INFO216:

Advanced Modelling

Theme, spring 2018:

Modelling and Programming the Web of Data

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Session S12: OWL DL

- Themes:
  - description logic
  - decision problems
  - OWL DL
  - Manchester OWL-syntax

Readings

- Forum links (cursory):
  - http://www.w3.org/TR/owl2-primer/
    - show: Turtle and Manchester syntax
    - hide: other syntaxes
  - Description Logic Handbook:
    - Chapter 1: Nardi & Brachman:
      Introduction to Description Logics
    - Chapter 2: Baader & Nutt:
      Formal Description Logics *(gets hard)*

Description Logic (DL)

Description logics

- Description Logic (DL)
  - a simple *fragment* of predicate logic
    - ...or, rather, a *family of such fragments*
  - not very *expressive* ("uttrykkskraftig")
  - but (can have) *good decision problems*, i.e.,
    - it answers *decision problems* (rather) quickly
- Suitable for describing *concepts* ("begreper")
  - formal basis for *OWL DL*
  - can be used to:
    - describe *concepts* and their *roles* ("Tbox")
    - describe *individuals* and their *roles* ("ABox")

Relationship to other logics

- *Proposition logics* are about *statements* (*propositions*):
  "Martha is a Woman" ⇐
  "Martha is Human" ∧ "Martha is Female"
- (First order) *predicate logics* are about *predicates* and *objects*:
  - $\forall x.(\text{Woman}(x) \Leftrightarrow \text{Human}(x) \wedge \text{Female}(x))$
- *Description logics* are about *concepts*:
  - $\text{Woman} \doteq \text{Human} \sqcap \text{Female}$
  - ...and also about *roles* and *individuals*
- There are many other logic systems:
  - *modal logics*: necessarily □, possibly ◊
  - *temporal logics*: always □, sometimes ◊, next time ○

Definition of concepts (“begreper”)

- **Woman ≐ Human ⊓ Female**
- **Man ≐ Human ⊓ ¬ Woman**
- **Parent ≐ Mother ⊔ Father**
    - concepts: **Human, Female, Woman…**
    - definition: ≐
    - conjuction (and): ⊓
    - disjunction (or): ⊔
    - negation (not): ¬
    - nested expressions: **(   )**
- **Childless** ≐ ..using Human and Parent..?

Definition of concepts ("begreper")

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  - nested expressions: **( )**
- **Childless ≐ Human ⊓ ¬ Parent**

Types of concepts ("begreper")

- $\mathbf{Woman} \doteq \mathbf{Human} \sqcap \mathbf{Female}$
- $\mathbf{Man} \doteq \mathbf{Human} \sqcap \neg\, \mathbf{Woman}$
- $\mathbf{Parent} \doteq \mathbf{Mother} \sqcup \mathbf{Father}$
  - atomic concepts: **Human, Female, Woman…**
  - complex concepts / concept expressions: $\neg\, \mathbf{Woman}$, $\mathbf{Human} \sqcap \mathbf{Female}$...
  - (atomic) base concepts: **Human, Female…**
    - only used in r.h.s. of expressions
  - (atomic) defined concepts: **Woman, Man…**
    - defined on the l.h.s. of an expression
    - unequivocality: each defined (or named) concept occurs in the l.h.s. of only one definition

l.h.s. = left-hand side, r.h.s. = right-hand side

Base and defined concepts and roles

- *Atomic base concepts* are given
  - *corresponds to OWL-NamedClasses that are* *not* *composed from other classes/properties/...*
- *Atomic defined / named concepts*
  - *corresponds to OWL-NamedClasses that are* *composed from other classes*
  - defined by *concept expressions*
  - name appears on the left side of an $\doteq$ definition
  - concept expression appears on the right side
- ...similar distinction between *base and defined roles* later

Roles

- **Mother** $\doteq$ **Female** $\sqcap$ **∃hasChild**.$\top$
- **Bachelor** $\doteq$ **Male** $\sqcap$ **¬∃hasSpouse**.$\top$
- **Uncle** $\doteq$ **Male** $\sqcap$ **∃hasSibling.Parent**
  - roles: **hasChild, hasSibling...**
  - universal concept ("top"): $\top$
  - existential restriction: **∃**
- **Grandparent** $\doteq$ ..using Human, hasChild, Parent..
- **Grandparent** $\doteq$ ..using only Human, hasChild..
- **Uncle** $\doteq$ ..using Male, hasSibling, hasChild..

