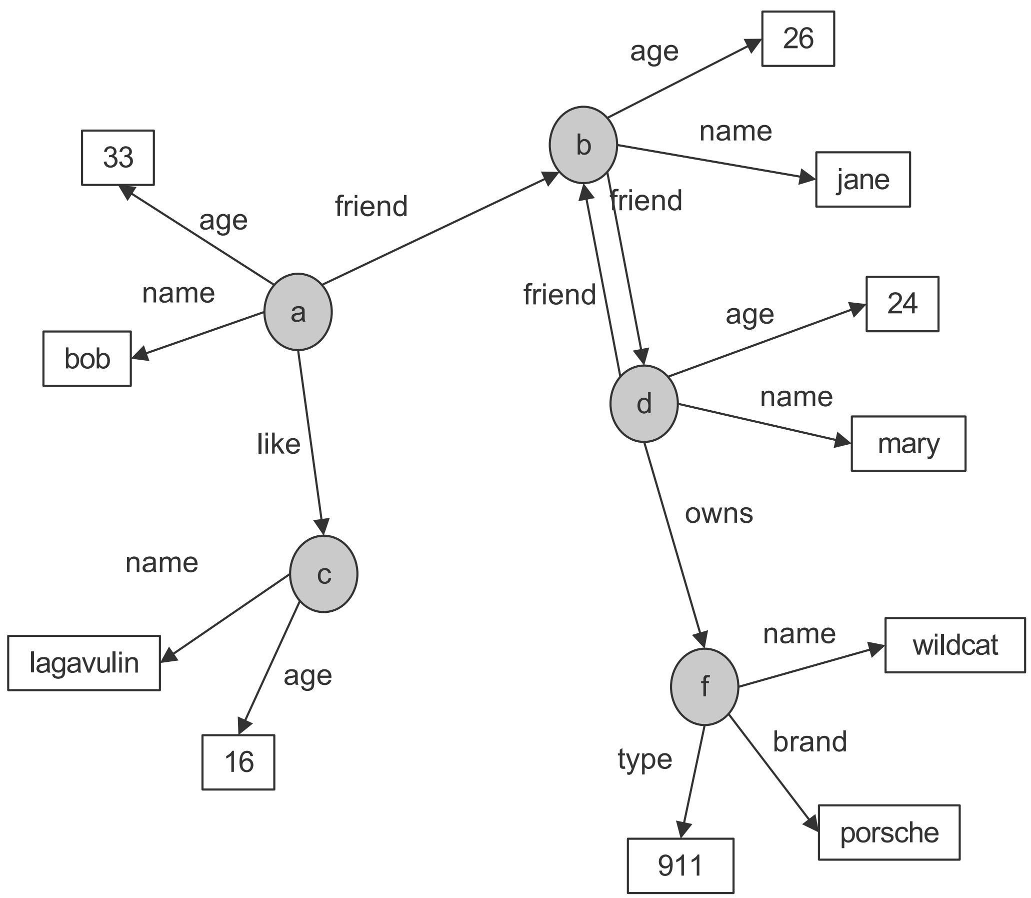
University of Applied Sciences and Arts Northwestern Switzerland
School of Business

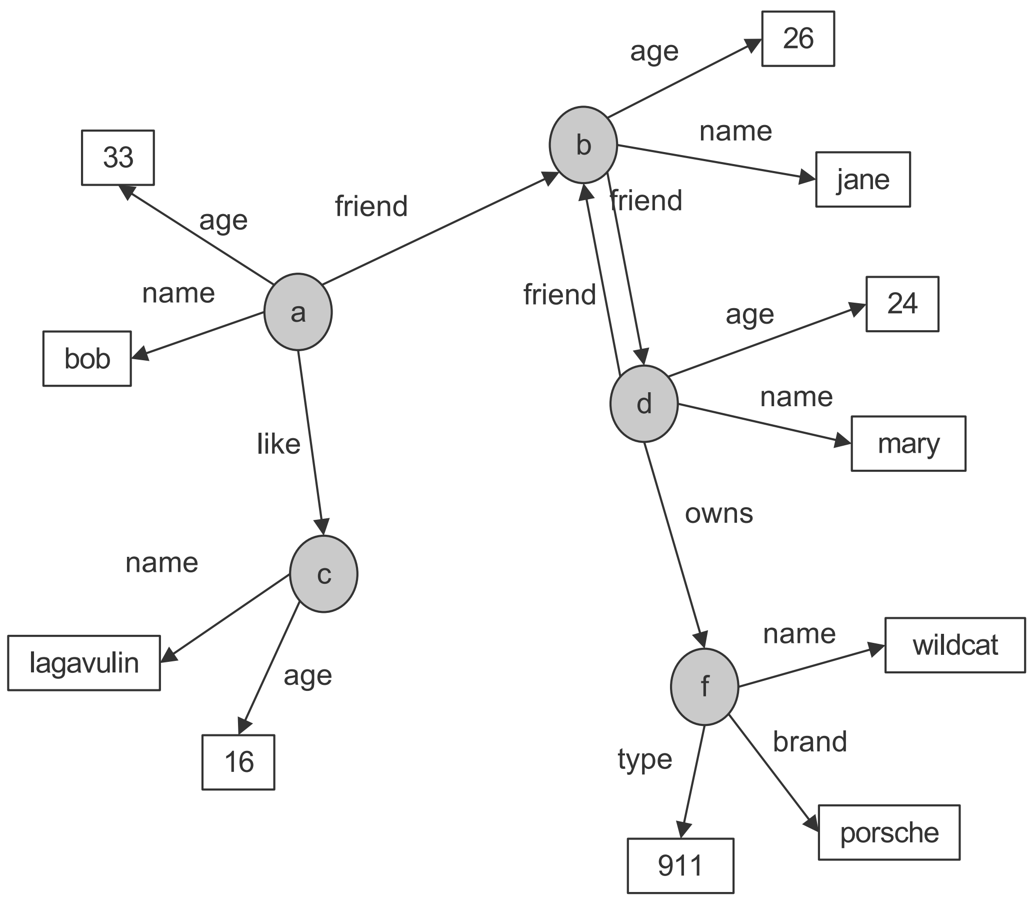
RDF and Knowledge Nets

AN EXAMPLE

Example: KnowledgeNets …



Example: KnowledgeNets and Facts




```
name(a,bob).
age(a,33).
friend(a,b).
like(a,c).

name(b,jane).
age(b,26).
friend(b,d).

name(c,lagavulin).
age(c,16).

name(d,tom).
age(d,24).
friend(d,b).
owns(d,f).

name(f,wildcat).
brand(f,porsche).
type(f,911).
```

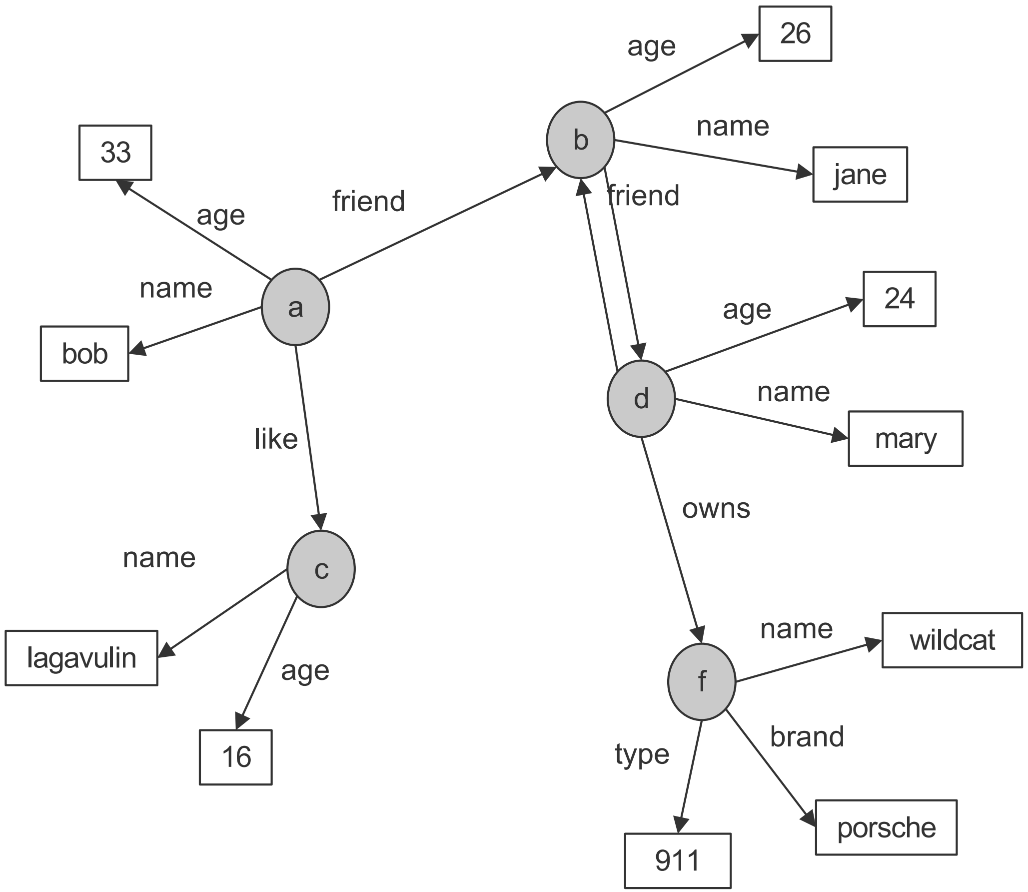
Triples

- Everything is stored in Triples

```
triple(<start-node>, <relationship>, <end-node>)
```

- Many triples are stored in a Triplestore.

Example: KnowledgeNets and Triples




```
triple(a,name,bob).
triple(a,age,33).
triple(a,friend,b).
triple(a,like,c).

triple(b,name,jane).
triple(b,age,26).
triple(b,friend,d).

triple(c,name,lagavulin).
triple(c,age,16).

triple(d,name,tom).
triple(d,age,24).
triple(d,friend,b).
triple(d,owns,f).

triple(f,name,wildcat).
triple(f,brand,porsche).
triple(f,type,911).
```

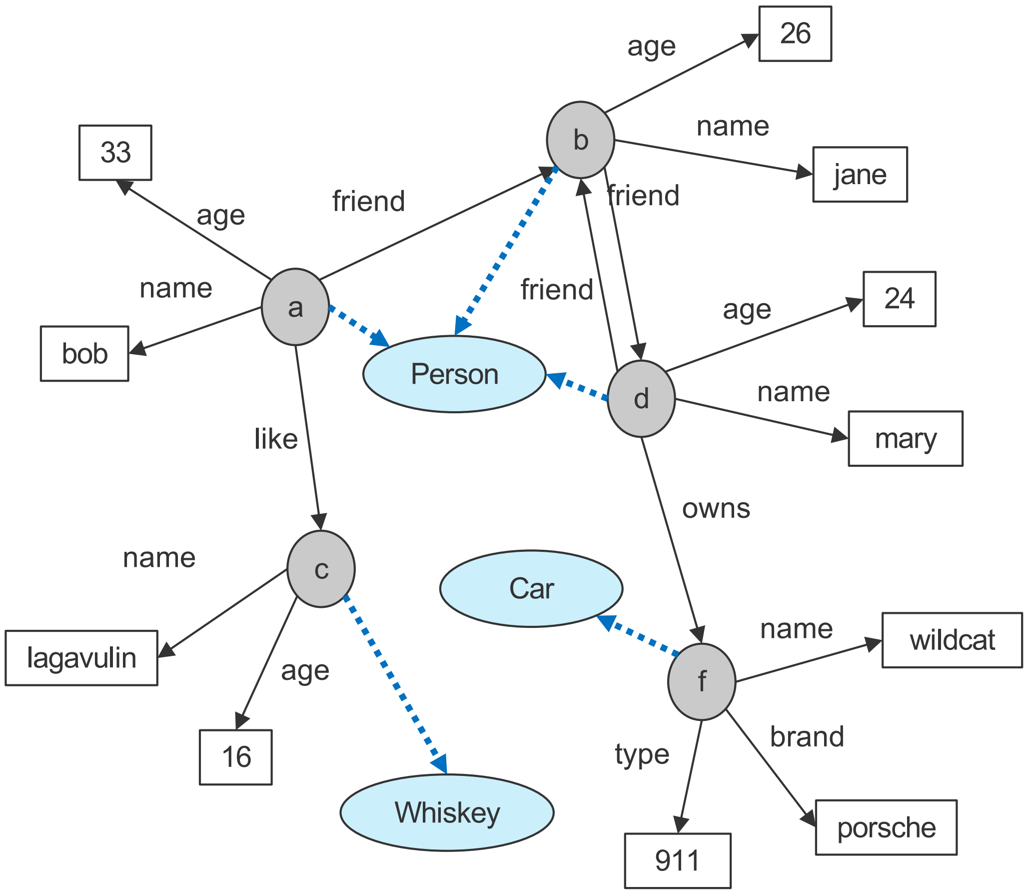
Types

- Some nodes are of a specific type
- Relationship to a type can be stored with "**rdf:type**"

```
triple(<start-node>, rdf:type, <Type>)
```

