Cypher: An Evolving Query Language for Property Graphs

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Schema

- 介绍了属性图和Cypher语言的语法结构
- 以事例的形式讲述Cypher查询过程
- Cypher中的核心元素：数据模型和查询语言
- pattern matching
- 比较Cypher语言和其他数据库查询语言的特征，描述其扩展性、先进性，并将发展成Cypher10

Introduce

- **Property graph database** such as Neo4j， JanusGraph and Sparksee have become more widespread in industry and academia.
- used in multiple domains, such as master data and knowledge management, recommendation engines,fraud detection, IT operations and network management, authorization and access control , bioinformatics , social networks, software system analysis , and in investigative journalism.

- Benefits:

    - explicit support for modeling graph data
    - native indexing
    - storage for fast graph traversal operations
    - built-in support for graph algorithms
    - the provision of graph language

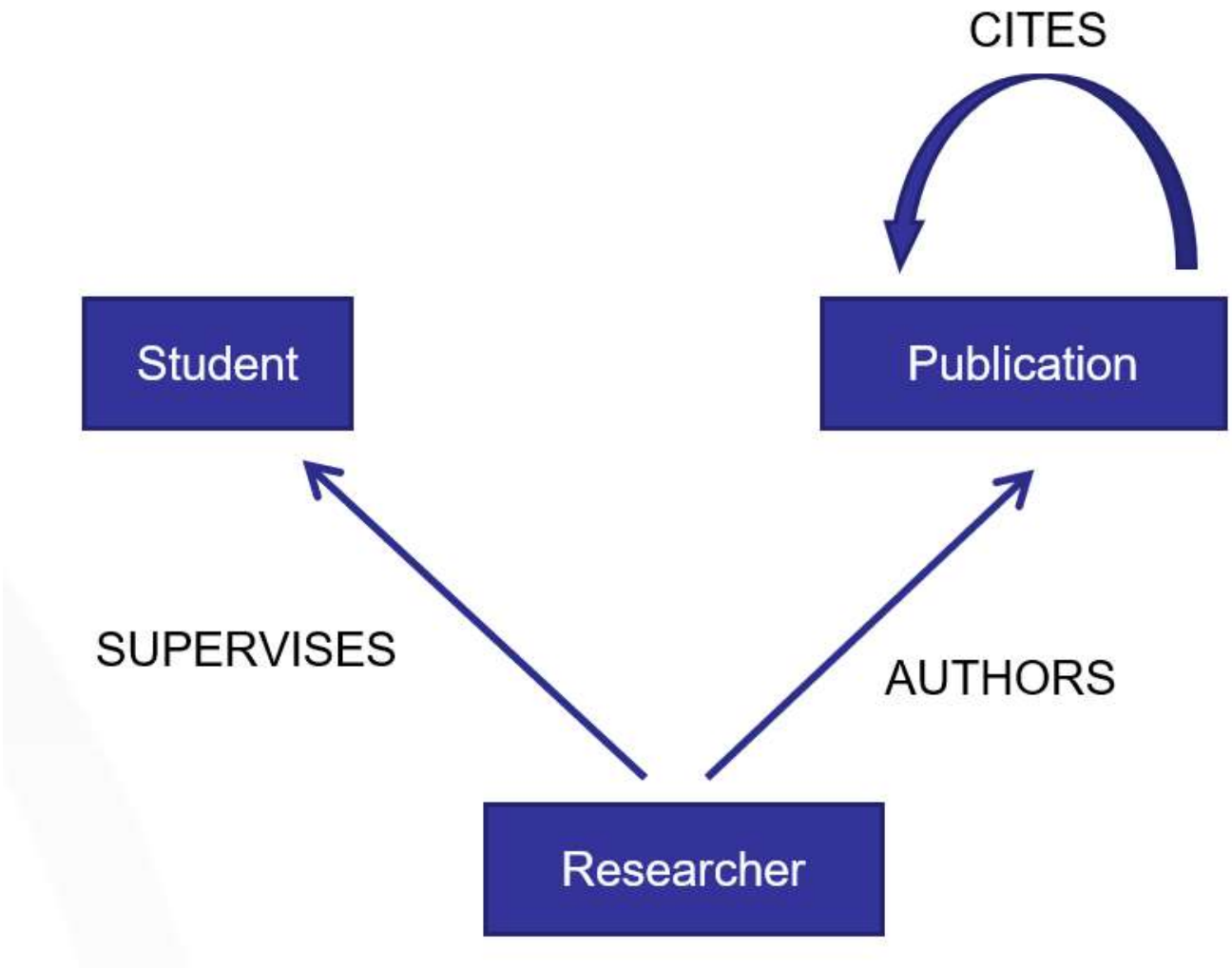
- **Cypher**: a well-established language for querying and updating property graph databases

