Querying RDF(S) with regular expressions

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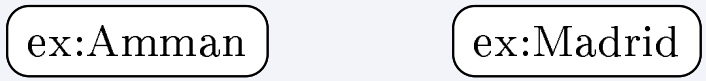
Querying RDF graphs



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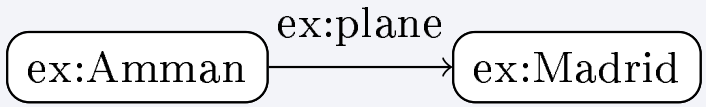

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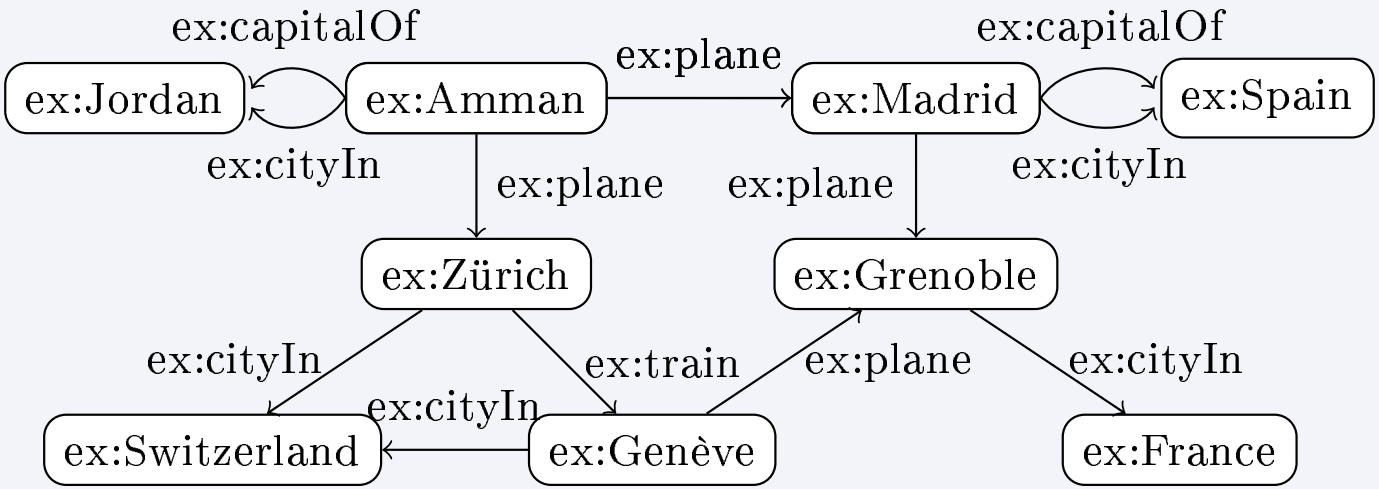

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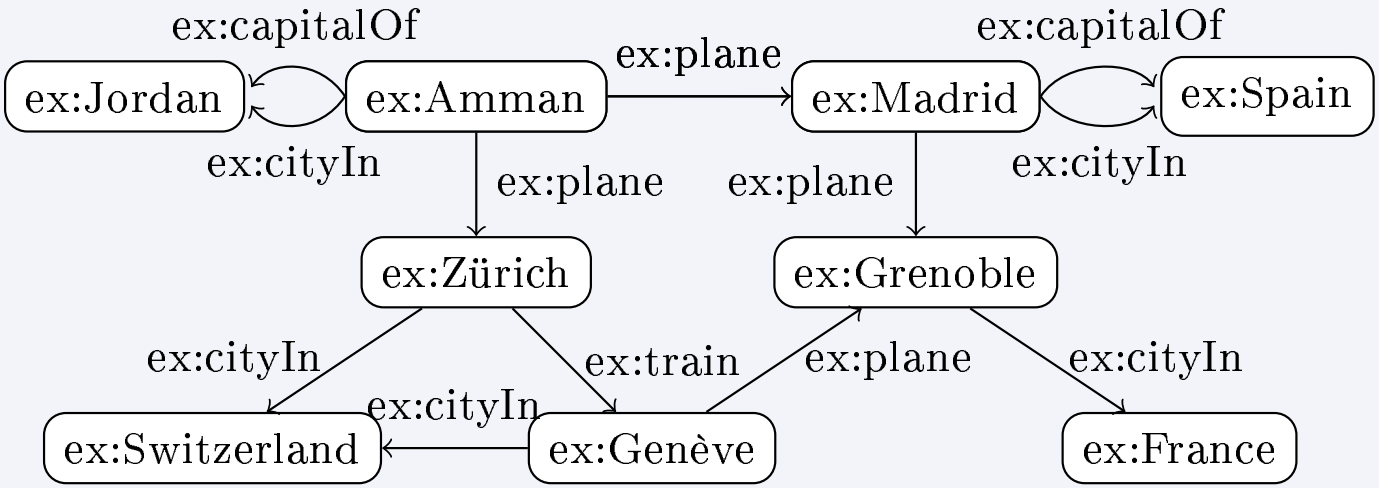

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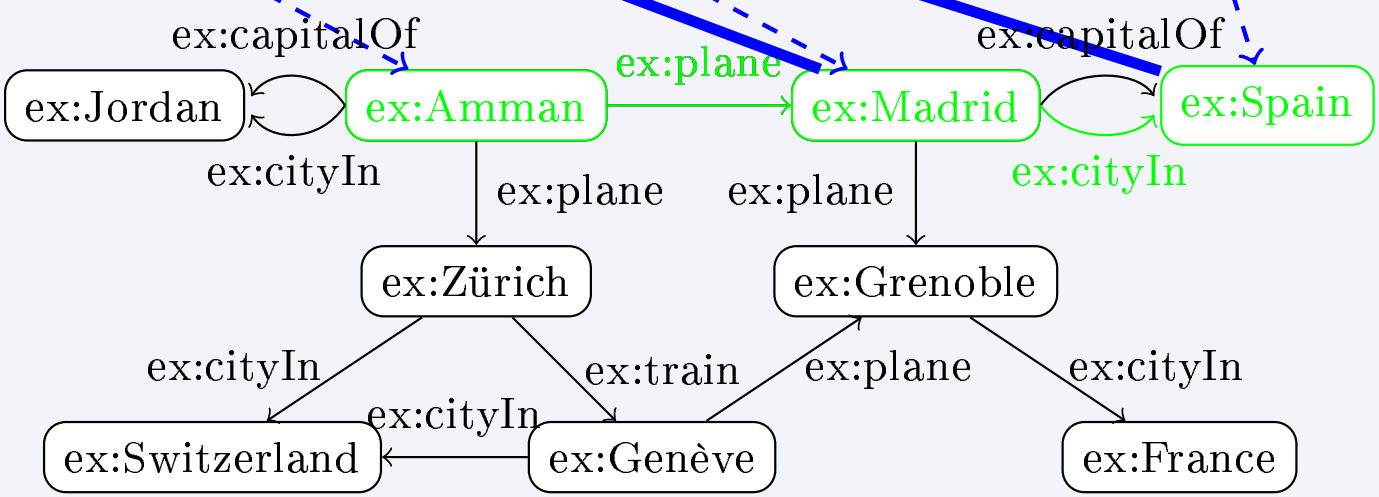

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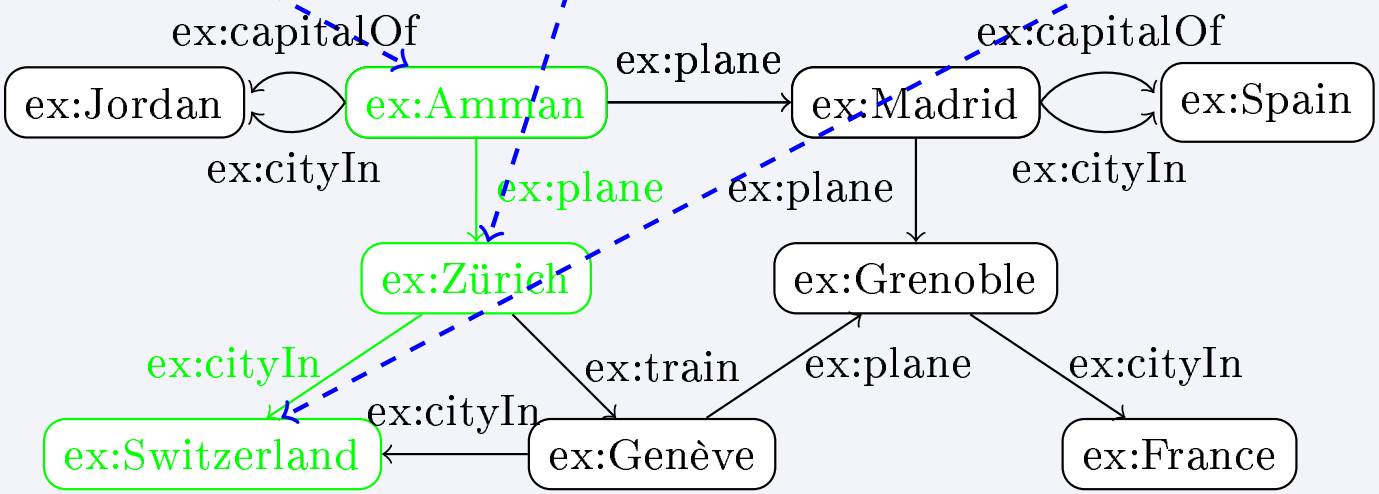

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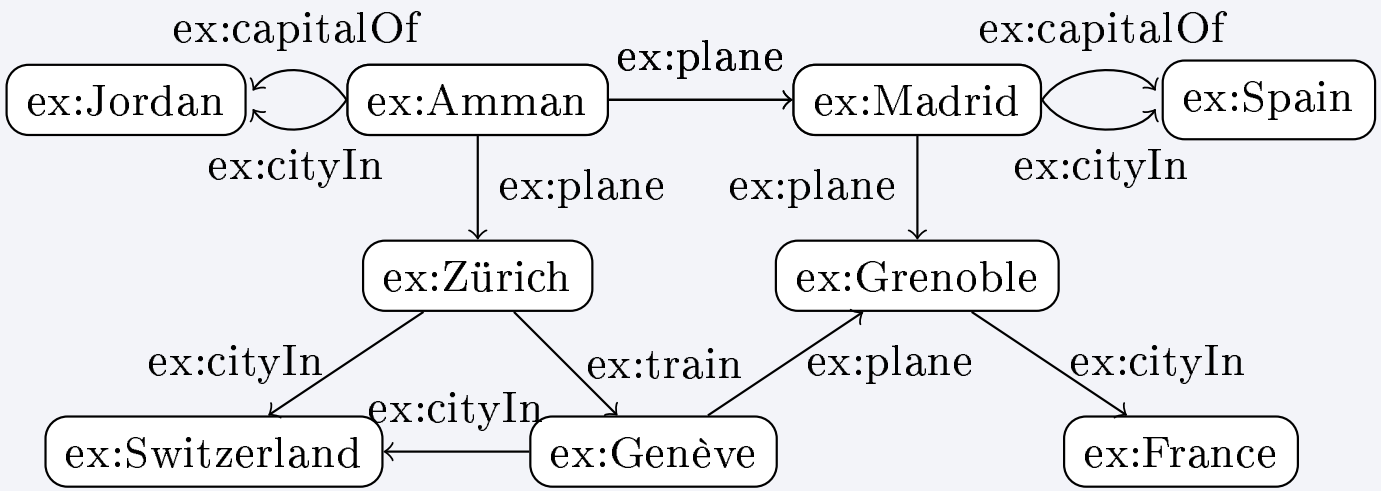

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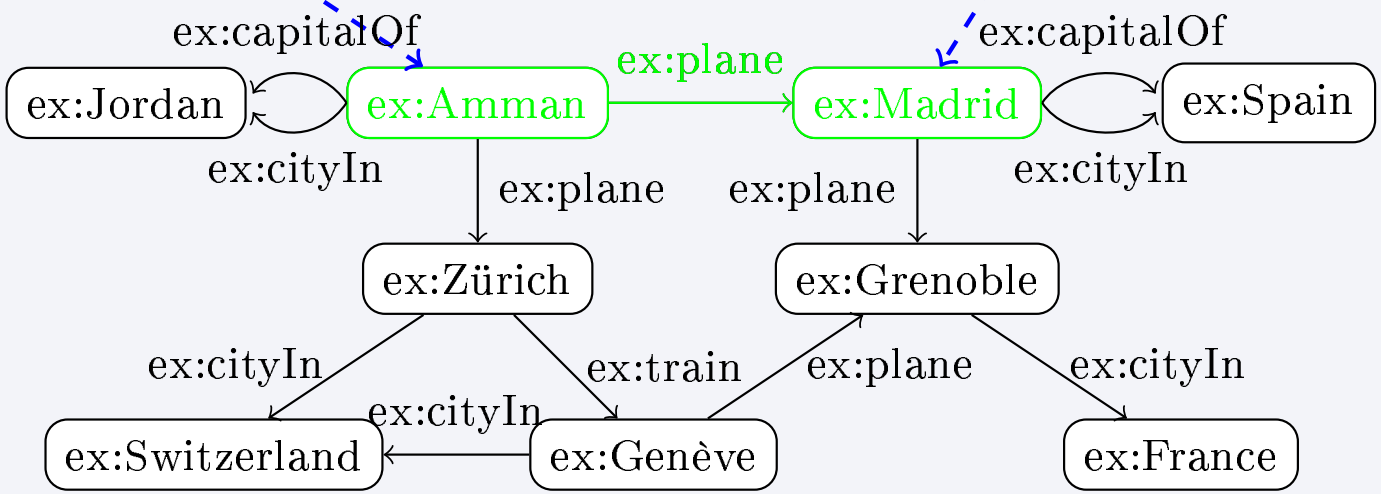

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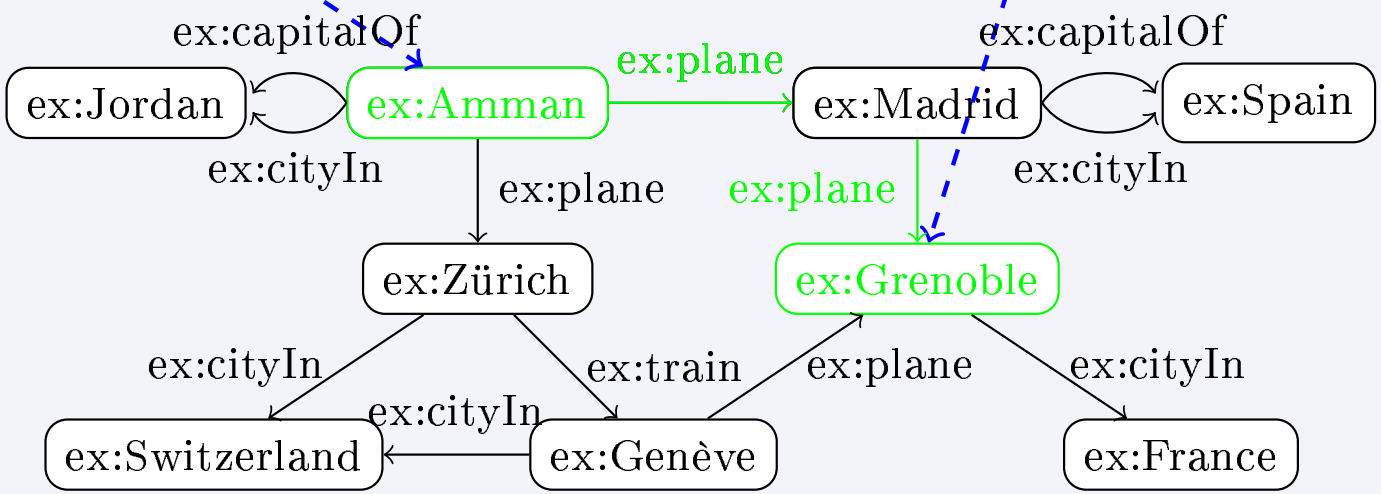

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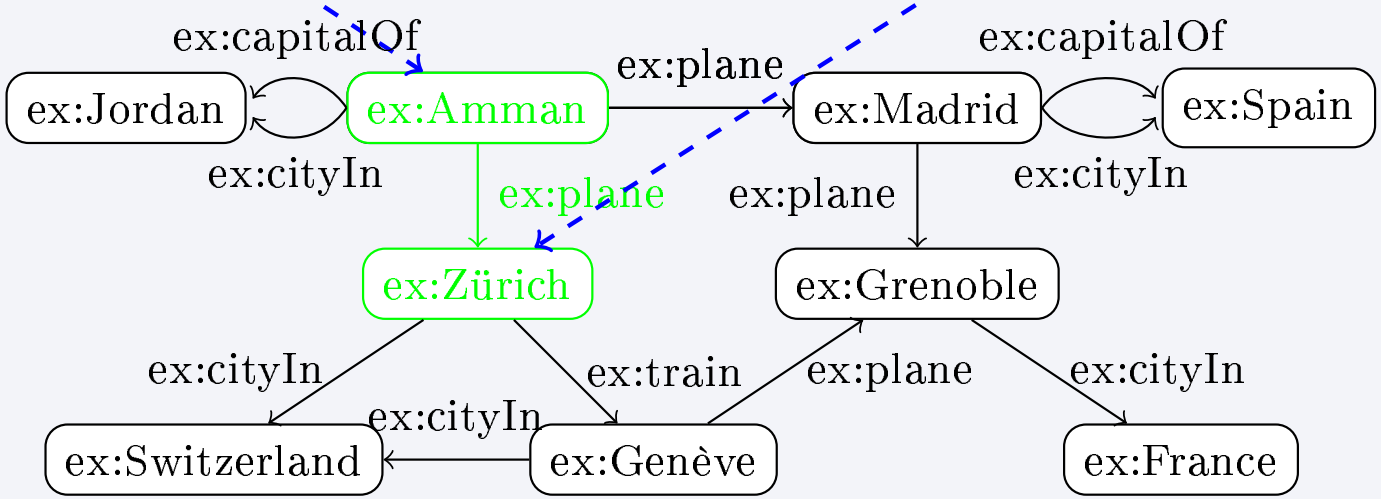

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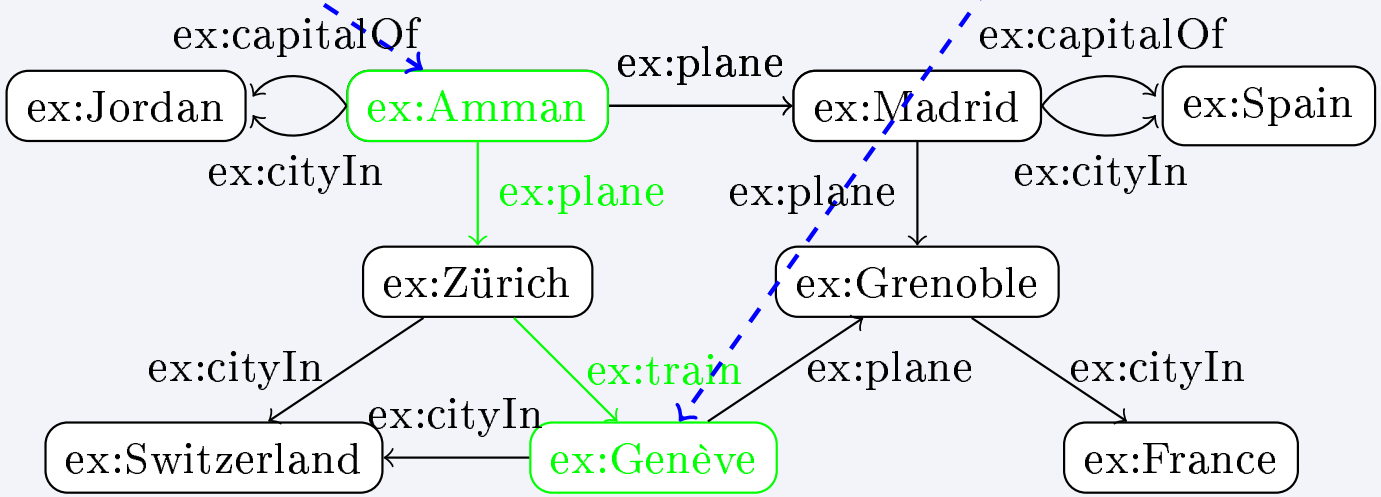

Querying RDF graphs

CPSPARQL Query:

```
SELECT ?City
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                        { ?Stop ex:capitalOf ?Country }
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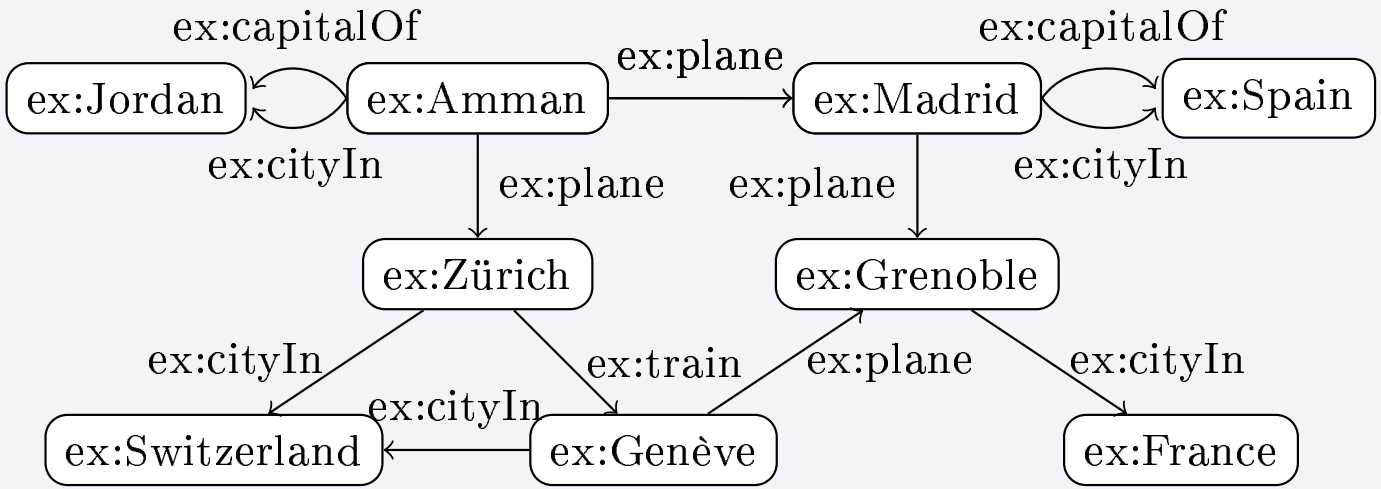

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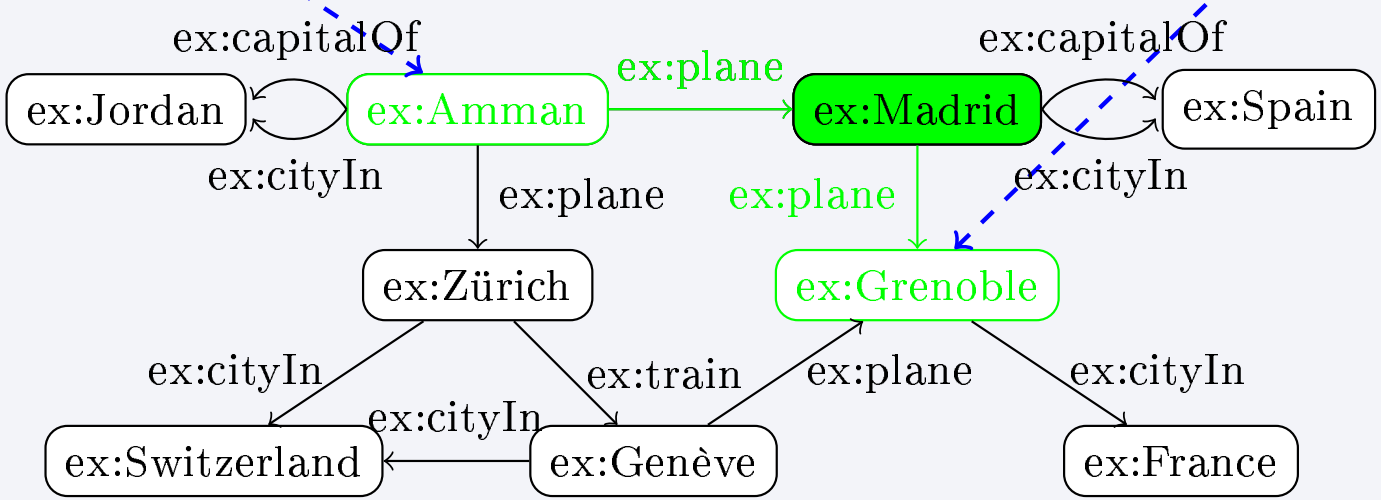

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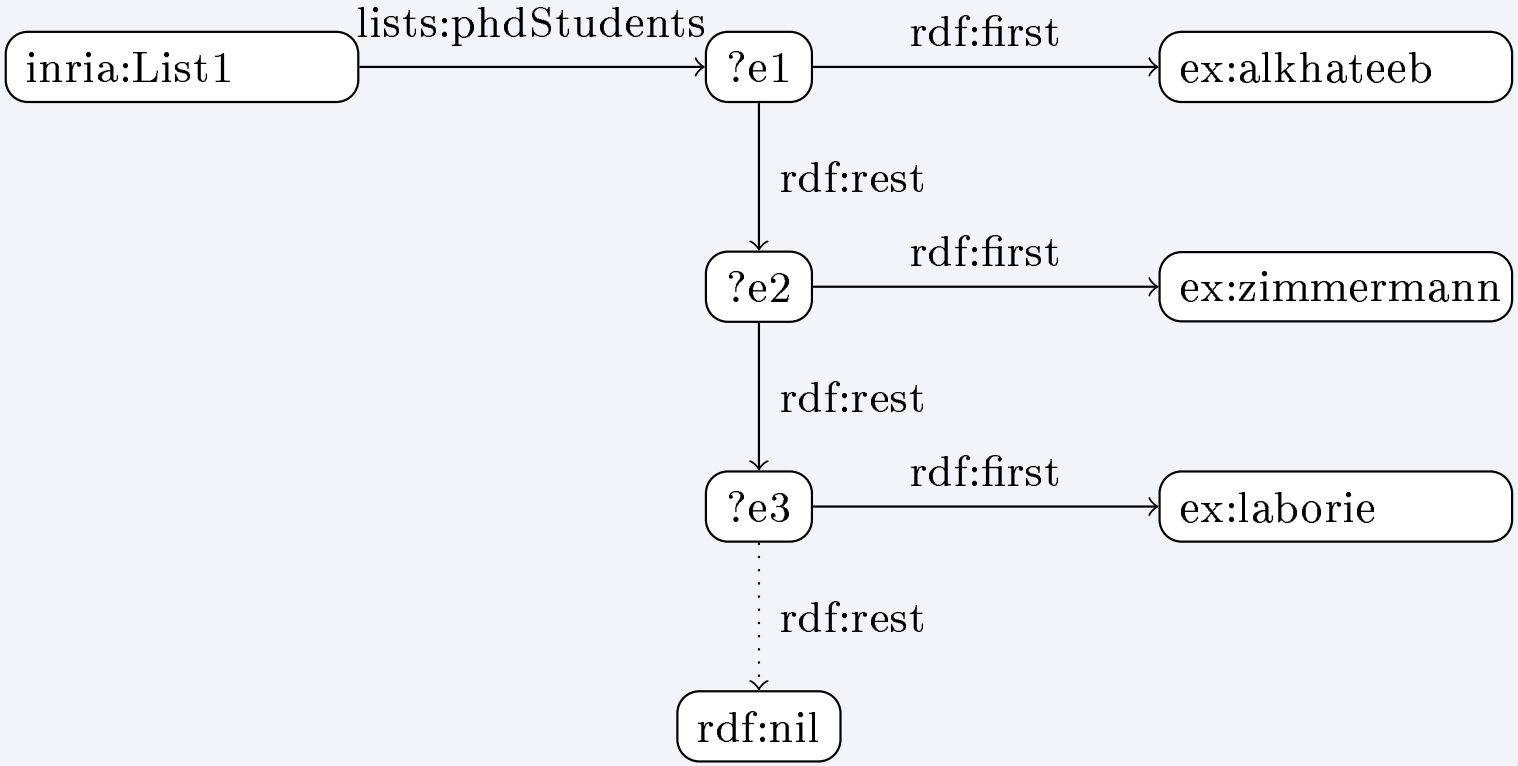

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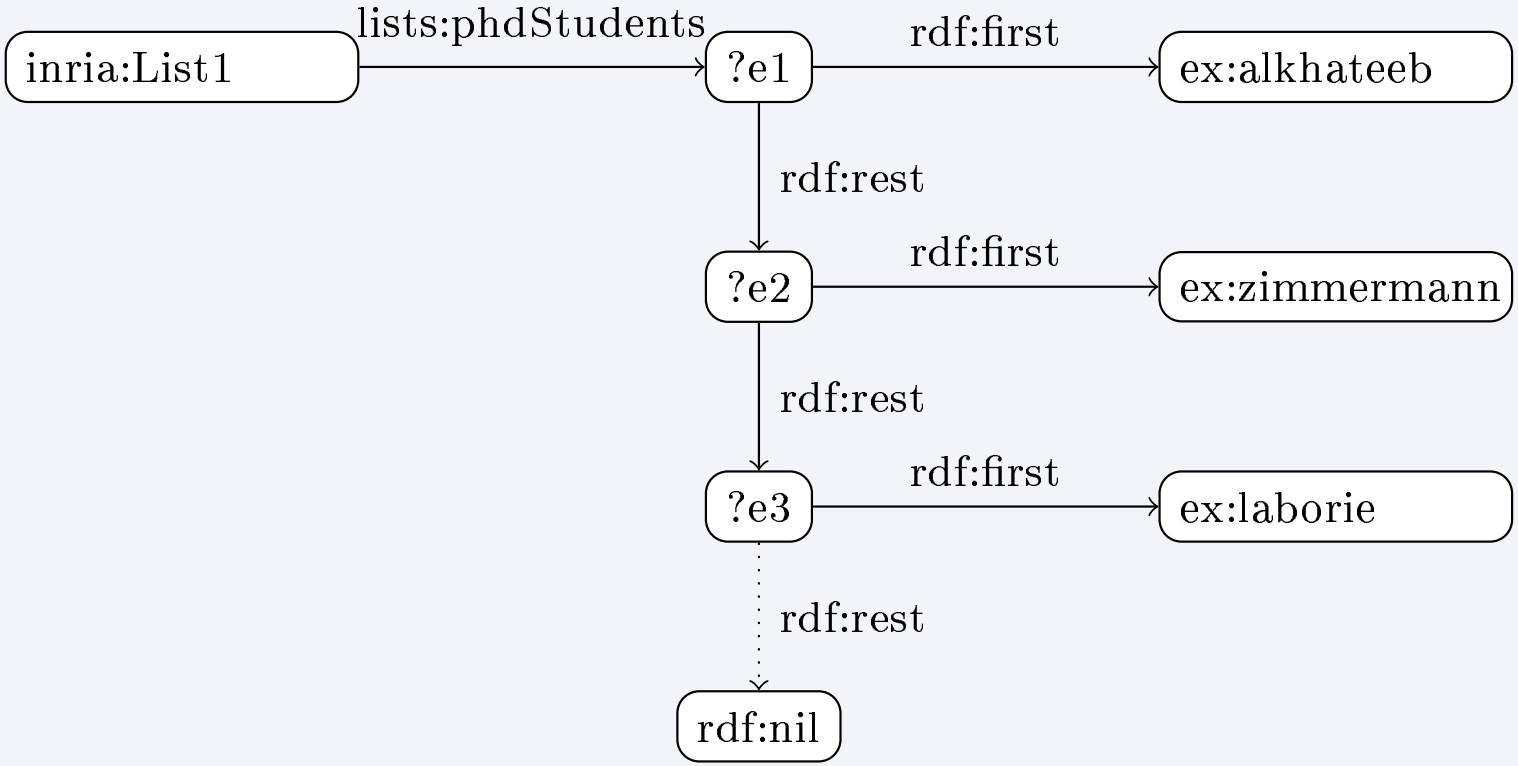


