Introduction to SHACL

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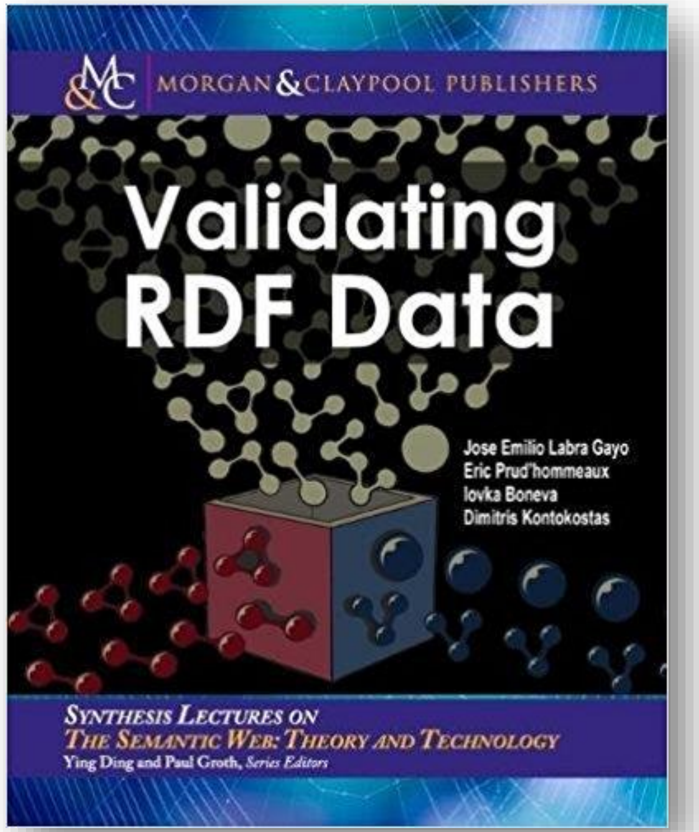
More info

Chapter 5 of Validating RDF Data book

- [Online HTML version]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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

WESO

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" .
```

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" .
```

