SHACL

W3C's Shapes Constraint Language

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based on
https://www.w3.org/TR/shacl/

How to use these slides?

- These slides are a first introduction to SHACL
- The goal is to thoroughly understand the basics of SHACL and not to cover the whole language
  - try to fully understand everything in this slides! *(that will be enough for the exam)*
- For full coverage of the language please consult the W3C recommendation at https://www.w3.org/TR/shacl/
- With these slides as introduction it should be rather easy to understand the W3C recommendation.

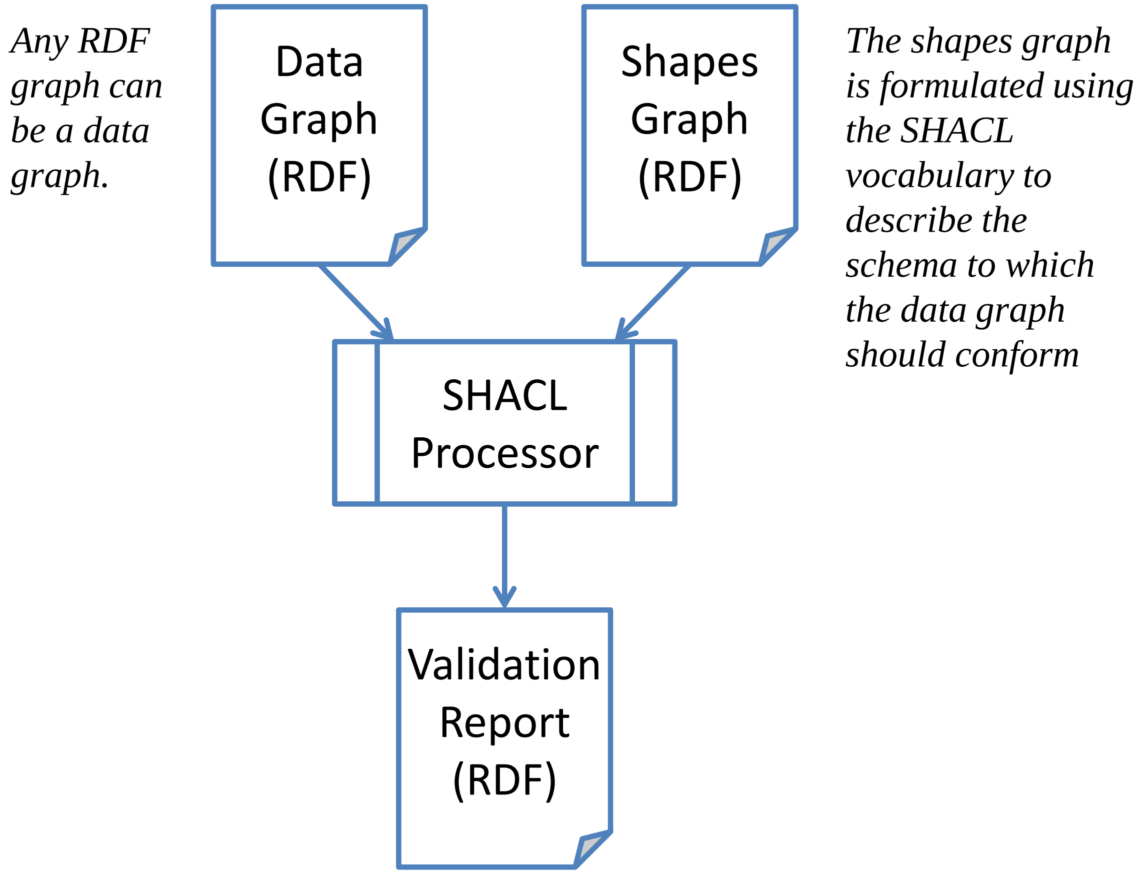
Why SHACL?

- With RDF Schema (RDFS) one can define vocabularies (sets of classes and properties) to be used in RDF data
- With OWL one can define the exact meaning of classes and properties in such vocabularies.
- What was missing in the semantic web stack was a way to specify structural constraints over RDF data similar to a database schema.

- Using RDFS we can specify a vocabulary consisting of classes Man, Woman, Person, hasFather, and hasMother and hasParent. We can specify:
  - every woman/man is also a person
  - a hasParent statement relates a person to a person
  - a hasMother/hasFather statement also expresses a hasParent statement and relates a person to a woman/man
- In OWL one can specify, using this vocabulary, that every person has exactly one mother and has exactly one father (without making a statement about whether these relationships are also recorded in the Knowledge Graph)
- In SHACL one can specify that every **description of a person** in some knowledge graph must come with exactly one statement with predicate hasMother and exactly one statement with hasFather.

SHACL

- The SHACL Shapes Constraint Language (SHACL) is a language for validating RDF graphs against a set of conditions.
- These conditions are provided as shapes and other constructs expressed in the form of an RDF graph.
- RDF graphs that are used in this manner are called "shapes graphs" in SHACL and the RDF graphs that are validated against a shapes graph are called "data graphs".
- As SHACL shape graphs are used to validate that data graphs satisfy a set of conditions they can also be viewed as a description of the data graphs that do satisfy these conditions.
- Such descriptions may be used for a variety of purposes beside validation, including user interface building, code generation and data integration.

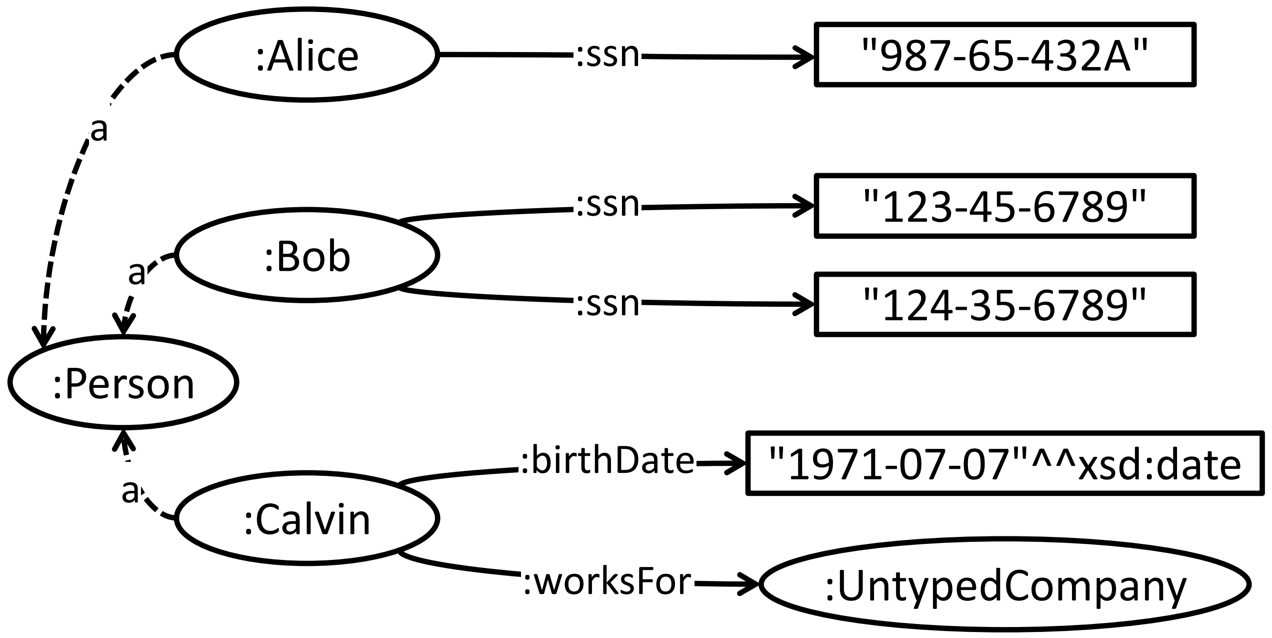

Any RDF graph can be a data graph.
Data Graph (RDF)
Shapes Graph (RDF)
The shapes graph is formulated using the SHACL vocabulary to describe the schema to which the data graph should conform
SHACL Processor
Validation Report (RDF)

The validation report is the result of the validation process that reports the conformance and the set of all validation results. The validation report is described with the SHACL Validation Report Vocabulary. It provides guidance on how to identify or fix violations in the data graph.

SHACL - First Example

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```



SHACL - First Example

Data Graph

```
:Alice    a :Person ;
          :ssn "987-65-432A" .
:Bob      a :Person ;
          :ssn "123-45-6789" ;
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:Calvin a :Person ;
          :birthDate "1971-07-07"^^xsd:date ;
          :worksFor :UntypedCompany .
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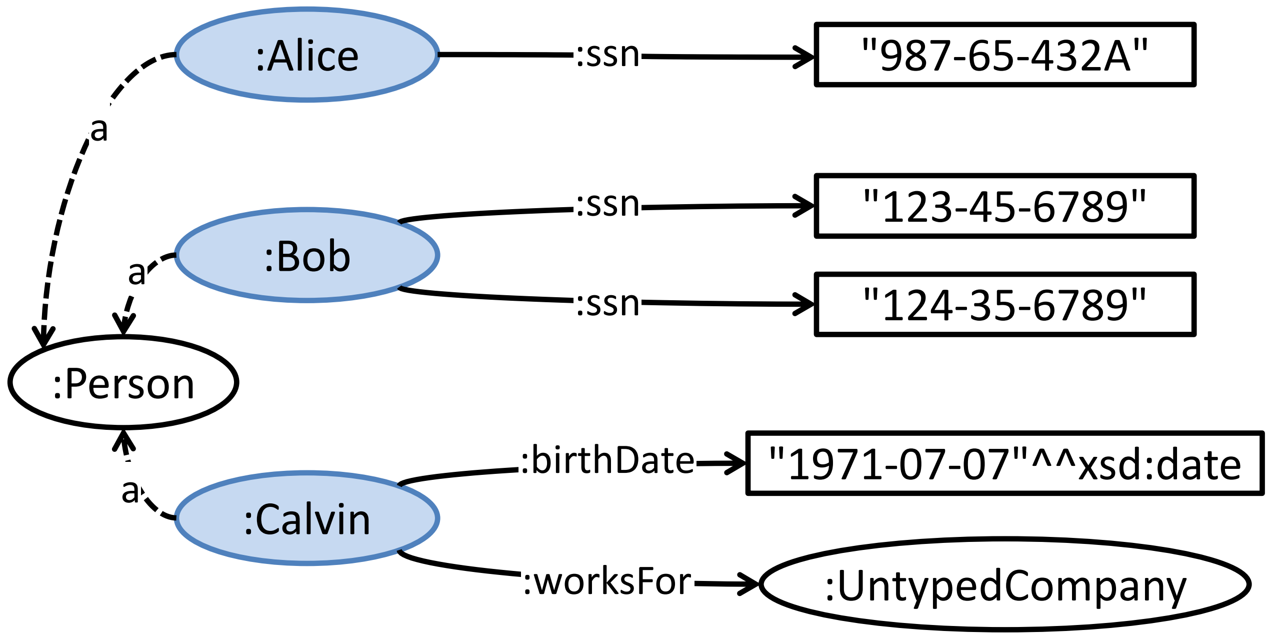


Let us define some structural constraints for descriptions of persons …

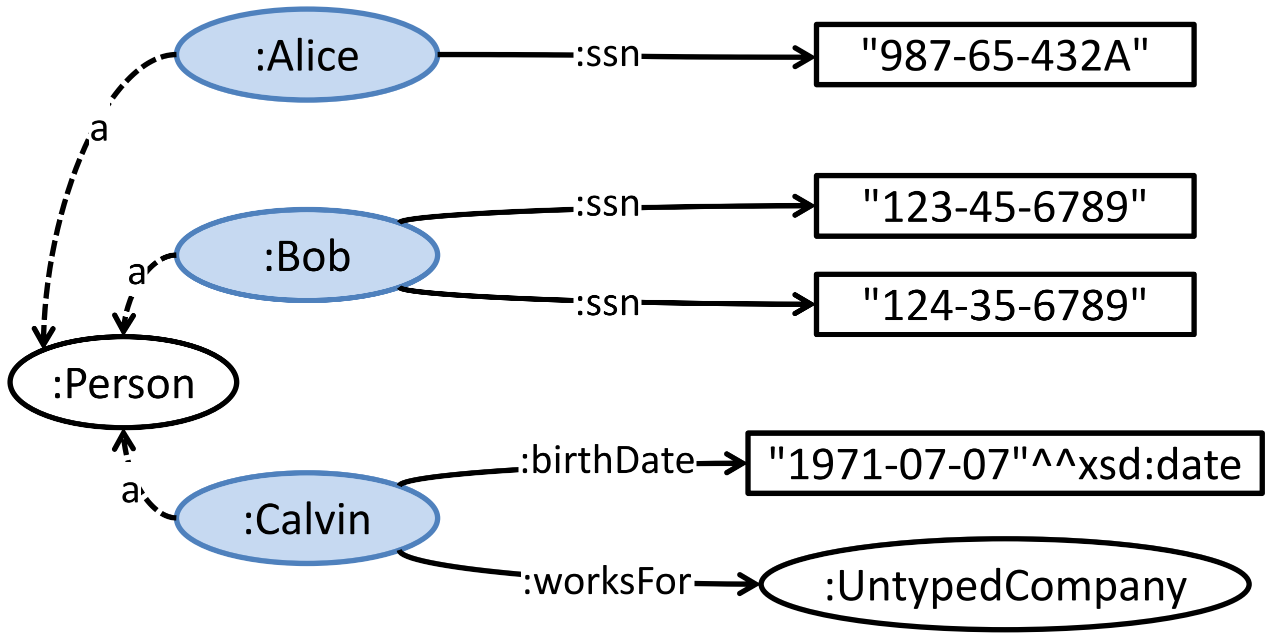
SHACL - First Example

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   ...  .
```



A SHACL instance of `:Person`

- ...