```
SELECT ?Element
WHERE { lists:phdStudents rdfs:range rdf:List .
        inria:List1 lists:phdStudents.rdf:rest*.rdf:first
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- We show that (C)PSPARQL extensions do not increase the overall complexity of SPARQL.
- We provide a rewriting method for evaluating SPARQL or (C)PSPARQL queries over RDF(S).

Outline

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PRDF syntax

- RDF syntax
- Regular expressions syntax
- Mixed 2 syntax

RDF syntax

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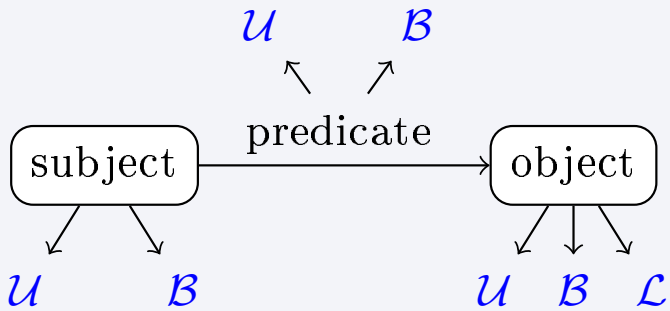

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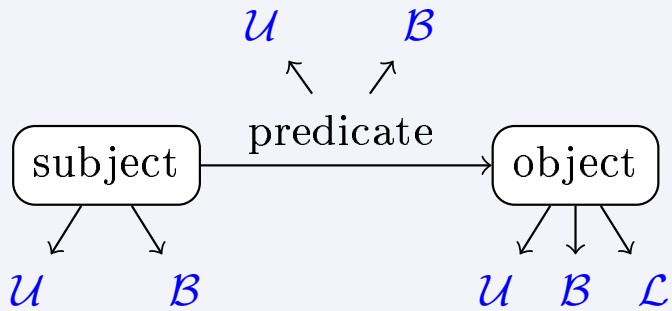

- (G)RDF graph: a set of (G)RDF triples

Regular Expressions

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Example (GRDF regular expressions)

$(\texttt{ex:plane} \mid \texttt{ex:train})^+ \cdot \texttt{?b5}$

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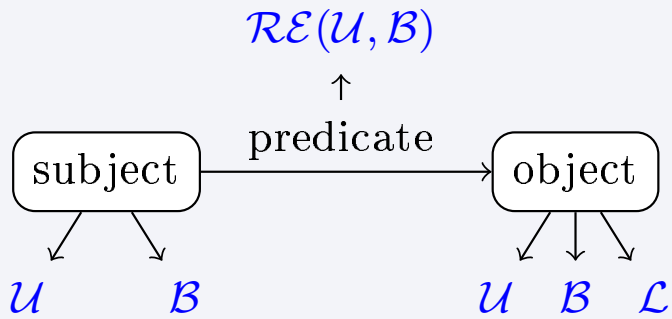

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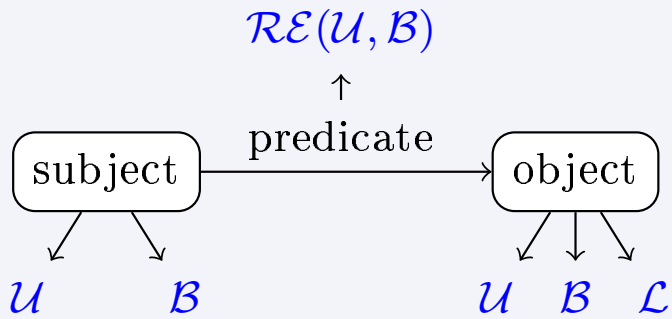

- PRDF graph: a set of PRDF triples

PRDF semantics

- RDF semantics
- Regular expressions semantics
- Mixed 2 semantics

GRDF Semantics

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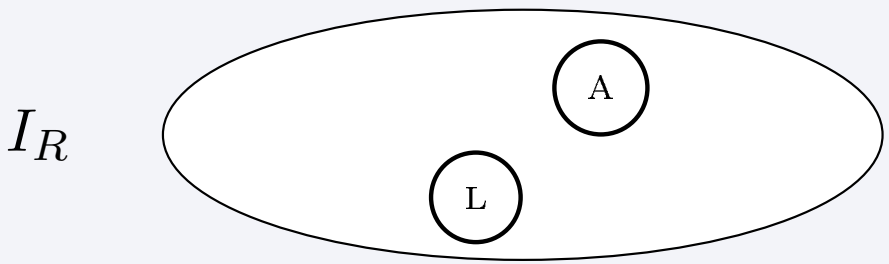
An interpretation of V is a 4-tuple $I = \langle I_R, I_P, \iota, I_{EXT} \rangle$, where:



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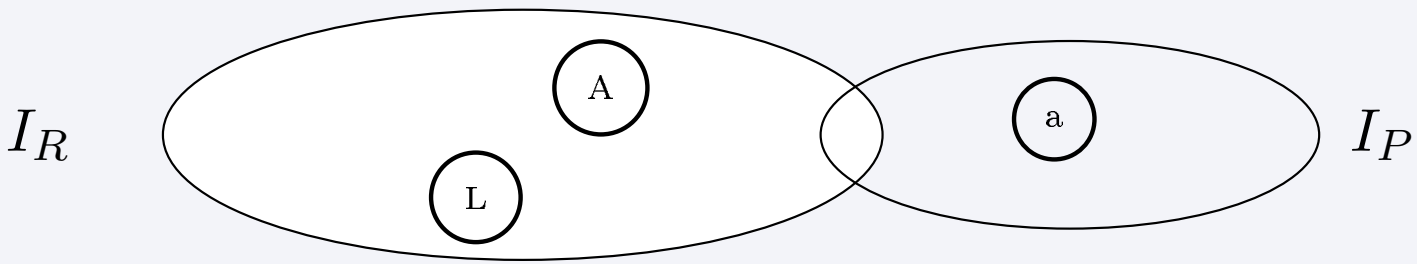

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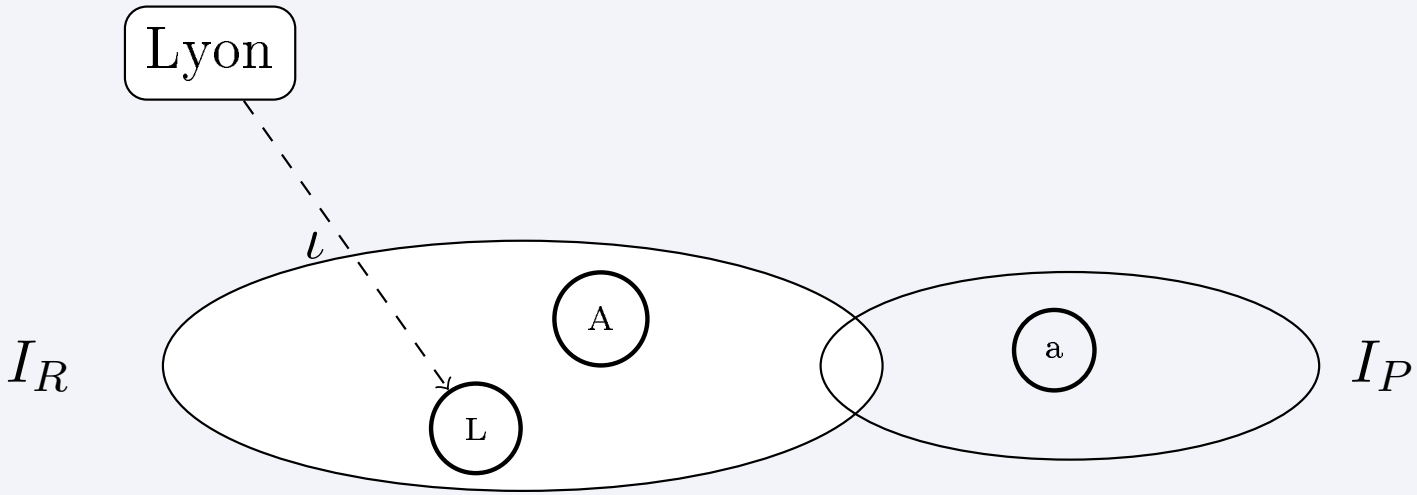

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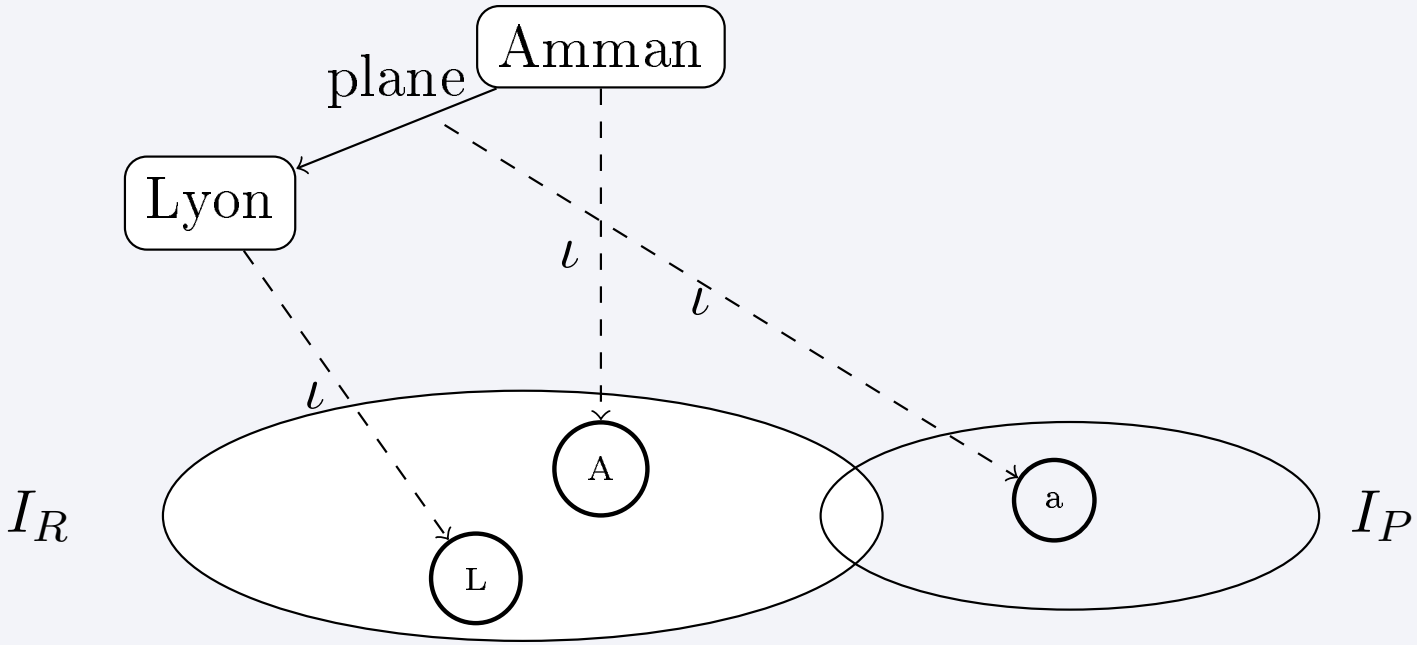

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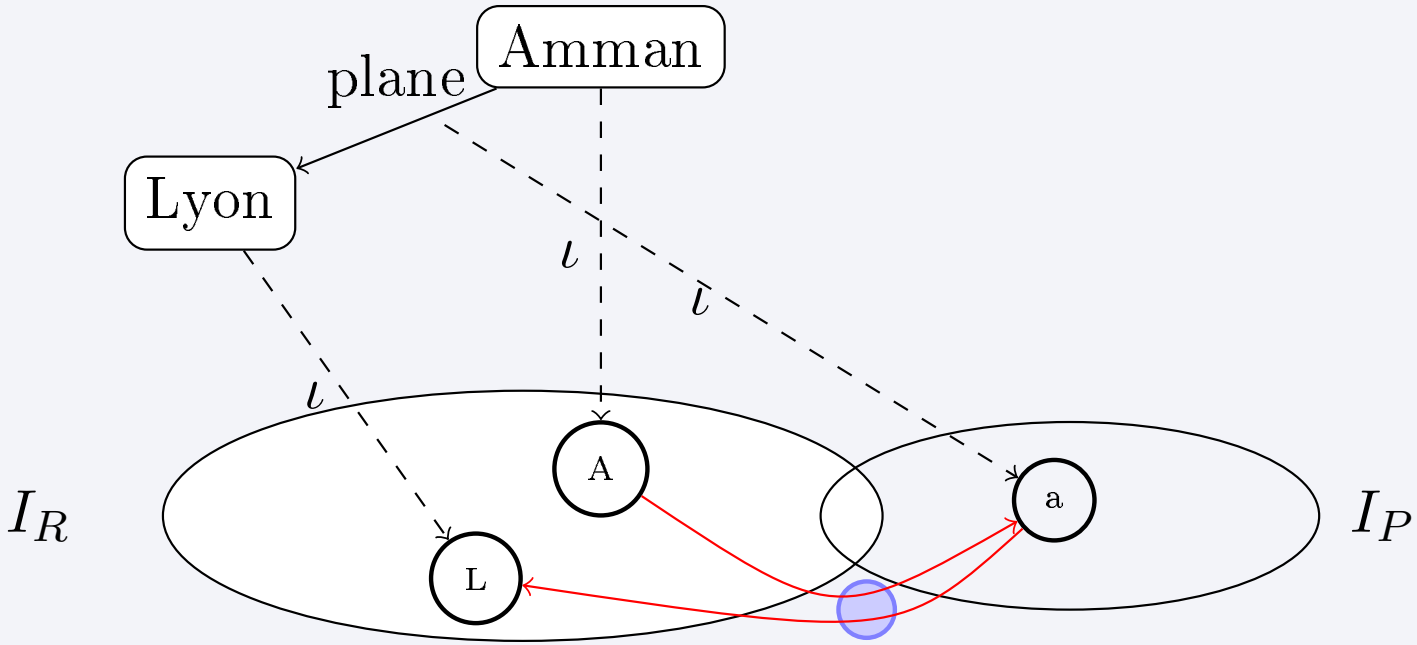

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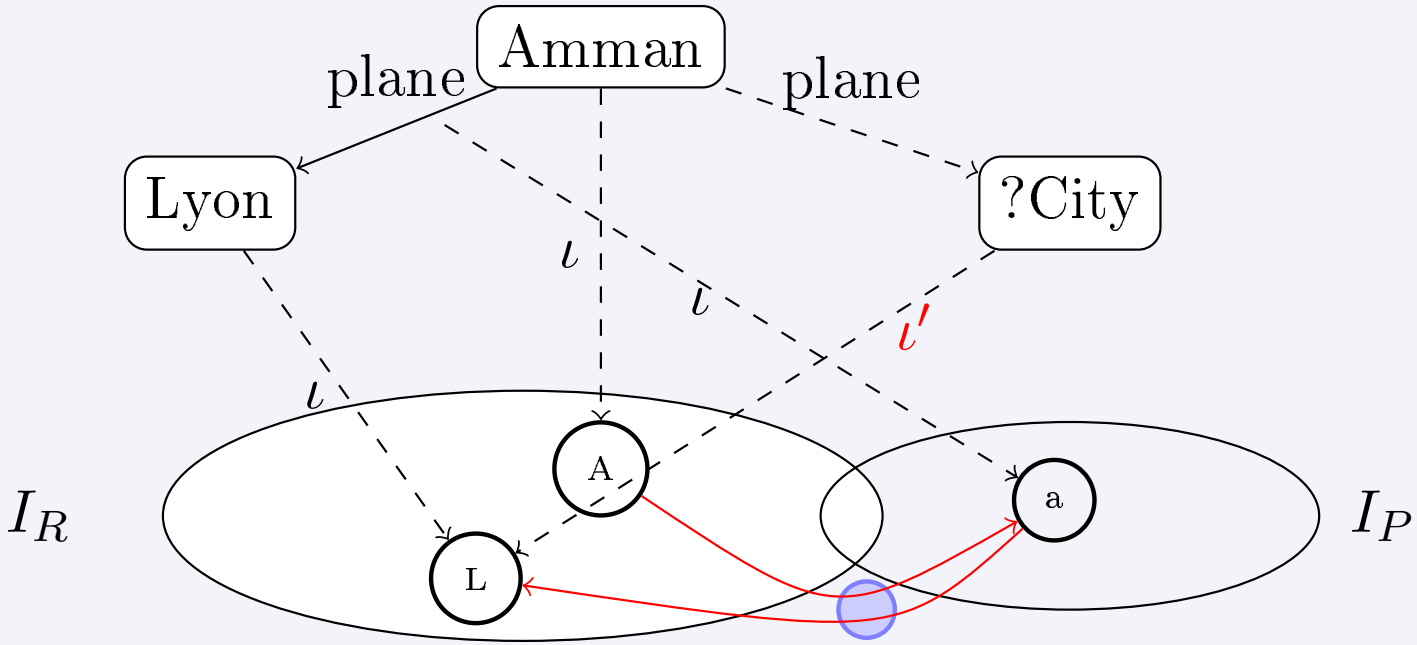

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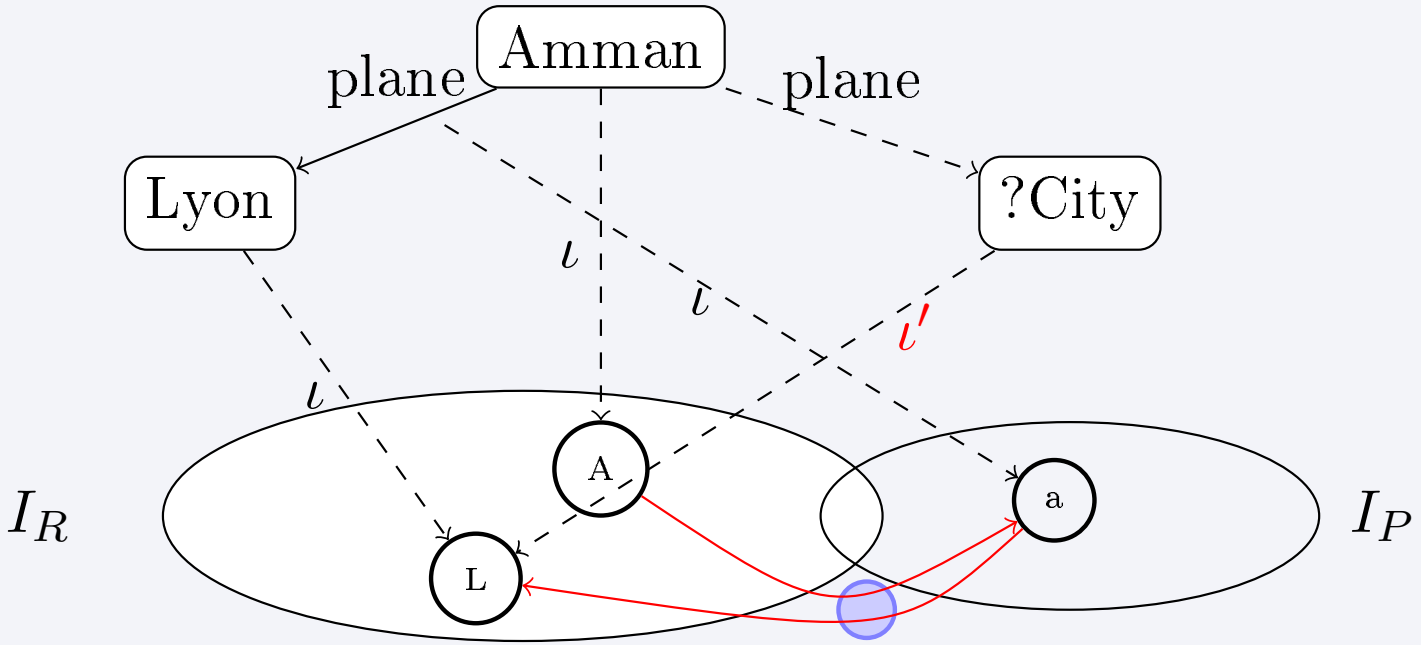

Definition (Models, consequence)

I is a model of a GRDF graph G iff $\exists$ an extension ι' of ι to $\mathcal{B}(G)$ such that $\forall \langle s, p, o \rangle \in G$, $\langle \iota'(s), \iota'(o) \rangle \in I_{EXT}(\iota'(p))$.

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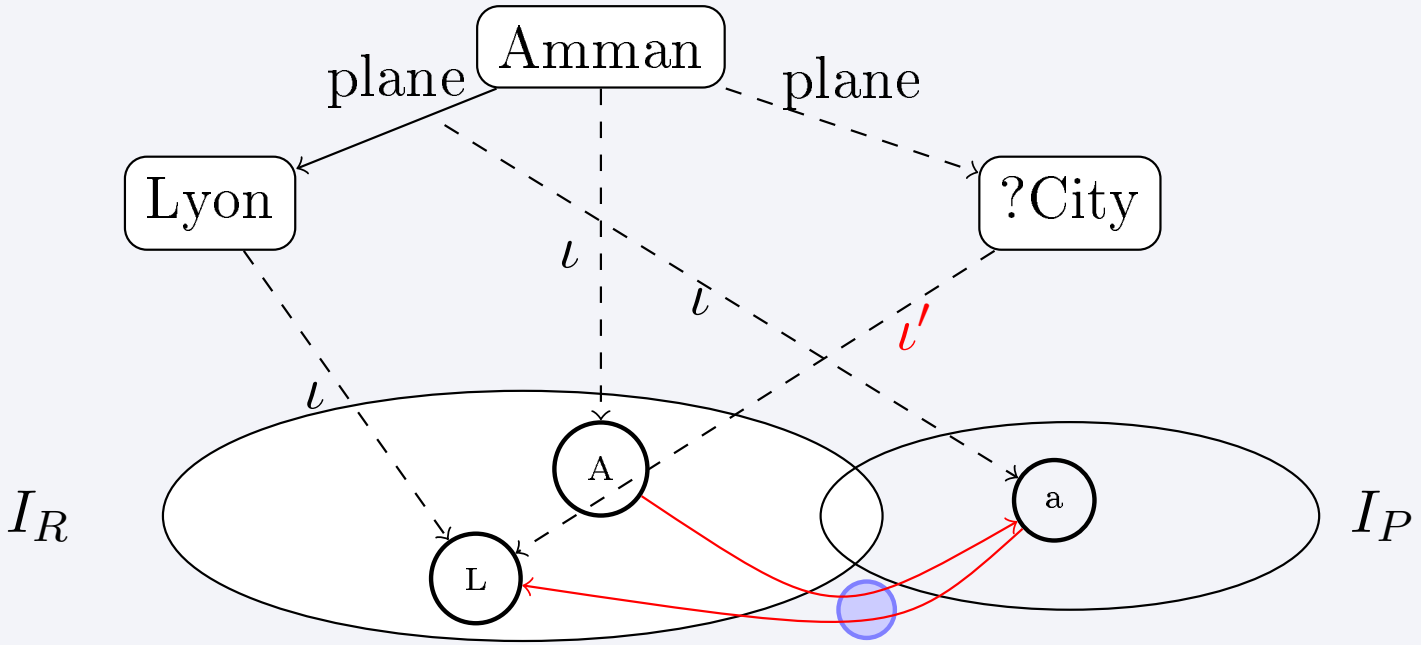
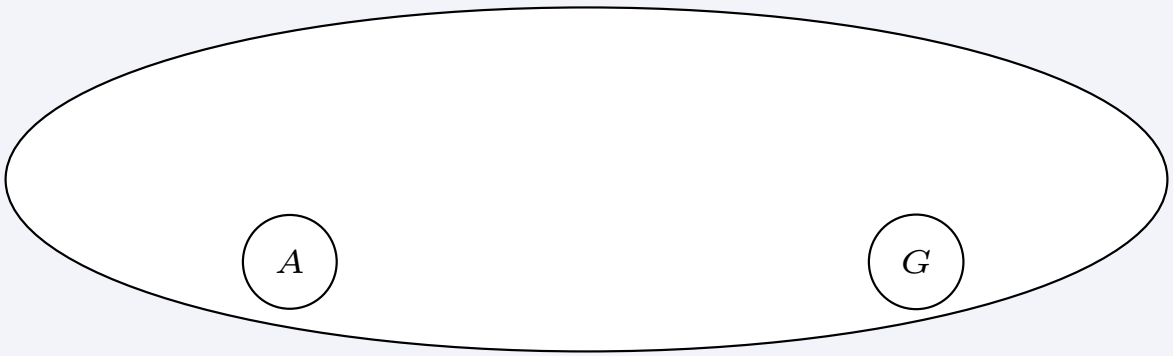


Definition (Models, consequence)

A graph H is a semantic consequence of a graph G, denoted $G \models H$, iff every model of G is a model of H.

