Outline

Navigation and Patterns

Rule-based languages

Moving to RDF

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Navigation and Patterns

Rule-based languages

Path Queries for RDF

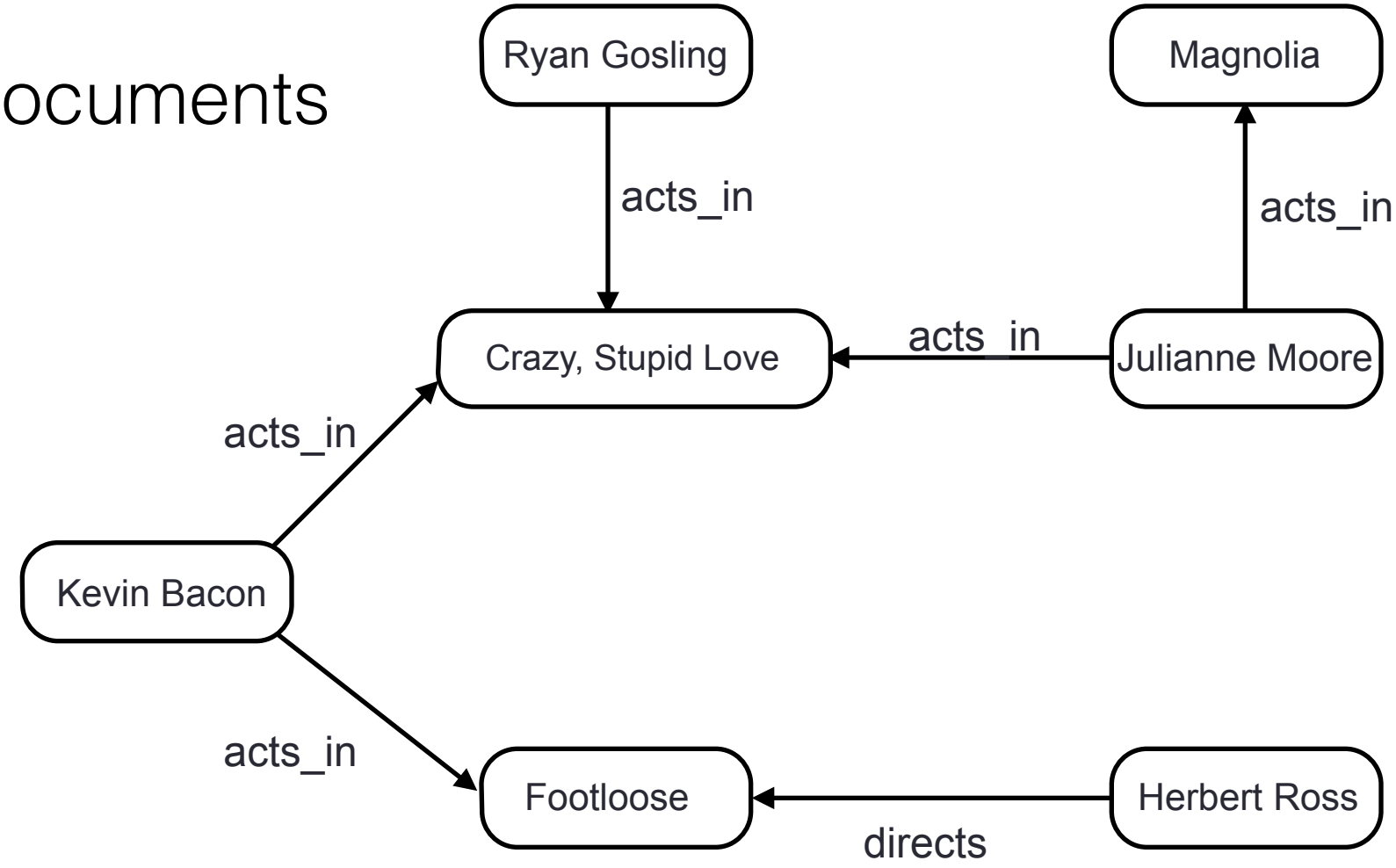
Moving to RDF

Triple Algebra

Practical Concerns

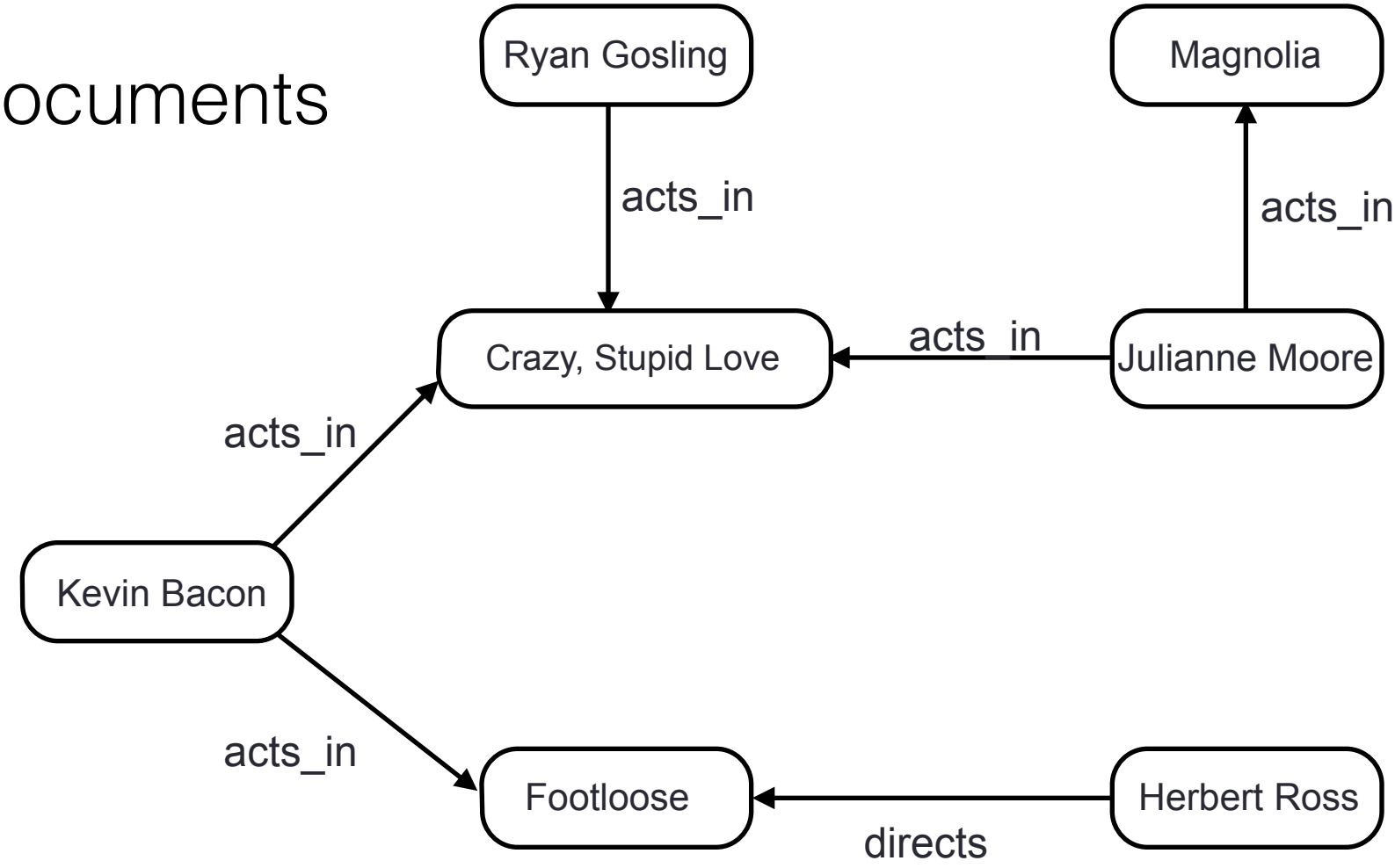
Lifting graph languages to support RDF graphs

RDF documents



Subject	Predicate	Object
Bacon	acts_in	Footloose
Ross	directs	Footloose
Moore	acts_in	Magnolia

RDF documents



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big difference v/s graphs:
labels are not fixed
Predicates store information

RDF documents

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Current navigation approaches treat RDF documents as graphs

acts_in	
Bacon	Footloose
More	Magnolia

directs	
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Property Paths

Essentially adding 2RPQs to SPARQL (query language for RDF)

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Property Paths

Essentially adding 2RPQs to SPARQL (query language for RDF)

To evaluate 2RPQs in RDF we treat them as graphs,
the predicates becomes the labels

Good thing: [Kostylev, R., Romero, Vrgoc 15]

