SHACL by example

RDF Validation tutorial

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SHACL

W3c Data Shapes WG deliverable

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

Inspired by SPIN, OSLC & bits of ShEx

SPARQL based extension mechanism

RDF vocabulary

- No human friendly syntax yet*

* A human friendly syntax inspired by ShEx is being considered by the WG

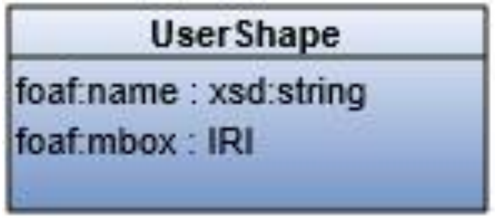
Some definitions about SHACL

- Shape: collection of scopes, filters and constraints
  - Scopes: specify which nodes in the data graph must follow the shape
  - Filters: Further limit the scope nodes to those that satisfy the filter
  - Constraints: Determine how to validate a node
- Shapes graph: an RDF graph that contains shapes
- Data graph: an RDF graph that contains data to be validated

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:Shape ;
   sh:scopeNode :alice, :bob, :carol ;
   sh:property [
    sh:predicate schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
  ] ;
  sh:property [
   sh:predicate schema:email ;
   sh:minCount 1;
   sh:maxCount 1;
   sh:nodeKind sh:IRI ;
  ] .
```

Shapes graph



UserShape

foaf:name : xsd:string

foaf:mbox : IRI

```
: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 http://goo.gl/FqXQpD

Scopes

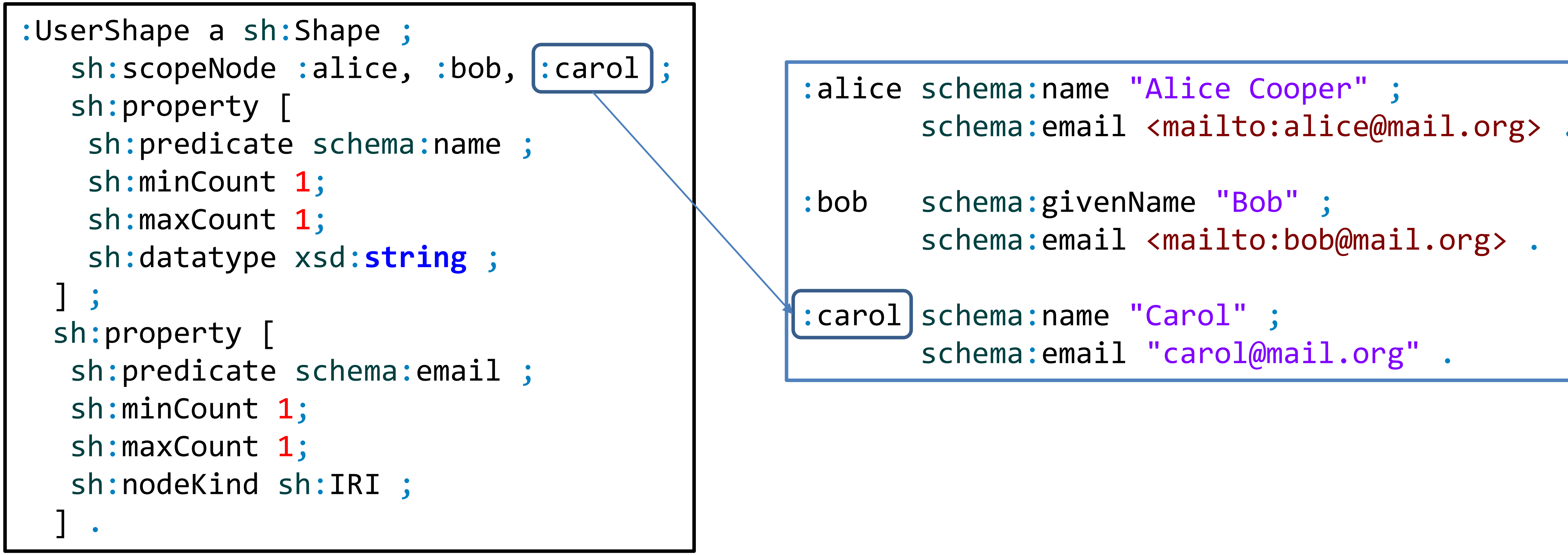
Scopes specify nodes that must be validated against the shape

Several types

Value	Description
scopeNode	Directly point to a node
scopeClass	All nodes that have a given type
scopeProperty	All nodes that have a given property
scope	General mechanism based on SPARQL

