ShEx by example

Validating RDF data tutorial

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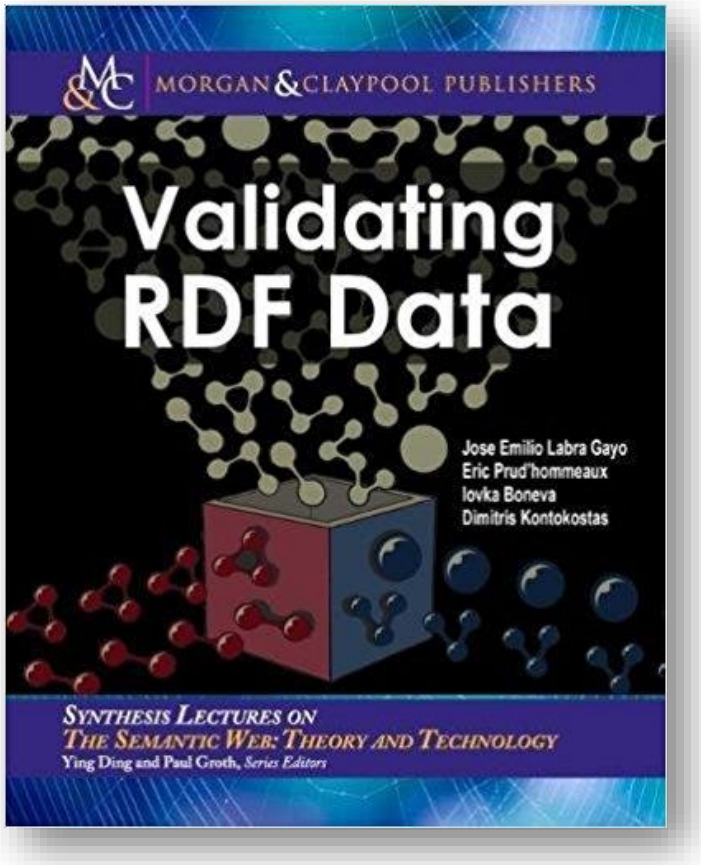
More info

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

Javascript: https://github.com/shexSpec/shex.js

Scala: http://labra.github.io/shaclex/

Ruby: https://ruby-rdf.github.io/shex/

Python: https://github.com/hsolbrig/PyShEx

Java: https://github.com/iovka/shex-java

Other prototypes: https://www.w3.org/2001/sw/wiki/ShEx

ShEx Online demos

Online Validator https://rawgit.com/shexSpec/shex.js/master/doc/shex-simple.html

- Based on Javascript implementation

RDFShape http://rdfshape.weso.es/

- Also has support for SHACL

ShEx-Java: http://shexjava.lille.inria.fr/

ShExValidata https://www.w3.org/2015/03/ShExValidata/

- Based on ShEx 1.0, 3 deployments for different profiles HCLS, DCat, PHACTS

First example

Shapes conforming to <User> must contain one property
schema:name with a value of type xsd:string

Prefix declarations as in Turtle

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

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

Note: We will omit prefix declarations and use the aliases from:
http://prefix.cc

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/tx1Mhf

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, :dave .