Evaluation/Containment results from graphs
transfer to Property Paths

Problem:
SPARQL + Property Paths requires a mixed strategy

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SPARLQ logically treats RDF documents as triples
Property Paths logically treats RDF documents as graph

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Even worse than lacking algebraic closure!

Very difficult to implement (requires different engines,
not clear how to optimise…)

Need a language

- Capable of expressing basic navigation (at least path queries)
- Closed Input/output:
  Evaluated over RDF,
  Producing RDF as input
- Algebraically closed

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Problem is, patterns are no longer binary!

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Defining the P^{+} operator over tertiary relations

For the binary case it's just the composition of relations

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But for tertiary relations we have several possibilities

How to define the P^+ operator?

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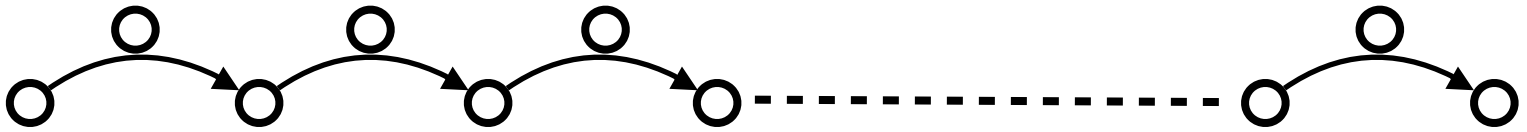
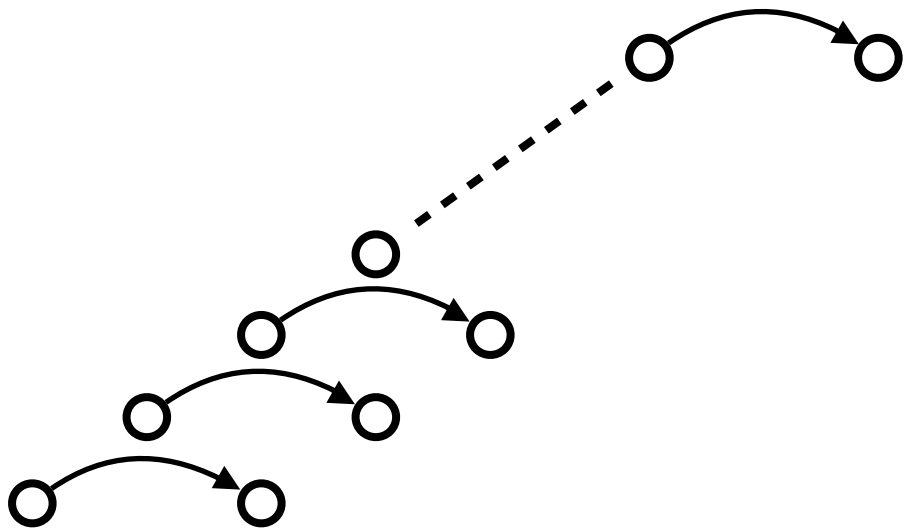


