Maverick: Discovering Exceptional Facts from Knowledge Graphs

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Exceptional Facts

Denzel Washington followed Sidney Poitier as only the second black to win the Best Actor award.

Entity of interest	Denzel Washington
Context	Best Actor award winners
Attributes	Ethnicity
Peculiar value	African American (only two satisfy)

Exceptional Facts

abc NEWS

Denzel Washington followed Sidney Poitier as only the second black to win the Best Actor award.

Entity of interest	Denzel Washington	Given an entity **x** **find**
Context	Best Actor award winners	A context
Attributes	Ethnicity	A set of attributes (subspace)
Peculiar value	African American (only two satisfy)	

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Exceptional Facts

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Entity of interest	Denzel Washington
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Peculiar value	African American (only two satisfy)

Given an entity **x**

find	**such that**
A context	the context has many entities, including **x**
A set of attributes (subspace)	**x** bears a peculiar value w.r.t. the subspace (few in the context have the value)

Exceptional Facts

Denzel Washington followed Sidney Poitier as only the second black to win the Best Actor award.

This was Brazil's first own goal in World Cup history.

Hillary Clinton becomes first female presidential nominee.

Applications

Computational Journalism

- Fact-finding
- Fact-checking
  - The first female presidential nominee was Victoria Woodhull, not Hillary Clinton (snopes.com)

Data Cleaning

Recommendation Systems

- Friends, news, and product promotion

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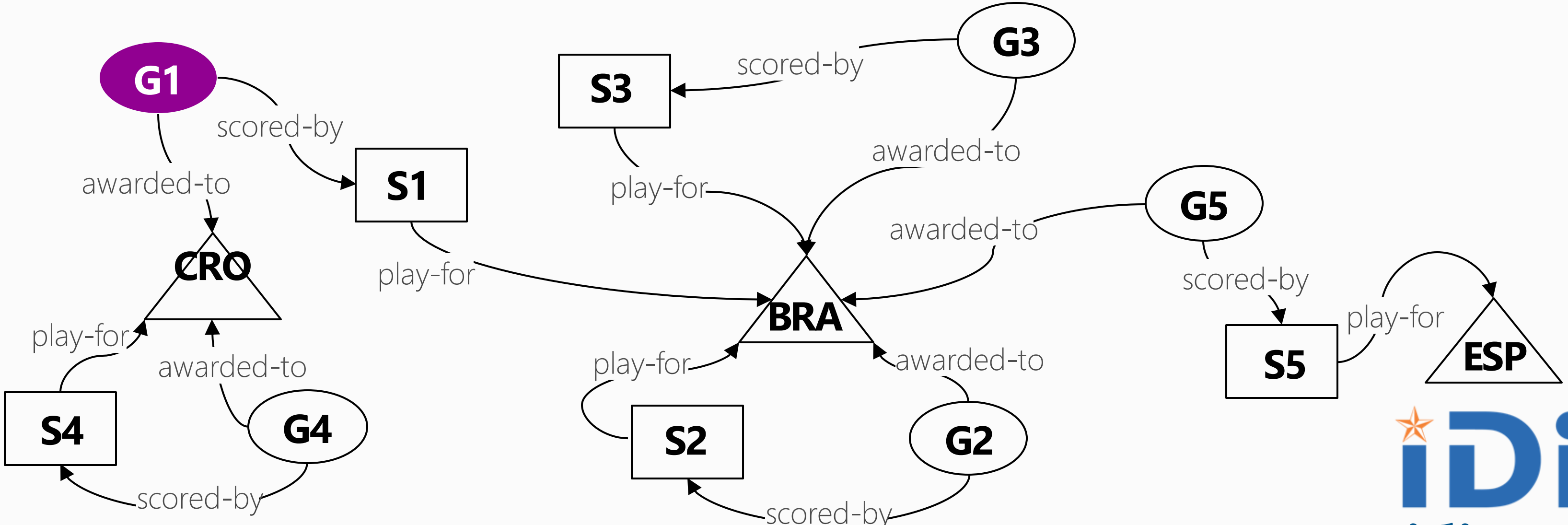
Exceptional Facts from Knowledge Graphs

What is exceptional about G1?