Roles

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Roles

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    - existential restriction: **∃**
- **Grandparent** $\doteq$ **Human** $\sqcap$ **∃hasChild.Parent**
- **Grandparent** $\doteq$ **Human** $\sqcap$
  ∃ hasChild.∃ hasChild.$\top$
- **Uncle** $\doteq$ ....using Male, hasSibling, hasChild....

Roles

- $\textbf{Mother} \doteq \textbf{Female} \sqcap \exists\textbf{hasChild}.\top$
- $\textbf{Bachelor} \doteq \textbf{Male} \sqcap \neg\exists\textbf{hasSpouse}.\top$
- $\textbf{Uncle} \doteq \textbf{Male} \sqcap \exists\textbf{hasSibling.Parent}$
  - roles: **hasChild, hasSibling...**
  - universal concept ("top"): $\top$
  - existential restriction: $\exists$
- $\textbf{Grandparent} \doteq \textbf{Human} \sqcap \exists\textbf{hasChild.Parent}$
- $\textbf{Grandparent} \doteq \textbf{Human} \sqcap \exists\ \textbf{hasChild}.\exists\ \textbf{hasChild}.\top$
- $\textbf{Uncle} \doteq \textbf{Male} \sqcap \exists\ \textbf{hasSibling}.\exists\ \textbf{hasChild}.\top$

Null concept

- **Male ⊓ Female ⊑ ⊥**
  - null concept ("bottom"): **⊥**
  - subsumption (sub concept): ⊑
  - equivalence: **≡**
- ≐ is used for *definitions* (or just ≡)
- ≡ are used for *equivalence axioms*
- ⊑ are used for *specialisation axioms*
- Note the use of ... ⊑ ⊥ ("subsumption of bottom")
  - to say that something is not the case
- *This was our first proper axiom!*
  - so far we have just defined *concepts*
  - we have not used them in proper *axioms*

Null concept

- **Male ⊓ Female ⊑ ⊥**
    - null concept ("bottom"): ⊥
    - subsumption (sub concept): ⊑
    - equivalence: **≡**
- ≐ is used for *definitions* (or just ≡)
- ≡ are used for *equivalence axioms*
- ⊑ are used for *specialisation axioms*
- Note the use of ... ⊑ ⊥ ("subsumption of bottom")
    - to say that something is not the case
- *But:*
    - definitions are a special type of equivalences
    - with a single atomic (defined) concept on the l.h.s.

More uses of roles

- **HappyFather ≐ Father ⊓ ∀hasChild.HappyPerson**
  - universal restriction: **∀**
- **MotherOfOne ≐ Mother ⊓ =1 hasChild.⊤**
- **Polygamist ≐ ≥3 hasSpouse.⊤**
  - number restrictions: **=, ≥, ≤**
- **Narsissist ≐ ∃hasLoveFor.Self**
  - **self references**: **Self**
- **MassMurderer** ≐ ...using hasKilled, Human...
- **SelfHater** ≐ ..using haterOf...

More uses of roles

- **HappyFather ≐ Father ⊓ ∀hasChild.HappyPerson**
    - universal restriction: **∀**
- **MotherOfOne ≐ Mother ⊓ =1 hasChild.**⊤
- **Polygamist ≐ ≥3 hasSpouse.**⊤
    - number restrictions: **=, ≥, ≤**
- **Narsissist ≐ ∃hasLoveFor.Self**
    - **self references**: **Self**
- **MassMurderer ≐ ≥4 hasKilled.Human**
- **SelfHater** ≐ ..using haterOf...