- Types are schema elements

Example: KnowledgeNets, Triples and Types




```
triple(a,rdf:type,Person)
triple(a,name,bob).
triple(a,age,33).
triple(a,friend,b).
triple(a,like,c).

triple(b,rdf:type,Person)
triple(b,name,jane).
triple(b,age,26).
triple(b,friend,d).

triple(c,rdf:type,Whiskey)
triple(c,name,lagavulin).
triple(c,age,16).

triple(d,rdf:type,Person)
triple(d,name,tom).
triple(d,age,24).
triple(d,friend,b).
triple(d,owns,f).

triple(f,rdf:type,Car)
triple(f,name,wildcat).
triple(f,brand,porsche).
triple(f,type,911).
```

RDF

Basic Ideas of RDF

- Basic building block: **object-attribute-value** triple
  - Simple form of object-orientation
  - Triple is (also) called a **statement**
  - Sometimes also called **Subject-Predicate-Object** in analogy to the simplified structure of English sentences.
- RDF data source = set of object-attribute-value triples
- RDF has been given a syntax in XML
  - This syntax inherits the benefits of XML
  - Other syntactic representations of RDF possible

The fundamental concepts of RDF

- Resources
- Properties
- Statements

Resources

- We can think of a resource as an object, an instance, a "thing" we want to talk about
  - In the example: a, b, c, d, ….
- Every resource has a URI, a Universal Resource Identifier
- A URI can be
  - a URL (Web address) or
  - some other kind of unique identifier
- Example: Every node is a resource

Properties

- They describe relations between resources
  - E.g. “name”, “age”, “brand”, etc.
- Properties are a special kind of resources
- Properties are also identified by URIs !!
- Advantages of using URIs:
  - A global, worldwide, unique naming scheme (idea)
  - Reduces the homonym problem of distributed data representation

Statements

- Statements assert the properties to resources
- A statement is an object-attribute-value triple
  - It consists of a resource, a property, and a value
- Values can be resources or **literals**
  - Literals are atomic values (strings, numbers, etc)

Three Views of a Statement

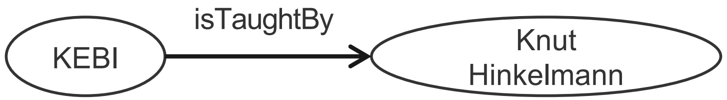
- A triple
- A piece of a graph
- A piece of XML code

Thus an RDF document can be viewed as:

- A set of triples
- A graph (Knowledge Net)
- An XML document

RDF SCHEMA

RDF and RDF Schema



- Want to express:
  - There are classes like Courses, Lecturers, Professors, Staff Members etc
  - Relationships between these classes
  - Relationship “isTaughtBy” starts from a Course and ends in a Acadenic Staff Member
- Want to do:
  - Assign (automatically) instances to (all of) their classes
  - Complete the relationships (also on the schema level)

Basic Ideas of RDF Schema

- RDF is a universal language that lets users describe resources in their own vocabularies
  - RDF does not assume, nor does it define semantics of any particular application domain
- The user can do so in RDF Schema using:
  - Classes and Properties
  - Class Hierarchies and Inheritance
  - Property Hierarchies
- The reasoning comes with the schema!

Classes and their Instances

- We must distinguish between
  - Concrete “things” (individual objects) in the domain: “KEBI”, “Knut Hinkelmann”, etc.
  - Sets of individuals sharing properties called classes: Course, Lecturer, Staff Member etc.
- Individual objects that belong to a class are referred to as instances of that class
- The relationship between instances and classes in RDF is defined through **rdf:type**

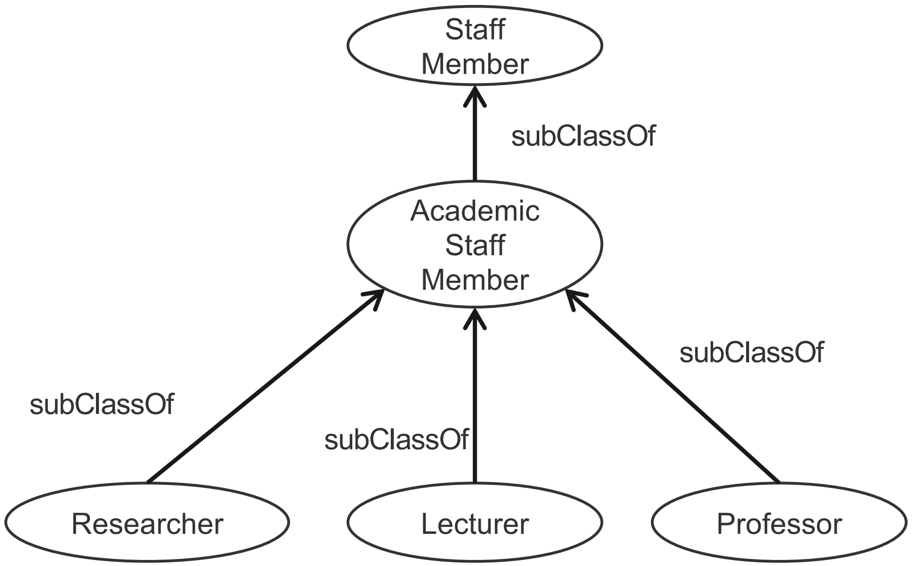
Nonsensical Statements disallowed through the Use of Classes

- KEBI is taught by Concrete Maths
  - We want courses to be taught by lecturers only
  - Restriction on values of the property "is taught by" (**range restriction**)
- Room AB1 is taught by Knut Hinkelmann
  - Only courses can be taught
  - This imposes a restriction on the objects to which the property can be applied (**domain restriction**)
- Range and Domain restrictions are defined with the relations **rdfs:range** and **rdfs:domain**

Class Hierarchies

- Classes can be organised in hierarchies
  - A is a subclass of B if every instance of A is also an instance of B
  - Then B is a superclass of A
- A subclass graph need not be a tree
- A class may have multiple superclasses
- The relationship between sub- and superclass is defined through **rdfs:subClassOf**

Class Hierarchy Example



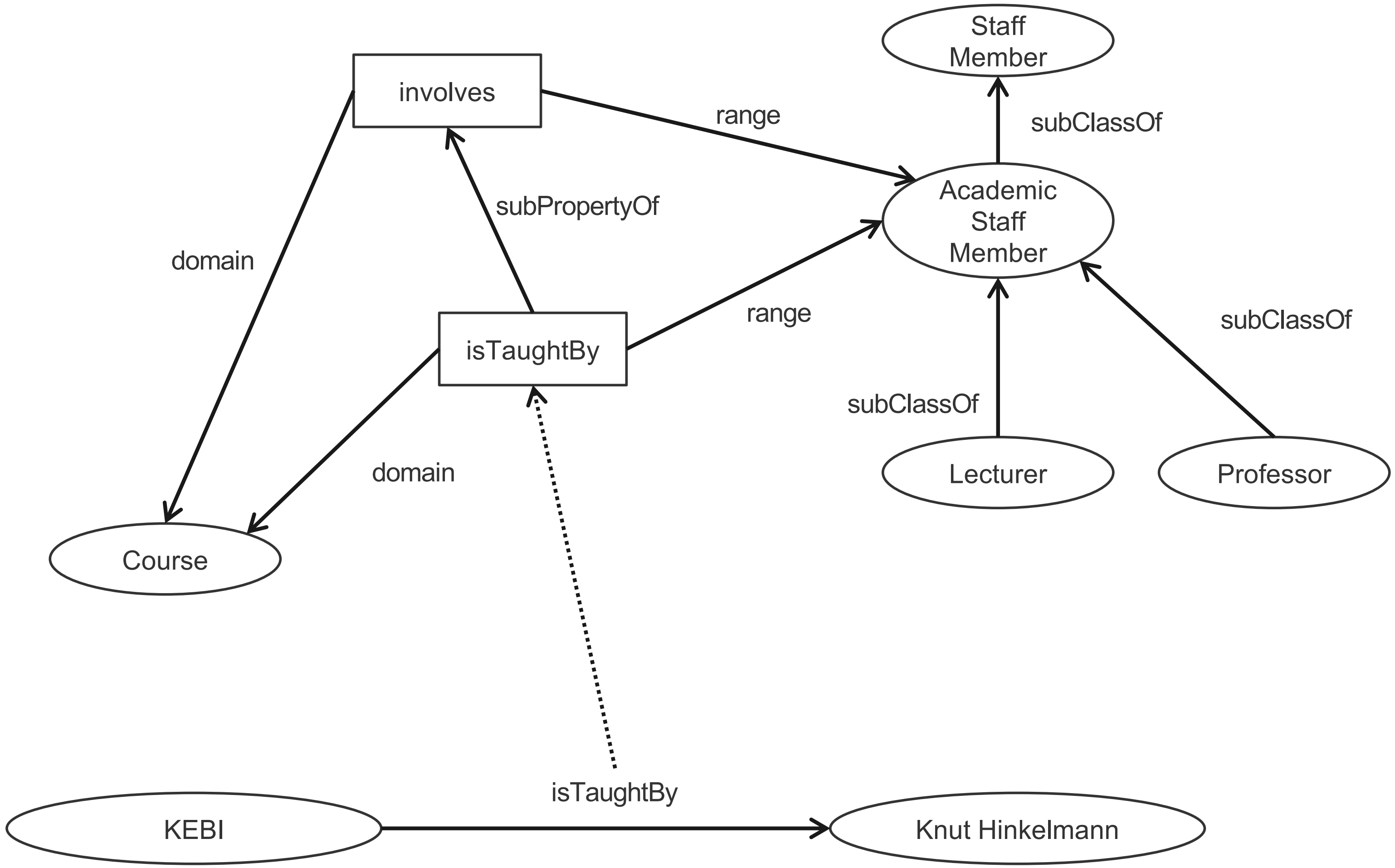
Inheritance in Class Hierarchies

- Range restriction: **Courses must be taught by academic staff members only**
- Barbara Re is a professor
- She inherits the ability to teach from the class of academic staff members
- This is done in RDF Schema by fixing the semantics of "is a subclass of"
  - It is not up to an application (RDF processing software) to interpret "is a subclass of"

