Center for Semantic Web Research

www.ciws.cl, @ciwschile

Three institutions

PUC, Chile

- Marcelo Arenas (Boss)
  - SW, data exchange, semistrucured data
- Juan Reutter
  - SW, graph DBs, DLs
- Cristian Riveros
  - data exchange, semistr. data
- Jorge Baier
  - planning, search
- Carlos Buil
  - SW

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Renzo Angles (SW)

Univ. of Chile

- Pablo Barceló (Deputy)
  - graph DBs, DB theory
- Claudio Gutierrez
  - SW, graph DBs
- Jorge Pérez
  - SW, data exchange
- Aidan Hogan
  - SW, semistr. data
- Bárbara Poblete
  - web mining, SNA
- Benjamín Bustos
  - multimedia

Alberto Mendelzon Workshop (AMW)

AMW 2016
PANAMA CITY

AMW 2016

- Panama City, 6-10 June, 2016
- PC Chairs:

  Altigran Soares da Silva (UFAM), Reinhard Pichler (TU Wien)
- Invited speakers:
  - Diego Calvanese (Data-driven verification)
  - Juliana Freire (Urban data)
  - Lise Getoor (Relational statistical learning)
  - Raghu Ramakrishnan (Big data)
- Long & short submissions (due on Feb. 29th, 2016)
- AMW School (4 tutorials), 4-5 June, 2016
- Very nice environment

Query Languages for Graph DBs: Bridging the Grap Between Theory and Practice

Pablo Barceló
DCC, Universidad de Chile
Center for Semantic Web Research (www.ciws.cl)

BACKGROUND AND OBJECTIVES

Graph databases

Trendy applications:

- Social network analysis
- Semantic web
- Scientific databases
- Software bug localization
- Geo-routing

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- Social network analysis
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More in general:

- Wherever connections are as important as data

What is a graph database?

A data management system that exposes a graph data model.[1]

[1] *Graph databases*. Robinson, Webber, & Eifrem. O'Reilly, 2013.

What is a graph database?

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Several existing graph DB engines and query languages:

- DEX/Sparksee - basic algebra
- IBM System G - Gremlin
- Neo4J - Cypher
- Oracle PGX - PGQL
- RDF stores (Virtuoso, AllegroGraph, Oracle, IBM) - SPARQL

[1] *Graph databases*. Robinson, Webber, & Eifrem. O'Reilly, 2013.

What graph databases are good for?

- Flexible modelling of interconnected data
- Agile evolution of the data model
- Scalable evaluation of join-intensive queries

My personal story

- Since 2009: Working on theory of query languages for graph DBs
- Since 2015: Working group of LDBC for the design of such language

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Conclusion:

- Theory and practice are more connected than expected

Objectives

- Identify topics of common interest for theoreticians and developers
- Formalize relevant concepts (syntax, semantics, terminology, etc)
- Understand tradeoff expressiveness/efficiency

THE DATA MODEL: PROPERTY GRAPHS

The data model is important as it must be:

- Flexible enough to accomodate scenarios of practical interest
- Simple enough to allow for a clean presentation
- Expressive enough for theoretical issues to appear in full force

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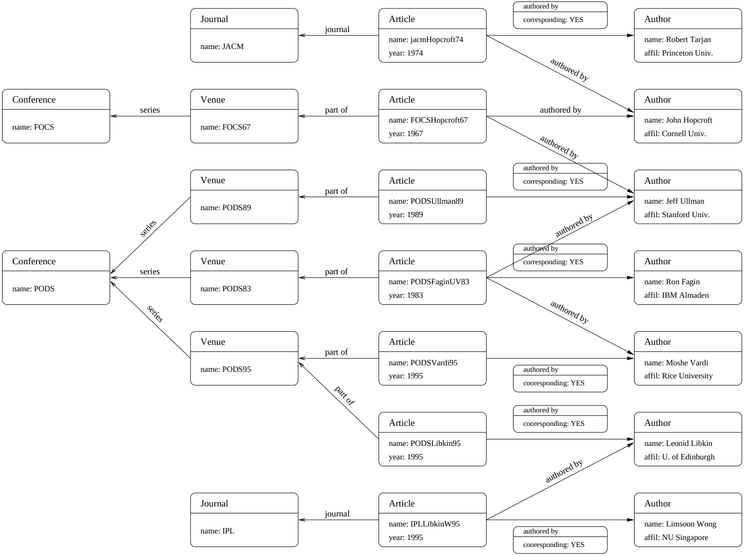
This is accomplished by the model of property graphs

A property graph



What is a property graph then?

