Introduction to SHACL

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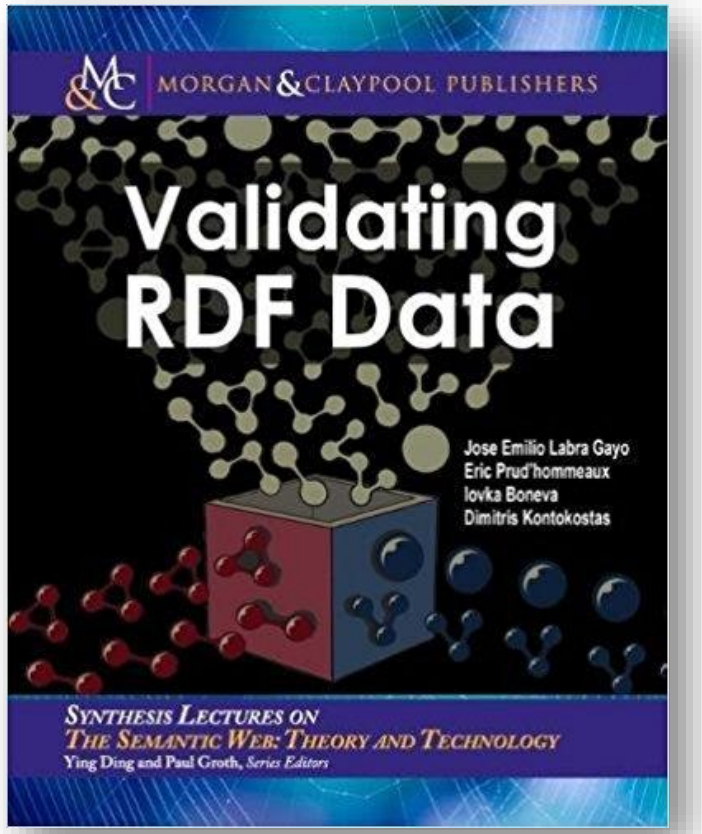
More info

Chapter 5 of Validating RDF Data book

[Online HTML version]



SHACL

W3C recommendation: https://www.w3.org/TR/shacl/ (July 2017)

Inspired by SPIN, OSLC & bits of ShEx

2 parts: SHACL-Core, SHACL-SPARQL

RDF vocabulary

Some SHACL implementations

Name	Parts	Language - Library	Comments
Topbraid SHACL API	SHACL Core, SPARQL	Java (Jena)	Used by TopBraid composer
SHACL playground	SHACL Core	Javascript (rdflib.js)	http://shacl.org/playground/
SHACL-S Part of SHaclEX	SHACL Core	Scala (Jena, RDF4j)	http://rdfshape.weso.es
pySHACL	SHACL Core, SPARQL	Python (rdflib)	https://github.com/RDFLib/pySHACL
Corese SHACL	SHACL Core, SPARQL	Java (STTL)	http://wimmics.inria.fr/corese
RDFUnit	SHACL Core, SPARQL	Java (Jena)	https://github.com/AKSW/RDFUnit
Jena SHACL	SHACL Core, SPARQL	Java (Jena)	https://jena.apache.org/
RDf4j SHACL	SHACL Core	Java (RDF4J)	https://rdf4j.org
Stardog	SHACL Core, SPARQL	Java	https://www.stardog.com
Zazuko SHACL	SHACL Core	Javascript	https://github.com/zazuko/rdf-validate-shacl
rudof NEW	SHACL core (in progress)	Rust	https://rudof-project.github.io/

RDFShape online demo supports: SHaclEX (SHACL-s), JenaSHACL, SHACL TQ (SHACL TopBraid API)

Basic example

```
prefix :       <http://example.org/>
prefix sh:     <http://www.w3.org/ns/shacl#>
prefix xsd:    <http://www.w3.org/2001/XMLSchema#>
prefix schema: <http://schema.org/>

:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property :hasName,
               :hasEmail .
:hasName sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string .
:hasEmail sh:path schema:email ;
   sh:minCount 1;
   sh:maxCount 1;
   sh:nodeKind sh:IRI .
```

Shapes graph

```
:alice schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

:bob   schema:firstName "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol schema:name "Carol" ;
       schema:email "carol@mail.org" .
```

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Data graph

Try it. RDFShape https://tinyurl.com/y46b2f8q

Same example with blank nodes

```
prefix :       <http://example.org/>
prefix sh:     <http://www.w3.org/ns/shacl#>
prefix xsd:    <http://www.w3.org/2001/XMLSchema#>
prefix schema: <http://schema.org/>

:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property [
    sh:path      schema:name ;
    sh:minCount 1; sh:maxCount 1;
    sh:datatype xsd:string ;
  ] ;
  sh:property [
   sh:path      schema:email ;
   sh:minCount 1; sh:maxCount 1;
   sh:nodeKind sh:IRI ;
  ] .
```

Shapes graph

```
:alice schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

:bob   schema:firstName "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol schema:name "Carol" ;
       schema:email "carol@mail.org" .
```