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

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

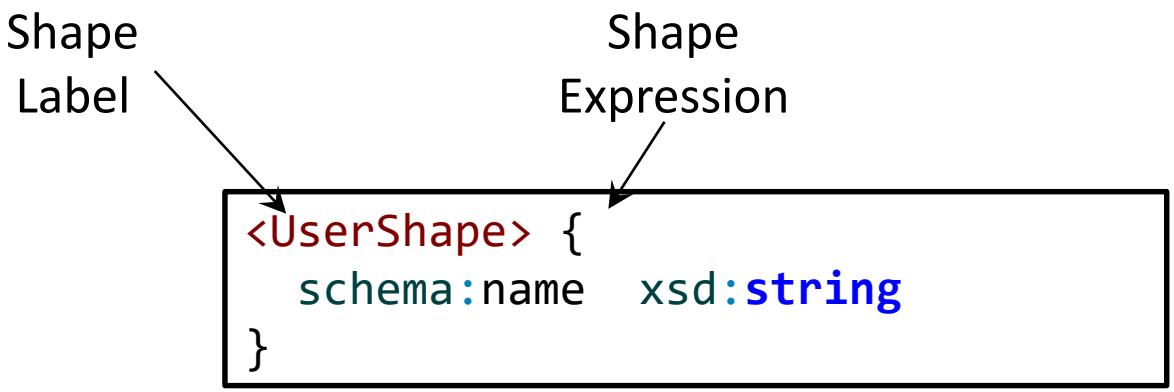
```
{ "type" : "Schema",
  "@context" : "http://www.w3.org/ns/shex.jsonld",
  "shapes" :[{"type" : "Shape",
    "id" : "http://a.example/UserShape",
    "expression" : {
    "type" : "TripleConstraint",
