1:KNOW]->(a2)
(a1)-[f2:KNOW]->(a3)
(a2)-[f3:KNOW]->(a3)
(a4)-[f4:KNOW]->(a2)
```

Sample Data

Sample graph with **movies and actors**



Sample Data (https://console.neo4j.org)



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

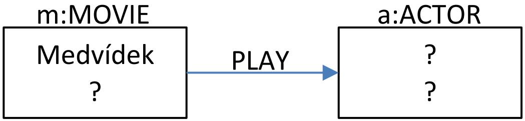
- E.g. `MATCH`, `RETURN`, `CREATE`, …
- Clauses can be (almost arbitrarily) **chained together**
  - Intermediate result of one clause is passed to a subsequent one

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

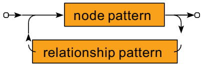
General clauses and their sub-clauses

- `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

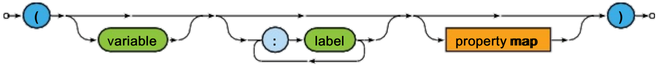
```
(m:MOVIE)-[r:PLAY]->(a:ACTOR)
(a:ACTOR {name: "Jiří Macháček"})-[r:PLAY]->(m:MOVIE)
```

Path Patterns

Node pattern

- Matches one data node

```
(a:ACTOR)
(m:MOVIE {title: "Samotáři"})
```



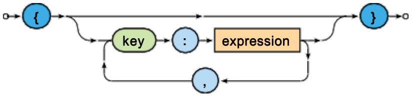
- **Variable**
  - Allows us to access a given node later on
- Set of **labels**
  - Data node must have **all the specified labels** to be matched

    MATCH (n:PERSON:ACTOR)
  - Labels are case sensitive
- **Property** map
  - Data node must have **all the requested properties** (including their values) to be matched (the order is unimportant)

Path Patterns

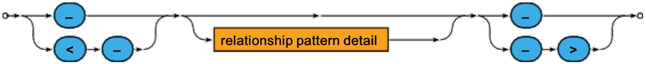
Property map

```
(m:MOVIE {title: "Vratné lahve"})
```



Relationship pattern

- Matches one data relationship

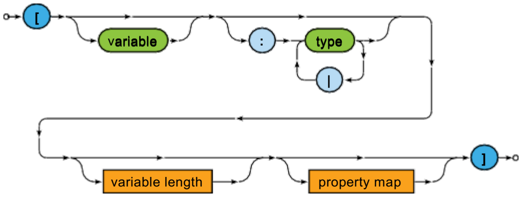


```
-[r:PLAY]->
-[r:PLAY {award: "Czech Lion"}]->
```

Path Patterns

Relationship pattern

```
-[r:PLAY]->
-[r:PLAY {award: "Czech Lion"}]->
```



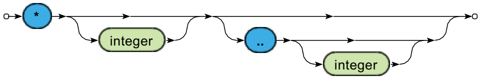
- **Variable**
  - Allows us to access a given node later on
- **Set of types**
  - Data relationship must be of **one of the enumerated types** to be matched

```
(a)-[r:TYPE1|TYPE2]->(b)
```

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..`

```
(a)-[r*1..3]->(b)
```

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)

Path Patterns

Example:

- are these queries equivalent?

```
(a1:ACTOR {name: "Ivan Trojan"})-[:PLAY]->(m:MOVIE)<-[:PLAY]-(a2:ACTOR)
```

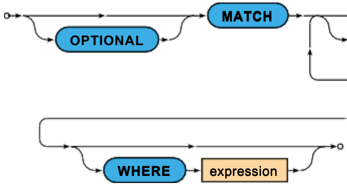
```
(a1:ACTOR {name: "Ivan Trojan"})<-[:PLAY]-(m:MOVIE)-[:PLAY]->(a2:ACTOR)
```

```
(a1:ACTOR {name: "Ivan Trojan"})-[:PLAY]-(m:MOVIE)-[:PLAY]-(a2:ACTOR)
```

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 p = (a:ACTOR)-[:PLAY]->(m:MOVIE {title: 'Medvídek’})
RETURN p;
```

Match Clause

WHERE sub-clause may provide additional constraints

- These constraints are **evaluated directly during the matching phase** (i.e. <u>not after it</u>)
- 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
(a1)	(m2)	(a2)
(a1)	(m2)	(a3)
(a1)	(m3)	(a2)

$\Rightarrow$

a.name
Jiří Macháček
Jitka Schneiderová
Jiří Macháček

The second query might be slightly more efficient because it can use an index on the name property of ACTOR nodes (if such an index exists) from the start of the query execution

Match Clause

Uniqueness requirement

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

```
MATCH (a:ACTOR)-[r:KNOWS]->(b: ACTOR)-[s:KNOWS]->(c: ACTOR)
```