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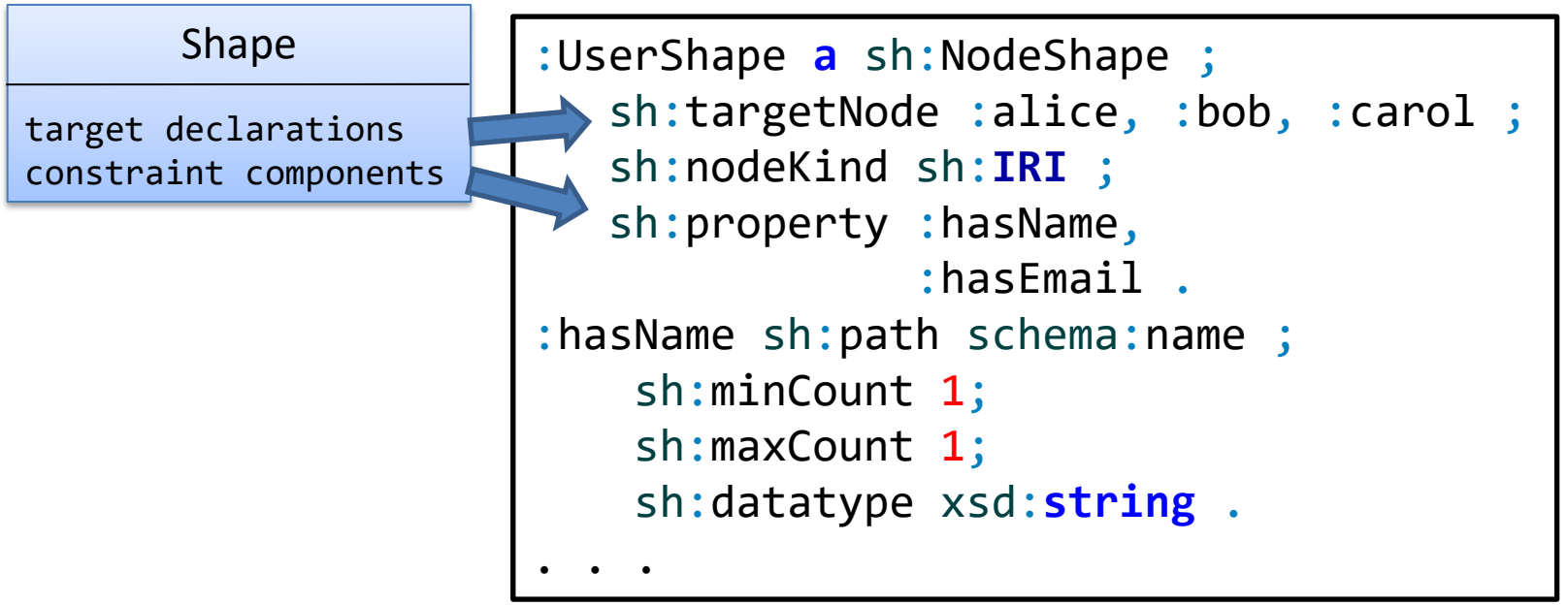
Data graph

Try it. RDFShape https://tinyurl.com/y4ycv2vn

Some definitions about SHACL

Shape: collection of targets and constraints components

- Targets: specify which nodes in the data graph must conform to a shape
- Constraint components: Determine how to validate a node



Shapes graph and data graph

Conceptually: 2 graphs

- Shapes graph: an RDF graph that contains shapes
- Data graph: an RDF graph that contains data to be validated

Note: They can be the same

```
:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property :hasName,
               :hasEmail .
:hasName sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string .
. . .
```

Shapes graph

```
:alice schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

:bob   schema:firstName "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol schema:name "Carol" ;
       schema:email "carol@mail.org" .
```

Data graph

Validation Report

The output of the validation process is a list of violation errors

No errors ⇒ RDF conforms to shapes graph

```
[ a              sh:ValidationReport ;
  sh:conforms    true
].
```

```
[ a              sh:ValidationReport ;
  sh:conforms    false ;
  sh:result      [
   a               sh:ValidationResult ;
   sh:focusNode    :bob ;
   sh:message
     "MinCount violation. Expected 1, obtained: 0" ;
   sh:resultPath schema:name ;
   sh:resultSeverity sh:Violation ;
   sh:sourceConstraintComponent
     sh:MinCountConstraintComponent ;
   sh:sourceShape  :hasName
] ;
...
```

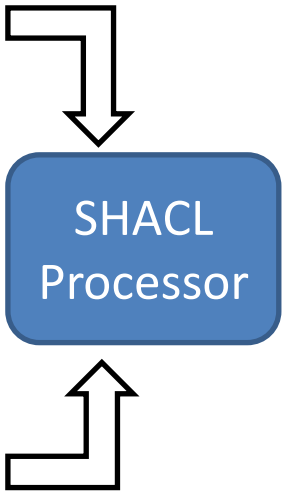
SHACL processor

Shapes graph with target declarations

```
:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property :hasName,
               :hasEmail .
:hasName sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string .
. . .
```

Data Graph

```
:alice schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org>.

:bob   schema:name "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol schema:name "Carol" ;
       schema:email <mailto:carol@mail.org>
.
```



Validation report

```
[ a              sh:ValidationReport ;
  sh:conforms    true
].
```

Importing shapes graphs

SHACL processors follow `owl:imports` declarations

It extends the current shapes graph with the imported shapes

```
:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property :hasName .
:hasName sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string .
```

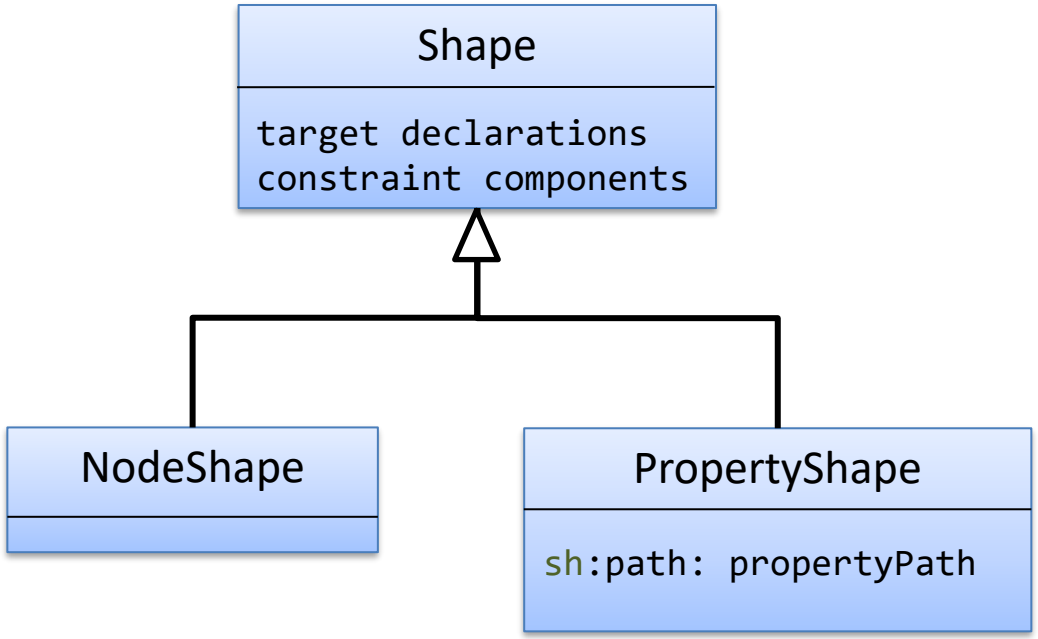
```
<> owl:imports <http://example.org/UserShapes> .

:TeacherShape a sh:NodeShape;
  sh:targetClass :Teacher ;
  sh:node :UserShape ;
  sh:property [
   sh:path :teaches ;
   sh:minCount 1;
   sh:datatype xsd:string;
 ] .
```