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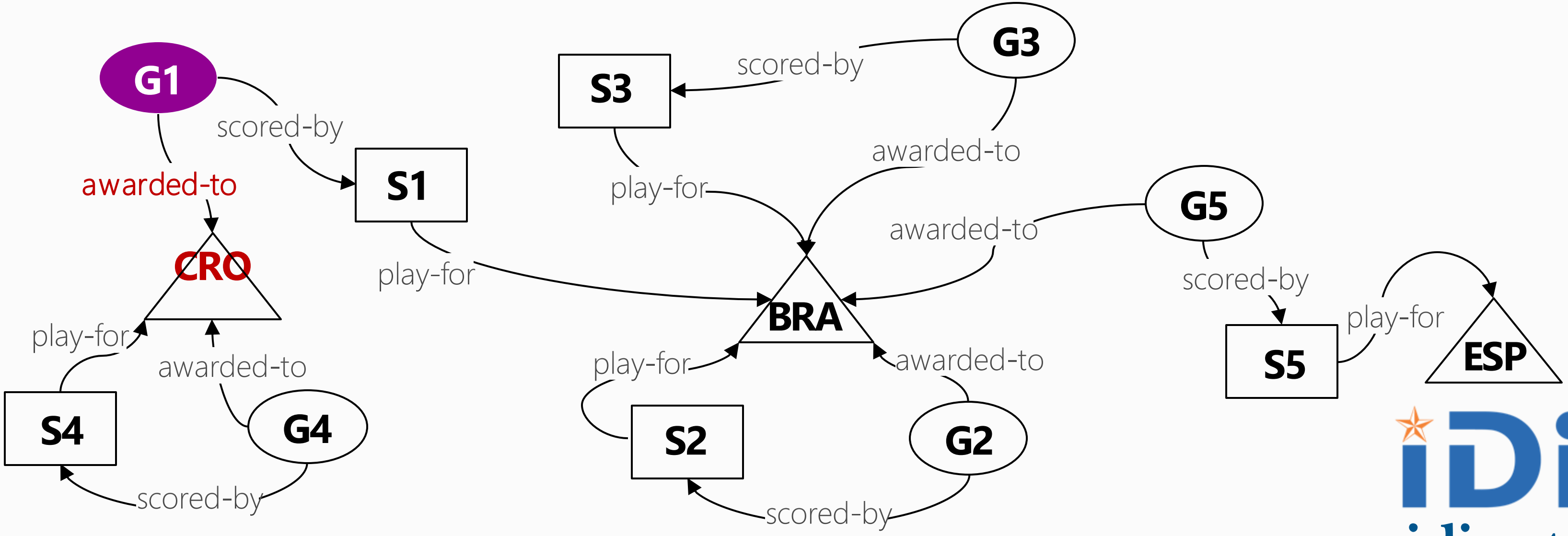
Modeling

Attributes: labels of incoming/outgoing edges

Subspace: a subset of attributes

G1. awarded-to = CRO



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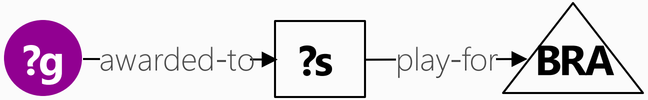
Modeling

Context: entities sharing some common characteristics

Defined by a pattern-variable pair



Goals scored by Brazilian players

Modeling

Context: entities sharing some common characteristics

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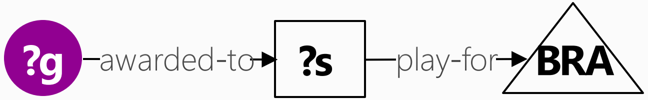