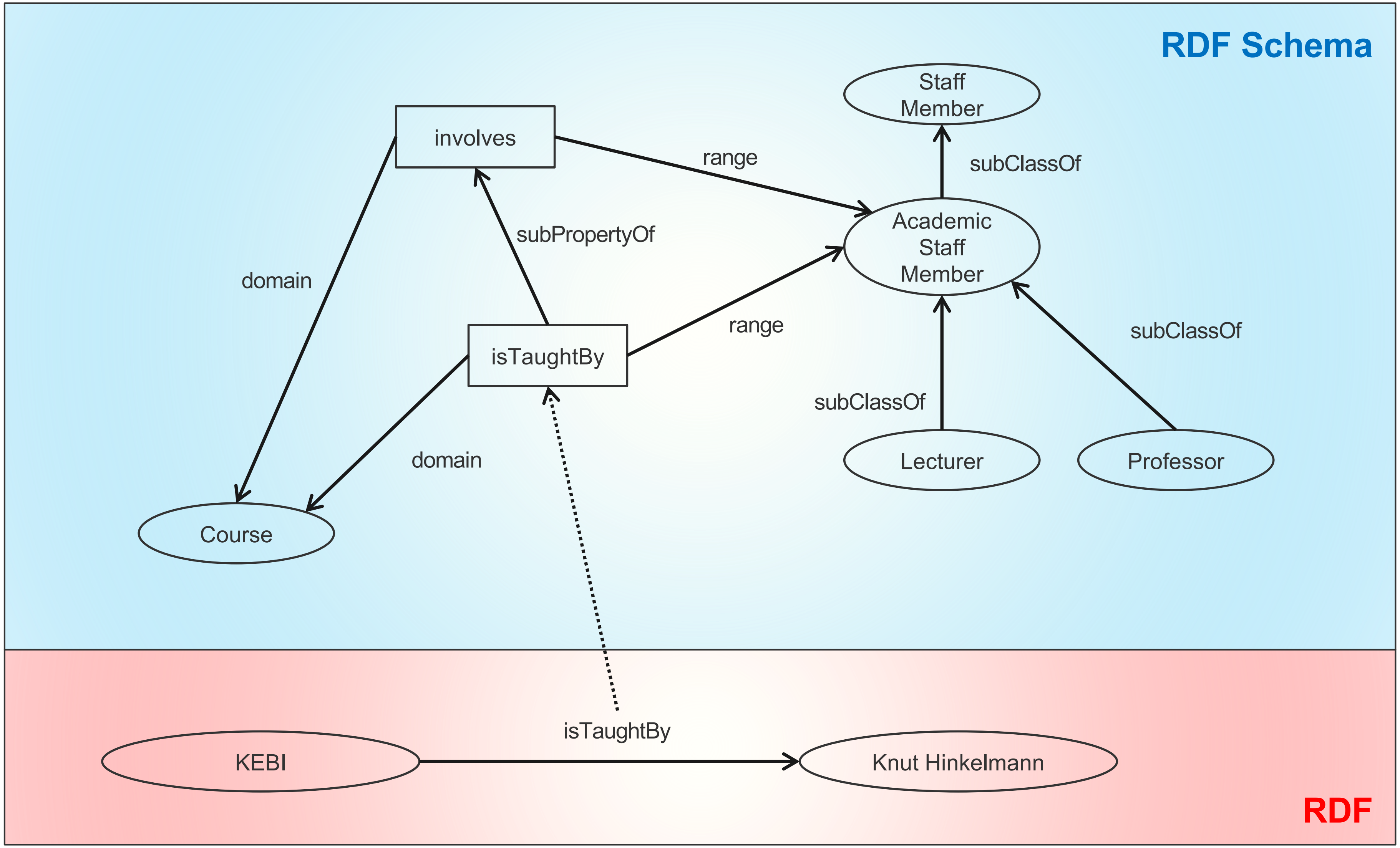
Property Hierarchies

- Hierarchical relationships for properties
  - E.g., “is taught by” is a subproperty of “involves”
  - If a course C is taught by an academic staff member A, then C also involves A
- The converse is not necessarily true
  - E.g., A may be the teacher of the course C, or
  - a tutor who marks student homework but does not teach C
- P is a subproperty of Q, if Q(x,y) is true whenever P(x,y) is true
- The relationship between sub- and superproperties is defined through **rdfs:subPropertyOf**

RDF Layer vs RDF Schema Layer



RDF Layer vs RDF Schema Layer



REASONING IN RDF SCHEMA

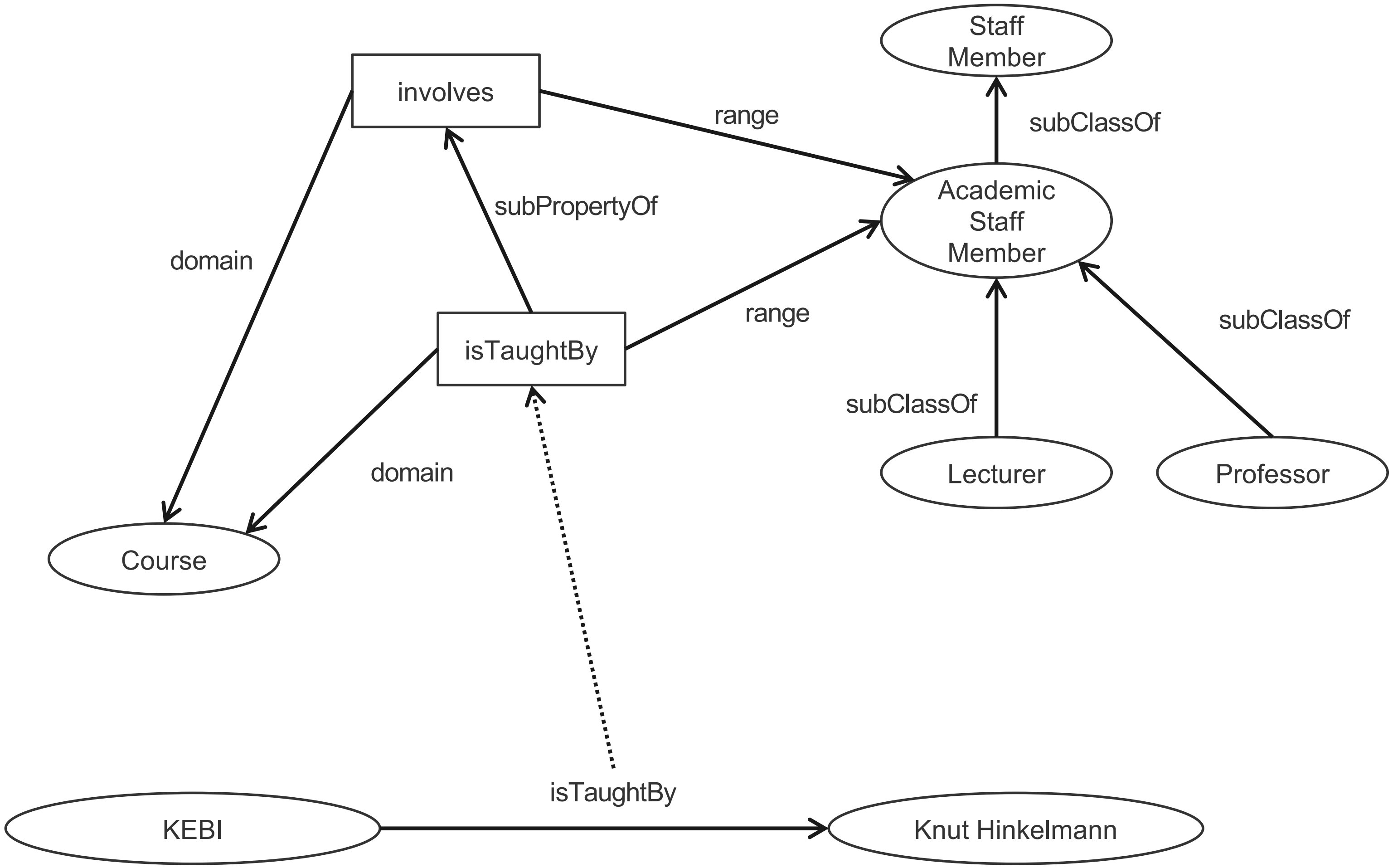
Semantics based on Inference Rules

- Semantics in terms of RDF triples
- … and sound and complete inference systems
- This inference system consists of inference rules of the form:

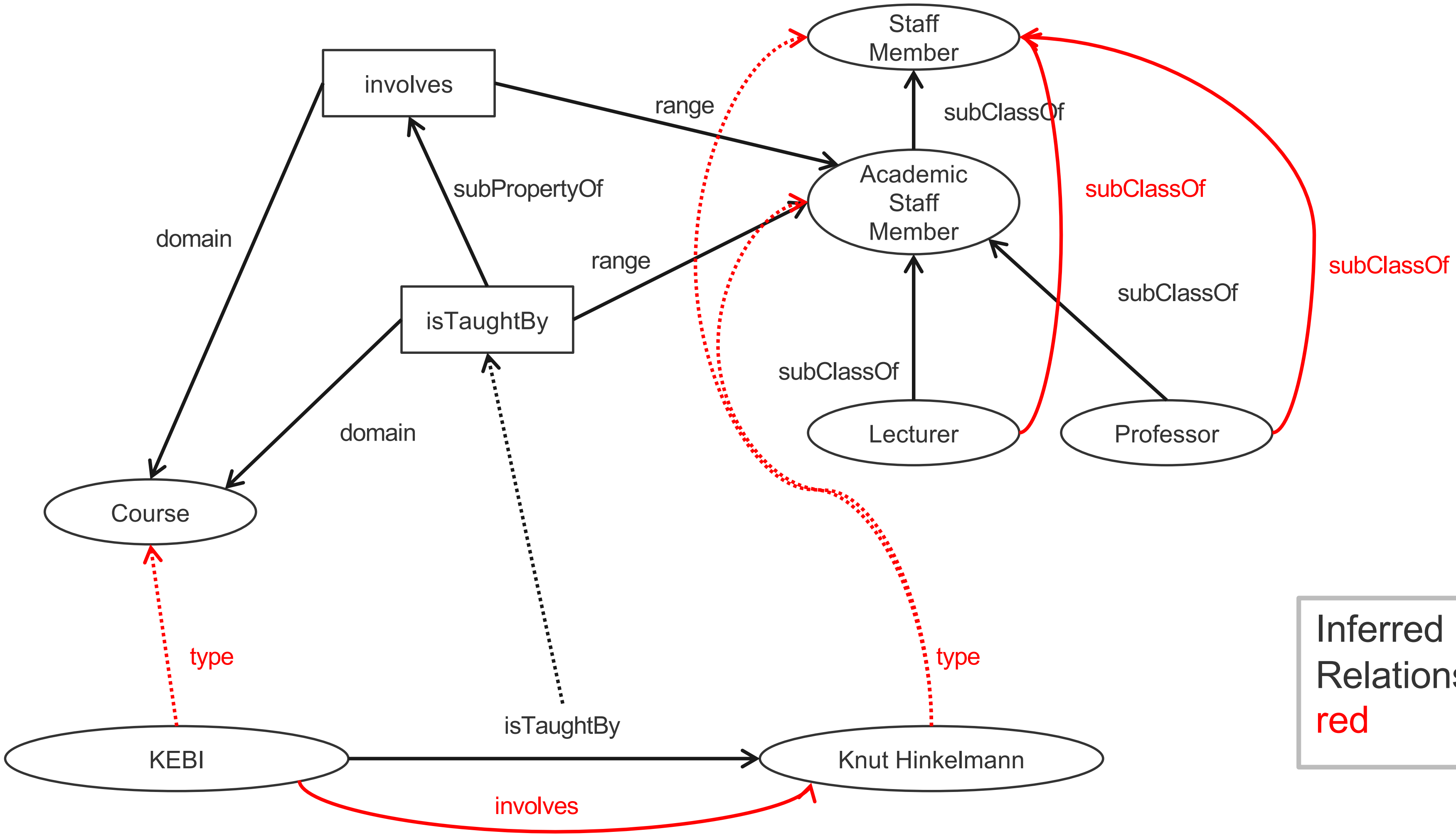
  IF E contains certain triples
  THEN add to E certain additional triples

- where **E** is an arbitrary set of RDF triples
- Sometimes inference rules also called entailment rules.

