Validating RDF data
ShEx & SHACL compared

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About me…

WESO (Web Semantics Oviedo) research group

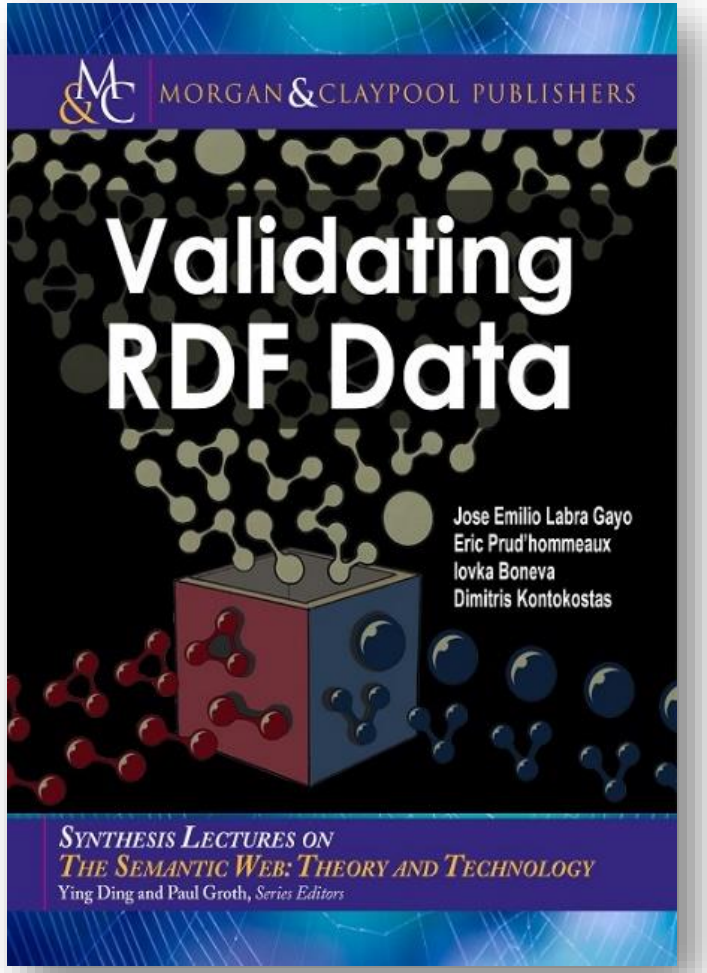
- Practical applications of semantic technologies
- Several domains: e-Government, e-Health

Some books:

- "*Validating RDF data*"
- "*Semantic web*" (in Spanish)

…and software:

- SHaclEX (Scala library, implements ShEx & SHACL)
- RDFShape (RDF playground)



HTML version: http://book.validatingrdf.com
Examples: https://github.com/labra/validatingRDFBookExamples

Contents

Short overview of RDF data model

Understanding the RDF validation problem

Short intro to ShEx

Short intro to SHACL

ShEx and SHACL compared

Conclusions & future work

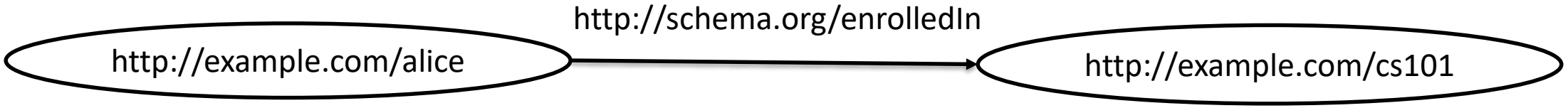
For longer presentations about ShEx/SHACL, see the ISWC'18 tutorial slides:
http://www.validatingrdf.com/tutorial/iswc2018/

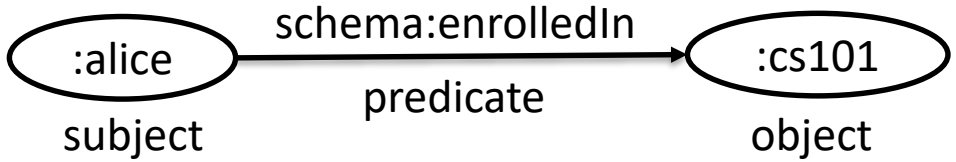
RDF Data Model

RDF Graph = set of triples

Triple = (subject, predicate, object)

Example:

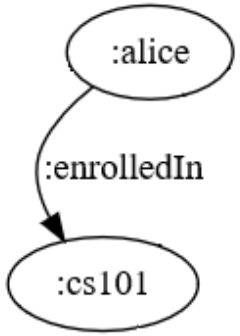




N-Triples representation

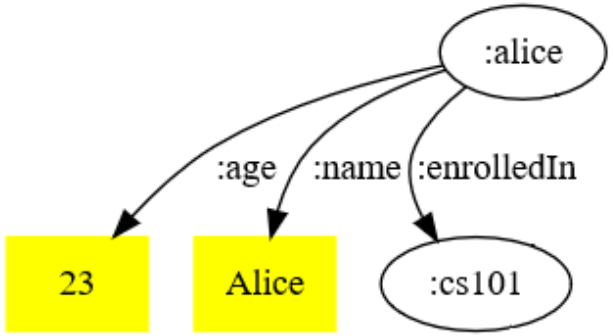
```
<http://example.com/alice> <http://schema.org/knows> <http://example.com/bob> .
```