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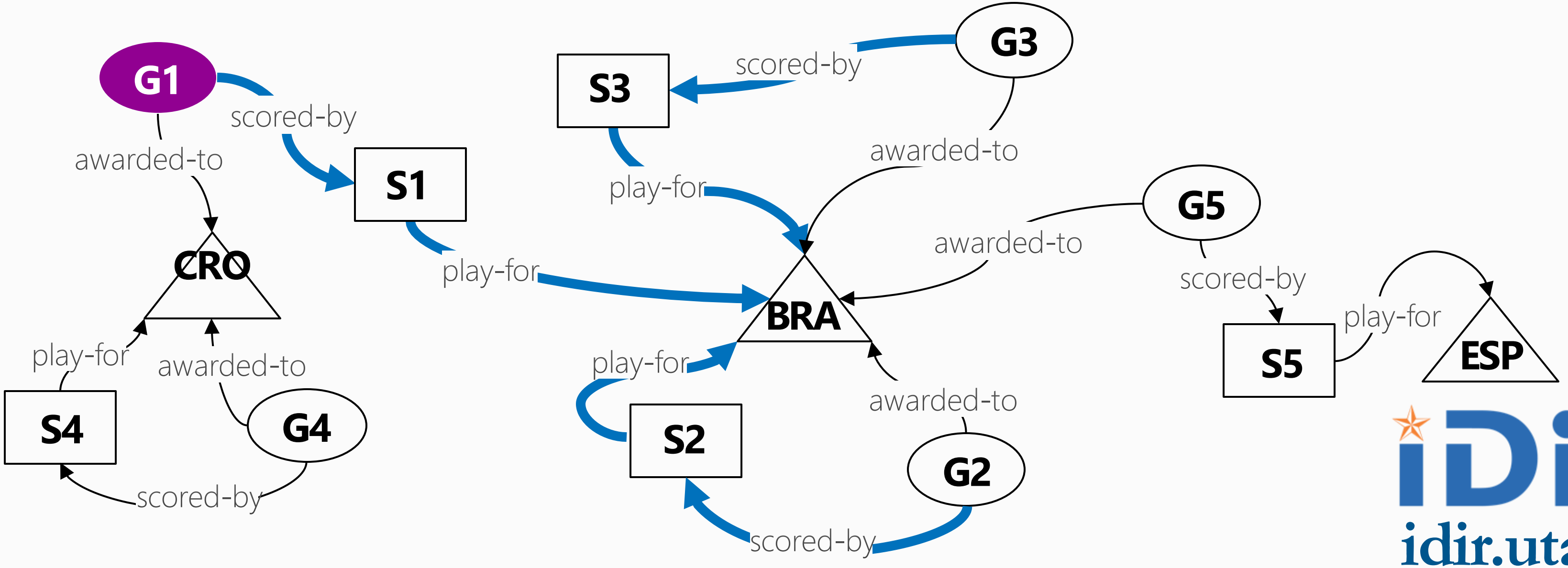

Modeling

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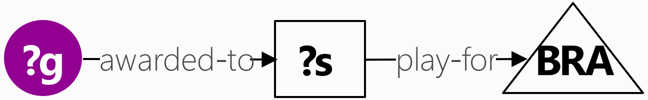
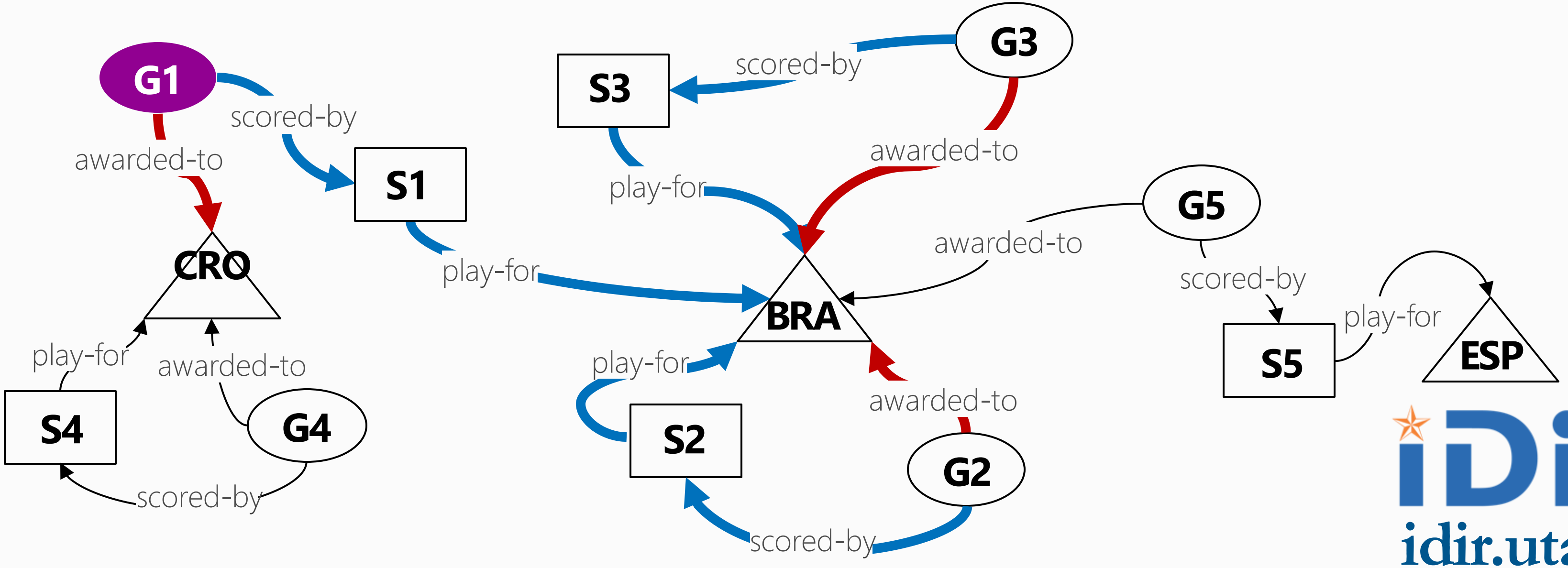