SHACL - First Example

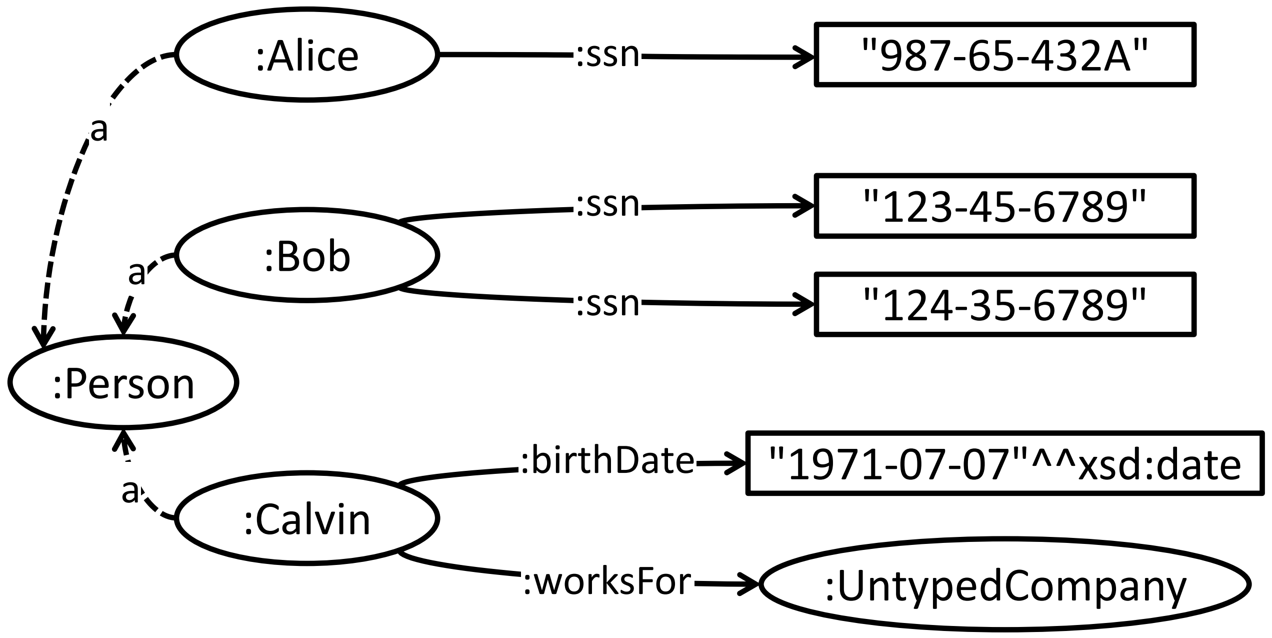
Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 .
```



A SHACL instance of `:Person`

- can have at most one value for the property `:ssn`.

SHACL - First Example

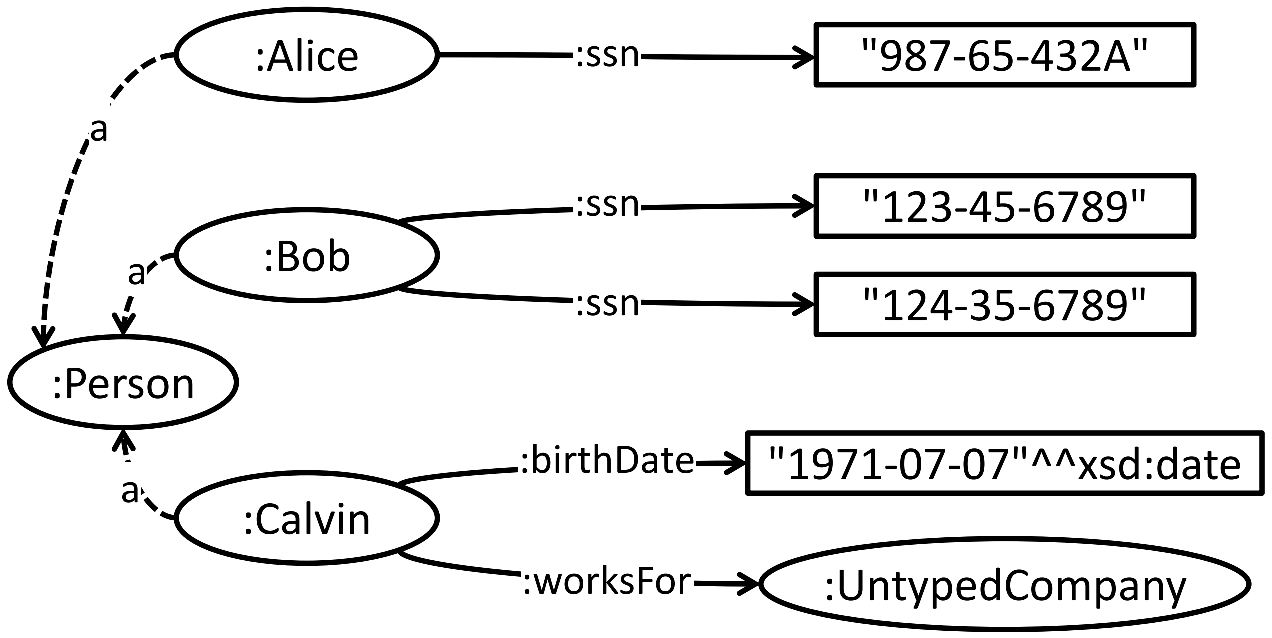
Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .
```



A SHACL instance of `:Person`

- can have at most one value for the property `:ssn`, and this value is a literal with the datatype `xsd:string` that matches a specified regular expression.

SHACL - First Example

Data Graph

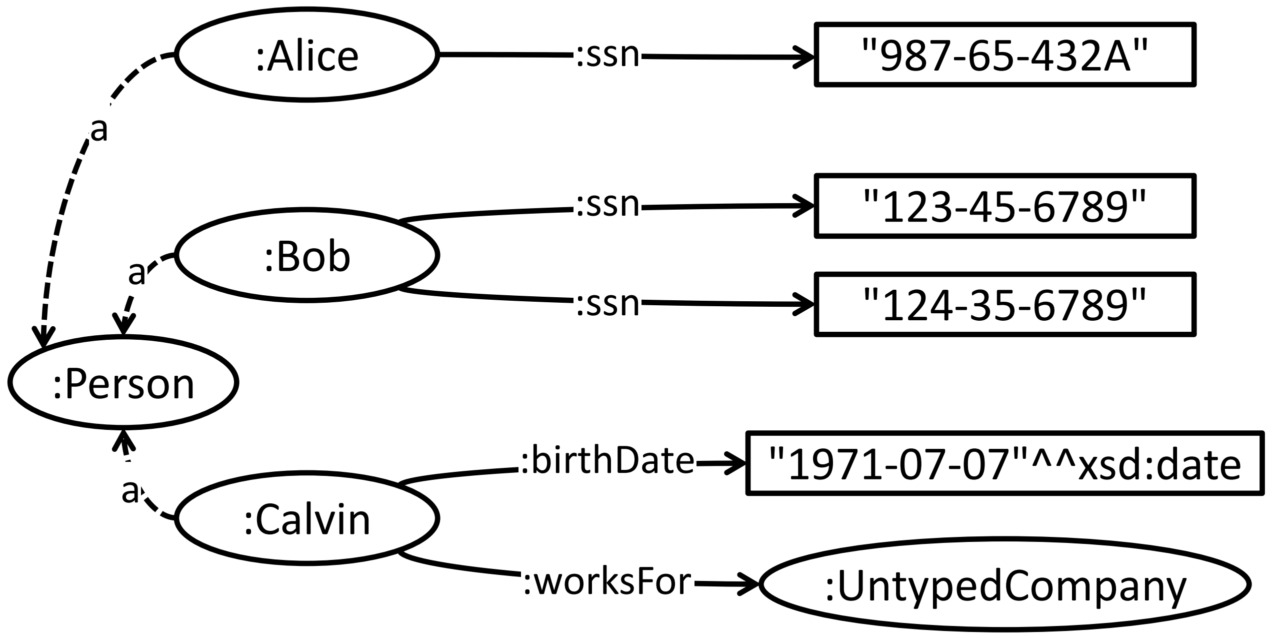
```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



A SHACL instance of `:Person`

- can have at most one value for the property `:ssn`, and this value is a literal with the datatype `xsd:string` that matches a specified regular expression.
- can have unlimited values for the property `:worksFor`, and these values are IRIs and SHACL instances of `:Company`.

SHACL - First Example

Data Graph

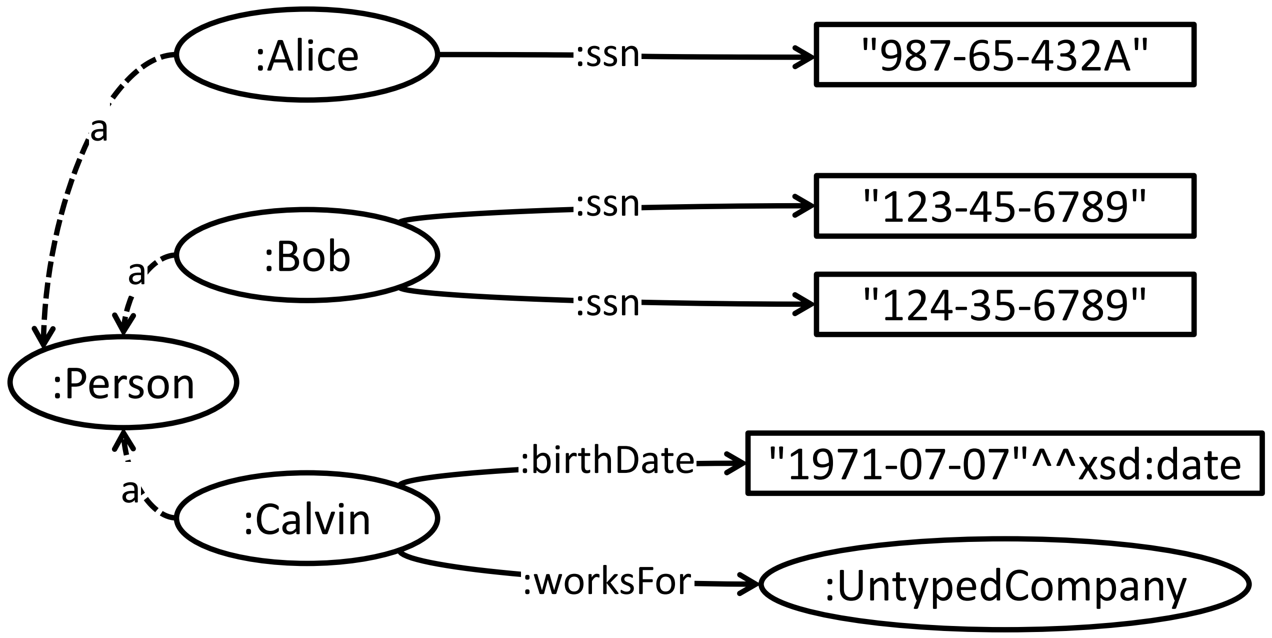
```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape ;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



A SHACL instance of `:Person`

- can have at most one value for the property `:ssn`, and this value is a literal with the datatype `xsd:string` that matches a specified regular expression.
- can have unlimited values for the property `:worksFor`, and these values are IRIs and SHACL instances of `:Company`.
- cannot have values for any other property apart from `:ssn`, `:worksFor` and `rdf:type`.

SHACL - First Example

Data Graph

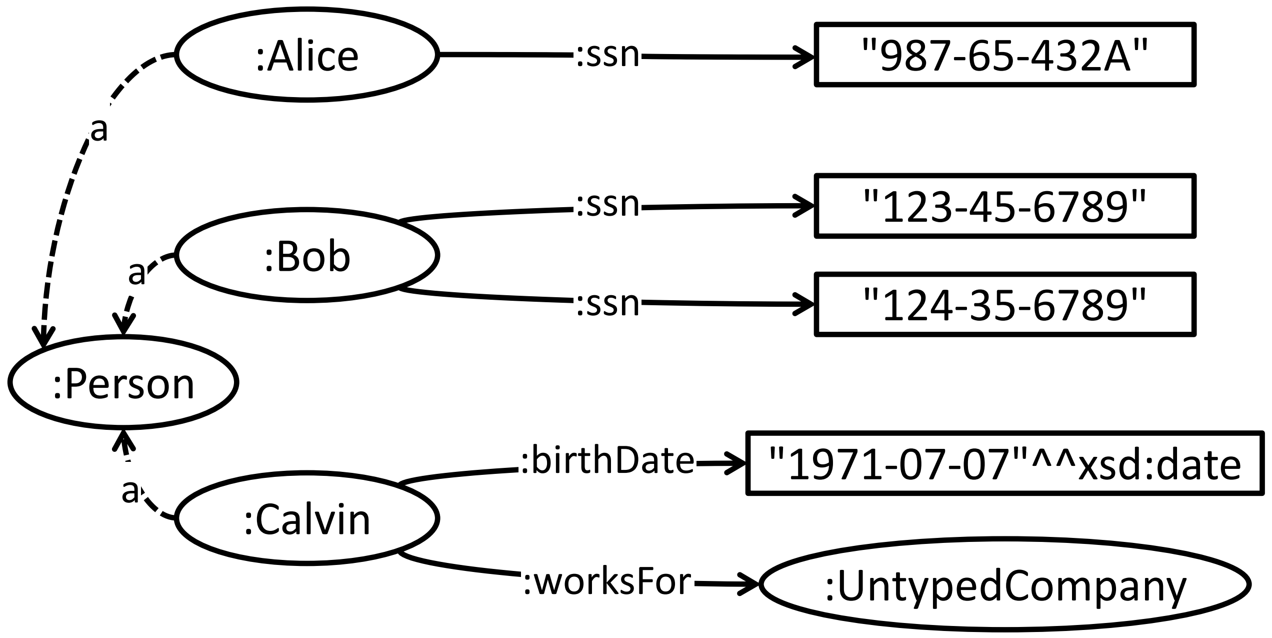
```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



Let the SHACL processor validate the data graph against the shapes graph ...

SHACL - First Example

Data Graph

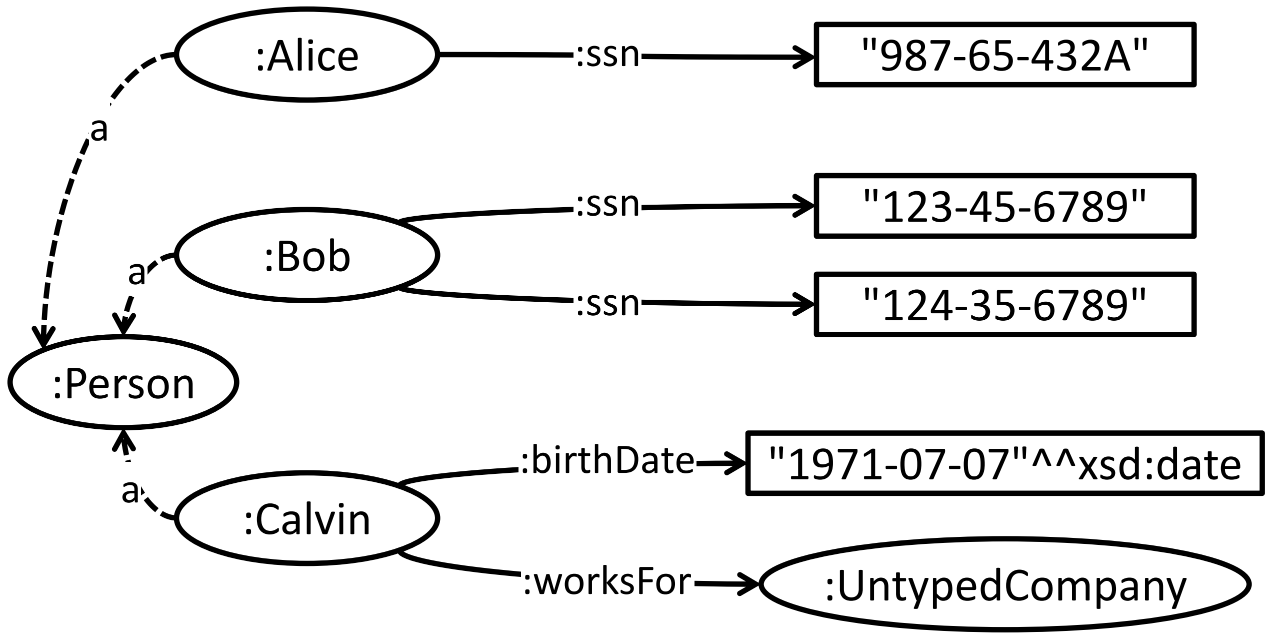
```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



Validation Report

```
[
 a sh:ValidationReport ;
 sh:conforms false ;
 ...
```

SHACL - First Example

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
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   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
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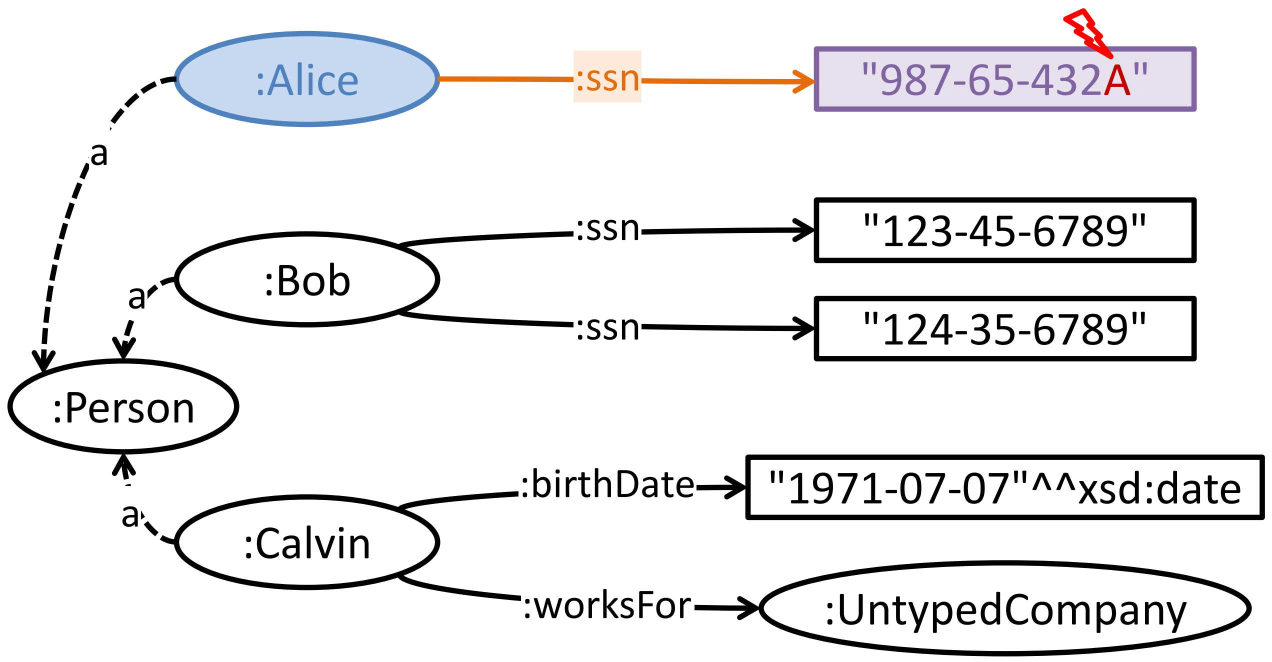
```



Validation Report