    "predicate" : "http://schema.org/name",
    "valueExpr" : { "type" : "NodeConstraint",
      "datatype"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

Some definitions

Schema = set of Shape Expressions

Shape Expression = labeled pattern

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



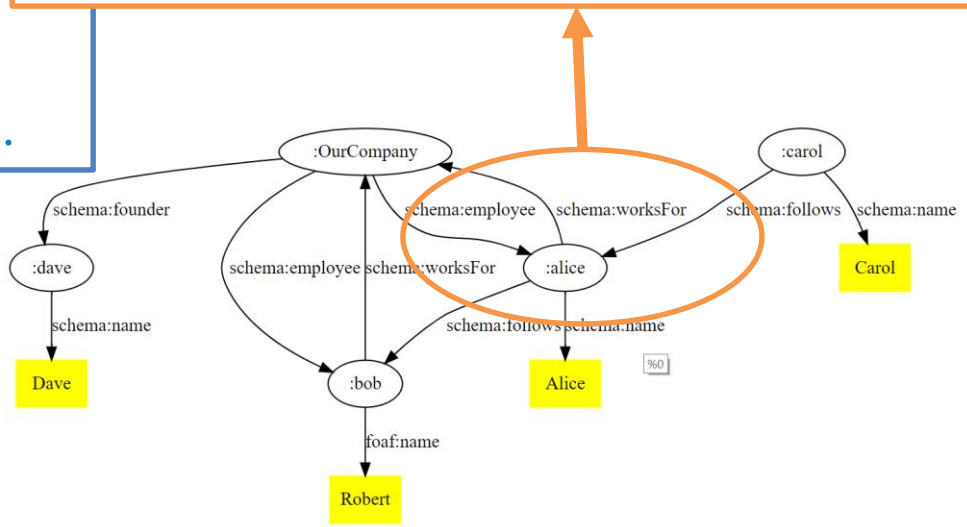
Focus Node and Neighborhood

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:

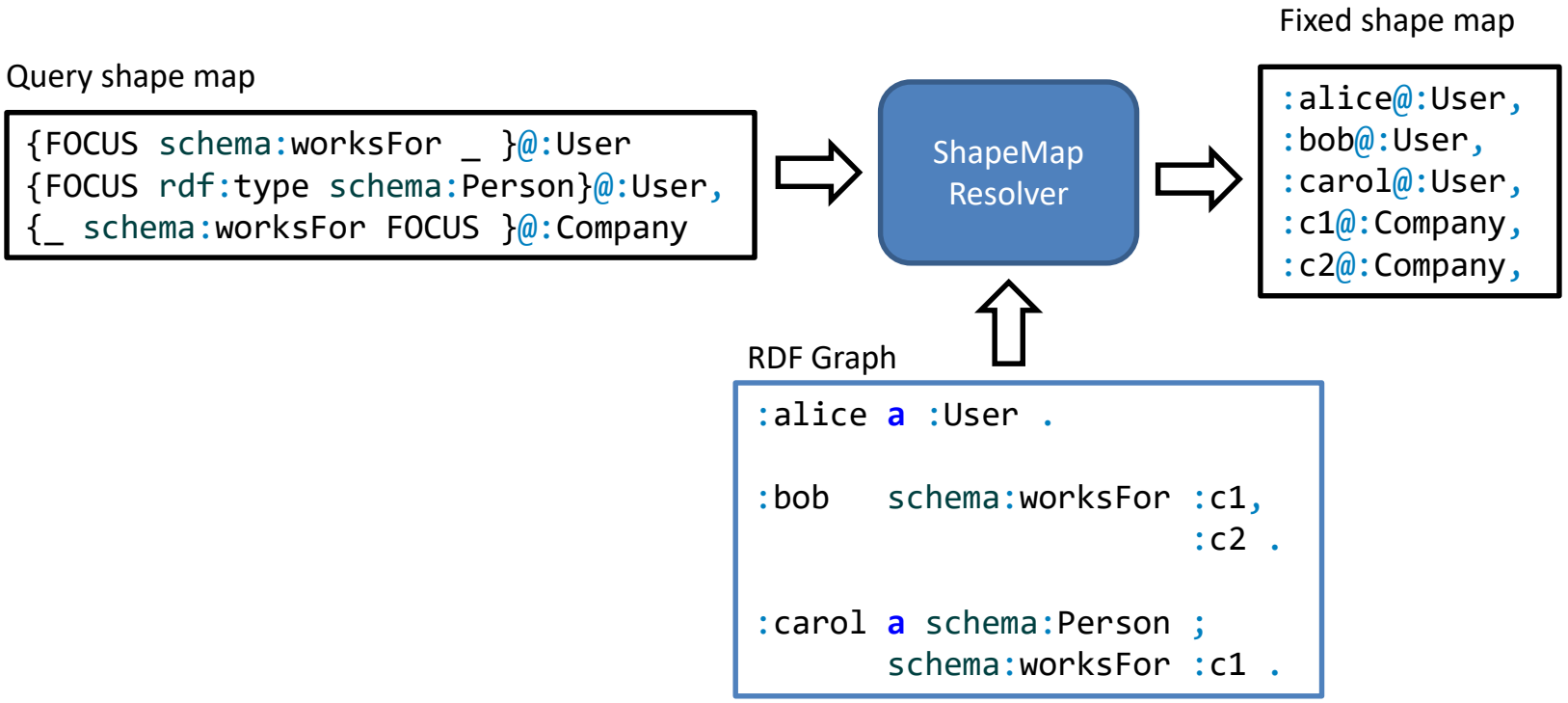
Query shape maps: Input shape maps (can be entiched)

Fixed shape maps: Simple pairs of node/shape

Result shape maps: Shape maps generated by the validation process