Goals scored by Brazilian players



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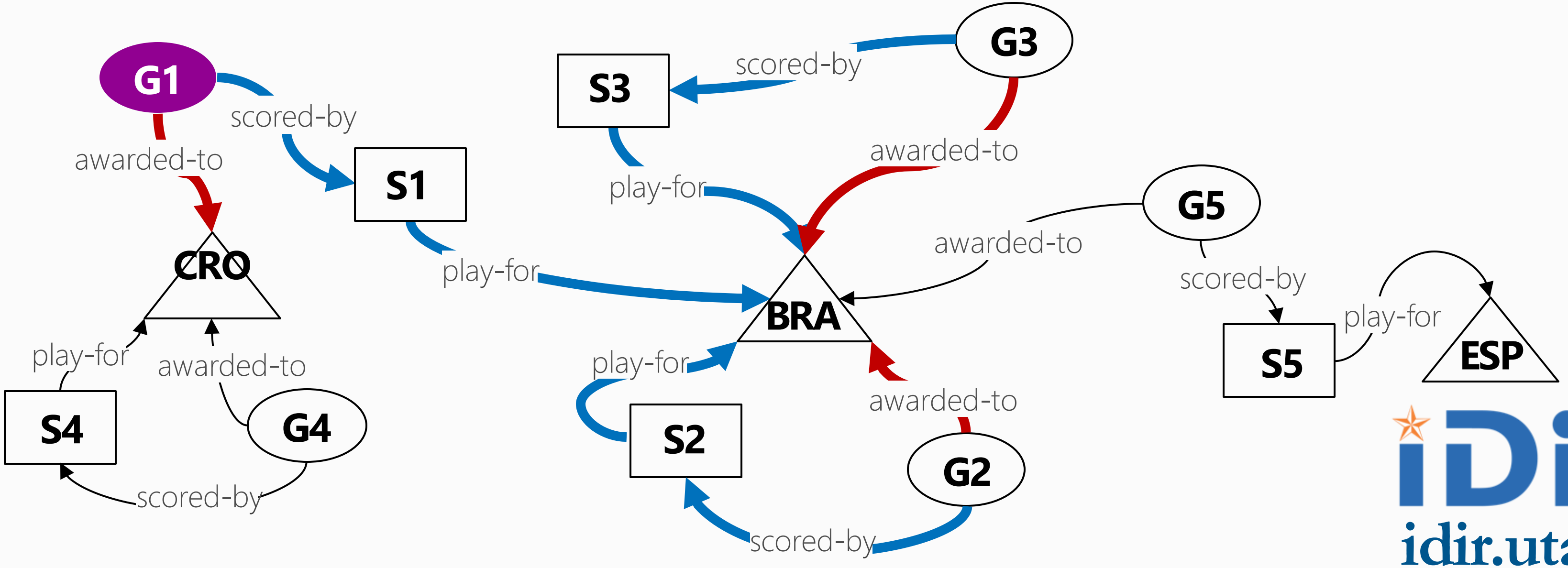
Modeling

What is exceptional about G1?

Among all the goals scored by BRA players, G1 is the only own goal.