Example for Inferences made by Inference Rules (1/2)



Example for Inferences made by Inference Rules (2/2)



Inferred Relationships in red

?x, ?p, ?<letter>
are variables

Example of Inference Rules

```
triple(Y,rdf:type,U) :-
          triple(X,P,Y),
          triple(P,rdfs:range,U).
```

IF (?x, ?p, ?y),

(?p, **rdfs:range**, ?u)

THEN (?y, **rdf:type**, ?u)

- Any resource **?y** which appears as the value of a property **?p** can be inferred to be a member (type) of **?u**
  - This shows that range definitions in RDF Schema are not used to restrict the range of a property, but rather to infer the membership of the range

?x, ?p, ?<letter>
are variables

Example of Inference Rules

IF (?x, ?p, ?y),

(?p, **rdfs:domain**, ?u)

THEN (?x, **rdf:type**, ?u)v

- Any resource **?x** which appears as the domain of a property **?p** can be inferred to be a member of the domain of **?p**, i.e. **?u**
  - This shows that range definitions in RDF Schema are not used to restrict the range of a property, but rather to infer the membership of the range

?x, ?p, ?<letter> are variables

Further Examples of Inference Rules

IF (?x, **rdf:type**, ?u),
(?u, **rdfs:subClassOf**, ?v)
THEN (?x, **rdf:type**, ?v)

IF (?u, **rdfs:subClassOf**, ?v),
(?v, **rdfs:subClassOf**, ?w)
THEN (?u, **rdfs:subClassOf**, ?w)

IF (?x, ?p, ?y)
THEN (?p, rdf:type, rdf:property)

RDF(S) Semantics: Examples

IF	(netherlands, **rdf:type,** EuropeanCountry),
	(EuropeanCountry, **rdfs:subClassOf,** Country)
THEN	(netherlands, **rdf:type,** Country)

IF	(aspirin, alleviates, headache),
	(alleviates, **rdfs:range,** Symptom)
THEN	(headache, **rdf:type,** Symptom)

RDF(S) Semantics: Examples

IF (Νετηερλανδσ, **rdf:type**, ΕυροπεανΧουντρψ),
(ΕυροπεανΧουντρψ, **rdfs:subClassOf**, Χουντρψ)
THEN (Νετηερλανδσ, **rdf:type**, Χουντρψ)

IF (ασπιριν, αλλεϖιατεσ, ηεαδαχηε),
(αλλεϖιατεσ, **rdfs:range**, σψμπτομ)
THEN (ηεαδαχηε, **rdf:type**, σψμπτομ)

All 13 RDFS entailment rules

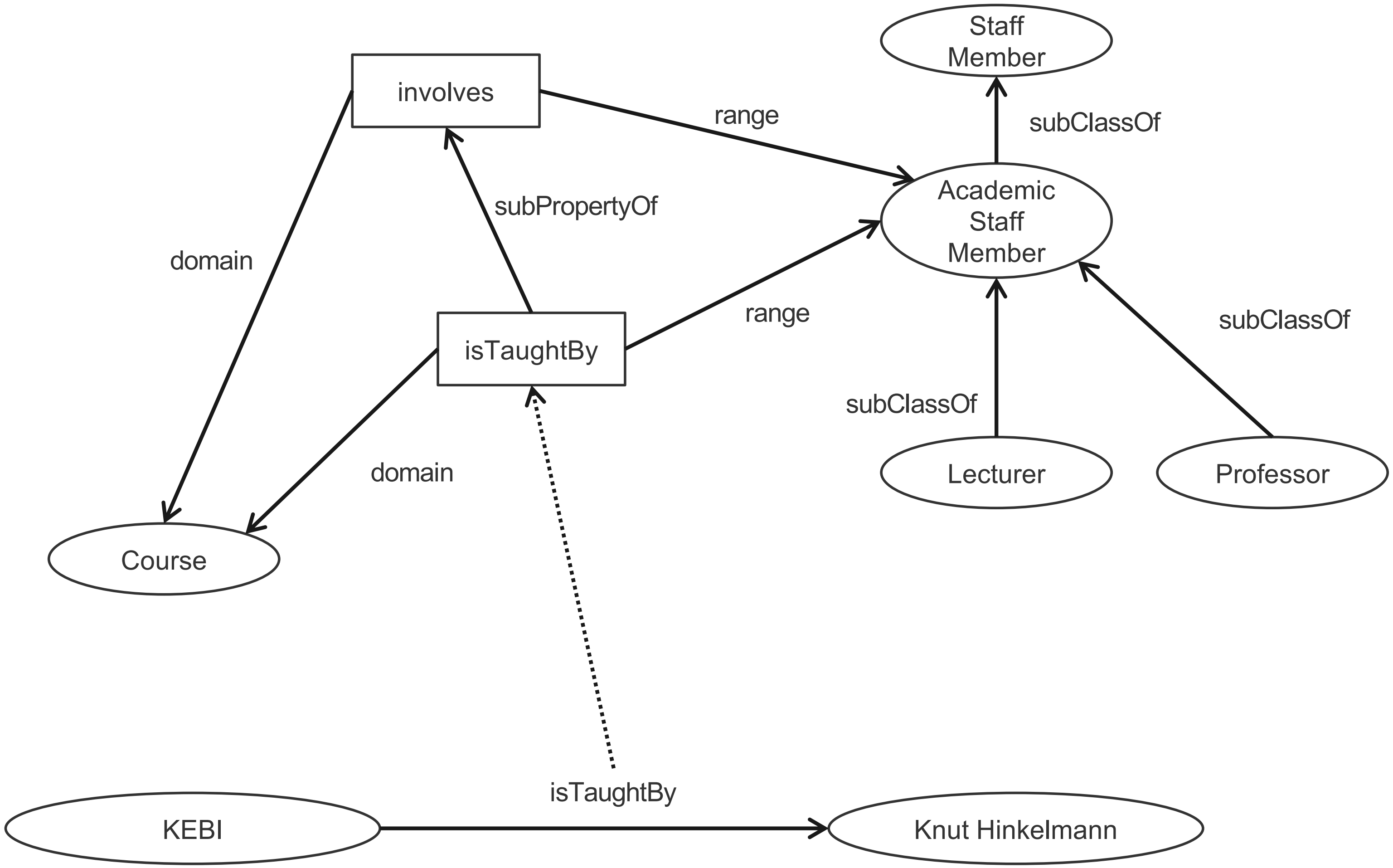
Rule Name	If E contains:	then add:
rdfs1	?u ?p ?n. where ?n is a plain literal (with or without a language tag).	_:nnn rdf:type rdfs:Literal . where _:nnn identifies a blank node allocated to ?n by rule lg.
rdfs2	?p rdfs:domain ?x . ?u ?p ?y .	?u rdf:type ?x .
rdfs3	?p rdfs:range ?x . ?u ?p ?v .	?v rdf:type ?x .
rdfs4a	?u ?p ?x .	?u rdf:type rdfs:Resource .
rdfs4b	?u ?p ?v.	?v rdf:type rdfs:Resource .
rdfs5	?u rdfs:subPropertyOf ?v . ?v rdfs:subPropertyOf ?x .	?u rdfs:subPropertyOf ?x .
rdfs6	?u rdf:type rdf:Property .	?u rdfs:subPropertyOf ?u .
rdfs7	?p rdfs:subPropertyOf ?q . ?u ?p ?y .	?u ?q ?y .
rdfs8	?u rdf:type rdfs:Class .	?u rdfs:subClassOf rdfs:Resource .
rdfs9	?u rdfs:subClassOf ?x . ?v rdf:type ?u .	?v rdf:type ?x .
rdfs10	?u rdf:type rdfs:Class .	?u rdfs:subClassOf ?u .
rdfs11	?u rdfs:subClassOf ?v . ?v rdfs:subClassOf ?x .	?u rdfs:subClassOf ?x .
rdfs12	?u rdf:type rdfs:ContainerMembershipProperty .	?u rdfs:subPropertyOf rdfs:member .
rdfs13	?u rdf:type rdfs:Datatype .	?u rdfs:subClassOf rdfs:Literal .

All 13 RDFS entailment rules (sorted)

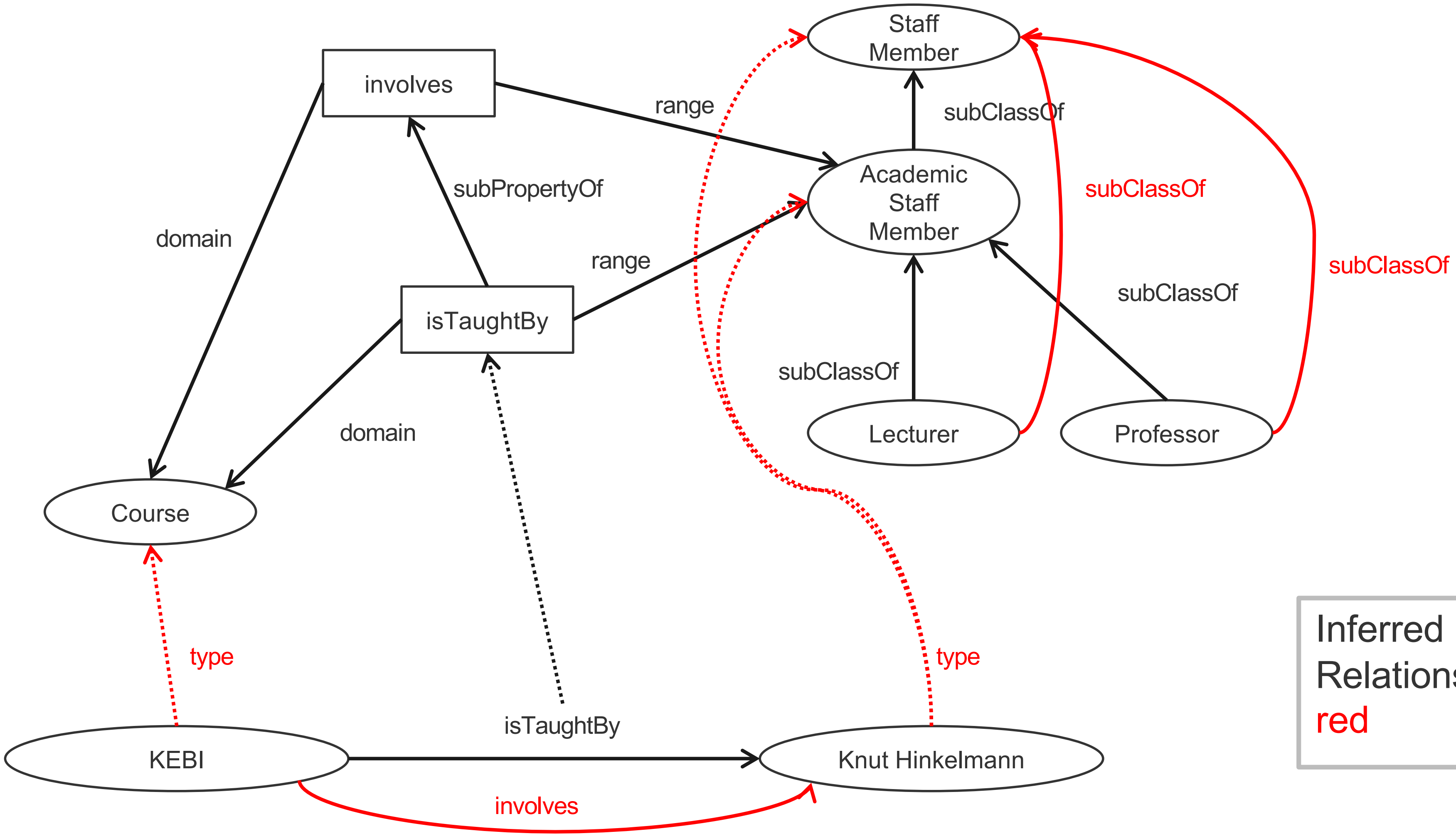
Rule Name	If E contains:	then add:
rdfs2	?p rdfs:domain ?x . ?u ?p ?y .	?u rdf:type ?x .
rdfs3	?p rdfs:range ?x . ?u ?p ?v .	?v rdf:type ?x .
rdfs5	?u rdfs:subPropertyOf ?v . ?v rdfs:subPropertyOf ?x .	?u rdfs:subPropertyOf ?x .
rdfs7	?p rdfs:subPropertyOf ?q . ?u ?p ?y .	?u ?q ?y .
rdfs9	?u rdfs:subClassOf ?x . ?v rdf:type ?u .	?v rdf:type ?x .
rdfs11	?u rdfs:subClassOf ?v . ?v rdfs:subClassOf ?x .	?u rdfs:subClassOf ?x .

Rule Name	If E contains:	then add:
rdfs6	?u rdf:type rdf:Property .	?u rdfs:subPropertyOf ?u .
rdfs10	?u rdf:type rdfs:Class .	?u rdfs:subClassOf ?u .
rdfs1	?u ?p ?n. where ?n is a plain literal (with or without a language tag).	_:nnn rdf:type rdfs:Literal . where _:nnn identifies a blank node allocated to ?n by rule lg.
rdfs4a	?u ?p ?x .	?u rdf:type rdfs:Resource .
rdfs4b	?u ?p ?v.	?v rdf:type rdfs:Resource .
rdfs8	?u rdf:type rdfs:Class .	?u rdfs:subClassOf rdfs:Resource .
rdfs12	?u rdf:type rdfs:ContainerMembershipProperty .	?u rdfs:subPropertyOf rdfs:member .
rdfs13	?u rdf:type rdfs:Datatype .	?u rdfs:subClassOf rdfs:Literal .

