Resolving Temporal Conflicts in Inconsistent RDF Knowledge Bases

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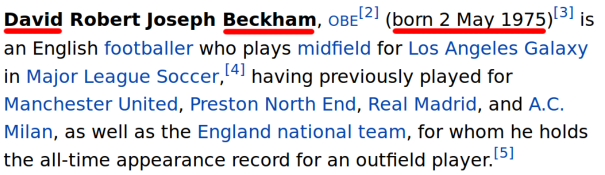
Motivation

http://en.wikipedia.org/wiki/David_beckham



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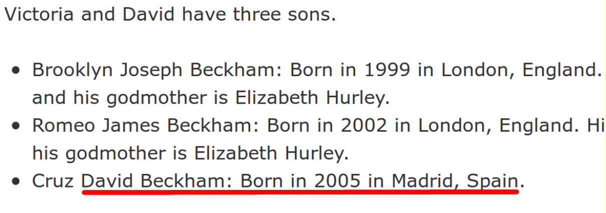
http://marriage.about.com/od/sports/a/davidbeckham.htm



Victoria and David have three sons.

- Brooklyn Joseph Beckham: Born in 1999 in London, England. and his godmother is Elizabeth Hurley.
- Romeo James Beckham: Born in 2002 in London, England. Hi his godmother is Elizabeth Hurley.
- Cruz David Beckham: Born in 2005 in Madrid, Spain.

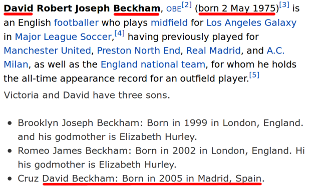
Extracting Facts

$$Facts \subset (Relation \times Entities \times Entities)$$

$$\text{Weight} \ : Facts \longrightarrow \mathbb{R}^{+}$$

$$\text{Time-Interval} \ : Facts \longrightarrow Intervals$$

Sources



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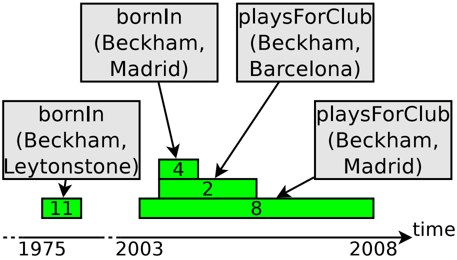
Noisy Facts



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playsForClub (Beckham, Barcelona)
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2
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Constraints

Temporal Constraints:

- Precedence (*before*)
- Non-overlapping (*disjoint*)

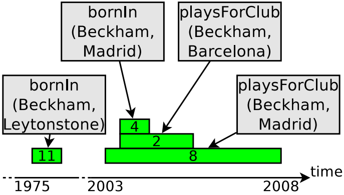
Non-temporal Constraint:

- Functional (*mutEx*)

Each Constraint:

- 2 relations from DB e.g. *bornIn*
- Both share a variable

Noisy Facts



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Constraints

$$\begin{pmatrix} bornIn(p, l, t_1) \wedge \\ playsForClub(p, c, t_2) \end{pmatrix} \rightarrow before(t_1, t_2)$$

$$\begin{pmatrix} playsForClub(p, c_1, t_1) \wedge \\ playsForClub(p, c_2, t_2) \wedge \\ c_1 \neq c_2 \end{pmatrix} \rightarrow disjoint(t_1, t_2)$$

Answering Queries

Goal: Return only consistent Facts

1. Obtain consistent $F \subseteq Facts$

$$\max_{F \subseteq Facts} \sum_{f \in F} w(f)$$

   where F fullfills constraints

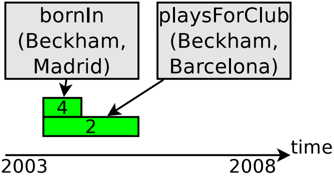
2. Answer query within F

- NP-hard

Query

$playsForClub(David\_Beckham, ?, ?)$

Facts



Constraint

$$\left(\begin{array}{c} bornIn(p, l, t_1) \wedge \\ playsForClub(p, c, t_2) \end{array} \right) \rightarrow before(t_1, t_2)$$