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Problem Formulation

Input

- Entity of interest v_0
- Exceptionality function χ
- Result size k

Output

- Top-k (context, subspace) pairs with regard to χ, in which v_0 stands out

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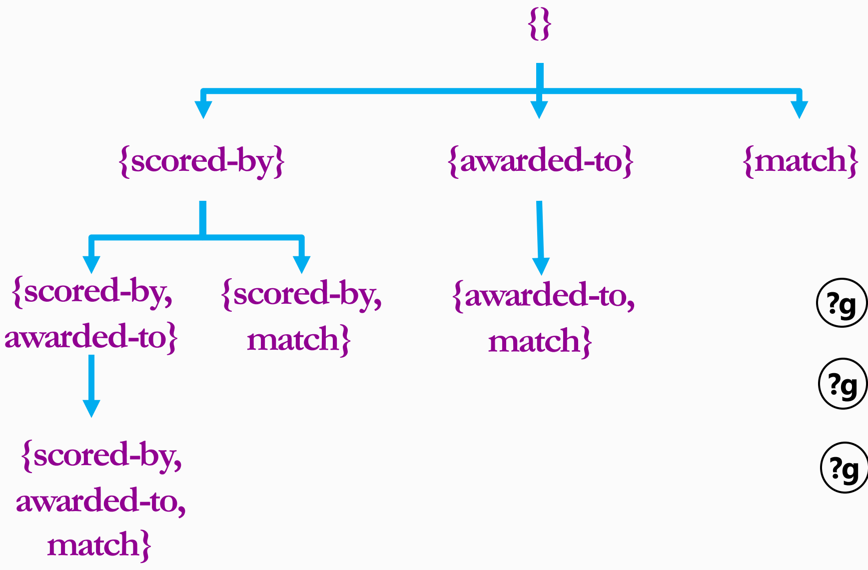
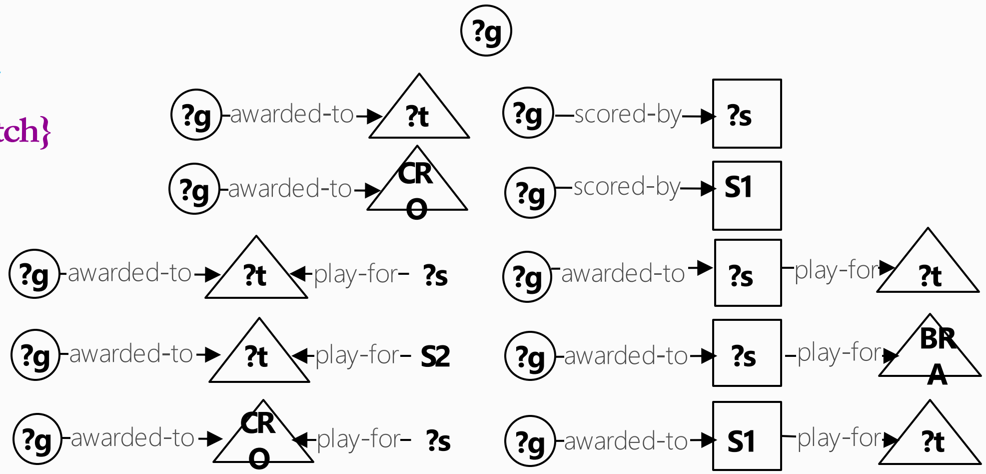
Challenges

- Number of attribute subspaces: $O(2^{|A_{v_0}|})$
- Number of patterns (contexts): $\Omega(2^{|V_G|})$





Related Work

Outlier detection

- Maverick finds conditions that make an object stand out, although the object may not necessarily be an outlier.

Outlying aspect mining

Challenges in adopting existing algorithms:

- Many assume a single-table model: a graph can be an extremely large and sparse table
- Conjunctive queries on a single table ≠ pattern queries
- Multiple tables: unclear how to handle joins
- Unclear how to handle set values