- It is a graph
- It is directed
- It is labeled in nodes and edges
- Nodes and edges can be attributed

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GRAPH PATTERNS

Graph patterns are:

The basic unit for querying property graphs

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Definition of graph pattern:

- A directed graph
- Nodes are given by variables $x, y, z, \ldots$
- Edges are given by variables $X, Y, Z, \ldots$
- Nodes and edges satisfy label and attribute constraints (selection)
  - E.g., $l(x) =$ Author, $l(Y) =$ authored by & Y@corresponding = YES
- Some of the variables are selected (projection)

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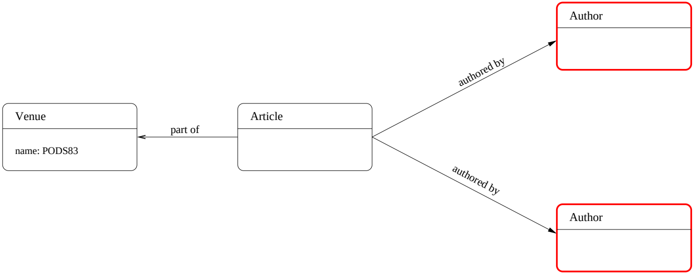
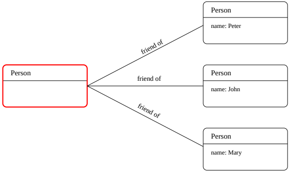
Example of a graph pattern

Find pairs of authors who coauthored a paper in PODS83:



More examples

Get the common friends of Peter, John and Mary:



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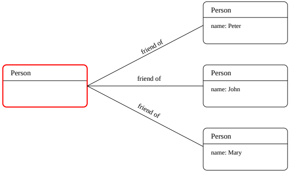
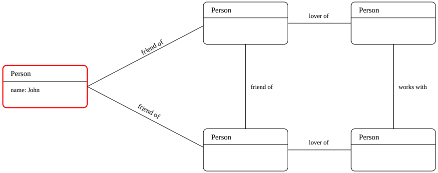


Find friends of John who are
(1) mutual friends, and (2) have lovers that are colleagues



Evaluation of graph patterns

1. Find all *matchings* of the pattern over the property graph
2. Project over the variables in the output

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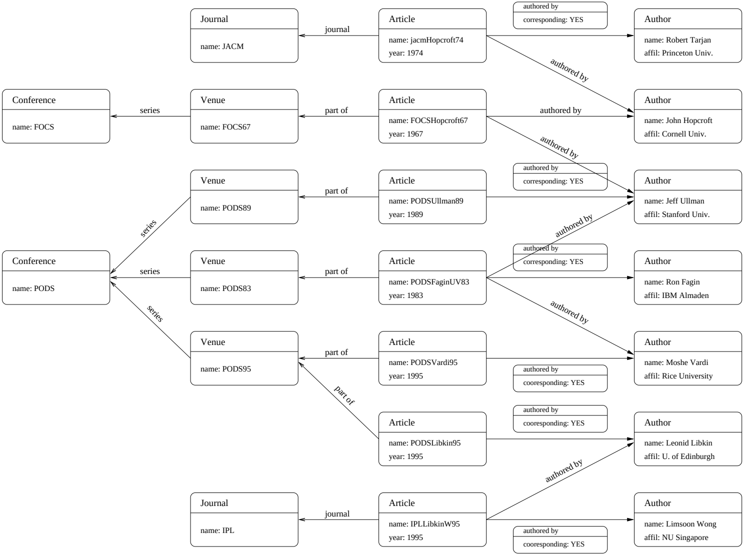
An example of evaluation

