CWM

Closed World Machine

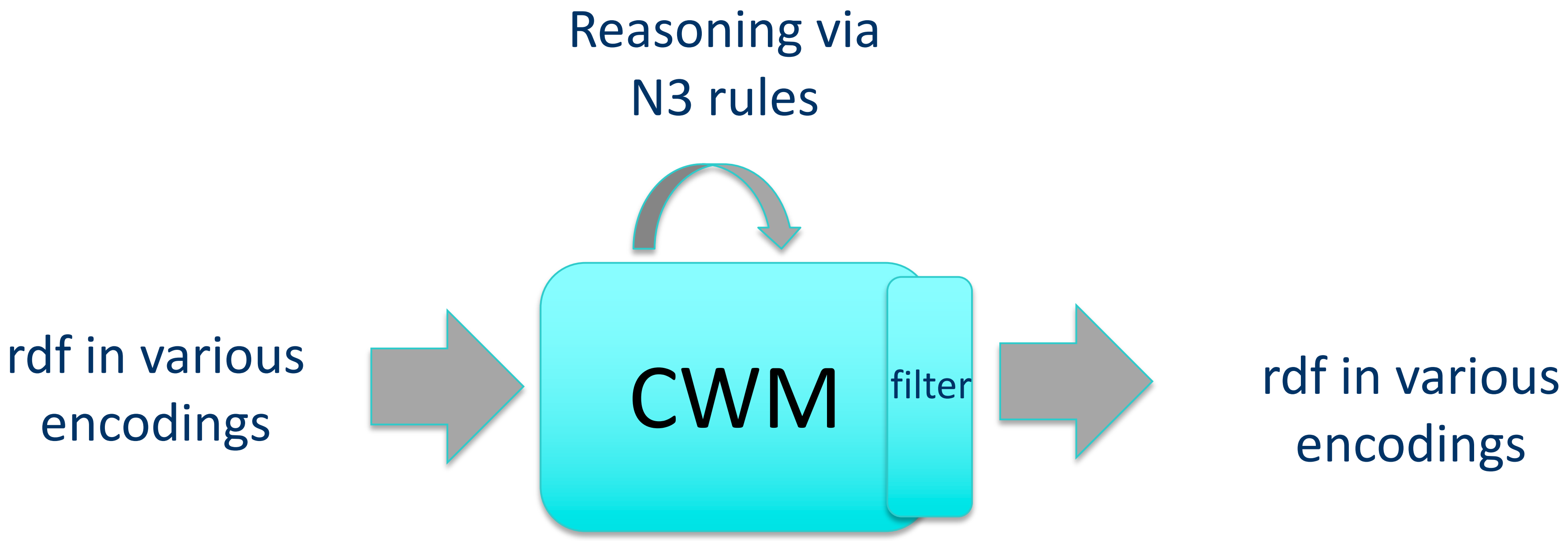
CWM Overview

- CWM is a simple Semantic Web program that can do the following tasks
  - Read and pretty-print several RDF formats
  - Store triples in a queryable in-memory triple store
  - Perform inferences via forward chaining rules
  - Perform builtin functions, e.g., comparing strings or numbers, retrieving resources, using an extensible builtins suite
- CWM was written in Python by Tim Berners-Lee and Dan Connolly of the W3C (circa 2000!)

What’s CWM good for?

- CWM is good for experimenting with RDF and RDFS and some OWL
- CWM’s rule based reasoner can’t cover all of OWL
- A good Unix command line tool
- rdfs:seeAlso
  - http://infomesh.net/2001/cwm/
  - http://w3.org/2000/10/swap/doc/Processing

CWM in a Nutshell



CWM command line

- Example: cwm --rdf foo.rdf --n3 > foo.n3
- Args are processed left to right (except for flags --pipe and –help
- Here’s what happens:
  - Switch to RDF/XML input-output format
  - Read in foo.rdf (use a filename or URI) and add triples to store
  - Switch to --n3 input-output format
  - Output triples in store to stdout in N3
  - Unix redirect captures output in foo.n3