Node and property shapes

2 types of shapes:

NodeShape: constraints about shapes of nodes

PropertyShapes: constraints on property path values of a node



NodeShape

PropertyShape

```
:UserShape a sh:NodeShape ;
    sh:targetNode :alice, :bob, :carol ;
    sh:nodeKind sh:IRI ;
    sh:property :hasName,
                :hasEmail .
:hasName sh:path schema:name ;
     sh:minCount 1;
     sh:maxCount 1;
     sh:datatype xsd:string .
. . .
```

Node Shapes

Constraints about a focus node

```
:UserShape  a sh:NodeShape ;
      sh:nodeKind     sh:IRI ;
      sh:targetClass  :User .
```

```
:alice a :User .

<http://example.org/bob> a :User .

_:1 a :User .
```

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Try it: https://tinyurl.com/y6qyqo5g

Property shapes

Constraints about a given property and its values for the focus node

- `sh:property` associates a shape with a property shape
- `sh:path` identifies the path

```
:User a sh:NodeShape ;
   sh:property [
      sh:path     schema:email ;
      sh:nodeKind sh:IRI
   ] .
```

```
:alice a :User ;
       schema:email <mailto:alice@mail.org> .

:bob   a :User;
       schema:email <mailto:bob@mail.org> .

:carol a :User;
       schema:email "carol@mail.org" .
```

Paths in property shapes

Subset of SPARQL property paths using the following names:

- `inversePath`
- `alternativePath`
- `zeroOrMorePath`
- `oneOrMorePath`
- `zeroOrOnePath`

```
:User a sh:NodeShape, rdfs:Class ;
   sh:property [
    sh:path [sh:inversePath schema:follows ];
    sh:nodeKind sh:IRI ;
  ] .
```

```
:alice a :User;
       schema:follows :bob .

:bob   a :User .                    ☹

:carol a :User;
       schema:follows :alice .

_:1 schema:follows :bob .
```

Constraint components

- Constraints associated with shapes
  - They have parameters whose values specify the constraints
  - SHACL-core provides a list of predefined constraint components
    - Most of them have one parameter which identifies them

Convention:
Parameter: sh:xx
Constraint component: sh:xxConstraintComponent

```
:UserShape a             sh:NodeShape ;
           sh:nodeKind   sh:IRI .
```

Constraint component
sh:nodeKindConstraintComponent

Parameter
sh:nodeKind

Value of Parameter
sh:IRI ;

NOTE: Custom constraint components can be defined in SHACL-SPARQL

Repeated parameter

Each value of the parameter declares a different constraint

```
:UserShape a          sh:NodeShape;
           sh:class   foaf:Person ;
           sh:class   schema:Person .
```

```
:alice a schema:Person, foaf:Person .

:bob a schema:Person .
```

SHACL Core constraint components

Type	Constraints
Cardinality	`minCount, maxCount`
Types of values	`class, datatype, nodeKind`
Values	`node, in, hasValue, property`
Range of values	`minInclusive, maxInclusive` `minExclusive, maxExclusive`
String based	`minLength, maxLength, pattern`
Language based	`languageIn, uniqueLang`
Logical constraints	`not, and, or, xone`
Closed shapes	`closed, ignoredProperties`
Property pair constraints	`equals, disjoint, lessThan, lessThanOrEquals`
Non-validating constraints	`name, description, order, group`
Qualified shapes	`qualifiedValueShape, qualifiedValueShapesDisjoint` `qualifiedMinCount, qualifiedMaxCount`

See later

Human friendly messages

Message declares the message that will appear in the validation report in case of violation

```
:UserShape a sh:NodeShape ;
   sh:targetClass :User ;
   sh:property [
    sh:path       schema:name ;
    sh:minCount   1 ;
    sh:message    "Where is the name?"
  ] .
```

```
:bob    a :User ;
        schema:alias "Bob" . ☹
```

```
:report a :ValidationReport ;
 sh:conforms false ;
 sh:result [ a sh:ValidationResult ;
  sh:resultSeverity            sh:Violation ;
  sh:sourceConstraintComponent sh:MinCountConstraintComponent ;
  sh:sourceShape               ... ;
  sh:focusNode                 :bob ;
  sh:resultPath                schema:name ;
   sh:resultMessage            "Where is the name?" ;
].
```

Severities

Declare the level of the violation

- 3 predefined levels: Violation (default), Warning, Info

```
:UserShape a sh:NodeShape ;
 sh:targetClass :User ;
 sh:property [
    sh:path     schema:name ;
    sh:datatype xsd:string ;
    sh:severity sh:Warning
  ] .
```

```
:bob    a :User ;
        schema:alias "Bob" .
```

```
:report a :ValidationReport ;
 sh:conforms false ;
 sh:result [ a sh:ValidationResult ;
   sh:resultSeverity      sh:Warning ;
   sh:sourceConstraintComponent sh:MinCountConstraintComponent ;
   sh:sourceShape               ... ;
   sh:focusNode                 :bob ;
   sh:resultPath                schema:name ;
   sh:resultMessage             "MinCount Error" ;
].
```

Deactivating shapes

Deactivate a shape

Useful when importing shapes

UserShapes

```
:UserShape a sh:NodeShape;
 sh:targetClass :User ;
 sh:property :HasName ;
 sh:property :HasEmail .

:HasName sh:path schema:name ;
  sh:datatype xsd:string .

:HasEmail sh:path schema:email ;
  sh:minCount 1;
  sh:nodeKind sh:IRI .
```

```
<> owl:imports <UserShapes> .

:TeacherShape  a  sh:NodeShape;
   sh:targetClass :Teacher ;
   sh:node        :UserShape ;
   sh:property [ sh:path      :teaches ;
    sh:minCount  1;
    sh:datatype  xsd:string;
  ] .

:HasEmail sh:deactivated true .
```

