ShEx by example

Validating RDF data tutorial

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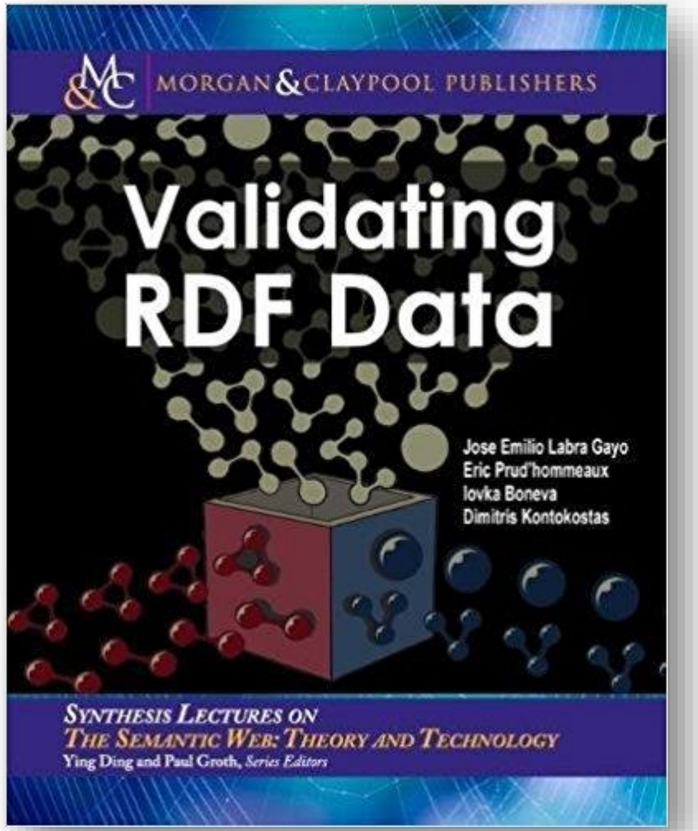
More info

Chapter 4 of Validating RDF Data book

[Online HTML version]



ShEx

ShEx (Shape Expressions Language)

Goal: RDF validation & description

Design objectives: High level, concise, human-readable, machine processable language

Syntax inspired by SPARQL, Turtle

Semantics inspired by RelaxNG

Official info: http://shex.io

ShEx as a language

Language based approach

- ShEx = domain specific language for RDF validation
- Specification: http://shex.io/shex-semantics/
- Primer: http://shex.io/shex-primer
- Different serializations:
  - ShExC (Compact syntax)
  - JSON-LD (ShExJ)
  - RDF obtained from JSON-LD (ShExR)

Short history of ShEx

2013 - RDF Validation Workshop

- Conclusions: "*SPARQL queries cannot easily be inspected and understood…*"
  - Need of a higher level, concise language
  - Agreement on the term "Shape"

2014 First proposal of Shape Expressions (ShEx 1.0)

2014 - Data Shapes Working Group chartered

- Mutual influence between SHACL & ShEx

2017 - ShEx Community Group - ShEx 2.0

2018 - ShEx 2.1

ShEx implementations and demos

Implementations:

- shex.js: Javascript
- Apache Jena ShEx: Java
- shex-s: Scala (Jena/RDF4j)
- PyShEx: Python
- shex-java: Java
- Ruby-ShEx: Ruby
- ShEx-ex: Elixir

Online demos & playgrounds

- ShEx-simple
- RDFShape
- ShEx-Java
- ShExValidata
- Wikishape

Simple example

Prefix declarations as in Turtle/SPARQL

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

<User> IRI {
 schema:name  xsd:string   ;
 schema:knows @<User>     *
}
```

Nodes conforming to `<User>` shape must:

- Be IRIs
- Have exactly one `schema:name` with a value of type `xsd:string`
- Have zero or more `schema:knows` whose values conform to <User>

RDF Validation using ShEx

Schema

```
<User> IRI {
 schema:name   xsd:string    ;
 schema:knows @<User>      *
}
```

Shape map

```
:alice@<User>✓
:bob   @<User>✓
:carol@<User>✗
:dave  @<User>✗
:emily@<User>✗
:frank@<User>✓
:grace@<User>✗
```

Try it (RDFShape): https://goo.gl/97bYdv
Try it (ShExDemo):https://goo.gl/Y8hBsW

Data

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

:bob   schema:knows :alice ;
       schema:name  "Robert".

:carol schema:name   "Carol", "Carole" .

:dave  schema:name   234 .

:emily foaf:name     "Emily" .

:frank schema:name "Frank" ;
       schema:email <mailto:frank@example.org> ;
       schema:knows :alice, :bob .

:grace schema:name "Grace" ;
       schema:knows :alice, _:1 .

_:1 schema:name  "Unknown" .
```

Validation process

Input: RDF data, ShEx schema, Shape map

Output: Result shape map

ShEx Schema

```
:User {
 schema:name  xsd:string ;
 schema:knows @:User *
}
```

Shape map

```
:alice@:User, :bob@:User, :carol@:User
```

RDF data

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

:bob   schema:knows :alice ;
       schema:name  "Robert".

:carol schema:name   "Carol", "Carole" .
```

ShEx Validator

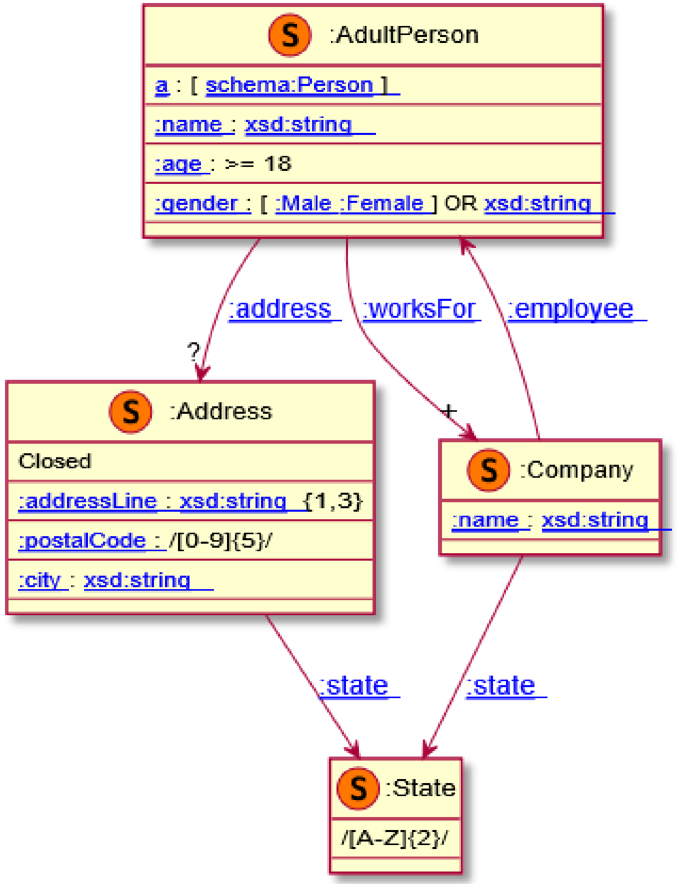
Result shape map