The property graph



An example of evaluation

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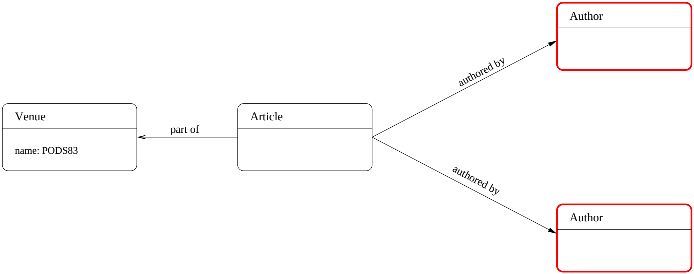
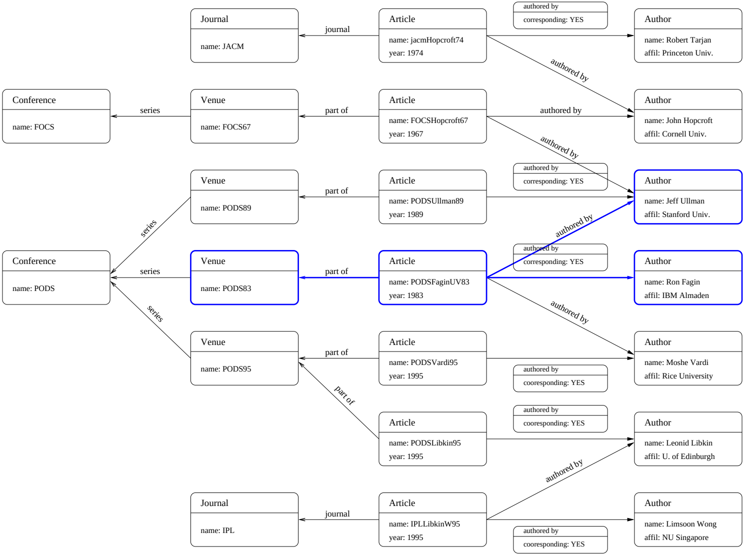