RDF Graph

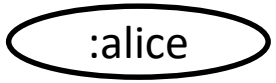


Basic statement = a simple triple

RDF Graph



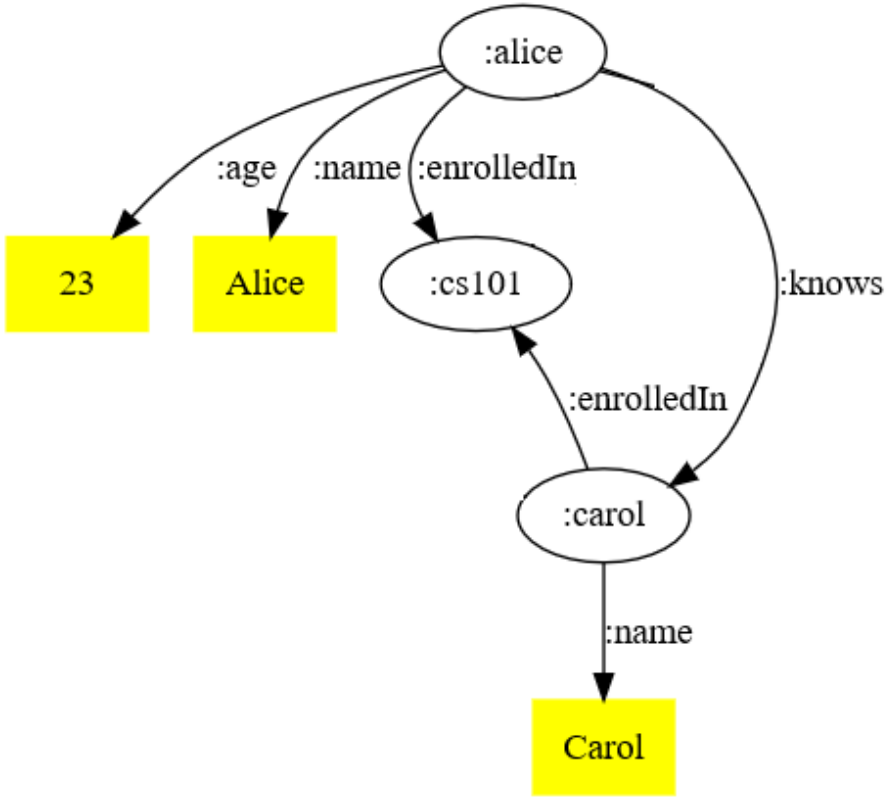
…we can add more statements



Circled nodes are IRIs

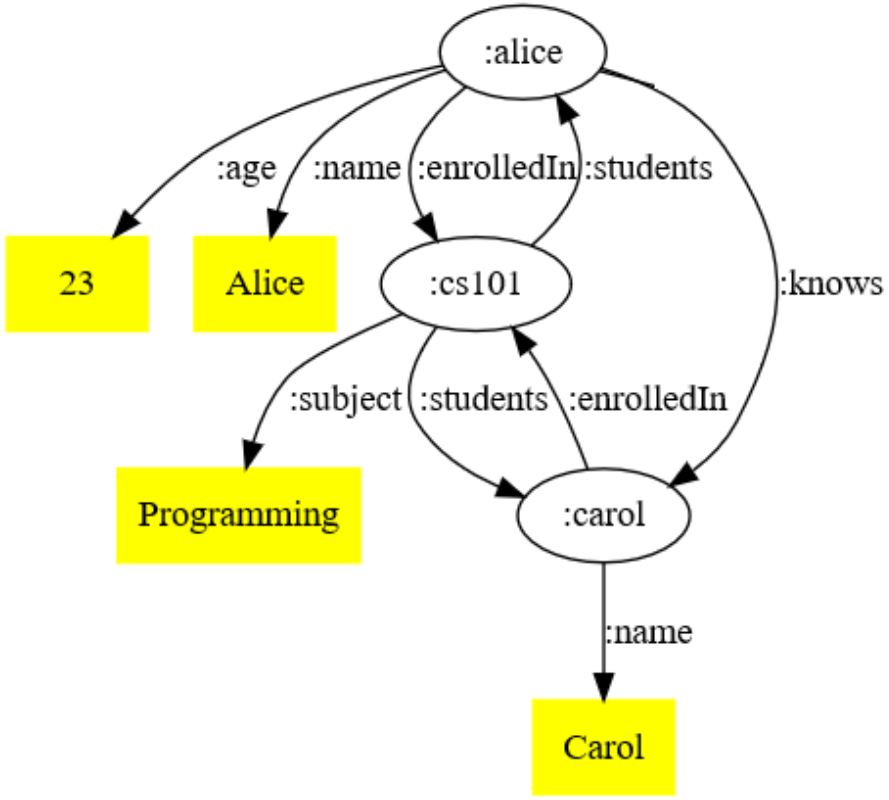
Yellow boxes are literals

RDF Graph



…more statements can be added…

RDF Graph

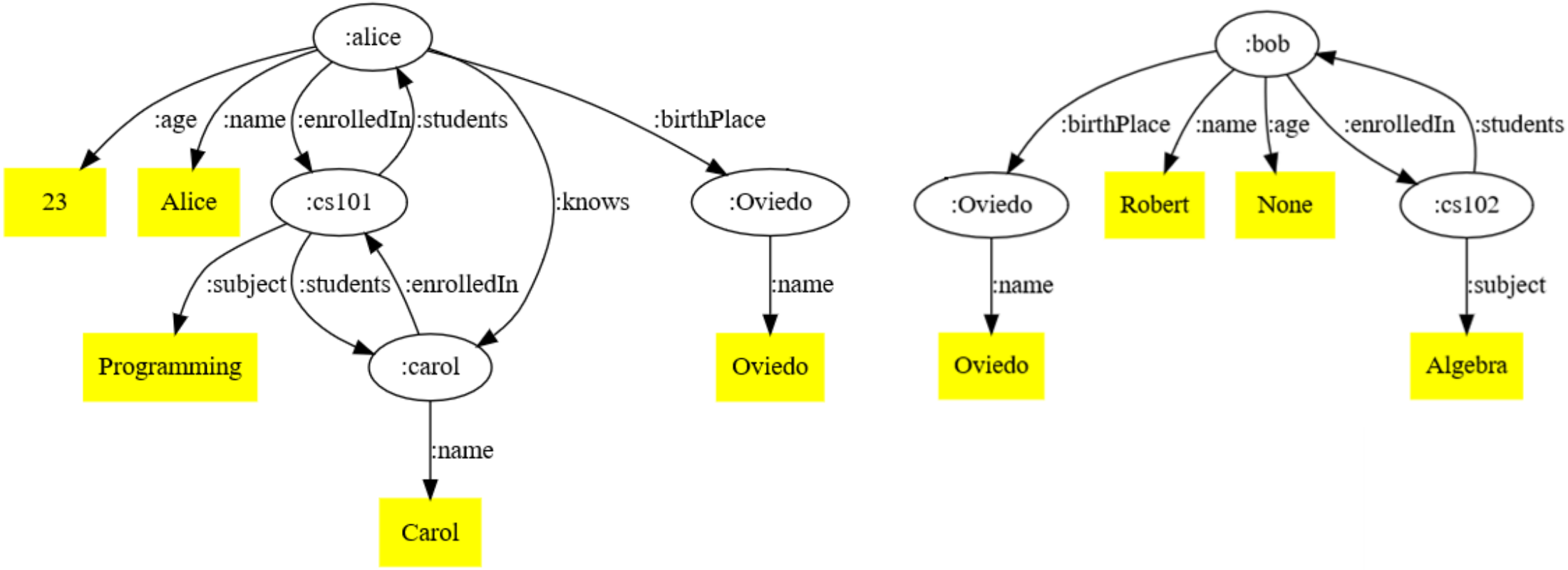


…and more…

Forming a graph

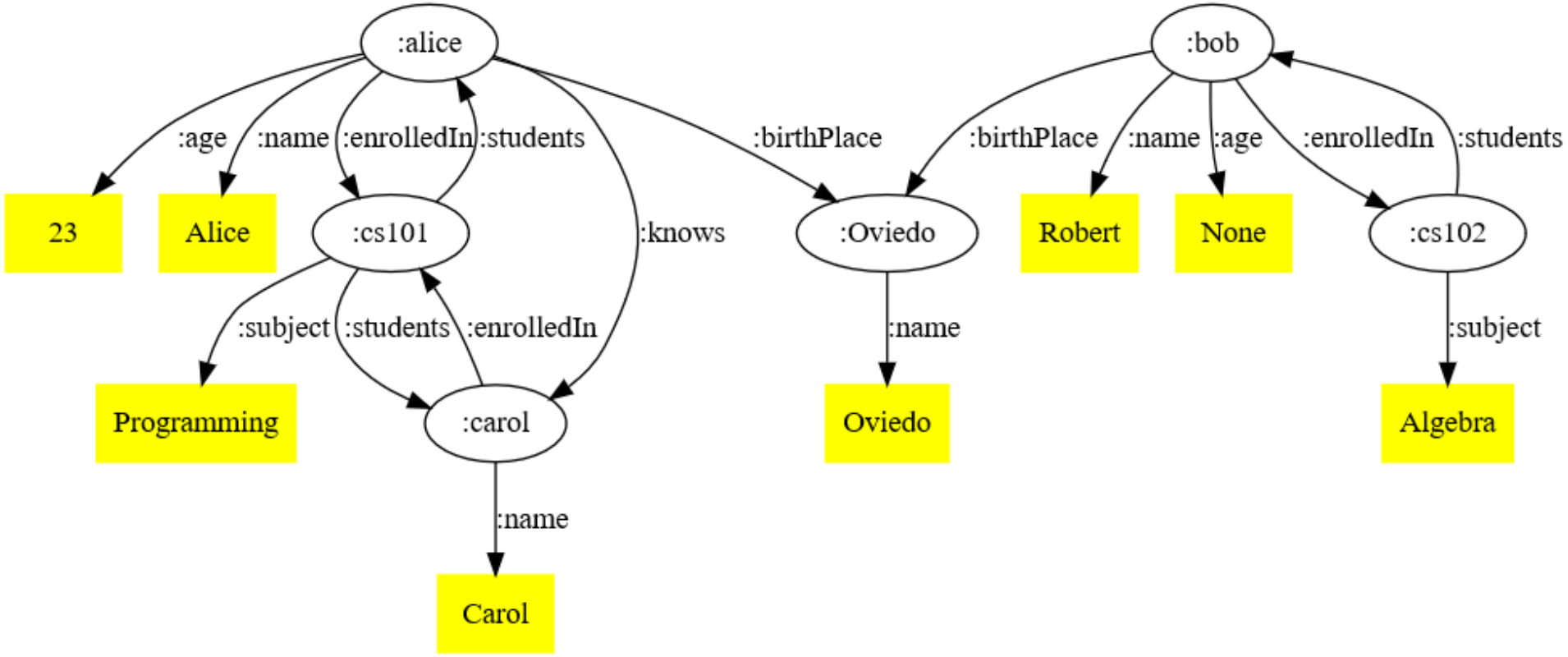
…which can contain cycles

RDF Graph



Graphs can be created independently

RDF Graph



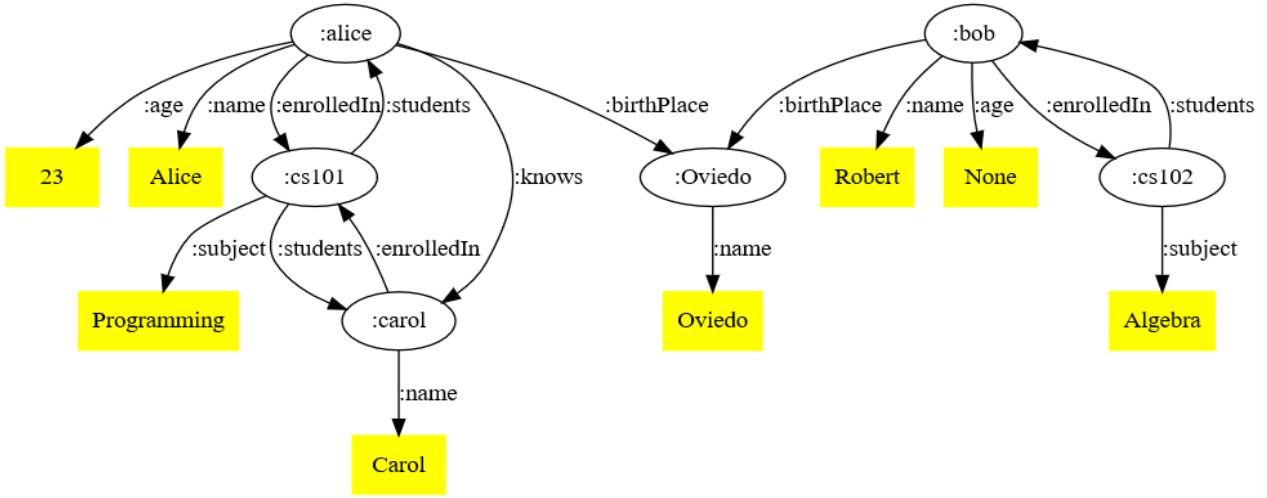
…and automatically merged

RDF helps information integration

RDF syntaxes

Several syntaxes:

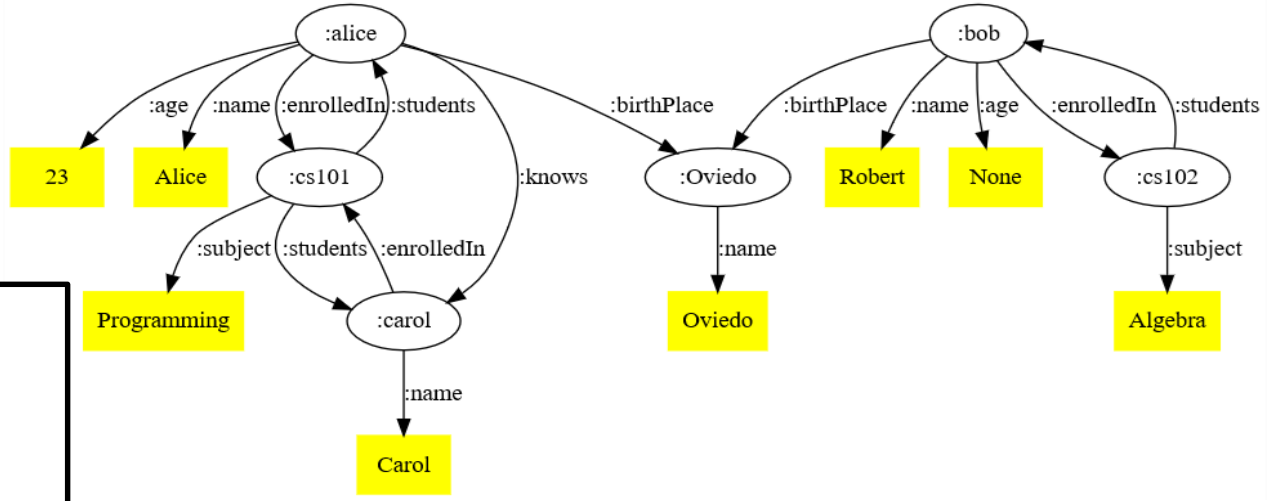
N-triples, Turtle, …




```
<http://example.org/alice> <http://example.org/name>       "Alice" .
<http://example.org/alice> <http://example.org/age>        "23"^^<http://www.w3.org/2001/XMLSchema#integer> .
<http://example.org/alice> <http://example.org/enrolledIn> <http://example.org/cs101> .
<http://example.org/alice> <http://example.org/knows>      <http://example.org/carol> .
<http://example.org/alice> <http://example.org/birthPlace> <http://example.org/Oviedo> .
<http://example.org/bob>   <http://example.org/name>       "Robert" .
<http://example.org/bob>   <http://example.org/age>        "None" .
<http://example.org/bob>   <http://example.org/birthPlace> <http://example.org/Oviedo> .
<http://example.org/bob>   <http://example.org/enrolledIn> <http://example.org/cs102> .
<http://example.org/carol> <http://example.org/name>       "Carol" .
<http://example.org/carol> <http://example.org/enrolledIn> <http://example.org/cs101> .
<http://example.org/cs101> <http://example.org/subject>    "Programming" .
<http://example.org/cs101> <http://example.org/students>   <http://example.org/alice> .
<http://example.org/cs101> <http://example.org/students>   <http://example.org/carol> .
<http://example.org/cs102> <http://example.org/subject>    "Algebra" .
<http://example.org/cs102> <http://example.org/students>   <http://example.org/bob> .
```