Classical graph reachability

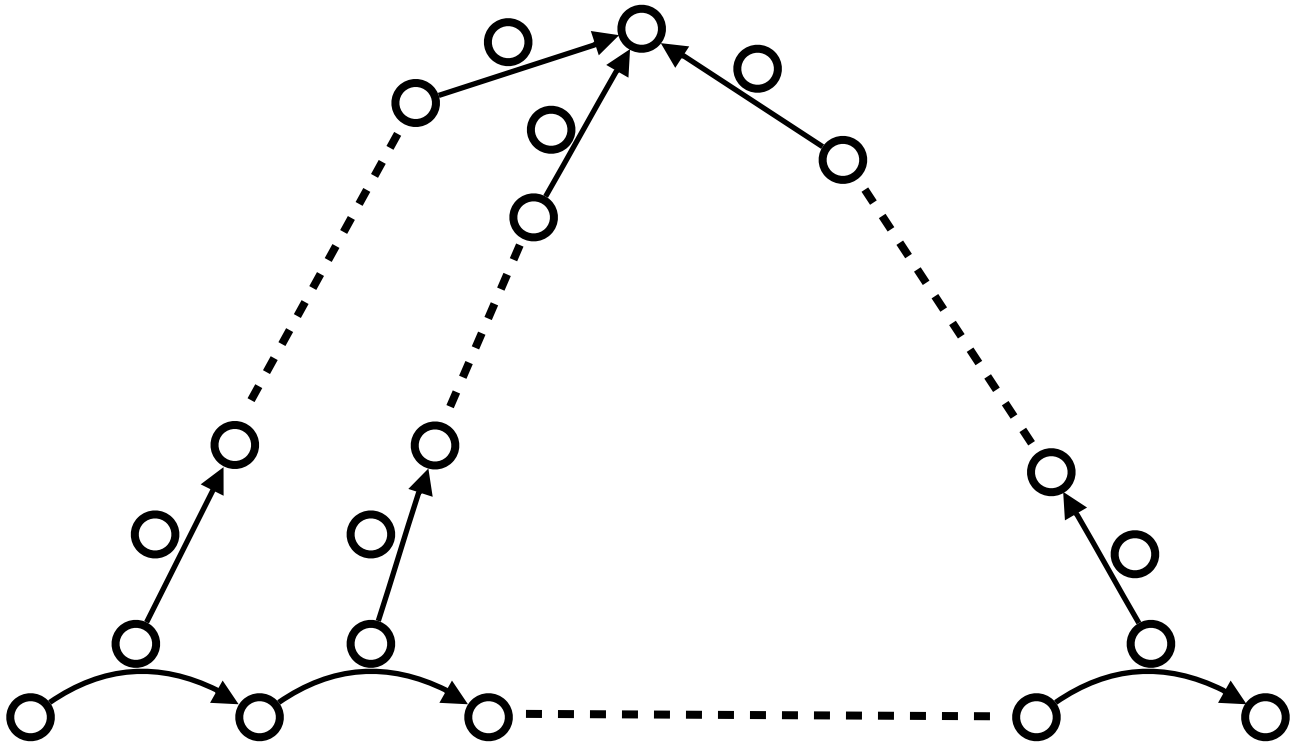
(middle element of triples represent labels, or properties)

How to define the P^+ operator?



Another possibility:
Use the middle element as start of next triple

How to define the P^+ operator?

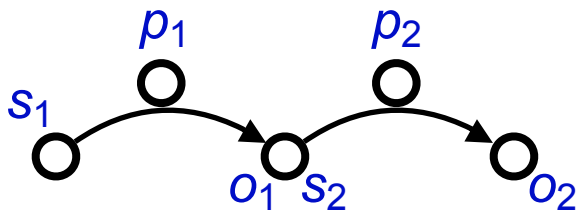


Combining different ways of reachability

How to define the P^+ operator?

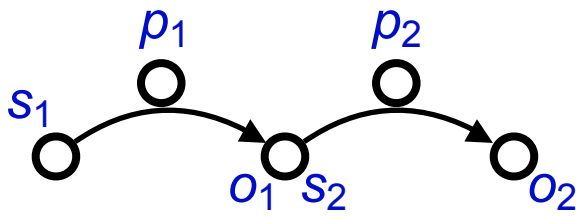
Main Idea: don't choose, just take all possibilities

Reachability over tertiary relations



Think of this operation:

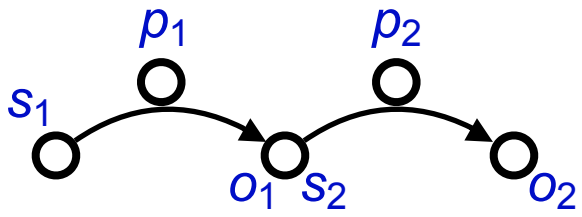
Reachability over tertiary relations



Think of this operation:

$$T(s_1, p_2, o_2) \leftarrow T(s_1, p_1, o_1), T(s_2, p_2, o_2) \;\; o_1 = s_2$$

Reachability over tertiary relations



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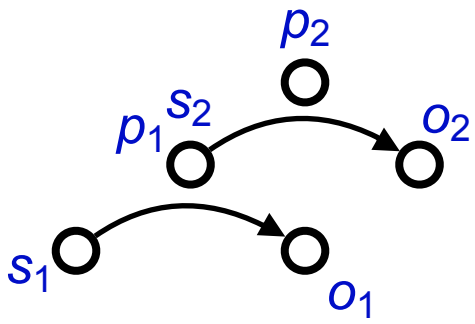

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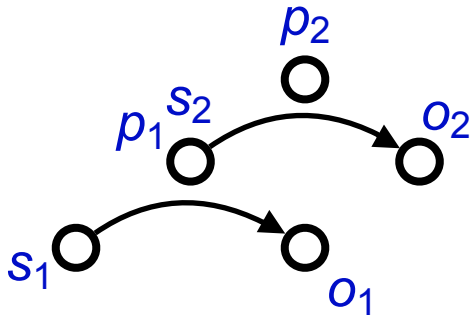