RDF-like semantics for regular expressions

- Does $\langle A, G \rangle$ supports $R = ((\texttt{train} \mid \texttt{plane})^+ \cdot \texttt{bus})$ in ι'?



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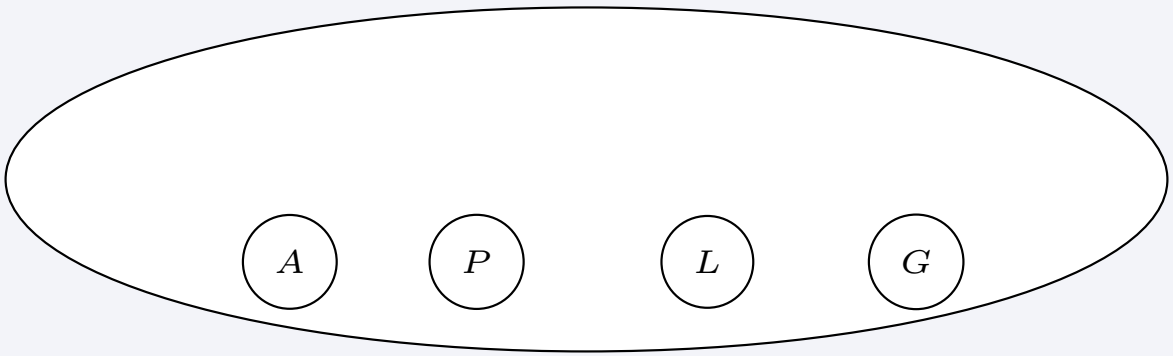

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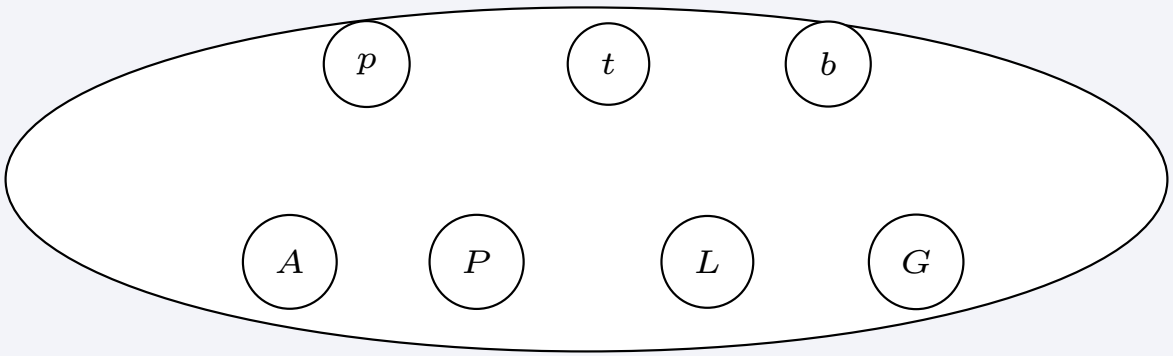

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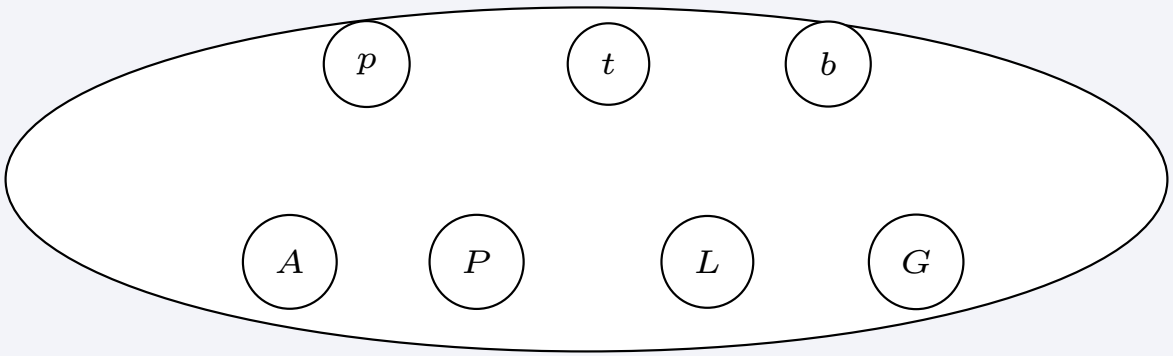
$$\texttt{plane} \cdot \texttt{train} \cdot \texttt{bus} \in L^*(R)$$



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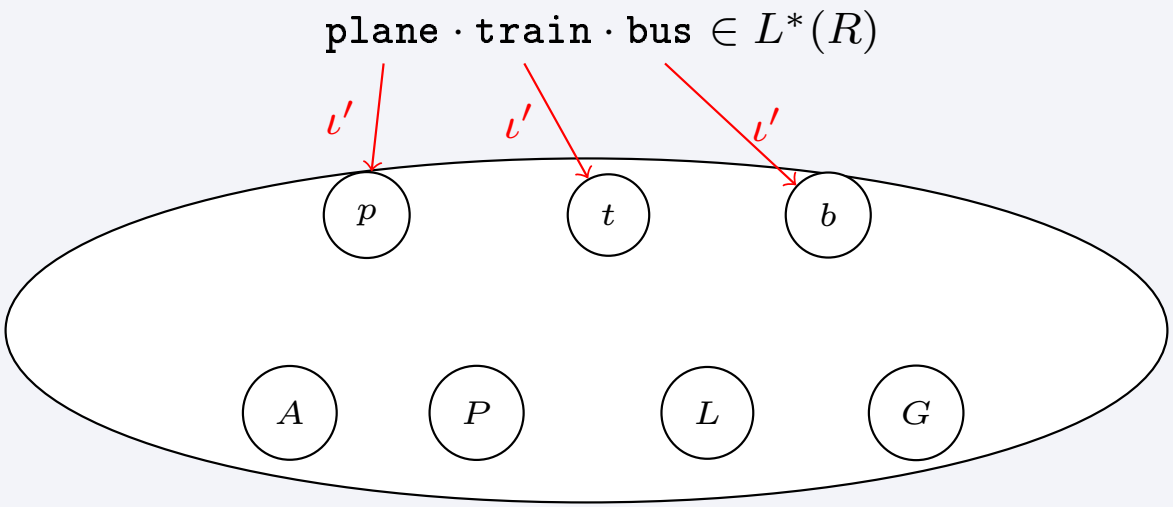

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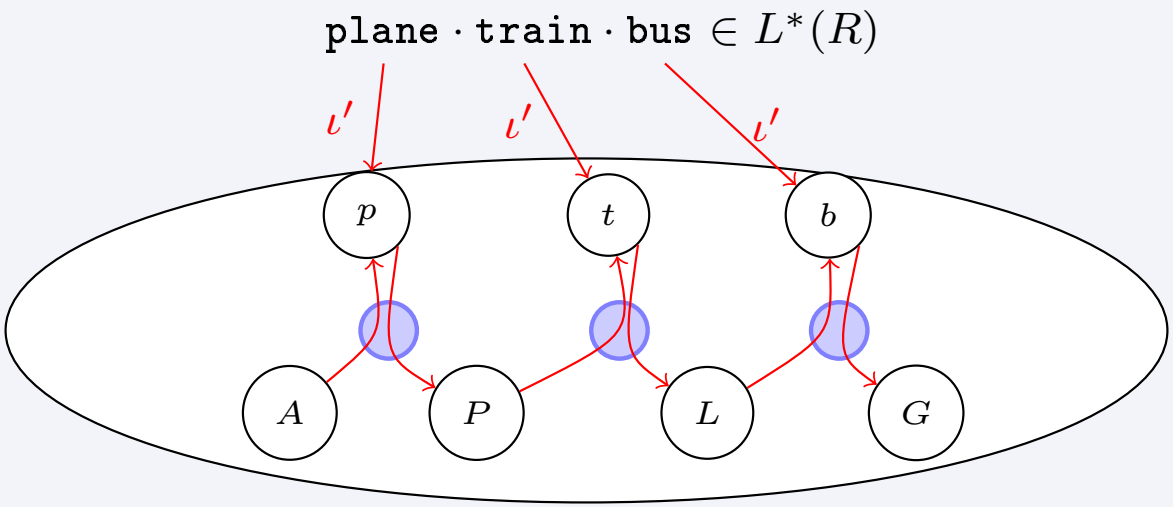

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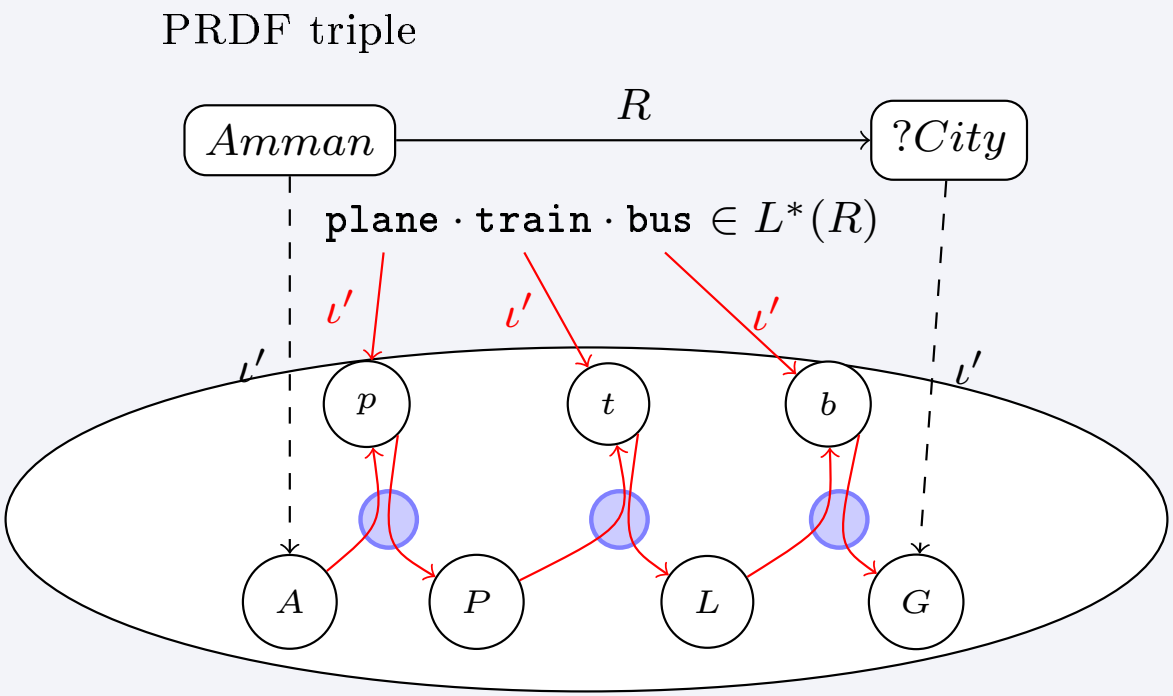

Definition

I is a model of a PRDF G iff $\exists$ an extension ι' of ι to $\mathcal{B}(G)$ such that $\forall\langle s, R, o\rangle \in G$, $\langle \iota'(s), \iota'(o)\rangle$ supports R in ι'.

Inference Mechanism: PRDF Homomorphism

- A PRDF graph H, and a GRDF graph G. Does $G \models_{PRDF} H$?

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  - RDF homomorphism
  - Path satisfiability
  - Mixed 2 mechanisms

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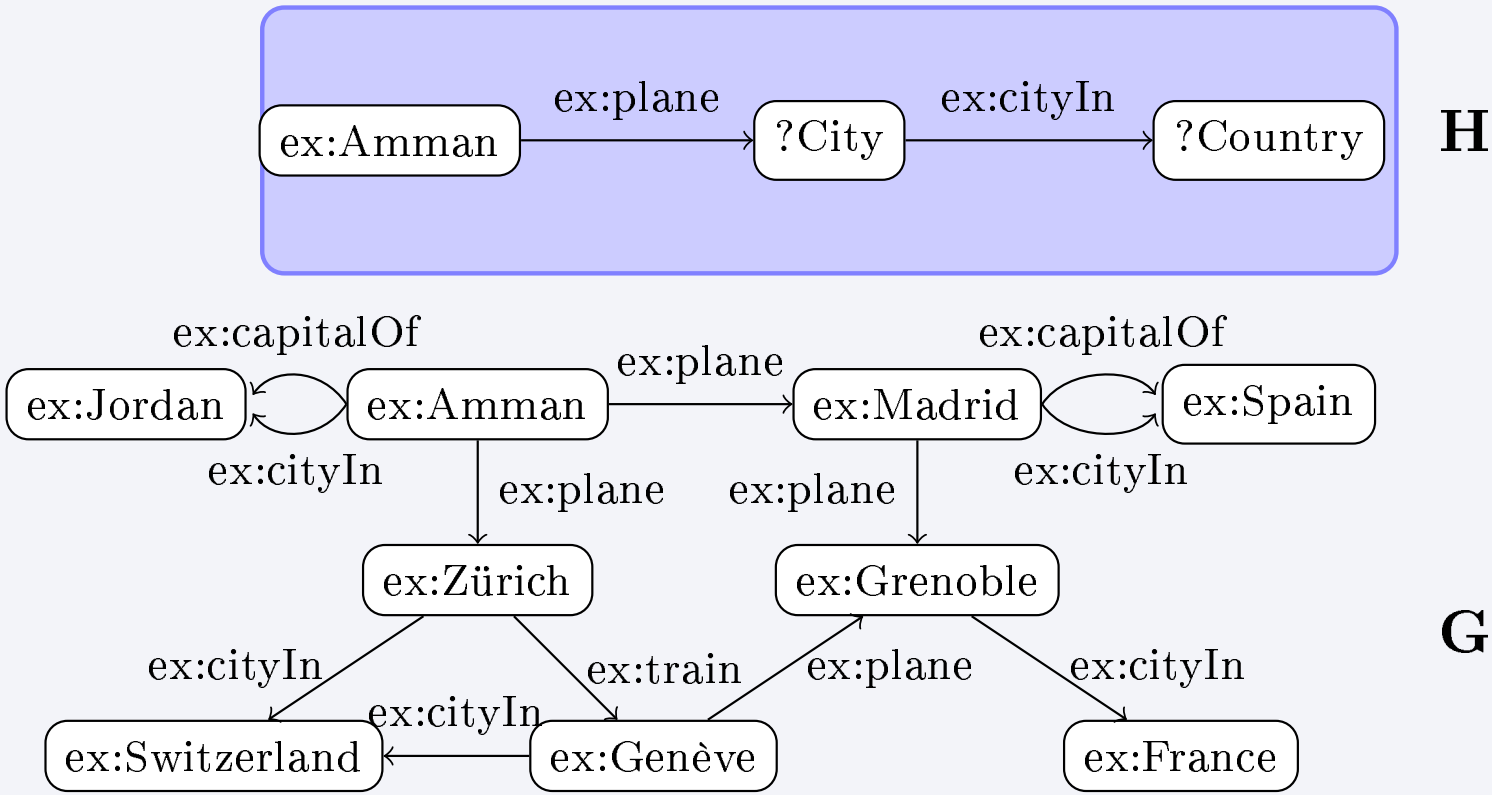
Theorem

Let G and H be two GRDF graphs. Then $G \models_{GRDF} H$ iff there exists a GRDF homomorphism from H into G.

GRDF Homomorphism: example



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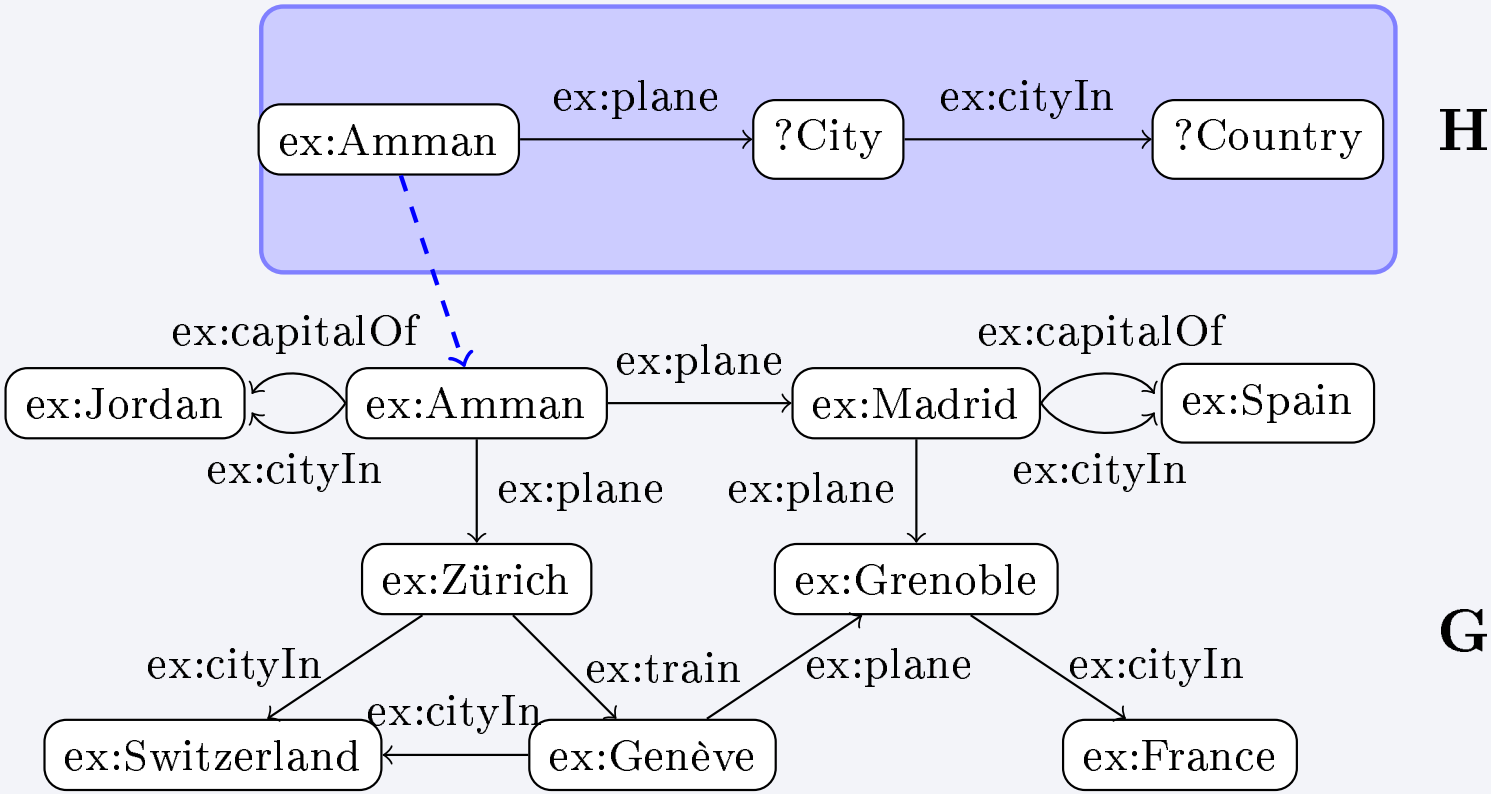

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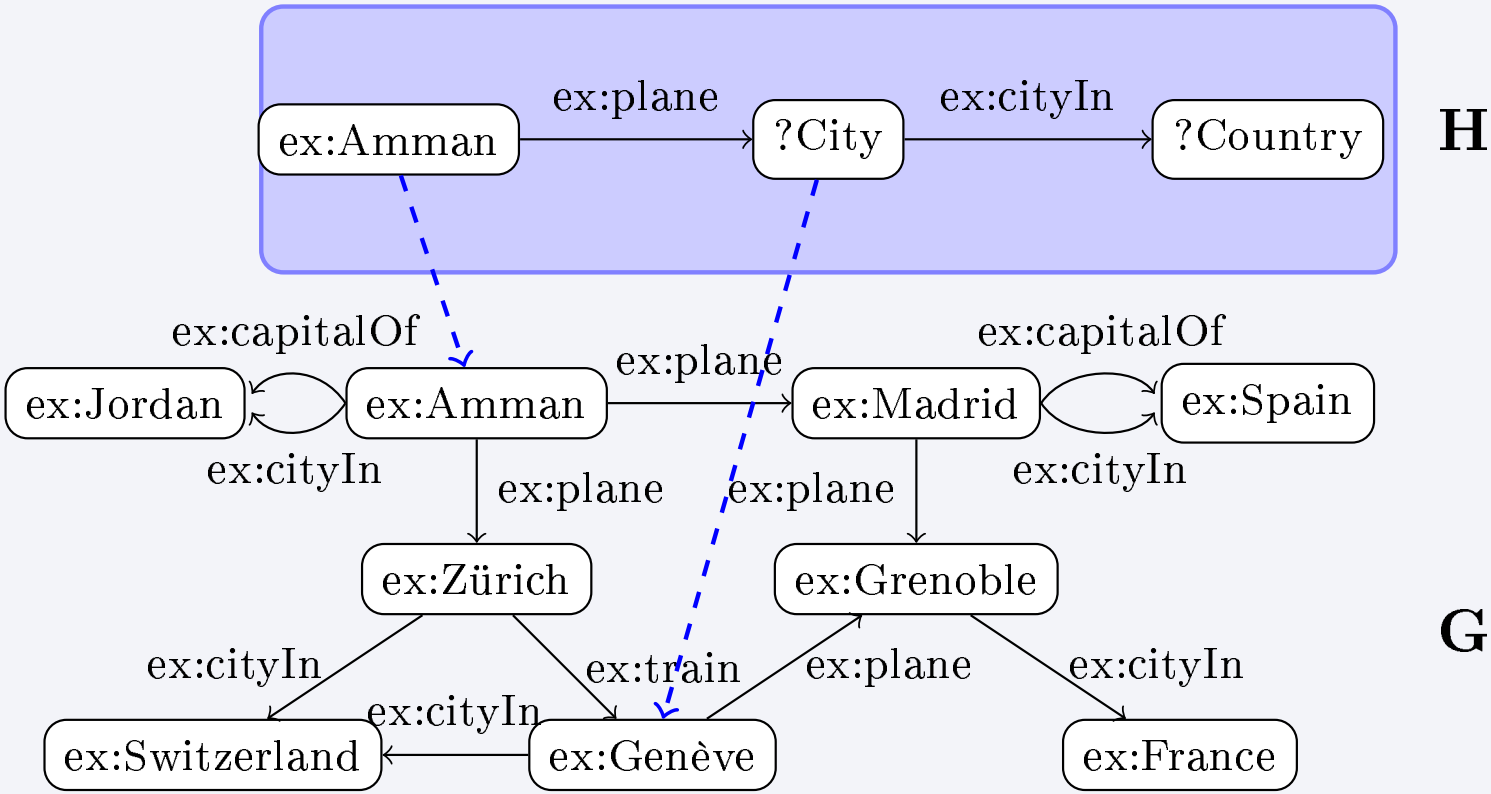

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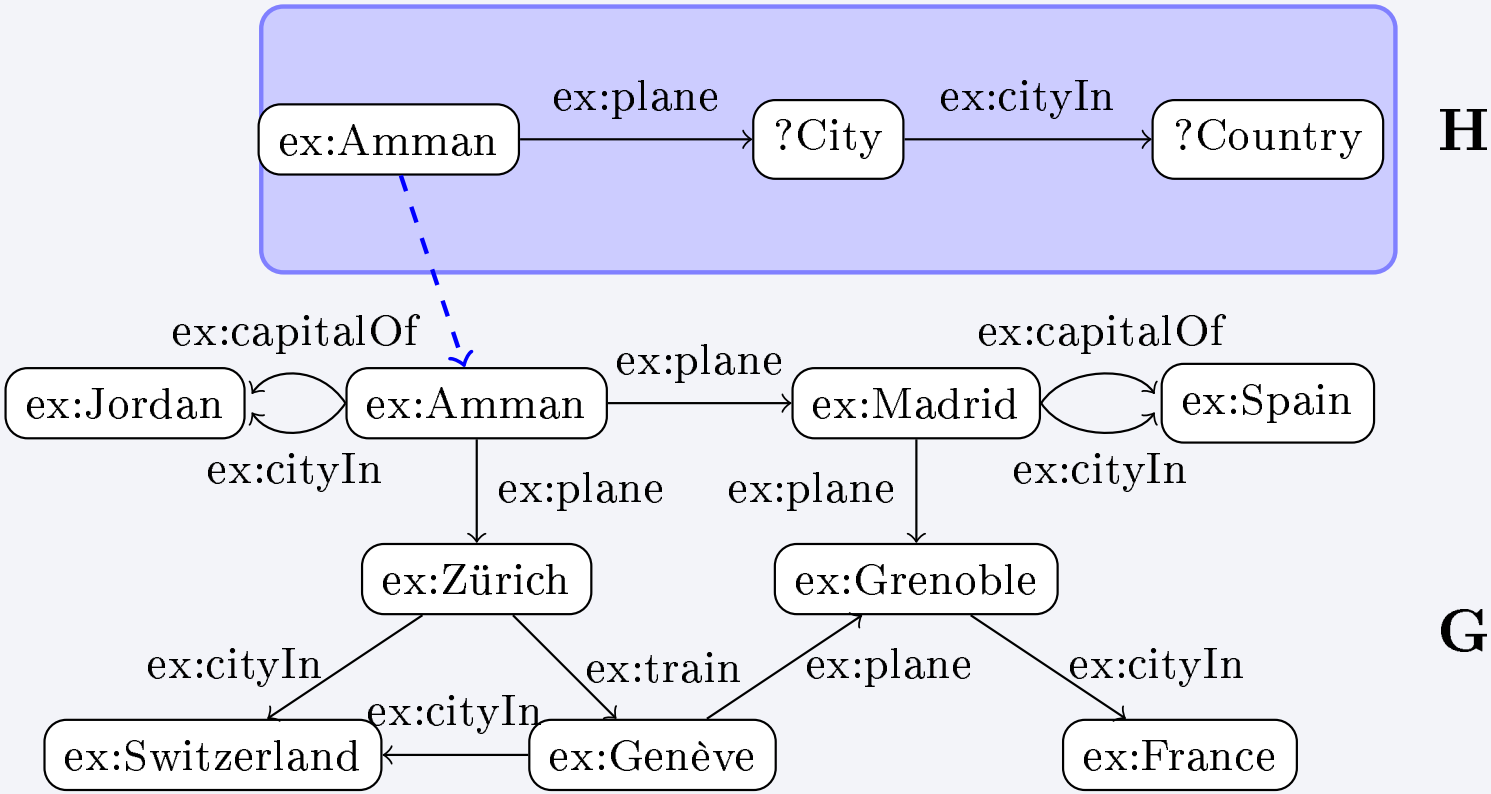