Turtle Syntax

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

:alice   :name          "Alice" ;
         :age           23 ;
         :enrolledIn    :cs101 ;
         :knows         :carol ;
         :birthPlace    :Oviedo .
:carol   :name          "Carol" ;
         :enrolledIn    :cs101 .
:cs101   :students      :alice , :carol ;
         :subject       "Programming" .
:bob     :name          "Robert" ;
         :age           "None" ;
         :enrolledIn    :cs102 ;
         :birthPlace    :Oviedo .
:cs102   :students      :bob ;
         :subject       "Algebra" .
```



Some simplifications

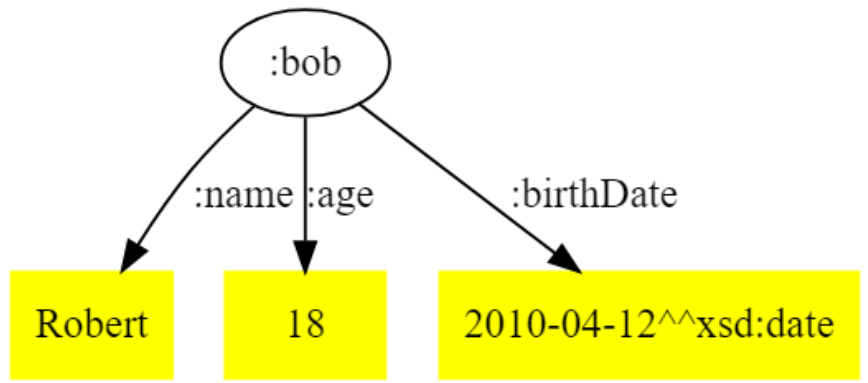
- prefix declarations
- ; when triples share the subject
- , when triples share subject and object

Try it: https://goo.gl/pK3Csh

Literals

Objects can also be literals

- Literals contain a lexical form and a datatype
- Common datatypes: XML Schema primitive datatypes
- If not specified, a literal has type xsd:string



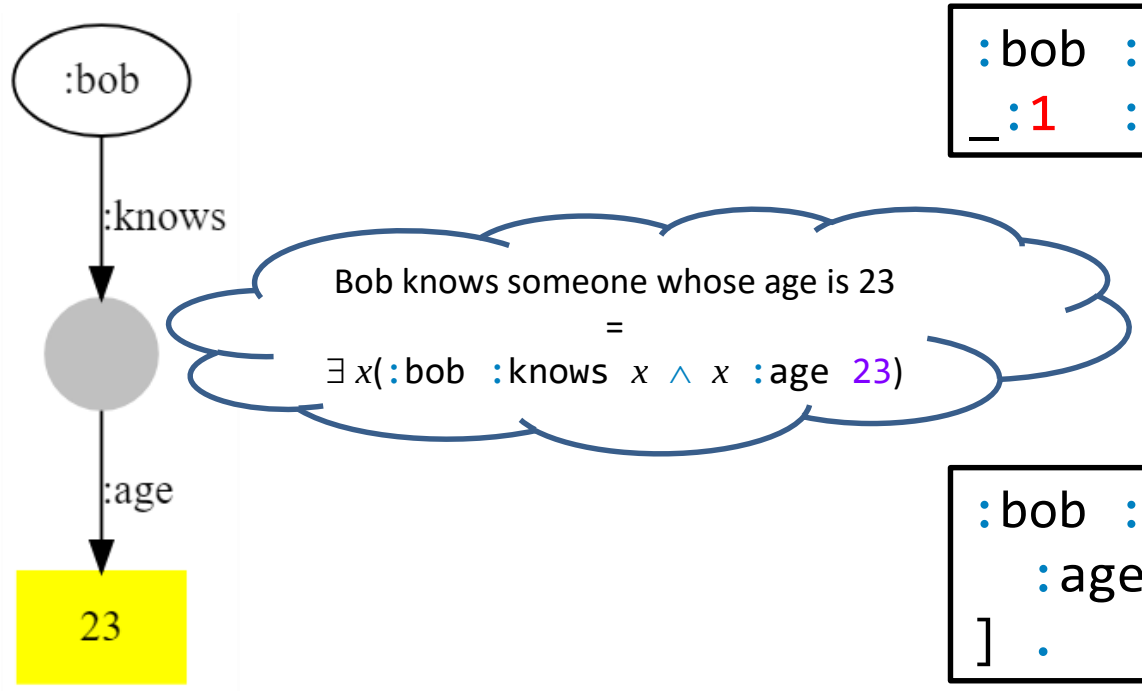

```
:bob    :name       "Robert"                 ;
        :age        18                       ;
        :birthDate  "2010-04-12"^^xsd:date   .
```

```
:bob    :name       "Robert"^^xsd:string     ;
        :age        "18"^^xsd:integer        ;
        :birthDate  "2010-04-12"^^xsd:date   .
```

Blank nodes

Subjects and objects can also be Blank nodes

Blank nodes can have local identifiers




```
:bob :knows _:1 .
_:1  :age 23 .
```

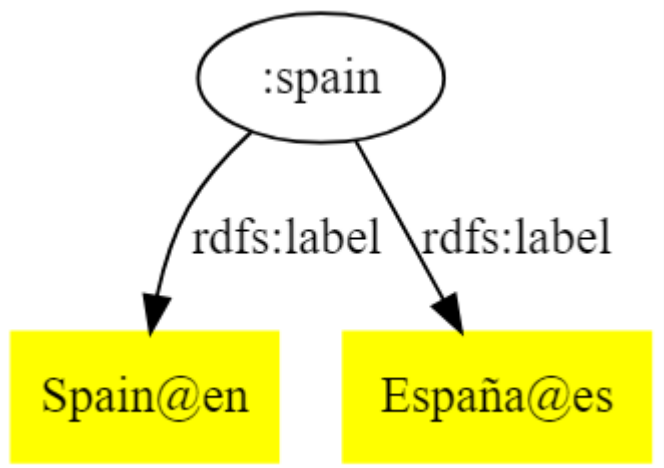
or

```
:bob :knows [
  :age 23
] .
```

Language tagged strings

String literals can be qualified by a language tag

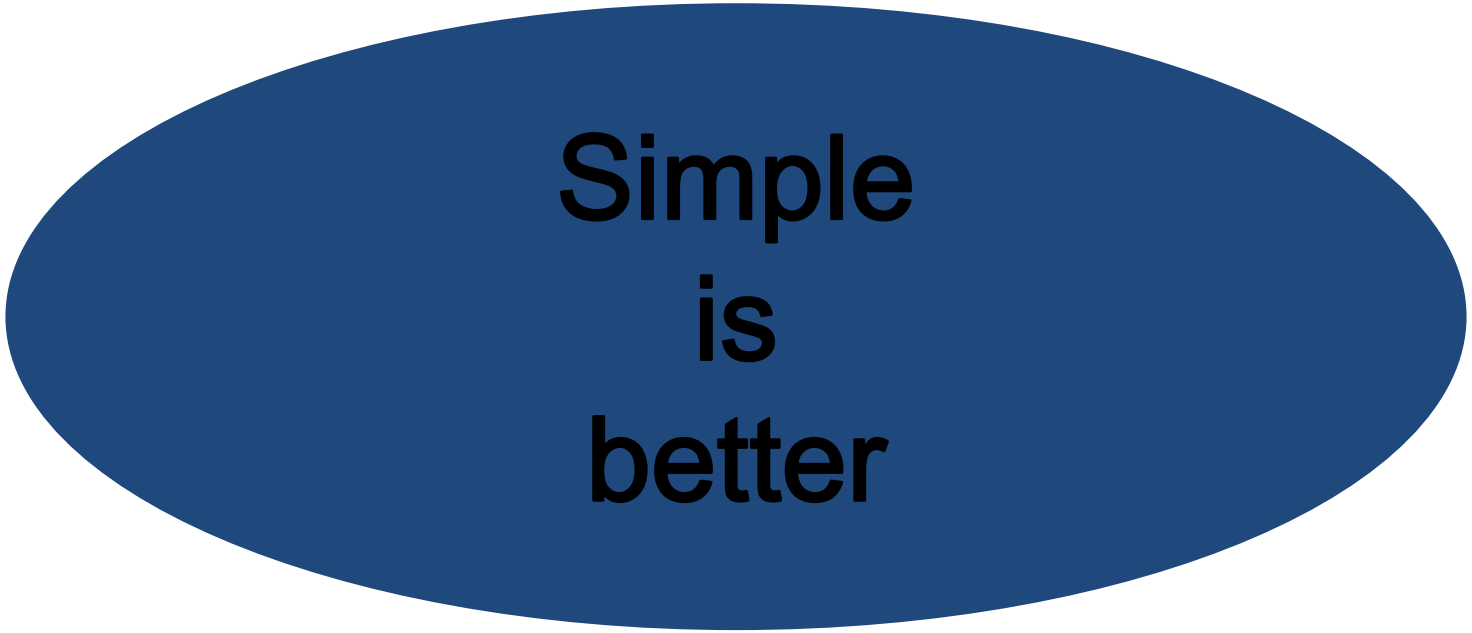
They have datatype `rdfs:langString`