On N3 and Turtle

- N3 notation was invented by Tim Berners Lee
- Not a standard, but a large subset is as Turtle
- What's in N3 but not in Turtle
  - Representing inference rules over RDF triples
  - Some other bits
- The rules part is most useful
  - Supplanted by SWRL and SPARQL
  - And by RIF (Rule Interchange Formalism)

Reasoning using N3 Rules

- N3 has a simple notation for Prolog like rules
- These are represented in RDF and can read these into CWM just like a data file
- Command line args tell CWM to reason

--apply=X : read rules from X, apply to store, adding conclusions

--rules : apply once the rules in the store to the store, adding conclusions

--filter=X : apply rules in X to the store, REPLACING the store with the conclusions

--think : apply rules in store to the store, adding conclusions to store, iteratively until a fix point reached, i.e. no more new conclusions are made

N3 facts and rules

Consider the following facts in N3/TTL:

```
:Pat owl:sameAs :Patrick .
:Man rdfs:subclassOf :Human .
:YoungMan rdfs:subclassOf :Man .
:has_father rdfs:domain :Human;
            rdfs:range :Man .
:Sara :has_father :Alan .
```

N3 allows to to define rules to infer and add new triples licensed by RDFS

```
:Sara a :Human .
:Alan a :Man .
:Alan a :Human .
```

N3 facts and rules

We can also add rules for a domain to a knowledge graph:

```
{ ?x :has_parent ?y } =>  { ?y :has_child ?x } .

{?x :has_parent ?y. ?y :has_brother ?z}
      => {?x :has_uncle ?z} .

{ :thermostat :temp ?x.  ?x math:greaterThan "70" }
=> { :cooling :power "high" } .
```

Implications in logic

- In logic, an implication is a sentence that is either *true* or *false*
  - Forall *x* man(*x*) => mortal(*x*)
- Of course, we may not know if it's true or false
- If we believe an implication is true, we can use it to derive new true sentences from others we believe true
  - *man(socrates)* therefore *mortal(socrates)*
- This is the basis for rule based reasoning systems
  - Prolog, Datalog, Jess, etc.

Quantifiers

- In classical logic, we have two quantifiers, forall (∀) and exists (∃)
  - ∀x ∃y has_child(x, y) => is_parent(x)
    - For all x, if there exists a y such that *x has_child y*, then x is a parent, or in other words
    - X is a parent if X has (at least) one child
  - You only need find **one** child to conclude that someone is a parent
- Variables (e.g., x and y) range over all *objects* in the universe, but for KB systems, we can narrow this to objects mentioned in the KB

Variables in rules implicitly quantified

- Most rule-based systems don’t use explicit quantifiers
- Variables are *implicitly* quantified as either $\forall$ or $\exists$, typically using the following scheme:
  - Variables in rule conclusion are *universally* quantified
  - Variables appearing *only* in premise are *existentially* quantified
- has_child(p,c) => isa_parent(p)   interpreted as

  $\forall$p $\exists$c has_child(p,c) => isa_parent(p)

Variables in rules implicitly quantified

- To see why this is a reasonable design decision for a rule language, consider

  $\forall x\ \forall y$ has_child(x, y) => isa_parent(x)

- What does this mean?

  X is a parent if we can prove that X has *every object* in our universe as a child

- Such rules are not often useful
- Many rule languages do have ways to express them, of course

Reasoning: Forward and Backward

- Rule based systems tend to use one of two reasoning strategies (and some do both)
  - Reasoning *forward* from known facts to new ones (find all people who are parents; is Bob among them?)
  - Reasoning *backward* from a conclusion posed as a query to see if it is true (Is Bob a parent?)
- Each has advantages and disadvantages which may effect its utility in a given use case
- CWM uses a forward reasoning strategy
  - We often want to compute all RDF triples that follow from a given set (i.e., find the deductive closure)