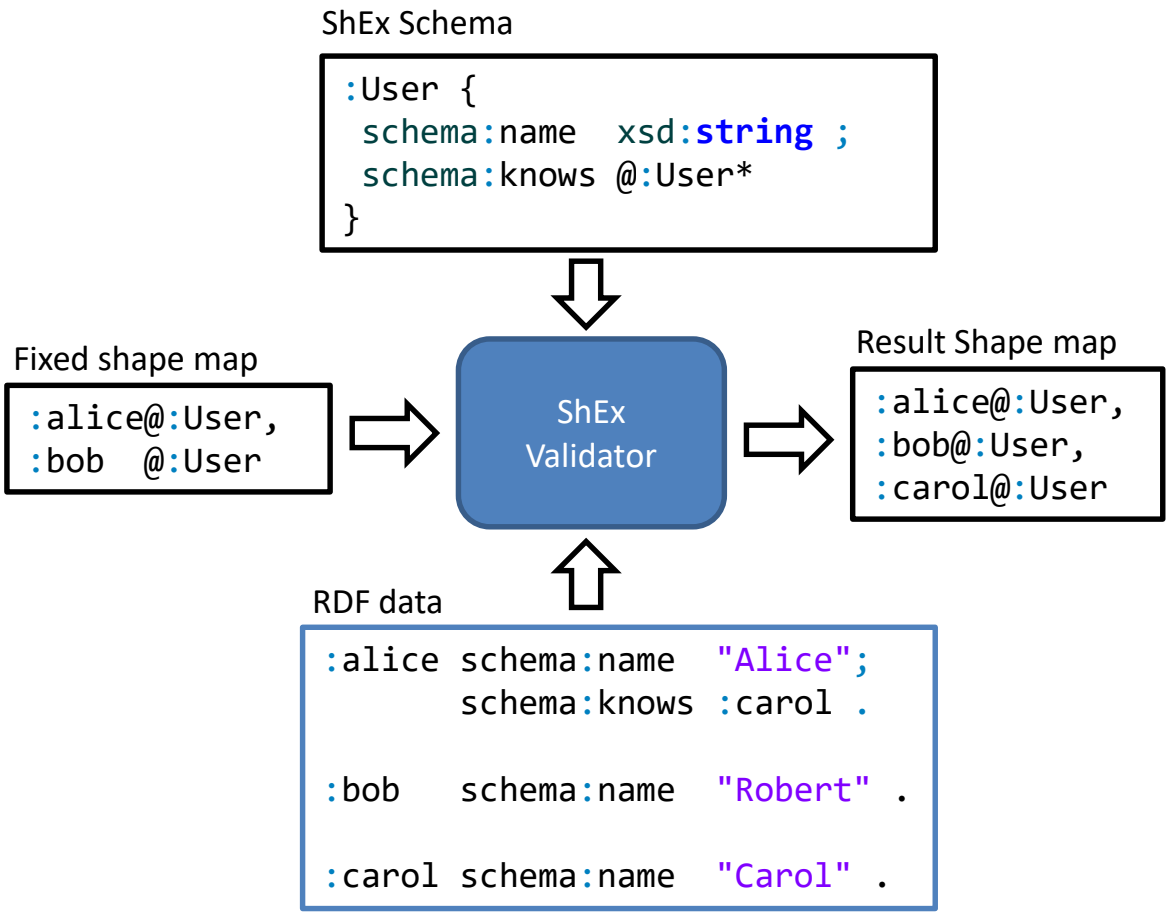
Shape map resolver

Converts query shape maps to fixed shape maps



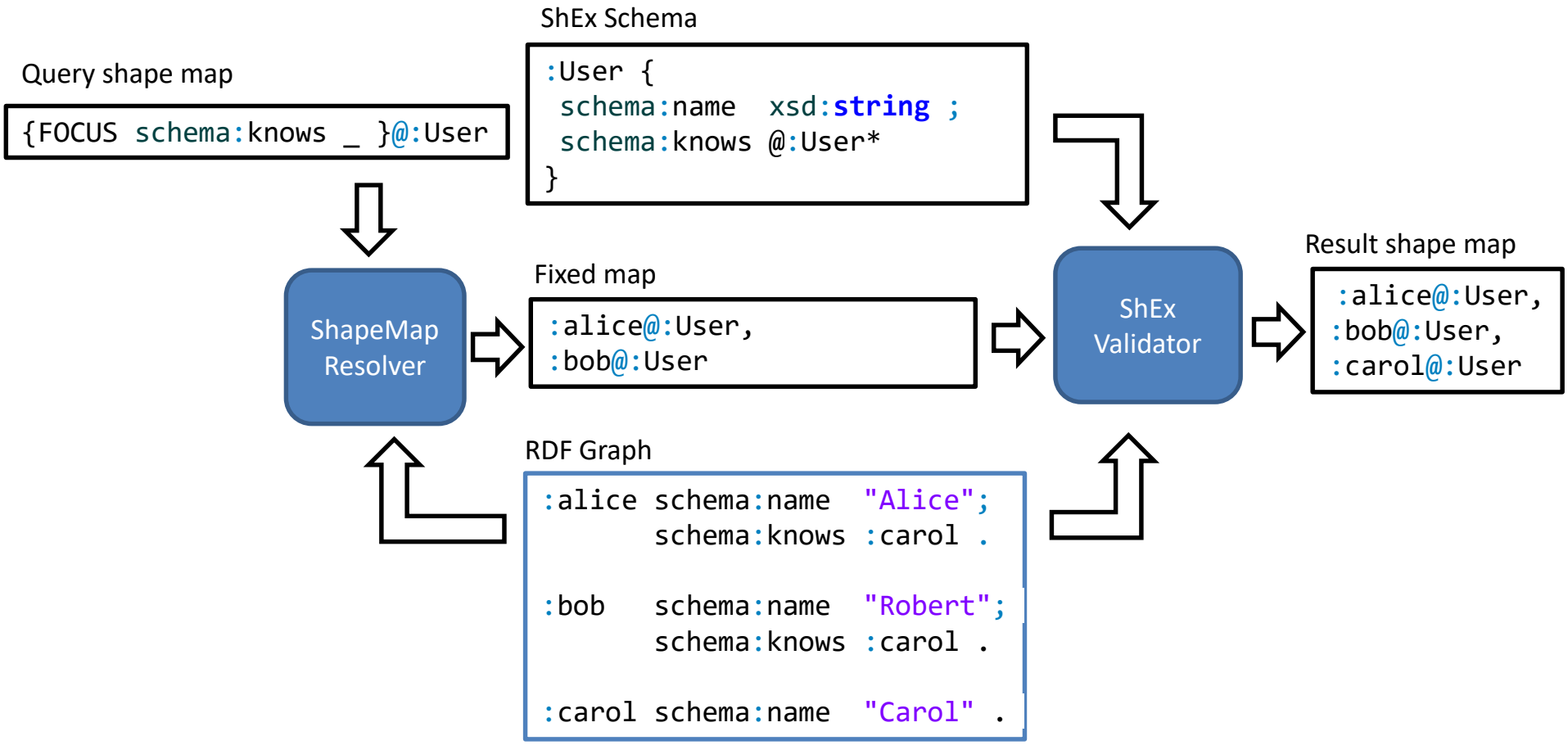
ShEx validator

In: schema, rdf data and fixed shape map, Out: result shape map



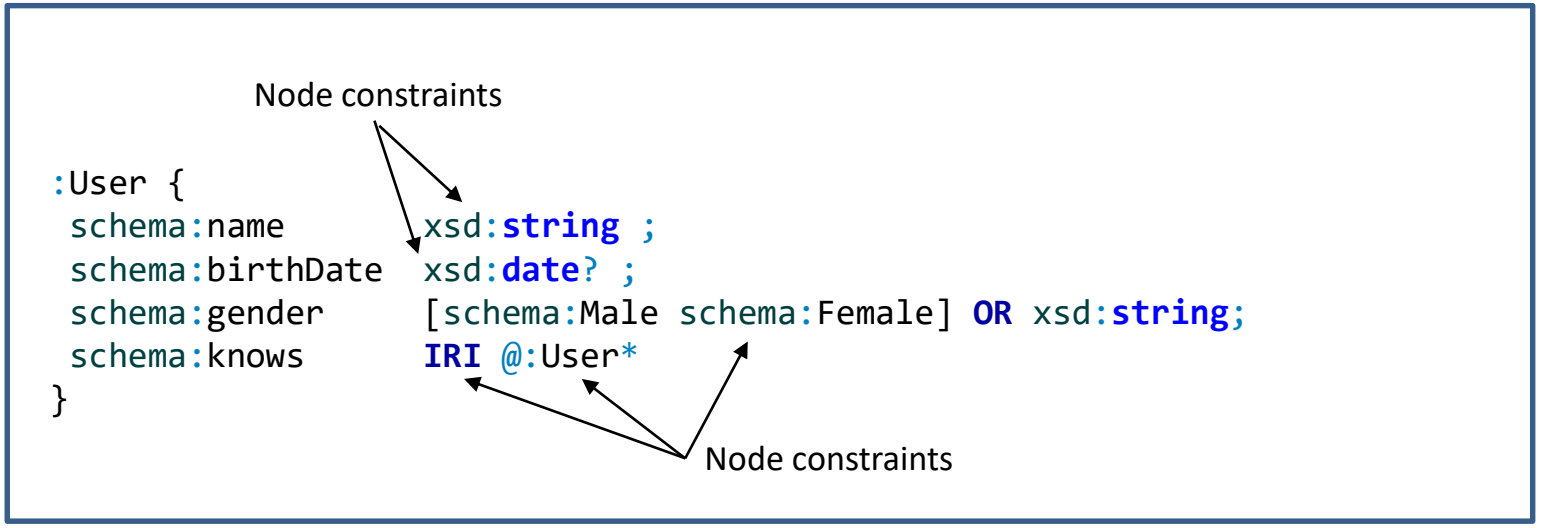
Validation process

2 stages: 1) Resolving shape query shape map, 2) validating