```
:alice@:User,
:bob@:User,
:carol@!:User
```

Example with more ShEx features

```
:AdultPerson EXTRA rdf:type {
 rdf:type    [ schema:Person ]             ;
 :name       xsd:string                    ;
 :age        MinInclusive 18               ;
 :gender     [:Male :Female] OR xsd:string ;
 :address    @:Address ?                   ;
 :worksFor   @:Company +
}
:Address CLOSED {
 :addressLine xsd:string {1,3}
 :postalCode  /[0-9]{5}/
 :state       @:State
 :city        xsd:string
}
:Company {
 :name     xsd:string
 :state    @:State
 :employee @:AdultPerson *
}
:State   /[A-Z]{2}/
```

```
:alice rdf:type :Student, schema:Person ;
 :name       "Alice" ;
 :age        20 ;
 :gender     :Male ;
 :address    [
  :addressLine  "Bancroft Way" ;
  :city         "Berkeley" ;
  :postalCode   "55123" ;
  :state        "CA"
 ] ;
 :worksFor  [
  :name        "Company" ;
  :state       "CA"      ;
  :employee    :alice
] .
```



Try it: https://tinyurl.com/yd5hp9z4

ShExC - Compact syntax

BNF Grammar: http://shex.io/shex-semantics/#shexc

Shares terms with Turtle and SPARQL

- Prefix declarations
- Comments starting by #
- a keyword = rdf:type
- Keywords aren't case sensitive (MinInclusive = MININCLUSIVE)

Shape Labels can be URIs or BlankNodes

ShEx-Json

JSON-LD serialization for Shape Expressions and validation results

```
prefix schema: <http://schema.org/>
prefix xsd:    <http://www.w3.org/2001/XMLSchema#>
base   <http://example.com/>

<User> {
  schema:name  xsd:string ;
}
```

equivalent

```
{ "type" : "Schema",
  "@context" : "http://www.w3.org/ns/shex.jsonld",
  "shapes" :[{"type" : "Shape",
    "id" : "http://a.example/UserShape",
    "expression" : {
    "type" : "TripleConstraint",
    "predicate" : "http://schema.org/name",
    "valueExpr" : { "type" : "NodeConstraint",
      "datatype" : "http://www.w3.org/2001/XMLSchema#string"
     }
   }
  }]
}
```

Some definitions

Schema = set of Shape Expressions

Shape Expression = labeled pattern

```
<label> {
  ...pattern...
}
```

Shape Label

Shape Expression

```
<UserShape> {
  schema:name  xsd:string
}
```

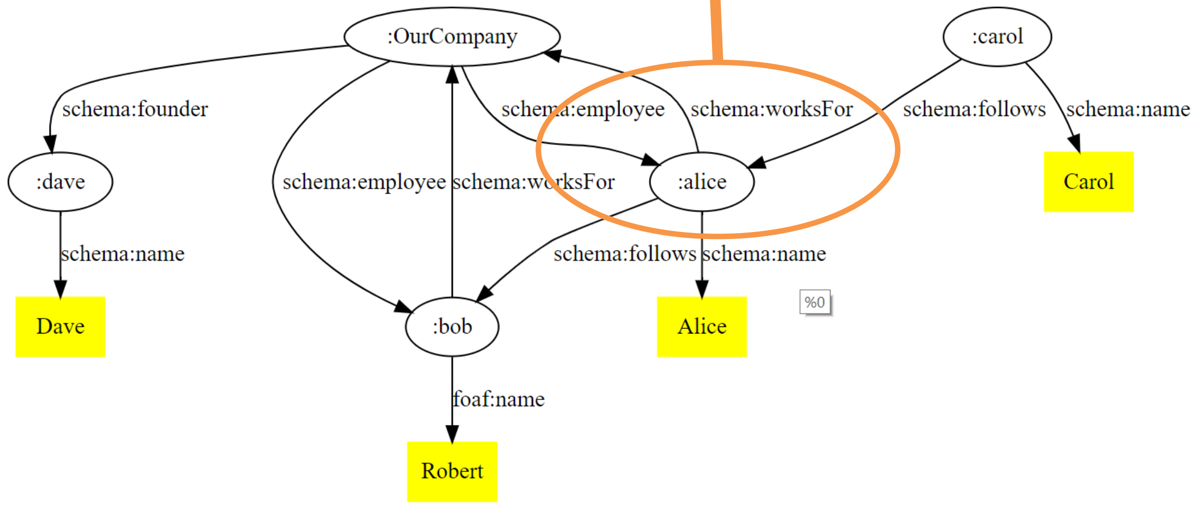
Focus Node and Neighborhood

Focus Node = node that is being validated

Neighborhood of a node = set of incoming/outgoing triples

```
:alice      schema:name     "Alice";
            schema:follows  :bob;
            schema:worksFor :OurCompany .

:bob        foaf:name       "Robert" ;
            schema:worksFor :OurCompany .

:carol      schema:name     "Carol" ;
            schema:follows  :alice .

:dave       schema:name      "Dave" .

:OurCompany schema:founder  :dave ;
            schema:employee :alice, :bob .
```

```
Neighbourhood of :alice = {
  (:alice,      schema:name,      "Alice")
  (:alice,      schema:follows,   :bob),
  (:alice,      schema:worksFor,  :OurCompany),
  (:carol,      schema:follows,   :alice),
  (:OurCompany, schema:employee,  :alice)
}
```



Shape maps

Shape maps declare which node/shape pairs are selected

- They declare the queries that ShEx engines solve
  - Example: Does `:alice` conform to `<User>` ?
    - `:alice@<User>`
  - Example: Do all subjects of `schema:knows` conform to `<User>` ?
    - `{FOCUS schema:knows _ }@<User>`

3 types of shape maps:

- Query shape maps: Input shape maps
- Fixed shape maps: Simple pairs of node/shape
- Result shape maps: Shape maps generated by the validation process

Shape map resolver

Converts query shape maps to fixed shape maps

Query shape map