First Approach

Maximum Weight Independent Set

- Binary constraints
- NP-hard
- Heuristics in $\Omega(|\mathit{Facts}|^2)$

Constraints

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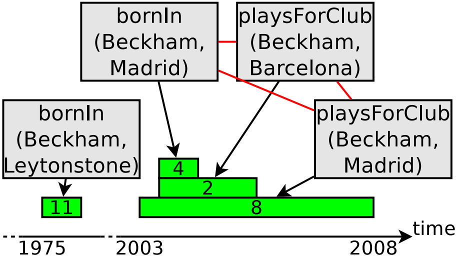

bornIn (Beckham, Madrid)

playsForClub (Beckham, Barcelona)

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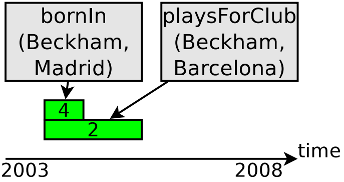
playsForClub (Beckham, Madrid)

Idea

Scheduling Problem

- Temporal constraints
- NP-hard
- Heuristics in $O(|Facts|\ log\ |Facts|)$

Facts



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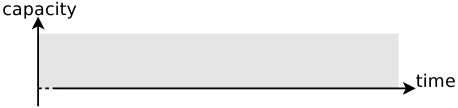
Scheduling Machine



Constraint

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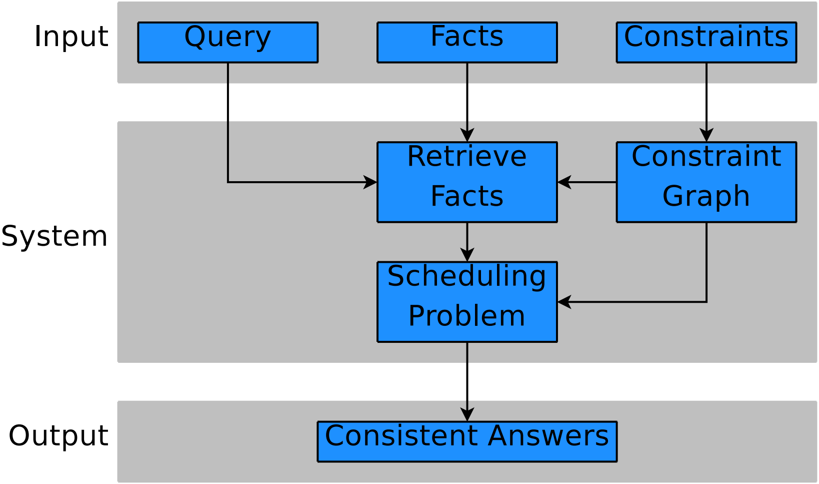
Overview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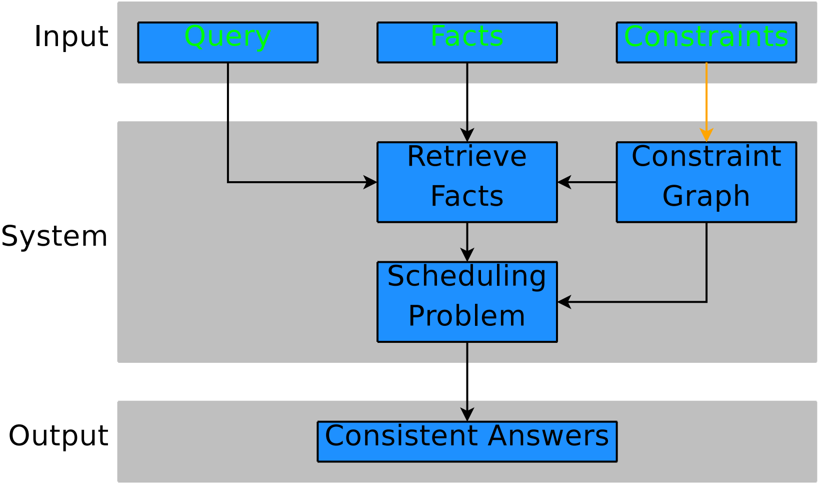
Retrieve Facts
Constraint Graph
Scheduling Problem
Output
Consistent Answers

Overview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Mapping

- *Relations → Vertices*
- *Constraints → Edges*

Constraints

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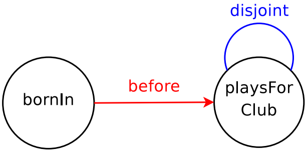
$\Rightarrow$