    - began life in the Neo4j product, but has now been implemented commercially in other products such as SAP HANA Graph, Redis Graph, Agens Graph (over PostgreSQL) and Memgraph.
    - Cypher is also used in several research projects (e.g., Ingraph ,Gradoop , and Cytosm) as well as in recent or incubating open-source projects, such as Cypher for Apache Spark and Cypher over Gremlin.
    - Cypher是线性查询，输入property graph，输出table

- 数据更新：
  - CREATE: creating new nodes and relationships
  - DELETE: moving entities
  - SET: updating properties
  - MERGE: try to match the given patten,and creates the pattern if no match was found

Example

Graph Schema：



- PS:图中有三个label，分别是researcher、Student、 Publication，三种关系:SUPERVISES、AUTHORS、CITES
- 研究员有指导的学生，研究员发表刊物，那么就是某刊物的作者，刊物之间可以互相引用。
- CITES我画成了自循环，但是大家这样理解比较合适：一个刊物可以被另外一个刊物引用。

Big graph:(整个数据库的属性图如下)

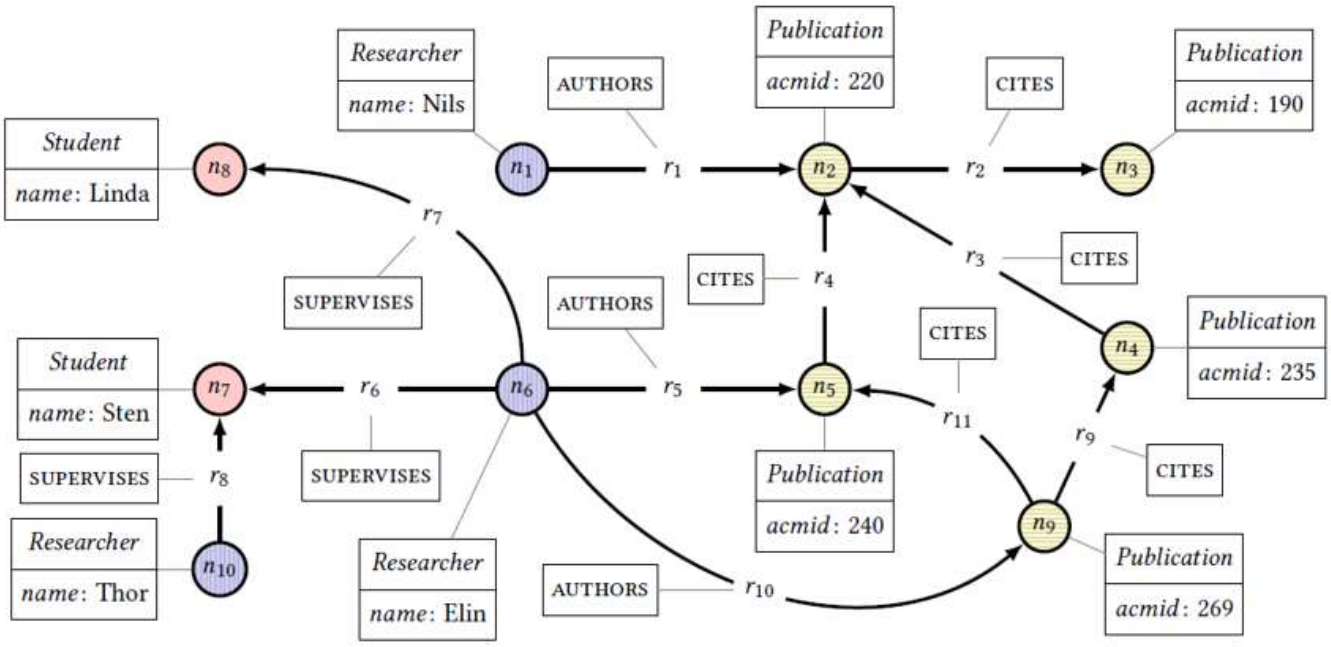


Figure 1: Example data graph showing supervision and citation data for researchers, students and publications

查询示例语句如下：

```
1 MATCH (r:Researcher)
2 OPTIONAL MATCH (r)-[:SUPERVISES]->(s:Student)
3 WITH r, count(s) AS studentsSupervised
4 MATCH (r)-[:AUTHORS]->(p1:Publication)
5 OPTIONAL MATCH (p1)<-[:CITES*]-(p2:Publication)
6 RETURN r.name, studentsSupervised,
7        count(DISTINCT p2) AS citedCount
```

Q: 返回图G中每个researcher的name，他们所supervises指向的学生数，以及他们撰写的出版物被其他出版物直接或间接引用的次数。

我们分析每一个语句的查询结果。

1. `MATCH (r:researcher)`