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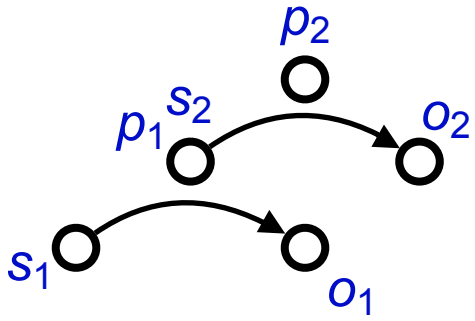

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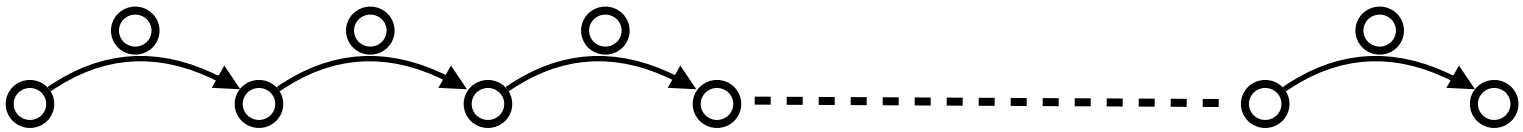
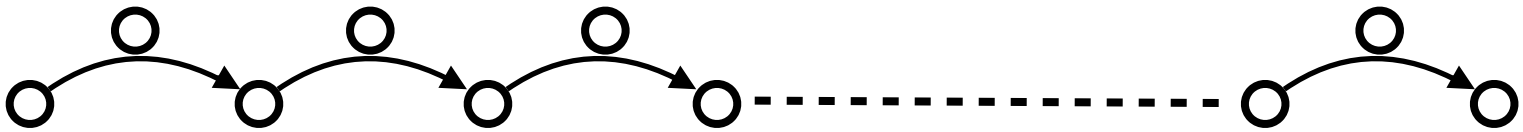


Classical graph reachability:

Reachability over tertiary relations



Classical graph reachability:

$$\left(T \overset{(s_1, p_2, o_2)}{\underset{o_1 = s_2}{\bowtie}} \right)^+$$

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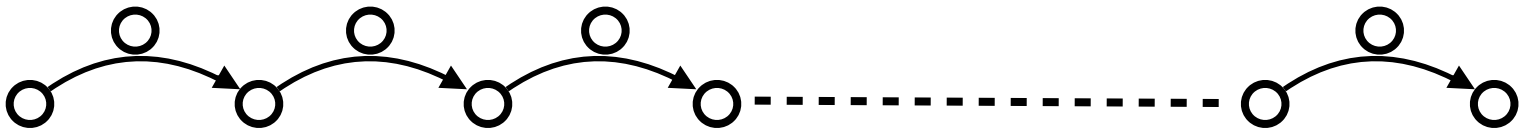

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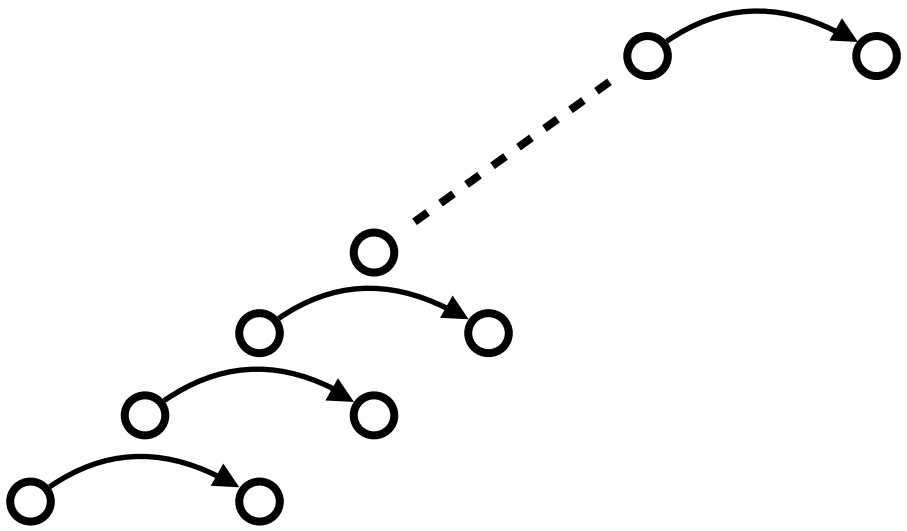

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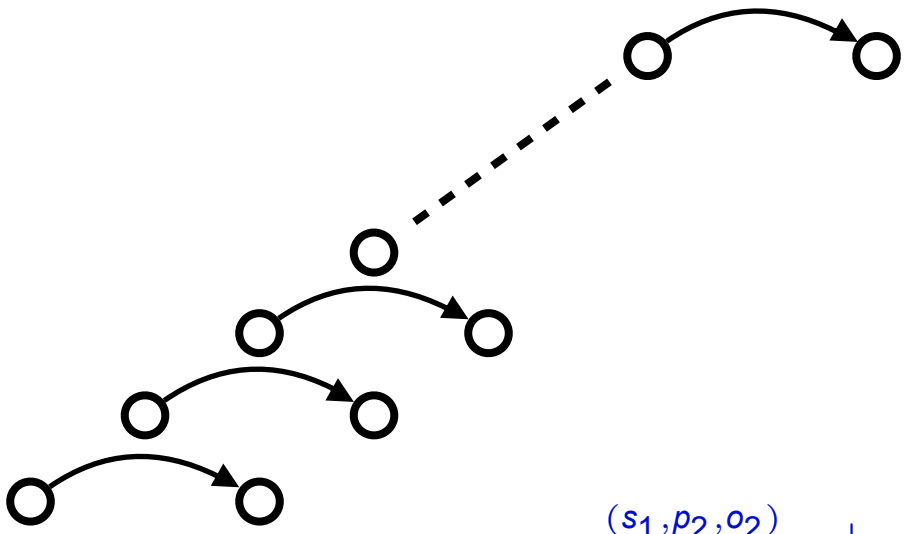