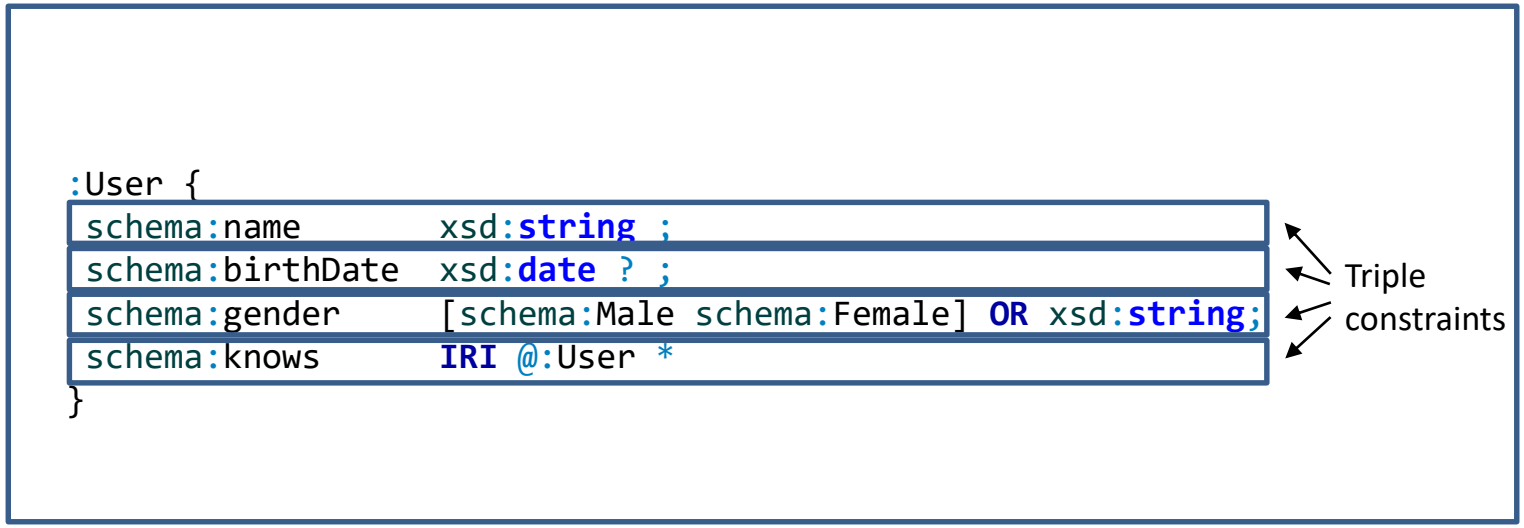
Node constraints

Constraints over an RDF node



Triple constraints

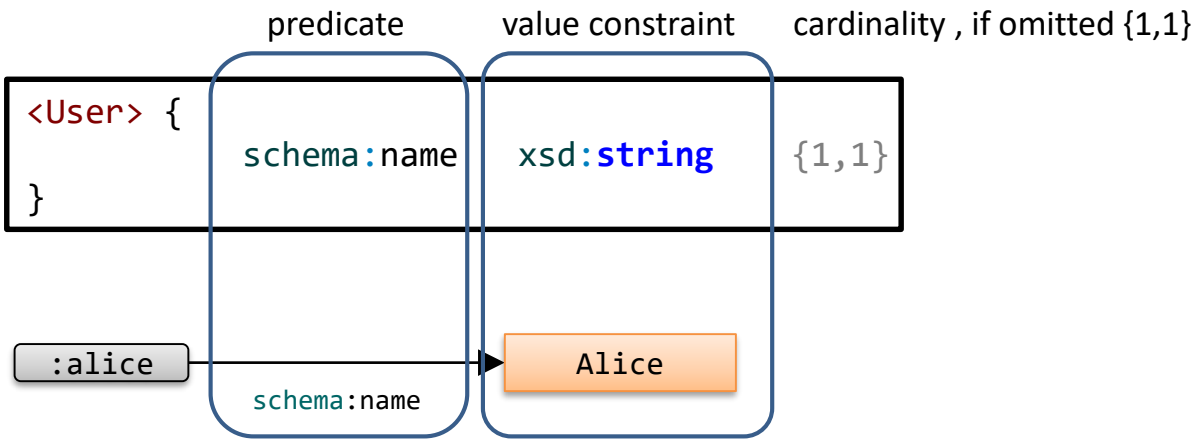
Constraints about the incoming/outgoing arcs of a node



Triple constraints

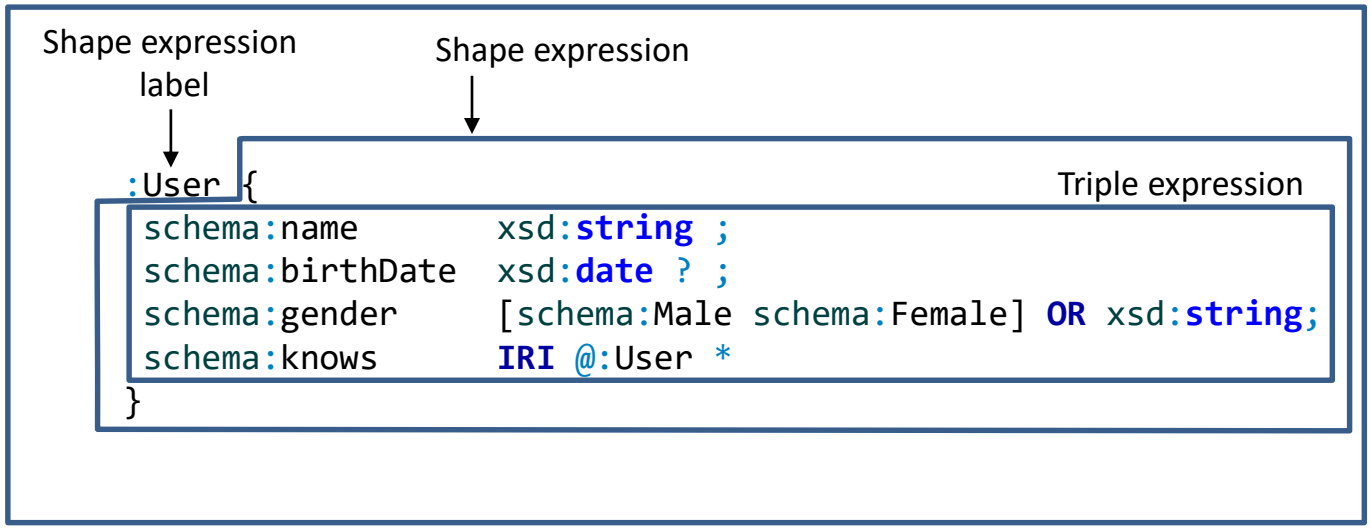
A basic expression consists of a Triple Constraint

Triple constraint ≈ predicate + value constraint + cardinality



Shape expressions

Labelled rules



Simple expressions and grouping

The operator ; can be used to group components

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 a 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 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" .
```