```
:spain rdfs:label "Spain"@en ;
       rdfs:label "España"@es .
```

...and that's all?

Yes, the RDF Data model is simple



RDF, the good parts...

RDF as an integration language

RDF as a *lingua franca* for semantic web and linked data

RDF data stores & SPARQL

RDF flexibility & integration

- Data can be adapted to multiple environments
- Open and reusable data by default

RDF for knowledge representation

RDF, the other parts

Consuming & producing RDF

- Multiple serializations: Turtle, RDF/XML, JSON-LD, ...
- Embedding RDF in HTML
- Describing and validating RDF content

Why describe & validate RDF?

For producers

- Developers can understand the contents they are going to produce
- Ensure they produce the expected structure
- Advertise and document the structure
- Generate interfaces

For consumers

- Understand the contents
- Verify the structure before processing it
- Query generation & optimization

Similar technologies

Technology	Schema
Relational Databases	DDL
XML	DTD, XML Schema, RelaxNG, Schematron
Json	Json Schema
RDF	?

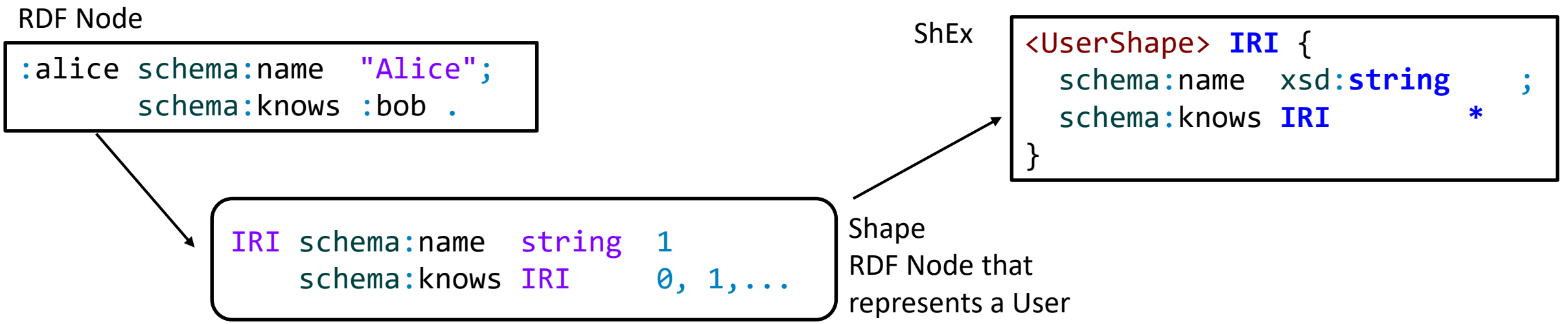
Fill that gap

Understanding the problem

RDF is composed by nodes and arcs between nodes

We can describe/check

- The form of the node itself (node constraint)
- The number of possible arcs incoming/outgoing from a node
- The possible values associated with those arcs



Understanding the problem

RDF is a flexible language

Complex objects & literals can be mixed

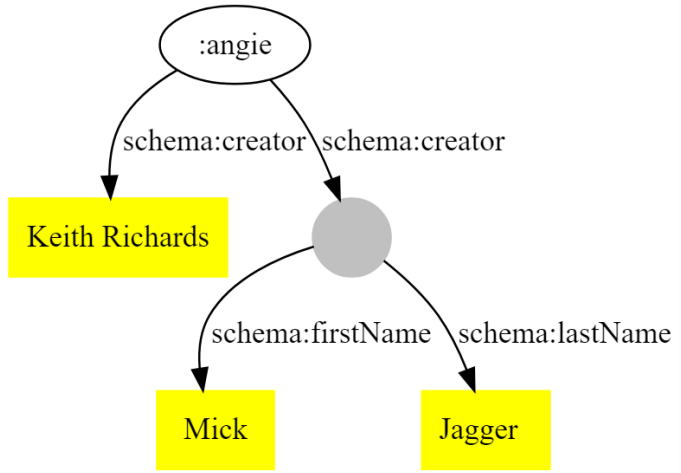
Example:

Values of `schema:creator` can be:

`string` or

`schema:Person`

```
:angie schema:creator "Keith Richards" ;
       schema:creator [
         schema:firstName "Mick" ;
         schema:lastName  "Jagger"
       ] .
```



Lots of examples at http://schema.org

Understanding the problem

Repeated properties

The same property can be used for different purposes in the same data

Example: A product must have 2 codes with different structure

```
:product schema:productID "isbn:123-456-789";
         schema:productID "code456" .
```

A practical example from FHIR

See: http://hl7-fhir.github.io/observation-example-bloodpressure.ttl.html

Understanding the problem

Shapes ≠ types

Nodes in RDF graphs can have 0, 1 or many `rdf:type` declarations

- A type can be used in multiple contexts, e.g. `foaf:Person`

Nodes are not necessarily annotated with discriminating types

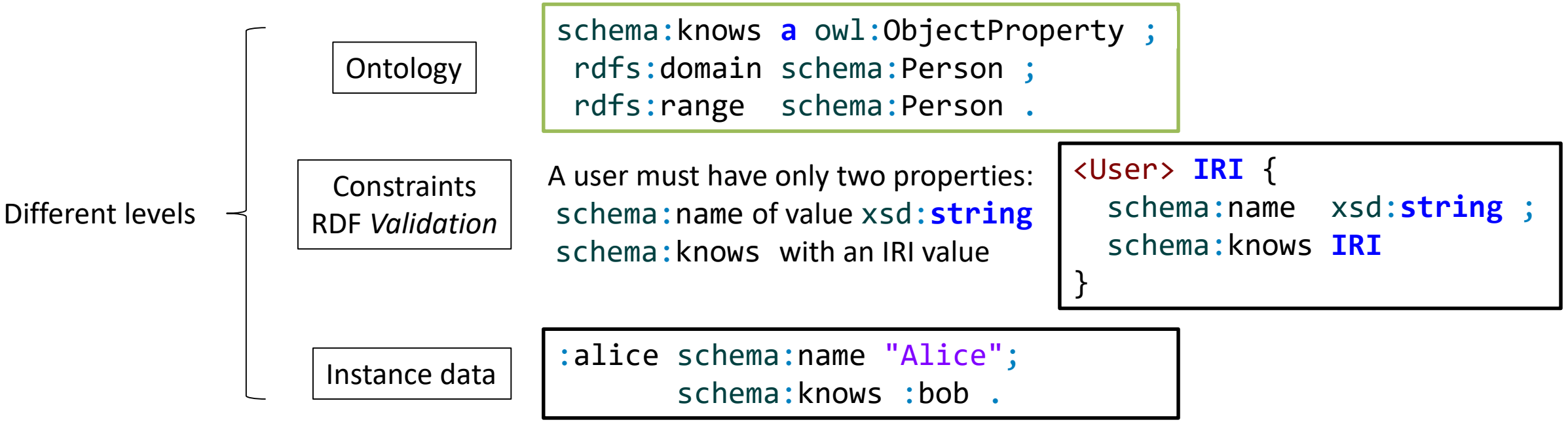
- Nodes with type `foaf:Person` can represent friends, students, patients,...
- Different meanings and different structure depending on context
- Specific validation constraints for different contexts

Understanding the problem

RDF validation ≠ ontology definition ≠ instance data

Ontologies are usually focused on domain entities

RDF validation is focused on RDF graph features (lower level)



Why not using SPARQL to validate?

Pros:

- Expressive
- Ubiquitous

Cons

- Expressive
- Idiomatic
  - many ways to encode the same constraint

Example: Define SPARQL query to check: There must be one `schema:name` which must be a `xsd:string`, and one `schema:gender` which must be `schema:Male` or `schema:Female`

```
ASK {{ SELECT ?Person {
        ?Person schema:name ?o .
      } GROUP BY ?Person HAVING (COUNT(*)=1)
   }
   { SELECT ?Person {
        ?Person schema:name ?o .
        FILTER ( isLiteral(?o) &&
                 datatype(?o) = xsd:string )
       } GROUP BY ?Person HAVING (COUNT(*)=1)
   }
   { SELECT ?Person (COUNT(*) AS ?c1) {
        ?Person schema:gender ?o .
      } GROUP BY ?Person HAVING (COUNT(*)=1)}
      { SELECT ?Person (COUNT(*) AS ?c2) {
        ?S schema:gender ?o .
        FILTER ((?o = schema:Female ||
                 ?o = schema:Male))
      } GROUP BY ?Person HAVING (COUNT(*)=1)}
      FILTER (?c1 = ?c2)
}
```

Previous/other approaches

SPIN, by TopQuadrant http://spinrdf.org/

SPARQL templates, Influenced SHACL

Stardog ICV: http://docs.stardog.com/icv/icv-specification.html

OWL with UNA and CWA

OSLC resource shapes: https://www.w3.org/Submission/shapes/

Vocabulary for RDF validation

Dublin Core Application profiles (K. Coyle, T. Baker)

http://dublincore.org/documents/dc-dsp/

RDF Data Descriptions (Fischer et al)

http://ceur-ws.org/Vol-1330/paper-33.pdf

RDFUnit (D. Kontokostas)

http://aksw.org/Projects/RDFUnit.html

...

ShEx and SHACL

2013 RDF Validation Workshop

- Conclusions of the workshop:
  - *There is a need of a higher level, concise language for RDF Validation*
- ShEx initially proposed (v 1.0)

2014 W3c Data Shapes WG chartered

2017 SHACL accepted as W3C recommendation

2017 ShEx 2.0 released as Community group draft

2018 ShEx 2.1 released

Short intro to ShEx

ShEx (Shape Expressions Language)

Concise and human-readable language for RDF validation & description

Syntax similar to SPARQL, Turtle

Semantics inspired by regular expressions & RelaxNG

2 syntaxes: Compact and RDF/JSON-LD

Official info: http://shex.io

Semantics: http://shex.io/shex-semantics/, primer: http://shex.io/shex-primer

ShEx implementations and playgrounds

Libraries:

- shex.js: Javascript
- SHaclEX: Scala (Jena/RDF4j)
- PyShEx: Python
- shex-java: Java
- Ruby-ShEx: Ruby

Online demos & playgrounds

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

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>✗
```