More uses of roles

- **HappyFather ≐ Father ⊓ ∀hasChild.HappyPerson**
  - universal restriction: **∀**
- **MotherOfOne ≐ Mother ⊓ =1 hasChild.⊤**
- **Polygamist ≐ ≥3 hasSpouse.⊤**
  - number restrictions: **=, ≥, ≤**
- **Narsissist ≐ ∃hasLoveFor.Self**
  - **self references**: **Self**
- **MassMurderer ≐ ≥4 hasKilled.Human**
- **SelfHater ≐ ∃haterOf.Self**

Inverse and transitive roles

- $\mathbf{Child} \doteq \mathbf{Human} \sqcap \exists \mathbf{hasChild}^{-}.\top$
- $\mathbf{hasParent} \doteq \mathbf{hasChild}^{-}$
- $\mathbf{hasSibling} \doteq \mathbf{hasSibling}^{-}$
- $\mathbf{BlueBlood} \doteq \forall \mathbf{hasParent}^{*}.\mathbf{BlueBlood}$
  - inverse role: $\mathbf{hasChild}^{-}$
  - symmetric role: $\mathbf{hasSibling}^{-}$
  - transitive role: $\mathbf{hasParent}^{*}$
- **Niece** ≐ ..Woman, hasChild, hasSibling..

Inverse and transitive roles

- $\texttt{Child} \doteq \texttt{Human} \sqcap \exists \texttt{hasChild}^{-}.\top$
- $\texttt{hasParent} \doteq \texttt{hasChild}^{-}$
- $\texttt{hasSibling} \doteq \texttt{hasSibling}^{-}$
- $\texttt{BlueBlood} \doteq \forall \texttt{hasParent}^{*}.\texttt{BlueBlood}$
  - inverse role: $\texttt{hasChild}^{-}$
  - symmetric role: $\texttt{hasSibling}^{-}$
  - transitive role: $\texttt{hasParent}^{*}$
- $\texttt{Niece} \doteq \texttt{Woman} \sqcap \exists \texttt{hasChild}^{-}.\texttt{hasSibling}.\top$
- *We have started to define roles*
  - so far, we have only defined *concepts*

Composite roles

- Similar to composite concepts, e.g.:
  - **hasUncle ≐ hasParent o hasBrother**
  - **hasLovedChild ≐ hasChild ⊓ hasLoveFor**
  - **hasBrother ≐ (hasSibling | Male)**
- Mostly *not* supported by reasoning engines
  - they have "bad decision problems"
    - meaning that they compute slowly or intractably
  - ...with some exceptions
- **hasDaughter** ≐ ..using hasChild, Female..

Composite roles

- Similar to composite concepts, e.g.:
  - **hasUncle ≐ hasParent o hasBrother**
  - **hasLovedChild ≐ hasChild ⊓ hasLoveFor**
  - **hasBrother ≐ (hasSibling | Male)**
- Mostly *not* supported by reasoning engines
  - they have “bad decision problems”
    - meaning that they compute slowly or intractably
  - ...with some exceptions
- **hasDaughter ≐ (hasChild | Female)**

TBox

- *Terminology box* (TBox):
  - a collection of axioms and definitions
  - axioms are equivalences or subsumptions:
    - *equivalence axioms* ($\equiv$):
      - composite concept (role) expressions on both sides
    - *subsumption* axioms ($\sqsubseteq$):
      - composite concept (role) expressions on both sides
  - terminology boxes can also contain definitions:
    - *definition axioms* ($\doteq$):
      - atomic defined / named concept (role) on the l.h.s.
      - composite concept (role) expression on the r.h.s
    - make it easier to write other axioms

Acyclic, definitional TBox

$$
\begin{aligned}
\mathsf{Woman} &\equiv \mathsf{Person} \sqcap \mathsf{Female} \\
\mathsf{Man} &\equiv \mathsf{Person} \sqcap \neg\mathsf{Woman} \\
\mathsf{Mother} &\equiv \mathsf{Woman} \sqcap \exists \mathsf{hasChild}.\mathsf{Person} \\
\mathsf{Father} &\equiv \mathsf{Man} \sqcap \exists \mathsf{hasChild}.\mathsf{Person} \\
\mathsf{Parent} &\equiv \mathsf{Father} \sqcup \mathsf{Mother} \\
\mathsf{Grandmother} &\equiv \mathsf{Mother} \sqcap \exists \mathsf{hasChild}.\mathsf{Parent} \\
\mathsf{MotherWithManyChildren} &\equiv \mathsf{Mother} \sqcap \geqslant 3\, \mathsf{hasChild} \\
\mathsf{MotherWithoutDaughter} &\equiv \mathsf{Mother} \sqcap \forall \mathsf{hasChild}.\neg\mathsf{Woman} \\
\mathsf{Wife} &\equiv \mathsf{Woman} \sqcap \exists \mathsf{hasHusband}.\mathsf{Man}
\end{aligned}
$$

Acyclic, and
contains only definitions!