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

Value expressions

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" .
```

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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"  .
```

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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 .
```

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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
ShEx can even be used to validate inference systems

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

Shape references

Defines that the value must match another shape

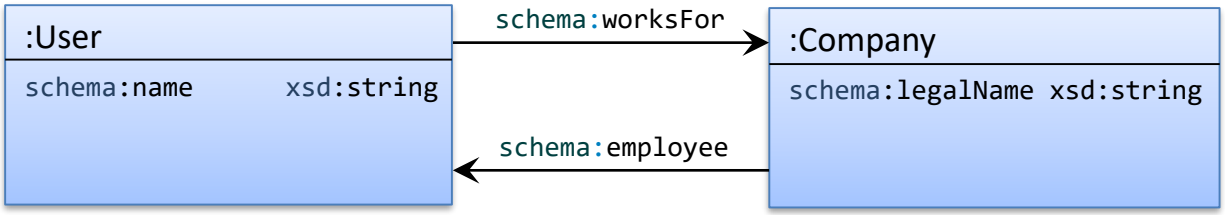
References are marked as @

```
:User {
 schema:worksFor @:Company ;
}

:Company {
 schema:name 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 references



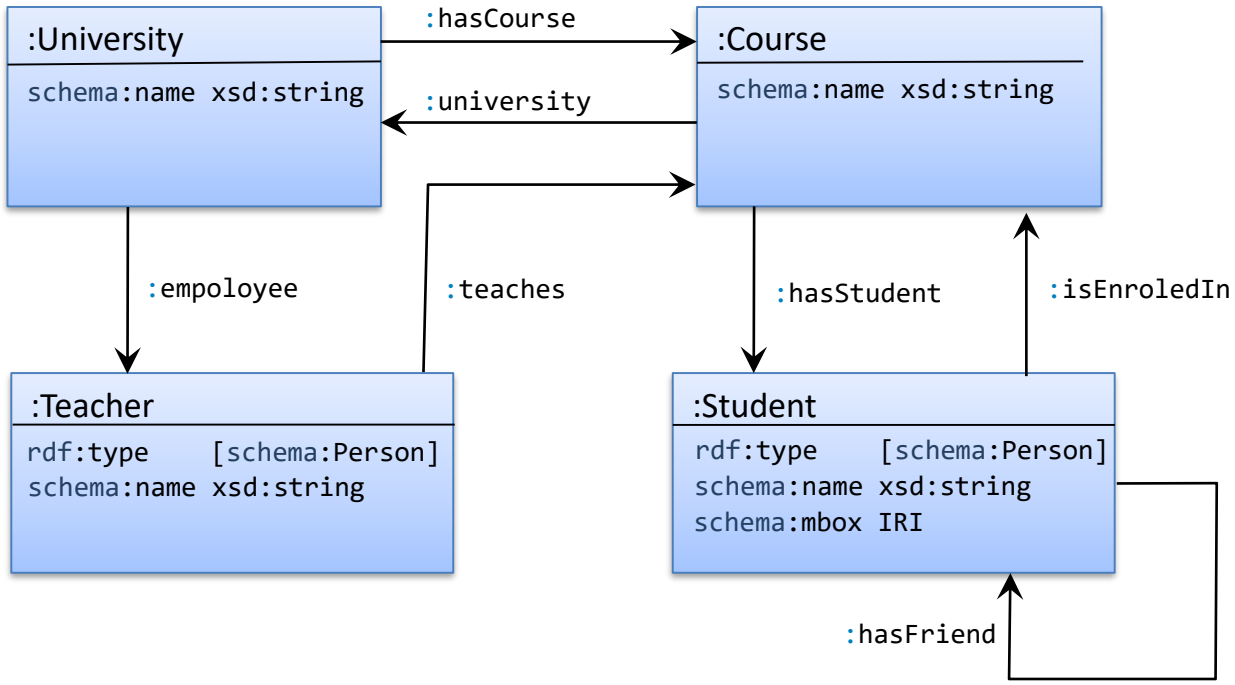

```
:User {
 schema:worksFor @:Company ;
}

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

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

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

:OurCompany
    schema:name "OurCompany" ;
    schema:employee :alice .

:Another
    schema:name 23 .
```

Try it: https://goo.gl/3mWqsd

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

Try it (ShExDemo): https://goo.gl/w4QWMS

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

Example:

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

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

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

Closed Shapes

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

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

Without closed, all match <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>*
}
```

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 .
```

☹

Composed Shapes

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

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
      }
```

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" ;  #Passes
       schema:familyName "Cooper" .

:bob   schema:name       "Robert" . #Fails

:carol schema:givenName  "Carol" ;  #Fails
       schema:name       "Carol" .
```

IF-THEN pattern

Combining OR, NOT and AND it is possible to define IF-THEN…

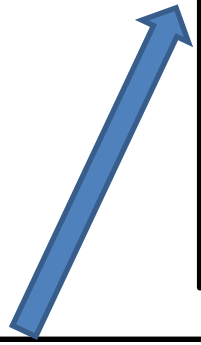
```
:Product { schema:productID . } AND
 NOT{ a [ schema:Vehicle ] }
 OR { schema:vehicleEngine . ;
      schema:fuelType .
 }
```

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> .
```

Cyclic dependencies with negation

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

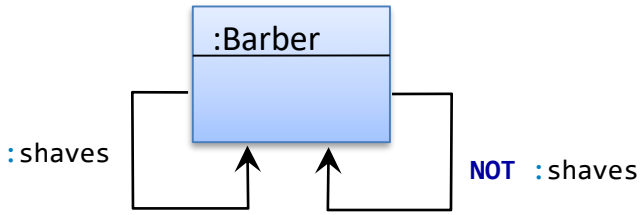
```
:Barber {                    # Violates the negation requirement
 :shaves      @:Person
} AND NOT {
 :shaves      @:Barber
}

: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

Constraint 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 ill-formed

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 .
```

Other features

Current ShEx version: 2.0

Several features have been postponed for next version

- UNIQUE
- Inheritance (extends/abstract)

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