N3 Rules: premis => conclusion

- An N3 rule has a *conjunction* of triples as a premise and a *conjunction* as a conclusion
- E.g.: 2nd element of a triple is always a property

  ```
  { ?S ?P ?O. } => { ?P a rdf:Property. }
  ```
- E.g.: Meaning of rdfs:domain

  ```
  { ?S ?P ?O. ?P rdfs:domain ?D.} => { ?S a ?D. }
  ```
- Variables begin with a ?.
- Variable in conclusions must appear in premise
- Every way to instantiate triples in premise with a set of KB triples yields new conclusion

Note: limited negation & disjunction

- What about disjunction, i.e., OR?
  - You're a parent if you have a son **or** a daughter
- Disjunction in the premise can be achieved using several rules
  - { ?S :has_son ?O.} => { ?S :has_child ?O.}
  - { ?S :has_daughter ?O.} => { ?S :has_child ?O.}
- No disjunction allowed in conclusion
  - Allowing this requires a much more complex proof algorithm
  - "When you have eliminated the impossible, whatever remains, however improbable, must be the truth"

Note: limited negation & disjunction

- No general logical negation is provided
  - This is a common constraint in rule based systems, e.g., Prolog
  - This makes reasoning amenable to efficient algorithms with some loss of expressive power
- Negation and disjunction supported in other ways in OWL and RIF and in other reasoners

N3 rules use cases

- Use N3 rules to implement the semantics of RDF, RDFS, and OWL vocabularies
  - See rdfs-rules.n3
  - See owl-rules.n3
- Use N3 rules to provide domain/application specific rules
  - See gedcom-relations.n3

A simple example

```
% more simple1.n3

# A simple example

@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix : <#> .

:john a foaf:Person;
   foaf:name "John Smith";
   foaf:gender "Male";
   foaf:name "John Smith" .
```

Invoking CWM (1)

```
% cwm simple1.n3
# Processed by Id: cwm.py,v 1.197 2007/12/13 15:38:39 syosi Exp
# using base file:///Users/finin/Sites/691s13/examples/n3/simple1.n3
#  Notation3 generation by notation3.py,v 1.200 2007/12/11 21:18:08 syosi
   Exp
#   Base was: file:///Users/finin/Sites/691s13/examples/n3/simple1.n3
@prefix : <#> .

    :john a <http://xmlns.com/foaf/0.1/Person>;
        <http://xmlns.com/foaf/0.1/gender> "Male";
        <http://xmlns.com/foaf/0.1/name> "John Smith" .
#ENDS
```

Invoking CWM (2)

```
n3> cwm –n3=/d   simple1.n3
# Processed by Id: cwm.py,v 1.197 2007/12/13 15:38:39 syosi Exp
# using base file:///Users/finin/Sites/691s13/examples/n3/simple1.n3
#  Notation3 generation by  notation3.py,v 1.200 2007/12/11 21:18:08 syosi Exp
#   Base was: file:///Users/finin/Sites/691s13/examples/n3/simple1.n3

   @prefix foaf: <http://xmlns.com/foaf/0.1/> .

   <#john>     a foaf:Person;
       foaf:gender "Male";
       foaf:name "John Smith" .
```

Some useful CWM flags

- CWM command has a lot of flags and switches
- Do cwm --help to see them
- Here are a few

```
--rdf  Input & Output ** in RDF/XML insead of n3 from now on
--n3  Input & Output in N3 from now on. (Default)
--n3=flags  Input & Output in N3 and set N3 flags
--ntriples  Input & Output in NTriples (equiv --n3=usbpartane -bySubject -quiet)
--apply=foo Read rules from foo, apply to store, adding conclusions to store
--think as -rules but continue until no more rule matches (or forever!)
--think=foo as -apply=foo but continue until no more rule matches (or forever!)
--data Remove all except plain RDF triples (formulae, forAll, etc)
--help print this message
```