```
...
sh:result
[ a sh:ValidationResult ;
  sh:resultSeverity sh:Violation ;
  sh:focusNode :Alice ;
  sh:resultPath :ssn ;
  sh:value "987-65-432A" ;
  sh:sourceConstraintComponent sh:RegexConstraintComp...;
  sh:sourceShape :SsnShape ] ;
...
```

SHACL - First Example

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
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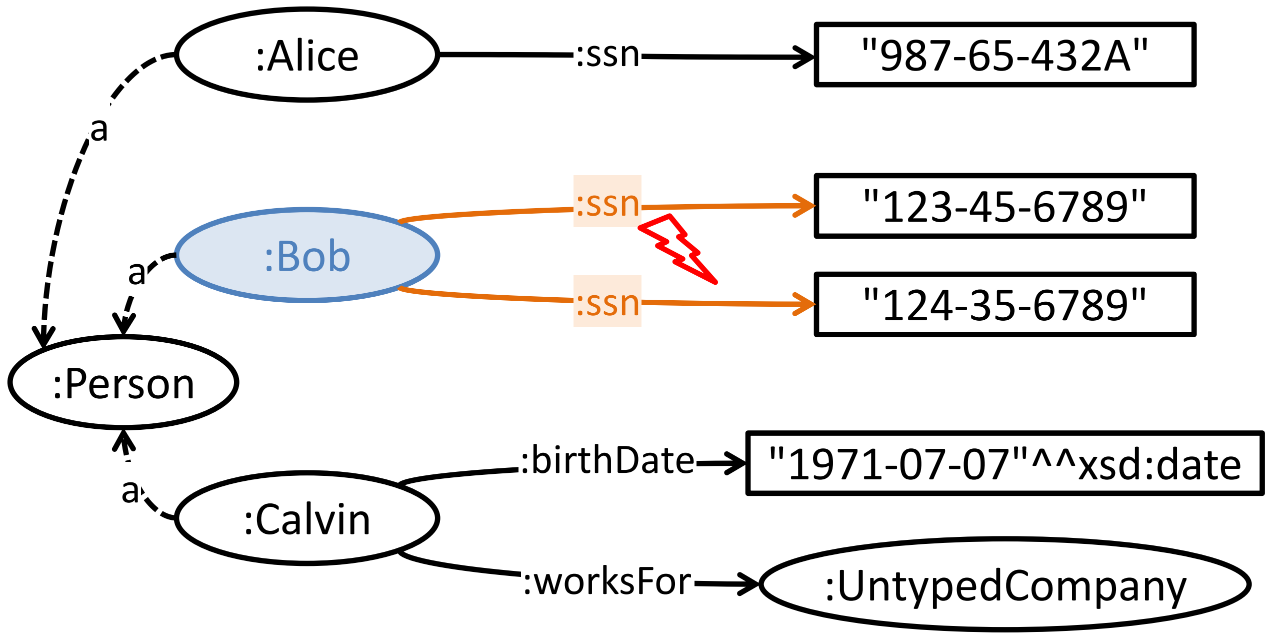
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



Validation Report

```
...
sh:result
[ a sh:ValidationResult ;
  sh:resultSeverity sh:Violation ;
  sh:focusNode :Bob ;
  sh:resultPath :ssn ;
  sh:sourceConstraintComponent sh:MaxCountConstraintC...;
  sh:sourceShape :SsnShape ] ;
...
```

SHACL - First Example

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```

Shapes Graph

```
:PersonShape  a sh:NodeShape;
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   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

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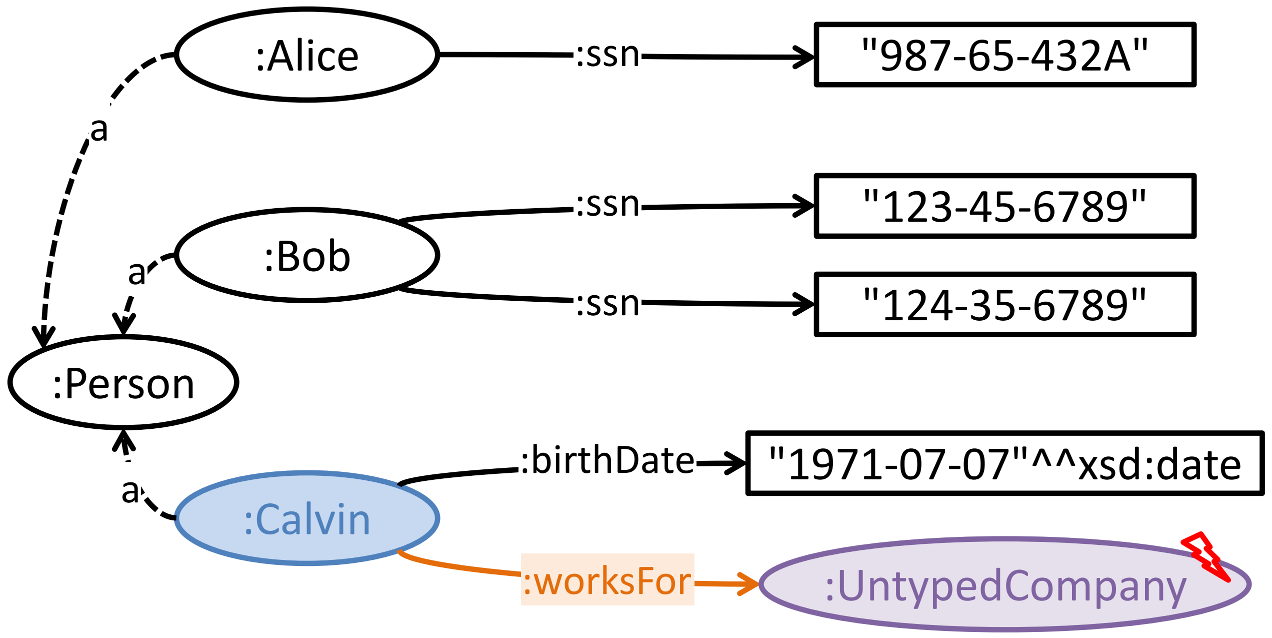
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



Validation Report

```
...
sh:result
[ a sh:ValidationResult ;
  sh:resultSeverity sh:Violation ;
  sh:focusNode :Calvin ;
  sh:resultPath :worksFor ;
  sh:value :UntypedCompany ;
  sh:sourceConstraintComponent sh:ClassConstraintComp...;
  sh:sourceShape :WorksForShape ] ;
...
```

SHACL - First Example

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
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```

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:PersonShape  a sh:NodeShape;
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   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
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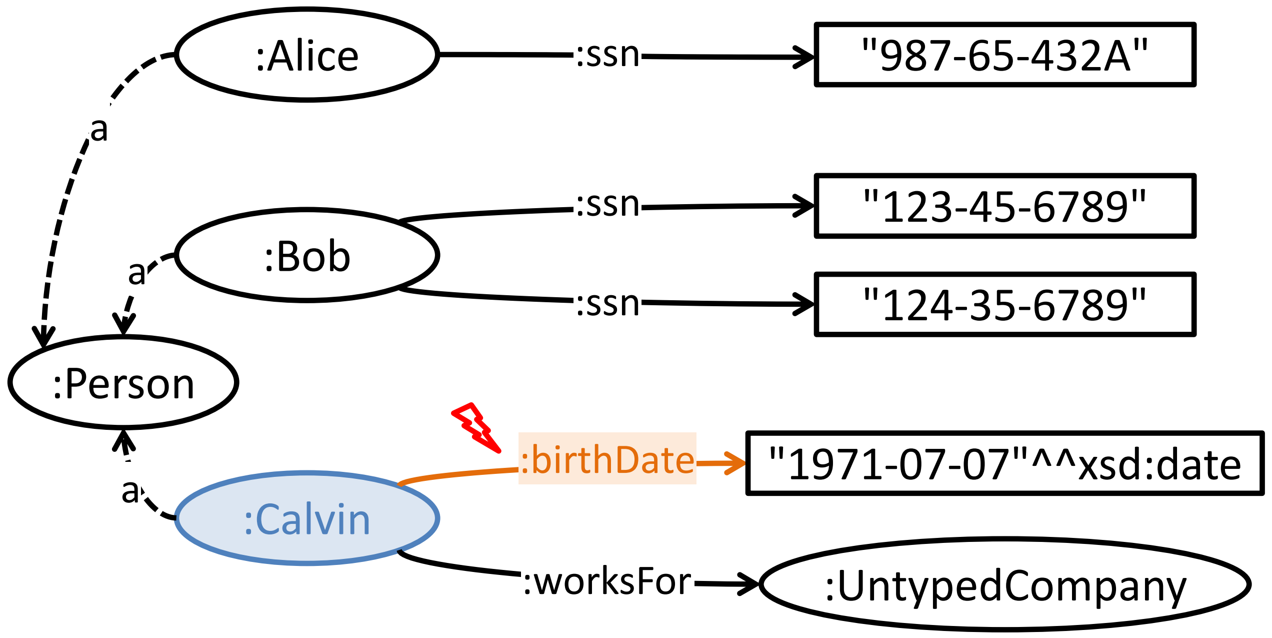


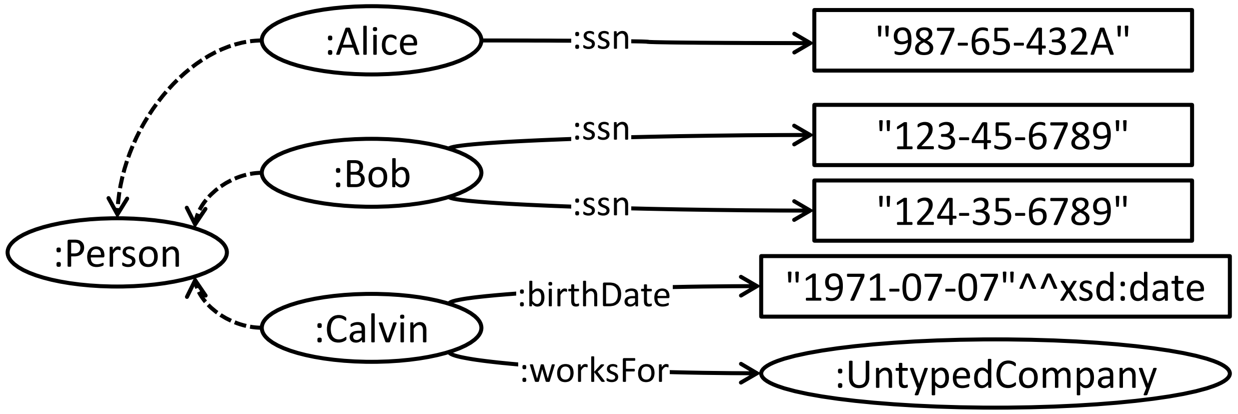
Validation Report

```
...
sh:result
[ a sh:ValidationResult ;
  sh:resultSeverity sh:Violation ;
  sh:focusNode ex:Calvin ;
  sh:resultPath ex:birthDate ;
  sh:value "1971-07-07"^^xsd:date ;
  sh:sourceConstraintComponent sh:ClosedConstraintComp...;
  sh:sourceShape :PersonShape ]
].
```

Visualization of Shapes Graphs (no standard)

Data Graph

```
:Alice   a :Person ;
         :ssn "987-65-432A" .
:Bob     a :Person ;
         :ssn "123-45-6789" ;
         :ssn "124-35-6789" .
:Calvin a :Person ;
         :birthDate "1971-07-07"^^xsd:date ;
         :worksFor :UntypedCompany .
```



Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
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:SsnShape  a sh:PropertyShape ;
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   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
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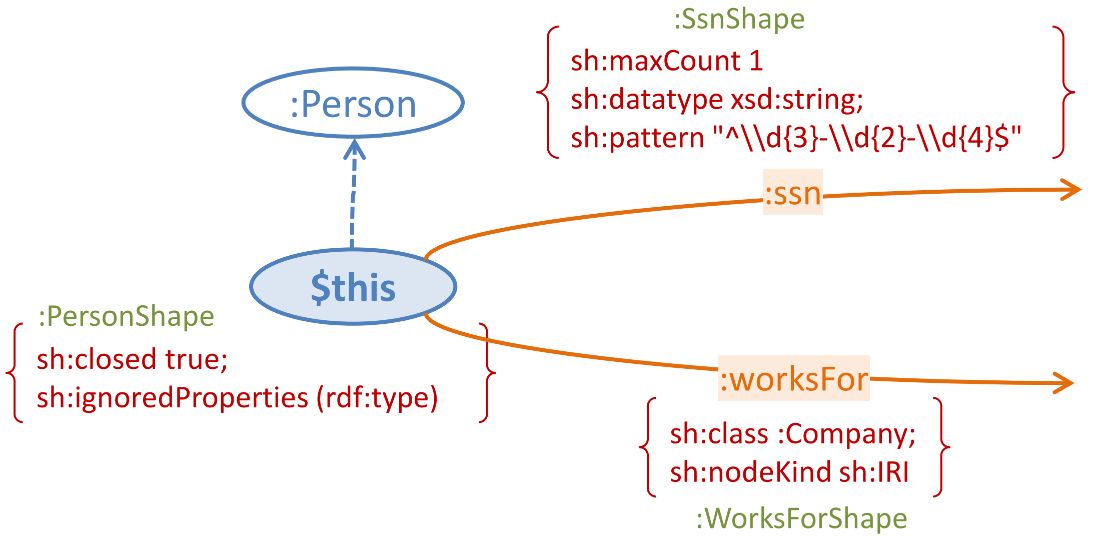
```



Components of Shapes Graphs and Shapes

Node Shape

- ≡ a shape that is not the subject of a sh:path statement.
- Node shapes specify constraints that need to be met with respect to focus nodes. In contrast to property shapes they primarily apply to the focus node itself, not to its property values.

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
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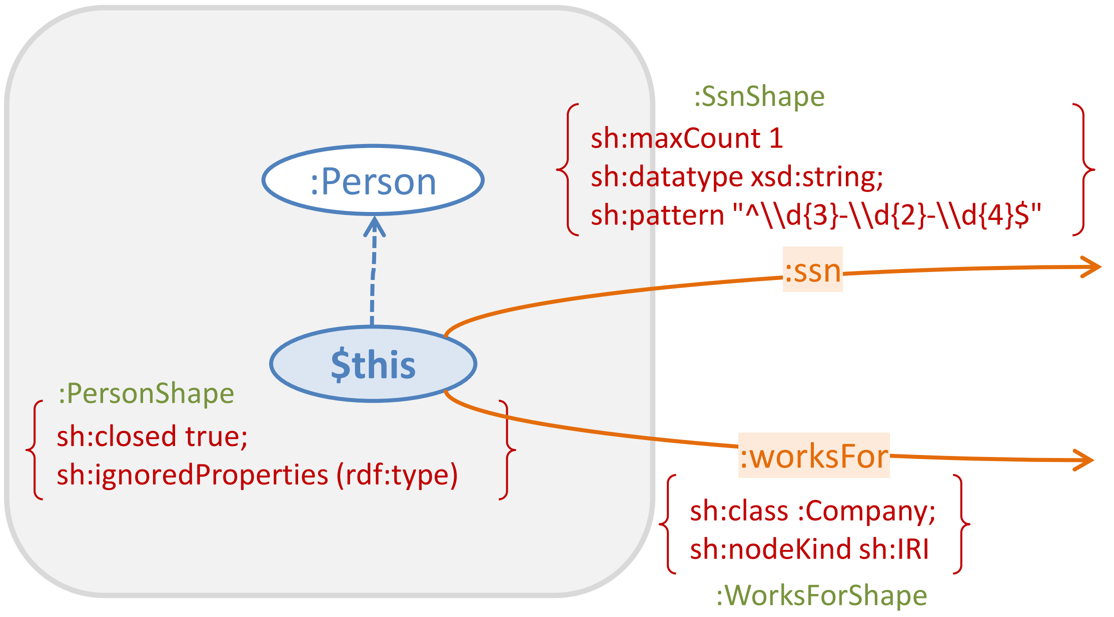

Components of Shapes Graphs and Shapes

Target Declaration

- can be understood as a query returning the set of focus nodes for a shape

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
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   sh:closed true ;
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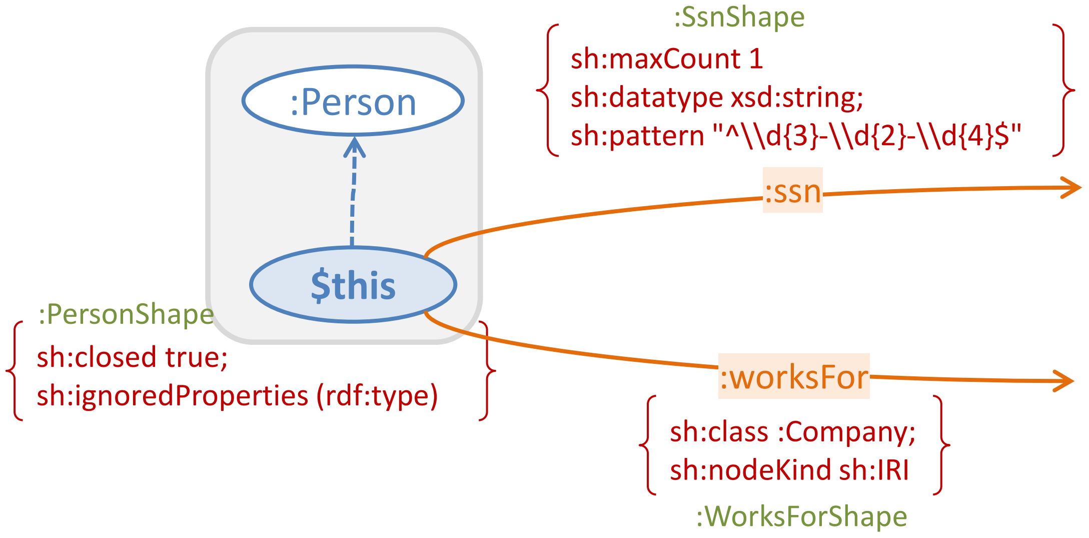

Components of Shapes Graphs and Shapes

Property Shape

- ≡ a shape that is the subject of a sh:path statement.
- A property shape has exactly one sh:path statement.

Shapes Graph