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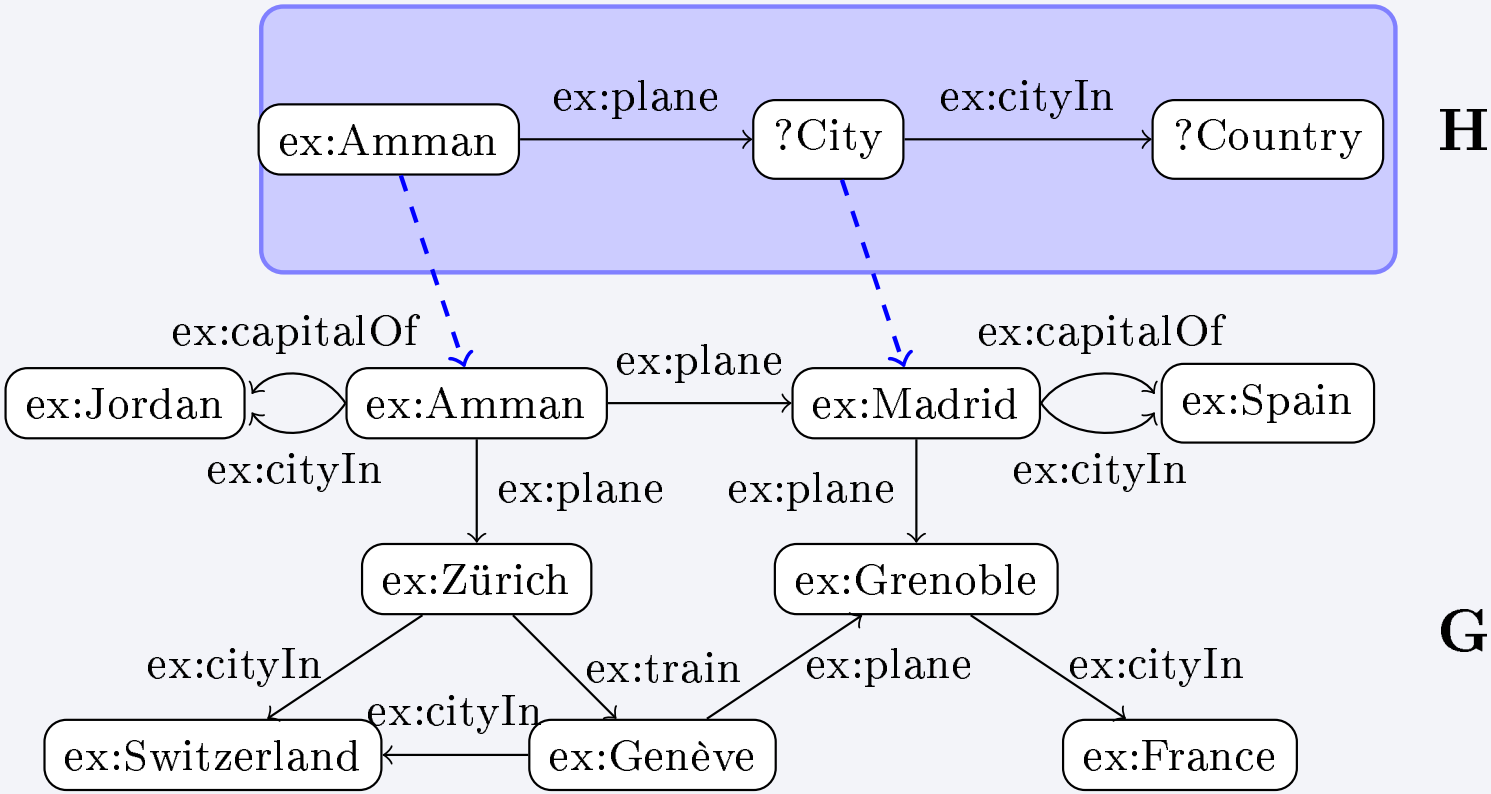

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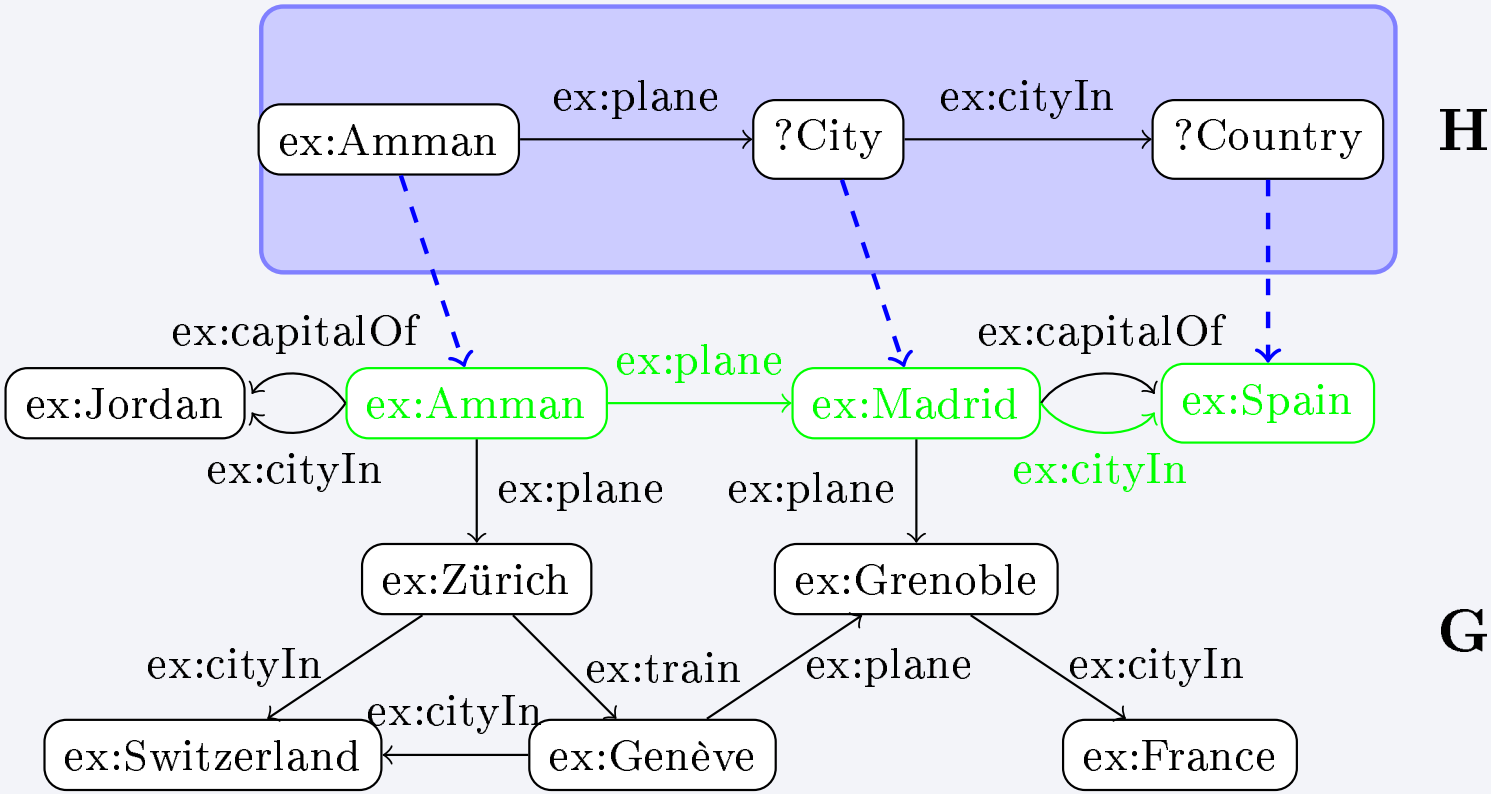
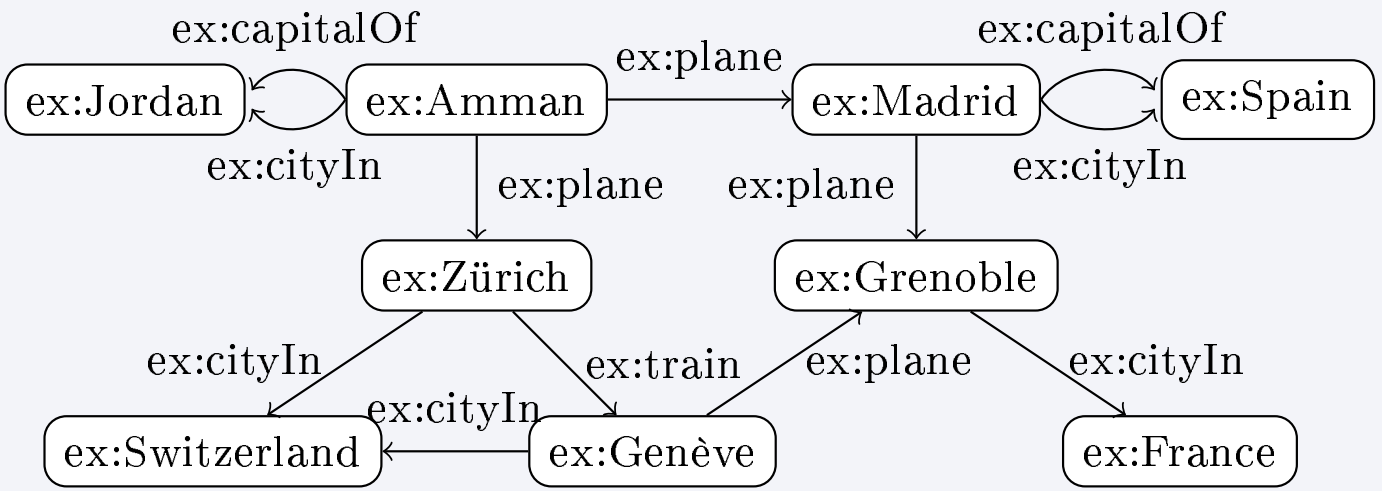


Path-satisfiability

PATH-SATISFIABILITY

- $R = (\text{ex:plane} \mid \text{ex:train})^+$



G

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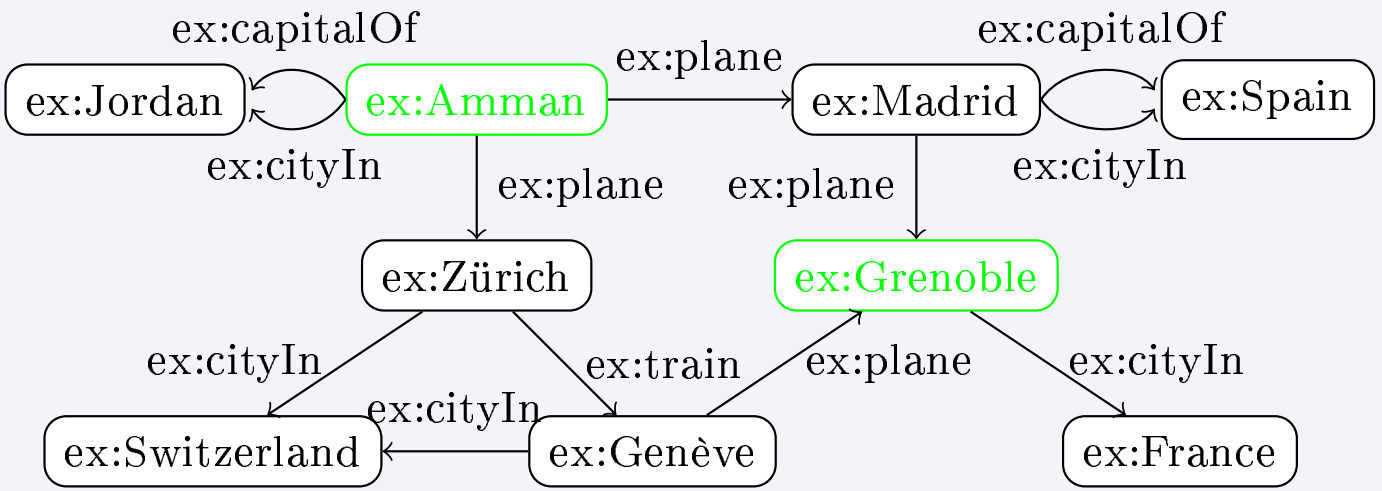

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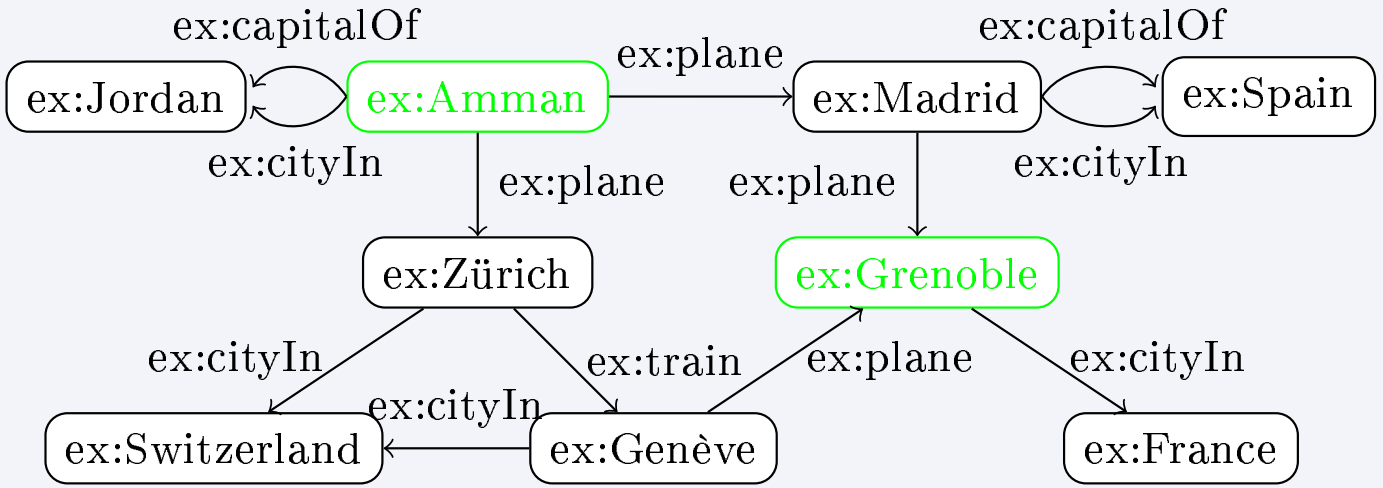

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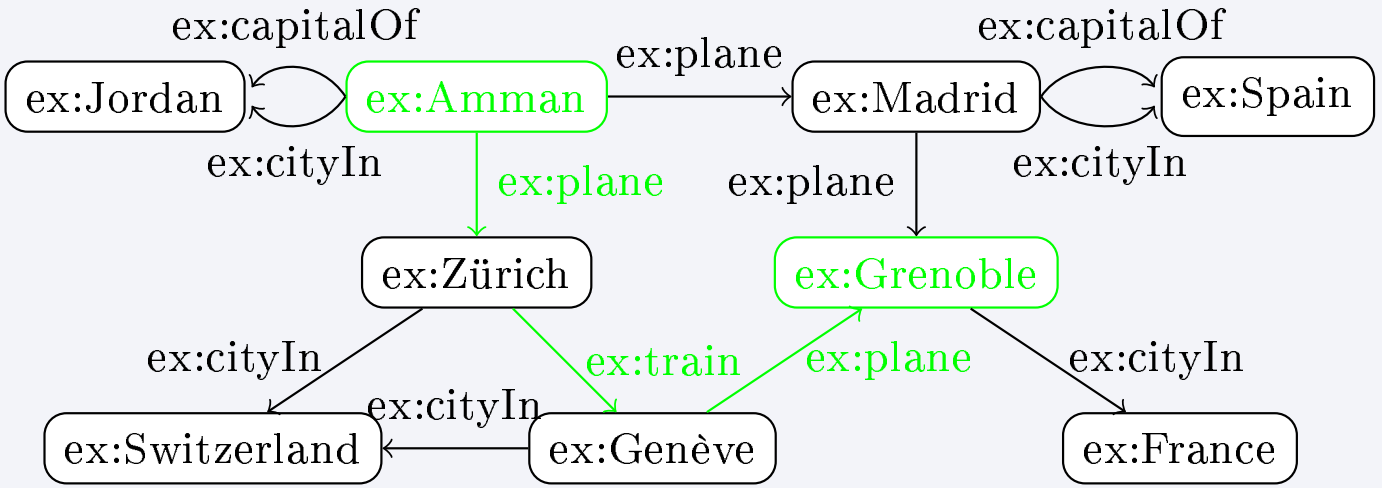

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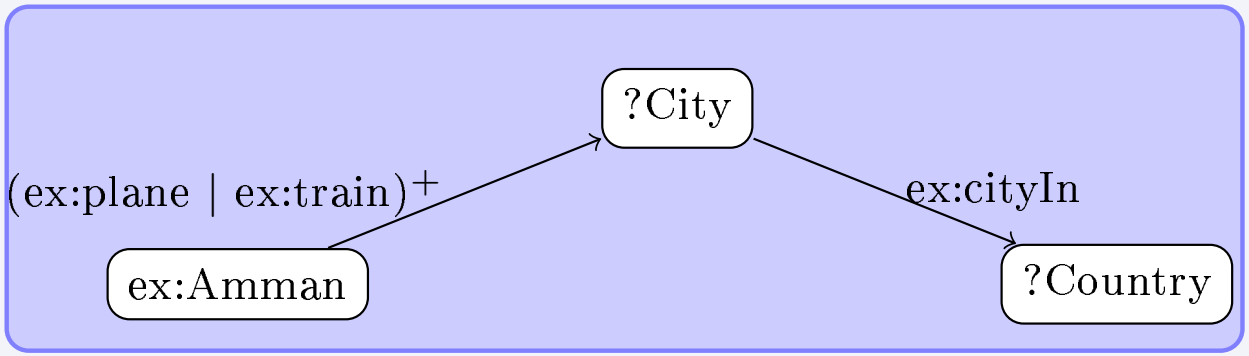
Theorem (Soundness and Completeness)

Let G be a GRDF graph, and H be a PRDF graph. Then there is a PRDF homomorphism from H into G iff $G \models_{PRDF} H$.

PRDF Homomorphism: example



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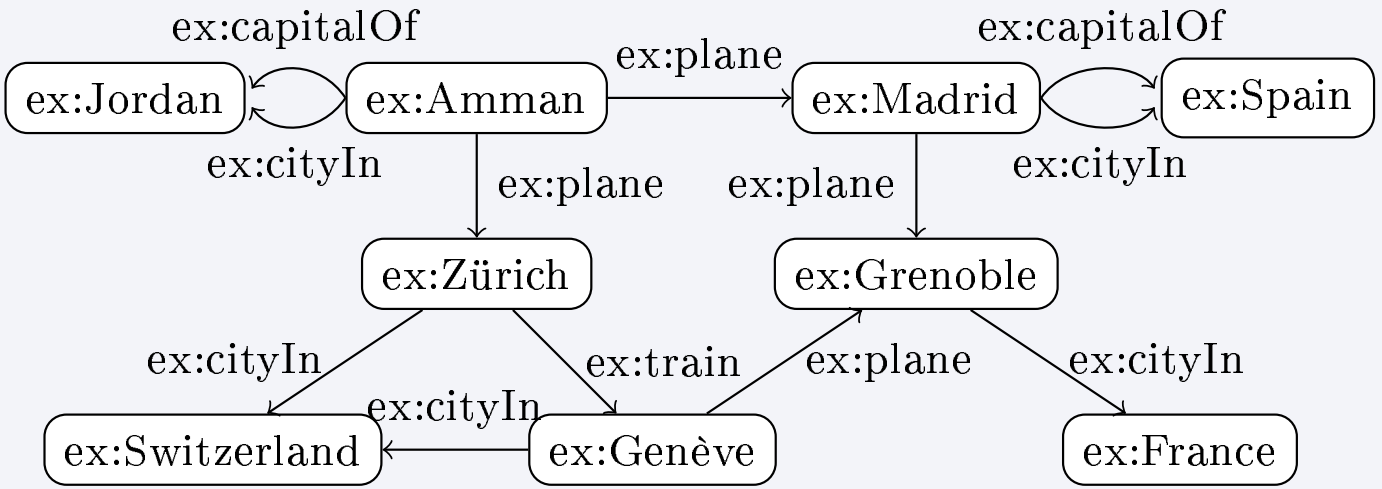

G

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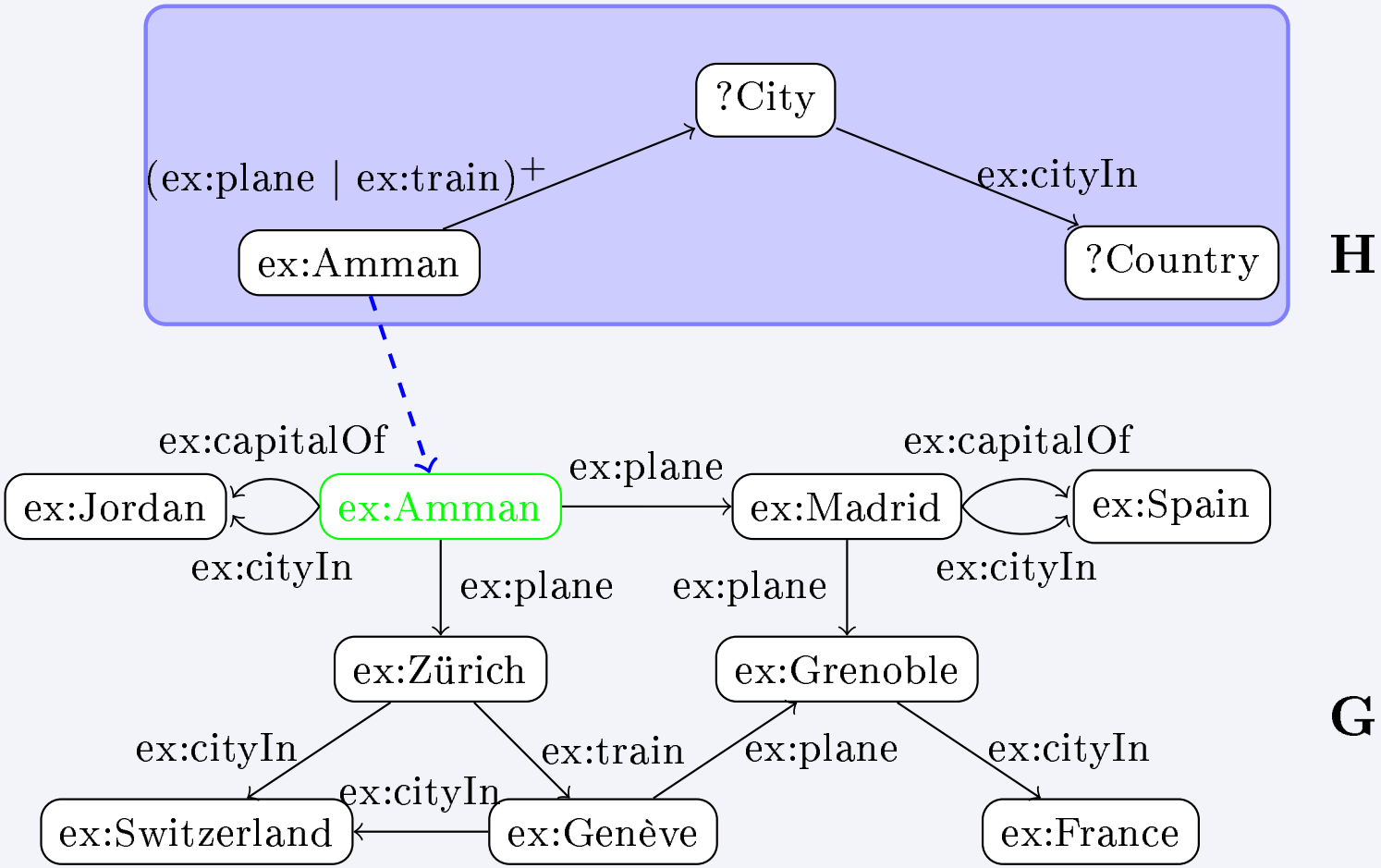

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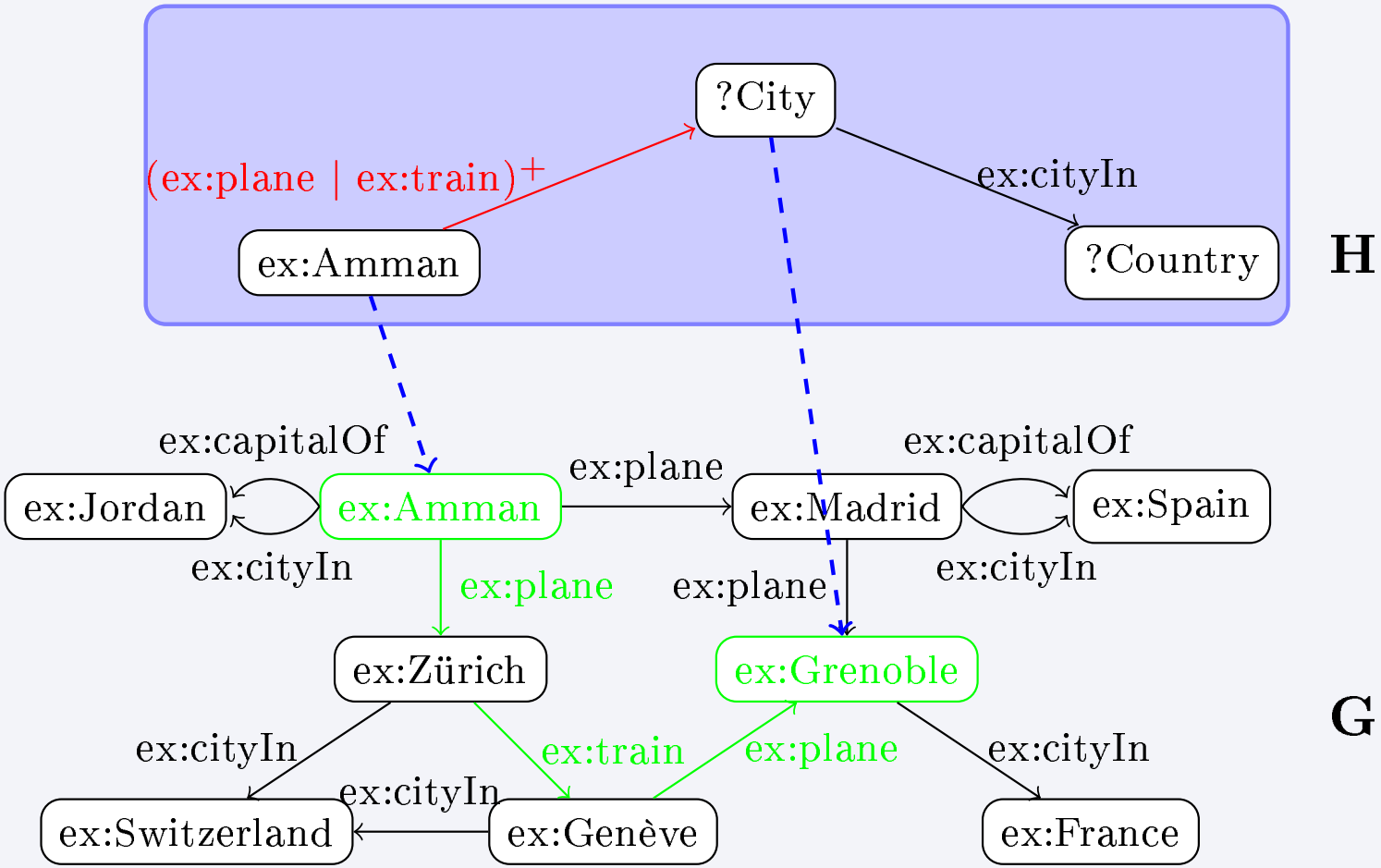