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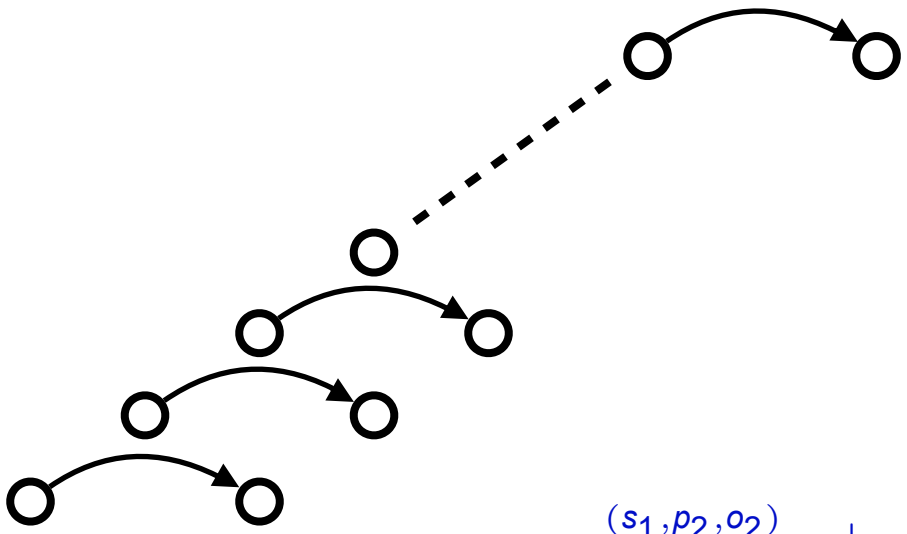

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Triple Algebra (TriAL)

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T is a TriAL expression
(T represents the whole set of triples)

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ϕ equalities over $\{s_1, s_2, p_1, p_2, o_2, o_2\}$

Positive TriAL

T is a TriAL expression
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if R and R' are TriAL expressions, then

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Recursive TriAL

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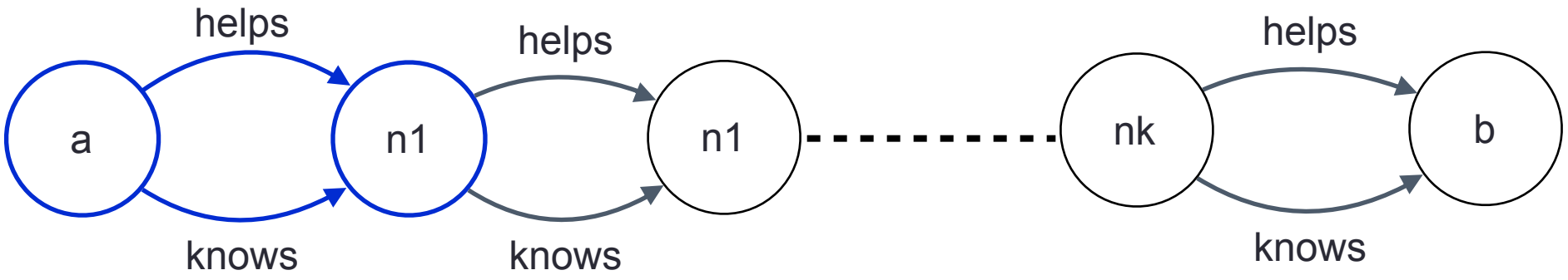
(note that these two are not necessarily the same)

Recursive Triple Algebra (examples)



Say u is a friend of v if
u knows v and u helps v

Find all nodes connected
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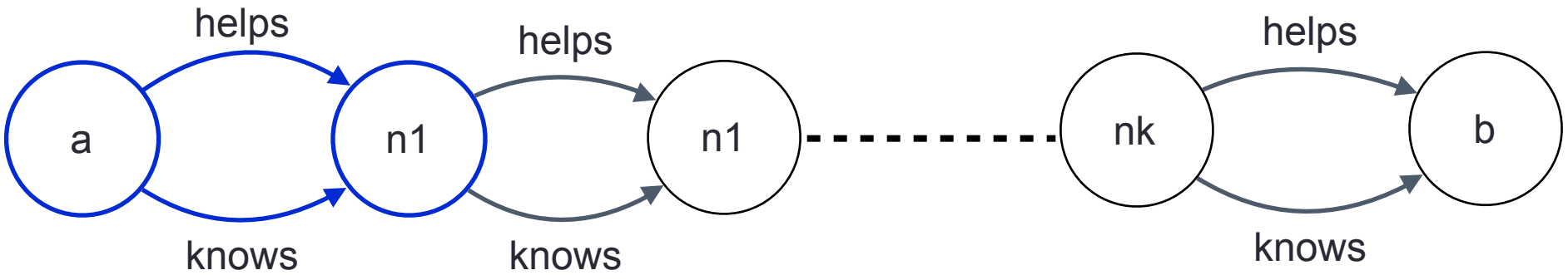

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Friends: $T \underset{s_1=s_2,\ o_1=o_2,\ p_1=\text{helps},\ p_2=\text{knows}}{\overset{(s_1,p_1,o_1)}{\bowtie}} R'$