```
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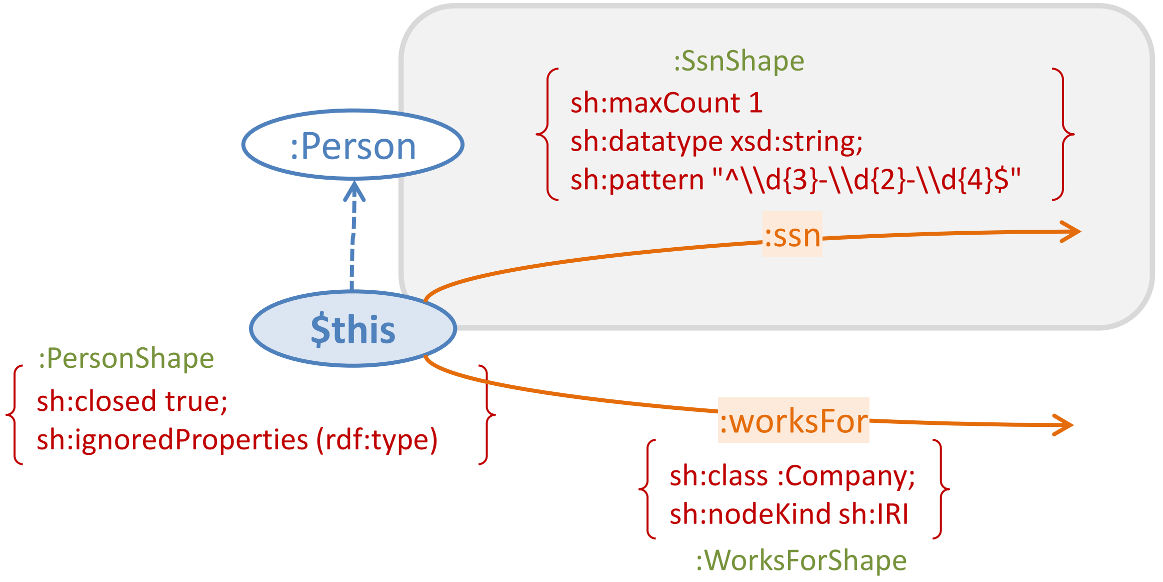

Components of Shapes Graphs and Shapes

Property Shape

- ≡ a shape that is the subject of a sh:path statement.
- A property shape has exactly one sh:path statement
- and may have its own target declaration but is typically referenced from (one or more) node shape(s) by sh:property statement(s) and then has as focus nodes the focus nodes of that node shape.

Shapes Graph

```
:PersonShape  a sh:NodeShape;
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:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
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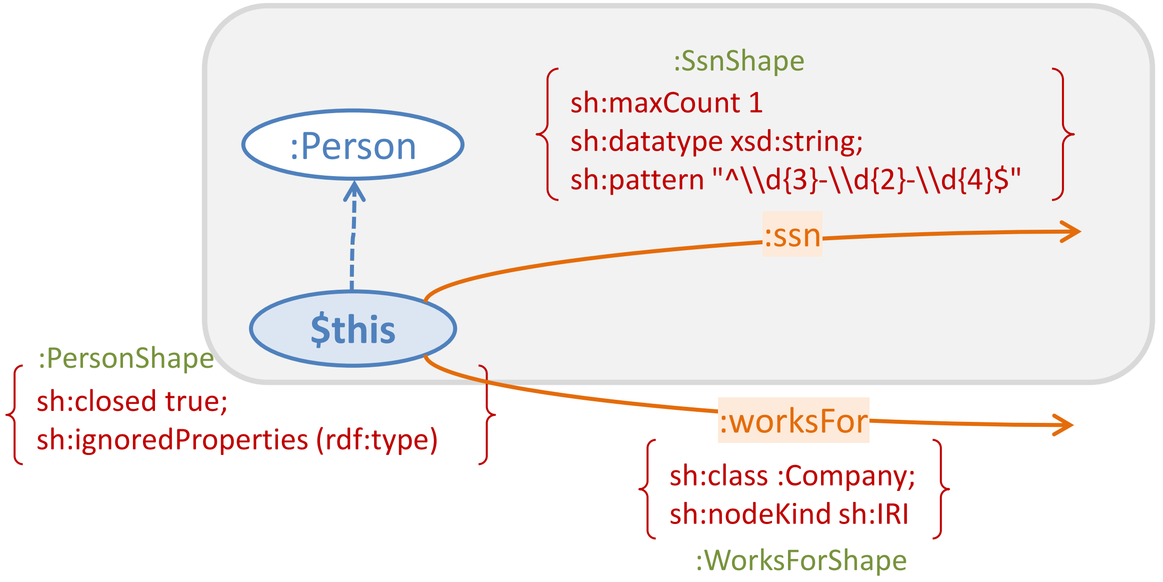

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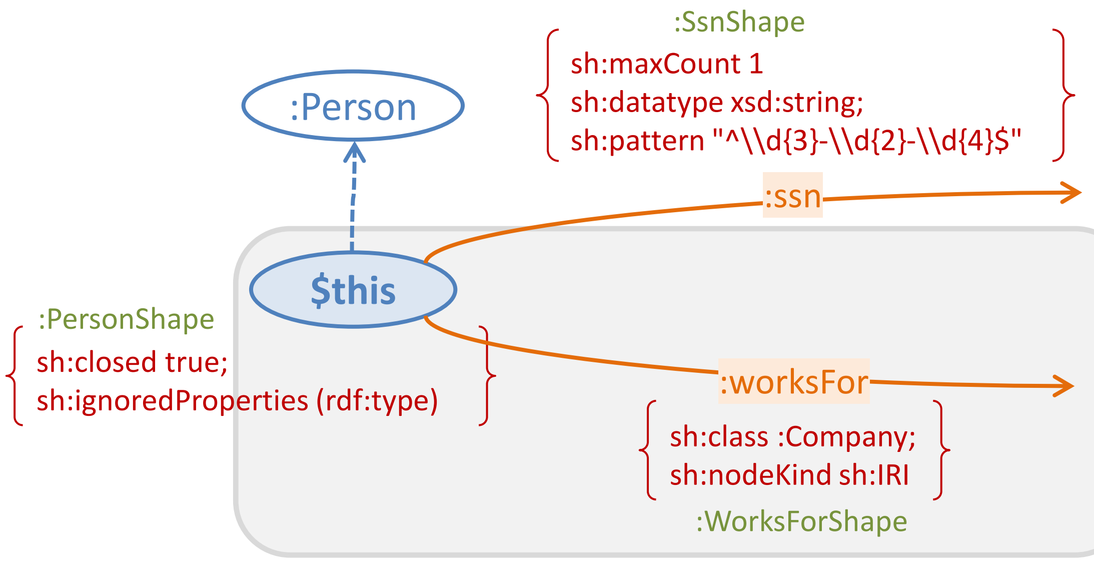
- A property shape has exactly one sh:path statement
- and may have its own target declaration but is typically referenced from (one or more) node shape(s) by sh:property statement(s) and then has as focus nodes the focus nodes of that node shape

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



Components of Shapes Graphs and Shapes

Constraint

- ≡ a condition that is true for every focus node of the shape (in a data graph that conforms to the shapes graph).

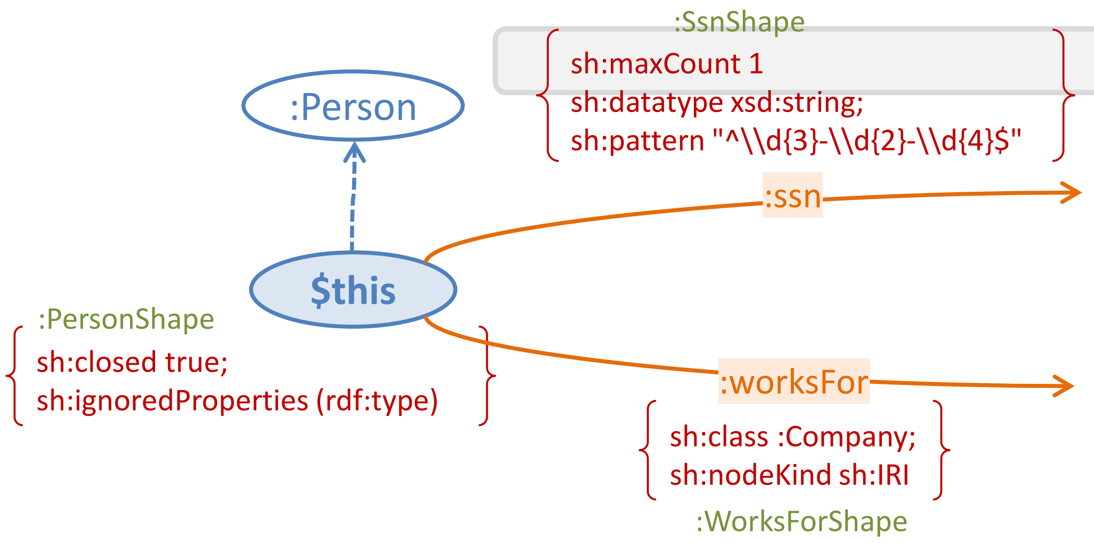
Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```

For example: Every focus node of SsnShape has at most one :ssn statement.



Components of Shapes Graphs and Shapes

Constraint

- ≡ a condition that is true for every focus node of the shape (in a data graph that conforms to the shapes graph).

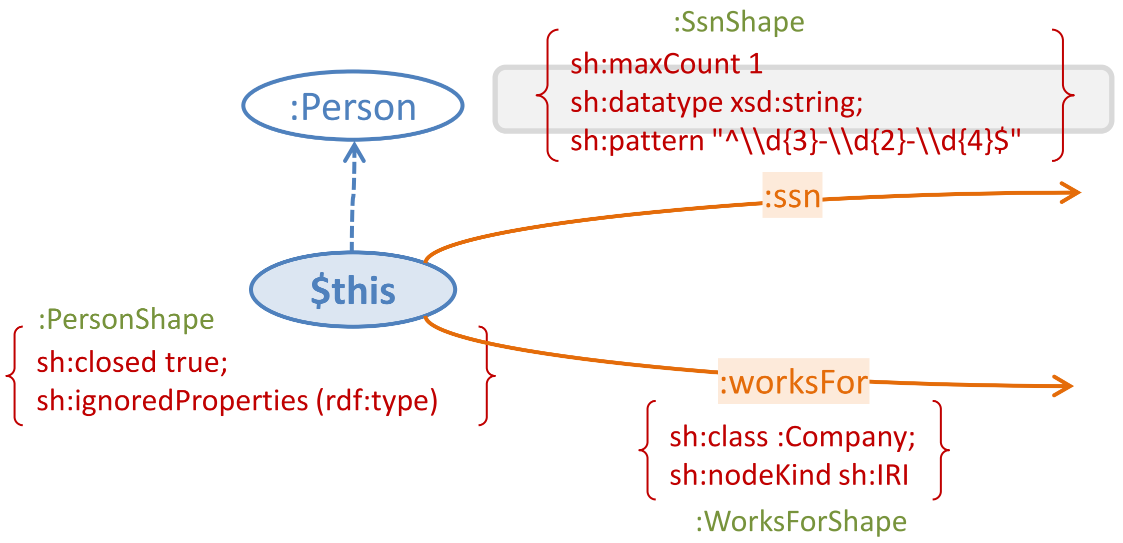
Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```

For example: For every focus node of SsnShape the value (object) of each of its :ssn statement must be of datatype xsd:string.



Components of Shapes Graphs and Shapes

Constraint

- ≡ a condition that is true for every focus node of the shape (in a data graph that conforms to the shapes graph).

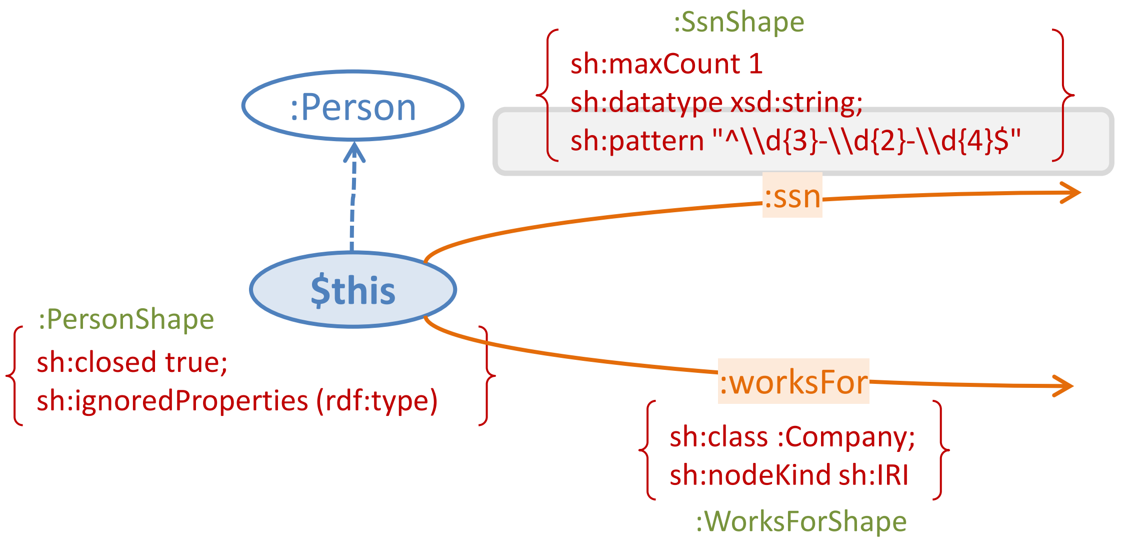
Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```

For example: For every focus node of SsnShape the value (object) of every :ssn statement must correspond to a given regular expression.



Components of Shapes Graphs and Shapes

Constraint

- ≡ a condition that is true for every focus node of the shape (in a data graph that conforms to the shapes graph).

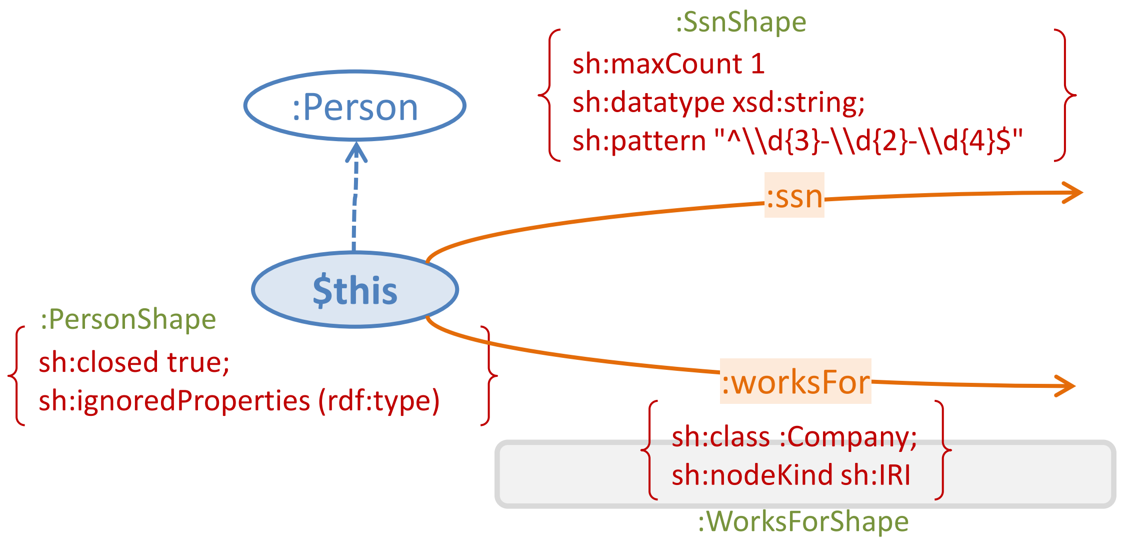
Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```

For example: For every focus node of WorksForShape the value (object) of each of its worksFor statements must be of class Company.



Components of Shapes Graphs and Shapes

Constraint

- ≡ a condition that is true for every focus node of the shape (in a data graph that conforms to the shapes graph).

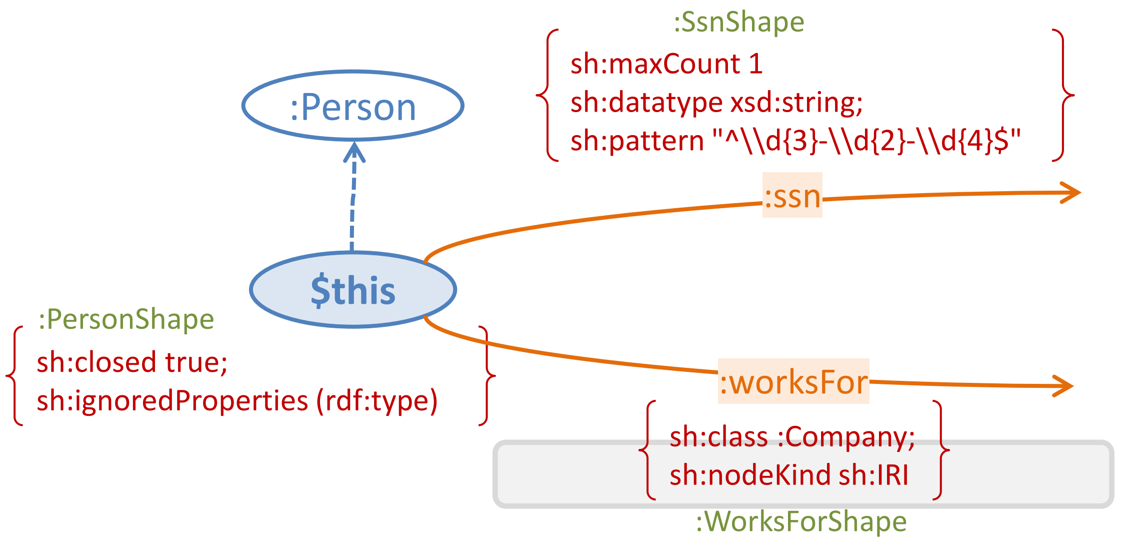
Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```

For example: For every focus node of WorksForShape the value (object) of each of its :worksFor statements must be a IRI.



Components of Shapes Graphs and Shapes

Constraint

- ≡ a condition that is true for every focus node of the shape (in a data graph that conforms to the shapes graph).
- one *constraint component*, e.g., the sh:ClosedConstraintComponent, can have multiple *parameters.*

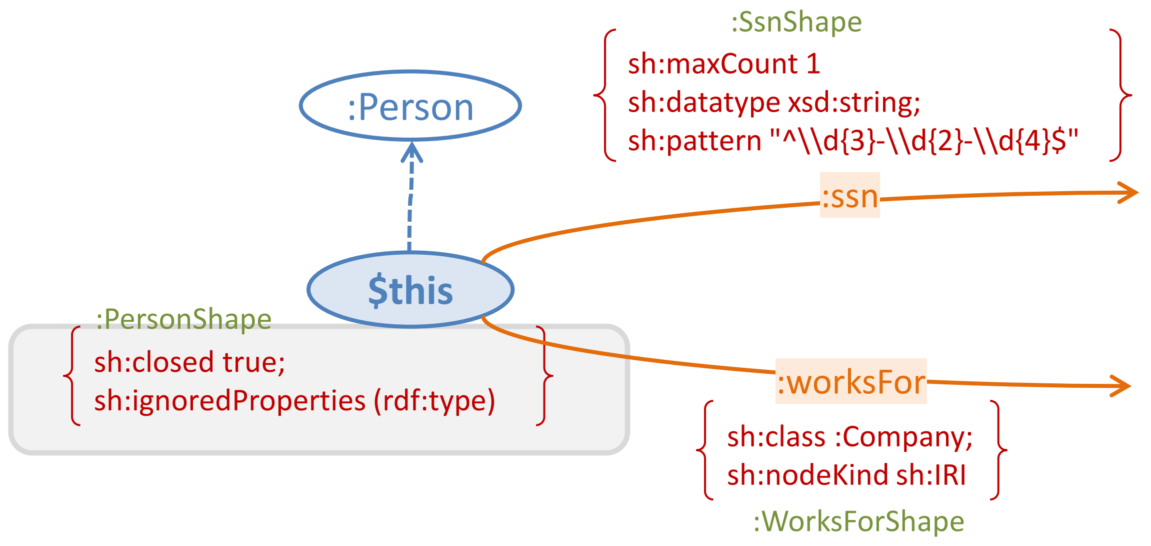
Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```

For example: A focus node of PersonShape may only be subject of statements with properties :ssn, :worksFor and rdf:type as



Components of Shapes Graphs and Shapes

SHACL Property Paths

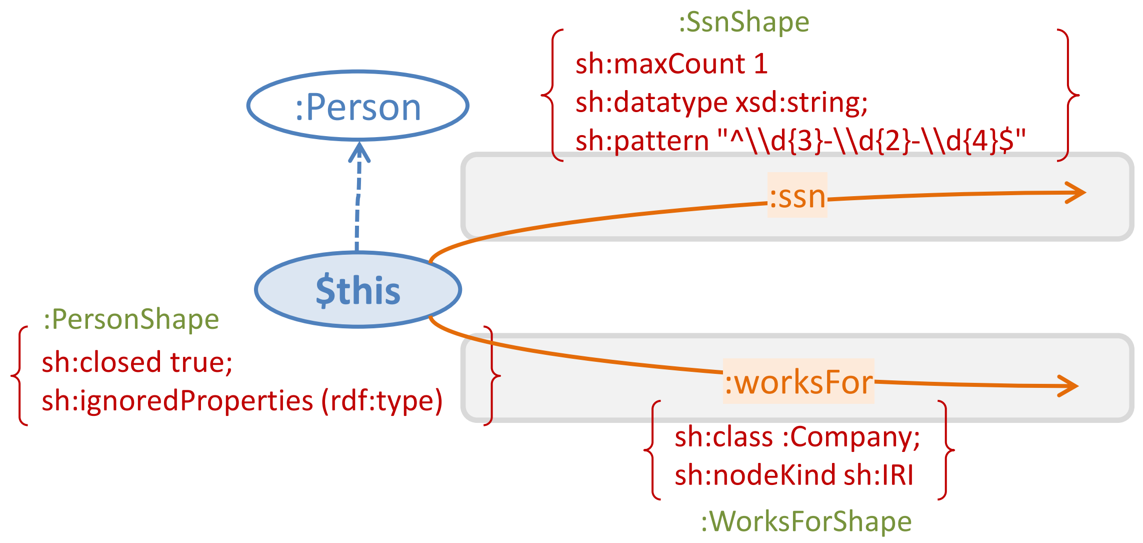
- In addition to predicate paths (see example), SHACL includes RDF terms to represent a subset of SPARQL property paths: InversePath, SequencePath, AlternativePath, ZeroOrMorePath, OneOrMorePath and ZeroOrOnePath.

Shapes Graph