Target declarations

Targets specify nodes that must be validated against the shape

Several types

Value	Description
`targetNode`	Directly point to a node
`targetClass`	All nodes that have a given type
`targetSubjectsOf`	All nodes that are subjects of some predicate
`targetObjectsOf`	All nodes that are objects of some predicate

Target node

Directly declare which nodes must validate the against the shape

```
:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:property [
    sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
  ] ;
  sh:property [
   sh:path schema:email ;
   sh:minCount 1;
   sh:maxCount 1;
   sh:nodeKind sh:IRI ;
  ] .
```

```
:alice schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

:bob   schema:givenName "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol schema:name "Carol" ;
       schema:email "carol@mail.org" .
```

Target class

Selects all nodes that have a given class

Looks for rdf:type declarations*

```
:UserShape a sh:NodeShape ;
 sh:targetClass :User ;
 sh:property [
    sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
 ] ;
 sh:property [
   sh:path schema:email ;
   sh:minCount 1;
   sh:maxCount 1;
   sh:nodeKind sh:IRI ;
 ] .
```

```
:alice a :User;
       schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

:bob   a :User;
       schema:givenName "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol a :User;
       schema:name "Carol" ;
       schema:email "carol@mail.org" .
```

* Also looks for rdfs:subClassOf*/rdf:type declarations

Implicit class target

A shape with type sh:Shape and rdfs:Class is a scope class of itself

The targetClass declaration is implicit

```
:User a sh:NodeShape, rdfs:Class ;
  sh:property [
     sh:path schema:name ;
     sh:minCount 1;
     sh:maxCount 1;
     sh:datatype xsd:string ;
  ] ;
  sh:property [
    sh:path schema:email ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:nodeKind sh:IRI ;
  ] .
```

```
:alice a :User;
       schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

:bob   a :User;
       schema:givenName "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol a :User;
       schema:name "Carol" ;
       schema:email "carol@mail.org" .
```

targetSubjectsOf

```
:UserShape a sh:NodeShape;
 sh:targetSubjectsOf :teaches ;
 sh:property [
    sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
 ] .
```

```
:alice :teaches :Algebra ;      #Passes as :UserShape
       schema:name "Alice" .

:bob   :teaches :Logic ;        #Fails as :UserShape
       foaf:name "Robert" .

:carol foaf:name 23 .           # Ignored
```

targetObjectsOf

```
:UserShape a              sh:NodeShape;
 sh:targetObjectsOf :isTaughtBy ;
 sh:property [
    sh:path      schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
 ] .
```

```
:alice schema:name "Alice" . #Passes as :UserShape

:bob   foaf:name "Robert" .  #Fails as :UserShape

:carol foaf:name 23 .        # Ignored

:algebra :isTaughtBy :alice, :bob .
```

Core constraint components

Type	Constraints
Cardinality	`minCount, maxCount`
Types of values	`datatype, class, nodeKind`
Values	`node, in, hasValue`
Range of values	`minInclusive, maxInclusive` `minExclusive, maxExclusive`
String based	`minLength, maxLength, pattern, stem, uniqueLang`
Logical constraints	`not, and, or, xone`
Closed shapes	`closed, ignoredProperties`
Property pair constraints	`equals, disjoint, lessThan, lessThanOrEquals`
Non-validating constraints	`name, value, defaultValue`
Qualified shapes	`qualifiedValueShape, qualifiedMinCount, qualifiedMaxCount`

Cardinality constraints

Constraint	Description
`minCount`	Restricts minimum number of triples involving the focus node and a given predicate. Default value: 0
`maxCount`	Restricts maximum number of triples involving the focus node and a given predicate. If not defined = unbounded

```
:User a sh:NodeShape ;
   sh:property [
    sh:path     schema:follows ;
    sh:minCount 2 ;
    sh:maxCount 3 ;
  ] .
```

```
:alice schema:follows :bob,
                      :carol .

:bob   schema:follows :alice .   ☹

:carol schema:follows :alice,
                      :bob,      ☹
                      :carol,
                      :dave .
```

Try it. https://tinyurl.com/y5wjrowt

Datatypes of values

Constraint	Description
datatype	Restrict the datatype of all value nodes to a given value

```
:User a sh:NodeShape ;
   sh:property [
    sh:path     schema:birthDate ;
    sh:datatype xsd:date ;
  ] .
```

```
:alice schema:birthDate "1985-08-20"^^xsd:date .

:bob   schema:birthDate "Unknown"^^xsd:date .

:carol schema:birthDate 1990 .
```

Try it: https://tinyurl.com/y42ec72v

Class of values

Constraint	Description
`class`	Verify that each node in an instance of some class It also allows instances of subclasses*

(*) The notion of SHACL instance is different from RDFS
It is defined as `rdfs:subClassOf*/rdf:type`

```
:User a sh:NodeShape, rdfs:Class ;
 sh:property [
  sh:path  schema:follows ;
  sh:class :User
 ] .
```

```
:Manager rdfs:subClassOf :User .

:alice a :User;
       schema:follows :bob .
:bob   a :Manager ;
       schema:follows :alice .
:carol a :User;
       schema:follows :alice, :dave .
:dave  a :Employee .
```

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Kind of values

Constraint	Description

nodeKind	Possible values:
	`BlankNode, IRI, Literal,`
	`BlankNodeOrIRI, BlankNodeOrLiteral, IRIOrLiteral`

```
:User a sh:NodeShape, rdfs:Class ;
  sh:property [
   sh:path     schema:name ;
   sh:nodeKind sh:Literal ;
  ];
  sh:property [
   sh:path     schema:follows ;
   sh:nodeKind sh:BlankNodeOrIRI
  ];
  sh:nodeKind sh:IRI .
```

```
:alice a :User;
       schema:name    _:1 ;
       schema:follows :bob .

:bob   a :User;
       schema:name  "Robert";
       schema:follows [ schema:name "Dave" ] .

:carol a :User;
       schema:name    "Carol" ;
       schema:follows "Dave"  .

_:1 a :User .
```