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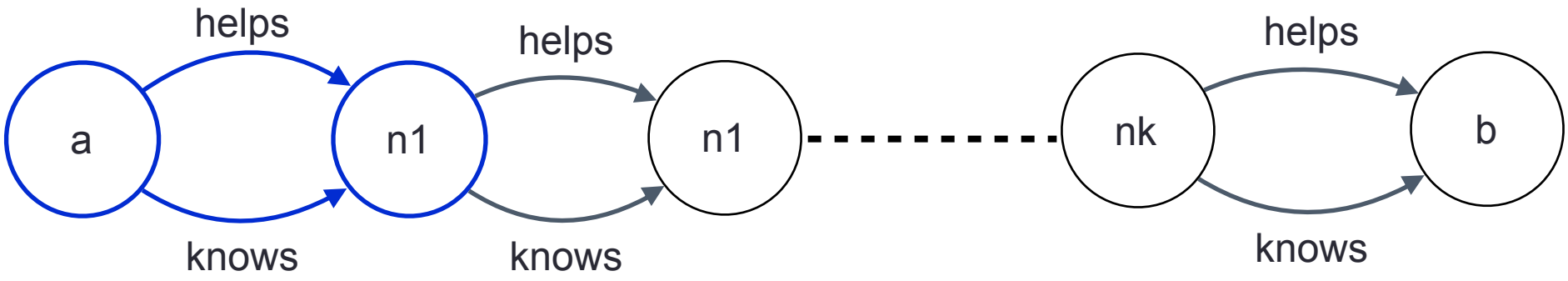

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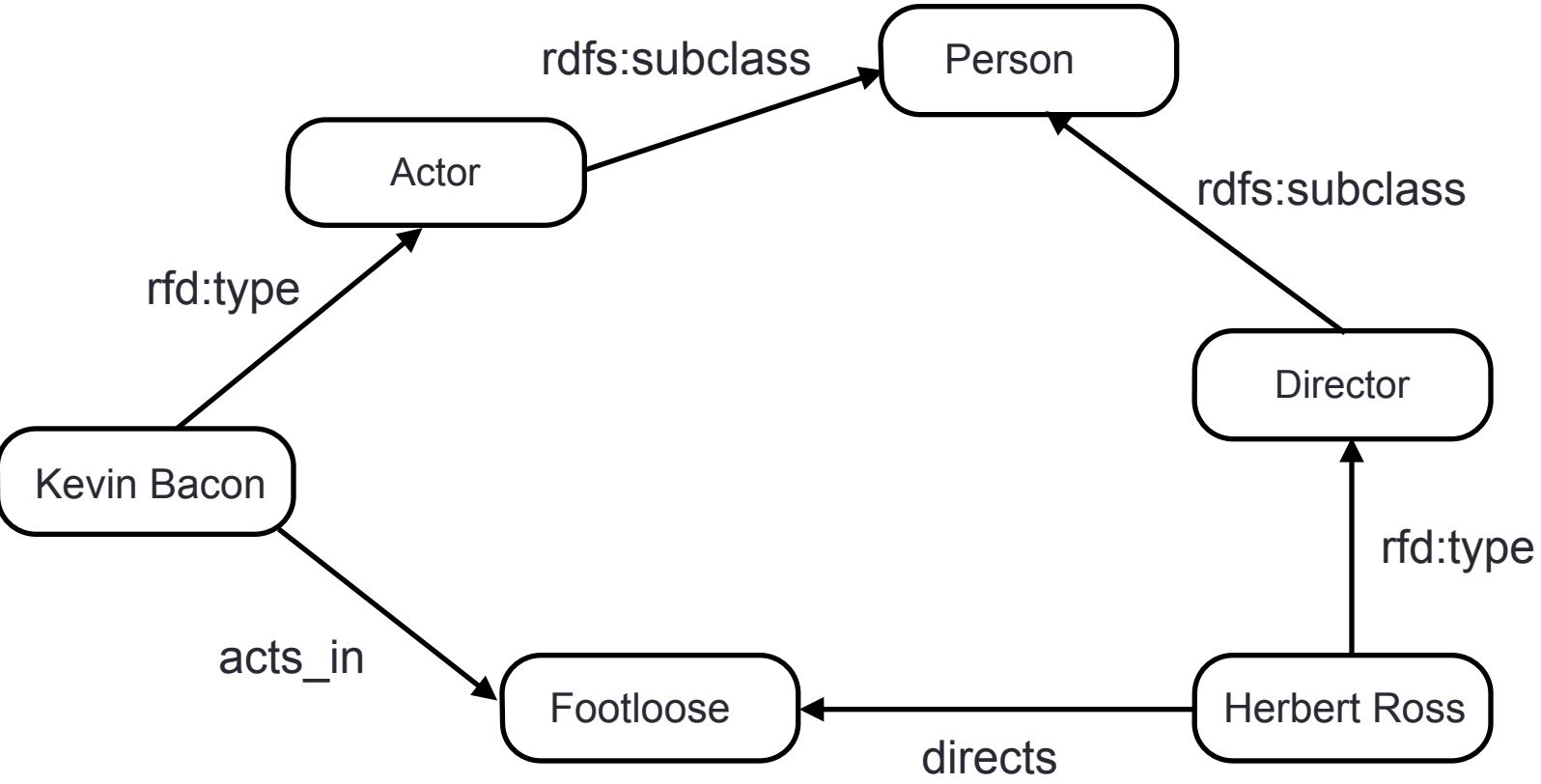
$$\left(\text{Friends} \overset{(s_1, p_2, o_2)}{\underset{o_1 = s_2}{\bowtie}}\right)^{+}$$

Recursive Triple Algebra (examples)