Example for Inferences made by Inference Rules (no Inference)

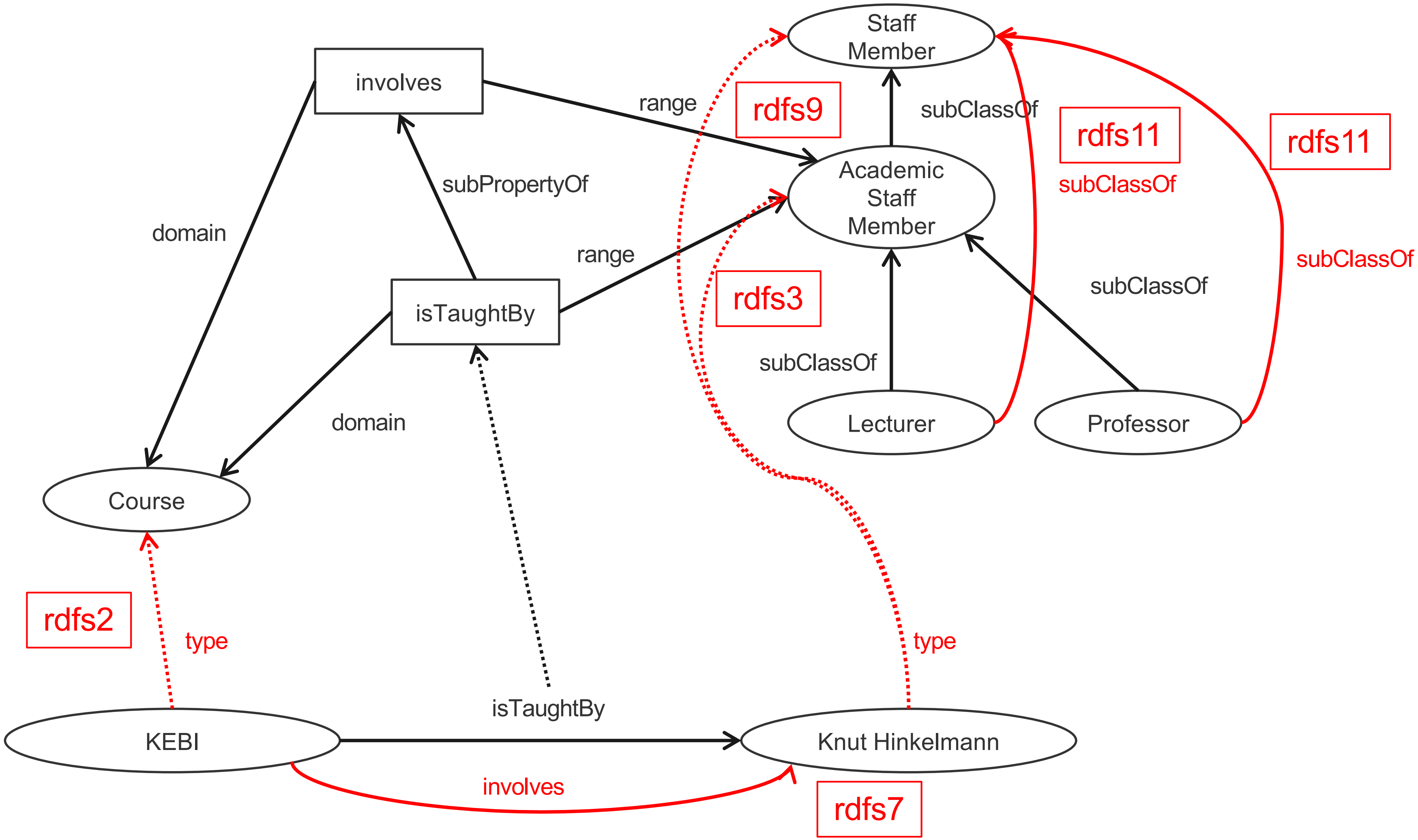


Example for Inferences made by Inference Rules ("useful" inferences)

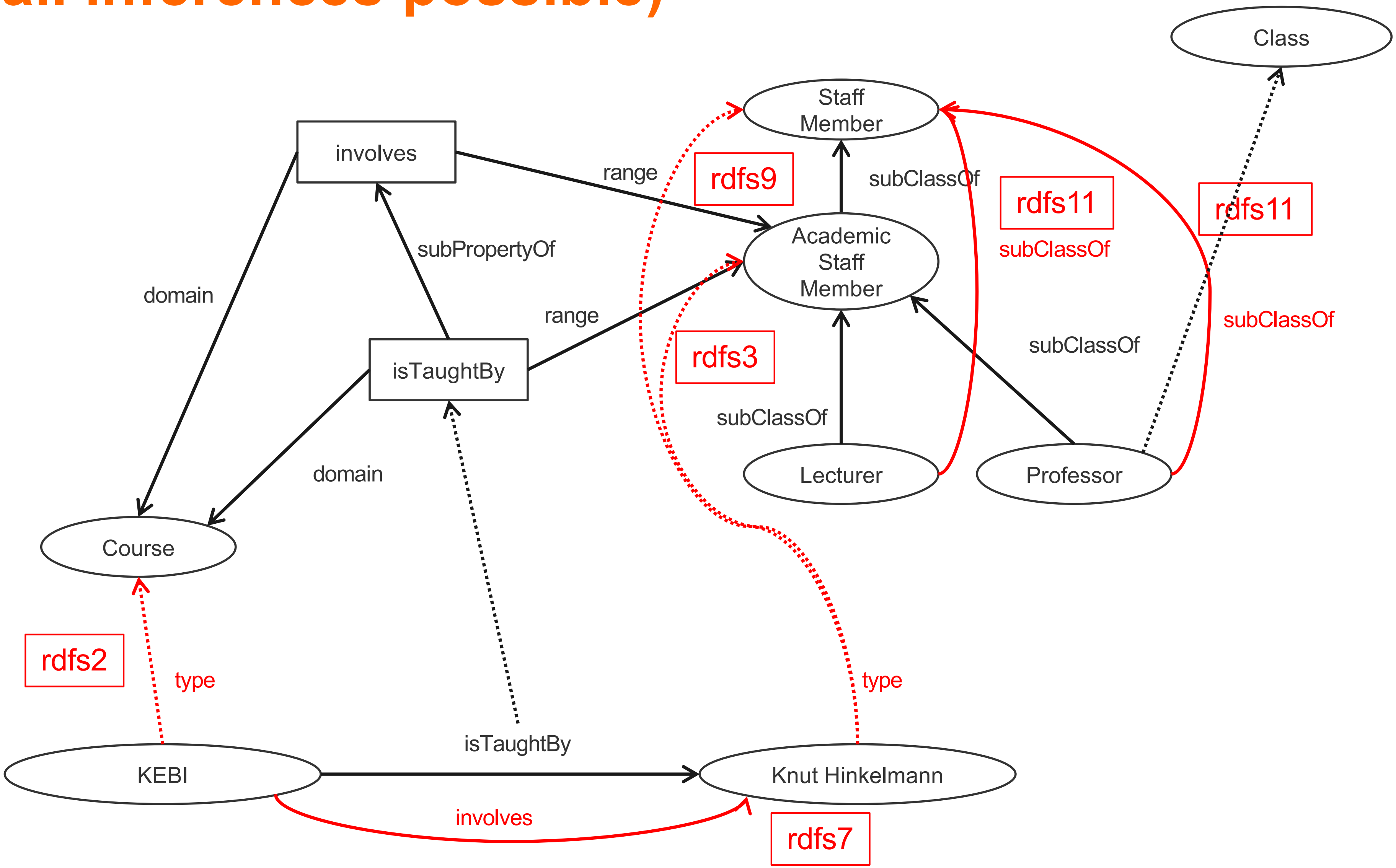


Inferred Relationships in red

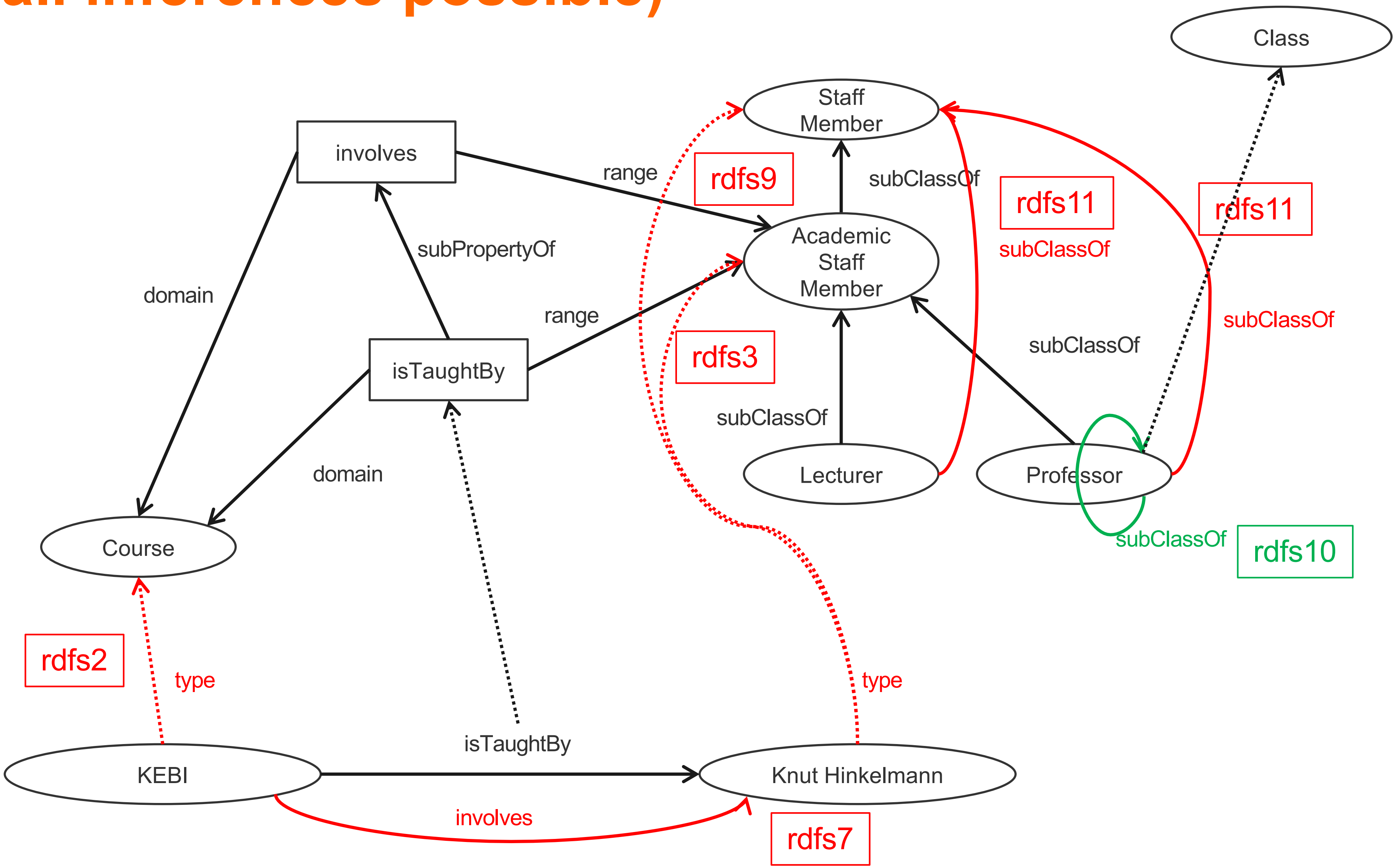
Example for Inferences made by Inference Rules (rules for “usefull” inferences)



Example for Inferences made by Inference Rules (all inferences possible)



Example for Inferences made by Inference Rules (all inferences possible)