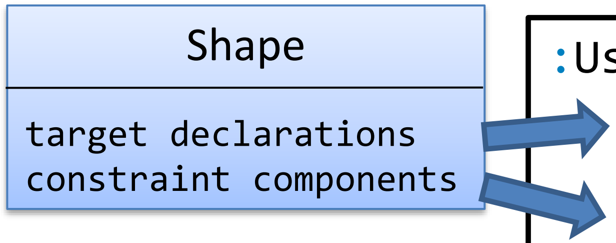
Data graph

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



```
: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 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

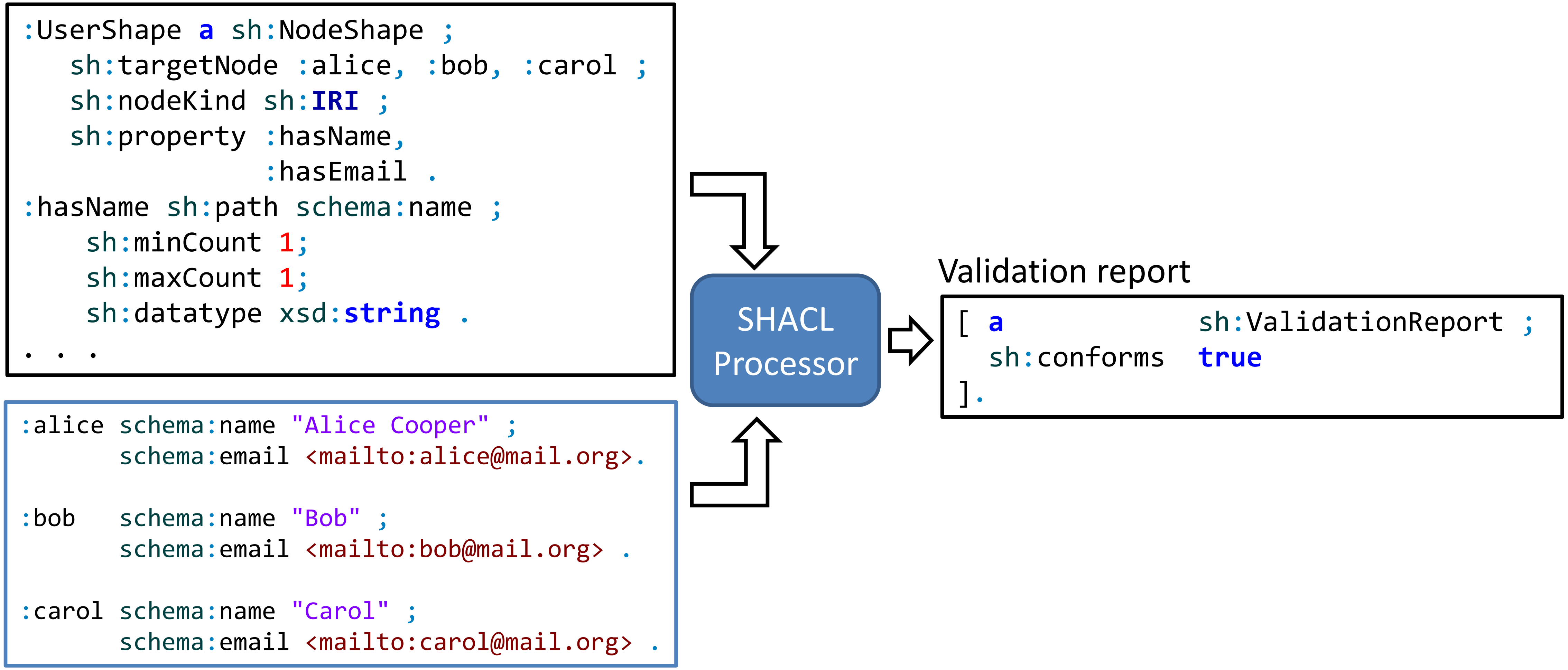
The output of the validation process is a list of violation errors

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 .
```

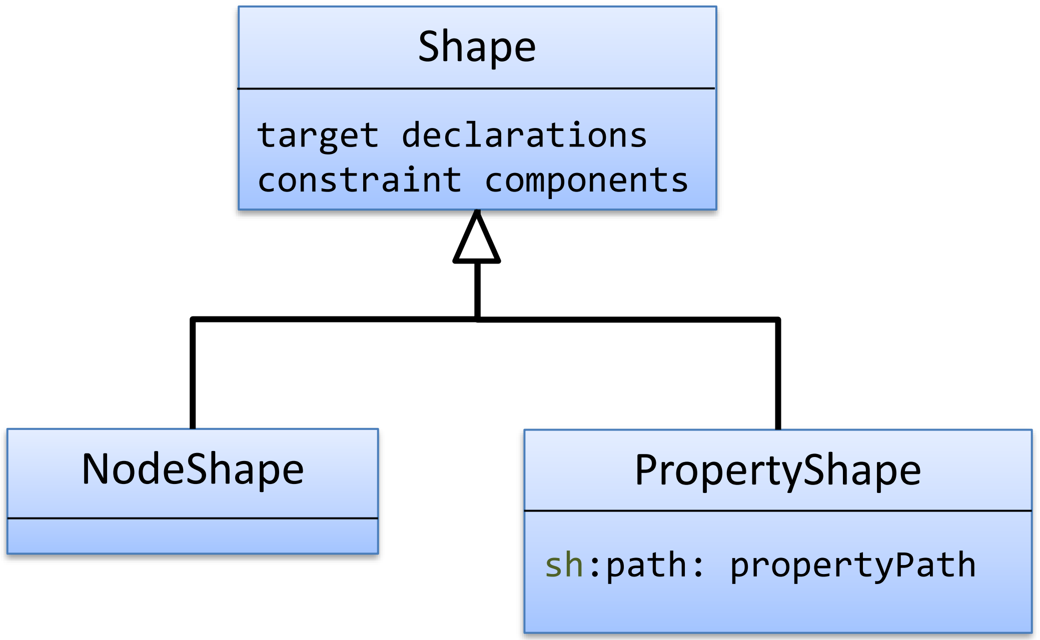
```
<> owl:imports <http://example.org/UserShapes> .

: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