Scope node

Directly declare which nodes must validate the against the shape



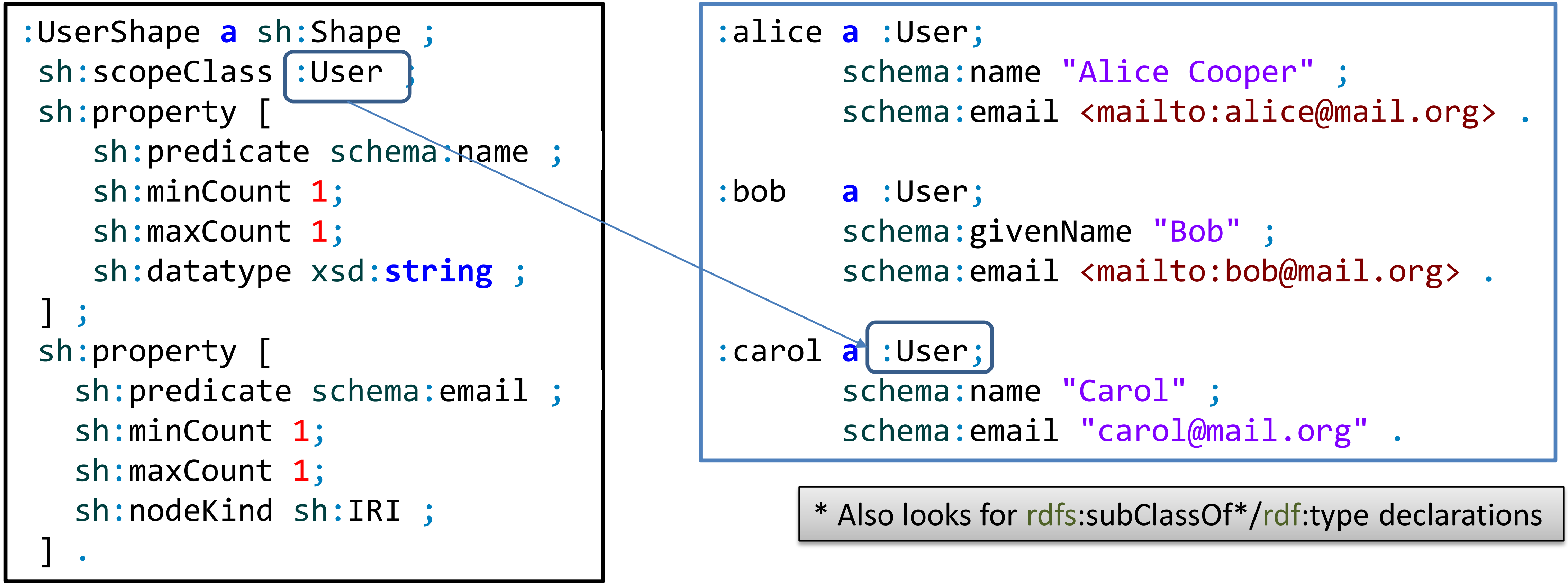
```
:UserShape a sh:Shape ;
   sh:scopeNode :alice, :bob, :carol ;
   sh:property [
    sh:predicate schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
  ] ;
  sh:property [
   sh:predicate schema:email ;
   sh:minCount 1;
   sh:maxCount 1;
   sh:nodeKind sh:IRI ;
  ] .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

```
: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" .
```

Scope class

Selects all nodes that have a given type

- Looks for rdf:type declarations*



```
:UserShape a sh:Shape ;
 sh:scopeClass :User ;
 sh:property [
    sh:predicate schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
 ] ;
 sh:property [
   sh:predicate 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 scope class

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

- The scopeClass declaration is implicit

```
:User a sh:Shape, rdfs:Class ;
  sh:property [
    sh:predicate schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string ;
  ] ;
  sh:property [
   sh:predicate 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" .
```

Constraints

Types of constraints

Type	Description
Node constraints	Constraints about a given focus node
Property constraints	Constraints about a property and the values of that property for a node
Inverse property constraints	Constraints about a property and the inverse values of that property for a node
General constraints	General mechanism based on SPARQL

Node Constraints

Constraints about a focus node

```
:User a sh:Shape ;
  sh:constraint [
    sh:nodeKind sh:IRI ;
  ] .
```

```
:alice a :User .

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

_:1 a :User . ☹
```

Property constraints

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

- `sh:property` associates a shape with a property constraint
- `sh:predicate` identifies the predicate

```
:User a sh:Shape ;
   sh:property [
      sh:predicate 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" .       ☹
```