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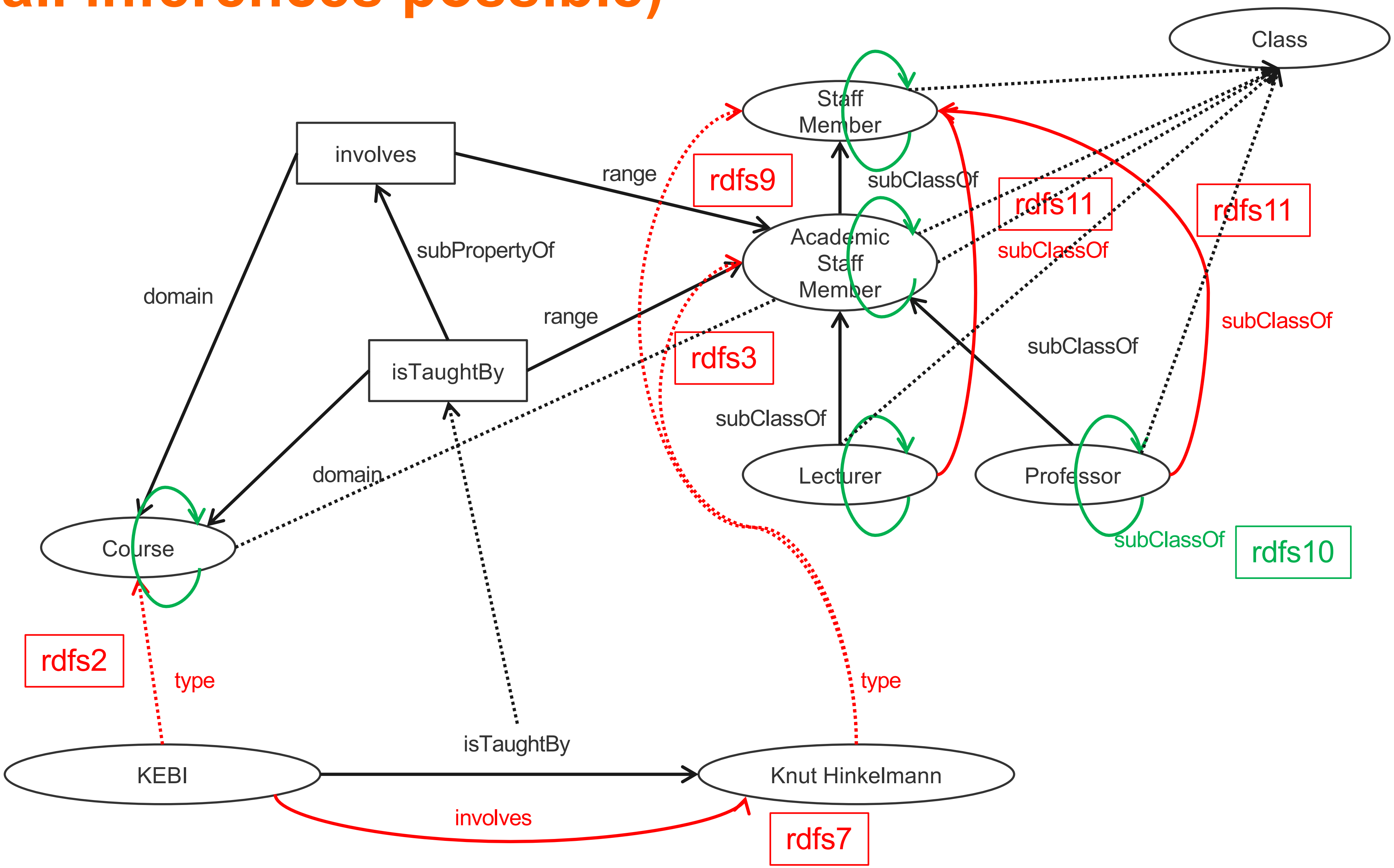
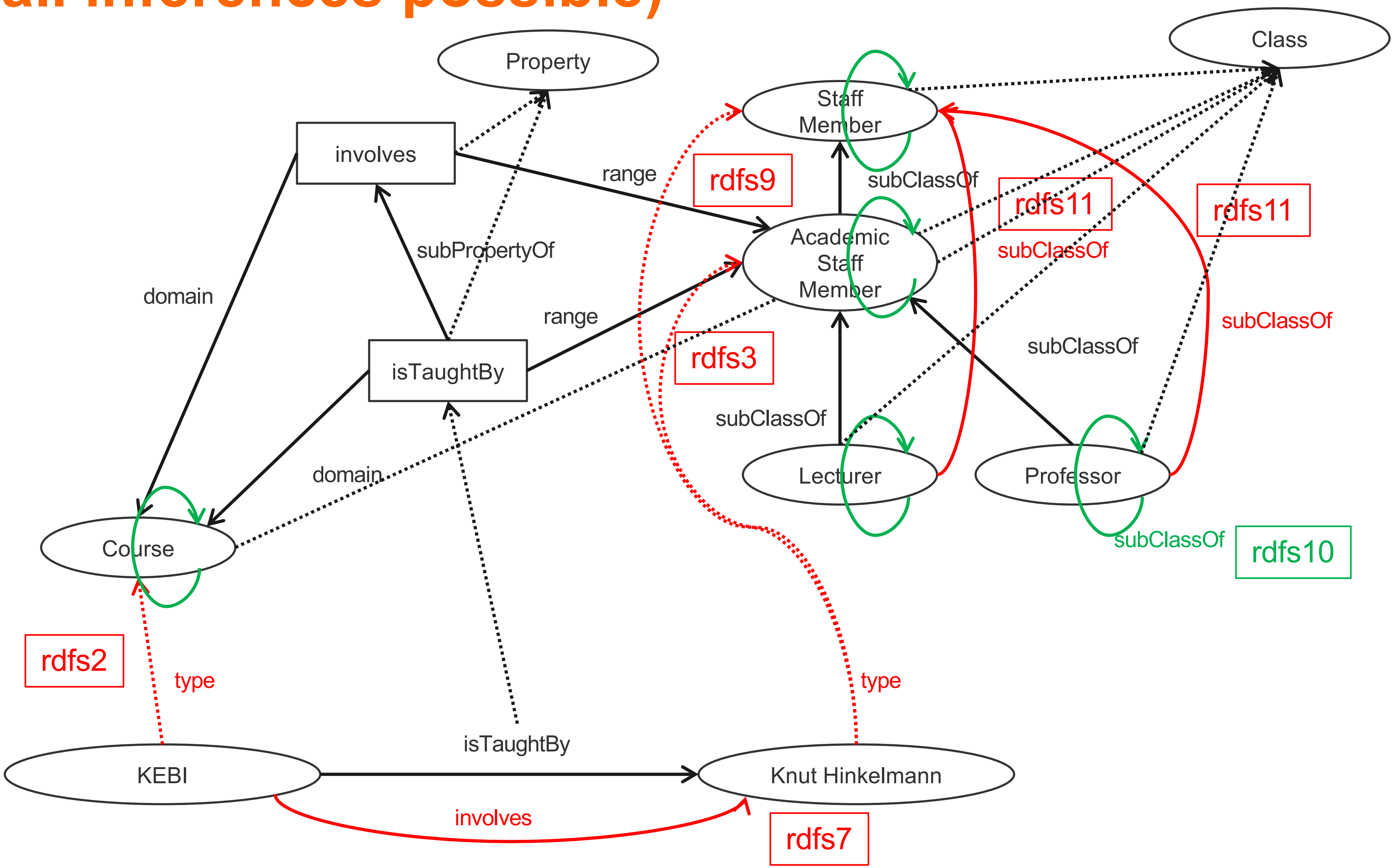


Example for Inferences made by Inference Rules (all inferences possible)



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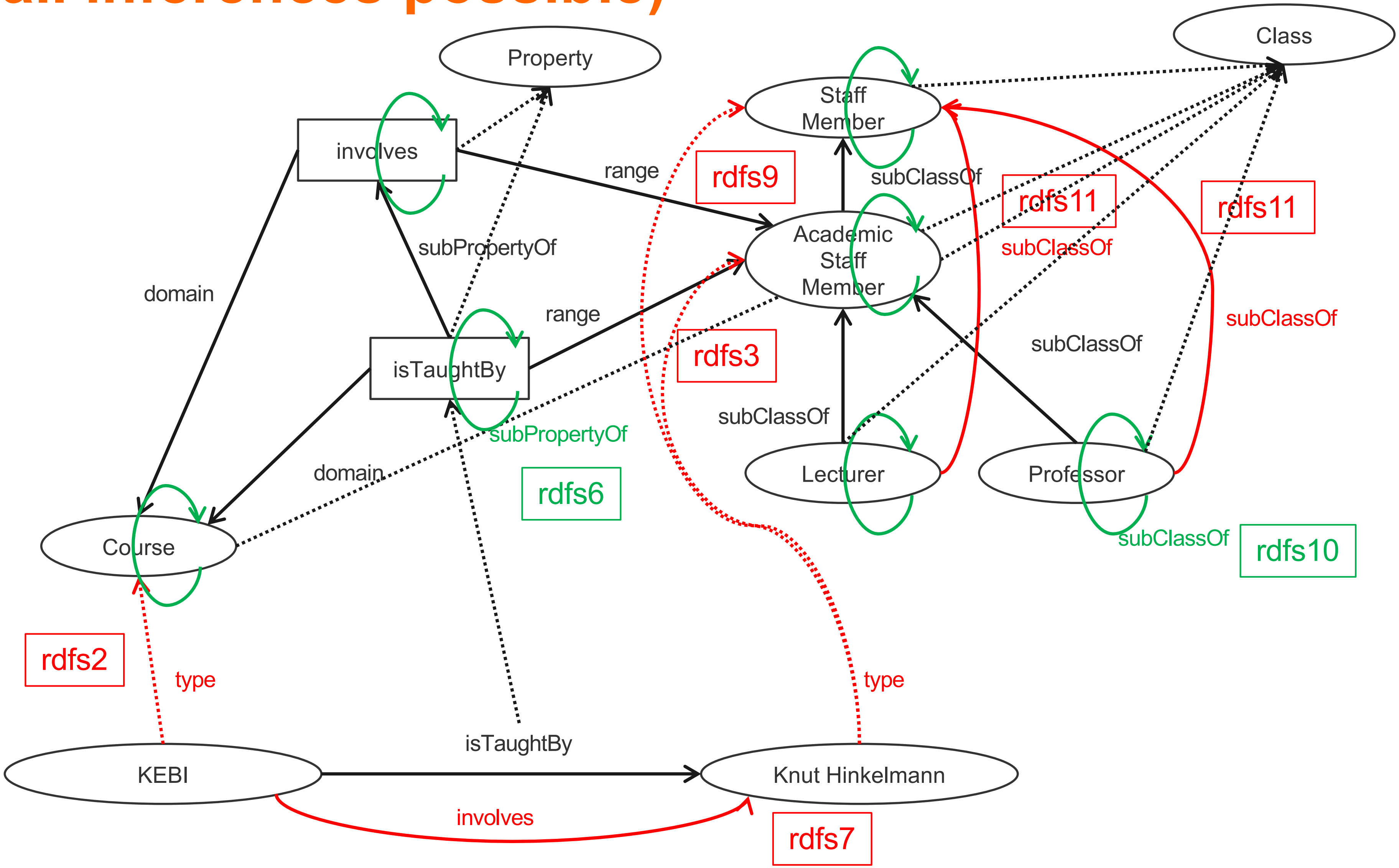
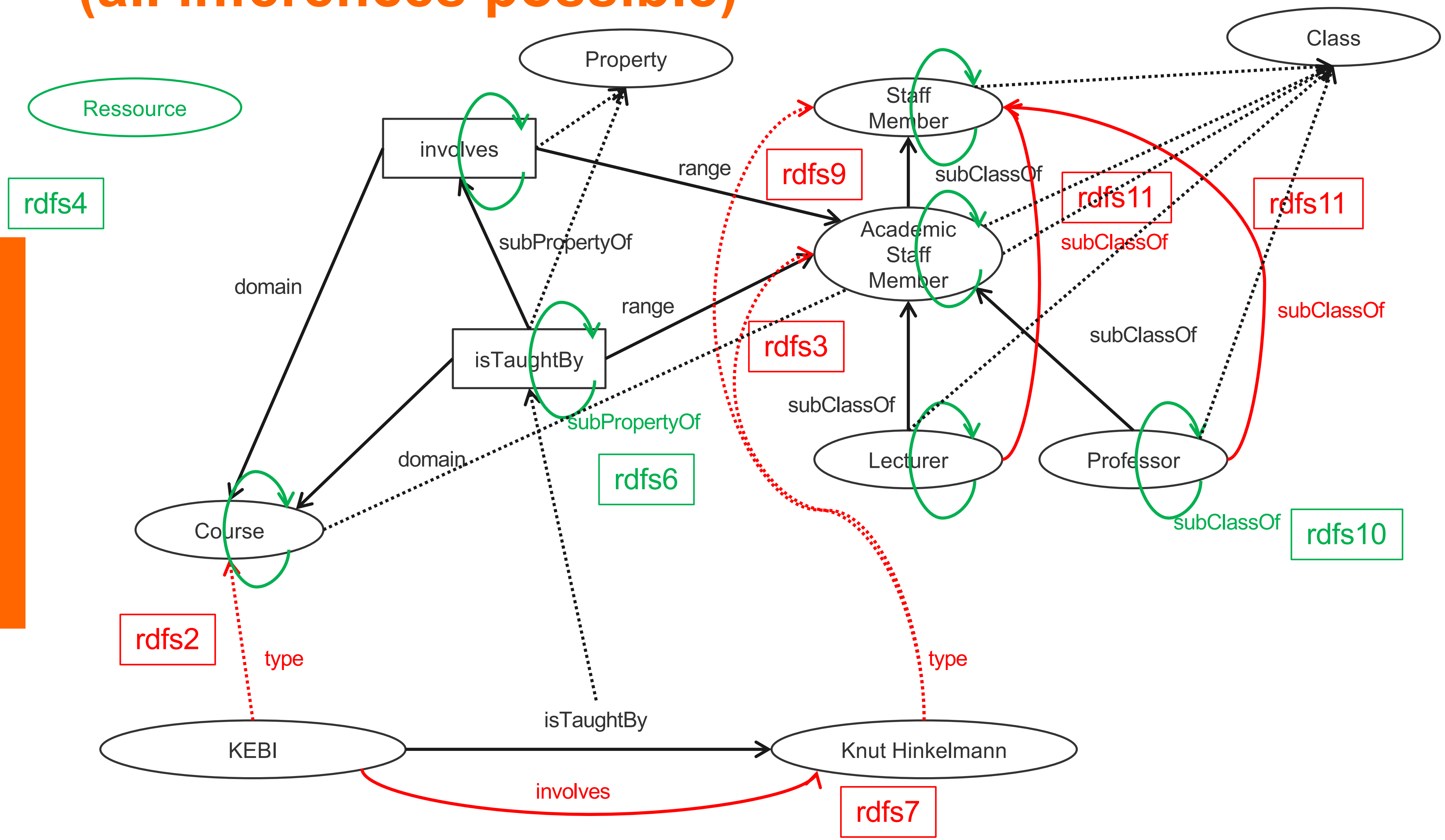
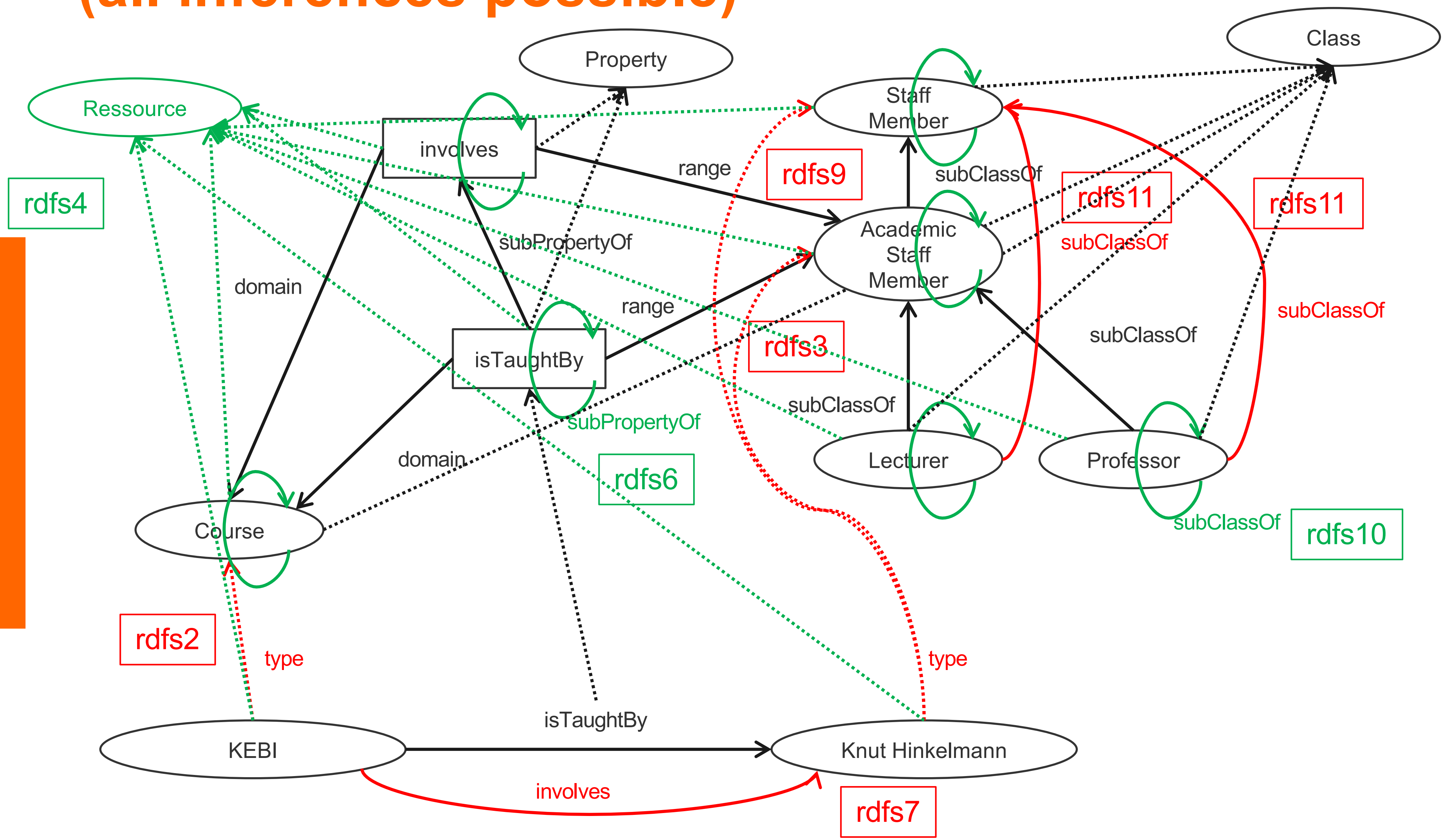