```
{FOCUS schema:worksFor _ }@:User
{FOCUS rdf:type schema:Person}@:User,
{_ schema:worksFor FOCUS }@:Company
```

ShapeMap Resolver

Fixed shape map

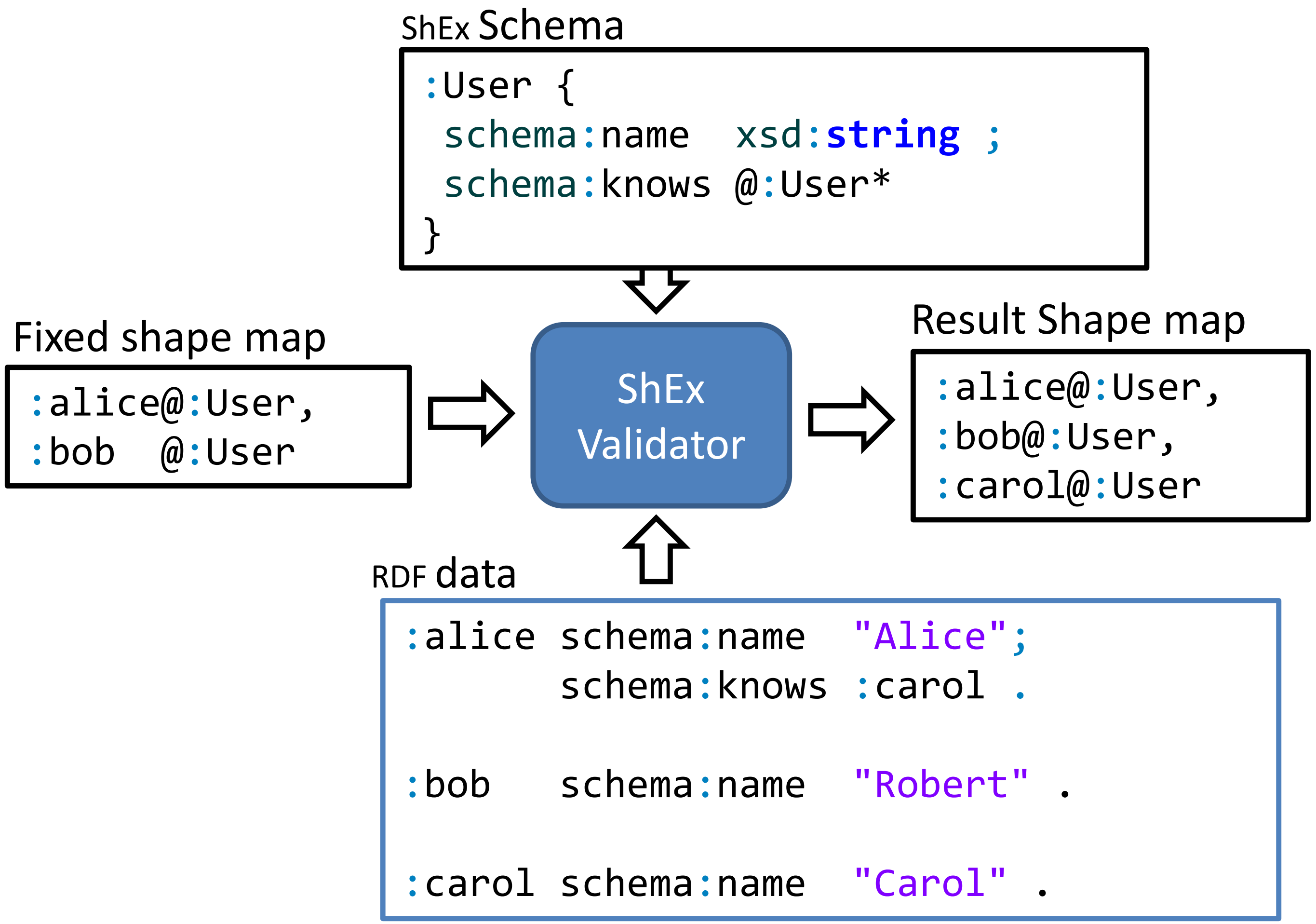
```
:alice@:User,
:bob@:User,
:carol@:User,
:c1@:Company,
:c2@:Company,
```

RDF Graph

```
:alice a :User .

:bob    schema:worksFor :c1,
                        :c2 .

:carol a schema:Person ;
       schema:worksFor :c1 .
```

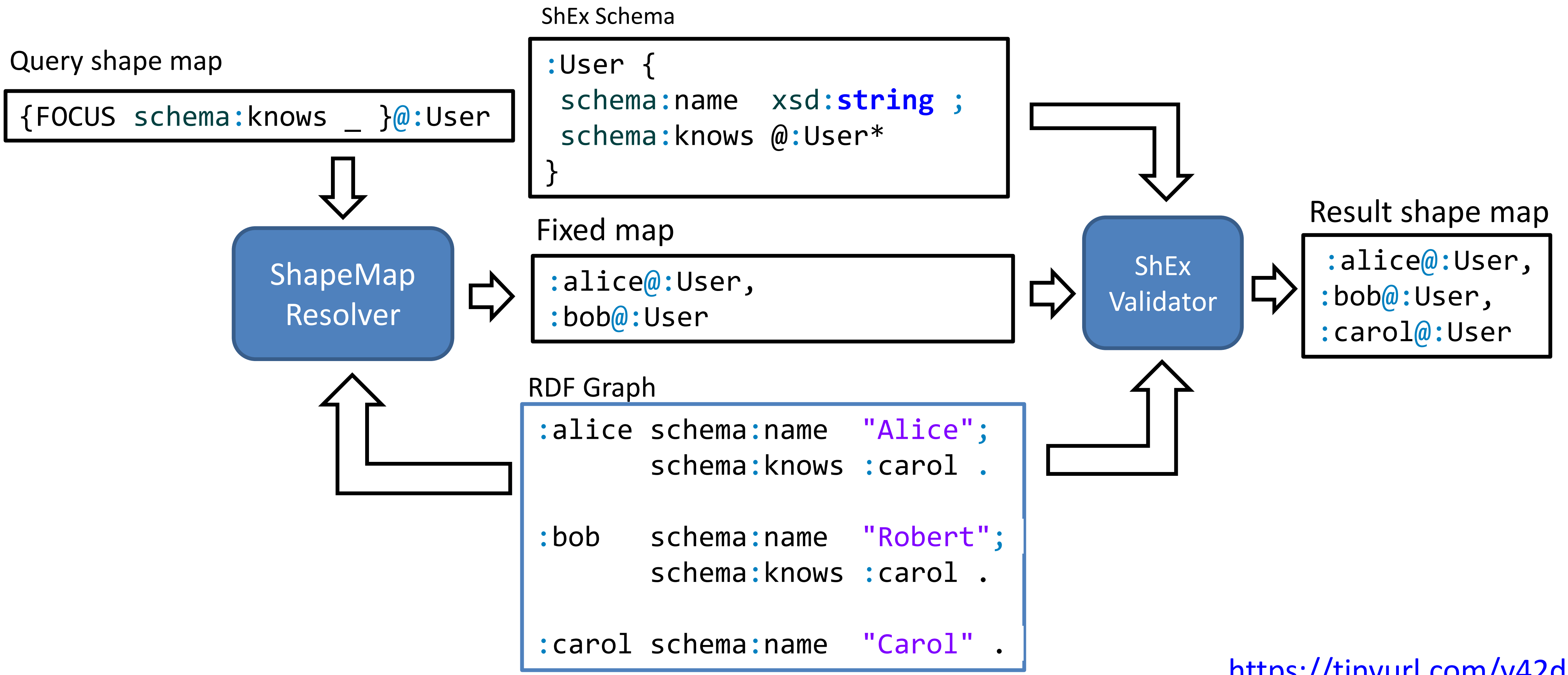
ShEx validator

Input: schema, rdf data and fixed shape map, Output: result shape map



Validation process

2 stages: 1) ShapeMap resolver
2) ShEx validator



https://tinyurl.com/y42dclaa

Query maps

A simple language that can be used to generate fixed shape maps

Specification: http://shex.io/shape-map/

Examples:

`:alice@:User`	Checks `:alice` as `:User`
`:alice@:User, :cmp@:Company`	Checks `:alice` as `:User` and `:cmp` as `:Company`
`{_ schema:knows FOCUS }@:User`	Checks nodes who `schema:know` some node
`{FOCUS schema:knows _ }@:User`	Checks nodes who are `schema:known by some node`

<pre>SPARQL """
prefix schema: <http://schema.org/>
 	
select ?node where {
 ?node schema:knows ?someone
}
"""@:User</pre>
	The same as before
	Any SPARQL query can be used to obtain focus nodes

Node constraints

Constraints over an RDF node

Node constraints