Inverse property constraints

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

- `sh:inverseProperty` associates shape with inverse property constraint
- `sh:predicate` identifies the predicate

```
:User a sh:Shape, rdfs:Class ;
   sh:inverseProperty [
    sh:predicate 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 .
```

Core constraint components

Type	Constraints
Cardinality	`minCount, maxCount`
Types of values	`class, datatype, nodeKind, classIn, datatypeIn`
Values	`valueShape, in, hasValue`

Range of values	`minInclusive, maxInclusive`
	`minExclusive, maxExclusive`

String based	`minLength, maxLength, pattern, stem, uniqueLang`
Logical constraints	`not, and, or`
Closed shapes	`closed, ignoredProperties`
Property pair constraints	`equals, disjoint, lessThan, lessThanOrEquals`
Non-validating constraints	`name, value, defaultValue`

Partitions	`partition`
	`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:Shape ;
   sh:property [
    sh:predicate 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. http://goo.gl/9AwtFK

Datatypes of values

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

```
:User a sh:Shape ;
   sh:property [
    sh:predicate schema:birthDate ;
    sh:datatype xsd:date ;
  ];
  sh:property [
    sh:predicate schema:jobTitle ;
    sh:datatypeIn (
       xsd:string
       rdf:langString
    )
  ] .
```

```
:alice schema:birthDate "1985-08-20"^^xsd:date;
       schema:jobTitle "CEO", "Director"@es .

:bob   schema:birthDate "2007-08-20"^^xsd:date;   ☹
       schema:jobTitle :unknown .

:carol schema:birthDate 1990 ;                     ☹
       schema:jobTitle "CTO" .
```

Try it: http://goo.gl/eDwxsU

Class of values

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

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

```
:User a sh:Shape, rdfs:Class ;
 sh:property [
  sh:predicate 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:Shape, rdfs:Class ;
  sh:property [
   sh:predicate schema:name ;
   sh:nodeKind sh:Literal ;
  ];
  sh:property [
   sh:predicate schema:follows ;
   sh:nodeKind sh:BlankNodeOrIRI
  ];
  sh:constraint [
   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:Shape, rdfs:Class ;
  sh:property [
   sh:predicate schema:affiliation ;
   sh:hasValue :OurCompany ;
  ];
  sh:property [
   sh:predicate 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
valueShape*	All values of a given property must have a given shape Recursion is not allowed in current SHACL

```
:User a sh:Shape, rdfs:Class ;
  sh:property [
   sh:predicate schema:worksFor ;
   sh:valueShape :Company ;
  ] .

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

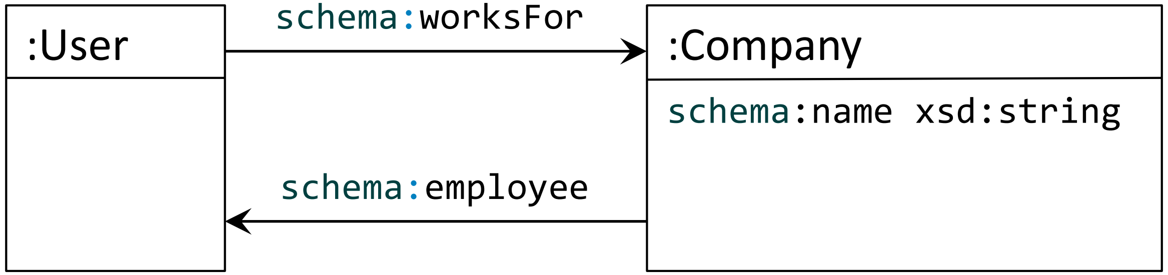
```
:alice a :User;
       schema:worksFor :OurCompany .

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

:OurCompany
    schema:name "OurCompany" .

:Another
    schema:name 23 .
```

*recently renamed as sh:shape

Value shapes and recursion

Could we define cyclic data models as the following?

```
:User a sh:Shape ;
  sh:property [
   sh:predicate schema:worksFor ;
   sh:valueShape :Company ;
  ] .

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



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

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

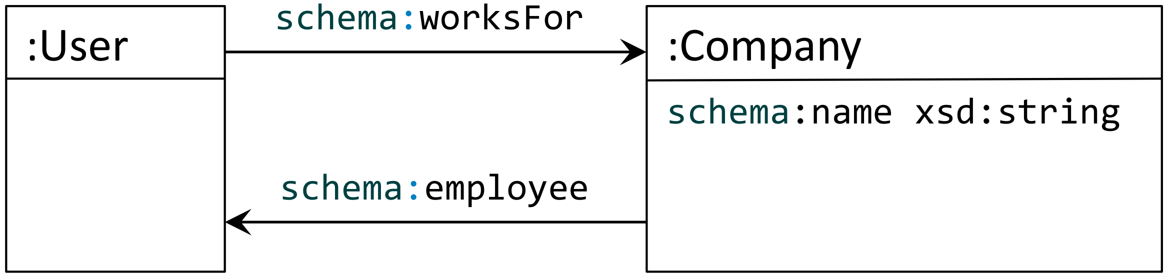
No, current SHACL specification doesn't allow this

Don't try it ☹

SHACL approach to avoid recursion

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

```
:User a sh:Shape ;
  sh:property [
   sh:predicate schema:worksFor ;
   sh:class :Company ;
  ] .