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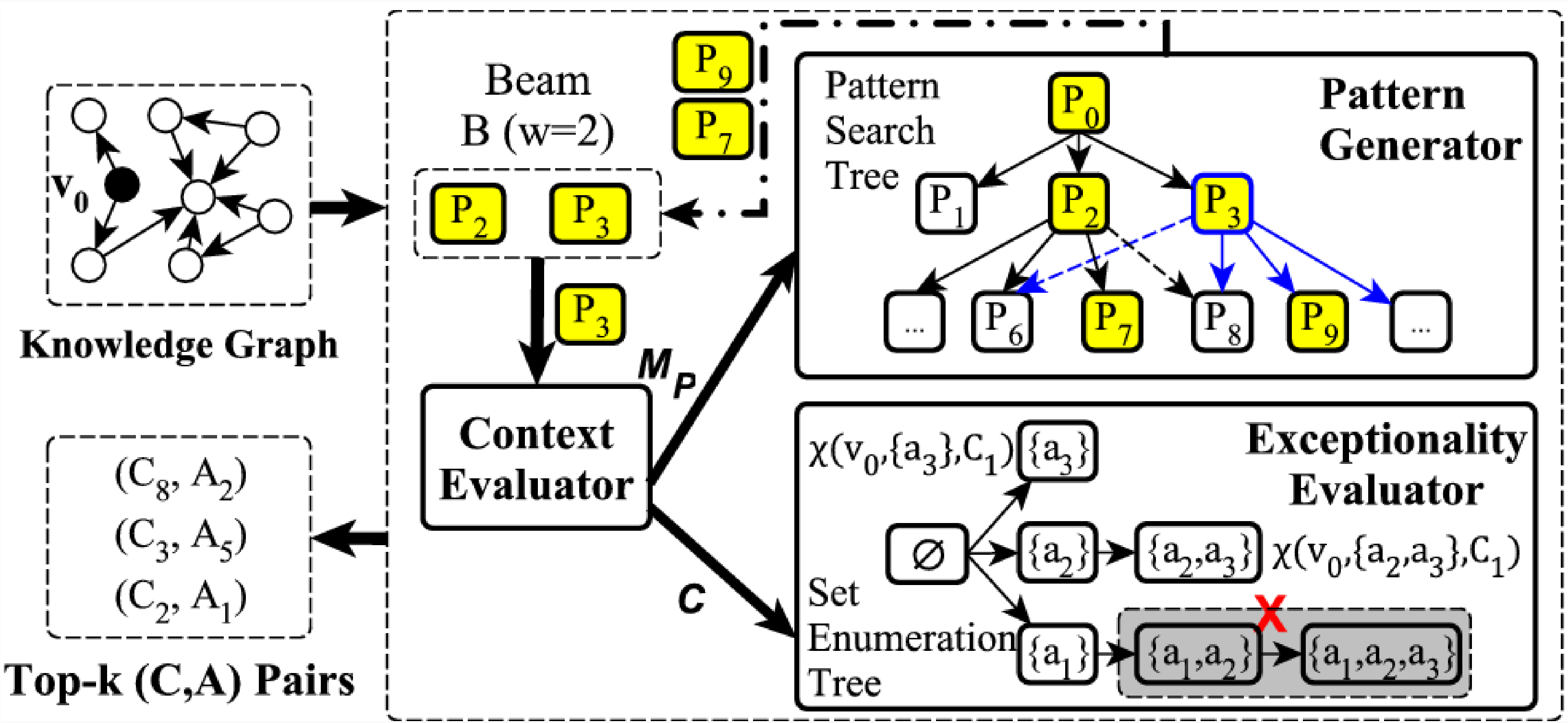
Maverick



Knowledge Graph
v_0
Top-k (C,A) Pairs
(C_8, A_2)
(C_3, A_5)
(C_2, A_1)
Beam
B (w=2)
P_2 P_3
P_9
P_7
P_3
Context Evaluator
M_P
C
Pattern Search Tree
Pattern Generator
P_0
P_1 P_2 P_3
... P_6 P_7 P_8 P_9 ...
Exceptionality Evaluator
$\chi(v_0,\{a_3\},C_1)$
$\{a_3\}$
∅
$\{a_2\}$
$\{a_2,a_3\}$
$\chi(v_0,\{a_2,a_3\},C_1)$
Set Enumeration Tree
$\{a_1\}$
$\{a_1,a_2\}$
$\{a_1,a_2,a_3\}$

Exceptionality Function χ

$\chi(v, A, C) \in \mathcal{R}$

outlierness (χ_o) [Angiuli2009TODS], one-of-the-few(χ_f) [Wu2012KDD], isolation scores (χ_i) [Liu2008ICDM]

