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

Human friendly syntax inspired by ShEx proposed as a WG Note *

* https://w3c.github.io/data-shapes/shacl-compact-syntax/

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: 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: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 ;
  ] .
```

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 http://goo.gl/FqXQpD

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
targetProperty	All nodes that have a given property
target	General mechanism based on SPARQL

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 type

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 target class

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 ;
  ] .
```

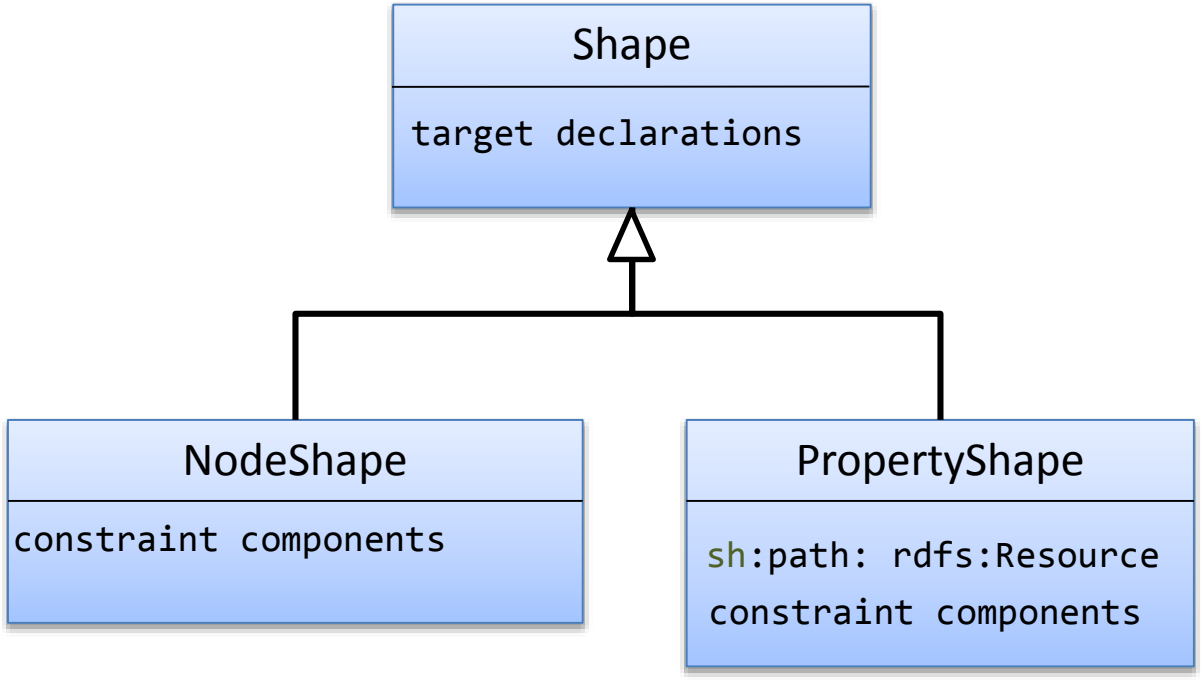
```
:alice a :User;
       schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

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

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

Types of shapes

Type	Description
Node shapes	Constraints about a given focus node
Property shapes	Constraints about a property and the values of a path for a node



Node Shapes

Constraints about a focus node

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

```
:alice a :User .

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

_:1 a :User . ☹
```

Property shapes

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

- `sh:property` associates a shape with a property constraint
- `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

Example with inverse path

`inversePath, zeroOrMorePath, alternativePath, oneOrMorePath, ...`

```
: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 .
```

Core constraint components

Type	Constraints
Cardinality	`minCount, maxCount`
Types of values	`class, datatype, 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. http://goo.gl/9AwtFK

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: 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*

(*) 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 .
```

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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 .
```

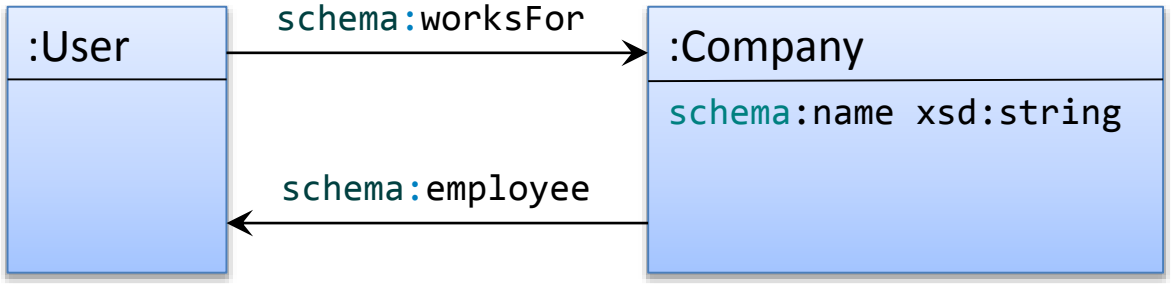
*recently renamed as sh:shape

Value shapes and recursion

Could 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 ;
 ]  .
```




```
: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

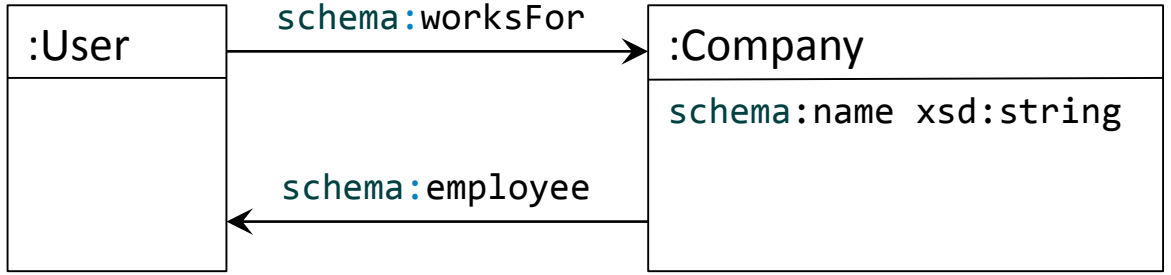
Don't try it ☹

SHACL approach to avoid recursion

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

```
:User a sh: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: 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
`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

Pending example...

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: 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: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: http://goo.gl/NrJl83

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" .  ☹
```

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

uniqueLang

Checks that no pair of nodes use the same language tag

```
:Country a sh:NodeShape ;
 sh:property [
  sh:path       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: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" .
```

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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: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" .
```

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: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: _____

Pending update (old version of SHACL

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

Pending update (old version of SHACL

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

Pending update (old version of SHACL

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

Pending update (old version of SHACL

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