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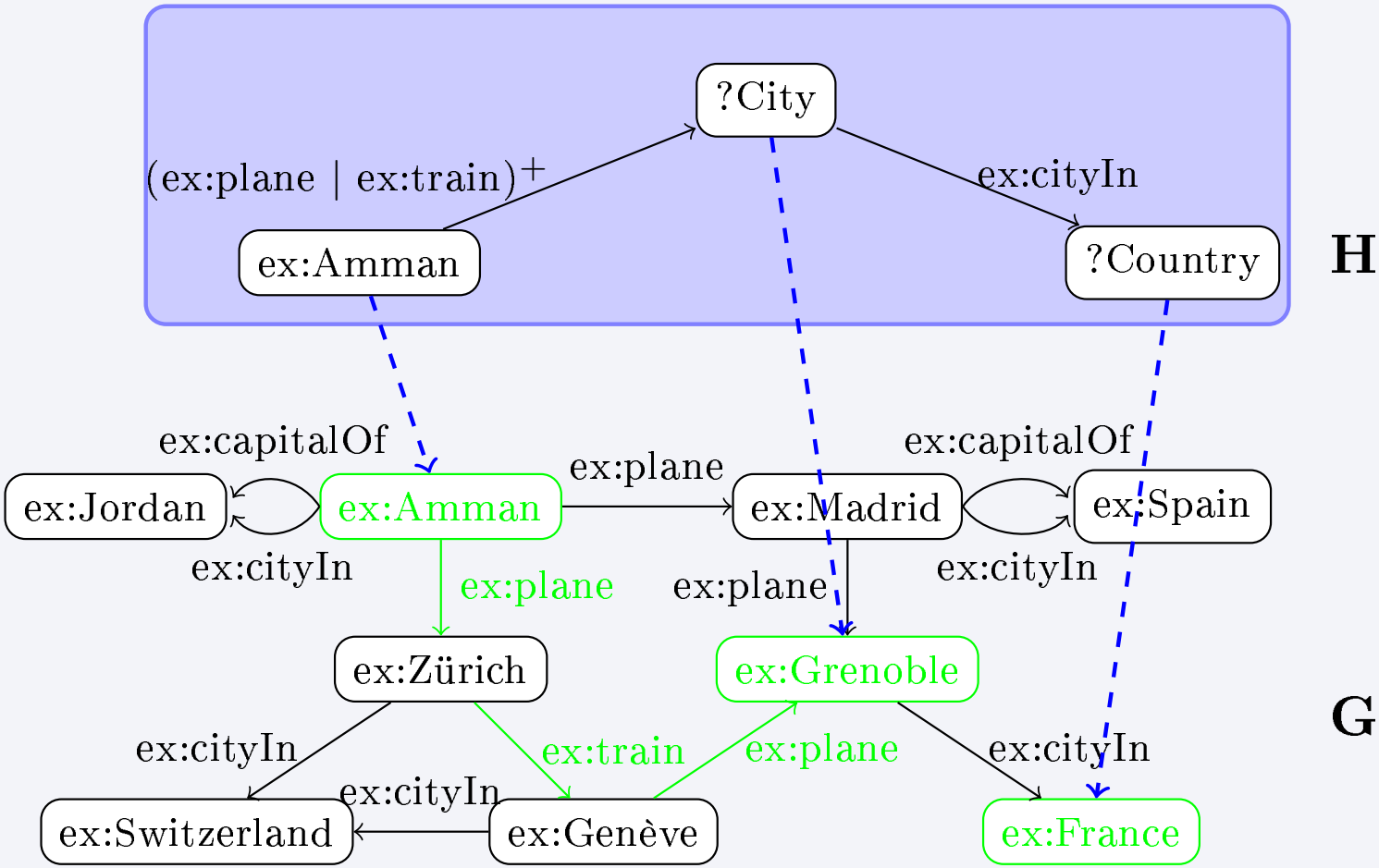

Outline

CPRDF syntax

$$\text{CPRDF} = \text{RDF} + \text{constrained regular expressions}$$

GRDF constraint

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- $\Phi = \Phi^E \cup \Phi^N$

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Constrained Regular Expressions

Definition (Constrained regular expression)

The set of constrained regular expressions $\mathcal{RE}(\mathcal{U}, \mathcal{B}, \Phi)$ is defined inductively by:

- if $u \in \mathcal{U}$ and $\psi \in \Phi^E$, then u, $!u$, $u\%\psi\%$, $!u\%\psi\%$, u^- and $u^-\%\psi\% \in \mathcal{RE}(\mathcal{U}, \mathcal{B}, \Phi)$;

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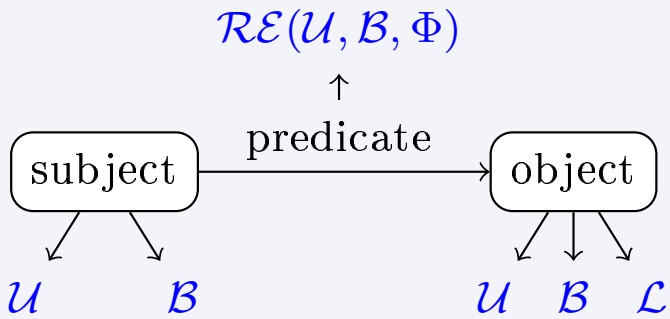
- if $R \in \mathcal{RE}(\mathcal{U}, \mathcal{B}, \Phi)$, $\psi \in \Phi^N$ is a constraint, then $R\%\psi\% \in \mathcal{RE}(\mathcal{U}, \mathcal{B}, \Phi)$.

CPRDF Syntax

- CPRDF Triple: $\langle subject, predicate, object \rangle \in (\mathcal{U} \cup \mathcal{B}) \times \mathcal{RE}(\mathcal{U}, \mathcal{B}, \Phi) \times \mathcal{T}$



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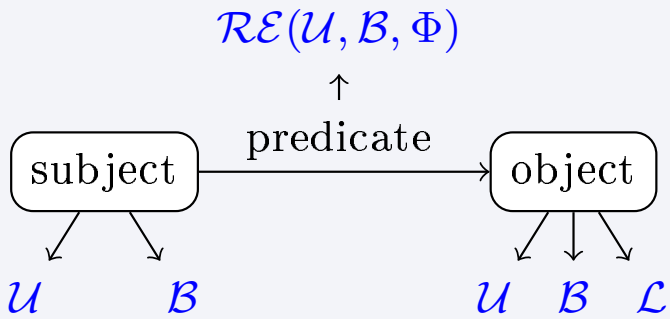

- CPRDF graph: a set of CPRDF triples

Satisfied constraint in an interpretation

Example

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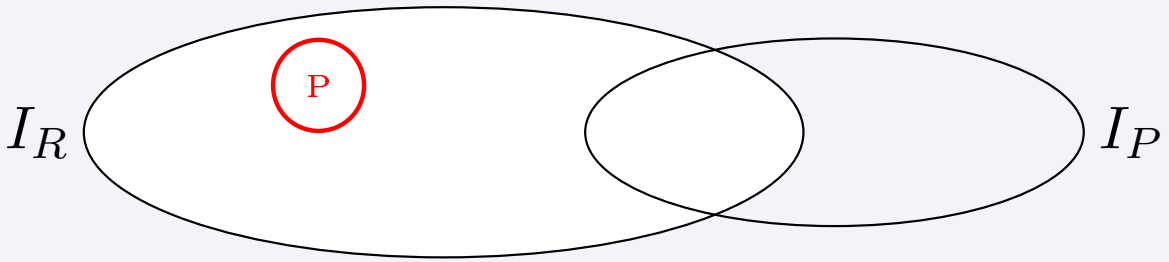

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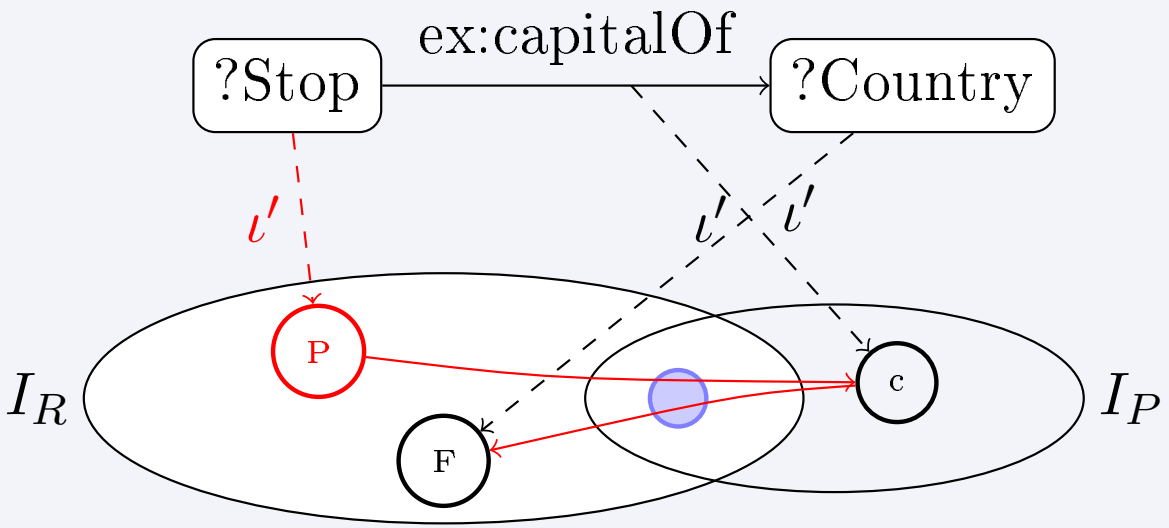

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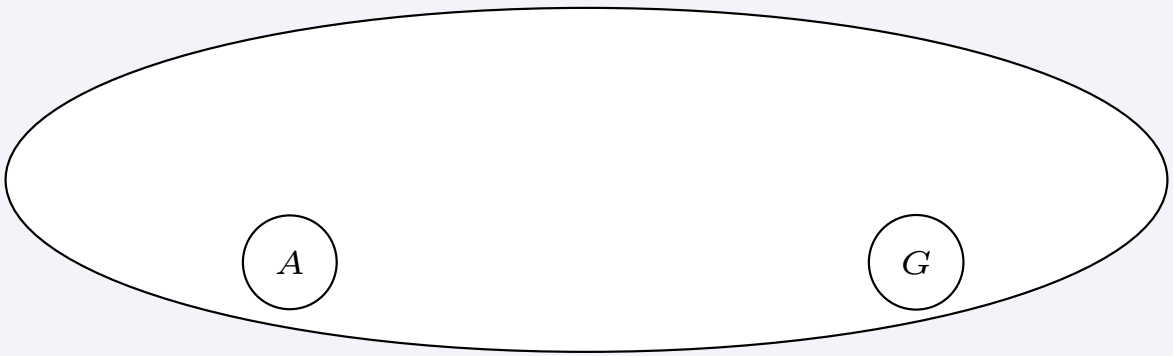

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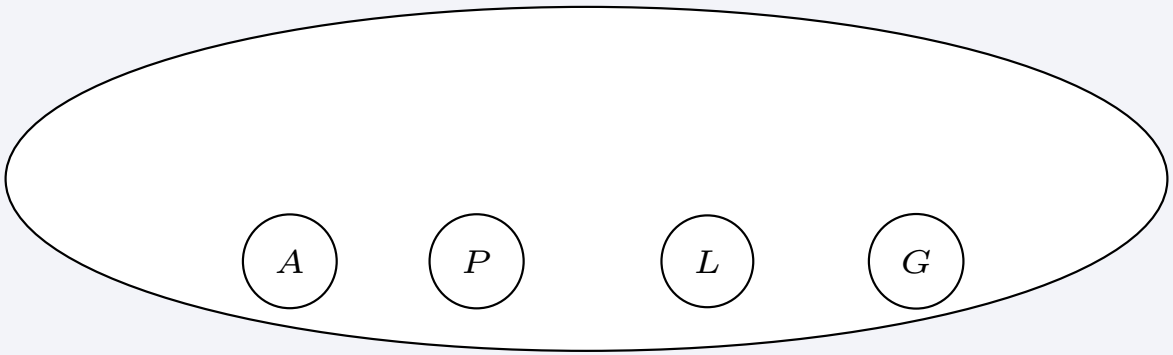

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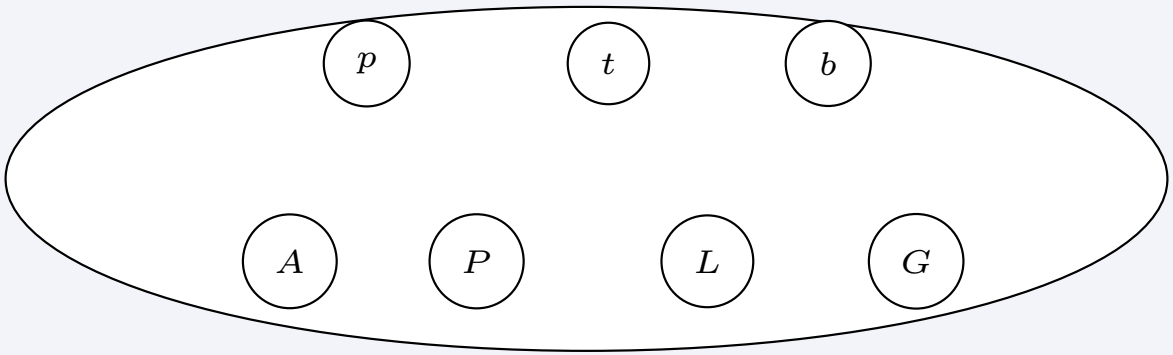

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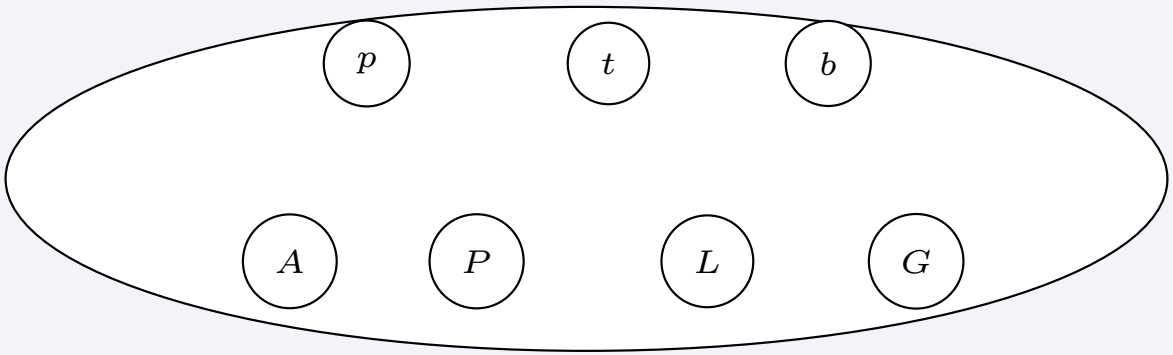
$$\texttt{plane} \cdot \texttt{train} \cdot \texttt{bus} \in L^{*}(R)$$



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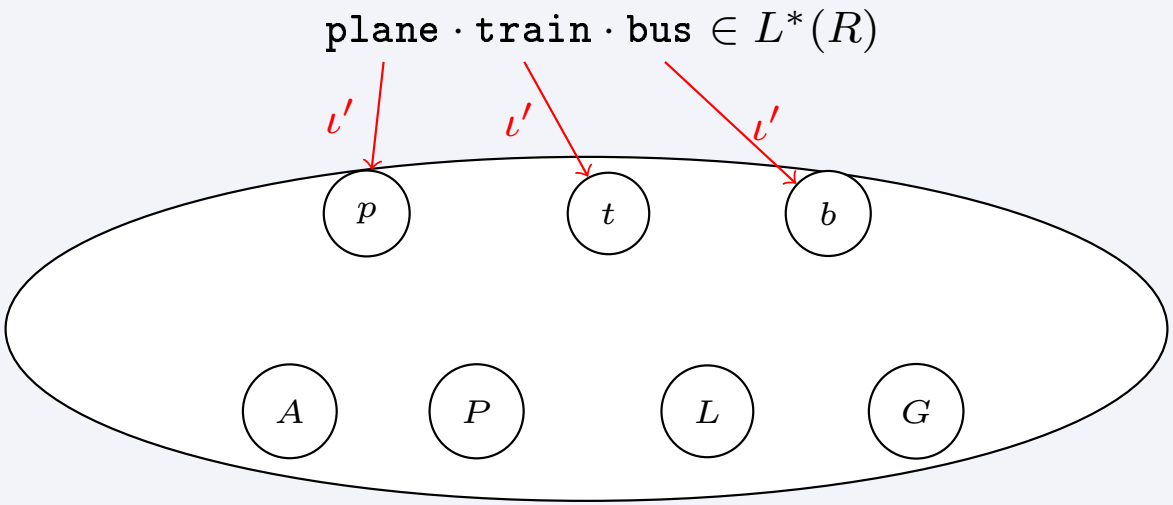

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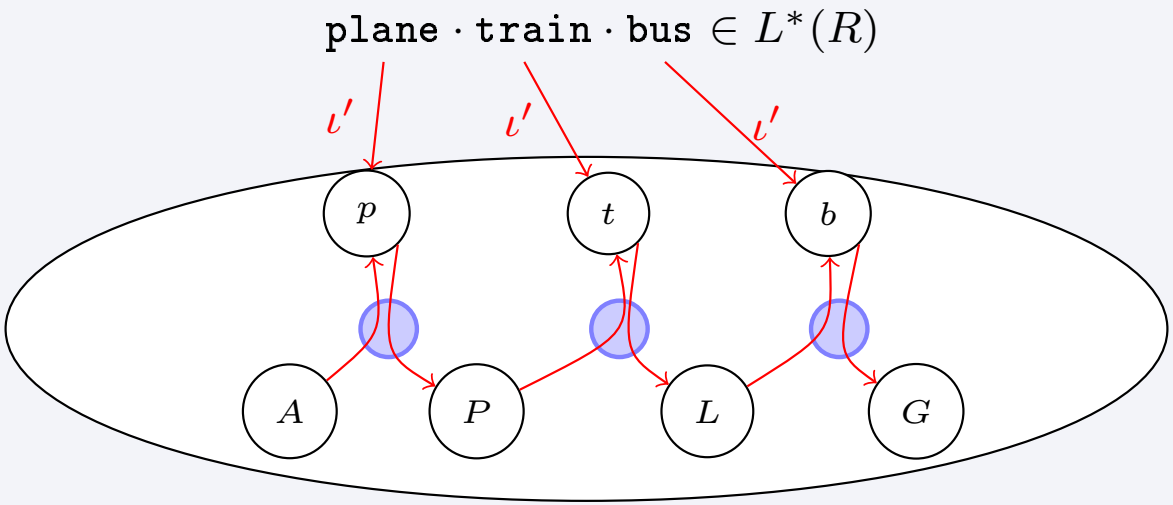

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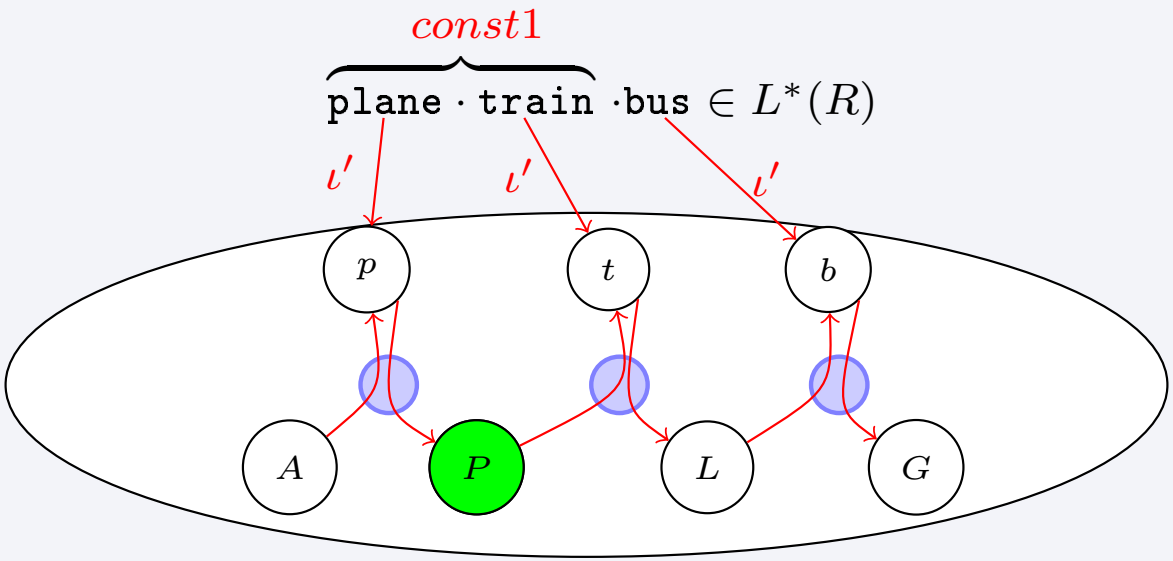

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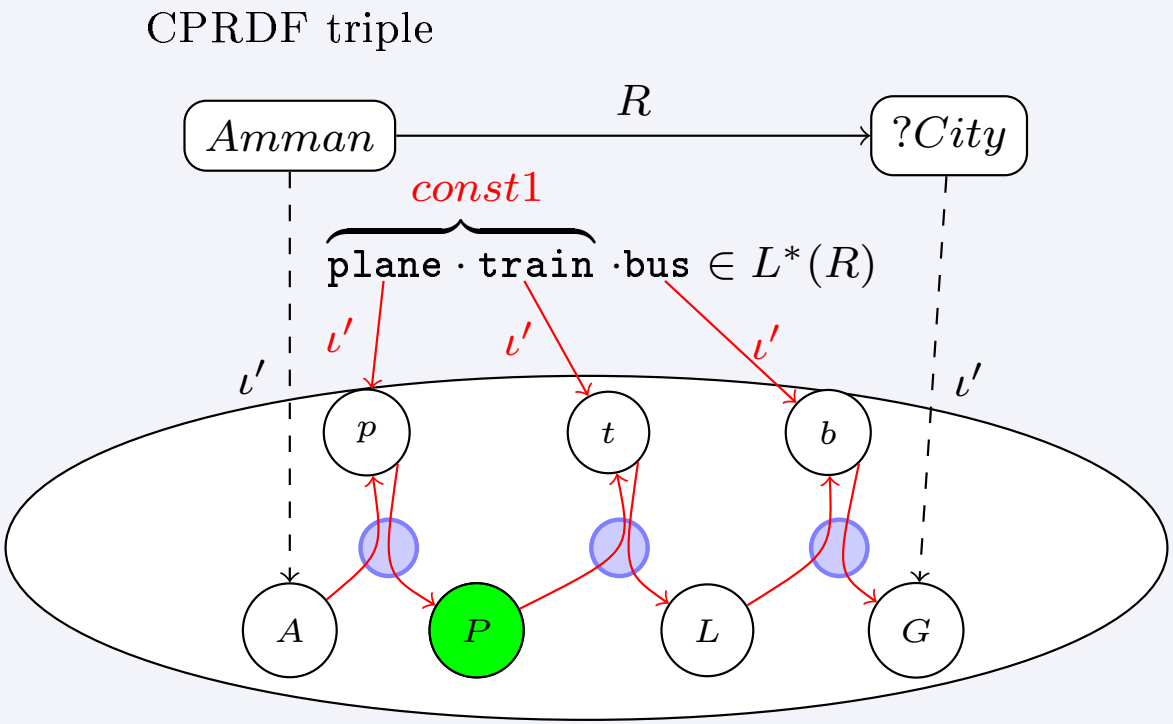

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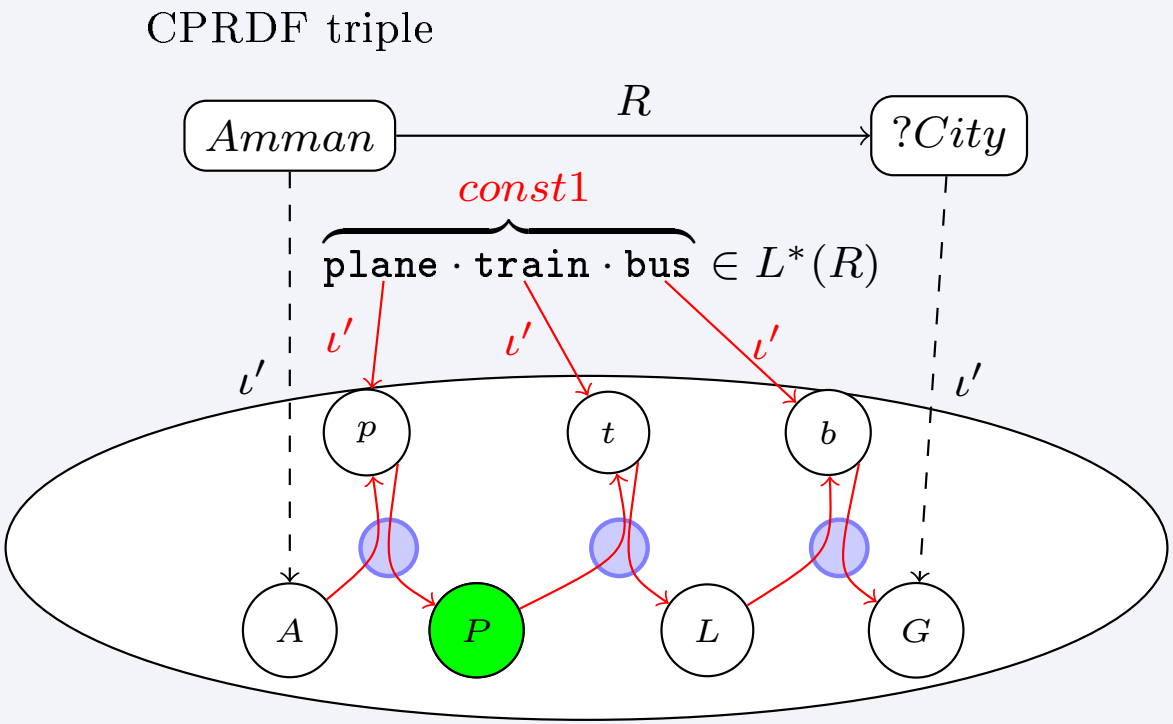

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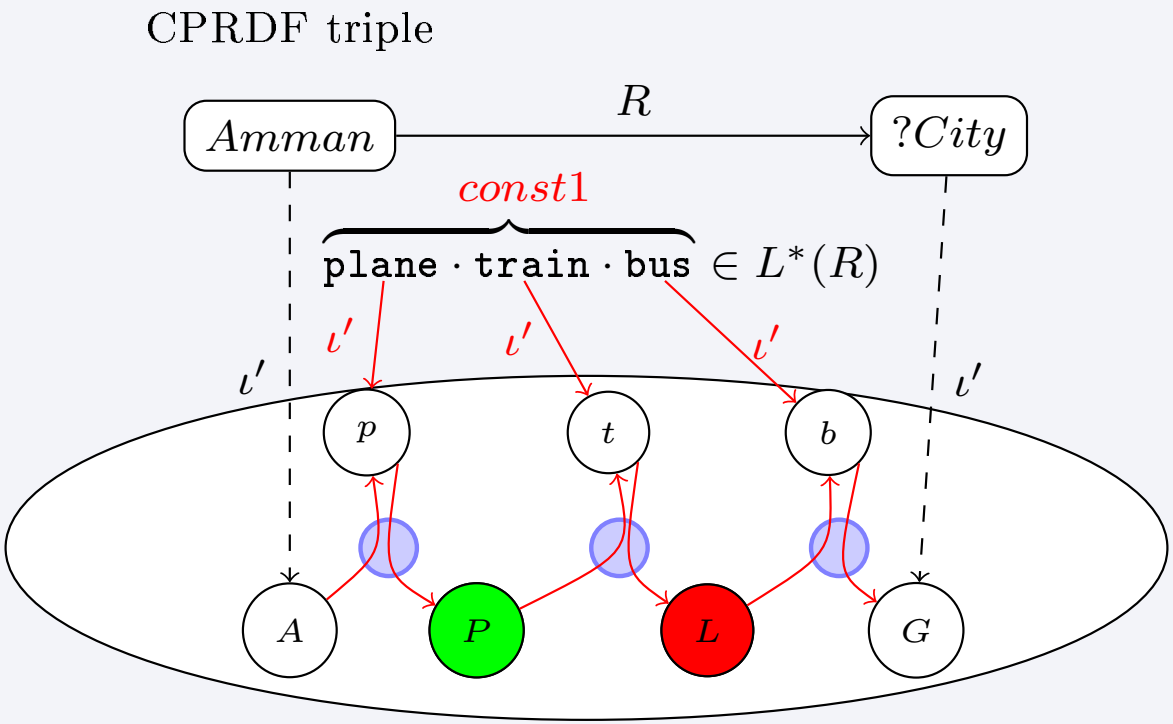