```
:PersonShape  a sh:NodeShape;
   sh:targetClass :Person ;
   sh:property :SsnShape, :WorksForShape;
   sh:closed true ;
   sh:ignoredProperties ( rdf:type ) .

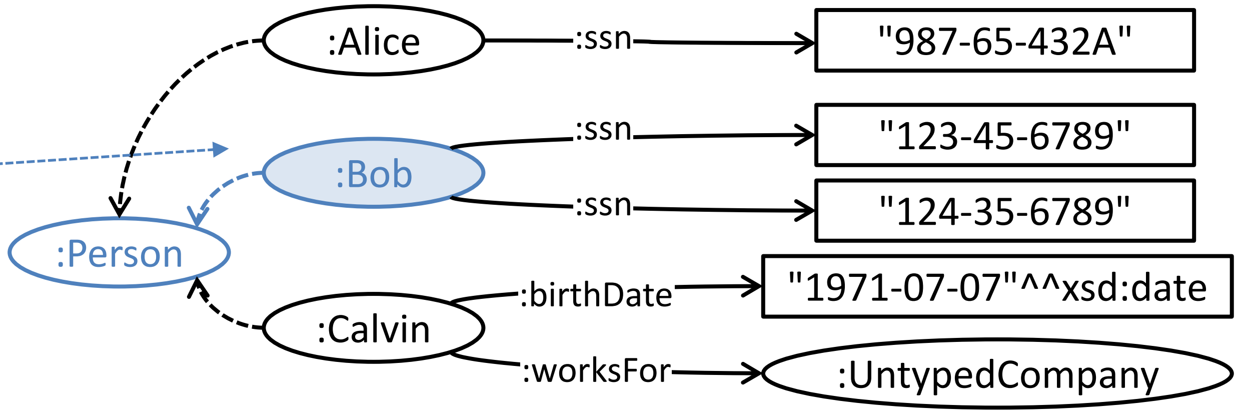
:SsnShape  a sh:PropertyShape ;
   sh:path :ssn ;
   sh:maxCount 1 ;
   sh:datatype xsd:string ;
   sh:pattern "^\\d{3}-\\d{2}-\\d{4}$" .

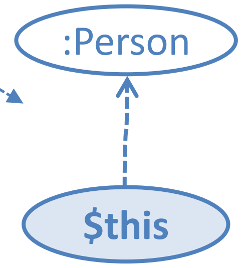
:WorksForShape  a sh:PropertyShape ;
   sh:path :worksFor ;
   sh:class :Company ;
   sh:nodeKind sh:IRI .
```



Focus Nodes and Target Declarations

- An RDF term that is validated against a shape using the triples from a data graph is called a **focus node**.
- The set of focus nodes for a shape may be identified as follows:
  - specified in a shape using **target declarations (see Example 2)**
  - specified in any constraint that references a shape in parameters of **shape-expecting constraint parameters**, e.g. sh:property (see Example 1) or sh:node, **(see Example 3)**
  - specified as explicit input to the SHACL processor for validating a specific RDF term against a shape (not exemplified)





A depiction of a target declaration (a target declaration is a graph pattern to match focus nodes)

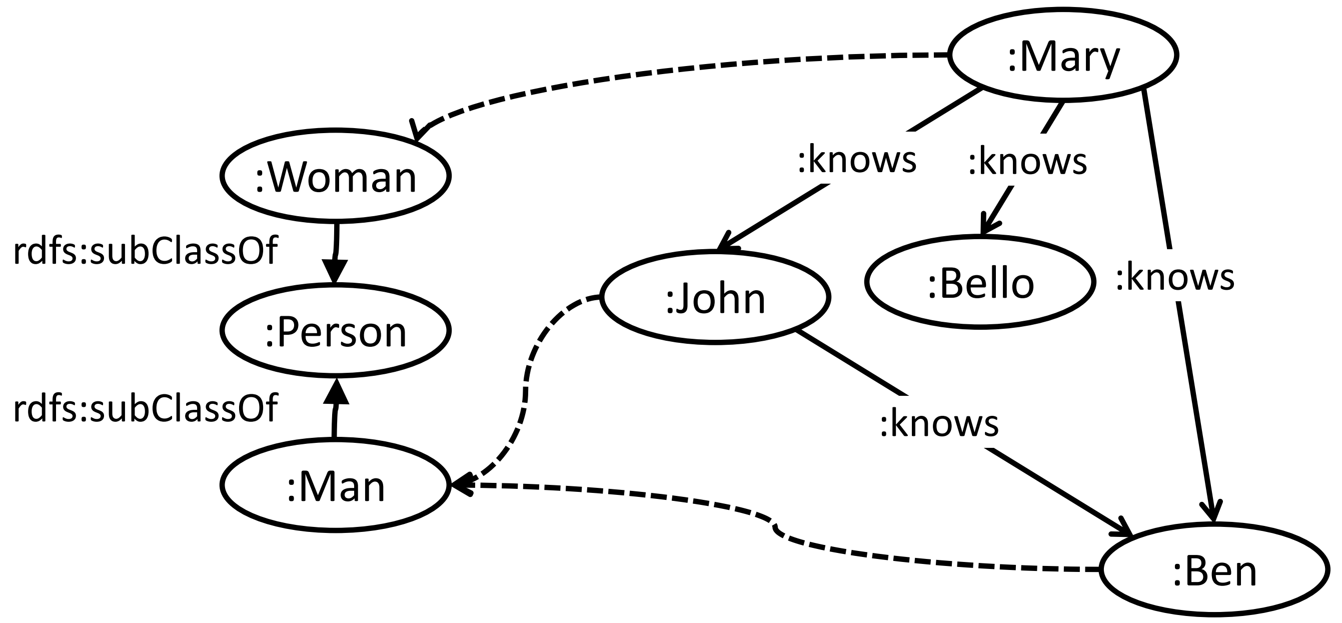
Example 2: Target Declarations

Data Graph

```
:Mary    a :Woman ;
         :knows :John, :Bob, :Bello.
:John    a :Man ;
         :knows :Ben .
:Ben     a :Man .
:Man     rdfs:subClassOf :Person.
:Woman   rdfs:subclassOf :Person.
```

Shapes Graph

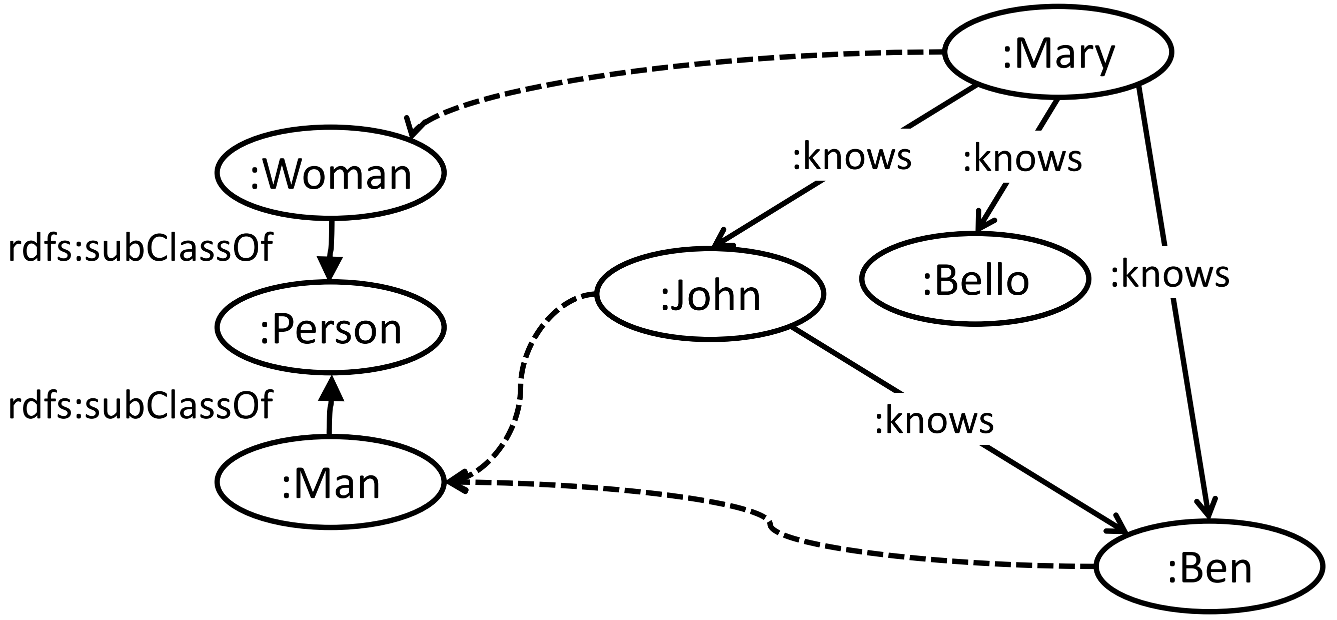
```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```



Example 2: Target Declarations

Data Graph

```
:Mary    a :Woman ;
         :knows :John, :Bob, :Bello.
:John    a :Man ;
         :knows :Ben .
:Ben     a :Man .
:Man     rdfs:subClassOf :Person.
:Woman   rdfs:subclassOf :Person.
```



müsste das nicht sh:NodeShape sein?