Constraint Graph



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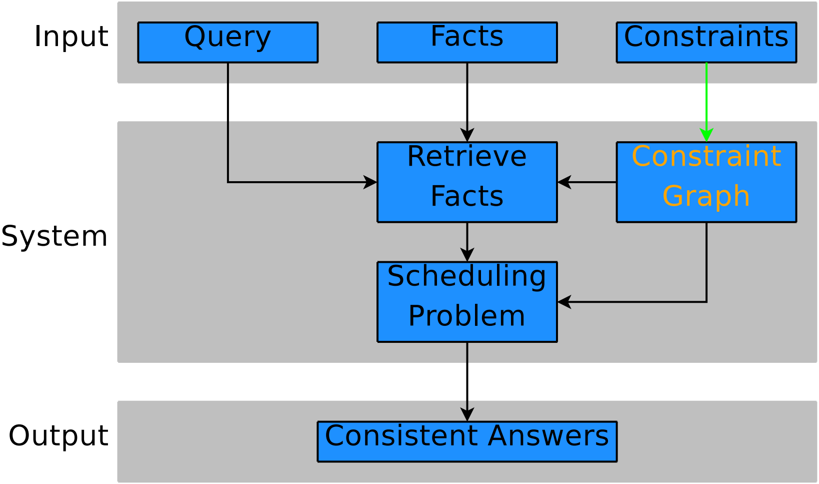
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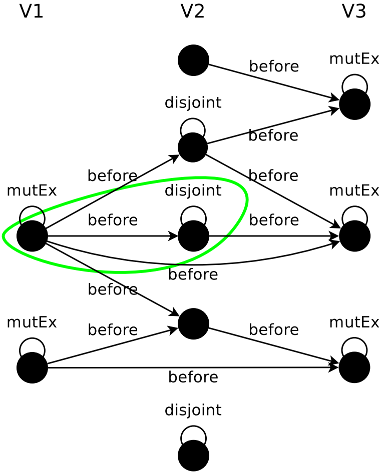
Constraint Graph

Constraints handled by Scheduling

- Tripartide graph $(V_1 \cup V_2 \cup V_3, E)$
- $V_1 \cup V_3$ must have *mutEx* loops
- V_2 can have *disjoint* loops
- *before* can edges point:
  - from V_1 to $V_2 \cup V_3$
  - or from V_2 to V_3



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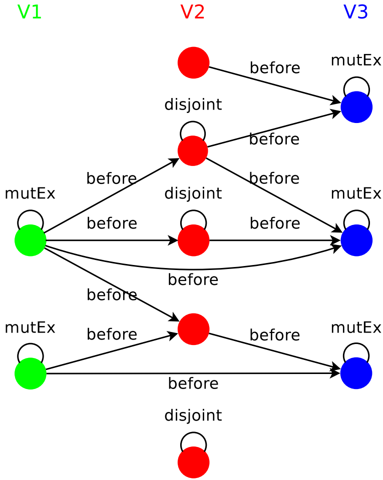

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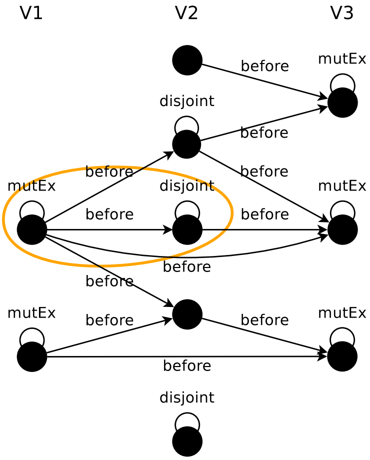

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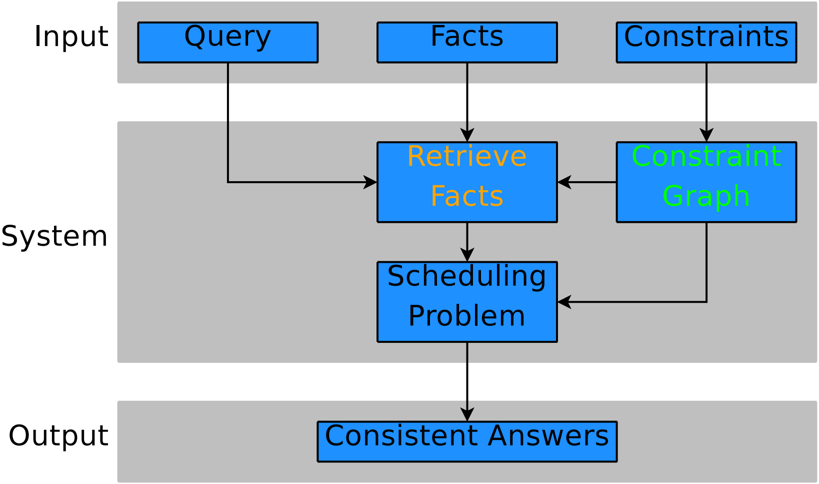
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Retrieving Facts