```
:User {
 schema:name        xsd:string ;
 schema:birthDate   xsd:date? ;
 schema:gender      [schema:Male schema:Female] OR xsd:string;
 schema:knows       IRI @:User*
}
```

Node constraints

Triple constraints

Constraints about the incoming/outgoing arcs of a node

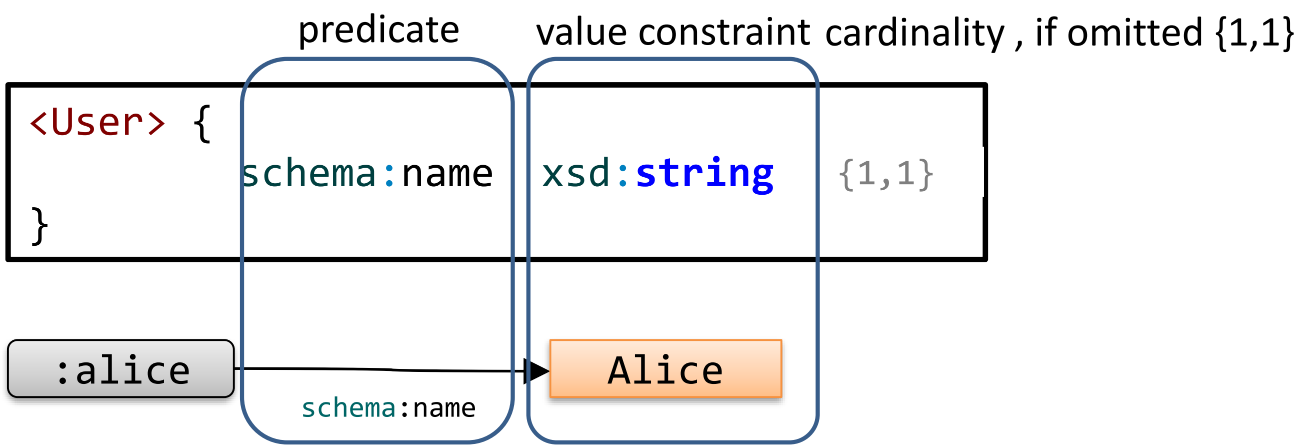
```
:User {
 schema:name        xsd:string ;
 schema:birthDate   xsd:date ? ;
 schema:gender      [schema:Male schema:Female] OR xsd:string;
 schema:knows       IRI @:User *
}
```

Triple constraints

Triple constraints

A basic expression consists of a Triple Constraint

Triple constraint ≈ predicate + value constraint + cardinality



Shape expressions

Labelled rules

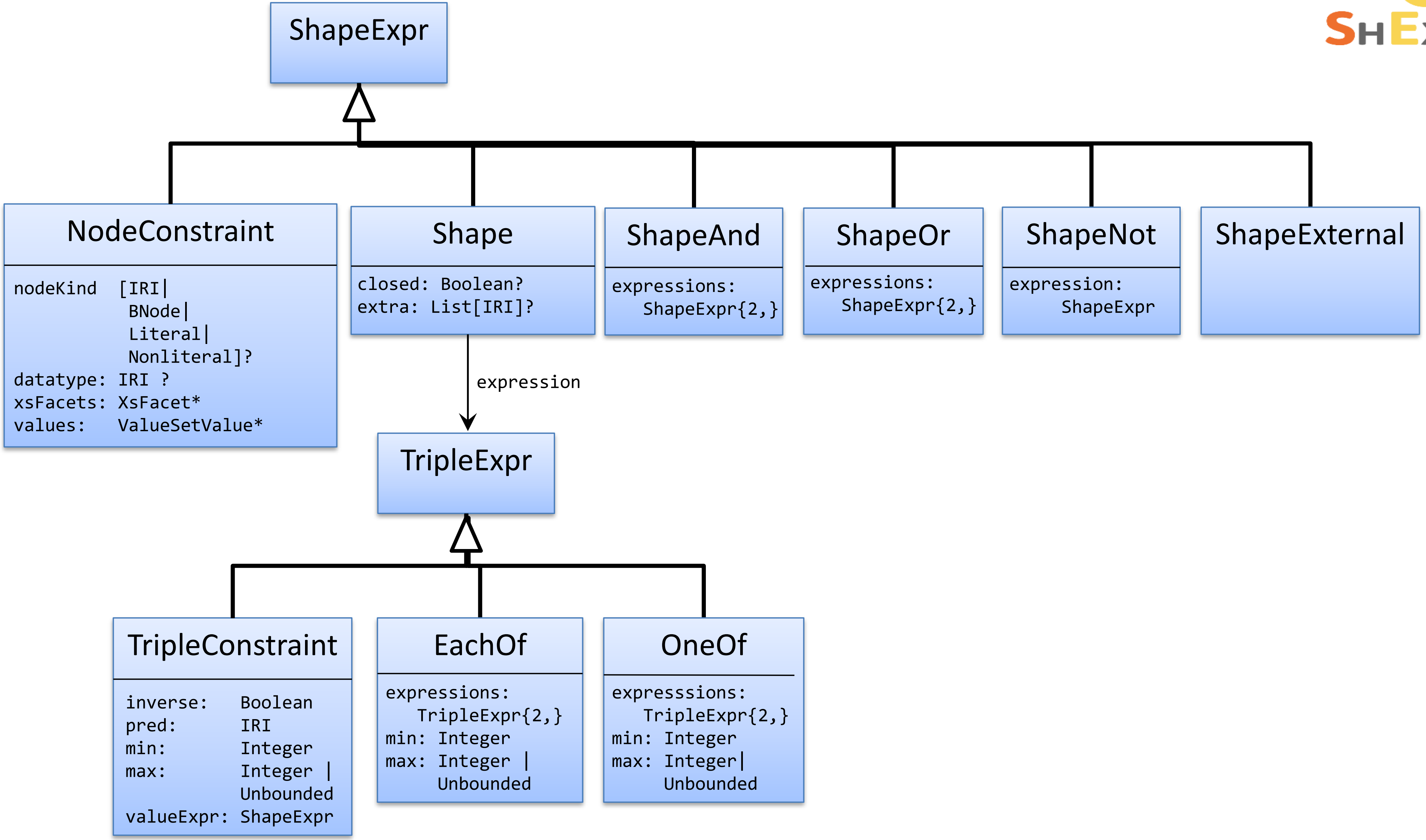
Shape expression label

Shape expression

Triple expression