RDFS in N3 (1)

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix owl: <http://www.w3.org/2002/07/owl#>.
…
rdfs:comment rdfs:domain rdfs:Resource; rdfs:range rdfs:Literal.
rdfs:domain rdfs:domain rdf:Property; rdfs:range rdfs:Class.
rdfs:label rdfs:domain rdfs:Resource; rdfs:range rdfs:Literal.
rdfs:range rdfs:domain rdf:Property; rdfs:range rdfs:Class.
rdfs:seeAlso rdfs:domain rdfs:Resource; rdfs:range rdfs:Resource.
rdfs:subClassOf rdfs:domain rdfs:Class; rdfs:range rdfs:Class.
rdfs:subPropertyOf rdfs:domain rdf:Property; rdfs:range rdf:Property.
rdf:type rdfs:domain rdfs:Resource; rdfs:range rdfs:Class.
…
```

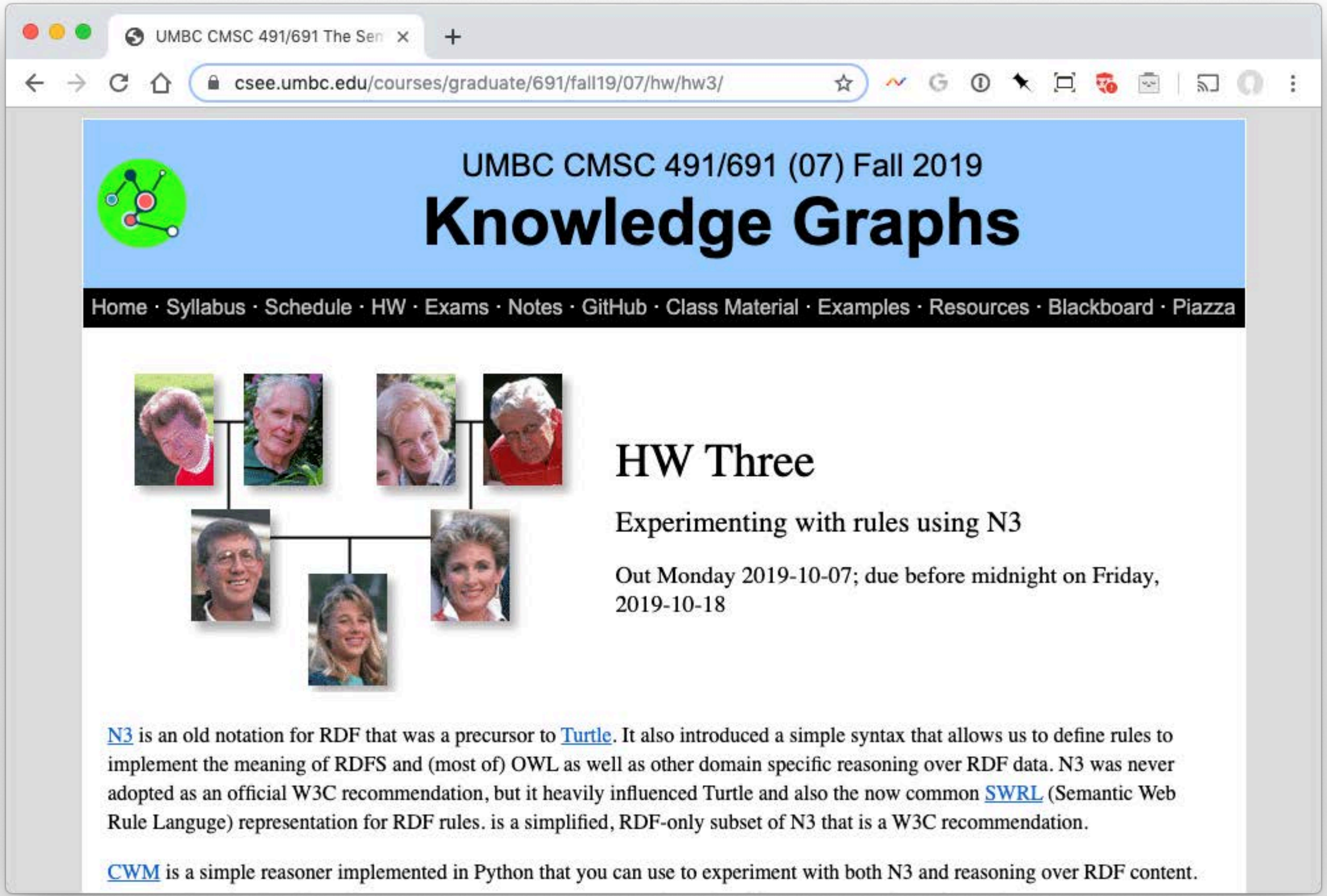
RDFS in N3 (2)