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Constraints on values

Constraint	Description
hasValue	Verifies that the focus node has a given value
in	Enumerates the value nodes that a property may have

```
:User a sh:NodeShape, rdfs:Class ;
  sh:property [
   sh:path      schema:affiliation ;
   sh:hasValue :OurCompany ;
  ];
  sh:property [
   sh:path schema:gender ;
   sh:in   (schema:Male schema:Female)
  ] .
```

```
:alice a :User;
       schema:affiliation :OurCompany ;
       schema:gender schema:Female .

:bob   a :User;
       schema:affiliation :AnotherCompany ;
       schema:gender schema:Male .

:carol a :User;
       schema:affiliation :OurCompany ;
       schema:gender schema:Unknown .
```

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Constraints on values with another shape

Constraint	Description
node	All values of a given property must have a given shape Recursion is not allowed in current SHACL

```
:User a sh:NodeShape, rdfs:Class ;
  sh:property [
   sh:path schema:worksFor ;
   sh:node :Company ;
  ] .

:Company a sh:Shape ;
  sh:property [
   sh:path     schema:name ;
   sh:datatype xsd:string ;
  ] .
```

```
:alice a :User;
       schema:worksFor :OurCompany .

:bob   a :User;
       schema:worksFor :Another .

:OurCompany
    schema:name "OurCompany" .

:Another
    schema:name 23 .
```

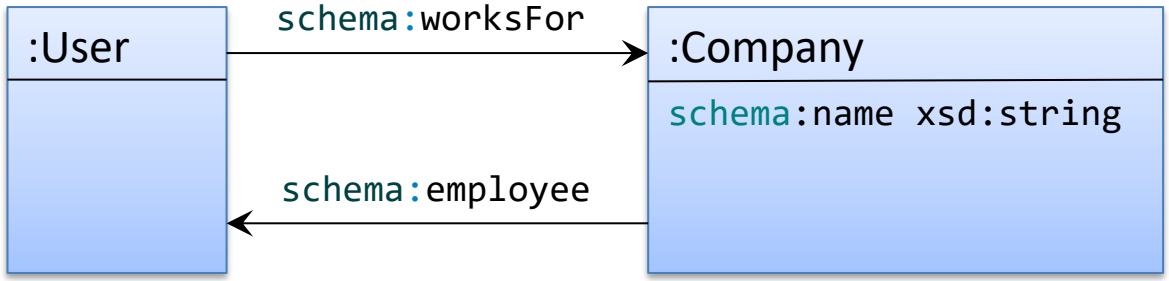
Value shapes and recursion

Can we define cyclic data models as the following?

```
:User a sh:NodeShape ;
  sh:property [
   sh:path  schema:worksFor ;
   sh:node :Company ;
  ] .

:Company a sh:Shape ;
  sh:property [
   sh:path     schema:name ;
   sh:datatype xsd:string ;
  ] ;
 sh:property [
   sh:path schema:employee ;
   sh:node :User ;
 ]  .
```

Try it: https://tinyurl.com/y3hkka6s




```
:alice schema:worksFor :OneCompany .
:bob   schema:worksFor :OneCompany .
:carol schema:worksFor :OneCompany .

:OneCompany schema:name "One" ;
  schema:employee :alice, :bob, :carol .
```

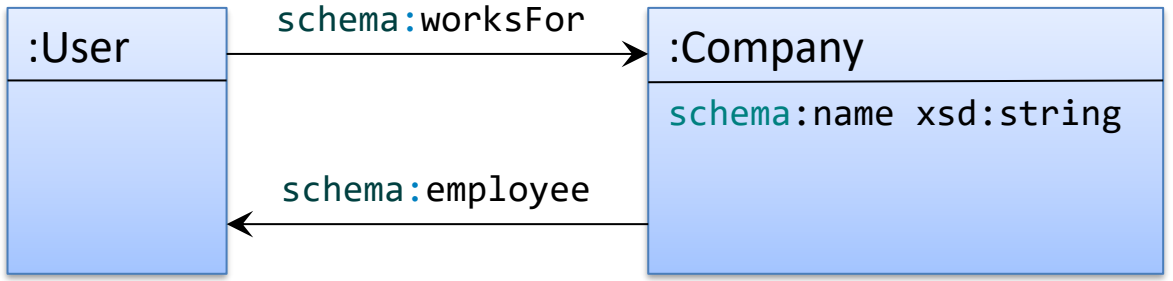
SHACL spec leaves this as implementation dependent

An approach to avoid recursion

Add rdf:type arcs for every resource and use `sh:class`

```
:User a sh:NodeShape ;
  sh:property [
   sh:path   schema:worksFor ;
   sh:class :Company ;
  ] .

:Company a sh:Shape ;
  sh:property [
   sh:path     schema:name ;
   sh:datatype xsd:string ;
  ] ;
 sh:property [
   sh:path   schema:employee ;
   sh:class :User ;
 ] .
```




```
:alice a :User ;
       schema:worksFor :OneCompany .
:bob   a :User ;
       schema:worksFor :OneCompany .
:carol a :User ;
       schema:worksFor :Something .

:OneCompany a :Company ;
       schema:name "One" ;
       schema:employee :alice, :bob, :carol .
```

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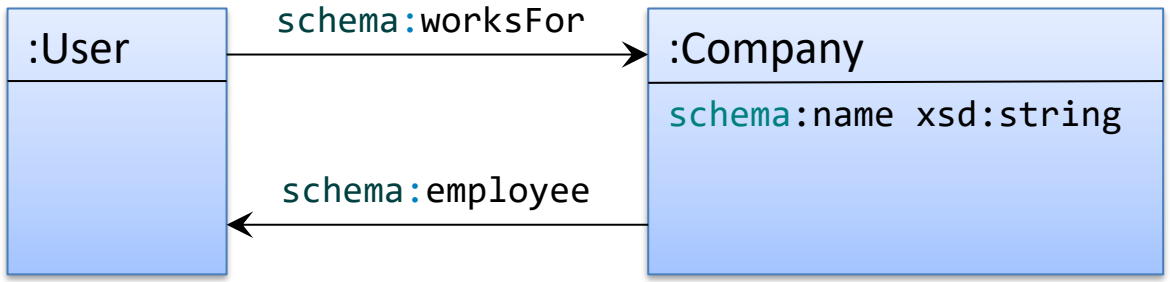
Try it: https://tinyurl.com/yynnts8o

Exercise:

Represent the previous shapes without recursion using property paths



Logical Operators

Constraint	Description
and	Conjunction of a list of shapes
or	Disjunction of a list of shapes
not	Negation of a shape
xone	Exactly one (similar XOR for 2 arguments)

Conjunction: and

Although it can be declared explicitly, it is the default behavior

```
:User a sh:NodeShape ;
  sh:and (
   [ sh:property [
      sh:path     schema:name;
      sh:minCount 1;
     ]
   ]
   [ sh:property [
      sh:path     schema:affiliation;
      sh:minCount 1;
     ]
   ]
  ) .
```

≡

```
:User a sh:Shape ;
   [ sh:property [
      sh:path     schema:name;
      sh:minCount 1;
     ]
   ]
   [ sh:property [
      sh:path     schema:affiliation;
      sh:minCount 1;
     ]
   ]
.
```

Disjunction: or

```
:User a sh:NodeShape ;
  sh:or (
   [ sh:property [
      sh:predicate foaf:name;
      sh:minCount 1;
     ]
   ]
   [ sh:property [
      sh:predicate schema:name;
      sh:minCount 1;
     ]
   ]
  ) .
```

```
:alice schema:name "Alice" .

:bob   foaf:name "Robert" .

:carol rdfs:label "Carol" .
```

Negation: not

```
:NotFoaf a sh:NodeShape ;
 sh:not [ a sh:Shape ;
  sh:property [
   sh:predicate foaf:name ;
   sh:minCount 1 ;
  ] ;
 ] .
```

```
:alice schema:name "Alice" .

:bob   foaf:name "Robert" .

:carol rdfs:label "Carol" .
```

Exactly one: xone

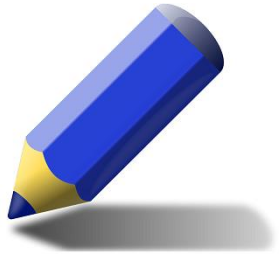
```
:UserShape a sh:NodeShape ;
  sh:targetClass :User ;
  sh:xone (
   [ sh:property [
       sh:path     foaf:name;
       sh:minCount 1;
     ]
   ]
   [ sh:property [
       sh:path     schema:name;
       sh:minCount 1;
     ]
   ]
  ) .
```

```
:alice a :User ;                  #Passes as :User
       schema:name "Alice" .

:bob   a :User ;                  #Passes as :User
       foaf:name   "Robert" .

:carol a :User ;                  #Fails as :User
       foaf:name   "Carol";
       schema:name "Carol" .

:dave  a :User ;                  #Fails as :User
       rdfs:label  "Dave" .
```



Exercise

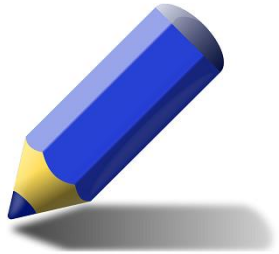
IF-THEN pattern

All products must have `:productID` and, if a product has `rdf:type schema:Vehicle` then it must have the properties `schema:vehicleEngine` and `schema:fuelType`

```
:p1 a :Book;                    # Conforms
    schema:productID      "P1" .

:p2 a schema:Vehicle ;          # Conforms
    schema:productID      "P2" ;
    schema:fuelType       "Gasoline" ;
    schema:vehicleEngine "X2" .

:p3 a schema:Vehicle ;           # Fails
    schema:productID      "P3" .
```



Exercise

IF-THEN-ELSE pattern

All products must have `:productID` and, if a product has `rdf:type` `schema:Vehicle` then it must have the properties `schema:vehicleEngine` and `schema:fuelType` else it must have `schema:category` with a string value.

Value ranges

Constraint	Description
minInclusive	<=
maxInclusive	>=
minExclusive	<
maxExclusive	>

```
:Rating a sh:NodeShape ;
 sh:property [
   sh:path          schema:ratingValue ;
   sh:minInclusive 1 ;
   sh:maxInclusive 5 ;
   sh:datatype      xsd:integer
 ] .
```

```
:bad        schema:ratingValue 1 .

:average    schema:ratingValue 3 .

:veryGood   schema:ratingValue 5 .

:zero       schema:ratingValue 0 .
```

Try it: https://tinyurl.com/yy4bsavj

String based constraints

Constraint	Description
`minLength`	Restricts the minimum string length on value nodes
`maxLength`	Restricts the maximum string length on value nodes
`pattern`	Checks if the string value matches a regular expression

minLength/maxLength

Checks the string representation of the value

- This cannot be applied to blank nodes
- If minLength = 0, no restriction on string length

```
:User a sh:NodeShape ;
 sh:property [
   sh:path      schema:name ;
   sh:minLength 4 ;
   sh:maxLength 10 ;
 ] .
```

```
:alice schema:name "Alice" .

:bob schema:name "Bob" .                    ☹

:carol  schema:name :Carol .                ?

:strange schema:name _:strange .            ☹
```

Try it: https://tinyurl.com/y5laj3vf

pattern

Checks if the values matches a regular expression
It can be combined with sh:flags

```
:Product a sh:NodeShape ;
 sh:property [
   sh:path    schema:productID ;
   sh:pattern "^P\\d{3,4}" ;
   sh:flags   "i" ;
 ] .
```

```
:car   schema:productID "P2345" .

:bus   schema:productID "p567" .

:truck schema:productID "P12" .   ☹

:bike  schema:productID "B123" .  ☹
```

Language based constraints

Constraint	Description
`languageIn`	Declares the allowed languages of a literal
`uniqueLang`	Specifies that no pair of nodes can have the same language tag

languageIn

Specifies the allowed language that a literal can have

```
:ProductShape a sh:NodeShape;
  sh:targetClass :Product ;
  sh:property [
    sh:path       rdfs:label ;
    sh:languageIn ("es" "en" "fr")
] .
```

```
:p234 a :Product ;
  rdfs:label "jamón"@es, "ham"@en .

:p235 a :Product ;
  rdfs:label "milk"@en .

:p236 a :Product ;
  rdfs:label "Käse"@de .

:p237 a :Product ;
  rdfs:label "patatas"@es ,
             "kartofeln"@de .
```

uniqueLang

Checks that no pair of nodes use the same language tag

```
:CountryShape a sh:NodeShape ;
  sh:targetClass :Country ;
  sh:property [
    sh:path       skos:prefLabel ;
    sh:uniqueLang true
] .
```