```
:User {
  schema:name          xsd:string ;
  schema:birthDate     xsd:date ? ;
  schema:gender        [schema:Male schema:Female] OR xsd:string;
  schema:knows         IRI @:User *
}
```

Structure of Shape Expressions



Simple expressions and grouping

The each-of operator ; combines triple expressions

Unordered sequence

```
:User {
 schema:name   xsd:string  ;
 foaf:age      xsd:integer ;
 schema:email  xsd:string  ;
}
```

```
:alice schema:name  "Alice";
       foaf:age     10 ;
       schema:email "alice@example.org" .

:bob   schema:name  "Robert Smith" ;            ☹
       foaf:age     45 ;
       schema:email <mailto:bob@example.org> .

:carol schema:name   "Carol" ;                  ☹
       foaf:age      56, 66 ;
       schema:email  "carol@example.org" .
```

Repeated properties

A repeated property indicates that **each of** the expressions must be satisfied

```
<User> {
 schema:name   xsd:string;
 schema:parent @<Male>;
 schema:parent @<Female>
}

<Male> {
 schema:gender [schema:Male ]
}

<Female> {
 schema:gender [schema:Female]
}
```

Means that <User> must have two parents, one male and another female

```
:alice schema:name   "Alice" ;
       schema:parent :bob, :carol .

:bob   schema:name   "Bob" ;
       schema:gender schema:Male .

:carol schema:name   "Carol" ;
       schema:gender schema:Female .
```

Try it (RDFShape): https://goo.gl/d3KWPJ

Cardinalities

Inspired by regular expressions

- Traditional operators: *, +, ?
- …plus cardinalities {m, n}
- If omitted {1,1} = default cardinality

*	0 or more
+	1 or more
?	0 or 1
`{m}`	m repetitions
`{m,n}`	Between m and n repetitions
`{m,}`	m or more repetitions

Example with cardinalities

```
<User> {
 schema:name xsd:string          ;
 schema:worksFor @<Company>    ? ;
 schema:follows  @<User>       *
}

<Company> {
 schema:founder  @<User>       ? ;
 schema:employee @<User> {1,100}
}
```

```
:alice      schema:name     "Alice";
            schema:follows  :bob;
            schema:worksFor :OurCompany .

:bob        schema:name     "Robert" ;
            schema:worksFor :OurCompany .

:carol      schema:name     "Carol" ;
            schema:follows  :alice .

:dave       schema:name      "Dave" .

:OurCompany schema:founder :dave ;
            schema:employee :alice, :bob .
```

Try it: https://goo.gl/ddQHPo

Choices - OneOf

The one-of operator | represents alternatives (either one or the other)

```
:User {
  schema:name  xsd:string ;
| schema:givenName xsd:string + ;
  schema:lastName  xsd:string
}
```

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

:bob   schema:givenName "Bob", "Robert" ;
       schema:lastName  "Smith" .

:carol schema:name      "Carol King" ;   ☹
       schema:givenName "Carol" ;
       schema:lastName  "King" .

:dave  foaf:name        "Dave" .         ☹
```

Try it (RDFShape): https://goo.gl/hCvyRN

Node constraints

Type	Example	Description
Anything	.	The value can be anything
Datatype	xsd:string	Matches a literal with datatype xsd:string
Kind	IRI BNode Literal NonLiteral	The object must have that kind
Value set	[:Male :Female]	The value must be :Male or :Female
Reference	@<User>	The value must have shape <User>
Composed with OR AND NOT	xsd:string OR IRI	The value must have datatype xsd:string or be an IRI
IRI Range	foaf:~	The value must start with the IRI associated with foaf
Any except...	- :Checked	Any value except :Checked

No constraint

A dot (.) matches anything ⇒ no constraint on values

```
:User {
 schema:name        . ;
 schema:affiliation . ;
 schema:email       . ;
 schema:birthDate   .
}
```

```
:alice
   schema:name         "Alice";
   schema:affiliation [ schema:name "OurCompany" ] ;
   schema:email        <mailto:alice@example.org> ;
   schema:birthDate    "2010-08-23"^^xsd:date .
```

Try it: https://goo.gl/LNVg4p

Datatypes

Datatypes are directly declared by their URIs

Predefined datatypes from XML Schema:

`xsd:string xsd:integer xsd:date …`

```
:User {
 schema:name      xsd:string;
 schema:birthDate xsd:date
}
```

```
:alice schema:name      "Alice";
       schema:birthDate "2010-08-23"^^xsd:date.

:bob   schema:name      "Robert" ;             ☹
       schema:birthDate "Unknown" .

:carol schema:name      _:unknown ;            ☹
       schema:birthDate 2012 .
```

Try it: https://goo.gl/neVWeC

Facets on Datatypes

It is possible to qualify the datatype with XML Schema facets

See: http://www.w3.org/TR/xmlschema-2/#rf-facets

Facet	Description
MinInclusive, MaxInclusive MinExclusive, MaxExclusive	Constraints on numeric values which declare the min/max value allowed (either included or excluded)
TotalDigits, FractionDigits	Constraints on numeric values which declare the total digits and fraction digits allowed
Length, MinLength, MaxLength	Constraints on string values which declare the length allowed, or the min/max length allowed
/… /	Regular expression pattern

Facets on Datatypes

```
:User {
 schema:name  xsd:string  MaxLength 10 ;
 foaf:age     xsd:integer MinInclusive 1 MaxInclusive 99 ;
 schema:phone xsd:string  /\\d{3}-\\d{3}-\\d{3}/
}
```

```
:alice schema:name  "Alice";
       foaf:age     10 ;
       schema:phone "123-456-555" .

:bob   schema:name  "Robert Smith" ;     ☹
       foaf:age     45 ;
       schema:phone "333-444-555" .

:carol schema:name  "Carol" ;            ☹
       foaf:age     23 ;
       schema:phone "23-456-555" .
```

Try it: https://goo.gl/8KanuJ

Node Kinds

Define the kind of RDF nodes: Literal, IRI, BNode, ...