Breadth-First Search

1. Start: Nodes matching Query
2. At each node:
    1. Retrieve Facts from DB
    2. If result $\neq \emptyset$: continue at not visited neighbours, pass argument

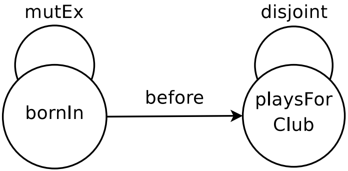
In General:

- For each shared Argument $\Rightarrow O(|Facts| \cdot |Constraints|)$

Query

$playsForClub(David\_Beckham, ?, ?)$

Constraint Graph



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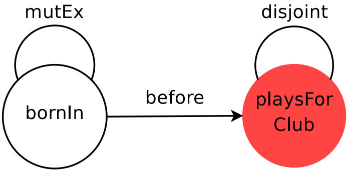

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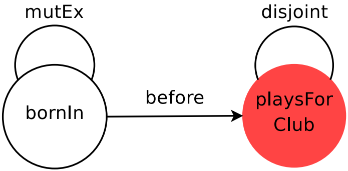

Select * from facts where rel=*playsForClub* and arg1=*David_Beckham*;

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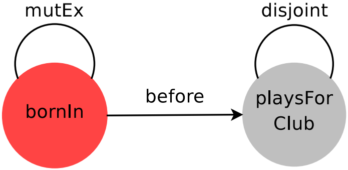

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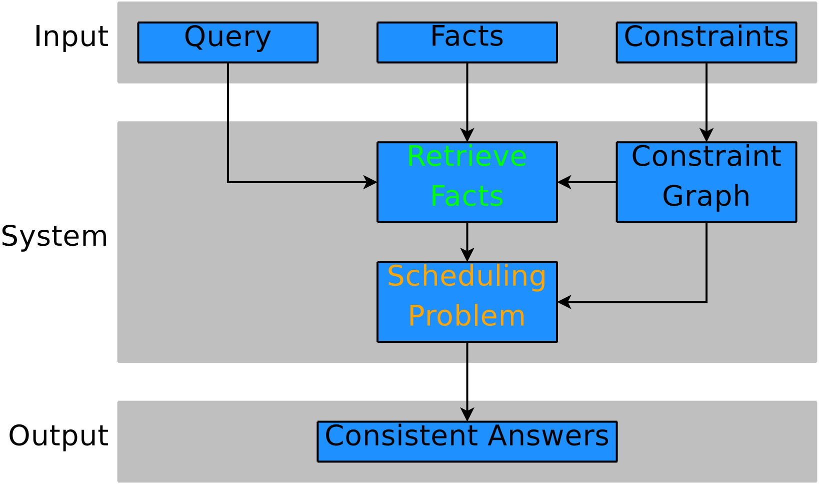
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Scheduling

Facts $\longrightarrow$ *Scheduling Jobs*

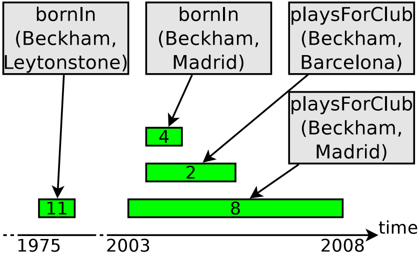
- Weight: Identical
- Capacity $\in [0, 1]$
- Begin: Identical or 0
- End: Identical or ∞

Depending on constraint graph

In General:

- Several Scheduling Machines
- $O(|F| log|F| + |F||machines|)$ [Bar-Noy et al., 2001]

Facts:



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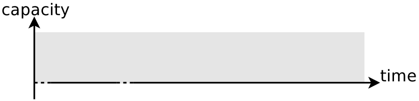

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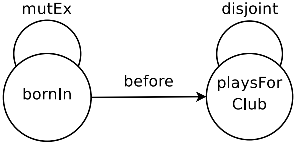