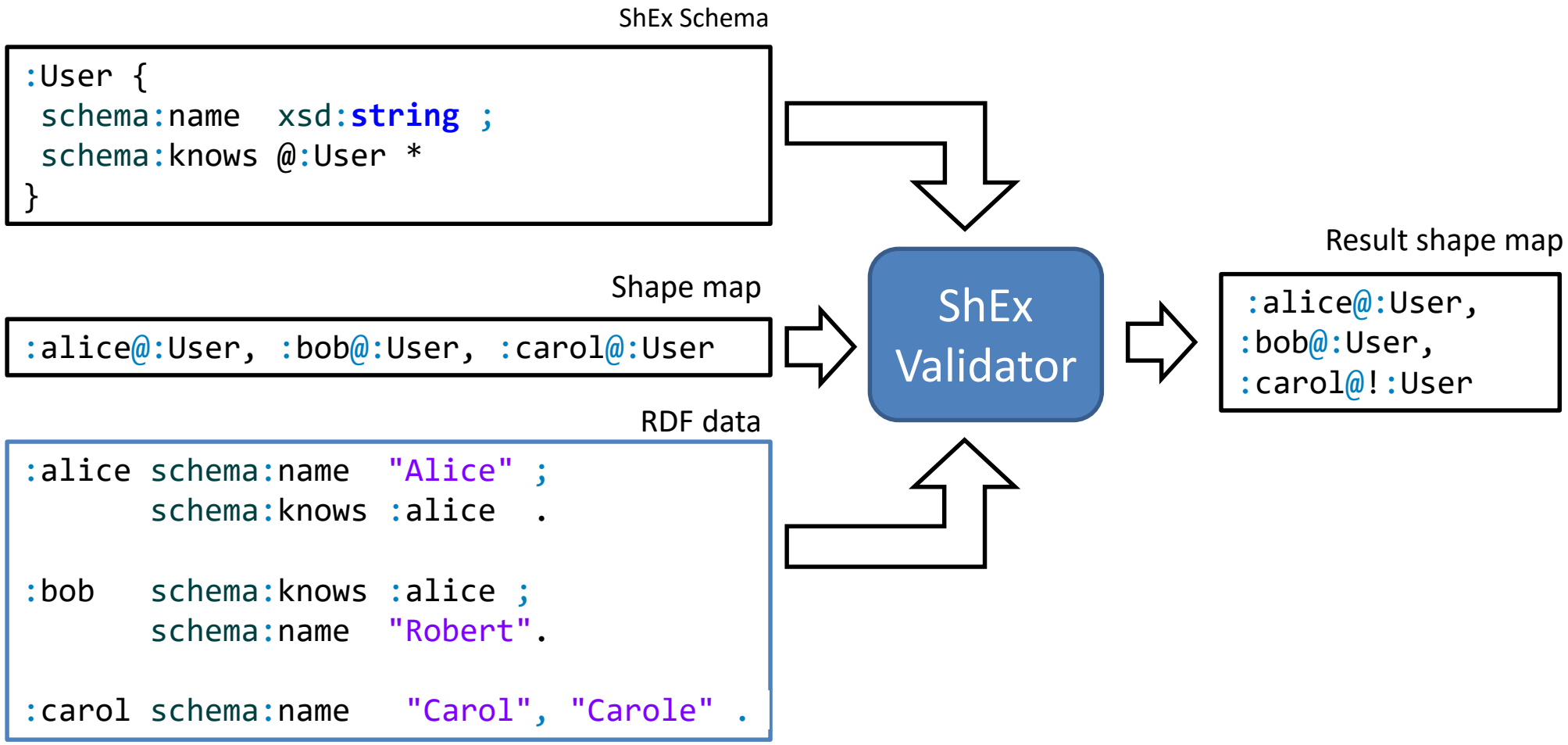
Try it (RDFShape): https://goo.gl/97bYdv
Try it (ShExDemo):https://goo.gl/Y8hBsW

```
: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

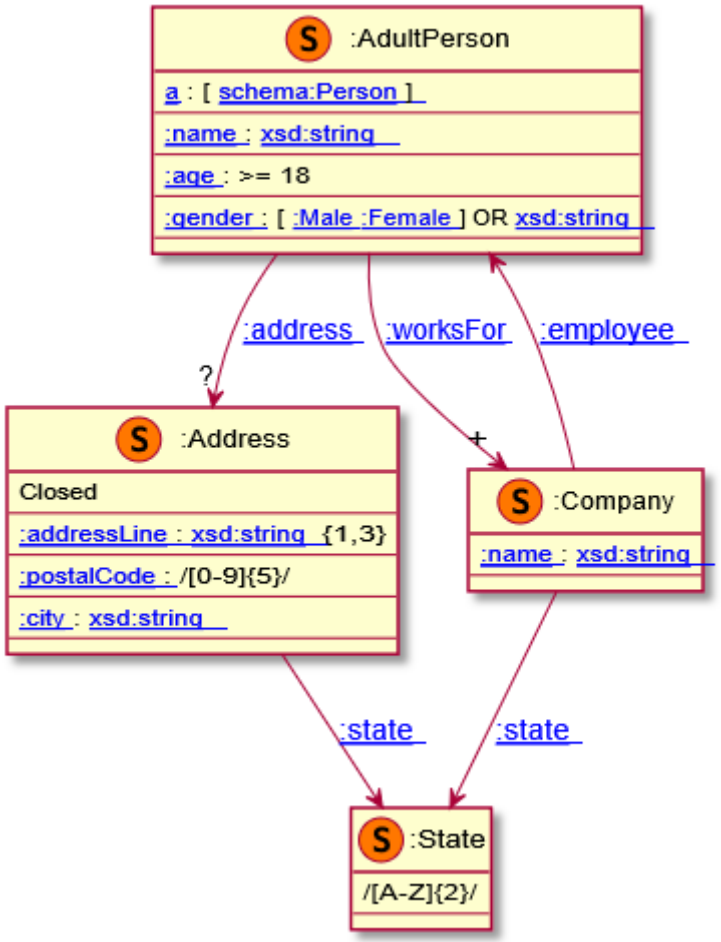
Output: Result shape map



Example with more ShEx features

```
:AdultPerson EXTRA a {
 a           [ 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  a :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

More info about ShEx

See:

ShEx by Example (slides):

https://figshare.com/articles/ShExByExample_pptx/6291464

ShEx chapter from Validating RDF data book:

http://book.validatingrdf.com/bookHtml010.html

Short intro to SHACL

W3C recommendation:

https://www.w3.org/TR/shacl/ (July 2017)

RDF vocabulary

2 parts: SHACL-Core, SHACL-SPARQL

SHACL implementations

Name	Parts	Language - Library	Comments
Topbraid SHACL API	SHACL Core, SPARQL	Java (Jena)	Used by TopBraid composer
SHACL playground	SHACL Core	Javascript (rdflib.js)	http://shacl.org/playground/
SHACLEX	SHACL Core	Scala (Jena, RDF4j)	http://rdfshape.weso.es
pySHACL	SHACL Core, SPARQL	Python (rdflib)	https://github.com/RDFLib/pySHACL
Corese SHACL	SHACL Core, SPARQL	Java (STTL)	http://wimmics.inria.fr/corese
RDFUnit	SHACL Core, SPARQL	Java (Jena)	https://github.com/AKSW/RDFUnit

Basic example

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

:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property :hasName,
               :hasEmail .
:hasName sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string .
:hasEmail sh:path schema:email ;
   sh:minCount 1;
   sh:maxCount 1;
   sh:nodeKind sh:IRI .
```

Shapes graph

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

:bob   schema:firstName "Bob" ;
       schema:email <mailto:bob@mail.org> .

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

☹ ☹

Data graph

Try it. RDFShape https://goo.gl/T1uuzv

Same example with blank nodes

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

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

Shapes graph

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

:bob   schema:firstName "Bob" ;
       schema:email <mailto:bob@mail.org> .

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

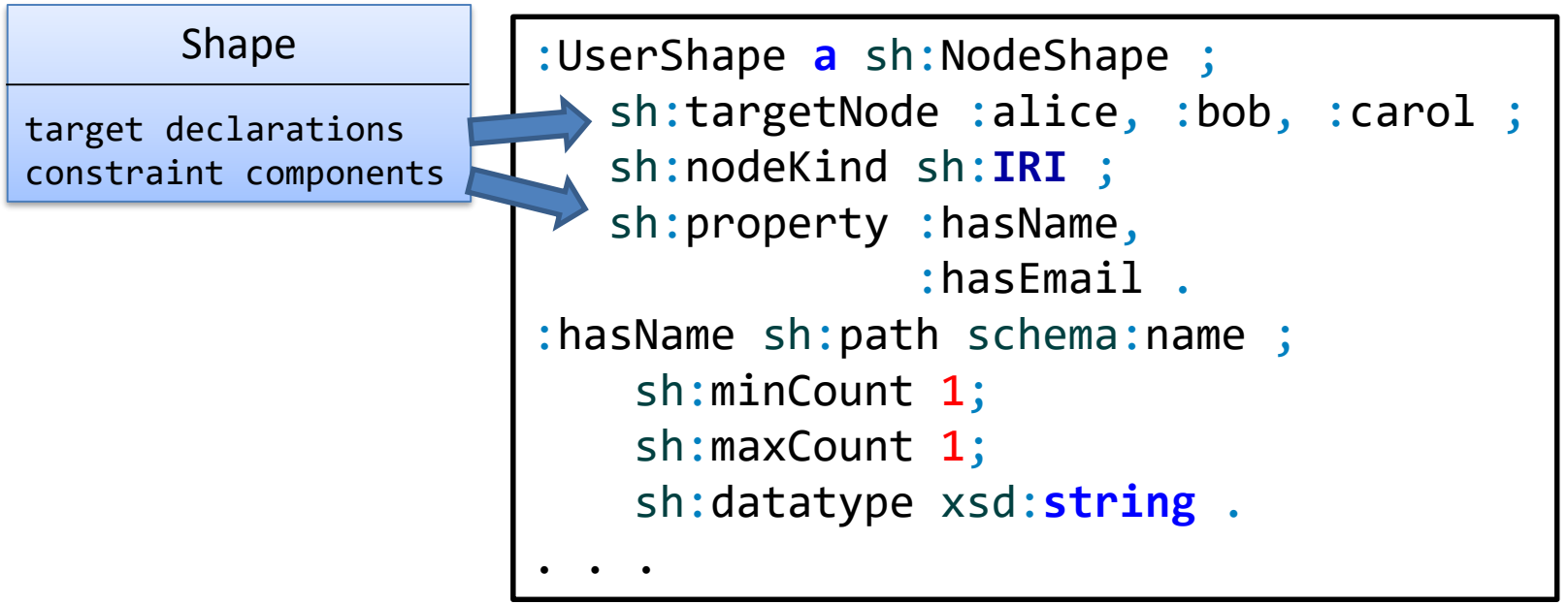
Data graph

Try it. RDFShape https://goo.gl/ukY5vq

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



Validation Report

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

No errors ⇒ RDF conforms to shapes graph

```
[ a              sh:ValidationReport ;
  sh:conforms    true
].
```

```
[ a              sh:ValidationReport ;
  sh:conforms    false ;
  sh:result      [
   a               sh:ValidationResult ;
   sh:focusNode    :bob ;
   sh:message
     "MinCount violation. Expected 1, obtained: 0" ;
   sh:resultPath schema:name ;
   sh:resultSeverity sh:Violation ;
   sh:sourceConstraintComponent
     sh:MinCountConstraintComponent ;
   sh:sourceShape  :hasName
] ;
...
```

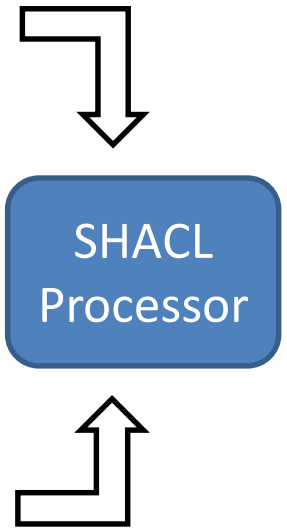
SHACL processor

Shapes graph

```
:UserShape a sh:NodeShape ;
   sh:targetNode :alice, :bob, :carol ;
   sh:nodeKind sh:IRI ;
   sh:property :hasName,
               :hasEmail .
:hasName sh:path schema:name ;
    sh:minCount 1;
    sh:maxCount 1;
    sh:datatype xsd:string .
. . .
```

Data Graph

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

:bob   schema:name "Bob" ;
       schema:email <mailto:bob@mail.org> .

:carol schema:name "Carol" ;
       schema:email <mailto:carol@mail.org> .
```



Validation report

```
[ a              sh:ValidationReport ;
  sh:conforms    true
].
```

Target declarations

Targets specify nodes that must be validated against the shape

Several types

Value	Description
`targetNode`	Directly point to a node
`targetClass`	All nodes that have a given type
`targetSubjectsOf`	All nodes that are subjects of some predicate
`targetObjectsOf`	All nodes that are objects of some predicate

Target node

Directly declare which nodes must validate the against the shape

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

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

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

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

Target class

Selects all nodes that have a given class

Looks for `rdfs:subClassOf*/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" .
```

Implicit class target

A shape with type sh:Shape and rdfs:Class is a target 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 ;
  ] .
```