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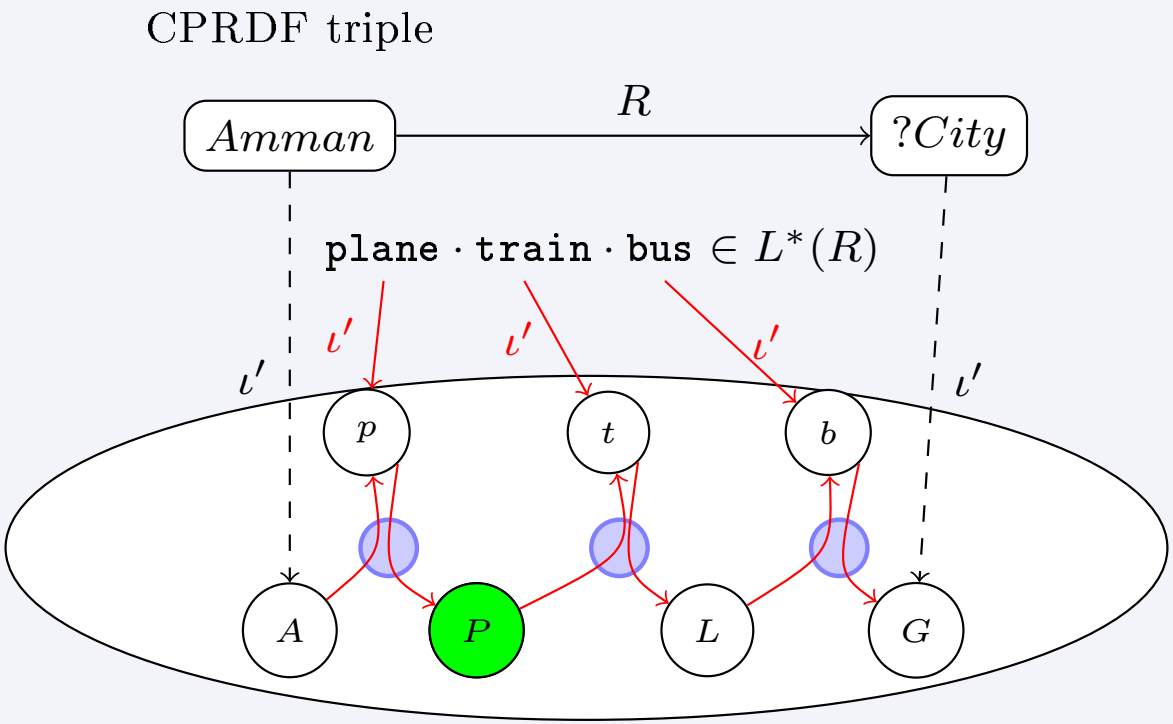
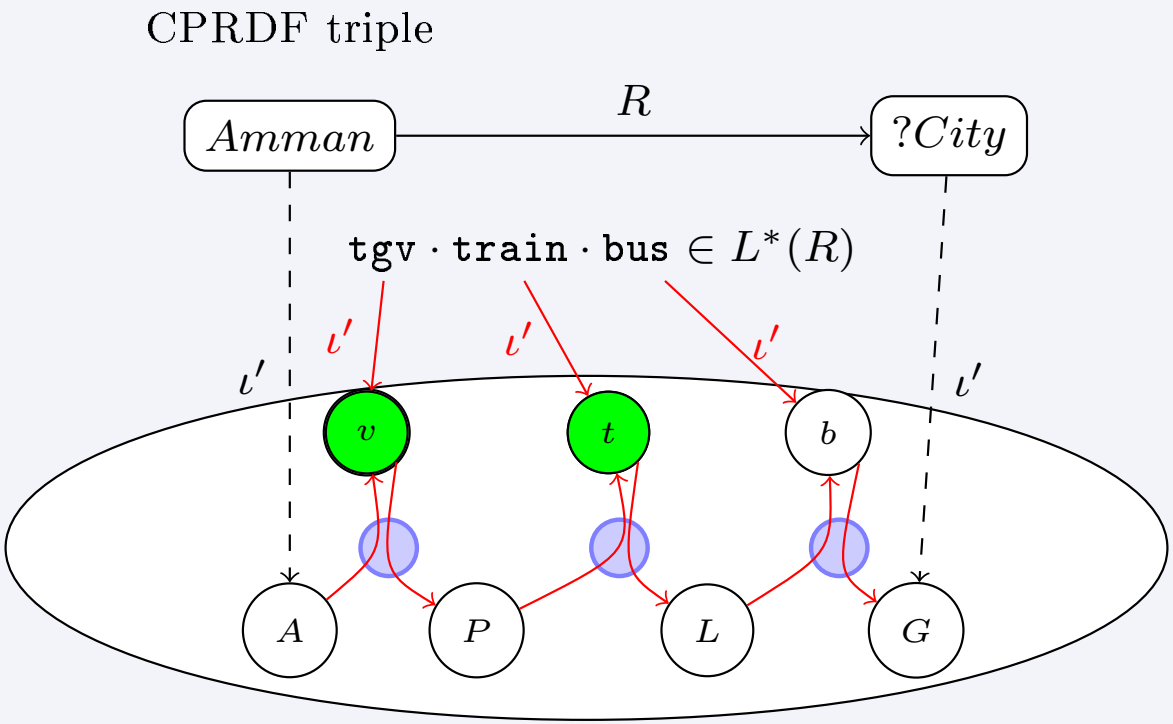


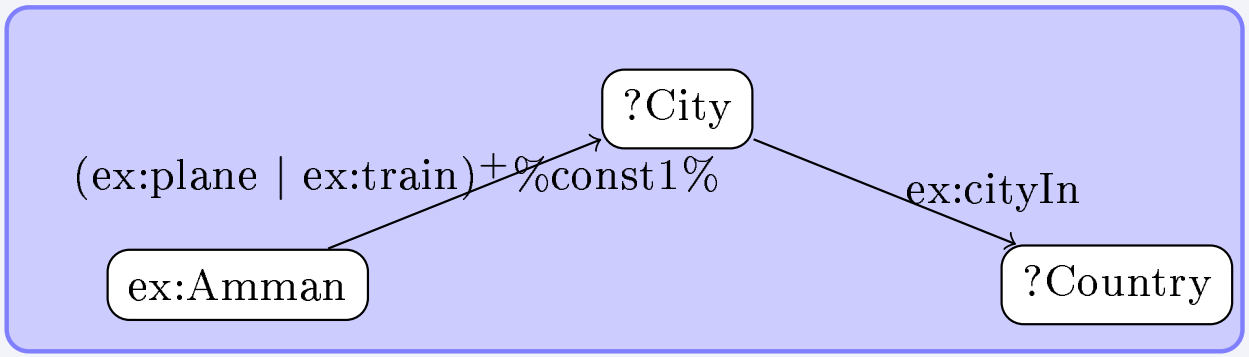
Semantics for constrained regular expressions

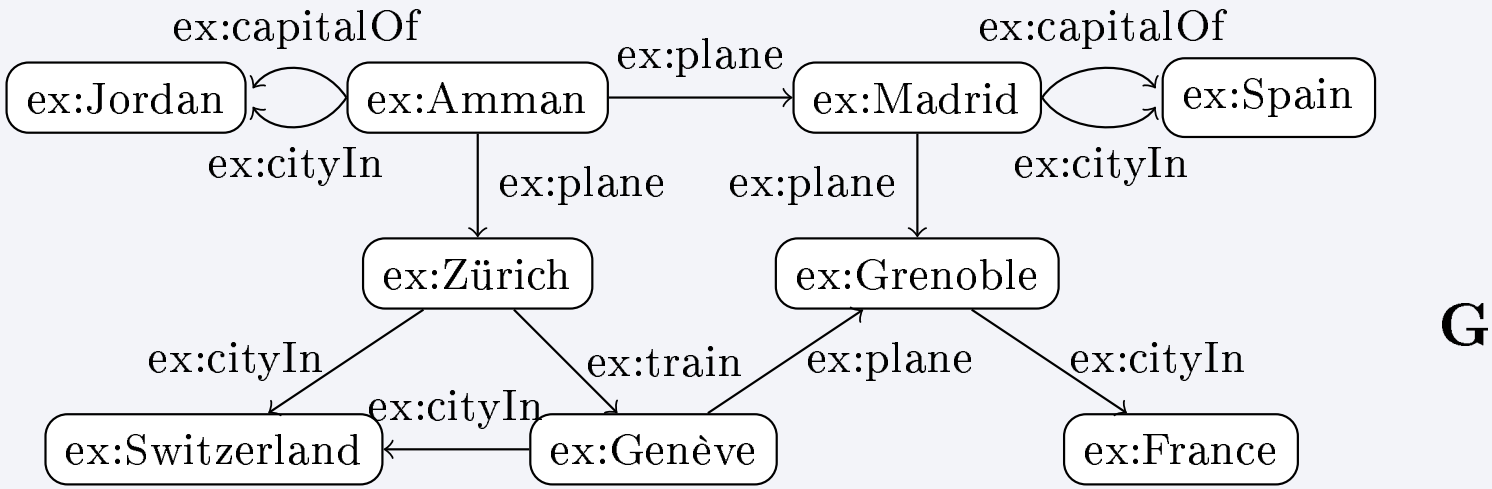
- $const1 =$ [EDGE ?Stop]:{(?Stop, subPropertyOf, train)}
- Does $\langle A, G \rangle$ supports $R = ((\#\%const1\%)^+ \cdot \texttt{bus})$ in ι'?



CPRDF Homomorphism: example

- const1 =]ALL ?Stop[: {?Stop ex:capitalOf ?Country }





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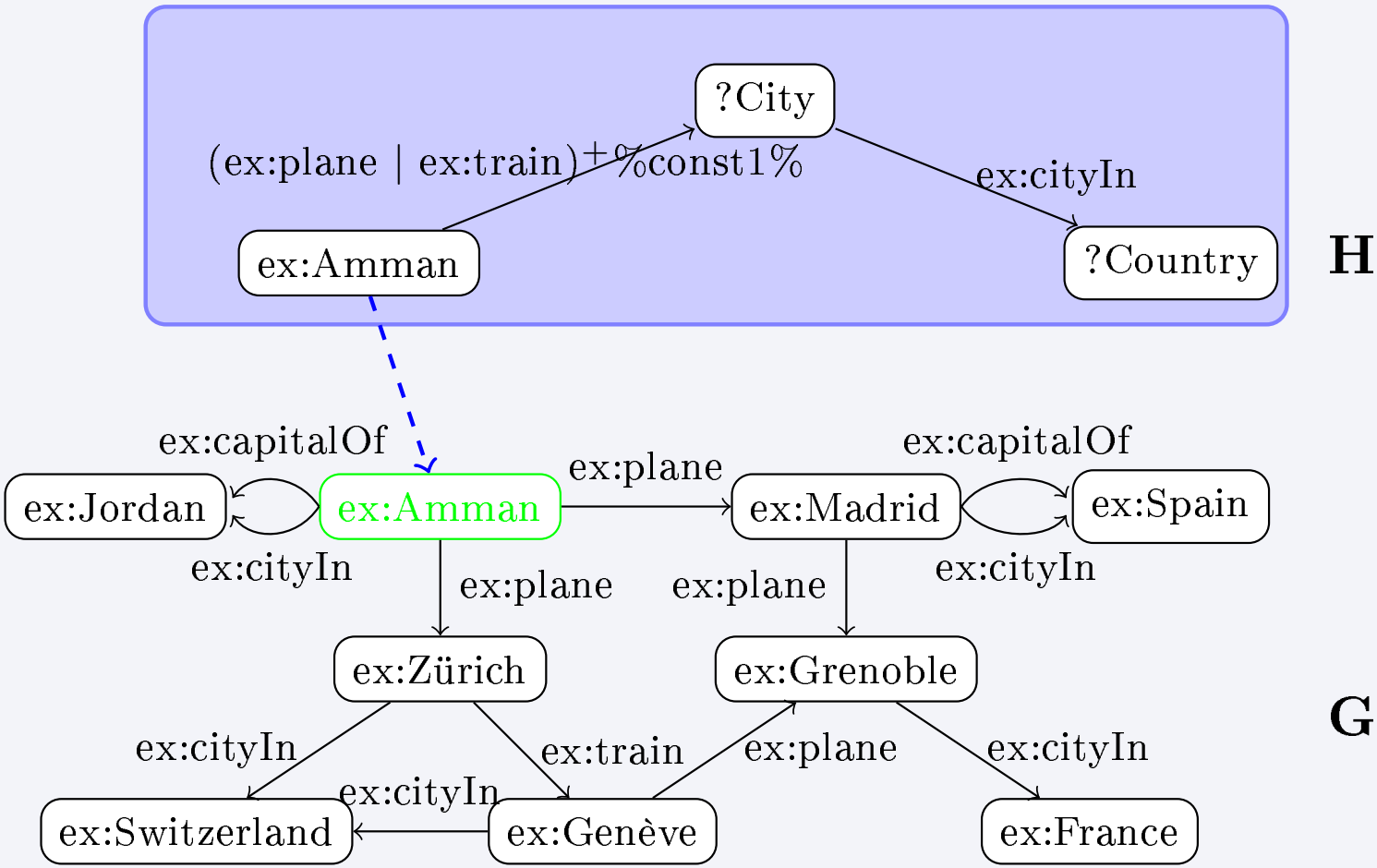

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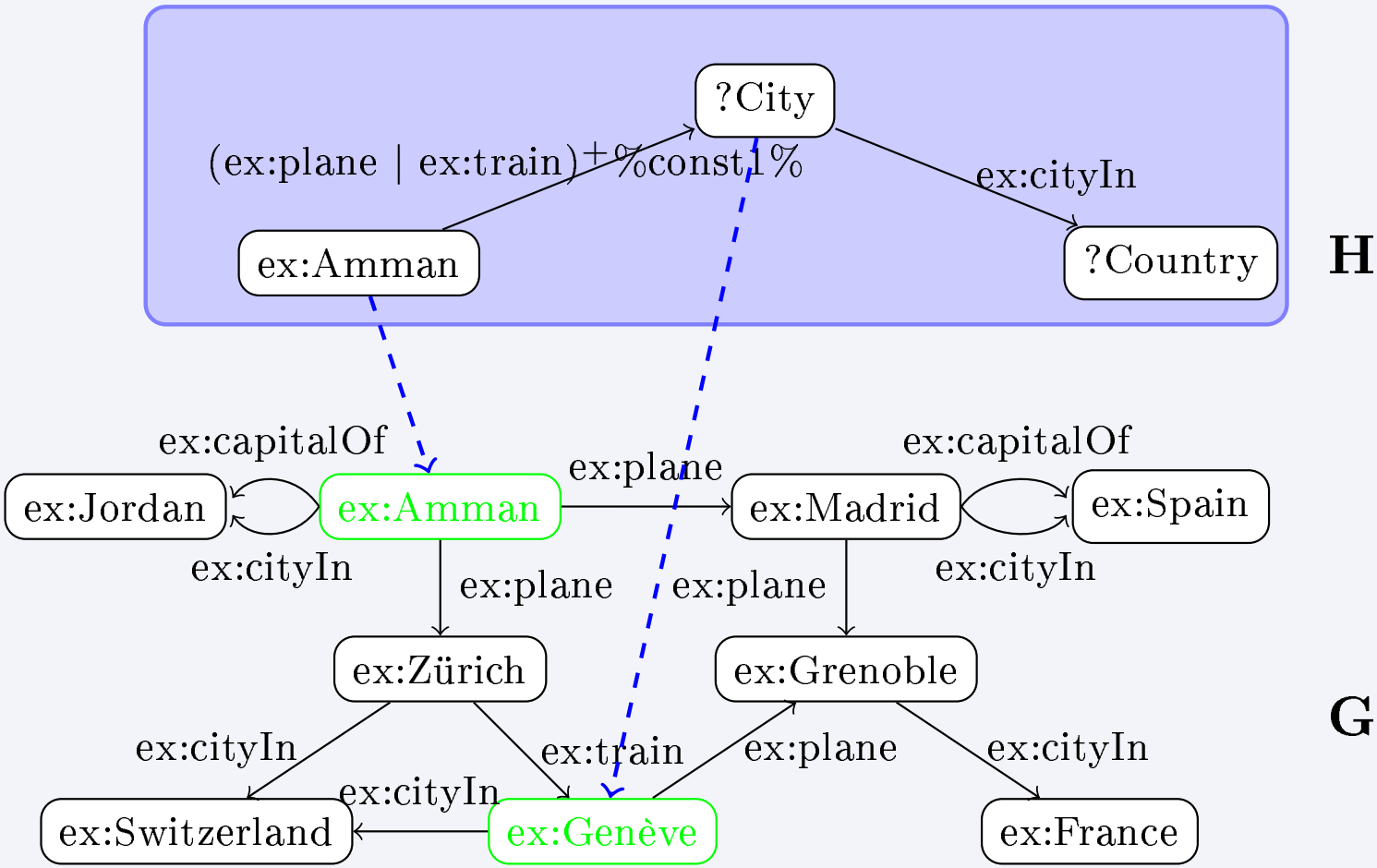

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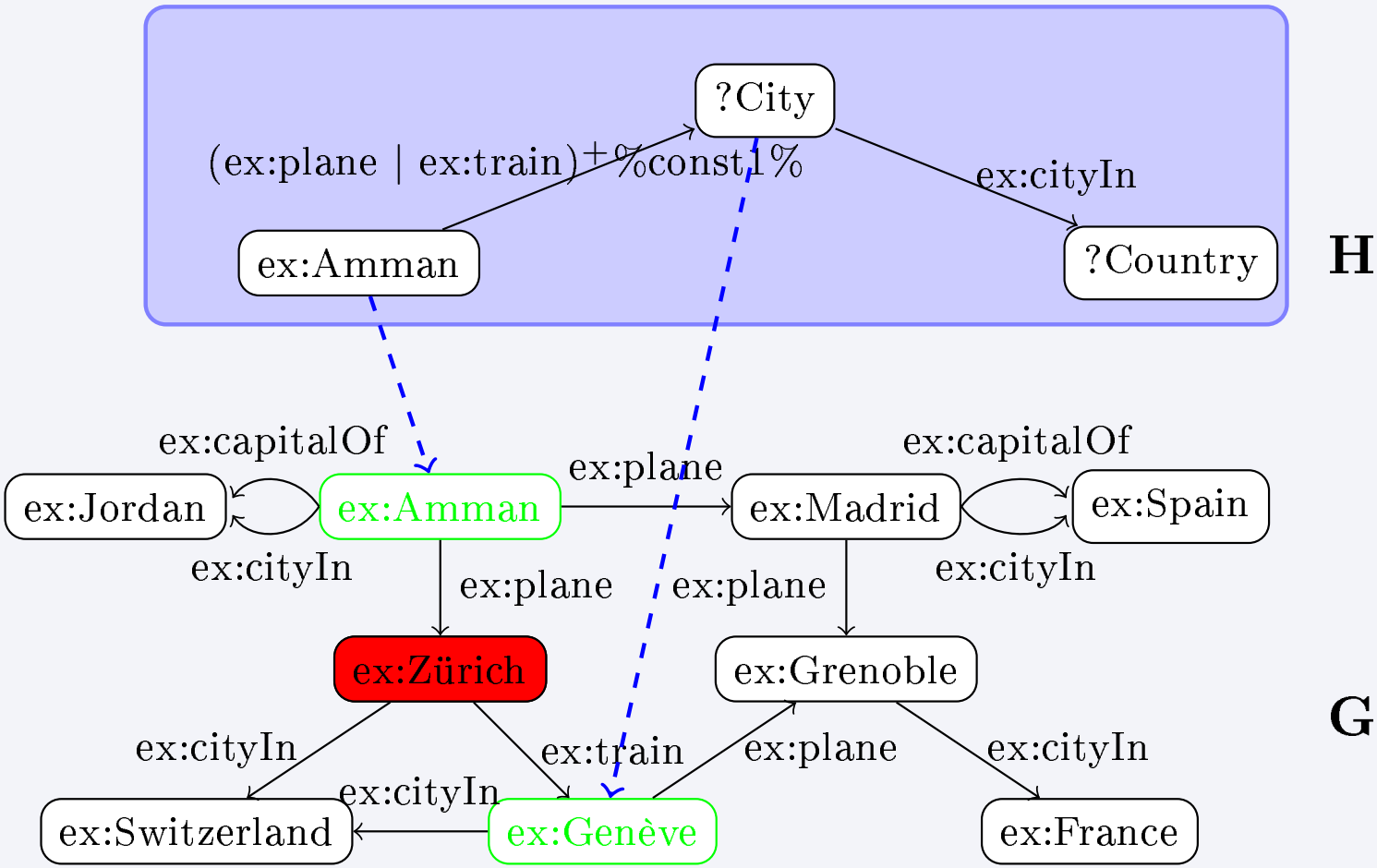

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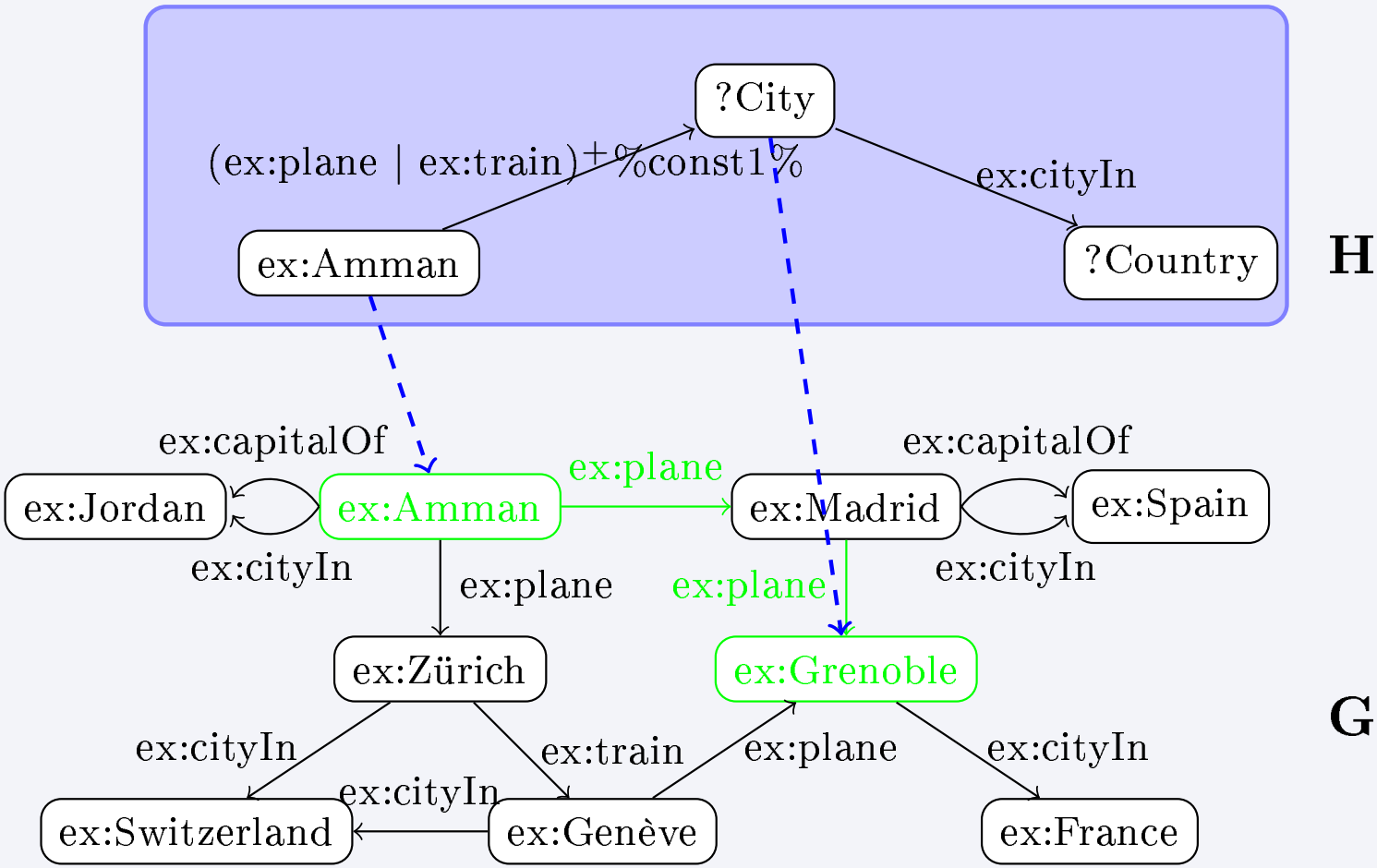

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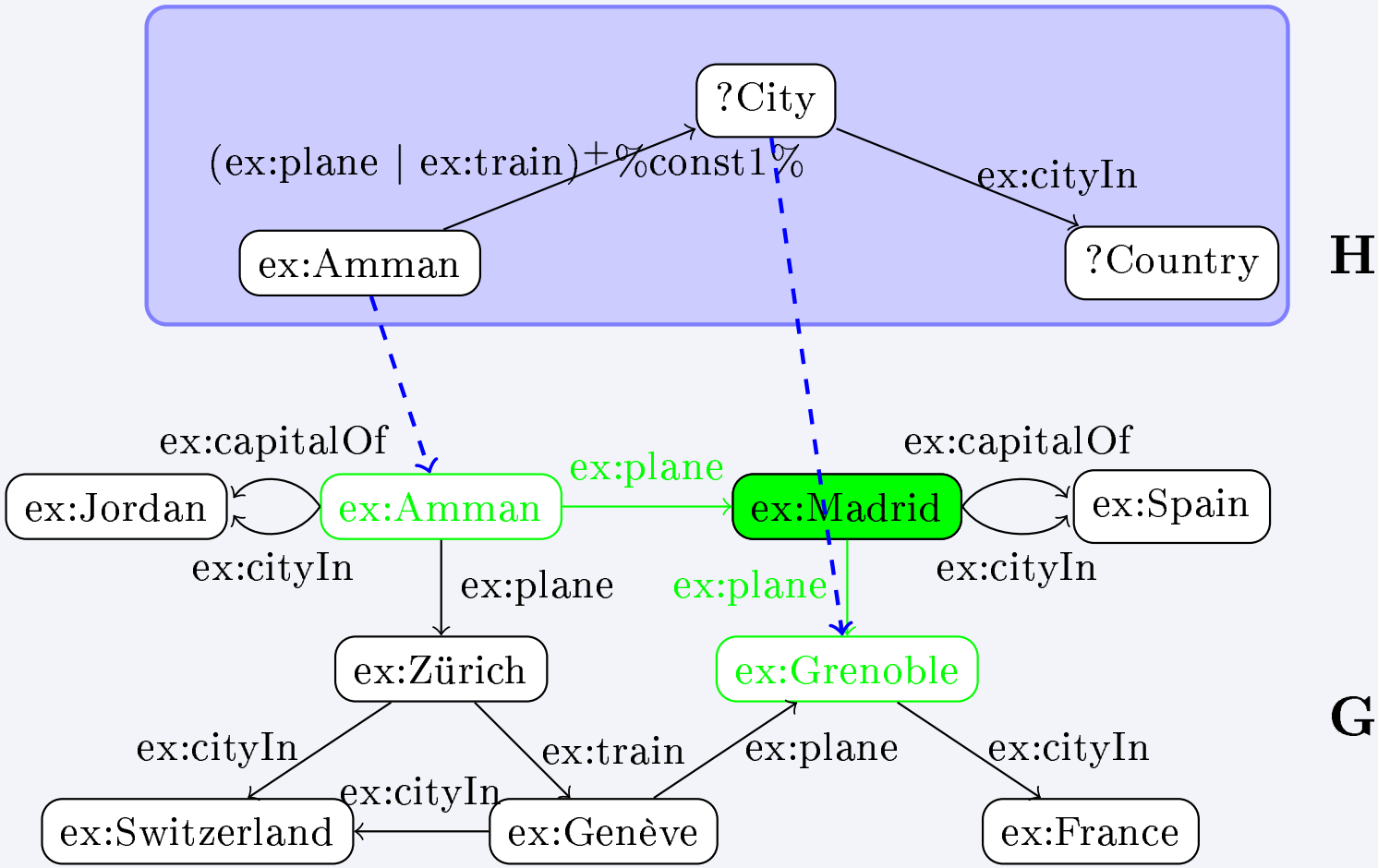