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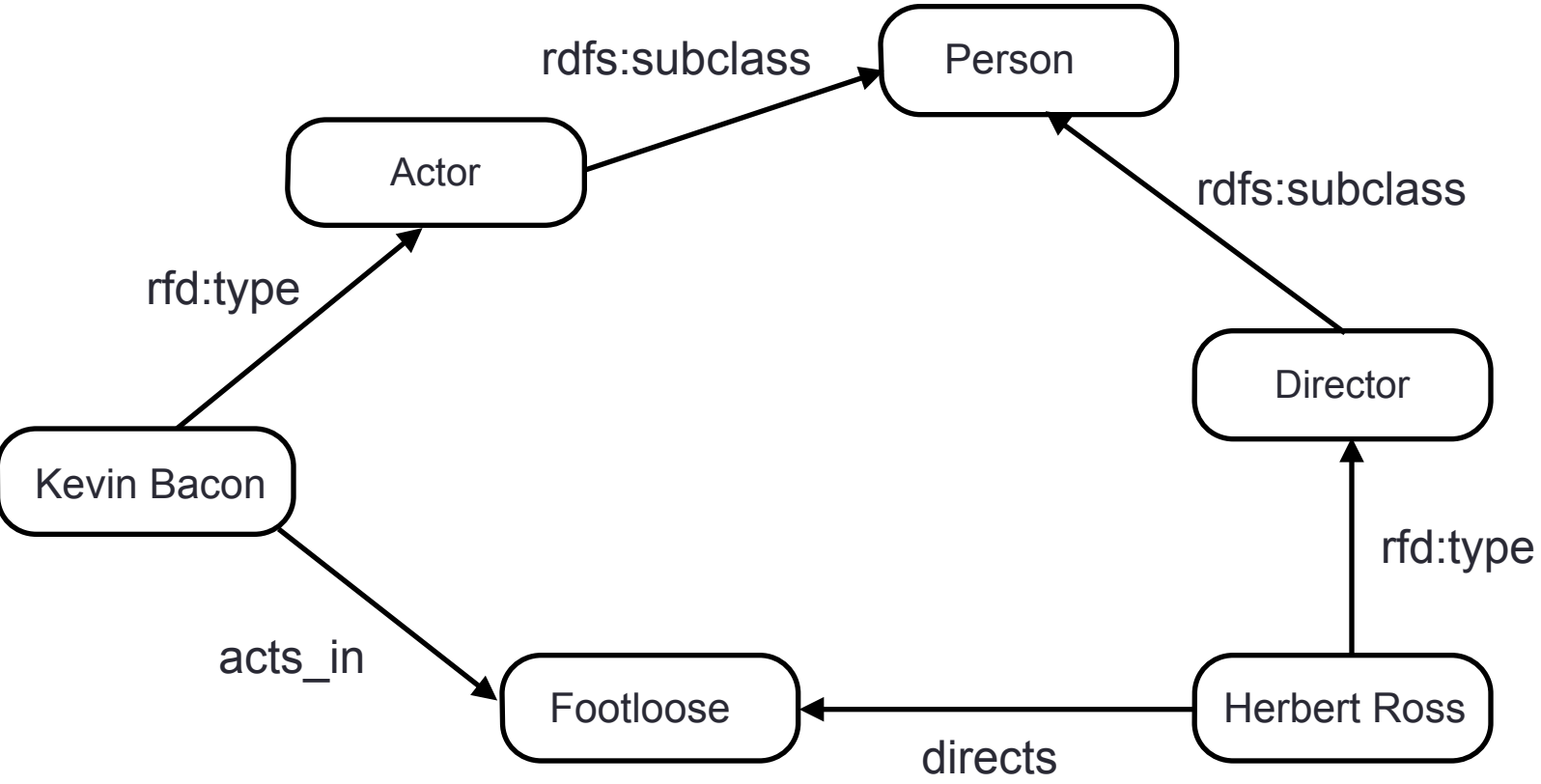

Applying transitivity of subclass:

$$\left(T \underset{o_1=s_2,\ p_1=\text{rdf:type},\ p_2=\text{rdf:subclass}}{\overset{(s_1,p_1,o_2)}{\bowtie}}\right)^{+}$$

Evaluation

Is a triple (s,p,o) in the evaluation of a recursive TriAL expression over a graph?

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Evaluation of recursive TriAL is: [Libkin, R., Vrgoc 13]

PTIME-complete
NLogSpace-complete if the expression is fixed

(almost the same than graph path queries)

Recursive Triple Algebra as Query Language

TriAL expressions are algebraically closed

but it is only a navigational primitive,
does not subsume CQs (graph patterns)

Think of them as the triplestore equivalent of path queries

Recursive Triple Algebra as Primitive

Can add TriAL expressions to CQs (graph patterns).
but language not algebraically closed anymore.

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Other option: Triplestore equivalent of regular queries?

Regular Queries using TriAL

$$S(z_1, z_2, z_3) \leftarrow R_1(u_1, v_1, w_1), \ \ldots, \ R_n(u_n, v_n, w_n)$$

Each R_i is either a predicate, a label,
or expressions $(P \bowtie)^+$ or $(\bowtie P)^+$,
for a predicate P

Same as before, queries are sets of non-recursive rules

Regular Queries using TriAL

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for a predicate P

Evaluation remains NP-complete
(NLogSpace-c if program is fixed)

Containment?

Moving to higher arities

$$S(\bar{z}) \leftarrow R_1(\bar{x}_1), \ldots, R_n(\bar{x}_n)$$

Each R_i is either a predicate, a label,
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Alternative for systems to implement
navigational patterns using a single engine

Recap

Definition of navigational primitives for triples is not immediate

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One option: Do “kleene closure” of joins:

$$(R \bowtie)^+ = R \cup R \bowtie R \cup (R \bowtie R) \bowtie R \cup \cdots$$

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Advantages: More expressive power,
Can compute navigation using Triplestore engine