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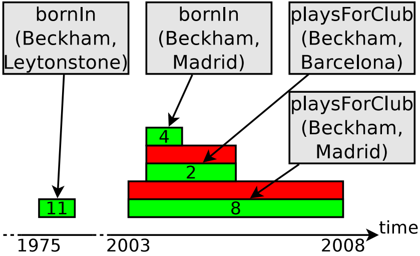
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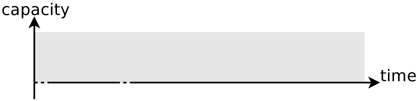

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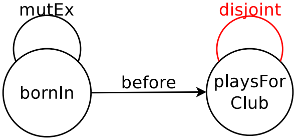

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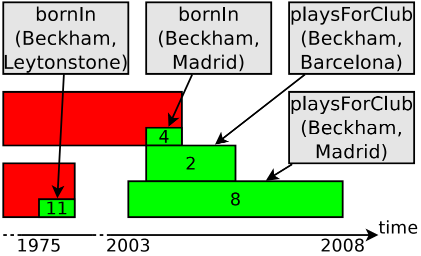
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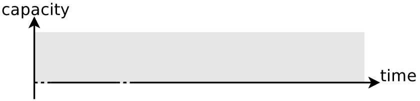

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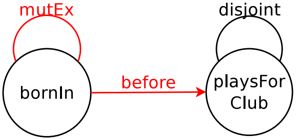

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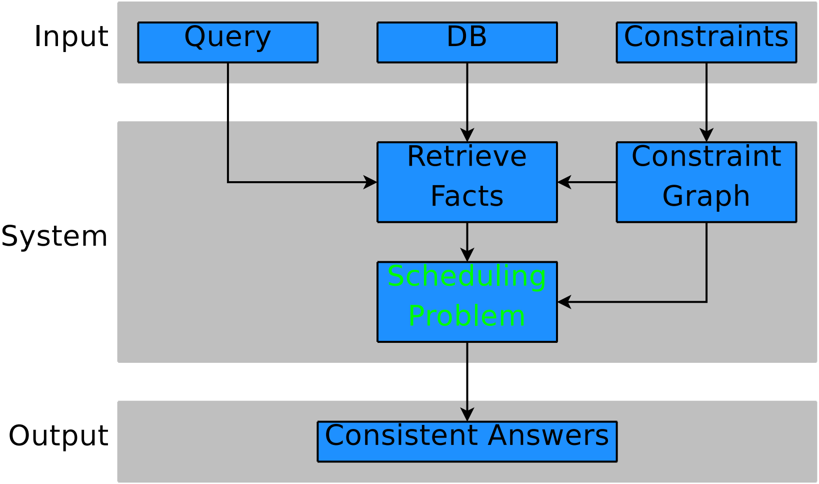
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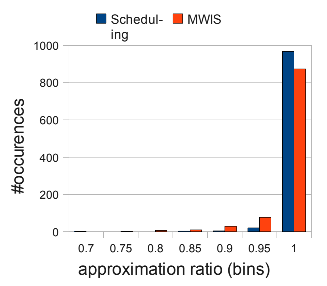
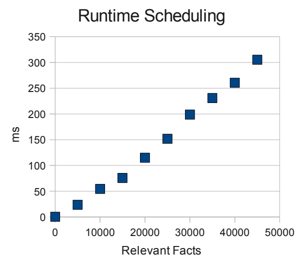
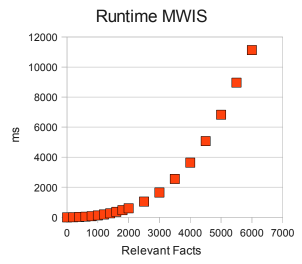
Experiments

- 4 correct facts, 20 noisy facts
- Approximation ratio : $\frac{W_{heuristic}}{W_{optimal}}$







The End

Conclusions

- Resolve conflicts by Scheduling
- Runtime in $O(n\ log\ n)$

Future Work

- Generalize Constraints
- Histograms instead of Intervals
- Probabilistic Reasoning

Bar-Noy, A., Bar-Yehuda, R., Freund, A., (Seffi) Naor, J., and Schieber, B. (2001).
A unified approach to approximating resource allocation and scheduling.
J. ACM, 48(5):1069–1090.