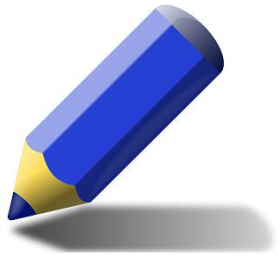
```
:spain  a :Country;
 skos:prefLabel "Spain"@en,
                "España"@es .

:france a :Country;
  skos:prefLabel "France",
                 "France"@en,
                 "Francia"@es .

:italy  a :Country .

:usa    a :Country;
        skos:prefLabel "USA"@en,
                       "United States"@en.
```

☹



Exercise

Nodes must have exactly one literal per language in English and Spanish for property `skos:prefLabel`

Property pair constraints

Constraint	Description
equals	The sets of values of both properties at a given focus node must be equal
disjoint	The sets of values of both properties at a given focus node must be different
lessThan	The values must be smaller than the values of another property
lessThanOrEquals	The values must be smaller or equal than the values of another property

```
:User a sh:NodeShape ;
 sh:property [
  sh:path   schema:givenName ;
  sh:equals foaf:firstName
 ];
 sh:property [
  sh:path      schema:givenName ;
  sh:disjoint  schema:lastName
] .
```

```
:alice schema:givenName "Alice";
       schema:lastName  "Cooper";
       foaf:firstName   "Alice" .

:bob   schema:givenName "Bob";
       schema:lastName  "Smith" ;
       foaf:firstName   "Robert" .

:carol schema:givenName "Carol";
       schema:lastName  "Carol" ;
       foaf:firstName   "Carol" .
```

☹

☹

Closed shapes

Constraint	Description
`closed`	Valid resources must only have values for properties that appear in `sh:property`
`ignoredProperties`	Optional list of properties that are also permitted

```
:User a sh:NodeShape ;
  sh:closed true ;
  sh:ignoredProperties ( rdf:type ) ;
  sh:property [
    sh:path schema:givenName ;
  ];
  sh:property [
    sh:path schema:lastName ;
  ] .
```

```
:alice schema:givenName "Alice";
       schema:lastName "Cooper" .

:bob   a :Employee ;
       schema:givenName "Bob";
       schema:lastName "Smith" .

:carol schema:givenName "Carol";
       schema:lastName "King" ;
       rdfs:label "Carol" .
```

Qualified value shapes

Problem with repeated properties

Example: Books have two IDs (an isbn and an internal code)

```
:Book a sh:NodeShape ;
   sh:property [
    sh:path     schema:productID ;
    sh:minCount 1;
    sh:datatype xsd:string ;
    sh:pattern  "^isbn"
  ];
  sh:property [
    sh:path     schema:productID ;
    sh:minCount 1;
    sh:datatype xsd:string ;
    sh:pattern  "^code"
  ] .
```

```
:b1 schema:productID "isbn:123-456-789" ;
    schema:productID "code234" .
```

It fails!!

Qualified value shapes

Qualified value shapes verify that certain number of values of a given property have a given shape

```
:Book a sh:NodeShape;
 sh:property [
  sh:path schema:productID ;
  sh:minCount 2; sh:maxCount 2; ];
 sh:property [
  sh:path schema:productID ;
  sh:qualifiedMinCount 1 ;
  sh:qualifiedValueShape [
   sh:pattern "^isbn"
 ]];
 sh:property [
  sh:path schema:productID ;
  sh:qualifiedMinCount 1 ;
  sh:qualifiedValueShape [
   sh:pattern "^code" ;
  ]] .
```

```
:b1 schema:productID "isbn:123-456-789" ;
    schema:productID "code234" .
```

Non-validating constraints

Can be useful to annotate shapes or design UI forms

Constraint	Description
name	Provide human-readable labels for a property
description	Provide a description of a property
order	Relative order of the property
group	Group several constraints together

```
:User a sh:NodeShape ;
 sh:property [
  sh:path schema:url ;
  sh:name "URL";
  sh:description "User URL";
  sh:order 1
];
 sh:property [
  sh:path schema:name ;
  sh:name "Name";
  sh:description "User name";
  sh:order 2
] .
```

Non-validating constraints

```
:User a sh:NodeShape ;
 sh:property [ sh:path schema:url ;
  sh:name "URL";
  sh:group :userDetails
];
 sh:property [ sh:path schema:name ;
  sh:name "Name"; sh:group :userDetails
];
sh:property [ sh:path schema:address ;
  sh:name "Address"; sh:group :location
];
sh:property [ sh:path schema:country ;
  sh:name "Country"; sh:group :location
] .
```

```
:userDetails a sh:PropertyGroup ;
  sh:order 0 ;
  rdfs:label "User details" .

:location a sh:PropertyGroup ;
  sh:order 1 ;
  rdfs:label "Location" .
```

An agent could generate a form like:

User details

URL: _____

Name: _____

Location

Address: _____

Country: _____

SHACL-SPARQL

SPARQL constraints

Constraints based on SPARQL code.

When the SPARQL query return validation errors a violation is reported

SPARQL constraints have type sh:SPARQLConstraint

Constraint	Description
`message`	Message in case of error
`sparql`	SPARQL code that is run
`prefixes`	Points to namespace prefix declarations defined by sh:declare: Each one has: sh:prefix: Prefix alias sh:namespace: namespace IRI

SPARQL constraints

Special variables are pre-binded by the SHACL-SPARQL processor

Constraint	Description
`$this`	Focus Node
`$shapesGraph`	Can be used to query the shapes graph in named graphs Similar to: `GRAPH $shapesGraph { ... }`
`$currentShape`	Current shape

SPARQL constraints

Mappings between result rows and error validation information

Constraint	Description
`sh:focusNode`	Value of `$this` variable
`sh:subject`	Value of `?subject` variable
`sh:predicate`	Value of `?predicate` variable
`sh:object`	Value of `?object` variable
`sh:message`	Value of `?message` variable
`sh:sourceConstraint`	The constraint that was validated against
`sh:sourceShape`	The shape that was validated against
`sh:severity`	sh:ViolationError by default or the value of sh:severity