Value	Description	Examples
Literal	Literal values	"Alice" "Spain"@en 23 true
IRI	IRIs	<http://example.org/alice> ex:alice
BNode	Blank nodes	_:1
NonLiteral	Blank nodes or IRIs	_:1 <http://example.org/alice> ex:alice

Example with node kinds

```
:User {
 schema:name    Literal ;
 schema:follows IRI
}
```

```
:alice schema:name    "Alice" ;
       schema:follows :bob .

:bob   schema:name    :Robert ;  ☹
       schema:follows :carol .

:carol schema:name    "Carol" ;  ☹
       schema:follows "Dave"  .
```

Try it: https://goo.gl/B6x2rE

Value sets

The value must be one of the values of a given set

Denoted by [and]

```
:Product {
 schema:color        [ "Red" "Green" "Blue" ] ;
 schema:manufacturer [ :OurCompany :AnotherCompany ]
}
```

```
:x1 schema:color "Red";
    schema:manufacturer :OurCompany .

:x2 schema:color "Cyan" ;
    schema:manufacturer :OurCompany .     ☹

:x3 schema:color "Green" ;
    schema:manufacturer :Unknown .        ☹
```

Try it: https://goo.gl/AJ1eQX

Single value sets

Value sets with a single element

- A very common pattern

```
<SpanishProduct> {
 schema:country [ :Spain ]
}

<FrenchProduct> {
 schema:country [ :France ]
}

<VideoGame> {
 a [ :VideoGame ]
}
```

```
:product1 schema:country :Spain .

:product2 schema:country :France .

:product3 a :VideoGame ;
          schema:country :Spain .
```

Note: ShEx doesn't interact with inference

It just checks if there is an rdf:type arc

- Inference can be done before/after validating
- It can even be used to validate inference systems

Try it: https://goo.gl/NpZN9n

Language tagged literals

```
:FrenchProduct {
 schema:label [ @fr ]
}

:SpanishProduct {
 schema:label [ @es @es-AR @es-ES ]
}
```

```
:car1 schema:label "Voiture"@fr .    # Passes as  :FrenchProduct

:car2 schema:label "Auto"@es .       # Passes as :SpanishProduct

:car3 schema:label "Carro"@es-AR .   # Passes as  :SpanishProduct

:car4 schema:label "Coche"@es-ES .   # Passes as  :SpanishProduct
```

Shape references

Defines that the value must match another shape

- References are marked as @

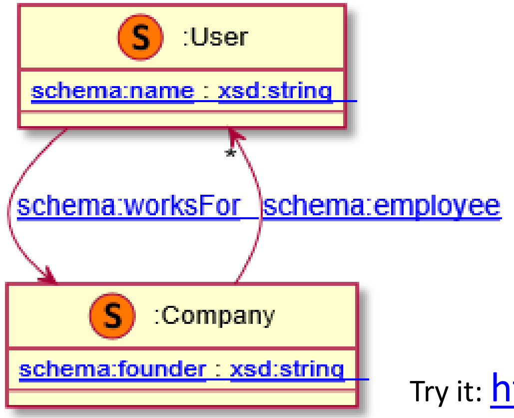
```
:User {
 schema:name xsd:string    ;
 schema:worksFor @:Company
}

:Company {
 schema:founder xsd:string
}
```

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

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

:OurCompany
       schema:name     "OurCompany" .

:Another
       schema:name      23 .              ☹
```

Try it: https://goo.gl/Q3SriH

Recursion and cyclic data models

```
:User {
 schema:name       xsd:string  ;
 schema:worksFor @:Company ;
}

:Company {
 schema:founder  xsd:string  ;
 schema:employee @:User *
}
```

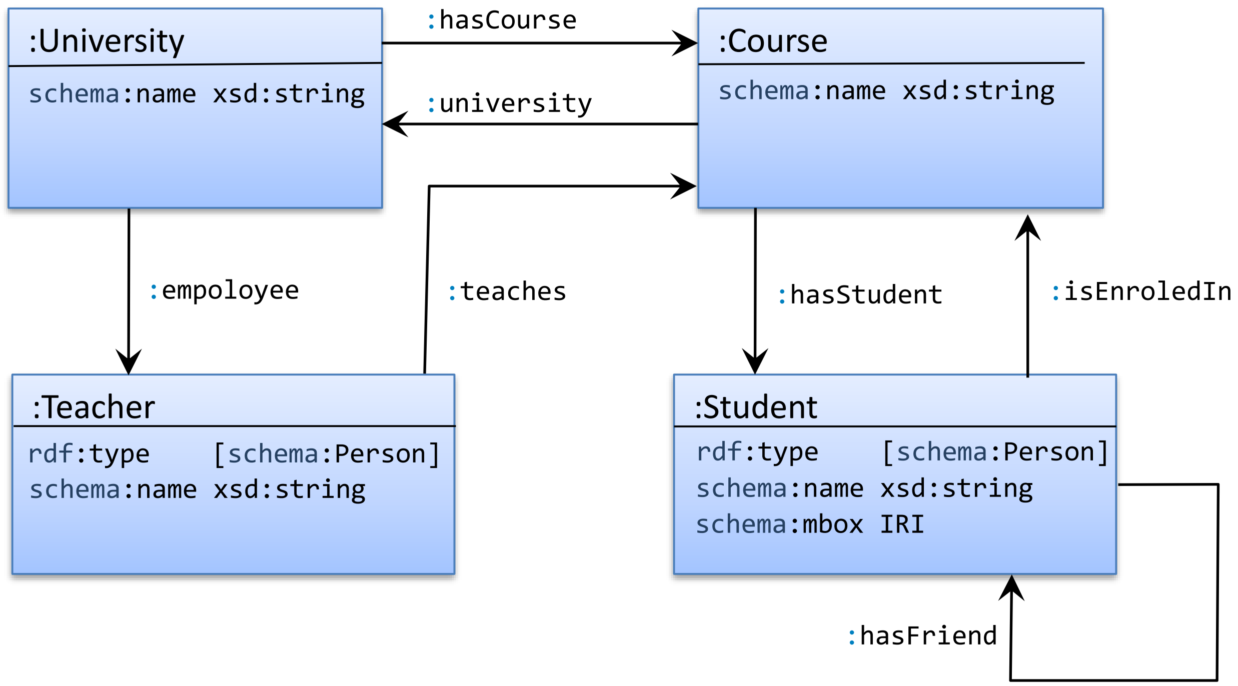



```
:alice    schema:name     "Alice";;
          schema:worksFor :OurCompany .