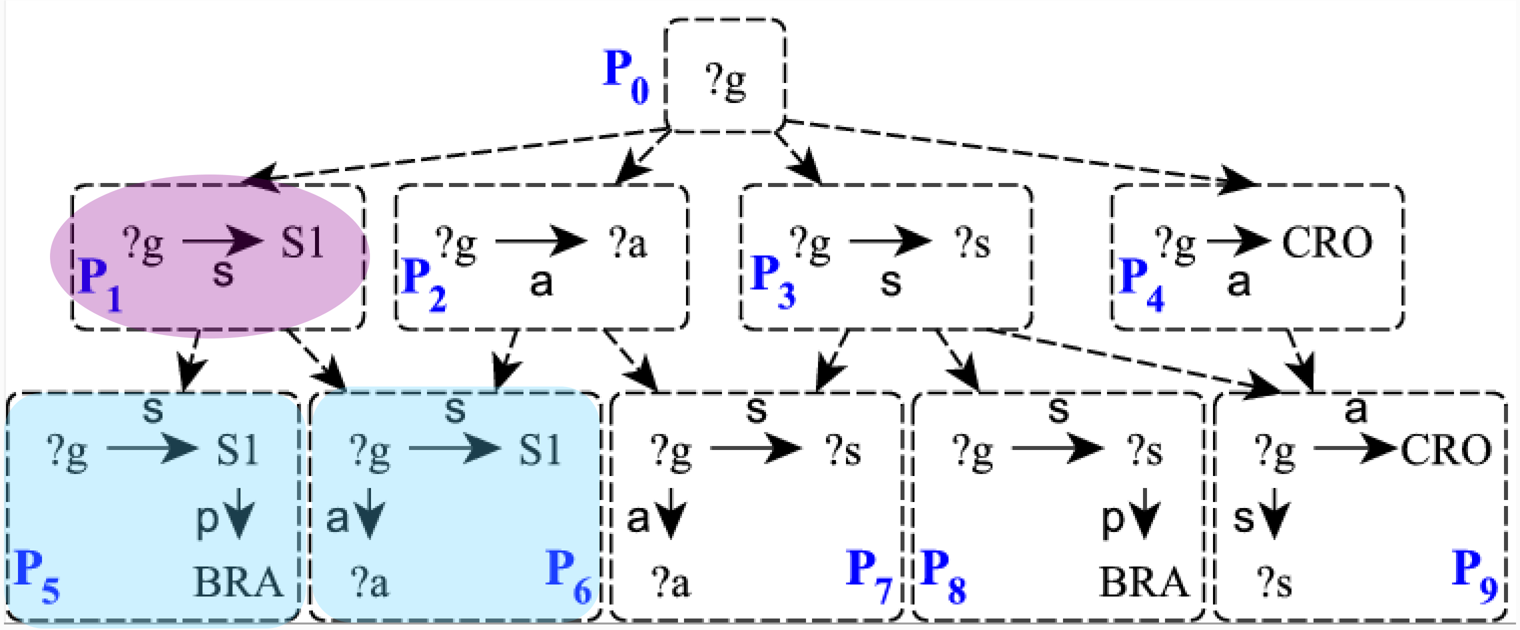
Upper bound function

Theorem 4.2 $$upper_o(v, A, C) = \sum_{S \in \mathcal{S}_A} (p_S)^2 - \frac{(2\, p_{v.A} + 1) \times |C| - 2}{|C|^2}$$

Theorem 4.3 $$upper_f(v, A, C) = |\{u \mid u \in \overline{C_v},\, p^A_{u.A} > 1/|C|\}| \Big/ |C|$$

Theorem 4.4 $$upper_i(v, A, C) = 1 - 2^{-\frac{-\log_2 \frac{1}{|C|}}{-q_{v.A} - sum_{S \in \mathcal{S}_A \setminus \{v.A\}}\, p_S \times \log_2 p_S}}$$

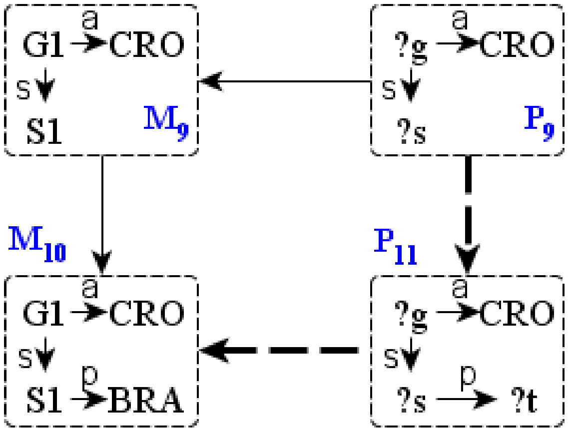
Pattern Generator (PG)



Match–based Pattern Generation

- Construct Partial Order of Valid Patterns

THEOREM 5.4. *Suppose P' is a child of $P \in \mathbb{P}$, i.e., $(P, P') \in E_{\mathbb{P}}$ and thus P' is a valid pattern with matches. Given any match M' to P', there exists a match M to P that is a subgraph of M', i.e., $\forall M' \in \mathcal{M}_{P'}, \exists M \in \mathcal{M}_P$ s.t. $V_M \subseteq V_{M'}$ and $E_M \subseteq E_{M'}$.*