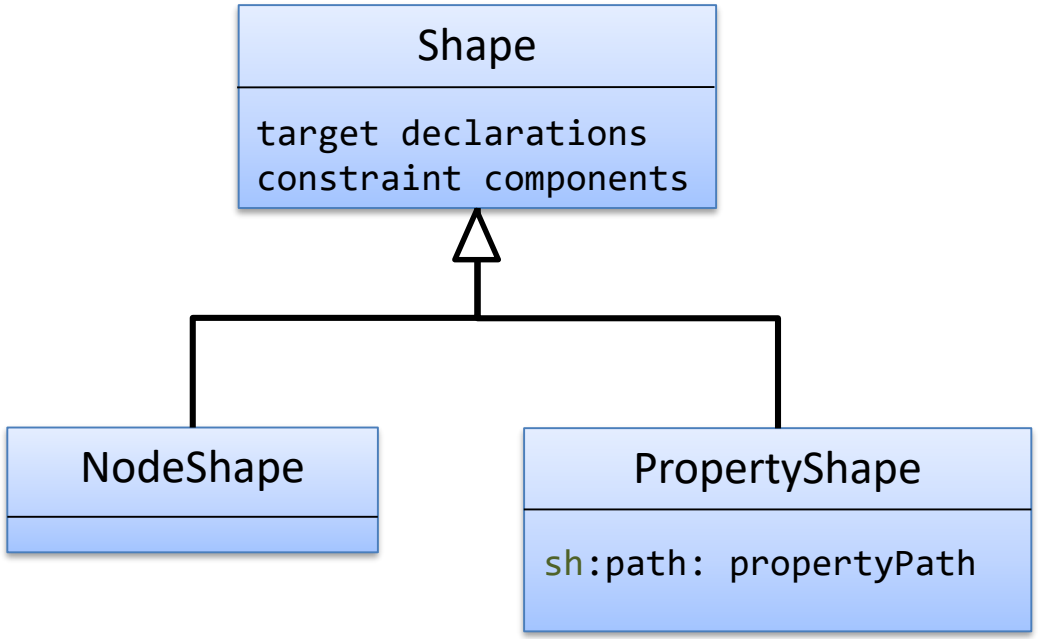
```
:alice a :User;
       schema:name "Alice Cooper" ;
       schema:email <mailto:alice@mail.org> .

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

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

Node and property shapes

2 types of shapes:

NodeShape: constraints about shapes of nodes

PropertyShapes: constraints on property path values of a node



NodeShape

PropertyShape

```
:UserShape a sh:NodeShape ;
    sh:targetNode :alice, :bob, :carol ;
    sh:nodeKind sh:IRI ;
    sh:property :hasName,
                :hasEmail .
:hasName sh:path schema:name ;
     sh:minCount 1;
     sh:maxCount 1;
     sh:datatype xsd:string .
. . .
```

Paths in property shapes

Subset of SPARQL property paths using the following predicates:

- `inversePath`
- `alternativePath`
- `zeroOrMorePath`
- `oneOrMorePath`
- `zeroOrOnePath`

```
:User a sh:NodeShape, rdfs:Class ;
   sh:property [
    sh:path [sh:inversePath schema:follows ];
    sh:nodeKind sh:IRI ;
  ] .
```

```
:alice a :User;
       schema:follows :bob .

:bob   a :User .

:carol a :User;
       schema:follows :alice .

_:1 schema:follows :bob .
```

SHACL Core built-in constraint components

Type	Constraints
Cardinality	`minCount, maxCount`
Types of values	`class, datatype, nodeKind`
Values	`node, in, hasValue, property`
Range of values	`minInclusive, maxInclusive` `minExclusive, maxExclusive`
String based	`minLength, maxLength, pattern`
Language based	`languageIn, uniqueLang`
Logical constraints	`not, and, or, xone`
Closed shapes	`closed, ignoredProperties`
Property pair constraints	`equals, disjoint, lessThan, lessThanOrEquals`
Non-validating constraints	`name, description, order, group`
Qualified shapes	`qualifiedValueShape, qualifiedValueShapesDisjoint` `qualifiedMinCount, qualifiedMaxCount`

Example w

In ShEx

```
:AdultPerson EXTRA a {
 a          [ 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}/
```

In SHACL

```
:AdultPerson a sh:NodeShape ;
 sh:property [
  sh:path rdf:type ;
  sh:qualifiedValueShape [
     sh:hasValue schema:Person
  ];
  sh:quali
  sh:quali
 ] ;
sh:targetN
  sh:prope
   sh:minC
   sh:data
 ] ;
 sh:proper
  sh:minCo
  sh:in (
 ] ;
 sh:proper
  sh:maxCo
  sh:minIn
 ] ;
sh:propert
  sh:node
  sh:minCount 1 ; sh
 ] ;
 sh:property [ sh:path :worksFor ;
   sh:node :Company ;
   sh:minCount 1 ; sh:maxCount
 ].
```

```
:Address a sh:NodeShape ;
 sh:closed true ;
 sh:property [ sh:path :addressLine;
   sh:datatype xsd:string ;
   sh:min
 ] ;
 sh:prope
   sh:pat
   sh:min
 ] ;
 sh:prope
   sh:dat
   sh:min
 ] ;
 sh:prope
   sh:nod
 ] .
```

```
:Company a sh:NodeShape ;
 sh:property [ sh:path :name ;
   sh:datatype xsd:string
   ] ;
 sh:property [
   sh:path :state ;
   sh:node :State
 ] ;
 sh:property [ sh:path :employee ;
   sh:node :AdultPerson ;
 ] ;.

:State a sh:NodeShape ;
   sh:pattern "[A-Z]{2}" .
```

Its recursive!!! (not well defined SHACL)
Implementation dependent feature

Try it: https://tinyurl.com/ycl3mkzr

More info about SHACL

SHACL by example (slides):

https://figshare.com/articles/SHACL_by_example/6449645

SHACL chapter at Validating RDF data book

http://book.validatingrdf.com/bookHtml011.html

ShEx and SHACL compared

Several common features…

Similar goal: describe and validate RDF graphs

Both employ the word "shape"

Node constraints similar in both languages

Constraints on incoming/outgoing arcs

Both allow to define cardinalities

Both have RDF syntax

Both have an extension mechanism

But some differences…

Underlying philosophy

Syntactic differences

Notion of a shape

Syntactic differences

Default cardinalities

Shapes and Classes

Recursion

Repeated properties

Property pair constraints

Uniqueness

Extension mechanism

Underlying philosophy

ShEx is more schema based

Shapes schemas look like grammars

Focus on description & validation results

- Result shape maps
- Info about conforming and non-conforming nodes

SHACL is more constraint based

Shapes ≈ collections of constraints

Main focus: validation errors

No info about conforming nodes

- How to difficult to distinguish between conforming nodes and nodes that have been ignored?
- RDFShape offers info about conforming node also

Semantic specification

ShEx semantics: mathematical concepts

Well-founded semantics*

- Recursion and negation using stratification
- Inspired by type systems and RelaxNG

*Semantics and Validation of Shapes Schemas for RDF
Iovka Boneva Jose Emilio Labra Gayo Eric Prud'hommeaux
ISWC'17

SHACL semantics = textual description + SPARQL

SHACL terms described in natural language

- SPARQL fragments used as helpers
- Recursion is implementation dependent

SHACL-SPARQL based on pre-binding

Syntactic differences

ShEx design focused on human-readability

Programming language design methodology

1. Abstract syntax
2. Different concrete syntaxes
   - Compact
   - JSON-LD
   - RDF
   - …

SHACL design focused on RDF vocabulary

Design centered on RDF terms

Lots of rules to define valid shapes graphs

https://w3c.github.io/data-shapes/shacl/#syntax-rules

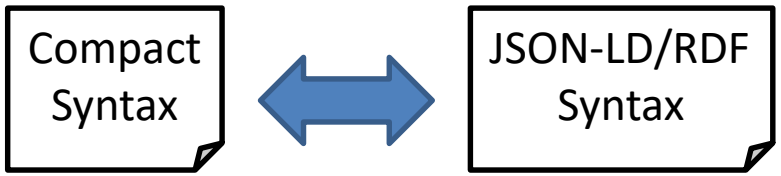
No compact syntax

Compact Syntax

ShEx compact syntax designed along the language

Test-suite with long list of tests

Round-trippable with JSON-LD syntax



SHACL has no compact syntax

A WG Note proposed a compact syntax

- It covered a subset of SHACL core
- No longer supported and no implementations

RDF vocabulary

ShEx vocabulary ≈ abstract syntax

ShEx RDF vocabulary obtained from the abstract syntax

- ShEx RDF serializations typically more verbose
- Can be round-tripped to Compact syntax

```
:User a sx:Shape;
  sx:expression [ a sx:EachOf ;
     sx:expressions (
       [ a sx:TripleConstraint ;
         sx:predicate schema:name ;
         sx:valueExpr [ a sx:NodeConstraint ;
                        sx:datatype xsd:string ]
       ]
       [ a sx:TripleConstraint ;
         sx:predicate schema:birthDate ;
         sx:valueExpr [ a sx:NodeConstraint ;
                        sx:datatype xsd:date ] ;
                        sx:min 0
                      ] )
  ].
```

SHACL is designed as an RDF vocabulary

Some rdf:type declarations can be omitted

- SHACL RDF serialization typically more readable

```
:User a sh:NodeShape ;
  sh:property [ sh:path schema:name ;
   sh:minCount 1; sh:maxCount 1;
   sh:datatype xsd:string
  ];
  sh:property [ sh:path schema:birthDate ;
   sh:maxCount 1;
   sh:datatype xsd:date
  ] .
```

Notion of Shape

In ShEx, shapes only define structure of nodes

Validation triggering by shape maps

- Select nodes/shapes to validate
- Goal: flexibility and reusability

Shape

```
:User IRI {
 schema:name xsd:string
}
```

Shape map

```
:alice@:User,
{FOCUS rdf:type :Person}@:User
```

In SHACL, shapes define structure and can have target declarations

Shapes can be associated with nodes or sets of nodes through target declarations

Shapes may be less reusable in other contexts

Shape

```
:User a sh:NodeShape, rdfs:Class ;
  sh:targetClass :Person ;
  sh:targetNode  :alice ;
  sh:nodeKind    sh:IRI ;
  sh:property [
   sh:path     schema:name ;
   sh:datatype xsd:string
  ] .
```

target declarations

structure

Default cardinalities

ShEx: default = (1,1)

```
:User {
 schema:givenName xsd:string
 schema:lastName  xsd:string
}
```

SHACL: default = (0,unbounded)

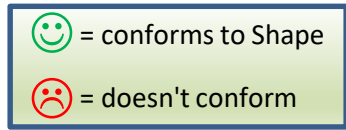
```
:User a sh:NodeShape ;
 sh:property [ sh:path schema:givenName ;
  sh:datatype xsd:string ;
 ];
 sh:property [ sh:path schema:lastName ;
  sh:datatype xsd:string ;
 ] .
```

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

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

```
:carol schema:lastName  "King" .
```

```
:dave  schema:givenName 23;
       schema:lastName  :Unknown .
```



Property paths

ShEx shapes describe neighborhood of focus nodes: direct/inverse properties

Examples with paths can be emulated using nested shapes