Shapes Graph

```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```

Validation Report

```
[
 a sh:ValidationReport ;
 sh:conforms false ;
 ...
```

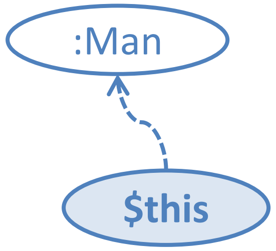
Example 2: Target Declarations

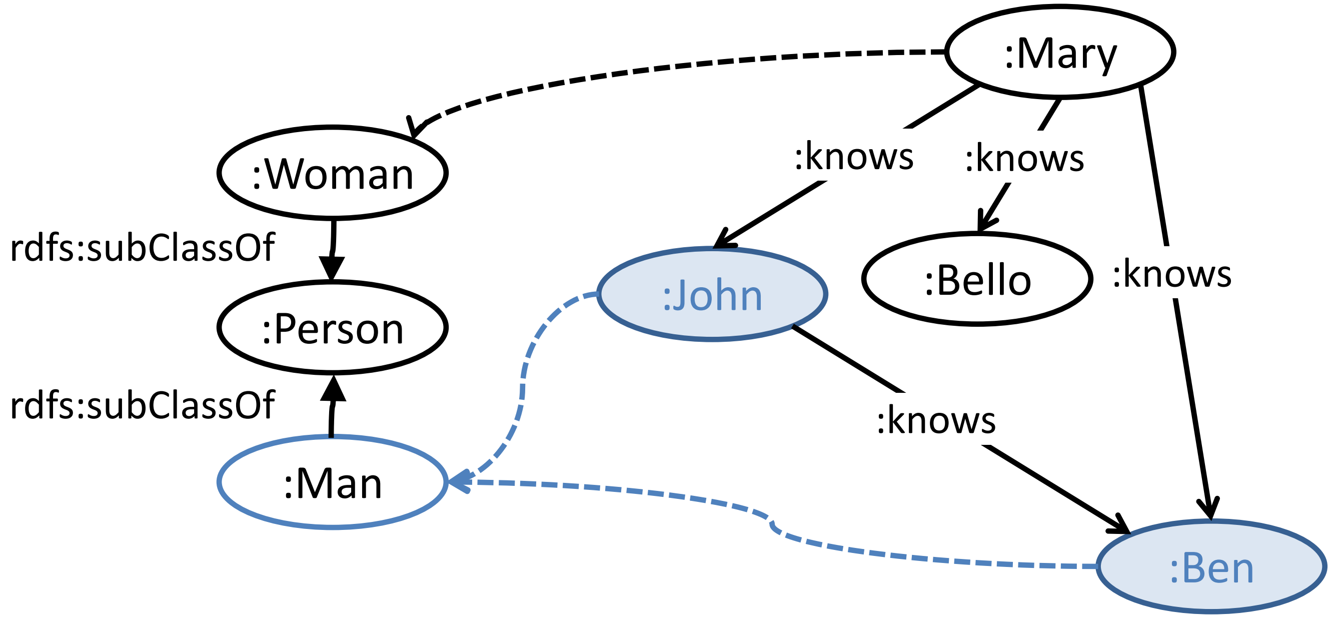
Data Graph

```
:Mary    a :Woman ;
         :knows :John, :Bob, :Bello.
:John    a :Man ;
         :knows :Ben .
:Ben     a :Man .
:Man     rdfs:subClassOf :Person.
:Woman   rdfs:subClassOf :Person.
```

Shapes Graph

```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```





Validation Report

```
...
sh:result [ ...
  sh:focusNode     :Ben ;
  sh:sourceShape   :ManShape ] ;
sh:result [ ...
  sh:focusNode     :John ;
  sh:sourceShape   :ManShape ] ;
...
```

Example 2: Target Declarations

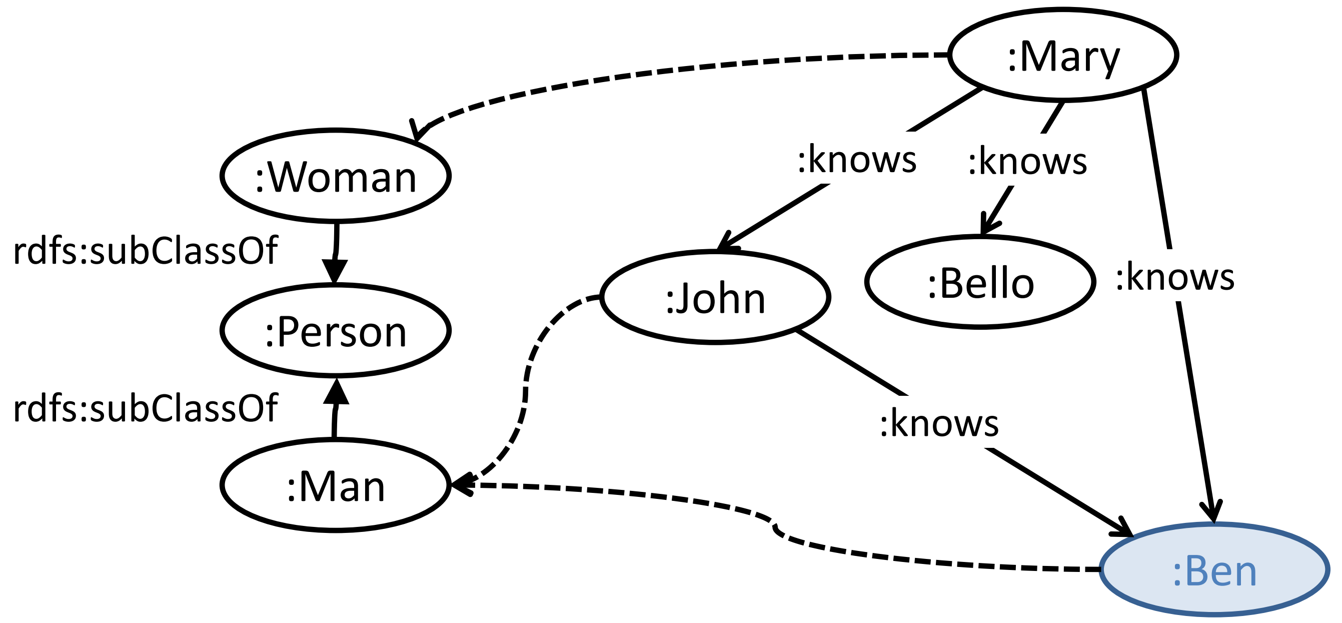
Data Graph

```
:Mary    a :Woman ;
         :knows :John, :Bob, :Bello.
:John    a :Man ;
         :knows :Ben .
:Ben     a :Man .
:Man     rdfs:subClassOf :Person.
:Woman   rdfs:subclassOf :Person.
```

Shapes Graph

```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```

$this = :Ben



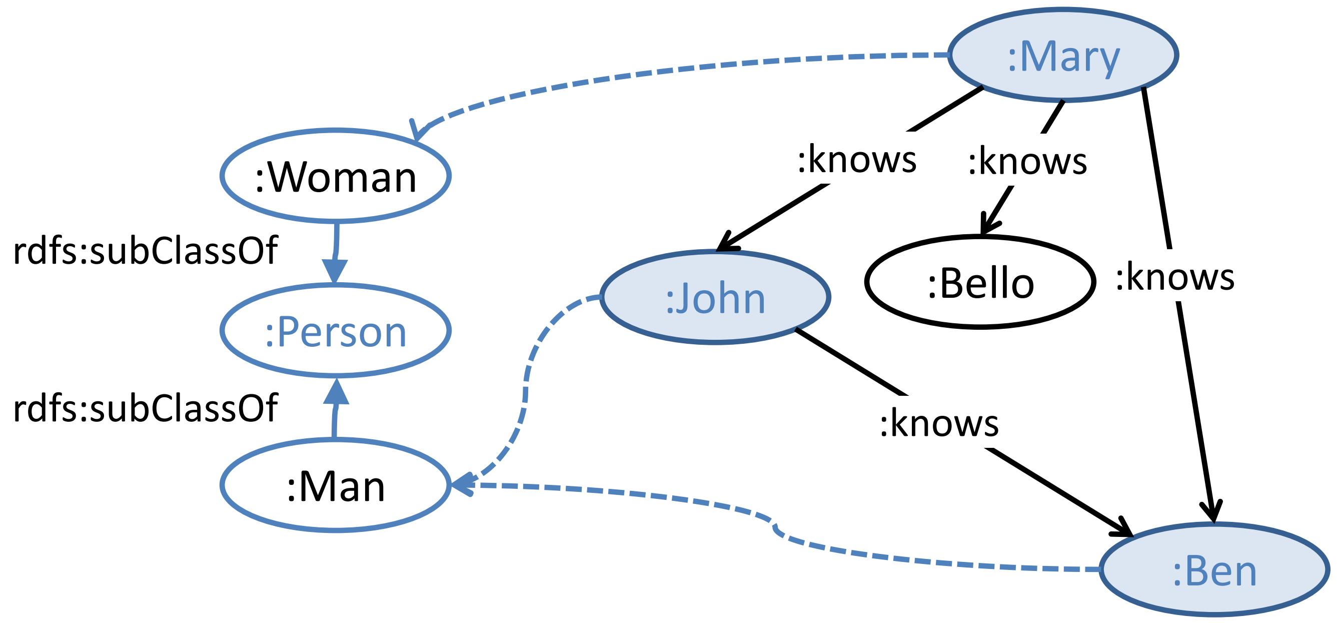
Validation Report

```
...
sh:result [ ...
  sh:focusNode     :Ben ;
  sh:sourceShape   :BenShape ] ;
...
```

Example 2: Target Declarations

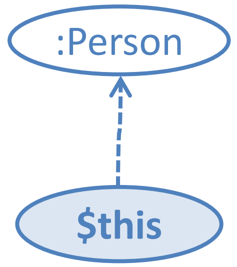
Data Graph

```
:Mary    a :Woman ;
         :knows :John, :Bob, :Bello.
:John    a :Man ;
         :knows :Ben .
:Ben     a :Man .
:Man     rdfs:subClassOf :Person.
:Woman   rdfs:subClassOf :Person.
```



Shapes Graph

```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```



Validation Report

```
 ...
sh:result [ ...
   sh:focusNode    :Mary ;
   sh:sourceShape  :PersonShape ] ;
sh:result [ ...
   sh:focusNode    :John ;
   sh:sourceShape  :PersonShape ] ;
sh:result [ ...
   sh:focusNode    :Ben ;
   sh:sourceShape  :PersonShape ] ;
...
```

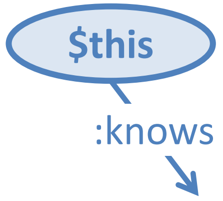
Example 2: Target Declarations

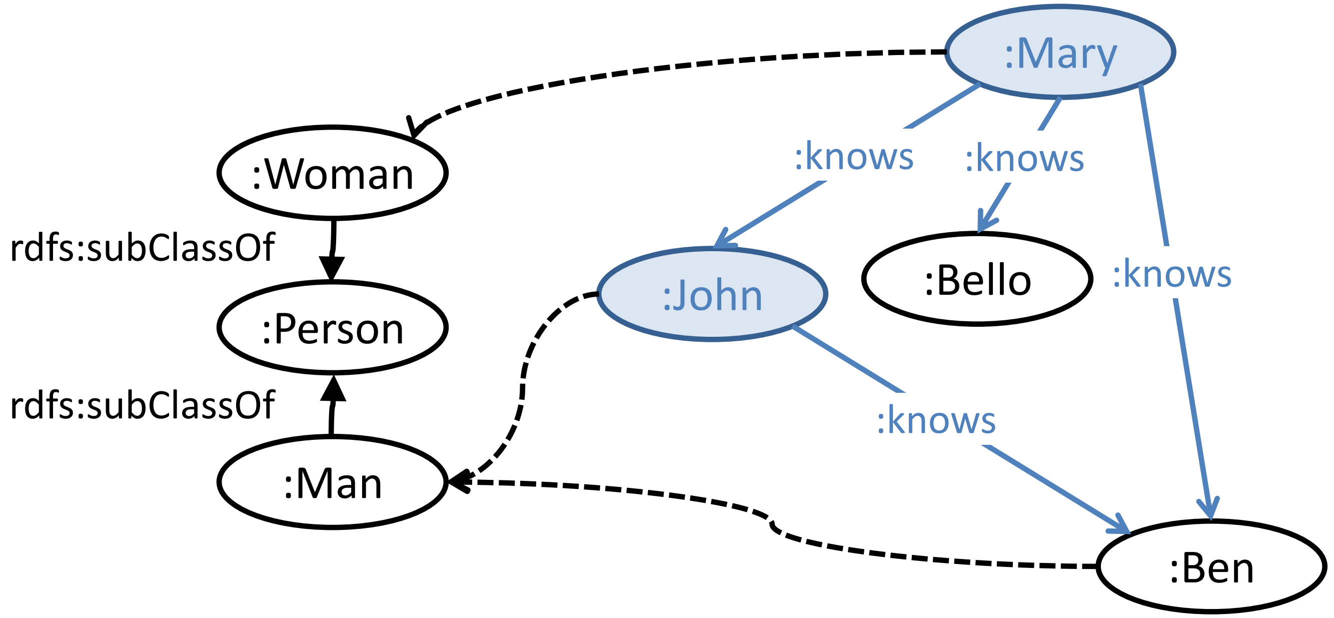
Data Graph

```
:Mary     a :Woman ;
          :knows :John, :Bob, :Bello.
:John     a :Man ;
          :knows :Ben .
:Ben      a :Man .
:Man      rdfs:subClassOf :Person.
:Woman    rdfs:subclassOf :Person.
```

Shapes Graph

```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```





Validation Report