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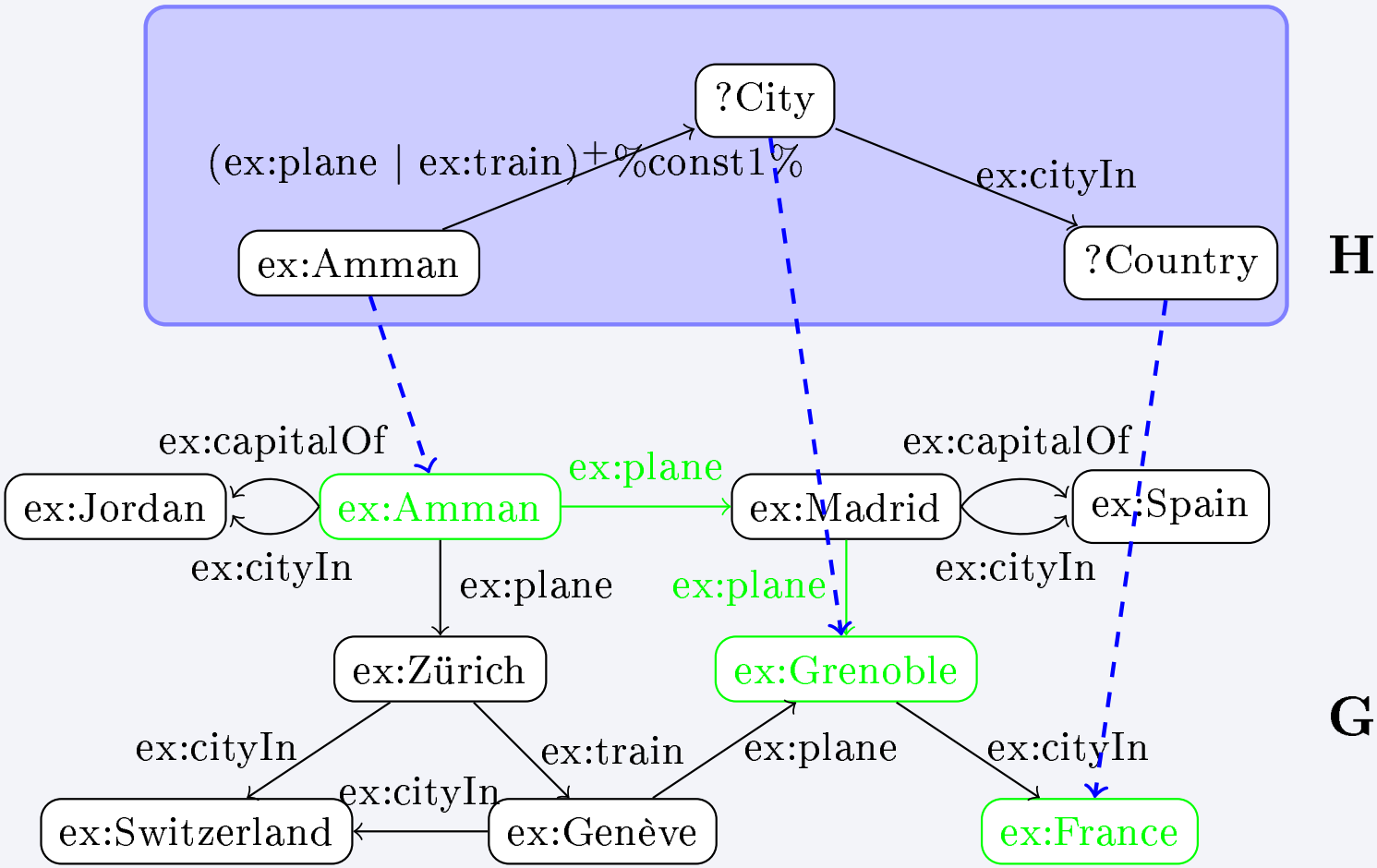
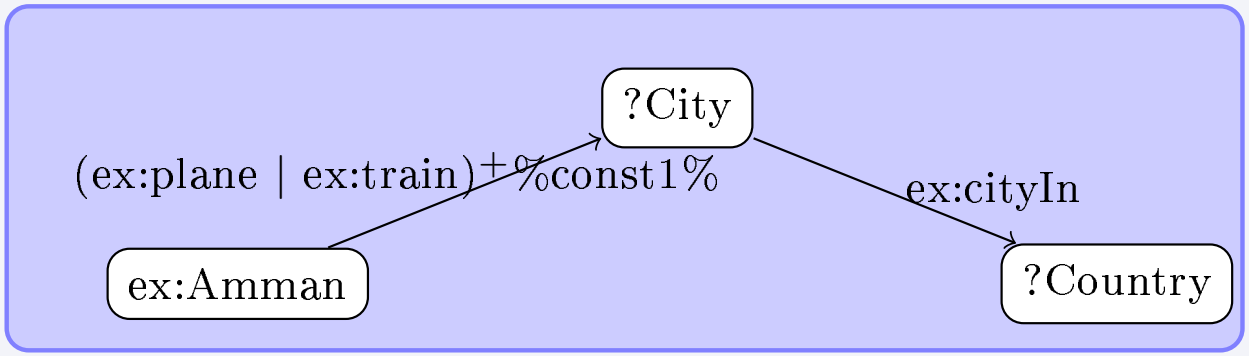
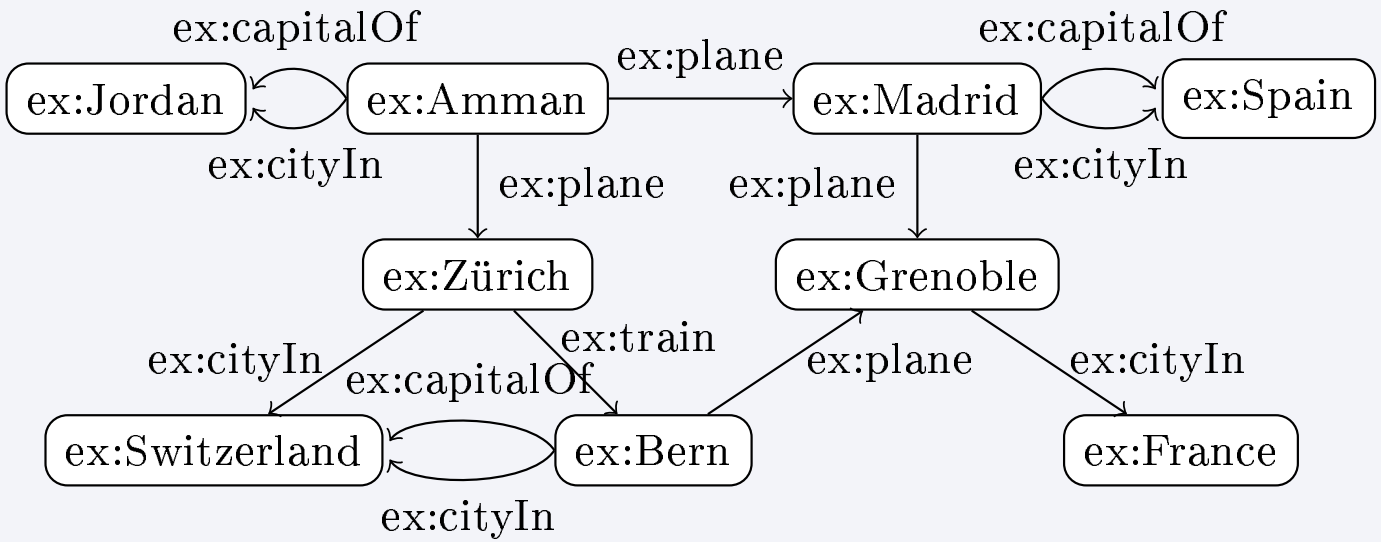


CPRDF Homomorphism: example

- const1 =]EXISTS ?Stop[: {?Stop ex:capitalOf ?Country }



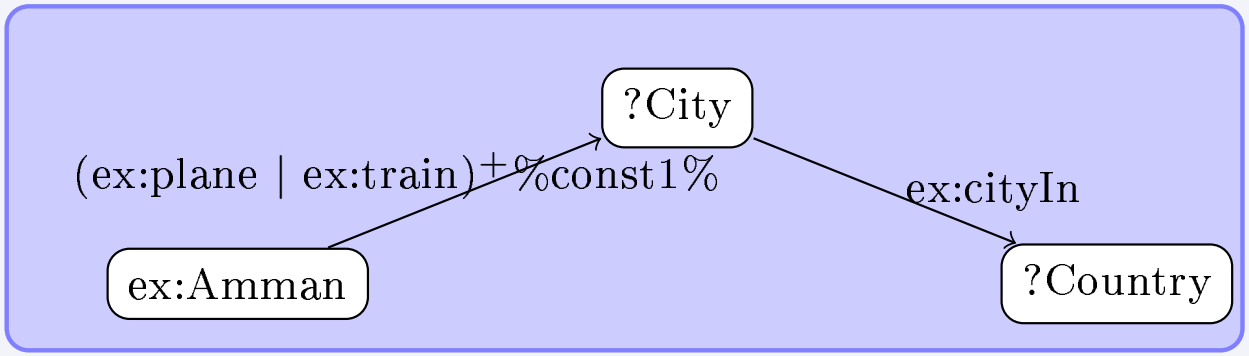
H



G

CPRDF Homomorphism: example

- const1 =]EXISTS ?Stop[: {?Stop ex:capitalOf ?Country }



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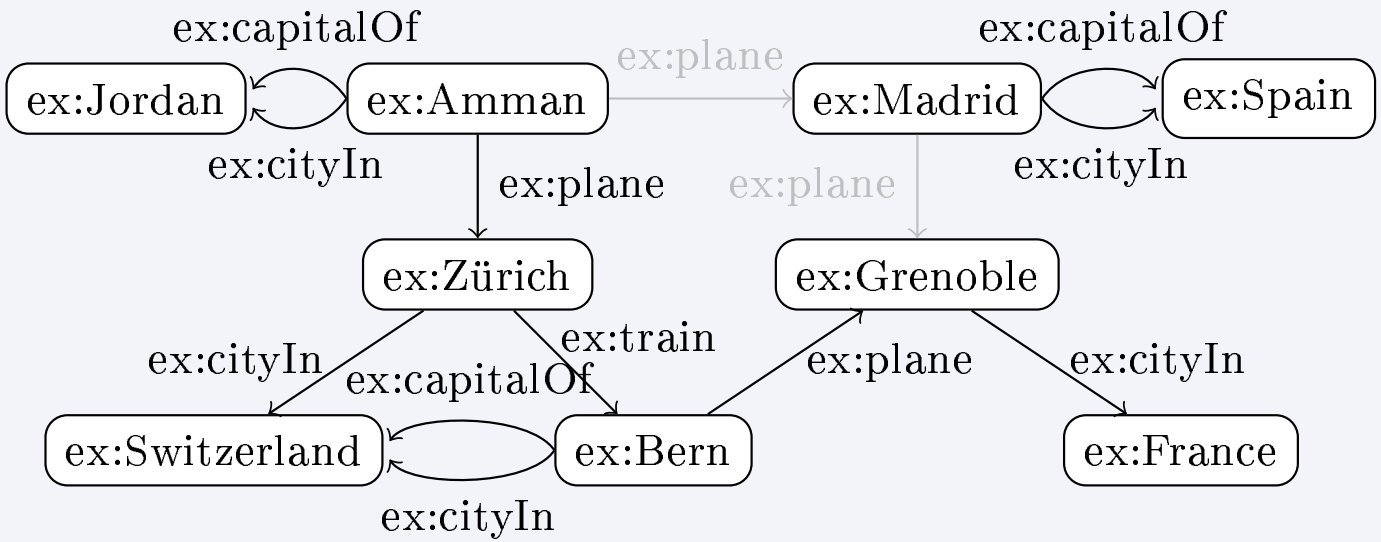

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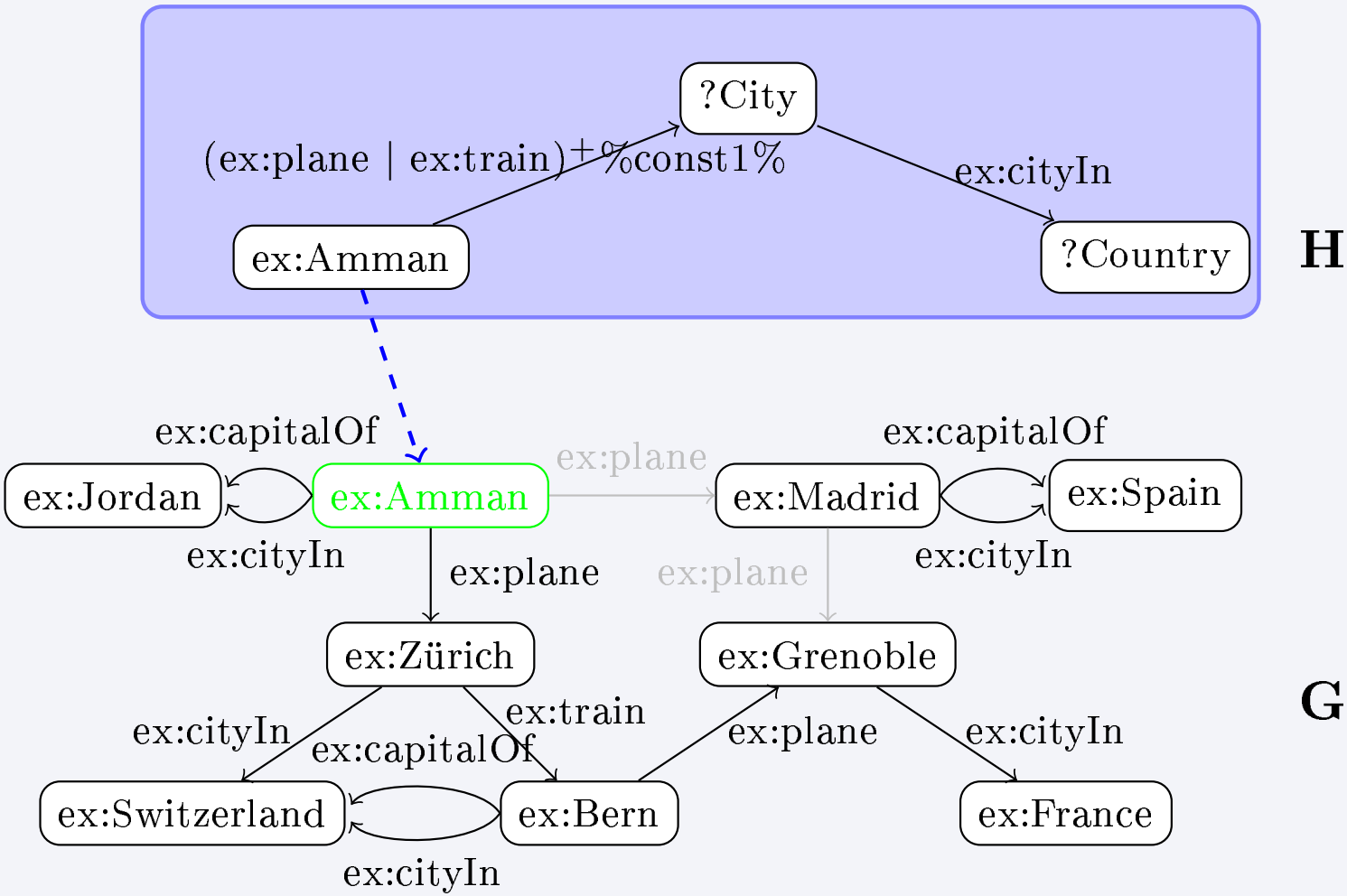

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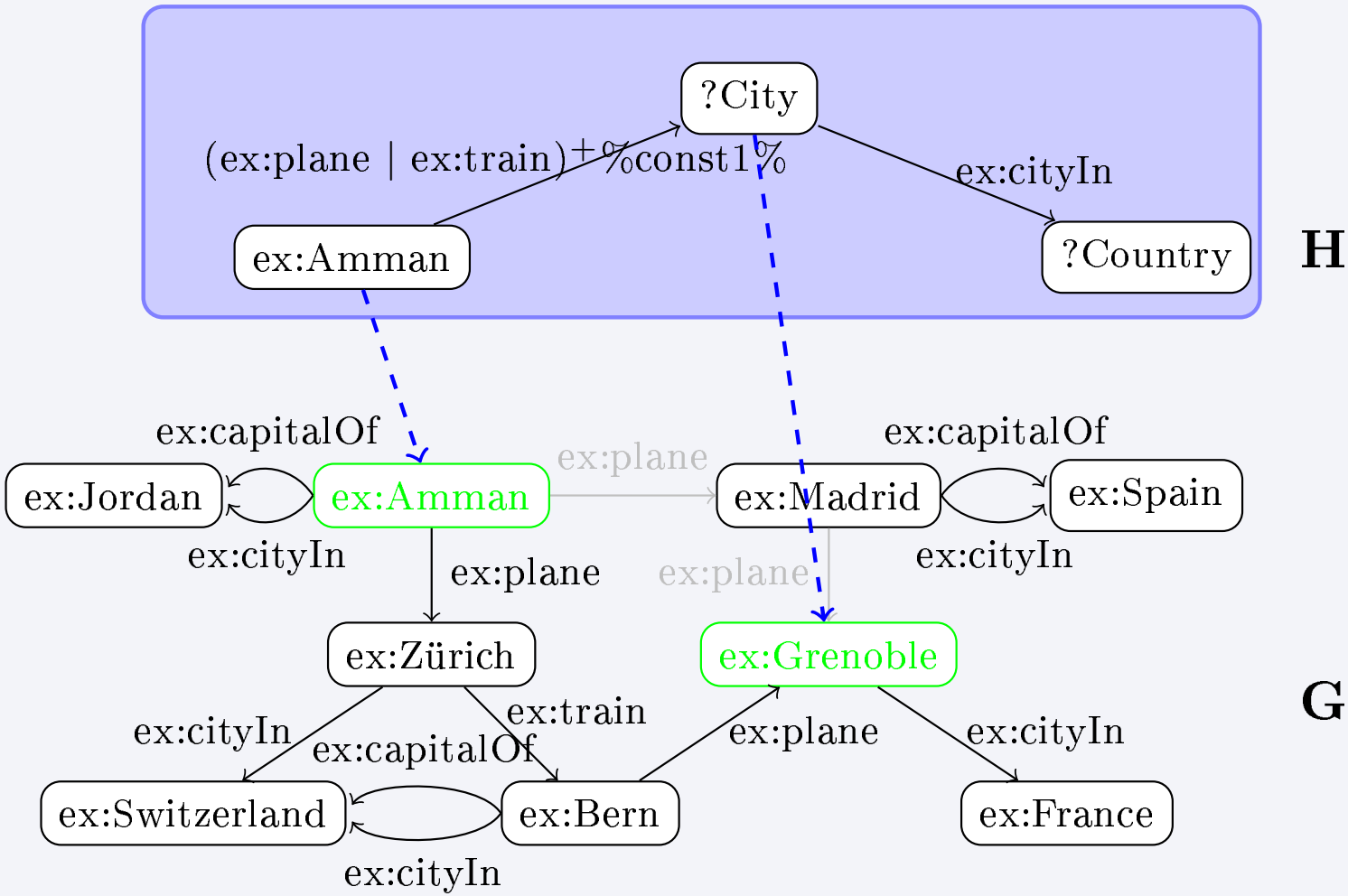

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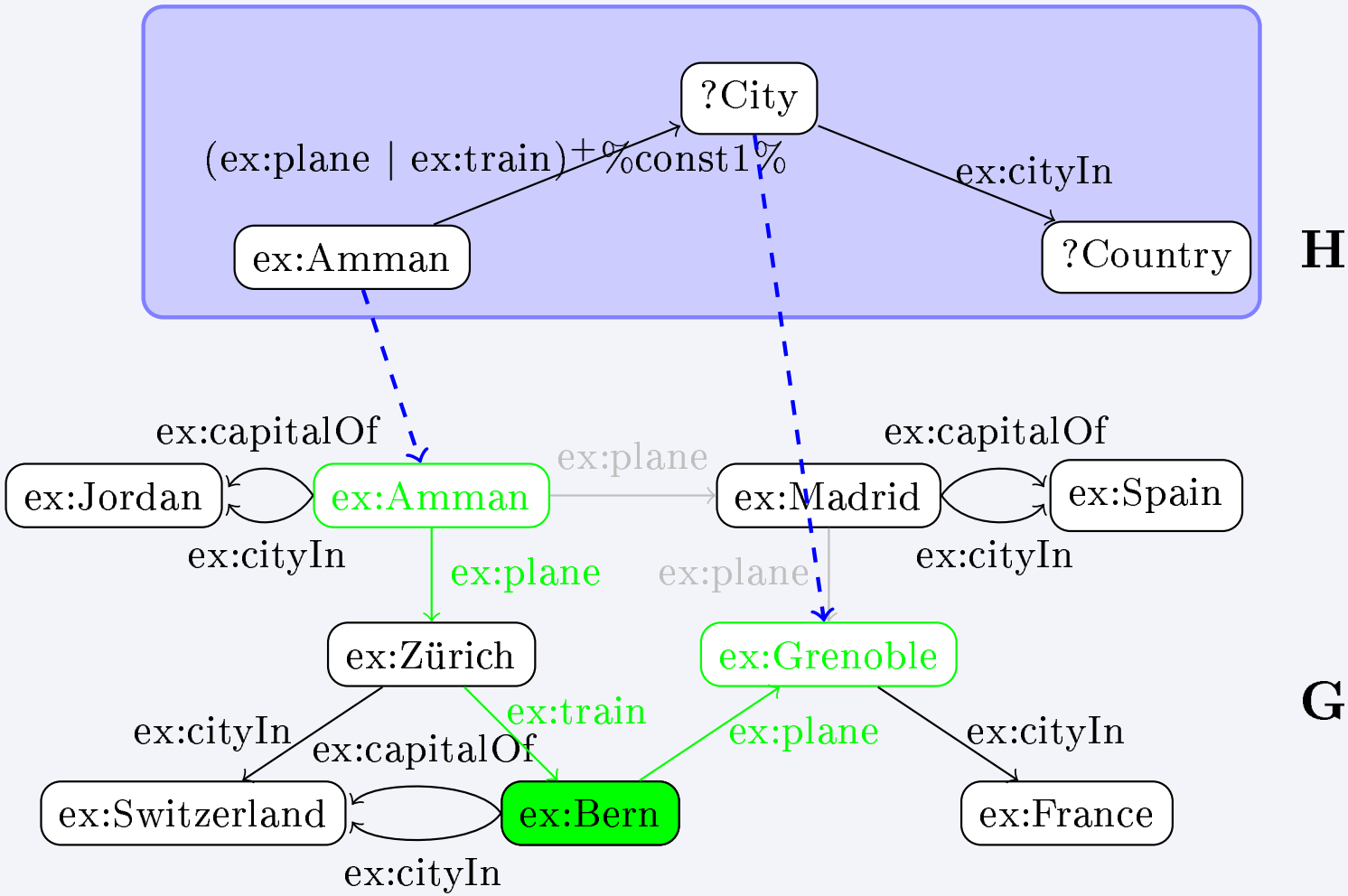

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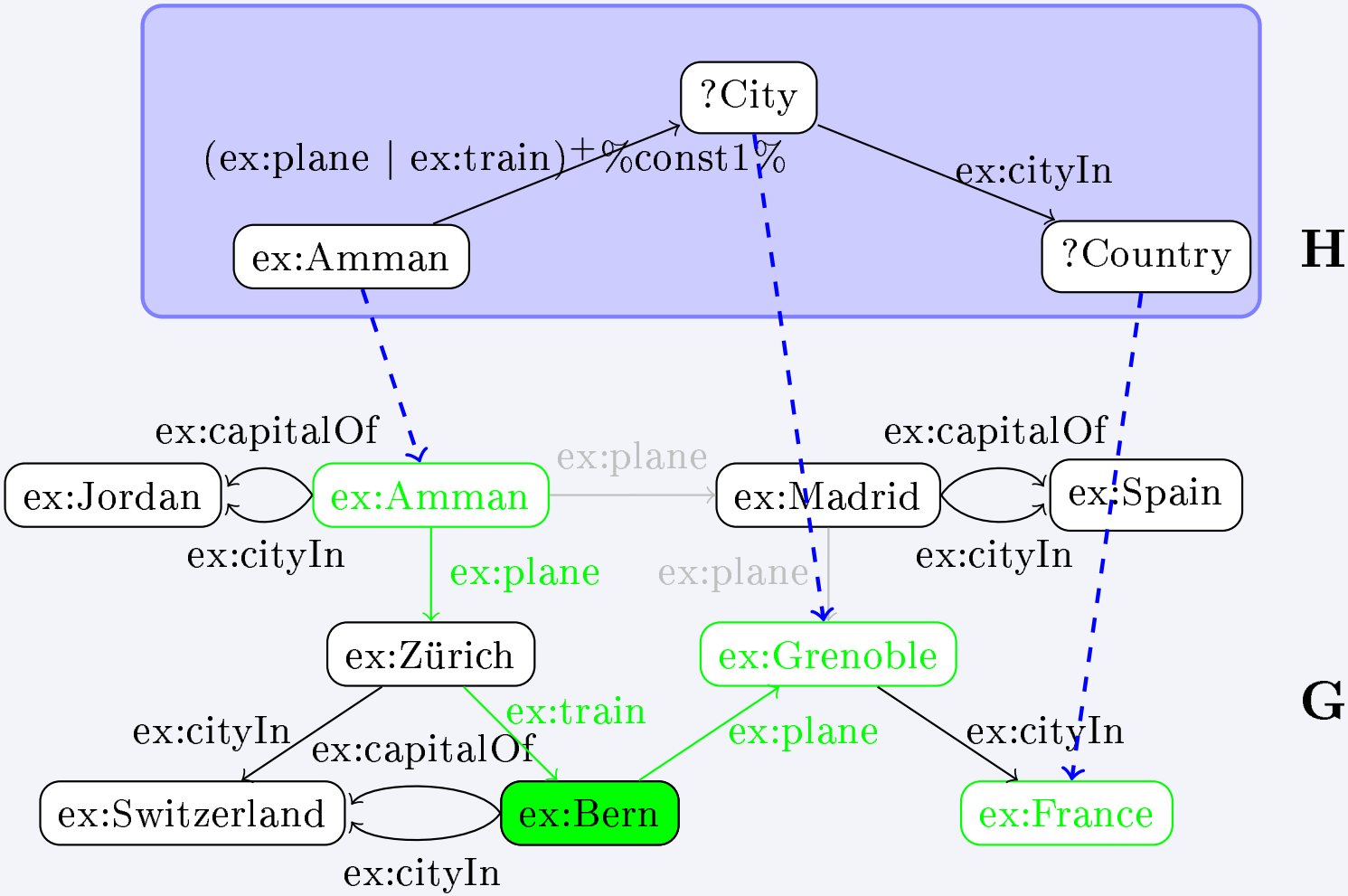

Outline

Graph patterns

SPARQL graph patterns

every GRDF graph is a graph pattern

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SPARQL graph patterns
every GRDF graph is a graph pattern
$(P_1$ `AND` $P_2)$ is a graph pattern
$(P_1$ `UNION` $P_2)$ is a graph pattern
$(P_1$ `OPT` $P_2)$ is a graph pattern
$(P_1$ `FILTER` $C)$ is a graph pattern

Graph patterns

PSPARQL graph patterns
every PRDF graph is a graph pattern
$(P_1$ `AND` $P_2)$ is a graph pattern
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Graph patterns

CPSPARQL graph patterns
every CPRDF graph is a graph pattern
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Queries

SPARQL query

`SELECT` $\vec{B}$
`FROM` u
`WHERE` P, where P is a SPARQL graph pattern.