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
```

m
(m2)
(m4)

⇒

m	a
(m2)	(a1)
(m2)	(a2)
(m2)	(a3)
(m4)	NULL

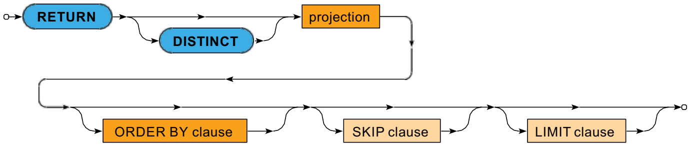
⇒

m.title	a.name
Samotáři	Ivan Trojan
Samotáři	Jiří Macháček
Samotáři	Jitka Schneiderová
Štěstí	NULL

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



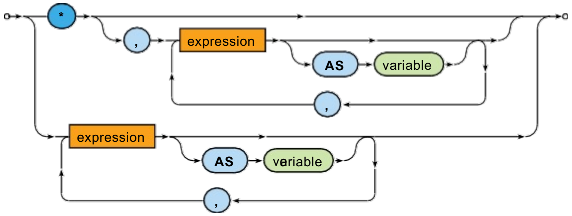
RETURN DISTINCT

- Duplicate solutions (rows) are removed

Return Clause

Projection

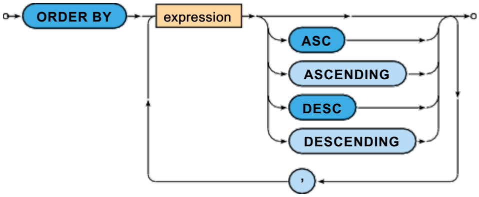
- `*` = **all the variables**
  - Can only be specified as the very first item
- `AS` allows to **explicitly (re)name** output records



Return Clause

ORDER BY sub-clause

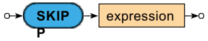
- Defines the **order of solutions** within the query result
  - Multiple criteria can be specified
  - Default direction is `ASC`
- The order is undefined unless explicitly defined
- Nodes and relationships as such cannot be used as criteria



Return Clause

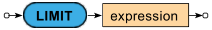
SKIP sub-clause

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



LIMIT sub-clause

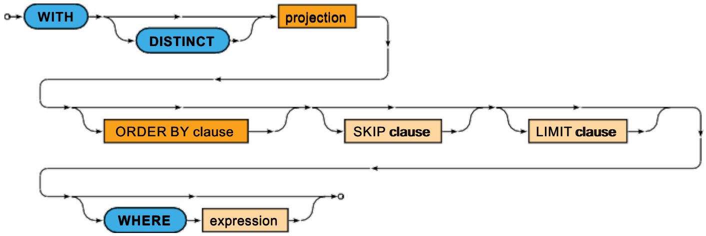
- Determines the **number of solutions to be included** in the query result



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, [(a)<-[:PLAY]-(movie:MOVIE) | movie] AS moviesList
RETURN a.name,
            SIZE(moviesList) AS movies
ORDER BY movies ASC;
```

The created list can contain 0

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

COUNT omits actors without movies

a
(a2)
(a3)

⇒

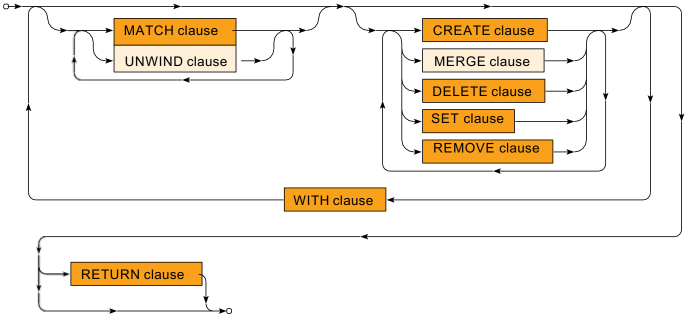
a	movies
(a2)	3
(a3)	1

⇒

a.name	movies
Jitka Schneiderová	1
Jiří Macháček	3

Query Structure

Chaining of Cypher clauses (*simplified*)



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

Query Structure

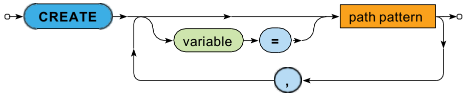
Query parts

- **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



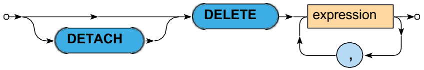
Example

```
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

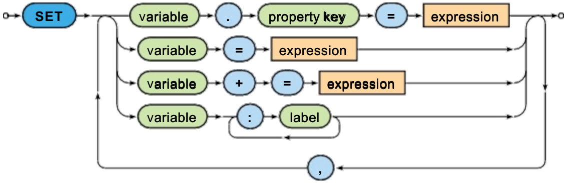
```
MATCH(:MOVIE { id: "stesti"})-[r:PLAY]->(a:ACTOR)
DELETE r
```

Write Clauses

```
MATCH (a:ACTOR { name: "Ivan Trojan" })
SET a += { year: 1964 }
RETURN a
```

SET clause

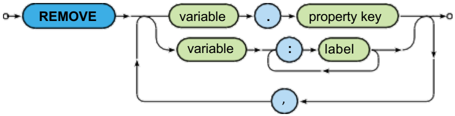
- Allows to…
  - **set a value of a particular property**
    - or remove a property when `NULL` is assigned
  - **replace properties** (all of them) with new ones
  - **add new properties** to the existing ones
  - **add labels** to nodes
- Cannot be used to set relationship types



Write Clauses

REMOVE clause

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



```
MATCH (a:ACTOR { name: "Ivan Trojan" })
REMOVE a.year
RETURN a
```

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, …

The shortest path

Find the shortest path between Ivan Trojan and Jiri Machacek

```
MATCH p = shortestPath((a1:ACTOR {name: "Ivan Trojan"})
                   -[*]-(a2:ACTOR {name: "Jitka Schneiderova"}))
RETURN p;
```

```
MATCH p = shortestPath((a1:ACTOR {name: "Ivan Trojan"})

                   -[r*]-(a2:ACTOR {name: "Jitka Schneiderova"}))

RETURN [node in nodes(p) | node.name] as names,

                   [rel in relationships(p) | type(rel)] as relations;
```

```
names: ["Ivan Trojan", "Jitka Schneiderova"] relations: ["KNOW"]
```

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`, …