:bob      schema:name     "Robert";          ☹
          schema:worksFor :Another .

:companyA schema:founder     "Carol";
          schema:employee    :alice .

:companyB schema:founder     "Another" .     ☹
          schema:employee    :unknown .
```

Try it: https://goo.gl/eMNiyR

Exercise

Define a Schema for the following domain model



IRI ranges

`uri:~` represents the set of all URIs that start with stem `uri`

```
prefix codes: <http://example.codes/>

:User {
  :status [ codes:~ ]
}
```

```
prefix codes: <http://example.codes/>
prefix other: <http://other.codes/>

:x1 :status codes:resolved .

:x2 :status other:done .                    ☹

:x3 :status <http://example.codes/pending> .
```

Try it: https://goo.gl/EC521J

IRI Range exclusions

The operator - excludes IRIs or IRI ranges from an IRI range

```
prefix codes: <http://example.codes/>

:User {
  :status [
      codes:~ - codes:deleted
  ]
}
```

```
:x1 :status codes:resolved .

:x2 :status other:done.                 ☹

:x3 :status <http://example.codes/pending> .

:x4 :status codes:deleted .             ☹
```

Try it: https://goo.gl/pU8u4b

Nested shapes

Syntax simplification to avoid defining two shapes

- Internally, the inner shape is identified using a blank node

```
User {
  schema:name      xsd:string ;
  schema:worksFor _:1
}

_:1 a [ schema:Company ] .
```

≡

```
:User {
  schema:name      xsd:string ;
  schema:worksFor {
    a [ schema:Company ]
  }
}
```

```
:alice schema:name     "Alice" ;
       schema:worksFor :OurCompany .

:OurCompany a schema:Company .
```

Try it (RDFShape): https://goo.gl/2Eoehi

Labeled constraints

`$label` <constraint> associates a constraint to a label

It can later be used as `&label`

```
:User {
 $:name ( schema:name .
        | schema:givenName . ;
          schema:familyName .
        ) ;
 schema:email IRI
}
:Employee {
  &:name ;
  :employeeId .
}
```

```
:Employee {
  ( schema:name .
  | schema:givenName . ;
    schema:familyName .) ;
  :employeeId .
}
```

Inverse triple constraints

^ reverses the order of the triple constraint

```
:User {
 schema:name      xsd:string ;
 schema:worksFor @:Company
}

:Company {
 a          [schema:Company] ;
 ^schema:worksFor @:User+
}
```

```
:alice schema:name "Alice";
       schema:worksFor :OurCompany .

:bob schema:name "Bob" ;
     schema:worksFor :OurCompany .

:OurCompany a schema:Company .
```

Try it (RDFShape): https://goo.gl/9FbHi3

Allowing other triples

Triple constraints limit all triples with a given predicate to match one of the constraints

This is called *closing a property*

Example:

```
<Company> {
 a [ schema:Organization ] ;
 a [ org:Organization ]
}
```

```
:OurCompany a org:Organization,
              schema:Organization .

:OurUniversity a org:Organization,      ☹
                 schema:Organization,
                 schema:CollegeOrUniversity .
```

Sometimes we would like to permit other triples (open the property)

Allowing other triples

`EXTRA <listOfProperties>` declares that a list of properties can contain extra values

```
<Company> EXTRA a {
 a [ schema:Organization ] ;
 a [ org:Organization ]
}
```

```
:OurCompany a org:Organization,
              schema:Organization .

:OurUniversity a org:Organization,
                 schema:Organization,
                 schema:CollegeOrUniversity .
```

Try it: https://goo.gl/MxZVts

Closed Shapes

CLOSED can be used to limit the appearance of any predicate not mentioned in the shape expression

If not specified, shapes are open by default

```
<User> {
 schema:name IRI;
 schema:knows @<User>*
}
```

```
:alice schema:name "Alice" ;
       schema:knows :bob .

:bob schema:name "Bob" ;
     schema:knows :alice .

:dave schema:name "Dave" ;
      schema:knows :emily ;
      :link2virus <virus> .

:emily schema:name "Emily" ;
       schema:knows :dave .
```

```
<User> CLOSED {
 schema:name IRI;
 schema:knows @<User>*
}
```

By default open, so all match `<User>`

With closed, only `:alice` and `:bob` match `<User>`

Node constraints

Constraints on the focus node

```
<User> IRI {
  schema:name xsd:string ;
  schema:worksFor IRI
}
```

```
:alice schema:name "Alice";
  :worksFor :OurCompany .

_:1 schema:name "Unknown";
  :worksFor :OurCompany .
```

☹

Composing Shape Expressions

It is possible to use AND , OR and NOT to compose shapes

```
:User {
 schema:name      xsd:string ;
 schema:worksFor IRI AND @:Company ?;
 schema:follows   IRI OR BNode *
}

:Company {
 schema:founder   IRI ?;
 schema:employee IRI {1,100}
}
```

```
:alice      schema:name      "Alice";
            schema:follows   :bob;
            schema:worksFor :OurCompany .

:bob        schema:name      "Robert" ;
            schema:worksFor [
             schema:Founder "Frank" ;
             schema:employee :carol ;
            ] .

:carol      schema:name      "Carol" ;
            schema:follows   [
             schema:name "Emily" ;
            ] .

:OurCompany schema:founder   :dave ;
            schema:employee :alice, :bob .
```

☹

Try it: https://goo.gl/auLBiu

Implicit AND

AND can be omitted between a node constraint and a shape

```
:User {
  schema:name xsd:string ;
  schema:worksFor IRI AND @:Company
}
```

⇔

```
:User {
  schema:name xsd:string ;
  schema:worksFor IRI @:Company
}
```

Conjunction of Shape Expressions

AND can be used to define conjunction on Shape Expressions

```
<User> { schema:name xsd:string ;
         schema:worksFor IRI
       }
       AND {
         schema:worksFor @<Company>
       }
```

Conjunctions are the default operator in SHACL

Using AND to extend shapes

AND can be used as a basic form of inheritance

```
:Person {
 a                     [ schema:Person ] ;
 schema:name           xsd:string  ;
}

:User @:Person AND {
 schema:name           MaxLength 20 ;
 schema:email          IRI
}

:Student @:User AND {
 :course               IRI *;
}
```

```
:alice a              schema:Person ;
       schema:name    "Alice" .

:bob schema:name      "Robert";
     schema:email     <bob@example.org> .

:carol a              schema:Person;
       schema:name    "Carol" ;
       schema:email <carol@example.org> .