Queries

PSPARQL query

`SELECT` $\vec{B}$
`FROM` u
`WHERE` P, where P is a PSPARQL graph pattern.

Queries

CPSPARQL query

`SELECT` $\vec{B}$
`FROM` u
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Example

SPARQL Query:

```
SELECT ?City
FROM <Transport>
WHERE { ex:Amman ex:plane ?City . }
```

Example

PSPARQL Query:

```
SELECT ?City
FROM <Transport>
WHERE { ex:Amman (ex:plane | ex:train)+ ?City . }
```

Example

CPSPARQL Query:

```
SELECT ?City
FROM <Transport>
WHERE {
      CONSTRAINT const1 ]ALL ?Stop[:
                        { ?Stop ex:capitalOf ?Country }
        ex:Amman (ex:plane | ex:train)+%const1% ?City .}
```

Answers to (CP/P)SPARQL graph patterns

- The set $\mathcal{S}(P, G)$ of answers to a SPARQL graph pattern P in a GRDF graph G is defined inductively in the following way:

P	$\mathcal{S}(P, G)$
GRDF graph	$\{\mu \mid \mu$ is a GRDF homomorphism$\}$
$(P_1$ `AND` $P_2)$	$\mathcal{S}(P_1, G) \bowtie \mathcal{S}(P_2, G)$
$(P_1$ `UNION` $P_2)$	$\mathcal{S}(P_1, G) \cup \mathcal{S}(P_2, G)$
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$(P_1$ `FILTER` $C)$	$\{\mu \in \mathcal{S}(P_1, G) \mid \mu(C) = \top\}$

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Answers to queries

- If $Q = \texttt{SELECT}\ \vec{B}\ \texttt{FROM}\ u\ \texttt{WHERE}\ P$ be a SPARQL/(C)PSPARQL query

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- The answers to Q are: $\{\mu(\vec{B}) \mid \mu \in \mathcal{S}(P, G)\}$

Outline

RDFS closure

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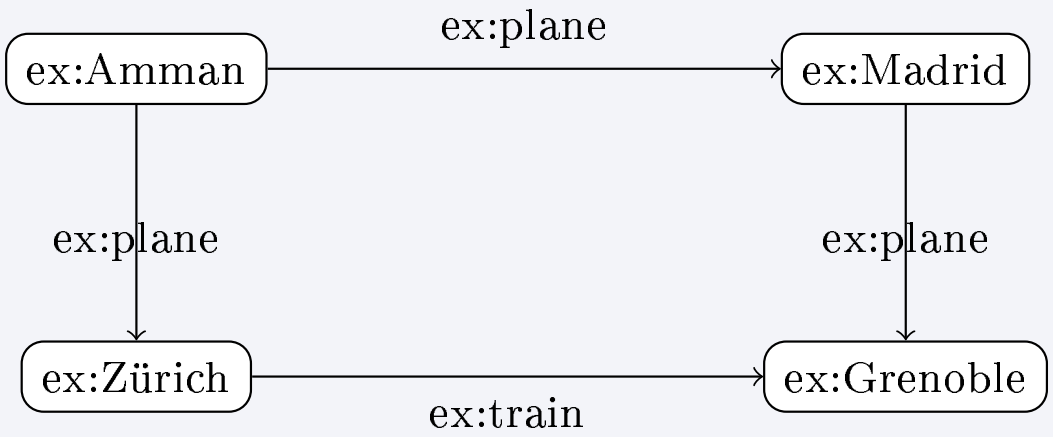
SELECT ?City
FROM <Transport>
WHERE { ex:Amman ex:transport ?City . }
```



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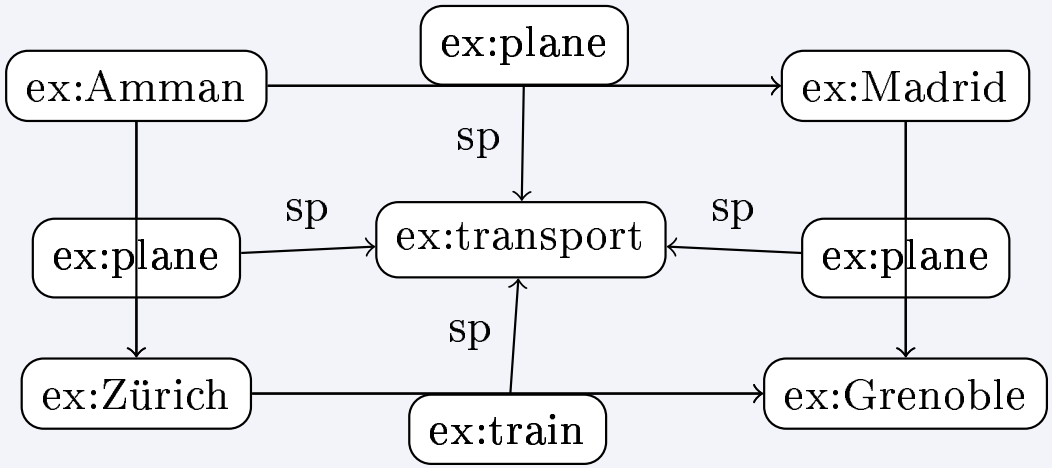

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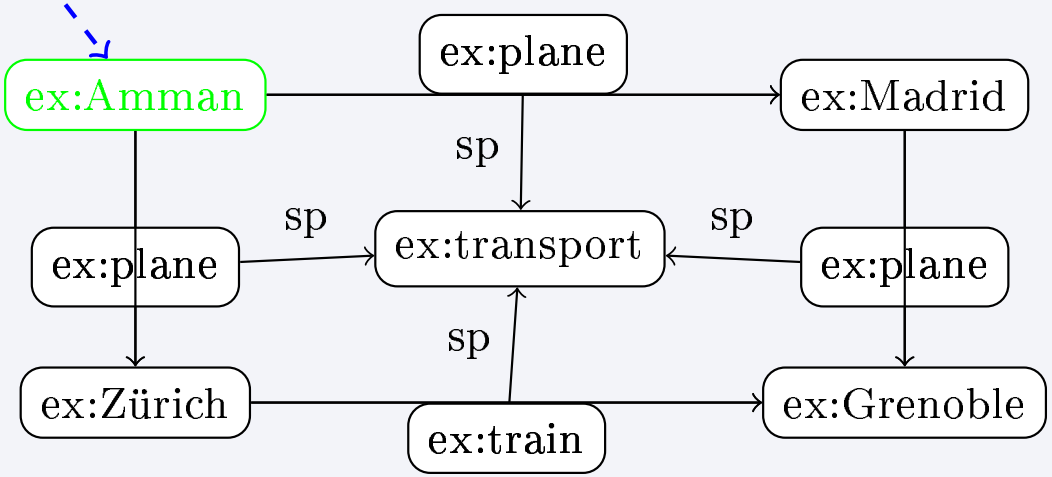

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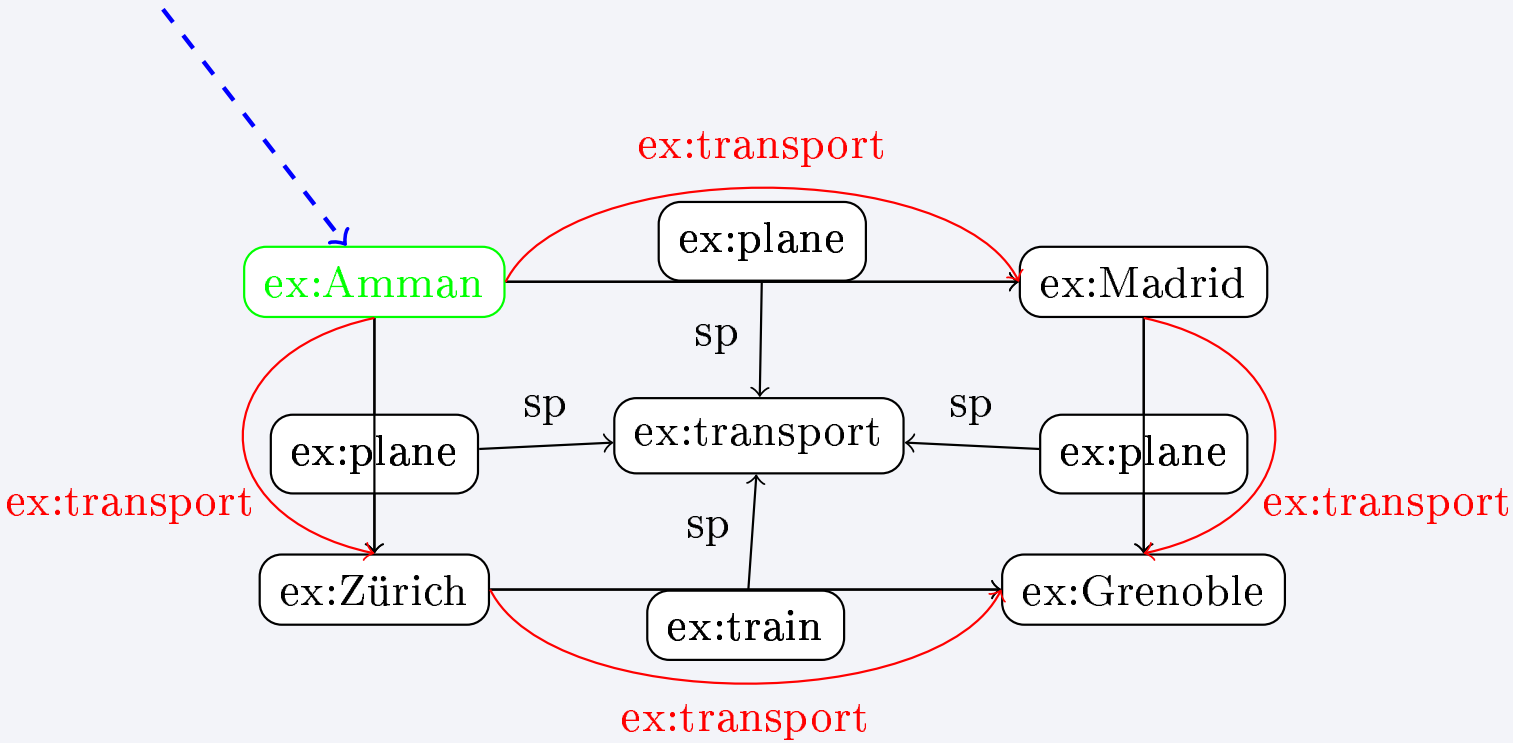

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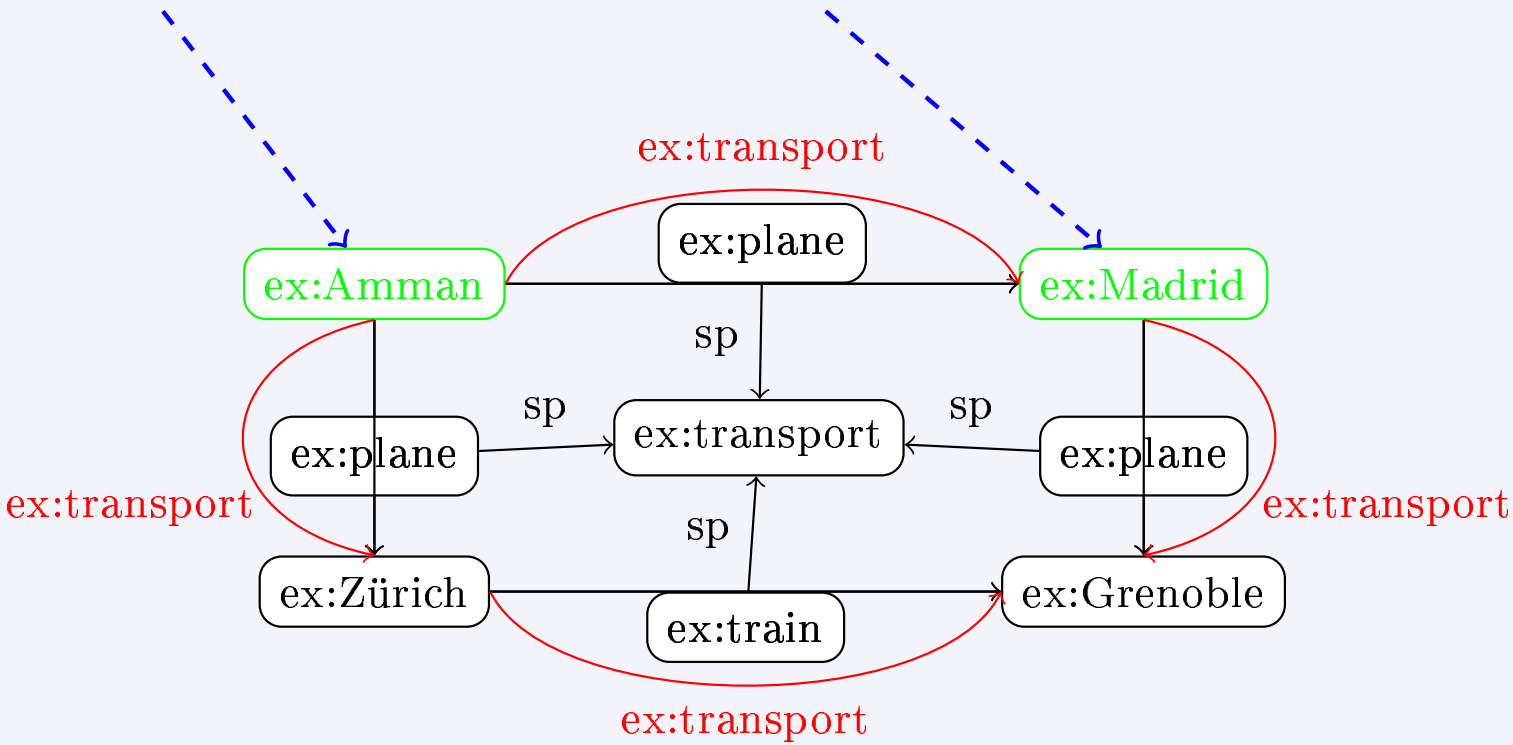

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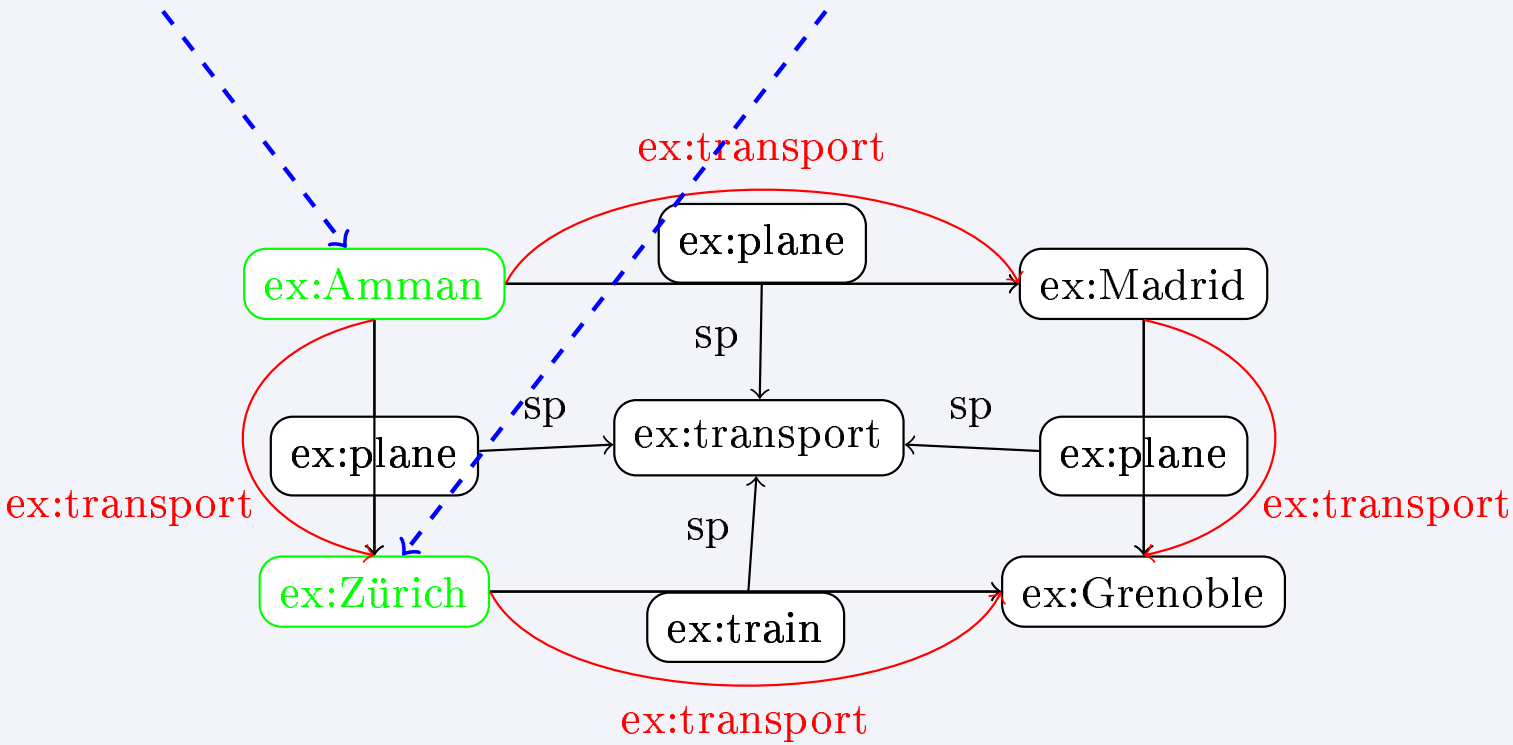

From SPARQL/RDFS to PSPARQL/RDF

SubClass: $\tau(\langle s, \mathtt{sc}, o\rangle) = \{\langle s, \mathtt{sc}^+, o\rangle\}$

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$$\frac{\langle s,\mathtt{type},z\rangle,\langle z,\mathtt{sc}^*,o\rangle}{\langle s,\mathtt{type},o\rangle} = \frac{\langle s,\mathtt{type}\cdot\mathtt{sc}^*,o\rangle}{\langle s,\mathtt{type},o\rangle}$$

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Domain rule: $\tau(\langle s, \mathtt{dom}, o\rangle) = \langle s, \mathtt{dom}, o\rangle$

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Domain rule: $\tau(\langle s, \mathtt{dom}, o\rangle) = \langle s, \mathtt{dom}, o\rangle$

Range rule: $\tau(\langle s, \mathtt{range}, o\rangle) = \langle s, \mathtt{range}, o\rangle$

Any property: $\tau(\langle s, p, o\rangle) = \{\langle s, ?x, o\rangle, \langle ?x, \mathtt{sp}^*, p\rangle\}$

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Any property: $\tau(\langle s, p, o\rangle) = \{\langle s, ?x, o\rangle, \langle ?x, \mathtt{sp}^*, p\rangle\}$

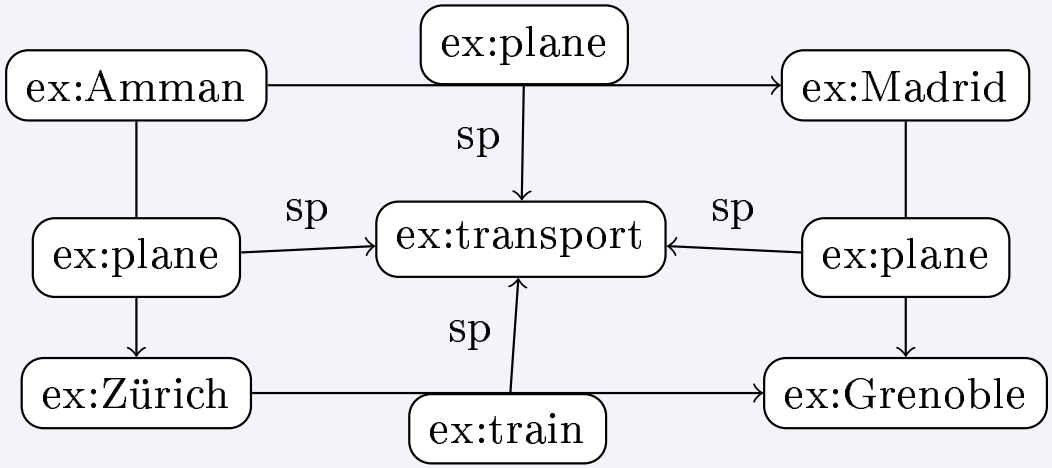
$$\rho\text{df [munoz2007]} = \{\mathtt{sc}, \mathtt{sp}, \mathtt{type}, \mathtt{dom}, \mathtt{range}\}$$

Theorem

Let G and P be two ρdf graphs, then $Eval(P, \hat{G}, \Omega)$ is equivalent to $Eval(\tau(P), G, \Omega)$.

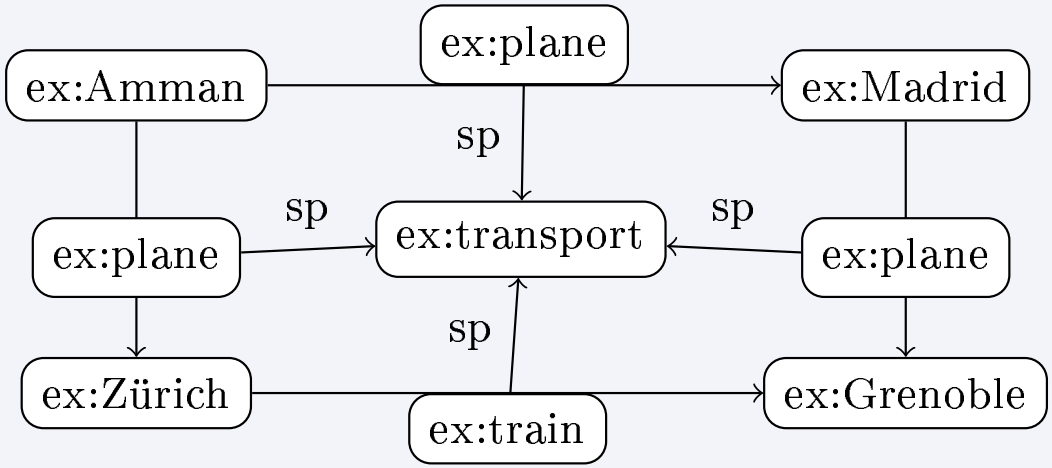
From SPARQL/RDFS to PSPARQL/RDF: example

```
SELECT ?City
FROM <Transport>
WHERE { ex:Amman ex:transport ?City . }
```



From SPARQL/RDFS to PSPARQL/RDF: example

```
SELECT ?City
FROM <Transport>
WHERE { ex:Amman ?P ?City. ?P sp* ex:transport . }
```



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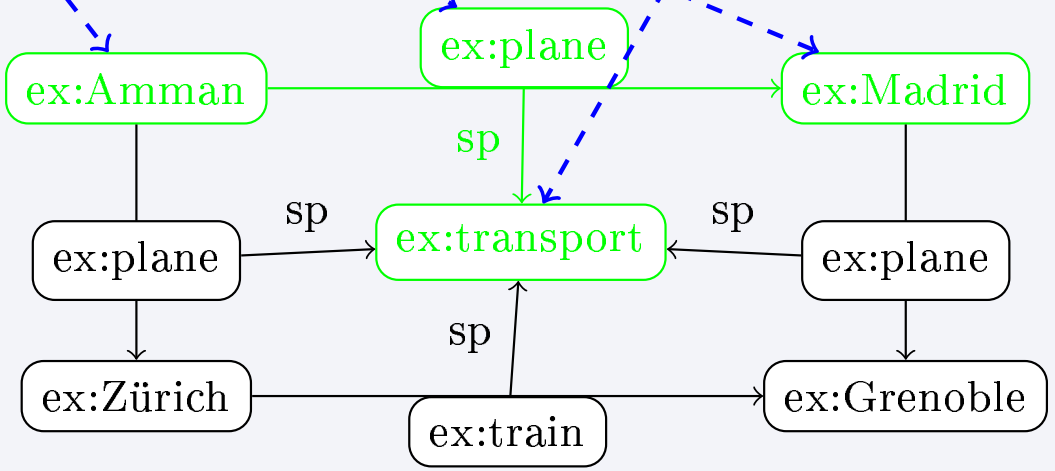

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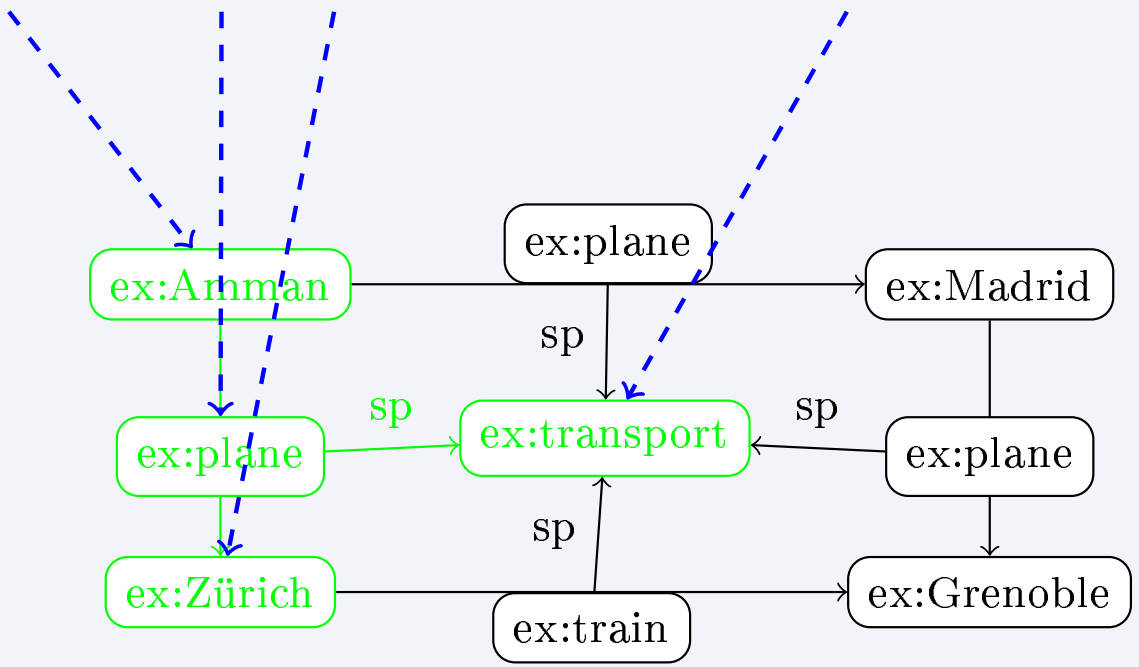

From PSPARQL/RDFS to CPSPARQL/RDF

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SELECT ?City
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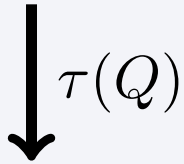


```
SELECT ?City
WHERE {
CONSTRAINT const1 [EDGE ?P]: { ?P sp* ex:transport . }
ex:Amman (# % const1 %)+ ?City .
}
```

From PSPARQL/RDFS to CPSPARQL/RDF

```
SELECT ?City
WHERE { ex:Amman (!ex:train)+ ?City . }
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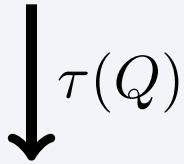


```
SELECT ?City
WHERE {
CONSTRAINT const1 [EDGE ?P]: { ?P (!sp)* ex:train . }
ex:Amman (# % const1 %)+ ?City .
}
```

Outline

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- We have implemented (C)PSPARQL (`psparql.inrialpes.fr`).

Further work

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- Using SPARQL for document generation and adaptation [alkhateeb et al., 2008]

Thanks

Questions and Comments?