Example for Inferences made by Inference Rules (all inferences possible)



Example for Inferences made by Inference Rules (all inferences possible)



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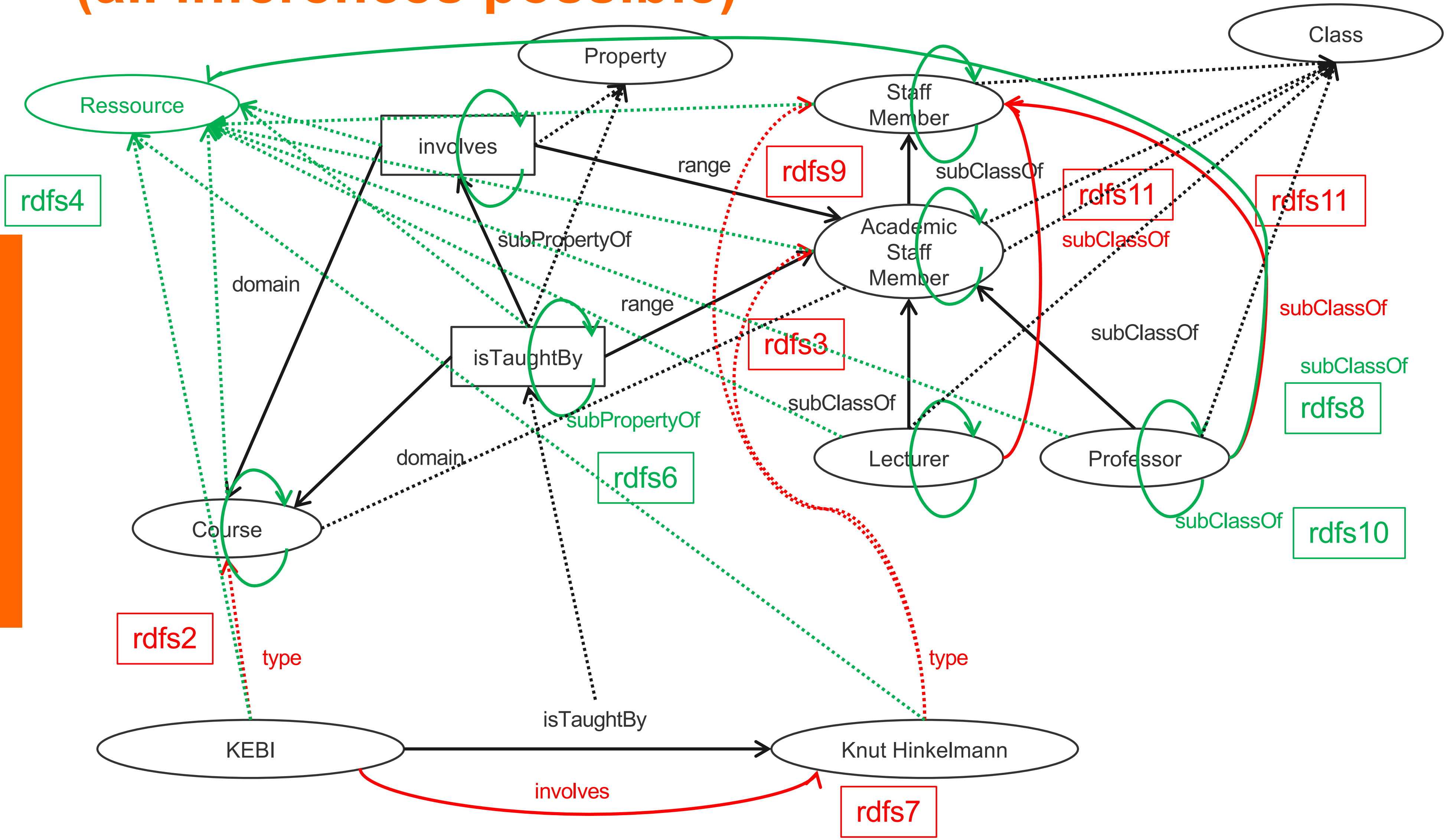
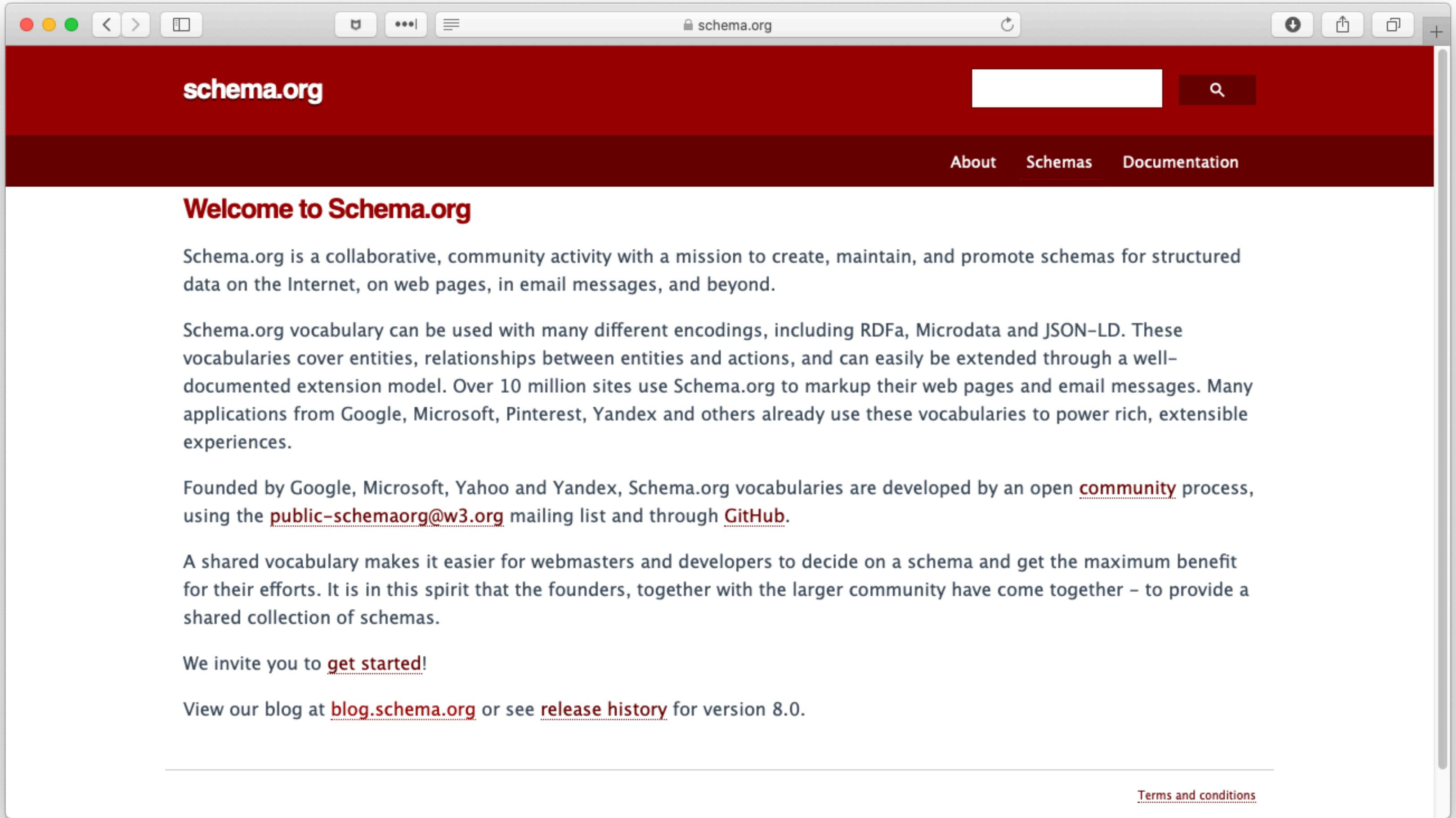


Summary

- RDF has a graph-based data model
- RDF has an XML-based syntax to support syntactic interoperability.
  - XML and RDF complement each other because RDF supports semantic interoperability
- RDF is domain-independent
- RDF Schema provides a mechanism for describing specific domains
- RDF Schema is a primitive ontology language
  - It offers certain modelling primitives with fixed meaning
- Key concepts of RDF Schema are class, subclass relations, property, subproperty relations, and domain and range restrictions
- There exist query languages for RDF and RDFS

GOOGLE'S KNOWLEDGE GRAPHS

schema.org



schema.org

About Schemas Documentation

Welcome to Schema.org

Schema.org is a collaborative, community activity with a mission to create, maintain, and promote schemas for structured data on the Internet, on web pages, in email messages, and beyond.