:Company a sh:Shape ;
  sh:property [
   sh:predicate schema:name ;
   sh:datatype xsd:string ;
  ] ;
 sh:property [
   sh:predicate 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: http://goo.gl/wlVZJR

Logical Operators

Constraint	Description
`and`	Conjunction of a list of shapes
`or`	Disjunction of a list of shapes
`not`	Negation of a shape

and

Default behavior

```
:User a sh:Shape ;
 sh:constraint [
  sh:and (
   [ sh:property [
      sh:predicate schema:name;
      sh:minCount 1;
     ]
   ]
   [ sh:property [
      sh:predicate schema:affiliation;
      sh:minCount 1;
     ]
   ]
  )
 ].
```

≡

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

or

```
:User a sh:Shape ;
 sh:constraint [
  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:Shape ;
 sh:constraint [
  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" .   ☹
```

Exclusive-or

There is no exclusive-or in SHACL

It must be defined in terms of and/or/not

Value ranges

Constraint	Description
minInclusive	
maxInclusive	
minExclusive	
maxExclusive	

```
:Rating
 a sh:Shape ;
 sh:property [
   sh:predicate schema:ratingValue ;
   sh:minInclusive 1 ;
   sh:maxInclusive 1 ;
   sh:datatype xsd:integer
 ] .
```

```
:bad schema:ratingValue 1 .

:average schema:ratingValue 3 .

:veryGood  schema:ratingValue 5 .

:zero schema:ratingValue 0 .  ☹
```

Try it: http://goo.gl/qnd66j

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
`stem`	Checks if all value nodes are IRIs and the IRI starts with a given string value
`uniqueLang`	Checks that no pair of nodes use the same language tag

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:Shape ;
 sh:property [
   sh:predicate 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: http://goo.gl/NrJl83

pattern

Checks if the values matches a regular expression

It can be combined with sh:flags

```
:Product
 a sh:Shape ;
 sh:property [
   sh:predicate 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" .     ☹
```

Try it: http://goo.gl/BsHpqu

stem

Checks if all value nodes are IRIs and those IRI start with a given string value

```
:W3People
 a sh:Shape ;
 sh:property [
   sh:predicate schema:url ;
   sh:stem "https://www.w3.org/People/"
] .
```

```
:eric  schema:url
          <https://www.w3.org/People/Eric> .

:timbl schema:url
          <https://www.w3.org/People/Berners-Lee> .

:alice schema:url
          <https://www.example.org/bob> . ☹
```

Try it: http://goo.gl/Krpao8

uniqueLang

Checks that no pair of nodes use the same language tag

```
:Country
 a sh:Shape ;
 sh:property [
  sh:predicate schema:name ;
  sh:uniqueLang true
] .
```

```
:spain  schema:name "Spain"@en,
                   "España"@es .

:france schema:name "France"@en,
                    "Francia"@es .

:usa    schema:name "USA"@en,
                    "United States"@en.
```

☹

Try it: http://goo.gl/B1PNcO

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:Shape ;
 sh:property [
  sh:predicate schema:givenName ;
  sh:equals foaf:firstName
];
 sh:property [
  sh:predicate 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" .
```

Try it: http://goo.gl/BFzMoz

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:Shape ;
 sh:constraint [
  sh:closed true ;
  sh:ignoredProperties ( rdf:type )
 ] ;
 sh:property [
  sh:predicate schema:givenName ;
];
 sh:property [
  sh:predicate 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" .
```