```
: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 .      ☹
```

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

Nodes that declare 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
C. Component: sh:xxConstraintComponent
```

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

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

Constraint component
`sh:nodeKindConstraintComponent`

Parameter
`sh:nodeKind`

Value of Parameter
`sh:IRI ;`

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 .
```

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 .                         ☹
```

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 .      ☹
```

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 .
```

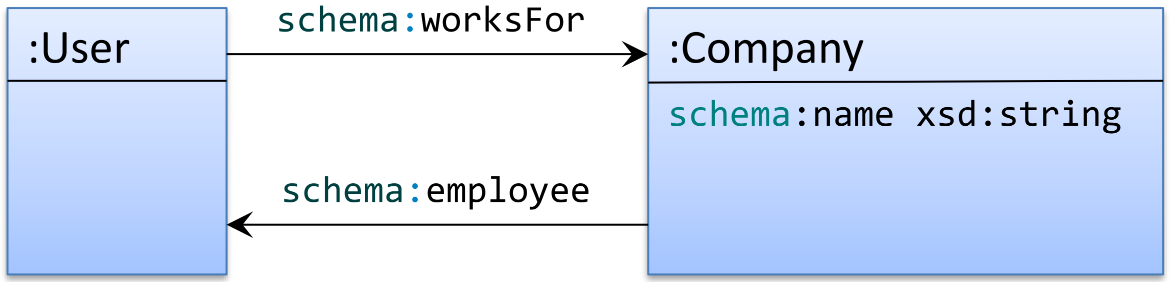
Value shapes and recursion

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 .
```

No, current SHACL specification doesn't allow this

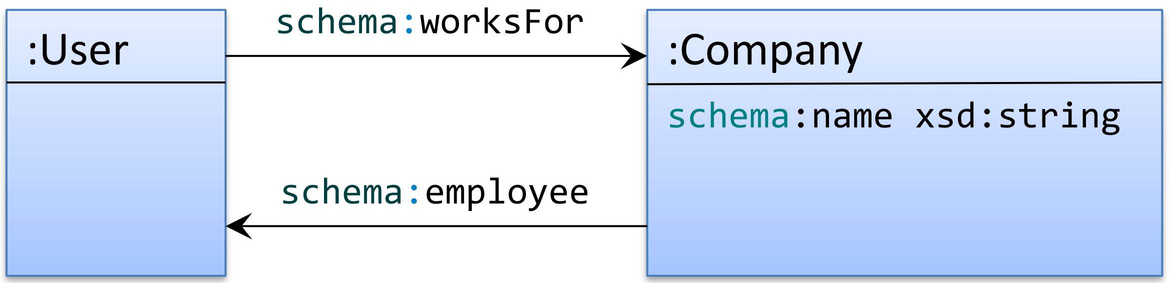
Depends on Implementation ☹

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 ;
 ] .
```



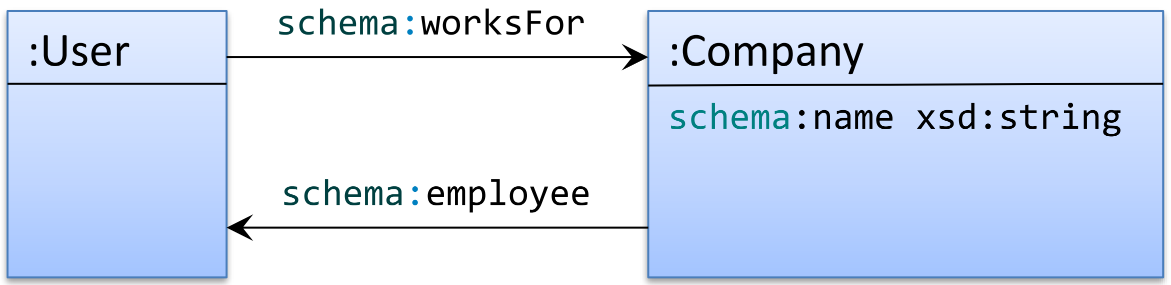
```
:alice a :User ;
       schema:worksFor :OneCompany .
:bob   a :User ;
       schema:worksFor :OneCompany .
:carol a :User ;
       schema:worksFor :Something .          ☹

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

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)

and

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;
     ]
   ]
.
```

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" .      ☹
```

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

```
: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!!