```
...
sh:result [ ...
  sh:focusNode     :Mary ;
  sh:sourceShape   :KnowsSubjectShape ] ;
sh:result [ ...
  sh:focusNode     :John ;
  sh:sourceShape   :KnowsSubjectShape ] ;
...
```

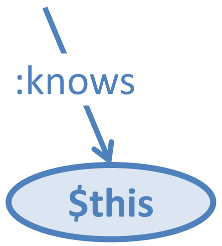
Example 2: Target Declarations

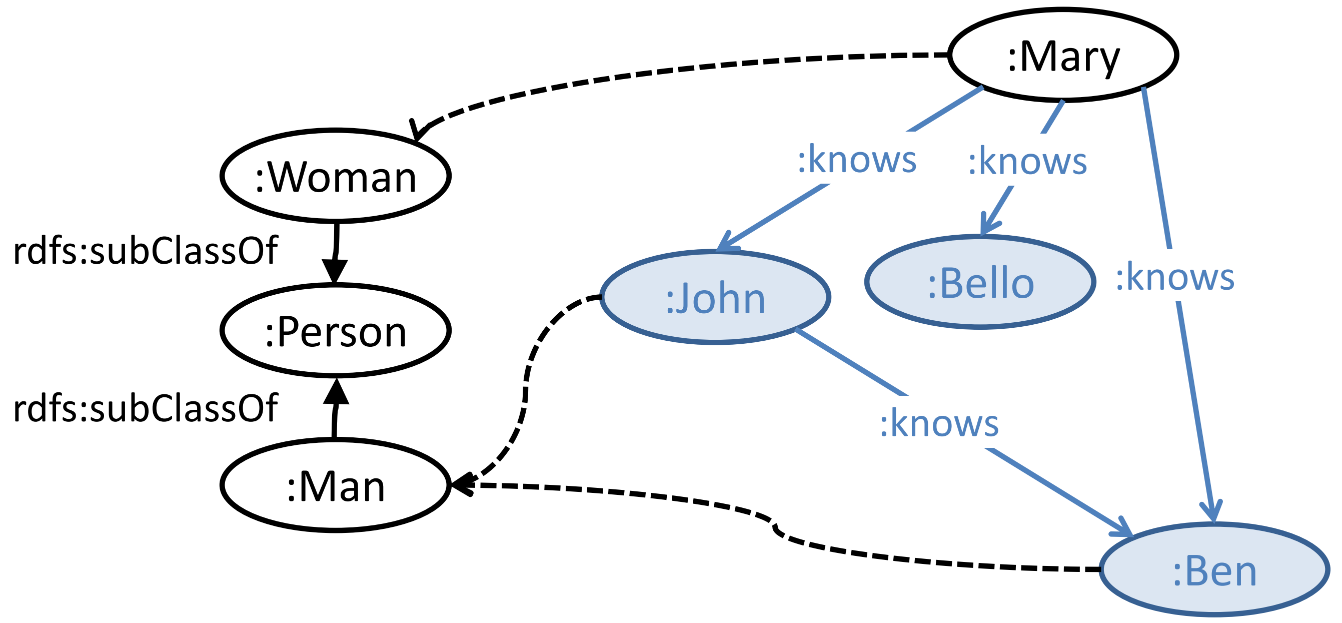
Data Graph

```
:Mary    a :Woman ;
         :knows :John, :Bob, :Bello.
:John    a :Man ;
         :knows :Ben .
:Ben     a :Man .
:Man     rdfs:subClassOf :Person.
:Woman   rdfs:subclassOf :Person.
```

Shapes Graph

```
:ManShape  a sh:PropertyShape ;
    sh:targetClass :Man ;
    sh:path :name; sh:minCount 1.
:BenShape a sh:PropertyShape ;
    sh:targetNode :Ben ;
    sh:path :name; sh:minCount 1.
:PersonShape a sh:PropertyShape ;
    sh:targetClass :Person ;
    sh:path :name; sh:minCount 1.
:KnowsSubjectShape  a sh:PropertyShape ;
    sh:targetSubjectsOf :knows ;
    sh:path :name; sh:minCount 1.
:KnowsObjectsShape  a sh:PropertyShape ;
    sh:targetObjectsOf :knows ;
    sh:path :name; sh:minCount 1.
```





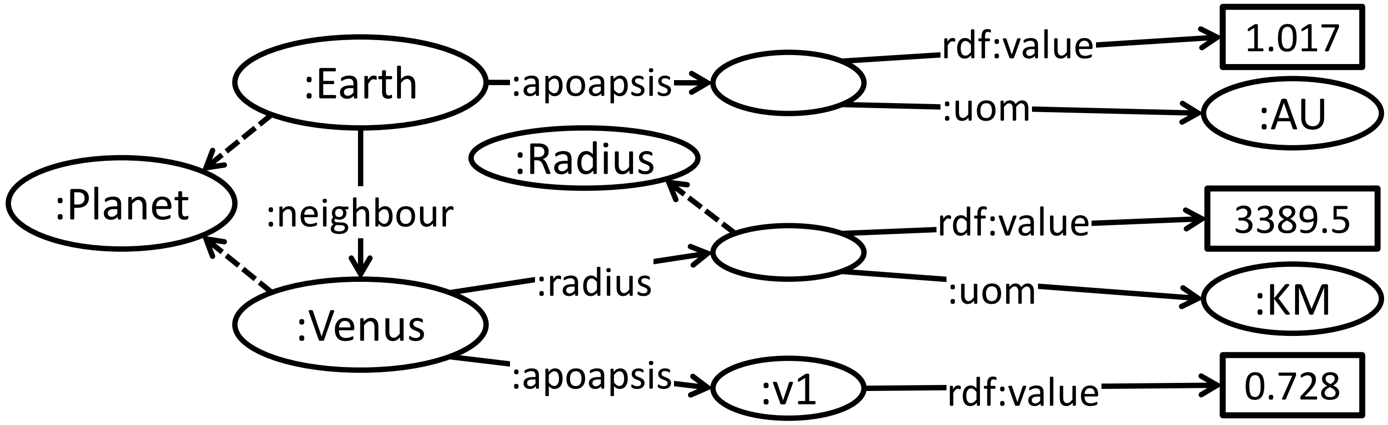
Validation Report

```
 ...
sh:result [ ...
  sh:focusNode     :Bello ;
  sh:sourceShape   :KnowsObjectShape ] ;
sh:result [ ...
  sh:focusNode     :John ;
  sh:sourceShape   : KnowsObjectShape ] ;
sh:result [ ...
  sh:focusNode     :Ben ;
  sh:sourceShape   : KnowsObjectShape ]
].
```

Example 3: References to Node Shapes

Data Graph

```
:Earth a :Planet ;
  :apoapsis [rdf:value 1.017; :uom :AU];
  :neighbour :Venus .
:Venus a :Planet;
  :apoapsis :v1;
  :radius [rdf:value 3389.5; :uom :KM ;
                 a :Radius] .
:v1 rdf:value 0.728.
```

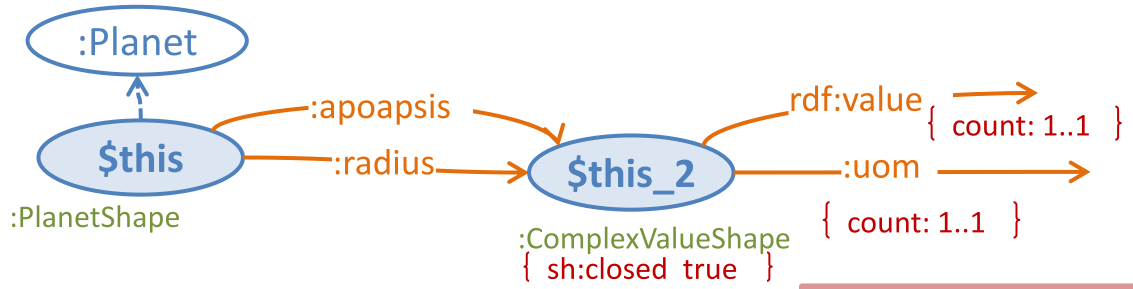


??

Shapes Graph

```
:PlanetShape  a sh:NodeShape ;
  sh:targetClass :Planet ;
  sh:property [
    sh:path :radius;
    sh:node :ComplexValueShape ];
  sh:property [
    sh:path :apoapsis;
    sh:node :ComplexValueShape ].

:ComplexValueShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path rdf:value;
    sh:minCount 1; sh:maxCount 1 ];
  sh:property [
    sh:path :uom;
    sh:minCount 1; sh:maxCount 1 ].
```



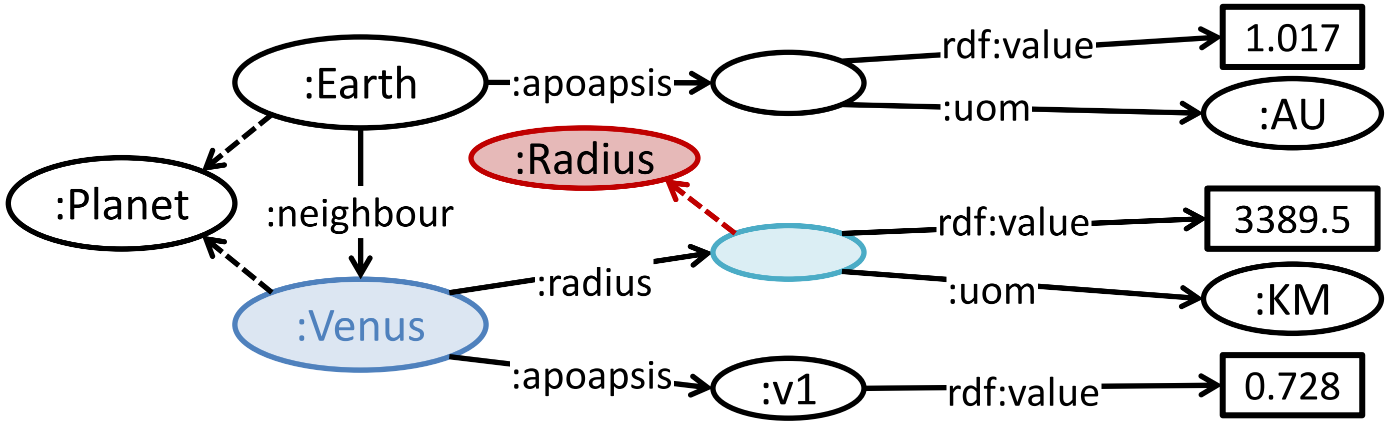
Validation Report

```
[
 a sh:ValidationReport ;
 sh:conforms  false ;
 ...
```

Example 3: References to Node Shapes

Data Graph

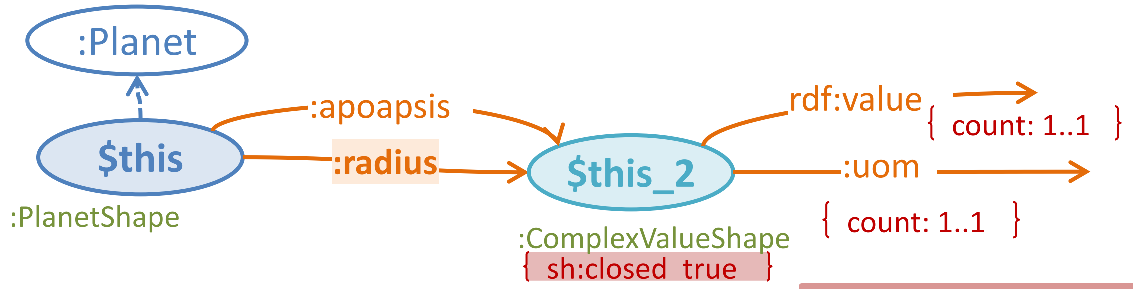
```
:Earth a :Planet ;
  :apoapsis [rdf:value 1.017; :uom :AU];
  :neighbour :Venus .
:Venus a :Planet;
  :apoapsis :v1;
  :radius [rdf:value 3389.5; :uom :KM,
               a :Radius] .
:v1 rdf:value 0.728.
```



Shapes Graph

```
:PlanetShape  a sh:NodeShape ;
  sh:targetClass :Planet ;
  sh:property [
    sh:path :radius;
    sh:node :ComplexValueShape ];
  sh:property [
    sh:path :apoapsis;
    sh:node :ComplexValueShape ].

:ComplexValueShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path rdf:value;
    sh:minCount 1; sh:maxCount 1 ];
  sh:property [
    sh:path :uom;
    sh:minCount 1; sh:maxCount 1 ].
```



Validation Report

```
...
sh:result [ a sh:ValidationResult ;
  sh:focusNode        :Venus ;
  sh:resultMessage "Node[<http://example.com/ns#Complex-
    ValueShape>] at focusNode _:B12..." ;
  sh:resultPath       :radius ;
  sh:resultSeverity sh:Violation ;
  sh:sourceConstraintComponent sh:NodeConstraintComponent;
  sh:sourceShape      []  ;
  sh:value            []
]; ...
```

Example 3: References to Node Shapes

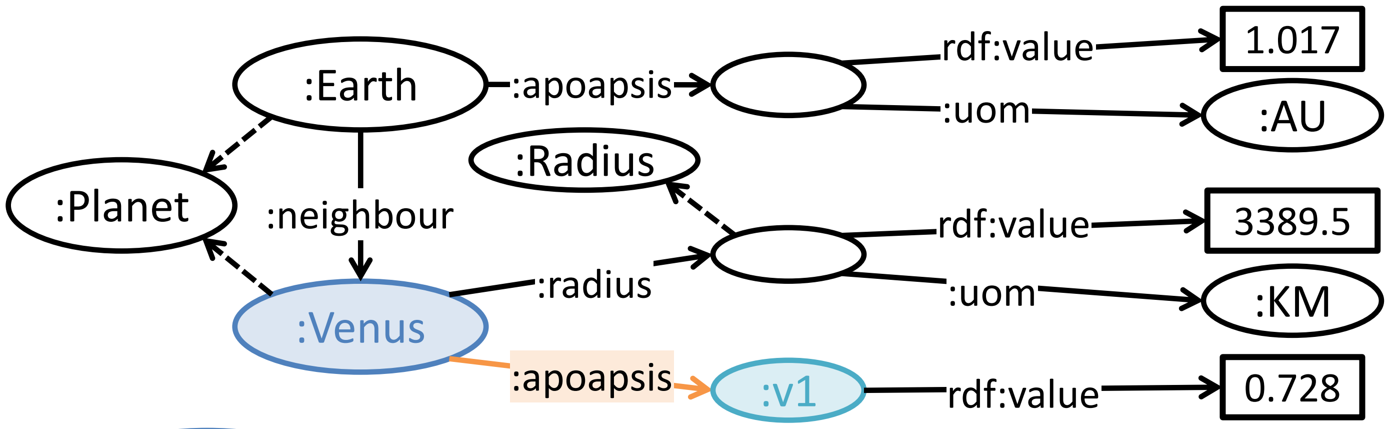
Data Graph

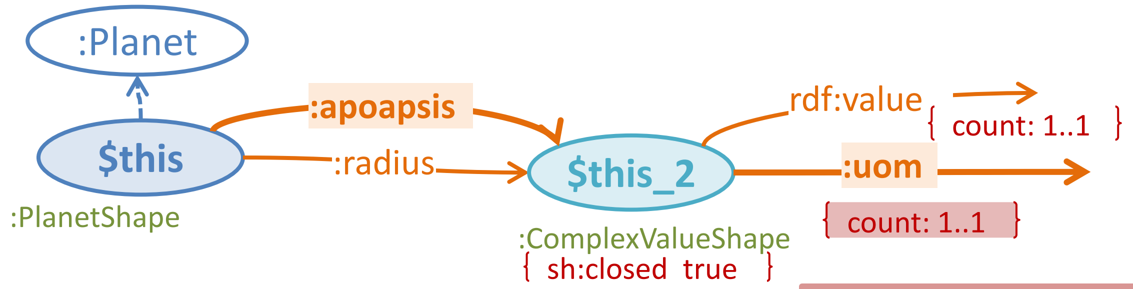
```
:Earth a :Planet ;
  :apoapsis [rdf:value 1.017; :uom :AU];
  :neighbour :Venus .
:Venus a :Planet;
  :apoapsis :v1;
  :radius [rdf:value 3389.5; :uom :KM,
                 a :Radius] .
:v1 rdf:value 0.728.
```

Shapes Graph

```
:PlanetShape  a sh:NodeShape ;
  sh:targetClass :Planet ;
  sh:property [
    sh:path :radius;
    sh:node :ComplexValueShape ];
  sh:property [
    sh:path :apoapsis;
    sh:node :ComplexValueShape ].

:ComplexValueShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path rdf:value;
    sh:minCount 1; sh:maxCount 1 ];
  sh:property [
    sh:path :uom;
    sh:minCount 1; sh:maxCount 1 ].
```





Validation Report

```
 ...
sh:result  [ a sh:ValidationResult ;
  sh:focusNode        :Venus ;
  sh:resultMessage "Node[<http://example.com/ns#Complex-
    ValueShape>] at focusNode <http://example.com/ns#v1>";
  sh:resultPath       :apoapsis ;
  sh:resultSeverity  sh:Violation ;
  sh:sourceConstraintComponent sh:NodeConstraintComponent;
  sh:sourceShape      []  ;
  sh:value            :v1
]] .
```

Example 4: Logical Constraint Components

Data Graph

```
:Earth a :Planet;
  :radius [rdf:value 3389.5; :uom :KM].
:Venus a :Planet;
  :radius [:nilReason "unknown"].
:Mars a :Planet;
  :radius [rdf:value 234.4].
:Mercury a :Planet;
  :radius [rdf:value 3389.5; :uom :KM; :nilReason "other"].
```

Shapes Graph

```
:PlanetShape  a sh:NodeShape ;
  sh:targetClass :Planet ;
  sh:property [
    sh:path :radius;
    sh:xone (:ComplexValueShape :NilShape)
  ].

:ComplexValueShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path rdf:value;
    sh:minCount 1; sh:maxCount 1 ];
  sh:property [
    sh:path :uom;
    sh:minCount 1; sh:maxCount 1 ].

:NilShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path :nilReason;
    sh:in ( "unknown" "inapplicable" "other" );
    sh:minCount 1; sh:maxCount 1 ].
```

The value of radius statements of instances of Planet is either a complex value or a node with a nil-reason.

Example 4: Logical Constraint Components

Data Graph

```
:Earth a :Planet;
  :radius [rdf:value 3389.5; :uom :KM].
:Venus a :Planet;
  :radius [:nilReason "unknown"].
:Mars a :Planet;
  :radius [rdf:value 234.4].
:Mercury a :Planet;
  :radius [rdf:value 3389.5; :uom :KM; :nilReason "other"].
```

Validation Report

```
[ a sh:ValidationReport ;
  sh:conforms  false ;
  sh:result  [
    a                  sh:ValidationResult ;
    sh:focusNode       :Mars ;
    sh:resultMessage   "Xone has 0 conforming shapes ..." ;
    sh:resultPath      :radius ;
    ... ] ;
  sh:result [
    a  sh:ValidationResult ;
    sh:focusNode       :Mercury ;
    sh:resultMessage   "Xone has 0 conforming shapes ..." ;
    sh:resultPath      :radius ;
    ... ]
] .
```

Shapes Graph

```
:PlanetShape  a sh:NodeShape ;
  sh:targetClass :Planet ;
  sh:property [
    sh:path :radius;
    sh:xone (:ComplexValueShape :NilShape)
  ].

:ComplexValueShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path rdf:value;
    sh:minCount 1; sh:maxCount 1 ];
  sh:property [
    sh:path :uom;
    sh:minCount 1; sh:maxCount 1 ].

:NilShape a sh:NodeShape ;
  sh:closed true;
  sh:property [
    sh:path :nilReason;
    sh:in ( "unknown" "inapplicable" "other" );
    sh:minCount 1; sh:maxCount 1 ].
```

Relevant SHACL Language Constructs for Exam

Basic vocabulary

- sh:Shape
  - sh:targetClass
- sh:NodeShape
  - sh:property
- sh:PropertyShape
  - sh:path
  - sh:maxCount
  - sh:minCount
  - sh:class
  - sh:datatype

Further relevant vocabulary

- sh:Shape
  - sh:targetNode
  - sh:targetSubjectOf
  - sh:targetObjectOf
- sh:NodeShape
  - sh:closed
  - sh:ignoredProperties
- sh:PropertyShape
  - sh:pattern
  - sh:nodeKind
  - sh:in

Advanced relevant vocabulary

- sh:PropertyShape
  - sh:node
  - sh:xone
- sh:Shape
  - sh:rule
- sh:SPARQLRule
  - sh:construct

https://www.w3.org/TR/shacl/

https://www.w3.org/TR/shacl-af/

Further Reading

- https://en.wikipedia.org/wiki/SHACL
- https://www.topquadrant.com/technology/shacl/tutorial/

- Shapes Constraint Language (SHACL), W3C Recommendation 20 July 2017, https://www.w3.org/TR/shacl/
  - SHACL Property Paths
  - Non-Validating Property Shape Characteristics
  - Core Constraint Components
  - SPARQL-based Constraints
  - ...

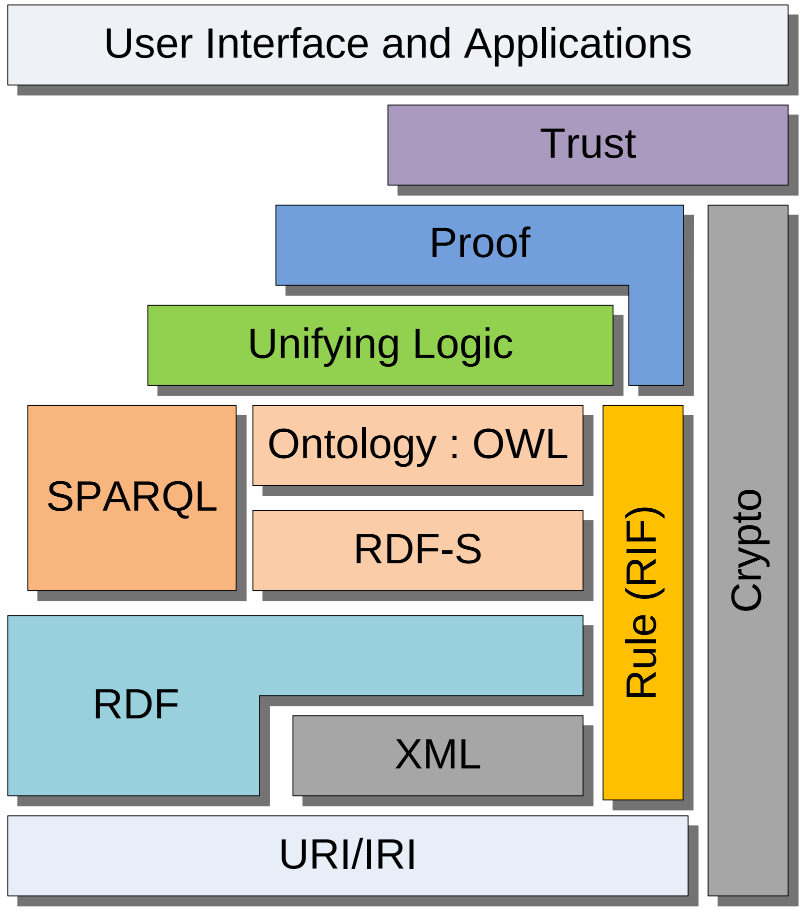
SHACL Rules

Bernd Neumayr
Johannes Kepler University Linz

based on
Shapes Constraint Language (SHACL) - W3C Recommendation 20 July 2017 - https://www.w3.org/TR/shacl/
SHACL Advanced Features - W3C Working Group Note 08 June 2017 - https://www.w3.org/TR/shacl-af/

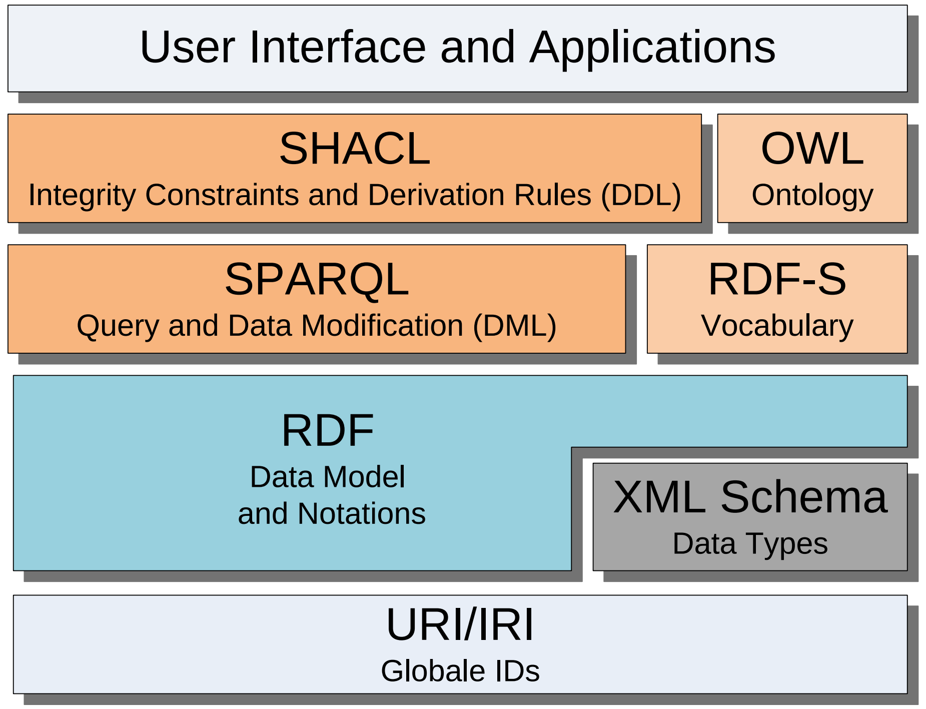
Knowledge Graph Technology Stack

Semantic Web Stack



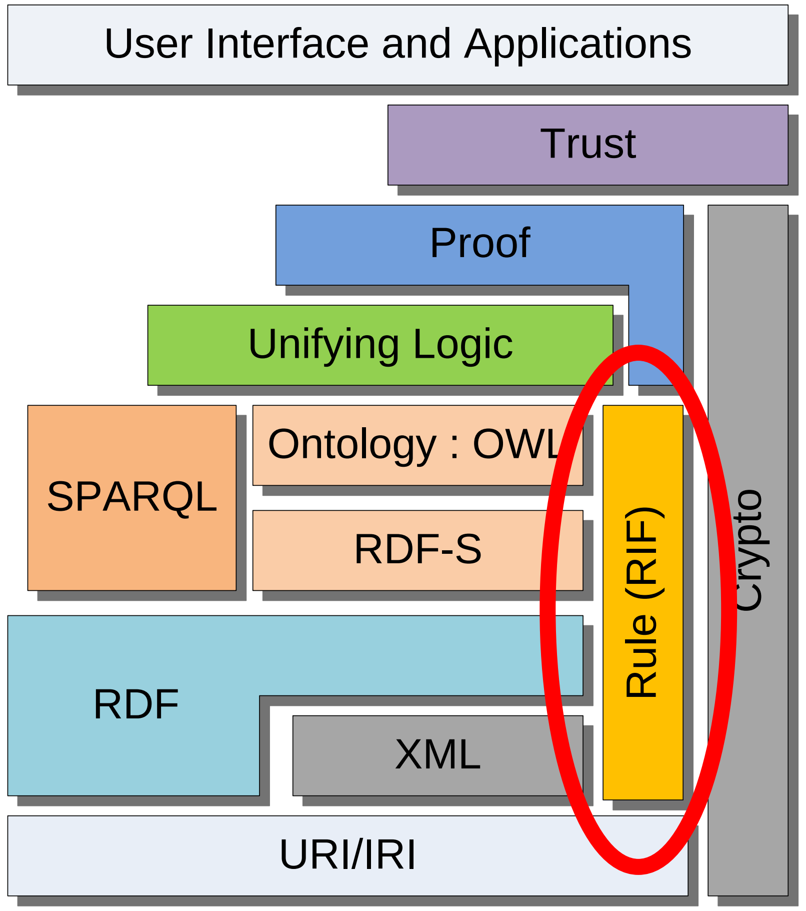
KG Technology Stack

(based on Semantic Web Technology)


User Interface and Applications
SHACL
Integrity Constraints and Derivation Rules (DDL)
OWL
Ontology
SPARQL
Query and Data Modification (DML)
RDF-S
Vocabulary
RDF
Data Model
and Notations
XML Schema
Data Types
URI/IRI
Globale IDs

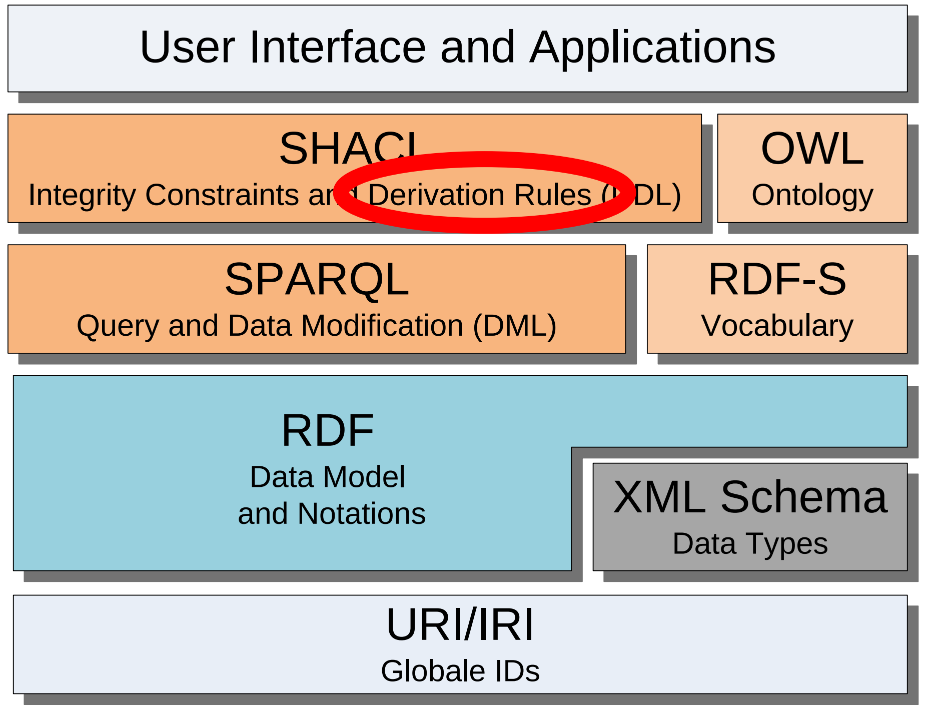
Knowledge Graph Technology Stack

Semantic Web Stack



KG Technology Stack

(based on Semantic Web Technology)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Motivation for SHACL Rules:

- Full integration with RDF/SPARQL/SHACL
- Express rule sets as RDF graphs
- Reuse SPARQL and SHACL

SHACL Rules – References for self study

- **SHACL property paths** allow to represent a subset of SPARQL property paths as RDF nodes
  https://www.w3.org/TR/shacl/#property-paths

- **SHACL functions** declare operations that produce an RDF term based on zero or more parameters and a data graph.
  https://www.w3.org/TR/shacl-af/#functions

- **Node expressions** are declared as RDF nodes in a shapes graph and instruct a SHACL engine how to compute a set of nodes for a given focus node.
  https://www.w3.org/TR/shacl-af/#node-expressions

- **SHACL rules** build on SHACL to form a light-weight RDF vocabulary for the exchange of rules that can be used to derive inferred RDF triples from existing asserted triples.
  https://www.w3.org/TR/shacl-af/#rules

SHACL Property Paths

SHACL property paths allow to represent a subset of SPARQL property paths as RDF nodes https://www.w3.org/TR/shacl/#property-paths , e.g.,

SPARQL Property Path	**SHACL Property Path**
`^ex:parent`	`[ sh:inversePath ex:parent ]`
`ex:parent/ex:firstName`	`( ex:parent ex:firstName )`
`rdf:type/rdfs:subClassOf*`	`( rdf:type [ sh:zeroOrMorePath rdfs:subClassOf ] )`
`ex:father|ex:mother`	`[ sh:alternativePath ( ex:father ex:mother  ) ]`
`rdfs:subClassOf+`	`[ sh:oneOrMorePath rdfs:subClassOf ]`