Try it: http://goo.gl/wcW16o

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

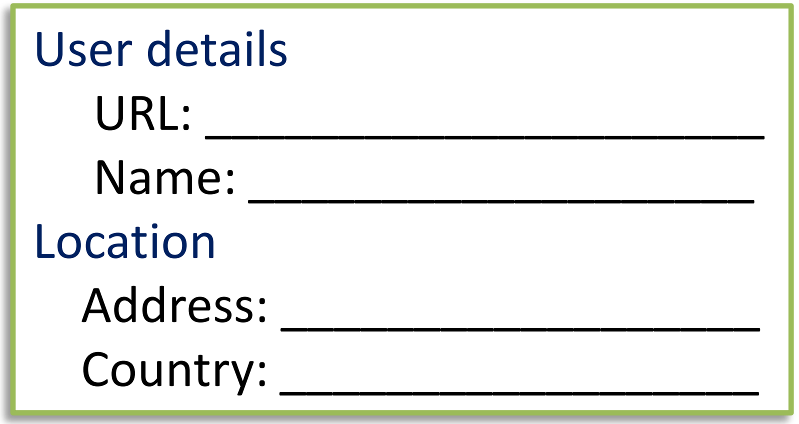
```
:User a sh:Shape ;
 sh:property [
  sh:predicate schema:url ;
  sh:name "URL";
  sh:description "User URL";
  sh:order 1
];
 sh:property [
  sh:predicate schema:name ;
  sh:name "Name";
  sh:description "User name";
  sh:order 2
] .
```

Non-validating constraints

```
:User a sh:Shape ;
 sh:property [ sh:predicate schema:url ;
  sh:name "URL";
  sh:group :userDetails
];
 sh:property [ sh:predicate schema:name ;
  sh:name "Name"; sh:group :userDetails
];
sh:property [ sh:predicate schema:address ;
  sh:name "Address"; sh:group :location
];
sh:property [ sh:predicate 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: _____________________

Partitions and qualified values

Problem with repeated properties

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

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

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

It fails!!

Try it: http://goo.gl/x7oHpi

Partitions and qualified value shapes

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

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

Try it: http://goo.gl/v6Zffe

Partitions and qualified value shapes

`partition` declares a partition on the set of values

```
:Book a sh:Shape ;
   sh:property [
    sh:predicate schema:productID ;
    sh:partition (
     [sh:minCount 1; sh:maxCount 1; sh:pattern "^isbn"]
     [sh:minCount 1; sh:maxCount 1; sh:pattern "^code"]
    )
   ] .
```

NOTE:
This feature is under development
The specification defines a Greedy algorithm and the violation errors depend on the order of the elements on the list
This can be tricky when some values overlap several elements in the partition

Don't try it
Not yet implemented

Filters

Filters limit the nodes that are in scope to those that satisfy the filter

Similar to: `"if <filter> then ..."`

```
:User a sh:Shape ;
 sh:scopeClass schema:Person ;
 sh:filterShape [
  a sh:Shape ; # Optional triple
  sh:property [
   sh:predicate schema:worksFor ;
   sh:hasValue :OurCompany ;
  ]
 ] ;
 sh:property [
  sh:predicate schema:url ;
  sh:stem "http://ourcompany.org/" ;
] .
```

```
:alice a schema:Person ;
 schema:worksFor :OurCompany ;
 schema:url <http://ourcompany.org/alice> .

:bob a schema:Person ;
 schema:worksFor :OurCompany ;
 schema:url <http://othercompany.org/bob> .

:carol a schema:Person ;
 schema:worksFor :OtherCompany ;
 schema:url <http://othercompany.org/carol> .
```

☹

Try it: http://goo.gl/vadFMk

SPARQL constraints

- Constraints based on SPARQL code.
  - The query returns validation errors

Constraint	Description
`SPARQLConstraint`	Type of constraints that will be considered as SPARQL constraints
`message`	Message in case of error
`sparql`	SPARQL code to be executed
`prefix`	Declare reusable prefix

SPARQL constraints

Special variables are used to bind values between SHACL and SPARQL processors

Constraint	Description
`$this`	Focus Node
`$shapesGraph`	`Can be used to query the shapes graph`
`$currentShape`	Current validated 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

Extension mechanism

SHACL offers an extension mechanism based on SPARQL

In principle, it should be possible to add other mechanisms

```
<http://www.w3.org/2000/01/rdf-schema#> sh:prefix "rdfs" .

:SpanishLabelsShape a sh:Shape ;
 sh:constraint [
  a sh:SPARQLConstraint ;
  sh:message "Values must be literals with Spanish language tag." ;
  sh:sparql """SELECT $this ($this AS ?subject)
                            (rdfs:label AS ?predicate)
                            (?value AS ?object)
    WHERE {  $this rdfs:label ?value .
    FILTER (!isLiteral(?value) || !langMatches(lang(?value), "es"))""" ;
 ] .
```

Try it: http://goo.gl/Wf1Lxn

Other features

Several features are currently under discussion

- SPARQL scopes and SPARQL functions
- Extension mechanism for other languages
- Recursion
- User-friendly syntax