WESO

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) .           ☹
```

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 .
```

```
: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)
  }"""
.
```

Two types of validators:
SPARQLSelectValidator
SPARQLASKValidator

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/

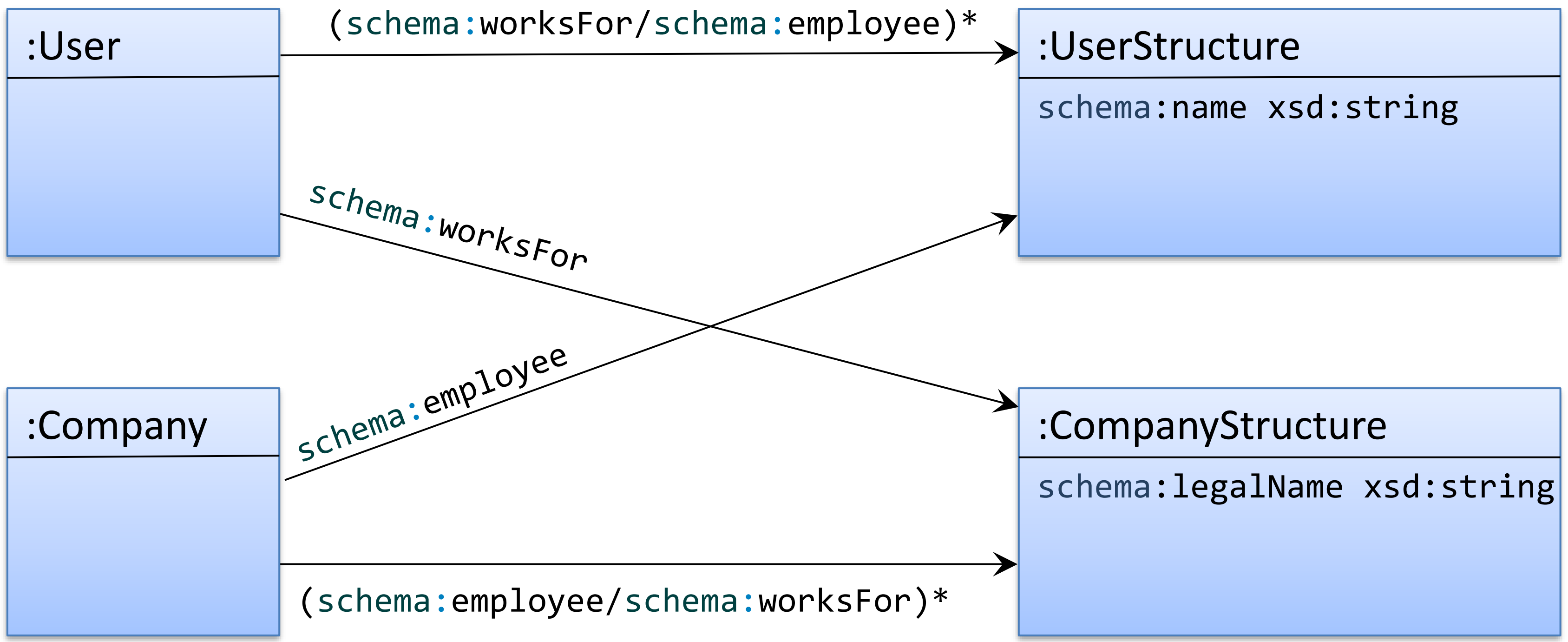
Other features

- SHACL accepted as Recommendation on July 2017
- SHACL community group created:
  - https://www.w3.org/community/shacl/
- Several features were postponed
  - Advanced features: https://w3c.github.io/data-shapes/shacl-af/
    - SHACL functions and rules
  - Compact syntax: https://w3c.github.io/shacl/shacl-compact-syntax/

End of presentation

Solutions to exercises

Simulate recursion with property paths


:User
(schema:worksFor/schema:employee)*
:UserStructure
schema:name xsd:string
schema:worksFor
schema:employee
:Company
:CompanyStructure
schema:legalName xsd:string
(schema:employee/schema:worksFor)*