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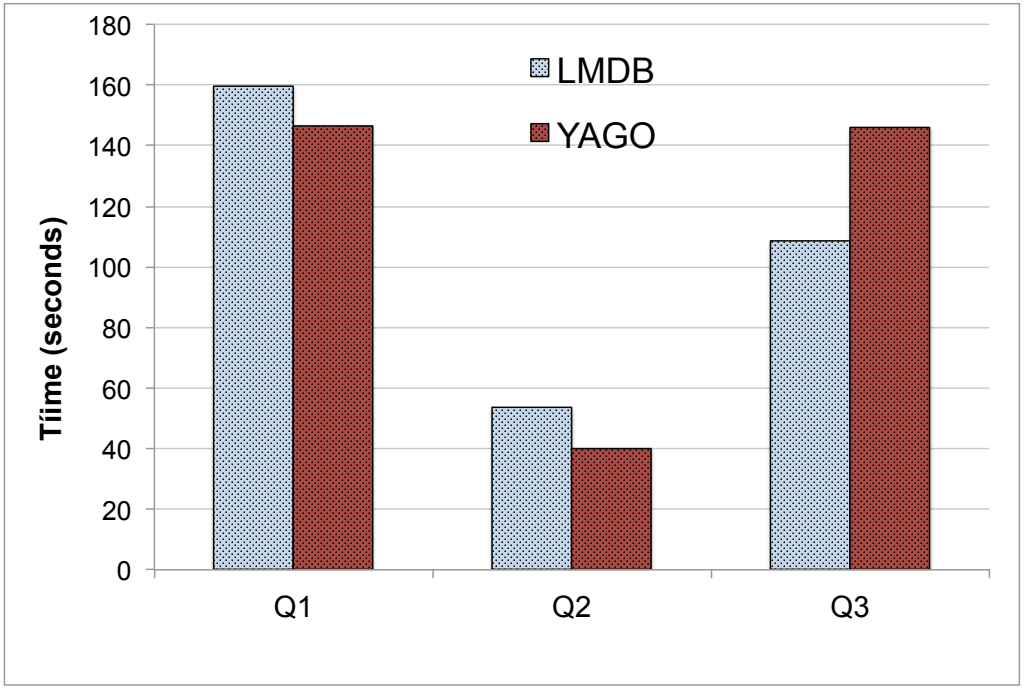
Does this work in practice at all?

Implemented a (superset) of this language, on top of SPARQL
- Recursive SPARQL

Needed to add comparison with constants
(very important in practice)

Datasets:

1. Linked Movie Database
2. Yago (only movie facts)



[R., Soto, Vrgoc 15]

Queries:

1. Actors connected to Kevin Bacon via $(\text{acted\_in} \mid \text{acted\_in}^{-})^{+}$
2. Actors connected to Kevin Bacon through movies with same director.
3. Actors connected to Bacon via movies in which the director is also an actor (like Clint Eastwood).

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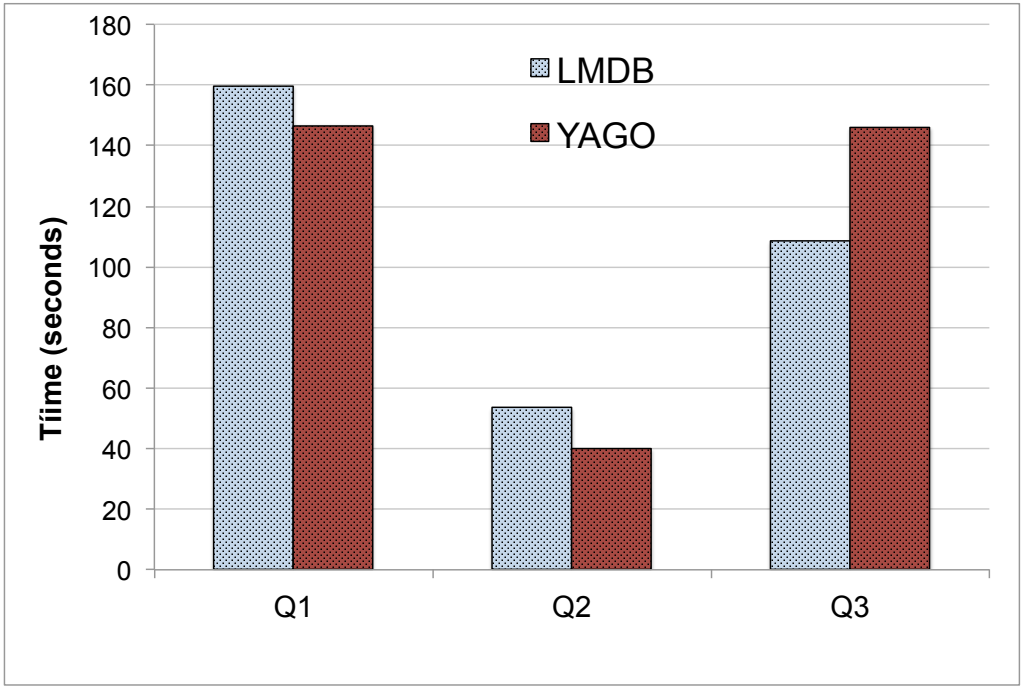

[R., Soto, Vrgoc 15]

Can express as a RQ or a recursive TriAL exp.

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Comparison with SPARQL Path Queries (Property Paths)

Compare our alternative with two RDF/SPARQL engines:

- Virtuoso
- Jena

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Compare our alternative with two RDF/SPARQL engines:

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none of them can compute all actors
connected to Kevin Bacon (under default settings).

We do it in 160 seconds

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Conclusions and Main Takeaways

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Graph DBs: Pattern matching + Navigation

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Slowly showing up in industry.

Need to think about algebraically closed languages

Main Takeaways

Graph DBs: Pattern matching + Navigation

Slowly showing up in industry.
Need to think about algebraically closed languages

Already have alternatives, but need to keep working!

Specially for RDF

Challenges and open problems

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User friendly Datalog-based query languages
Translation from Datalog to lower level algebra for systems

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Queries returning paths.

- any path?
- shortest path?
- all paths?

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So far only navigation.

What about comparing values?
Arithmetic?