:dave  a     schema:Person;
       schema:name  "Carol" ;
       schema:email <carol@example.org>;
       :course      :algebra .
```

Disjunction of Shape Expressions

OR can be used to define disjunction of Shape Expressions

```
:User { schema:name xsd:string }
   OR { schema:givenName xsd:string ;
        schema:familyName xsd:string
      }
```

Inclusive-or

```
:User { schema:name xsd:string
      | schema:givenName xsd:string ;
        schema:familyName xsd:string
      }
```

Exclusive-or

Disjunction of datatypes

```
:Product {
 rdfs:label          xsd:string OR rdf:langString;
 schema:releaseDate xsd:date OR xsd:gYear OR
                    [ "unknown-past" "unknown-future" ]
}
```

```
:p1 a :Product ;                                      #Passes as a :Product
    rdfs:label "Laptop";
    schema:releaseDate "1990"^^xsd:gYear .

:p2 a :Product ;                                      #Passes as a :Product
    rdfs:label "Car"@en ;
    schema:releaseDate "unknown-future" .

:p3 a :Product ;                                      #Fails as a :Product
    rdfs:label :House ;
    schema:releaseDate "2020"^^xsd:integer .
```

Exercise

Emulate recursive property paths in ShEx

A node conforms to :Person if it has rdf:type schema:Person or if it has a type that is a rdfs:subClassOf some type that has rdf:type schema:Person

```
:alice     a schema:Person .             #Passes as :Person

:bob       a :Teacher .                  #Passes as :Person

:carol     a :Assistant .                #Passes as :Person

:Teacher   rdfs:subClassOf schema:Person .
:Assistant rdfs:subClassOf :Teacher .
```

Negation

NOT s creates a new shape expression from a shape s.

Nodes conform to NOT s when they do not conform to s.

```
:NoName Not {
  schema:name .
}
```

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

:bob   schema:name       "Robert" .          ☹

:carol schema:givenName  "Carol" ;           ☹
       schema:name       "Carol" .
```

Try it: https://goo.gl/GMvXy7

IF-THEN pattern

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

```
:kitt schema:productID "C21";      # Passes as :Product
      a schema:Vehicle;
      schema:vehicleEngine :x42 ;
      schema:fuelType :electric .

:bad  schema:productID "C22";      # Fails as :Product
      a schema:Vehicle;
      schema:fuelType :electric .

:c23  schema:productID "C23" ;     # Passes as :Product
      a schema:Computer .
```

IF-THEN-ELSE pattern

If a product has type schema:Vehicle, then it must have the properties schema:vehicleEngine and schema:fuelType, otherwise, it must have the property schema:category with a xsd:string value.

```
:kitt a schema:Vehicle;                # Passes as :Product
      schema:vehicleEngine :x42 ;
      schema:fuelType :electric .

:c23  a schema:Computer ;              # Passes as :Product
      schema:category "Laptop" .

:bad1 a schema:Vehicle;                # Fails as :Product
      schema:fuelType :electric .

:bad2 a schema:Computer .              # Fails as :Product
```

Cyclic dependencies with negation

One problem of combining NOT and recursion is the possibility of declaring ill-defined shapes

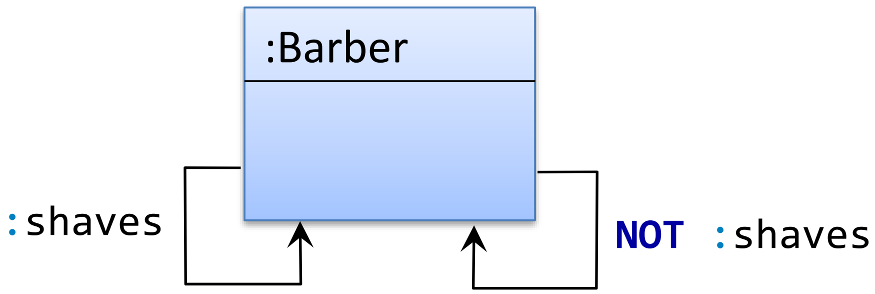
```
:Barber {                    # Violates the negation requirement
 :shaves     @:Person
} AND NOT {
 :shaves     @:Barber
}

:Person {
 schema:name xsd:string
}
```

```
:albert :shaves :dave .          # Passes as a :Barber

:bob schema:name "Robert" ;      # Passes as a :Person
     :shaves :bob .              # Passes :Barber?

:dave schema:name "Dave" .       # Passes as a :Person
```

Restriction on cyclic dependencies and negation

Requirement to avoid ill formed data models:

Whenever a shape refers to itself either directly or indirectly, the chain of references cannot traverse an occurrence of the negation operation NOT.



:Barber shape is rejected

Semantic Actions

Arbitrary code attached to shapes

- Can be used to perform operations with side effects
- Independent of any language/technology
  - Several extension languages: GenX, GenJ (http://shex.io/extensions/)

```
<Person> {
 schema:name xsd:string,
 schema:birthDate xsd:dateTime
 %js:{ report = _.o; return true; %},
 schema:deathDate xsd:dateTime
 %js:{ return _[1].triple.o.lex > report.lex; %}
 %sparql:{
   ?s schema:birthDate ?bd . FILTER (?o > ?bd) %}
}
```

```
:alice schema:name "Alice" ;
   schema:birthDate "1980-01-23"^^xsd:date ;
   schema:deathDate "2013-01-23"^^xsd:date .

:bob schema:name "Robert" ;
   schema:birthDate "2013-08-12"^^xsd:date ;
   schema:deathDate "1990-01-23"^^xsd:date .
```

Importing schemas

The import statement allows to import schemas

http://example.org/Person.shex

```
:Person {
   $:name ( schema:name .
          | schema:givenName . ; schema:familyName .
          ) ;
   schema:email .
}
```

```
import <http://example.org/Person.shex>

:Employee {
    &:name ;
    schema:worksFor <CompanyShape>
}

:Company {
    schema:employee @:Employee ;
    schema:founder  @:Person ;
}
```

```
:alice schema:name     "Alice";
       schema:worksFor :OurCompany .

:OurCompany schema:employee :alice ;
            schema:founder  :bob .

:bob schema:name "Robert" ;
     schema:email <mailto:bob@example.com> .
```

Annotations

Annotations are lists (predicate, object) that can be associated to an element

Specific annotations can be defined for special purposes, e.g. forms, UI, etc.

```
:Person {
 schema:name      xsd:string
  // rdfs:label     "Name"
  // rdfs:comment  "Name of person" ;

 schema:birthDate xsd:date
   // rdfs:label     "birthDate"
   // rdfs:comment  "Birth of date" ;
}
```

Other features

Current ShEx version: 2.1

Some features postponed for next version

- Inheritance (extends/abstract)
- UNIQUE

Future work & contributions

More info http://shex.io

- ShEx currently under active development
- Curent work
  - Improve error messages
  - Inheritance of shape expressions

If you are interested, you can help

- List of issues: https://github.com/shexSpec/shex/issues