TBox

- *Acyclic TBoxes:*
  - contains only definitions
  - subsumption axioms can (sometimes) be removed:
    - $T \sqsubseteq C$ is transformed into $T \doteq \bar{T} \sqcap C$
      - Example:

        Male $\sqsubseteq$ **Human** is transformed into

        Male $\doteq$ **Maleness** $\sqcap$ **Human**
    - *when only a single l.h.s. term*
  - every defined concept (or role) can be *expanded* into an expression of only atomic base concepts (or roles)
- *Expanded concepts* (or *roles*)
  - defined only in terms of *atomic base concepts* (and *roles*)
  - expanded, definitional TBox

Expanded definitional TBox

Only atomic base concepts on the right hand sides!

$$
\begin{aligned}
\mathsf{Woman} &\equiv \mathsf{Person} \sqcap \mathsf{Female}\\
\mathsf{Man} &\equiv \mathsf{Person} \sqcap \neg(\mathsf{Person} \sqcap \mathsf{Female})\\
\mathsf{Mother} &\equiv (\mathsf{Person} \sqcap \mathsf{Female}) \sqcap \exists \mathsf{hasChild}.\mathsf{Person}\\
\mathsf{Father} &\equiv (\mathsf{Person} \sqcap \neg(\mathsf{Person} \sqcap \mathsf{Female})) \sqcap \exists \mathsf{hasChild}.\mathsf{Person}\\
\mathsf{Parent} &\equiv ((\mathsf{Person} \sqcap \neg(\mathsf{Person} \sqcap \mathsf{Female})) \sqcap \exists \mathsf{hasChild}.\mathsf{Person})\\
&\quad \sqcup ((\mathsf{Person} \sqcap \mathsf{Female}) \sqcap \exists \mathsf{hasChild}.\mathsf{Person})\\
\mathsf{Grandmother} &\equiv ((\mathsf{Person} \sqcap \mathsf{Female}) \sqcap \exists \mathsf{hasChild}.\mathsf{Person})\\
&\quad \sqcap \exists \mathsf{hasChild}.(((\mathsf{Person} \sqcap \neg(\mathsf{Person} \sqcap \mathsf{Female}))\\
&\qquad\qquad \sqcap \exists \mathsf{hasChild}.\mathsf{Person})\\
&\qquad\qquad \sqcup ((\mathsf{Person} \sqcap \mathsf{Female})\\
&\qquad\qquad\quad \sqcap \exists \mathsf{hasChild}.\mathsf{Person}))\\
\mathsf{MotherWithManyChildren} &\equiv ((\mathsf{Person} \sqcap \mathsf{Female}) \sqcap \exists \mathsf{hasChild}.\mathsf{Person}) \sqcap \geqslant 3\, \mathsf{hasChild}\\
\mathsf{MotherWithoutDaughter} &\equiv ((\mathsf{Person} \sqcap \mathsf{Female}) \sqcap \exists \mathsf{hasChild}.\mathsf{Person})\\
&\quad \sqcap \forall \mathsf{hasChild}.(\neg(\mathsf{Person} \sqcap \mathsf{Female}))\\
\mathsf{Wife} &\equiv (\mathsf{Person} \sqcap \mathsf{Female})\\
&\quad \sqcap \exists \mathsf{hasHusband}.(\mathsf{Person} \sqcap \neg(\mathsf{Person} \sqcap \mathsf{Female}))
\end{aligned}
$$

Statements about individuals

- So far axioms about concepts and roles (*TBox*)
- Also two types of axioms about individuals (*ABox*):
  - *class assertion* (using a *concept*):

    Märtha : Female ⊓ Royal
  - *role assertion* (using a *role*):

    <Märtha, EmmaTallulah> : hasChild

    <Märtha, HaakonMagnus> : hasBrother
- *Axioms* about concepts/roles and *assertion axioms* about individuals/roles are used to create knowledge bases:
  - concepts, roles in the *TBox* (aka “the tags”)
  - individuals, roles in the *ABox* (“the tagged data”)

Syntaxes differ a bit...