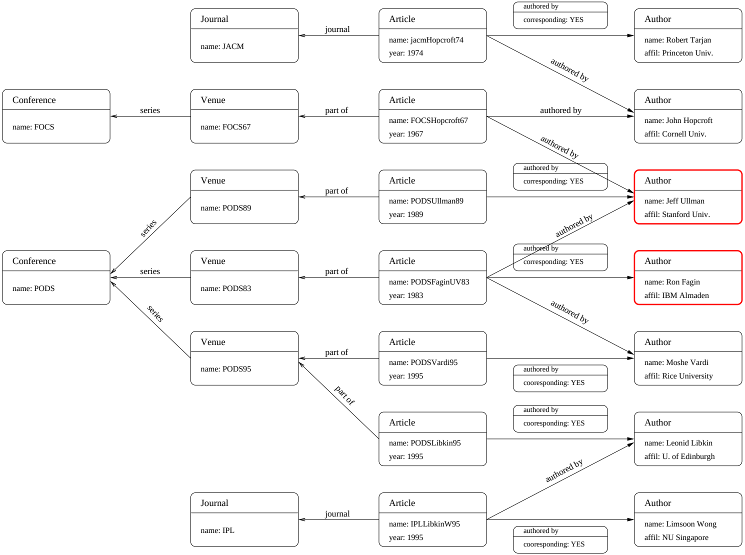
An example of evaluation

A matching



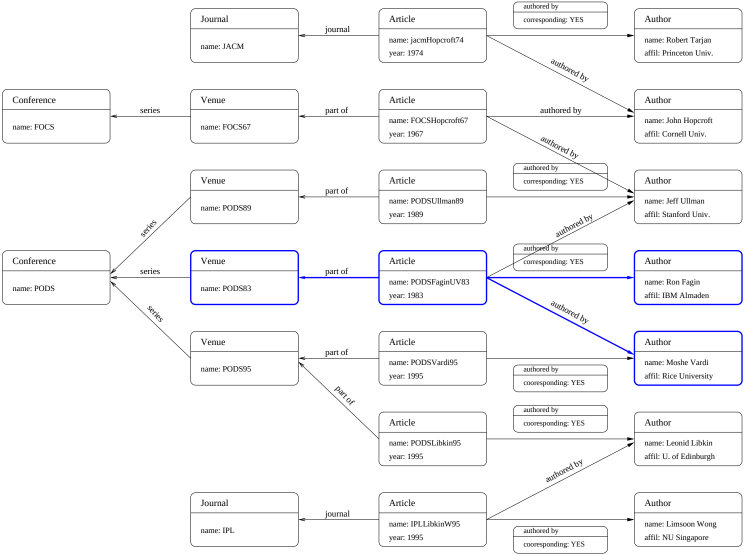
An example of evaluation

Its projection



An example of evaluation

Another matching



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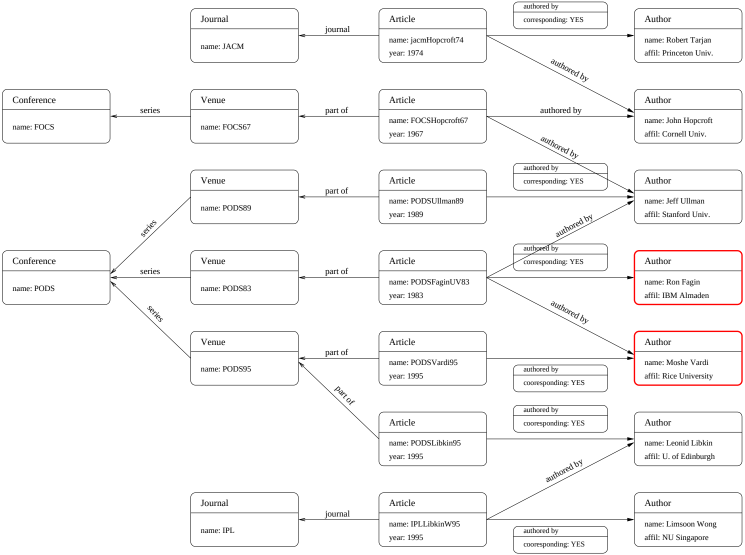

But what is a matching?

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A mapping from:

- nodes of the pattern to nodes of the graph, and
- edges of the pattern to edges of the graph

which preserves the structure of the pattern in the graph

Different notions of matching

Homomorphism: No restriction on the mapping

- $\neq$ nodes in the pattern can map to the same node in the graph

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Mostly studied in database theory (PODS)

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Implemented in some graph DB engines (Neo4J)

Is there a matching?

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An NP-complete problem

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An NP-complete problem

How to address this problem?

Solution 1: Restriction on graph patterns

In many applications, graph patterns are *tame*:

- Homomorphism/isomorphism can be solved efficiently for them

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In many applications, graph patterns are *tame*:

- Homomorphism/isomorphism can be solved efficiently for them

Tame: The underlying graph is almost acyclic

- Bounded *treewidth* (database/graph theory)

Solution 2: Heuristics for real-world datasets

Structural optimization techniques for reducing search space:

- Join ordering, prunning, indexes (database systems)

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Structural optimization techniques for reducing search space:

- Join ordering, prunning, indexes (database systems)

Real databases have structure that can be exploited

Solution 3: Inexact evaluation

Use weaker forms of matching that can be evaluated efficiently:

- Bisimulations, approximations (database theory/systems)

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- Bisimulations, approximations (database theory/systems)

Compromise the quality of the answer in favor of efficiency

Solution 4: Use different notions of complexity

Graphs and patterns are different beasts:

- Graphs are BIG, patterns are small

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Graphs and patterns are different beasts:

- Graphs are BIG, patterns are small

Assume pattern is fixed (data complexity/database theory):

- Matching can be solved very efficiently

Solution modifiers on graph patterns

Relational operations:

- Union
- Difference
- Cartesian product

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Relational operations:

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- Difference
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The language becomes relational complete

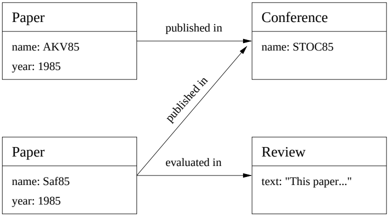
OPTIONAL: An important solution modifier

Allows to match parts of the data only if available

- Important in the context of semistructured data
- Developed by the RDF community
- Corresponds to *left-outer join* in relational algebra

An example with OPTIONAL

The property graph



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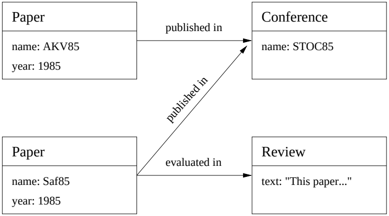

The pattern with optional

$$(x, \text{published\_in}, y) \text{ OPTIONAL } (y, \text{evaluated\_in}, z)$$

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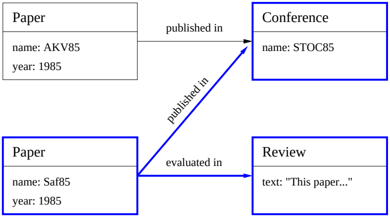

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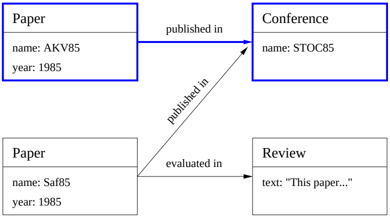