Schema.org vocabulary can be used with many different encodings, including RDFa, Microdata and JSON-LD. These vocabularies cover entities, relationships between entities and actions, and can easily be extended through a well-documented extension model. Over 10 million sites use Schema.org to markup their web pages and email messages. Many applications from Google, Microsoft, Pinterest, Yandex and others already use these vocabularies to power rich, extensible experiences.

Founded by Google, Microsoft, Yahoo and Yandex, Schema.org vocabularies are developed by an open community process, using the public-schemaorg@w3.org mailing list and through GitHub.

A shared vocabulary makes it easier for webmasters and developers to decide on a schema and get the maximum benefit for their efforts. It is in this spirit that the founders, together with the larger community have come together – to provide a shared collection of schemas.

We invite you to get started!

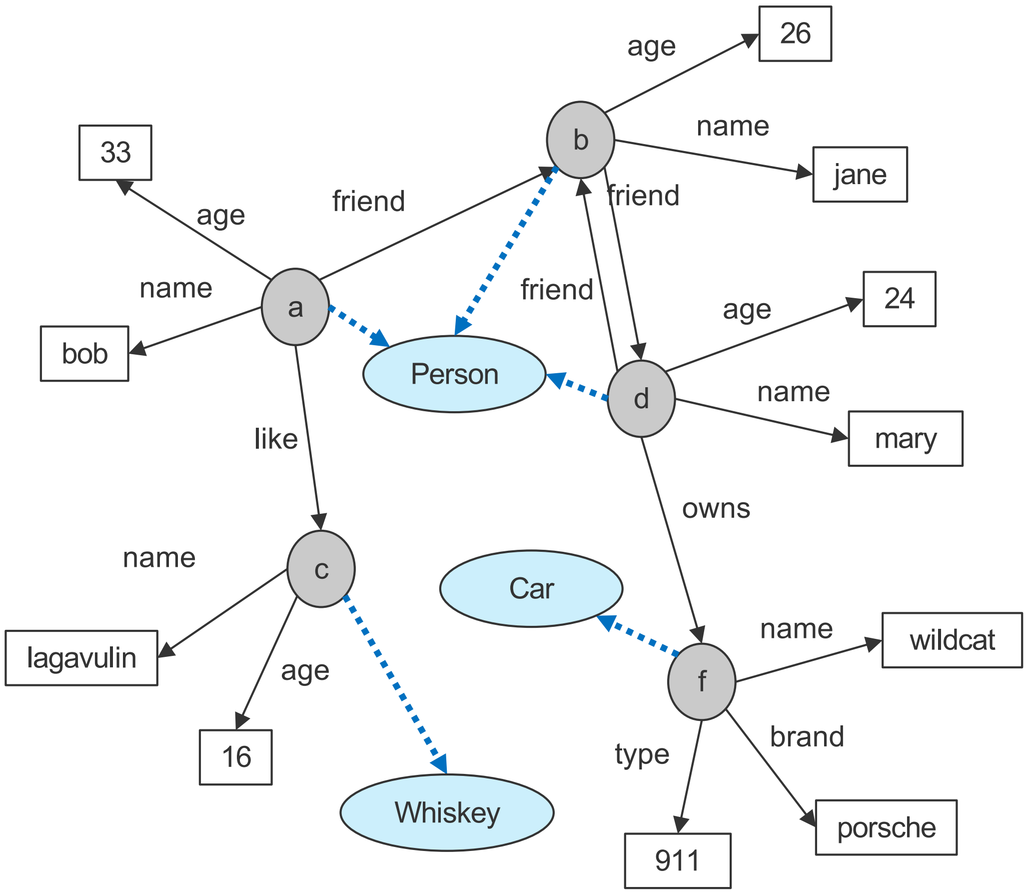
View our blog at blog.schema.org or see release history for version 8.0.

Terms and conditions

SPARQL: A QUERY LANGUAGE

```
name(a,bob).        triple(a,name,bob).
age(a,33).          triple(a,age,33).
friend(a,b).        triple(a,friend,b).
like(a,c).          triple(a,like,c).
name(b,jane).       triple(b,name,jane).
age(b,26).          triple(b,age,26).
friend(b,d).        triple(b,friend,d).
```

Example: Quering



Formulate the following queries

- Who has whom as friend?
  - ?- friend(X,Y).
  - ?- triple(X,friend,Y).
  - SELECT ?X ?Y
    WHERE { ?X friend ?Y.}
- Who are the friend-of-a-friend of whom?
  - ?- friend(X,Y), friend(Y,Z).
  - ?- triple(X,friend,Y), triple(Y,friend,Z).
  - SELECT ?X ?Z
    WHERE { ?X friend ?Y.
    ?Y friend ?Z. }
- Who has friends older than 25
  - ?- friend(X,Y), age(Y,A), A > 25.
  - ?- triple(X,friend,Y), triple(Y,age,A), A > 25.
  - SELECT ?X ?Y ?A
    WHERE { ?X friend ?Y.
    ?Y age ?A.
    FILTER ?A > 25. }

SPARQL Query Syntax

SPARQL similar to select-from-where syntax (like SQL):

- *PREFIX*: prefix information

```
prefix
        uni: <http://www.fhnw.ch/schema.rdfs#>
```

- *SELECT*: the entities (variables) you want to return

```
select ?X ?Y ?A
```

- *WHERE*: the (sub)graph you want to get the information from

```
where  { ?X friend ?Y. ?Y age ?A.
```

- additional constraints on objects, using operators

```
          FILTER  ?A > 25. }
```

SPARQL

- It provides facilities to:
  - Extract information in the form of URIs, blank nodes, plain and typed literals
  - Extract RDF subgraphs
  - Construct new RDF graphs based on information in the queried graphs
- Feature
  - Matching graph patterns
  - Query terms – based on Turtle syntax
  - Terms delimited by "<>" are relative URI references
  - Data description format - Turtle

Query forms

- **SELECT**
  - returns all, or a subset of the variables bound in a query pattern match
  - returned in a table
  - formats : XML or RDF/XML
- **CONSTRUCT**
  - returns an RDF graph constructed by substituting variables in a set of
  - triple templates
- **DESCRIBE**
  - returns an RDF graph that describes the resources found.
- **ASK**
  - returns whether a query pattern matches or not.

Query result: example

- Query: “return all those which has friends older than 25 with the cities they contain, and their areacodes, if known”

```
select ?X ?Y ?A
where { ?X friend ?Y. ?Y age ?A.
        FILTER ?A > 25}
```

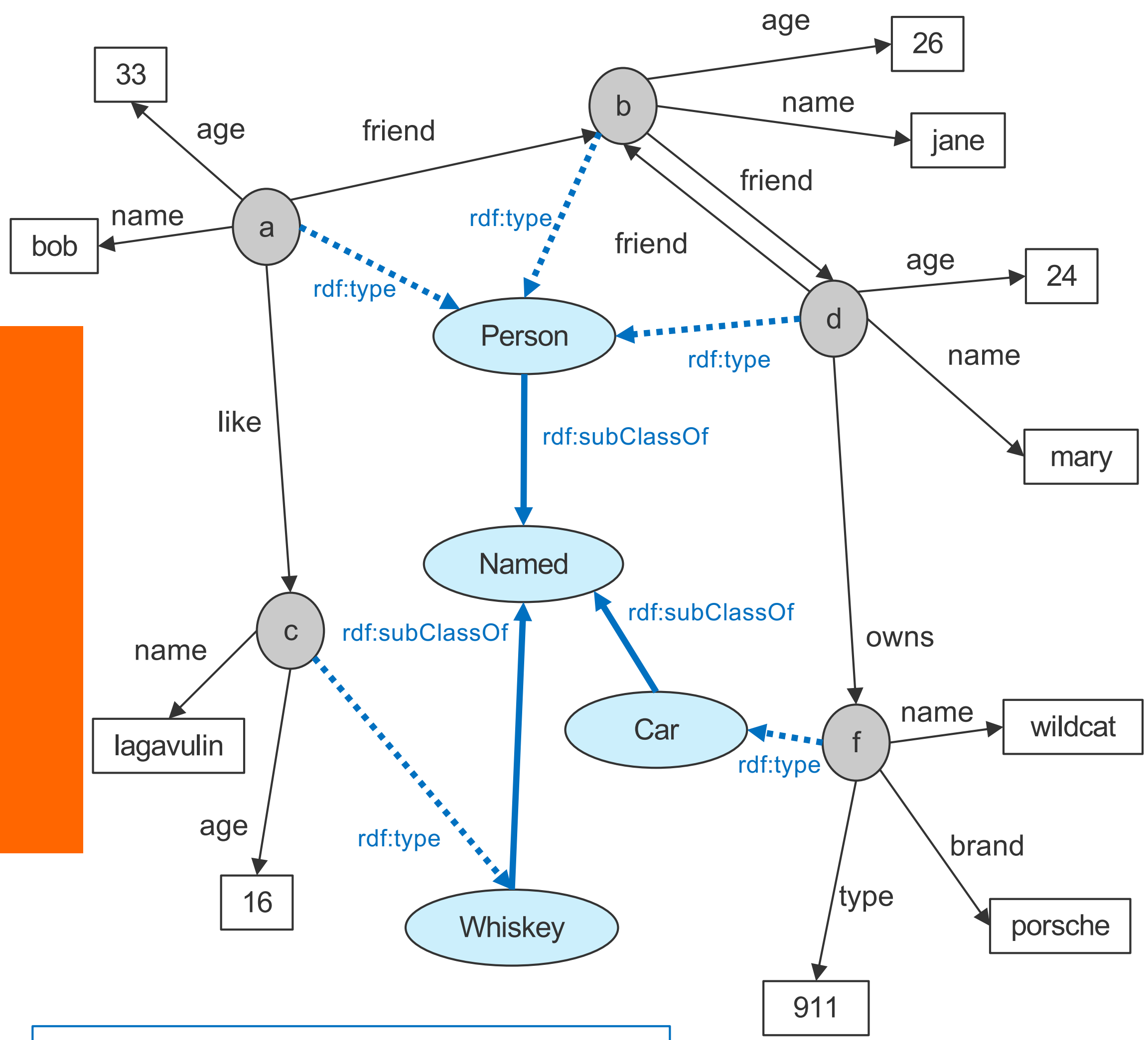
- Result (table of bindings):

X	Y	A
a	b	26
c	b	26

Schema Querying

- SPARQL has support for Schema querying
  - Class instances
  - Subclasses, Subproperties
  - etc.
- SPARQL “interprets” RDF(S) semantics
  - RDF and RDFS predicates explicitly mapped to their formal semantics
    - Transitivity of subClassOf property, inheritance of class instances, etc.
  - So it is not just querying the data graph
    (but the graph which is computed virtually with the entailment rules)

Example: Schema Quering




```
name rdfs:domain Named
```

Formulate the following queries

- Who are Persons?

  ?- triple(X,rdf:type,Person).
  SELECT ?X
  WHERE { ?X rdf:type Person.}

- Which are named items?

  ?- triple(X,rdf:type,Named).
  SELECT ?X
  WHERE { ?X rdf:type Named.}

- What are the subclasses of Named?

  SELECT ?X
  WHERE { ?X rdfs:subClassOf Named.}