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Datasets and Experiments

WCGoals

Created based on FIFA.com

11 node types, 13 edge types

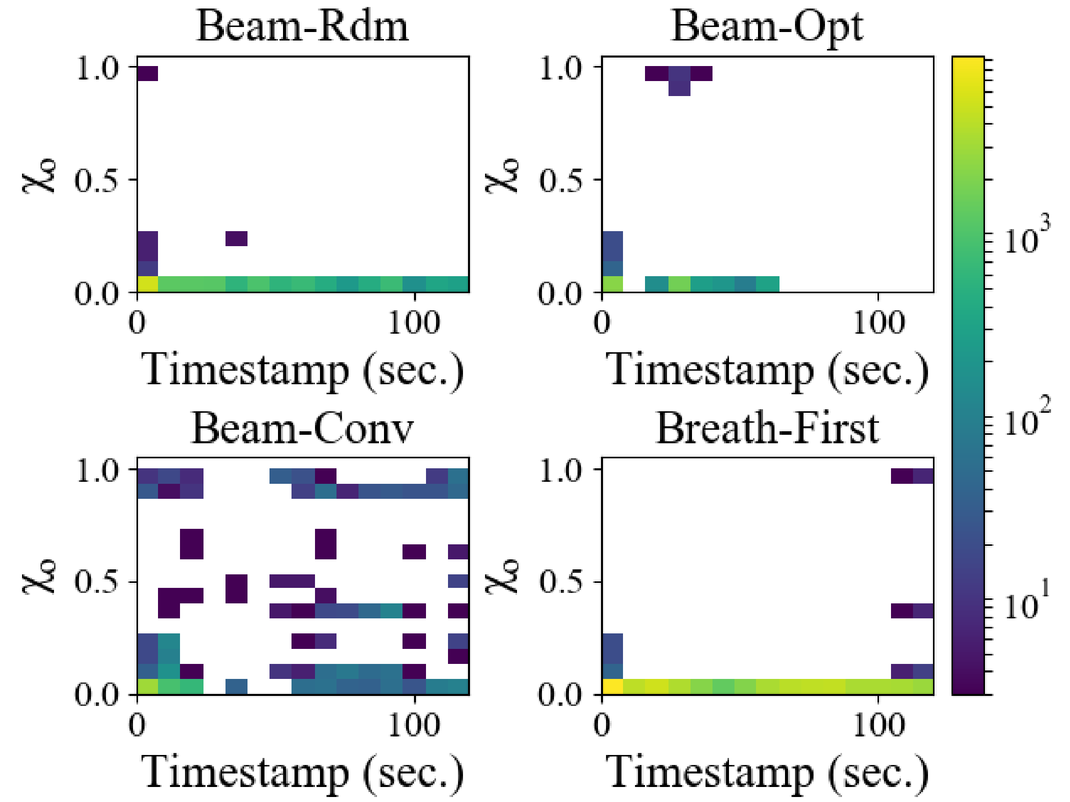
49,078 nodes, 158,114 edges

Film-Award

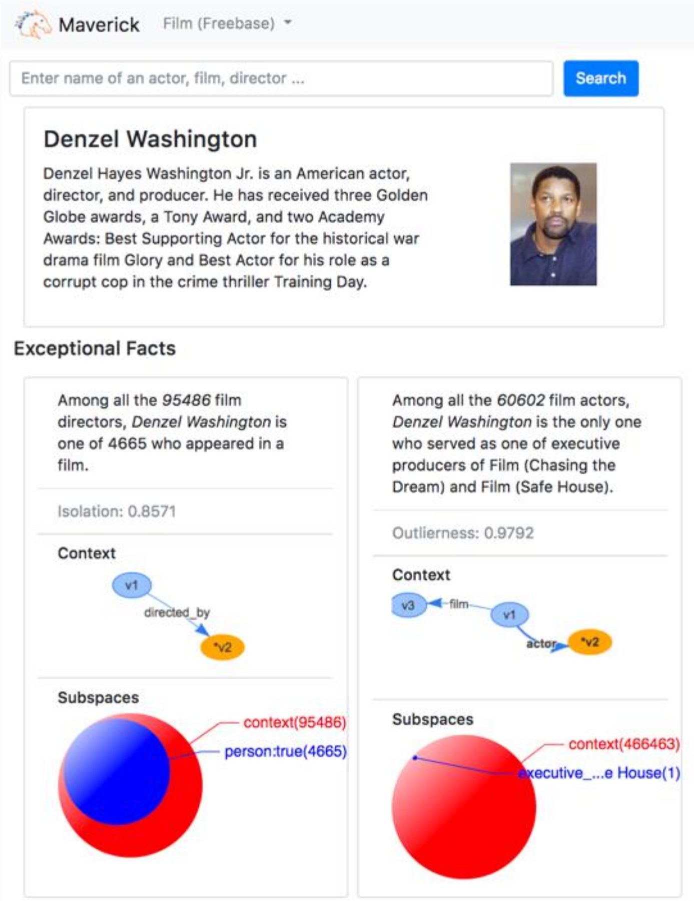
A subgraph of Freebase

95 node types, 117 edge types

5,437,628 nodes, 10,879,448 edges



See you in Rio



VLDB2018 demo

Maverick: A System for Discovering Exceptional Facts from Knowledge Graphs

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