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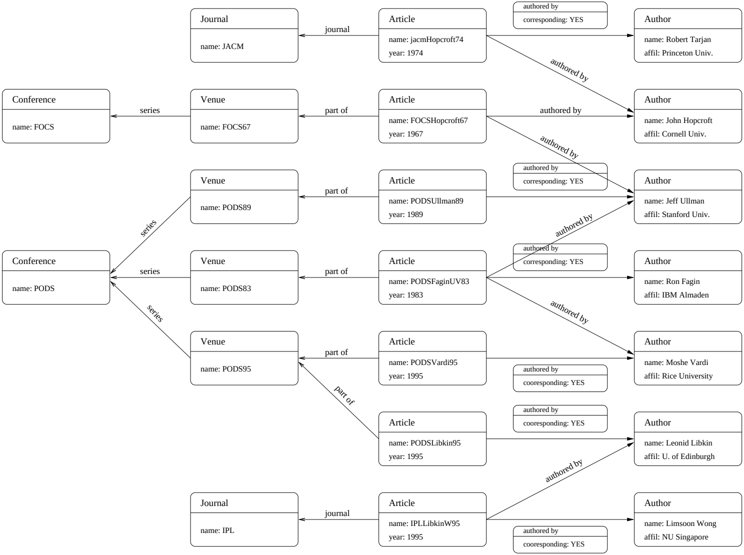
Conclusion

- Graph patterns are a versatile and simple language for querying PGs
- Graph pattern evaluation comes in different flavors
- This problem is challenging (theory/practice)
- Different operators can be added in order to increase expressiveness

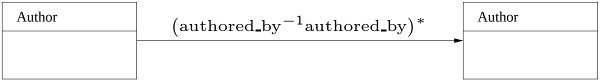
Graphs are there to be navigated

Recall our property graph?



Graphs are there to be navigated

Find pairs of authors linked by a coauthorship sequence



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No support for regular path queries (database theory, RDF, DL)

- Is there a directed path whose label satisfies a regex?

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Not really (in theory):

- Convert the regex into an automata
- Take the cross product of the property graph and the automata
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Cost is linear in the size of the data and the regex

But, what is the semantics?

Is there a path or a simple path?

- Database theory concentrates on the former (why?)
- Graph DB engines implement the latter (why?)

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Our algorithm evaluates RPQs under arbitrary path semantics

Is it possible to use it under a simple path semantics?

RPQs under simple paths

Is there a simple path whose label satisfies a regex?

- This problem is NP-complete even if the regex is fixed!
- High complexity only dependent on the size of the data

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Example: Consider the RPQ $(aa)^*$

1. It asks whether there is a simple path of even length from x to y
2. This problem is NP-complete

Adding RPQs to graph patterns

Give rise to the class of conjunctive RPQs

- Has received considerable attention in theory
- (Essentially) unexplored from a practical point of view
- Challenging because of matching and RPQ evaluation

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No! We can allow stronger forms of recursion (DB theory, DL, MC):

- Navigate with branching
  (nested regexs, similar evaluation to RPQs)
- Allow transitive closure on top of conjunctive RPQs
  (regular queries, harder to evaluate)
- Allow arbitrary recursion
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Conclusions (really, questions)

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RETURNING PATHS

Paths in the output

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But, what does it mean to return all paths?

... there can be infinitely many

Systems return simple paths

... but there can be exponentially many

Even more interesting for RPQs

- Return a shortest path whose label satisfies a regex
- And all shortest paths
- Return all paths whose label satisfies a regex
- And all paths

A solution from database theory

Instead of returning all paths ...

return a *compact* representation of them

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Compact representation: A property graph with all paths in the output

- Can be constructed efficiently (in data) for arbitrary paths
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Conclusions

- Returning paths is difficult under all interpretations
- "All paths" can be compactly represented, but simple paths cannot
- The right semantics still needs to be settled

UNGROUPING

Paths can appear in the output

Paths can appear in the output

We can *ungroup* them

- List the nodes that appear in them

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We can check if a path visits all nodes

- Travelling salesman problem!

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Interaction with other operators expresses even more complex properties

A query language for paths

- Variables for paths and nodes
- Can check if a node belongs to a path
- Can check if the label of a path satisfies a regex
- Closure under quantification over nodes and paths

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Question

- What ungropuing can do and should do?

FINAL THOUGHTS

Final thoughts

- Exciting times for studying graph DBs (theory/practice)
- Lots of fine tuning needed
- Some issues still unexplored:
  - Comparing paths
  - Ranking of answers
  - Constraints

MANY THANKS

Bibliography

Surveys:

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