    - 在这句语句中，r是instance，researcher是label
2. `OPTIONAL MATCH (r)-[:SUPERVISES]->(s:Student)`
    - OPTIONAL MATCH与MATCH的区别在于，OPTIONAL MATCH会返回查询结果为NULL的记录。
    - SUPERVISES为关系的label，(r)-[:SUPERVISES]->(s:Student)表示找出researcher对应指导的学生实例
    - 1、2两句语句执行结果如下：

r	s
n_1	null
n_6	n_7
n_6	n_8
n_{10}	n_7

3. `WITH r,count(s) AS studentsSupervised`
   - AS：取别名
   - count(s):计算上面找出的学生数
   - 在with语句前面部分找出的子图作为with语句后面查询的驱动表

r	studentsSupervised
n_1	0
n_6	2
n_{10}	1

4. `MATCH (r)-[:AUTHORS]->(p1:Publication)`
   - n10不写是因为MATCH不返回NULL的记录

r	studentsSupervised	p1
n_1	0	n_2
n_6	2	n_5
n_6	2	n_9

5. `OPTIONAL MATCH (p1)-[:CITES*]->(p2:Publication)`
   - CITES后面的 `*` 表示任意步长，当然也可以指定步长，比如 `CITES*1..3` 表示跳一步到三步
   - 结果中的n9有两个是因为n9可以有两条路径达到n2

r	studentsSupervised	p1	p2	
n_1	0	n_2	n_4	
n_1	0	n_2	n_9	†
n_1	0	n_2	n_5	
n_1	0	n_2	n_9	†
n_6	2	n_5	n_9	
n_6	2	n_9	null	

6、7. `RETURN r.name,studentsSupervised,count(DISTINCT p2) AS citedCount`

- 返回最后的结果

r.name	studentsSupervised	citedCount
Nils	0	3
Elin	2	1

Examples from industry

Q1: A real-world query from the network management domain

```
MATCH (svc:Service)<-[:DEPENDS_ON*]-(dep:Service)
RETURN svc, count(DISTINCT dep) AS dependents
ORDER BY dependents DESC
LIMIT 1
```

- The query returns the component that is depended upon – both directly and indirectly – by the largest number of entities.
- order by: 排序，可指定增序还是降序
- LIMIT：取几行记录
- MATCH中的箭头可以向左也可以向右