```
:GrandSon {
 :parent { :parent . + } + ;
 (:father . | :mother .) + ;
^:knows :Person
}
```

SHACL shapes can also describe whole property paths following property paths

```
:GrandSon a sh:NodeShape ;
  sh:property [
   sh:path (schema:parent schema:parent) ;
   sh:minCount 1
  ];
  sh:property [
   sh:path [
    sh:alternativePath (:father :mother) ]
  ];
  sh:minCount 1
 ] ;
 sh:property [
   sh:path [sh:inversePath :knows ] ]
   sh:node :Person ;
   sh:minCount 1
 ]
.
```

Property paths

ShEx shapes describe neighborhood of focus nodes: direct/inverse properties

Recursion paths can be emulated with auxiliary shapes

```
:GrandParent {
 schema:knows @:PersonKnown*;
}
:PersonKnown @:Person {
schema:knows @:PersonKnown*
}

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

SHACL shapes can use property paths

```
:GrandParent a sh:NodeShape ;
 sh:property [
  sh:path [ sh:zeroOrMorePath schema:knows] ;
  sh:node :Person ;
 ] .


:Person a sh:NodeShape ;
 sh:property [
  sh:path schema:name ;
   sh:datatype xsd:string ;
   sh:minCount 1; sh:maxCount 1
  ] .
```

Property paths

ShEx shapes describe neighborhood of focus nodes: direct/inverse properties

Control about cardinalities

```
:Invoice {
 :payment {
   :amount xsd:decimal
 }
}
```

SHACL shapes can use property paths

Some pathological cases

```
:Invoice a sh:NodeShape ;
 sh:property [
  sh:path (:payment :amount ) ;
  sh:datatype xsd:decimal ;
  sh:minCount 1; sh:maxCount 1
] .
```

☺ ☺

```
:i1 :payment  [ :amount  3.0 ] .
```

☹

```
:i2 :payment  [ :amount  3.0 ] ;
    :payment  [ :amount  2.0 ] .
```

☹ ☺ ?

```
:i3 :payment  [ :amount  2.0 ] ;
    :payment  [ :amount  2.0 ] .
```

Try it: https://tinyurl.com/y97npq5s

Try it: https://tinyurl.com/yabl4v95

Inference

ShEx doesn't mess with inference

Validation can be invoked before or after inference

rdf:type is considered an arc as any other

- No special meaning
- The same for rdfs:Class, rdfs:subClassOf, rdfs:domain, rdfs:range, ...

SHACL: Some constructs have special meaning

The following constructs have special meaning in SHACL

- rdf:type
- rdfs:Class
- rdfs:subClassOf
- owl:imports

Other constructs like rdfs:domain, rdfs:range,... have no special meaning

sh:entailment can be used to indicate that some inference is required

Inference and triggering mechanism

ShEx has no interaction with inference

It can be used to validate a reasoner

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

In SHACL, RDF Schema inference can affect which nodes are validated

Partial implicit RDFS inference but not all

```
:User a sh:NodeShape, rdfs:Class ;
 sh:property [ sh:path schema:name ;
   sh:datatype xsd:string;
].
```

```
:Teacher rdfs:subClassOf :User .
:teaches rdfs:domain :Teacher .

:alice a :Teacher ;
       schema:name 23 .

:bob   :teaches :Algebra ;
       schema:name 34 .

:carol :teaches :Logic;
       schema:name "King" .
```

With or without RDFS inference	No RDFS inference	RDFS inference
☹	☹	☹
☹	Ignored	☹
☺	Ignored	☺

☺ = conforms to Shape

☹ = doesn't conform

Repeated properties

ShEx (;) operator handles repeated properties

```
:Person {
 :parent {:gender [:Male   ] } ;
 :parent {:gender [:Female ] }
}
```

SHACL needs qualifiedValueShapes for repeated properties

Example. A person must have 2 parents, one male and another female

Direct approximation (wrong):

```
:Person a sh:NodeShape;
  sh:property [ sh:path :parent;
    sh:node [ sh:property [ sh:path :gender ;
     sh:hasValue :Male ; ]] ;
  ];
  sh:property [ sh:path :parent;
    sh:node [ sh:property [ sh:path :gender ;
     sh:hasValue :Female ]];
  ]
.
```

This says that a person must have a parent which is at the same time male and female

Repeated properties

ShEx (;) operator handles repeated properties

SHACL needs qualifiedValueShapes for repeated properties

Example. A person must have 2 parents, one male and another female

```
:Person {
 :parent {:gender [:Male ] } ;
 :parent {:gender [:Female ] }
}
```

Solution with qualifiedValueShapes:

```
:Person a sh:NodeShape, rdfs:Class ;
 sh:property [ sh:path :parent;
  sh:qualifiedValueShape [ sh:property [ sh:path :gender ;
  sh:hasValue :Male ] ] ;
  sh:qualifiedMinCount 1; sh:qualifiedMaxCount 1
 ];
 sh:property [ sh:path :parent;
  sh:qualifiedValueShape [ sh:property [ sh:path :gender ;
   sh:hasValue :Female ] ] ;
   sh:qualifiedMinCount 1; sh:qualifiedMaxCount 1
 ] ;
 sh:property [ sh:path :parent;
   sh:minCount 2; sh:maxCount 2
 ]
.
```

It needs to count all possibilities

Recursion

ShEx handles recursion

Well founded semantics

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

Recursive shapes are undefined in SHACL*

Implementation dependent

Direct translation generates recursive shapes

```
:Person a sh:NodeShape ;
 sh:property [ sh:path schema:name ;
  sh:datatype xsd:string
 ];
 sh:property [ sh:path schema:knows ;
  sh:node :Person
 ]
.
```

Undefined because it is recursive

*Semantics and Validation of Recursive SHACL
Julien Corman, Juan L. Reutter and Ognjen Savkovic, ISWC'18

Recursion (with target declarations)

ShEx handles recursion

Well founded semantics

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

Recursive shapes are undefined in SHACL

Implementation dependent

Can be simulated with target declarations

- Example with target declatations
- It needs discriminating arcs

```
:Person a sh:NodeShape, rdfs:Class ;
 sh:property [ sh:path schema:name ;
  sh:datatype xsd:string
 ];
 sh:property [ sh:path schema:knows ;
  sh:class :Person
 ]
.
```

It requires all nodes to have `rdf:type Person`

Recursion (with property paths)

ShEx handles recursion

Well founded semantics

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

Recursive shapes are undefined in SHACL

Implementation dependent

Can be simulated property paths

```
:Person a sh:NodeShape ;
 sh:property [
  sh:path schema:name ; sh:datatype xsd:string ];
 sh:property [
  sh:path [sh:zeroOrMorePath schema:knows];
  sh:node :PersonAux
 ].

:PersonAux a sh:NodeShape ;
 sh:property [
  sh:path schema:name ; sh:datatype xsd:string
 ].
```

Closed shapes

In ShEx, CLOSED affects all properties

```
:Person CLOSED {
  schema:name xsd:string
| foaf:name  xsd:string
}
```

In SHACL, sh:closed only affects properties declared at top-level

Properties declared inside other shapes are ignored

```
:Person a sh:NodeShape ;
  sh:targetNode :alice ;
  sh:closed true ;
  sh:or (
   [ sh:path schema:name ; sh:datatype xsd:string ]
   [ sh:path foaf:name ; sh:datatype xsd:string ]
  ) .
```

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

 = conforms to Shape

 = doesn't conform

Closed shapes and paths

Closed in ShEx acts on all properties

```
:Person CLOSED {
   schema:name xsd:string |
   foaf:name xsd:string
}
```

In SHACL, closed ignores properties mentioned inside paths

```
:Person a sh:NodeShape ;
  sh:closed true ;
  sh:property [
    sh:path [
     sh:alternativePath
       ( schema:name foaf:name )
    ] ;
    sh:minCount 1; sh:maxCount 1;
    sh:datatype xsd:string ] ;
.
```

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

 = conforms to Shape

 = doesn't conform

Property pair constraints

This feature was posponed in ShEx 2.1

Not supported yet

```
:UserShape {
 $<givenName> schema:givenName xsd:string ;
 $<firstName> schema:firstName xsd:string ;
 $<birthDate> schema:birthDate xsd:date ;
 $<loginDate> :loginDate xsd:date ;
 $<givenName> =  $<firstName> ;
 $<givenName> != $<lastName> ;
 $<birthDate> <  $<loginDate>
}
```

SHACL supports equals, disjoint, lessThan, ...

```
:UserShape a sh:NodeShape ;
 sh:property [
   sh:path schema:givenName ;
   sh:datatype xsd:string ;
   sh:disjoint schema:lastName
 ] ;
 sh:property [
   sh:path foaf:firstName ;
   sh:equals schema:givenName ;
 ] ;
 sh:property [
   sh:path schema:birthDate ;
   sh:datatype xsd:date ;
   sh:lessThan :loginDate
 ] .
```

Uniqueness (defining unique Keys)

This feature was postponed in ShEx 2.1

Not supported yet

```
:UserShape {
  schema:givenName xsd:string ;
  schema:lastName xsd:string ;
  UNIQUE(schema:givenName, schema:lastName)
}
```

Not supported yet

```
:Country {
 schema:name . + ;
 UNIQUE(LANGTAG(schema:name))
}
```

No support for generic unique keys

sh:uniqueLang offers partial support for a very common use case

Uniqueness can be done with SHACL-SPARQL

```
:Country a sh:NodeShape ;
 sh:property [
  sh:path schema:name ;
  sh:uniqueLang true
] .
```

Modularity

ShEx has EXTERNAL and import keywords

import imports shapes from URI

external declares that a shape definition can be retrieved elsewhere

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

http://example.org/UserShapes

```
import <http://example.org/UserShapes>

:TeacherShape :UserShape AND {
 :teaches . ;
 :teacherCode external
}
```

SHACL supports owl:imports

SHACL processors follow `owl:imports`

```
:UserShape a sh:NodeShape ;
 sh:property [ sh:path schema:name ;
 sh:datatype xsd:string
] .
```

http://example.org/UserShapes

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

:TeacherShape a sh:NodeShape;
   sh:node :UserShape ;
   sh:property [ sh:path :teaches ;
    sh:minCount 1;
] ;
```

Reusability - Extending shapes (1)

ShEx shapes can be extended by conjunction

```
:Product {
  schema:productId xsd:string
  schema:price xsd:decimal
}

:SoldProduct @:Product AND {
 schema:purchaseDate xsd:date ;
 schema:productId /^[A-Z]/
}
```

SHACL shapes can also be extended by conjunction

Extending by composition

```
:Product a sh:NodeShape, rdfs:Class ;
  sh:property [ sh:path schema:productId ;
    sh:datatype xsd:string
  ];
  sh:property [ sh:path schema:price ;
    sh:datatype xsd:decimal
  ].