```
{?S ?P ?O} => {?P a rdf:Property}.
{?S ?P ?O} => {?S a rdfs:Resource}.
{?S ?P ?O} => {?O a rdfs:Resource}.

{?P rdfs:domain ?C. ?S ?P ?O} => {?S a ?C}.
{?P rdfs:range ?C. ?S ?P ?O} => {?O a ?C}.

{?Q rdfs:subPropertyOf ?R. ?P rdfs:subPropertyOf ?Q}
      => {?P rdfs:subPropertyOf ?R}.
{?P rdfs:subPropertyOf ?R. ?S ?P ?O} => {?S ?R ?O}.

{?A rdfs:subClassOf ?B. ?S a ?A} => {?S a ?B}.
{?B rdfs:subClassOf ?C. ?A rdfs:subClassOf ?B}
      => {?A rdfs:subClassOf ?C}.
```

Demonstration

- Install cwm
  - pip install cwm
- Download files in the n3 examples directory http://cs.umbc.edu/courses/graduate/691/fall19/07/examples/n3/

HW3



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Knowledge Graphs

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HW Three

Experimenting with rules using N3

Out Monday 2019-10-07; due before midnight on Friday, 2019-10-18

N3 is an old notation for RDF that was a precursor to Turtle. It also introduced a simple syntax that allows us to define rules to implement the meaning of RDFS and (most of) OWL as well as other domain specific reasoning over RDF data. N3 was never adopted as an official W3C recommendation, but it heavily influenced Turtle and also the now common SWRL (Semantic Web Rule Languge) representation for RDF rules. is a simplified, RDF-only subset of N3 that is a W3C recommendation.

CWM is a simple reasoner implemented in Python that you can use to experiment with both N3 and reasoning over RDF content.

Summary

- CWM is a relatively simple program that lets you manipulate and explore RDF and Semantic Web technology
- It's limited in what it can do and not very efficient
- But useful and "close to the machine"
- Written in Python
- There are related tools in Python, see rdflib
- And lots more tools in other languages

genesis

```
# A simple example of family relations using
    the gedcom vocabulary.

@prefix gc:
    <http://www.daml.org/2001/01/gedcom/
    gedcom#>.
@prefix log:
    <http://www.w3.org/2000/10/swap/log#
    >.
@prefix owl:
    <http://www.w3.org/2002/07/owl#>.
@prefix : <#> .
# data from the Bible in GEDCOM form
:fam1 a gc:Family.

:Able gc:sex gc:Male;
  gc:givenName "Able";
  gc:childIn :fam1;
  owl:differentFrom :Cain.
```

```
:Cain gc:sex gc:Male;
  gc:givenName "Cain";
  gc:childIn :fam1;
  owl:differentFrom :Able.

:Adam gc:sex gc:Male;
  gc:givenName "Adam";
  gc:spouseIn :fam1;
  owl:differentFrom :Eve.

:Eve gc:sex gc:Female;
  gc:givenName "Eve";
  gc:spouseIn :fam1;
  owl:differentFrom
```