Q2: A query in the domain of fraud detection

```
MATCH (accHolder:AccountHolder)-[:HAS]->(pInfo)
WHERE pInfo:SSN OR pInfo:PhoneNumber
                OR pInfo:Address
WITH pInfo,
     collect(accHolder.uniqueId) AS accountHolders,
     count(*) AS fraudRingCount
WHERE fraudRing > 1
RETURN accountHolders,
     labels(pInfo) AS personalInformation,
     fraudRingCount
```

- pInfo 后面三个为label，可以将pInfo理解为节点信息，那么语句的意思就是信息可以是SSN，或者PhoneNumber，或者Address
- WHERE后面跟着的是一些过滤条件，这些过滤条件也可以放在MATCH后面，比如第一个where后面跟着实例的标签，那么也可以写成MATCH (accHolder:AccountHolder)-[:HAS]->(pInfo:SSN:PhoneNumber:Address)
- collect(): 返回表达式表示的值，放入list并返回
- labels(): 返回一个节点的所有标签，以list的形式返回

FORMAL SPECIFICATION

- The key elements of Cypher are as follows:
    - data model, that includes values, graphs, and tables;
    - query language, that includes expressions, patterns, clauses, and queries.
- Property graphs

- $N = \{n_1, \ldots, n_{10}\}$;
- $R = \{r_1, \ldots, r_{11}\}$;
- $\text{src} = \left\{ \begin{array}{llll} r_1 \mapsto n_1, & r_4 \mapsto n_5, & r_7 \mapsto n_6, & r_{10} \mapsto n_6 \\ r_2 \mapsto n_2, & r_5 \mapsto n_6, & r_8 \mapsto n_{10}, & r_{11} \mapsto n_9 \\ r_3 \mapsto n_4, & r_6 \mapsto n_6, & r_9 \mapsto n_9 & \end{array} \right\}$;
- $\text{tgt} = \left\{ \begin{array}{llll} r_1 \mapsto n_2, & r_4 \mapsto n_2, & r_7 \mapsto n_8, & r_{10} \mapsto n_9 \\ r_2 \mapsto n_3, & r_5 \mapsto n_5, & r_8 \mapsto n_7, & r_{11} \mapsto n_5 \\ r_3 \mapsto n_2, & r_6 \mapsto n_7, & r_9 \mapsto n_4 & \end{array} \right\}$;
- $\iota(n_1, \text{name}) = \text{Nils}$, $\iota(n_2, \text{acmid}) = 220$, $\iota(n_3, \text{acmid}) = 190, \ldots,$ $\iota(n_{10}, \text{name}) = \text{Thor}$;
- $\lambda(n_1) = \lambda(n_6) = \lambda(n_{10}) = \{\text{Student}\}$, $\lambda(n_2) = \lambda(n_3) = \lambda(n_4) = \lambda(n_5) = \lambda(n_9) = \{\text{Publication}\}, \lambda(n_7) = \lambda(n_8) = \{\text{Researcher}\}$;
- $\tau(r) = \begin{cases} \text{AUTHORS} & \text{for } r \in \{r_1, r_5, r_{10}\}, \\ \text{SUPERVISES} & \text{for } r \in \{r_6, r_7, r_8\}, \\ \text{CITES} & \text{for } r \in \{r_2, r_3, r_4, r_9, r_{11}\}. \end{cases}$

  - We now refer to the property graph in Figure 1 and show how, for a sample of its nodes and relationships, it is formally represented in this model as a graph `G = (N, R, src, tgt, ι, λ, τ )` .
  - N: 实例
  - R: 关系
  - src：从关系到源节点这样的存储结构
  - tgt：从关系到目标节点这样的存储结构
  - ι(n1,name)=Nils: 节点1的名字叫Nils，存储(key,value)的形式
  - λ(n1)={Student}: 存储节点label
  - τ(r)=AUTHORS: 存储关系的label