:SoldProduct a sh:NodeShape, rdfs:Class ;
  sh:and (
   :Product
    [ sh:path schema:purchaseDate ;
      sh:datatype xsd:date]
    [ sh:path schema:productId ;
     sh:pattern "^[A-Z]" ]
  ) .
```

Reusability - Extending shapes (2)

ShEx: no special treatment for `rdfs:Class`, `rdfs:subClassOf`, ...

By design, ShEx has no concept of Class

- Not possible to extend by declaring subClass relationships
- No interaction with inference engines

SHACL shapes can also be extended by leveraging subclasses

Extending by leveraging subclasses

```
:Product a sh:NodeShape, rdfs:Class ;
  ...as before...

:SoldProduct a sh:NodeShape, rdfs:Class ;
  rdfs:subClassOf :Product ;
  sh:property [ sh:path schema:productId ;
     sh:pattern "^[A-Z]"
   ] ;
  sh:property [ sh:path schema:purchaseDate ;
     sh:datatype xsd:date
  ] .
```

SHACL subclasses may differ from RDFS/OWL subclases

Reusability - Extending shapes (3)

ShEx 2.2 Extension by aggregation

`extends` keyword added to the language

```
:Product {
 :code /P[0-1]{4}/ ;
}

:Book extends :Product {
 :code /^isbn:[0-1]{10}/
}
```

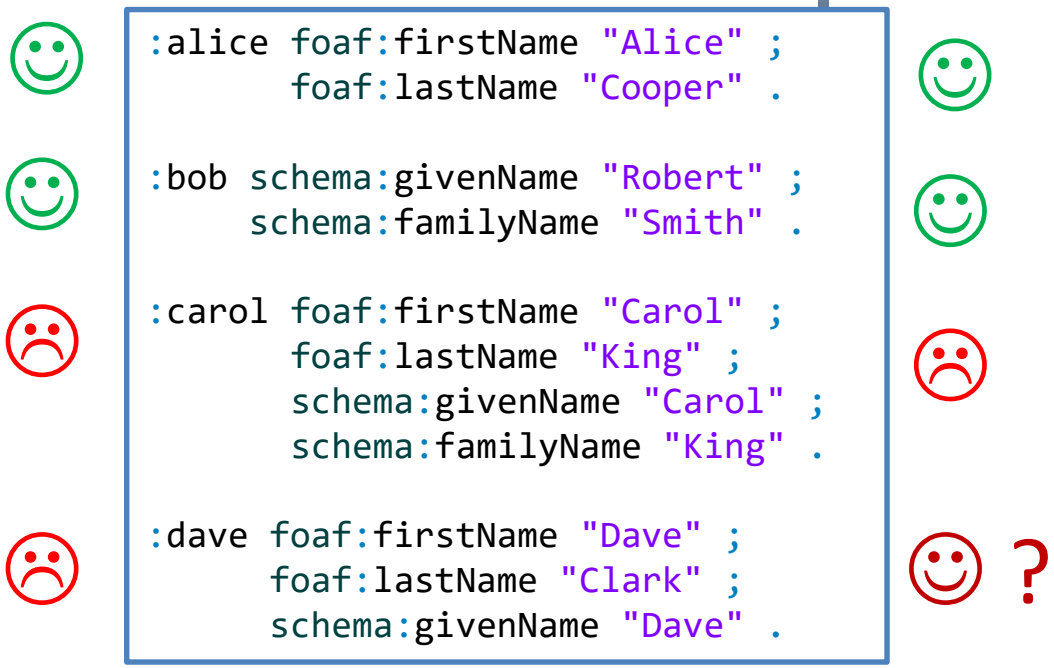
```
:phone    :code "P4356" .

:mobyDick :code "P4789",
                "isbn:9876543210"
```

SHACL: no extensión by aggregation

Exclusive-or and alternatives

ShEx operator | declares choices

```
:Person {
  foaf:firstName . ; foaf:lastName .
| schema:givenName . ; schema:familyName .
}
```



```
:alice foaf:firstName "Alice" ;
       foaf:lastName "Cooper" .

:bob schema:givenName "Robert" ;
     schema:familyName "Smith" .

:carol foaf:firstName "Carol" ;
       foaf:lastName "King" ;
       schema:givenName "Carol" ;
       schema:familyName "King" .

:dave foaf:firstName "Dave" ;
      foaf:lastName "Clark" ;
      schema:givenName "Dave" .
```

SHACL provides sh:xone for exactly one, but…

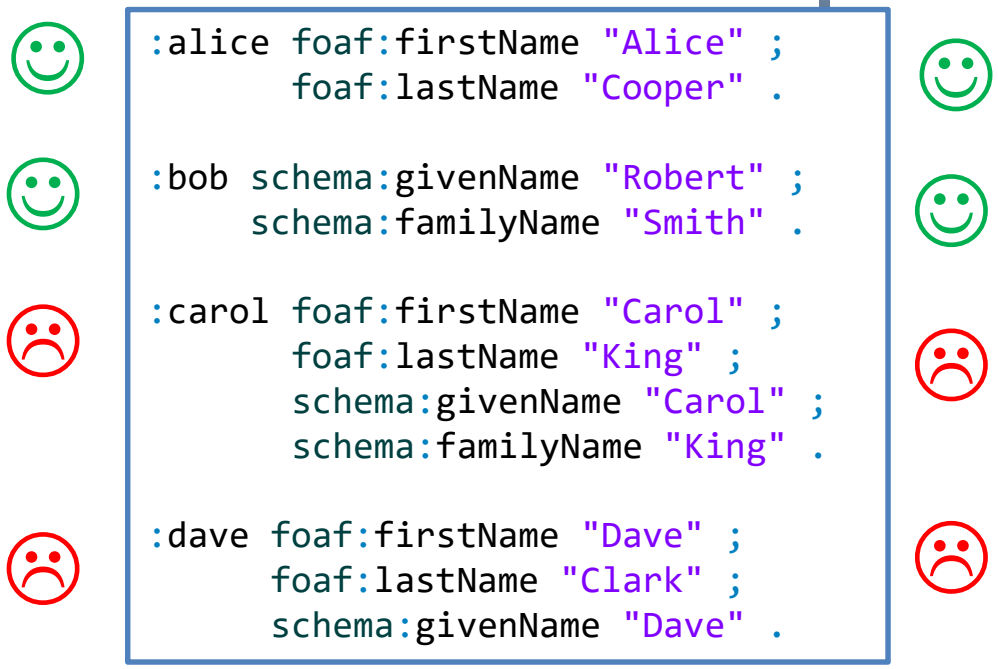
```
:PersonShape a sh:NodeShape;
 sh:targetClass :Person ;
 sh:xone (
 [ sh:property [
    sh:path foaf:firstName;
    sh:minCount 1; sh:maxCount 1
   ] ;
   sh:property [
    sh:path foaf:lastName;
    sh:minCount 1; sh:maxCount 1
 ]]
 [ sh:property [
    sh:path schema:givenName;
    sh:minCount 1; sh:maxCount 1
   ] ;
   sh:property [
    sh:path schema:familyName;
    sh:minCount 1; sh:maxCount 1
 ]]
) .
```

It doesn't check partial matches

Exclusive-or and alternatives

ShEx operator | declares choices

```
:Person {
  foaf:firstName . ; foaf:lastName .
| schema:givenName . ; schema:familyName .
}
```



```
:alice foaf:firstName "Alice" ;
       foaf:lastName "Cooper" .

:bob schema:givenName "Robert" ;
     schema:familyName "Smith" .

:carol foaf:firstName "Carol" ;
       foaf:lastName "King" ;
       schema:givenName "Carol" ;
       schema:familyName "King" .

:dave foaf:firstName "Dave" ;
      foaf:lastName "Clark" ;
      schema:givenName "Dave" .
```

SHACL solution with normalization…

```
:Person a sh:N
 sh:or (
  [ sh:propert
     sh:path f
     sh:minCou
     sh:maxCou
    ];
    sh:propert
     sh:path f
     sh:minCou
     sh:maxCou
    ];
   sh:property
    sh:path sc
    sh:maxCoun
   ];
   sh:property
    sh:path sc
    sh:maxCoun
   ];
 )
.
```

```
 [ sh:property [
    sh:path foaf:firstName;
    sh:maxCount 0
   ];
   sh:property [
    sh:path foaf:lastName;
    sh:maxCount 0
   ];
   sh:property [
    sh:path schema:givenName;
    sh:minCount 1;
    sh:maxCount 1
   ] ;
   sh:property [
    sh:path schema:familyName;
    sh:minCount 1;
    sh:maxCount 1
   ];
 ] )
.
```

Annotations

ShEx allows annotations but doesn't have predefined annotations yet

Annotations can be declared by //

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

Any kind of annotations can be defined, some proposals:

- Form generation for UI
- Severities: MUST, SHOULD, etc.

SHACL allows any kind of annotations and has some non-validating built-in annotations

Built-in properties: `sh:name`, `sh:description`, `sh:defaultValue`, `sh:order`, `sh:group`

```
:Person a sh:NodeShape ;
 sh:property [
  sh:path        schema:name ;
  sh:datatype    xsd:string ;
  sh:name        "Name" ;
  sh:description "Name of person"
  rdfs:label     "Name";
 ] .
```

Apart of the built-in annotations,
SHACL can also use any other annotation

Validation report

ShEx 2.0 defines a result shape map

It contains both positive and negative node/shape associations

SHACL defines a validation report

Describes only the structure of errors

In practice, difficult to distinguish between:

- nodes that are valid
- nodes that are ignored (not validated)

Some properties can be used to control which information is shown

sh:message

sh:severity

Extension mechanism

ShEx uses semantic actions

Semantic actions allow any future processor

They can be used also to transform RDF

```
:Event {
 schema:startDate xsd:date  %js:{ start = o %} ;
 schema:endDate   xsd:date  %js:{ end = o %}   ;
 %js: { start < end %}
}
```

SHACL has SHACL-SPARQL

SHACL-SPARQL allows new constraint components defined in SPARQL

[See example in next slide]

It is possible to define constraint components in other languages, e.g. Javascript

Stems

ShEx can describe stems

Stems are built into the language

Example:

The value of :homePage starts by <http://company.com/>

```
:Employee {
 :homePage [ <http://company.com/> ~ ]
}
```

Stems are not built-in

Can be defined using SHACL-SPARQL

```
:StemConstraintComponent
 a sh:ConstraintComponent ;
 sh:parameter [ sh:path :stem  ] ;
  sh:validator [ a sh:SPARQLAskValidator ;
   sh:message "Value does not have stem {$stem}";
   sh:ask """
    ASK {
     FILTER (!isBlank($value) &&
       strstarts(str($value),str($stem)))
     }"""
 ] .
```

```
:Employee a sh:NodeShape ;
 sh:targetClass :Employee ;
 sh:property [
  sh:path :homePage ;
  :stem <http://company.com/>
 ] .
```

Some future work ideas

- ShEx ⇔ SHACL
  - Recursion & negation
- Inference of shapes from data
- Visualization & authoring tools
- Validation usability (better error information/visualization)
- RDF Stream validation

End of presentation