SPARQL constraints

Example: Name must be the concatenation of singleName and familyName

```
:UserShape a sh:NodeShape ;
 sh:targetClass :User ;
 sh:sparql [ a sh:SPARQLConstraint ;
  sh:message "schema:name must equal schema:givenName+schema:familyName";
  sh:prefixes [ sh:declare [
    sh:prefix "schema" ;
    sh:namespace "http://schema.org/"^^xsd:anyURI ;
   ]] ;
 sh:select
  """SELECT $this (schema:name AS ?path) (?name as ?value)
     WHERE {
      $this schema:name ?name .
      $this schema:givenName ?givenName .
      $this schema:familyName ?familyName .
      FILTER (!isLiteral(?value) ||
              !isLiteral(?givenName) || !isLiteral(?familyName) ||
              concat(str(?givenName), ' ', str(?familyName))!=?name )
     }""" ;
] .
```

```
:alice a :User ;
  schema:givenName "Alice" ;
  schema:familyName "Cooper" ;
  schema:name "Alice Cooper" .

:bob a :User ;
  schema:givenName "Bob" ;
  schema:familyName "Smith" ;
  schema:name "Robert Smith" .
```

☹

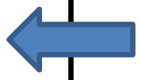
https://tinyurl.com/y6p7zyon

SPARQL constraint components

SHACL-SPARQL allows to declare custom constraint components

Once defined, they can be used like bult-in constraint components

```
:ProductShape a sh:NodeShape ;
 sh:targetClass :Product ;
 sh:property [
  sh:path     :color ;
  :size       3 ;
  sh:minCount 1 ;
 ] .
```



```
:c1 :color (255 0 255) .

:c2 :color (255 0 210 345) .

:c3 :color (255 0) .
```

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☹

SPARQL constraint components

```
:FixedListConstraintComponent
 a sh:ConstraintComponent ;
 sh:parameter [
  sh:path        :size ;
  sh:name        "Size of list" ;
  sh:description "The size of the list" ;
 ] ;
 sh:labelTemplate "Size of values: \"{$size}\"" ;
 sh:propertyValidator :fixedLengthValidator .
```

Two types of validators:
SPARQLSelectValidator
SPARQLASKValidator

```
:fixedLengthValidator  a sh:SPARQLSelectValidator ;
  sh:message
   "{$PATH} must have length {?size}, not {?count}" ;
  sh:prefixes [ sh:declare [
    sh:prefix "rdf" ;
    sh:namespace
     "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   ]
  ] ;
  sh:select """SELECT $this ?value $count WHERE {
     $this $PATH ?value .
     { SELECT $this ?value
              (COUNT(?member) AS ?count)
              $size WHERE {
          ?value rdf:rest*/rdf:first ?member
      } GROUP BY $this ?value $size
     }
     FILTER (!isBlank(?value) || ?count != $size)
  }"""
.
```

https://tinyurl.com/y3l5ksah

SPARQL constraint components

Property	Description
`sh:parameter`	Declares the parameters of the constraint component The values are subclasses of property shapes sh:path declares the parameter name sh:optional declares if the parameter is optional
`sh:labelTemplate`	Suggests how constraints are rendered. Can refer to parameter names using: `$varName`
`sh:nodeValidator`	Associates a node shape validator
`sh:propertyValidator`	Associates a property shape validator

SPARQL based validators can be SELECT or ASK based validators

SHACL and inference systems

SHACL uses a subset of RDFS for target declarations

rdfs:subClassOf, rdf:type, owl:imports

A shapes graph containing sh:entailment with value E indicates the SHACL processor the kind of entailment to apply to the data

Possible values:

RDFS: http://www.w3.org/ns/entailment/RDFS

OWL 2 RDF based: http://www.w3.org/ns/entailment/OWL-RDF-Based

...and more, see: https://www.w3.org/TR/sparql11-entailment/

Other features

SHACL 1.2 is currently in progress:

Data Shapes github repo (issues): https://github.com/w3c/data-shapes

Some current drafts:

- SHACL core: https://w3c.github.io/data-shapes/shacl12-core/
- SPARQL extensions: https://w3c.github.io/data-shapes/shacl12-sparql/
- Node expressions: https://w3c.github.io/data-shapes/shacl12-node-expr/
- Other proposals:
  - Inference rules, compact syntax

Node expressions

Can generate values for nodes

```
:Person a sh:NodeShape ;
  sh:property [
   sh:path :fullName ;
   sh:minCount 1; sh:maxCount 1;
   sh:values [ sh:prefixes :prefixes ;
    sh:select """
      SELECT ?fullName
      WHERE {
        $this :firstName ?firstName .
        $this :lastName  ?lastName .
        BIND (CONCAT(?firstName, " ", ?lastName) AS ?fullName) .
     } """ ] ] .

:prefixes sh:declare [ sh:prefix "" ;
    sh:namespace "http://example.org/"^^xsd:anyURI ;
] .
```

Validating reifiers

Current proposal from https://github.com/w3c/data-shapes/issues/300

```
ex:Researcher a sh:NodeShape ;
  sh:property [
    sh:path :employer ;
    sh:nodeKind sh:IRI ;
    sh:reifierShape ex:EmployerQualifier ;
    sh:reificationRequired true .
 ] .
ex:EmployerQualifier a sh:NodeShape ;
 sh:property [ sh:path :start ;
   sh:datatype xsd:gYear ;
   sh:minCount 1 ; sh:maxCount 1
 ];
 sh:property [ sh:path :end ;
   sh:datatype xsd:gYear ;
   sh:minCount 1 ; sh:maxCount 1
 ] .
```

```
:timbl rdfs:label "Tim Berners Lee" ;
  :employer :CERN
     {| :start "1984"^^xsd:gYear ;
        :end   "1994"^^xsd:gYear |}
     {| :start "1980"^^xsd:gYear ;
        :end   "1980"^^xsd:gYear |} .
```

```
:timbl :employer  :CERN .
_:r rdf:reifies   << :timbl :employer :CERN >> .
_:r :start "1984"^^xsd:gYear ;
    :end   "1994"^^xsd:gYear .
_:s rdf:reifies   << :timbl :employer :CERN >> .
_:s :start "1980"^^xsd:gYear ;
    :end   "1980"^^xsd:gYear .
```

End of presentation

Solutions to exercises

Simulate recursion with property paths