- So far axioms about concepts and roles (*TBox*)
- Also two types of axioms about individuals (*ABox*):
  - – *class assertion* (using a *concept*):
    `Female(Märtha),(Female ⊓ Royal)(Märtha)`
  - – *role assertion* (using a *role*):
    `hasChild(Märtha, EmmaTallulah)`
    `hasBrother(Märtha, HaakonMagnus)`
- *Axioms* about concepts/roles and *assertion axioms* about individuals/roles are used to create knowledge bases:
  - concepts, roles in the *TBox* (aka “the tags”)
  - individuals, roles in the *ABox* (“the tagged data”)

Summary of axioms

- Terminology axioms (in the TBox):
  - subsumptions: $C \sqsubseteq D$
  - equivalences: $C \equiv D$

    corresponds to: $C \sqsubseteq D$, $D \sqsubseteq C$
  - definitions: $A \doteq C$

C and D are *expressions*, A is a *defined concept*!

- Individual assertion axioms (in the ABox):
  - class assertions: a:C
  - role assertions: <a,b>:R

a and b are *individuals*. R is a *role*!

- A knowledge base $\mathcal{K} = (\mathcal{T}, \mathcal{A})$ consists of
  - TBox: $\mathcal{T}$ and ABox: $\mathcal{A}$

Decision Problems

Reasoning over knowledge bases

- *What more can we do with ontologies?*
- For example:
  - a *security ontology* that describes an organisation and its computer systems as concepts, roles and individuals
  - can answer *competency questions*, e.g.:
    - are all the *security levels* subclasses of one another?
    - what is the highest security level of a *temporary*?
    - what is the necessary security level of a *component*?
    - which employees have access to *critical data*?
    - for which *security roles* is an employee qualified?
    - which individuals are *suspicious persons*?
  - *DL offers a clear and compact way or representing and reasoning about questions such as these!*

Decision problems

- A computational problem with a yes/no answer, e.g.
  - is C *subsumed* by D ($\mathcal{K} \models \mathtt{C} \sqsubseteq \mathtt{D}$)?
  - are C and D *consistent* ($\mathcal{K} \models \mathtt{a:(C} \sqcap \mathtt{D)}$)?
  - does *a* *belong* to C ($\mathcal{K} \models \mathtt{a:C}$)?
  - is *a* *R-related* to *b* ($\mathcal{K} \models \mathtt{\langle a,b \rangle :R}$)?
- *Decidability ("bestembarhet")*:
  - we can always calculate the yes/no answer in finite time
- *Semi-decidability ("semibestembarhet")*:
  - we can always calculate a yes-answer in finite time,
    ...but not always a no-answer
- *Undecidability ("ubestembarhet"):*
  - we cannot always calculate the answer in finite time

C and D are classes,
a and b are individuals.
R is a role!

Decision problems for concepts

- There are four basic decision problems for concepts:
  - consistency: whether there is an individual $\mathtt{a}$ so that

    $\mathcal{T} \models \mathtt{a{:}C}$,

    $\mathcal{T} \not\models \mathtt{C} \sqsubseteq \bot$
  - subsumption: $\mathcal{T} \models \mathtt{C} \sqsubseteq \mathtt{D}$,

    $\mathcal{T} \models \mathtt{C} \sqcap \neg\mathtt{D} \sqsubseteq \bot$
  - equivalence: $\mathcal{T} \models \mathtt{C} \equiv \mathtt{D}$ *or* $\mathtt{C} \equiv_{\mathcal{T}} \mathtt{D}$,

    $\mathcal{T} \models \mathtt{C} \sqsubseteq \mathtt{D},\ \mathtt{D} \sqsubseteq \mathtt{C}$
  - disjunction: $\mathcal{T} \models \mathtt{C} \sqcap \mathtt{D} \sqsubseteq \bot$
- *All four can be reduced to subsumption or consistency!*
- $\mathcal{T}$ can be *emptied*, by expanding all its concepts

Decision problems for individuals

- Decision problems for individuals and roles:
  - instance checking: $\mathcal{A} \models$ **a:C**,

    $\not\models \mathcal{A} \sqcap \neg$**(a:C)**

    is individual ***a*** *member of class/concept* ***C****?*
  - role checking: $\mathcal{A} \models$ **<a,b>:R**,

    $\not\models \mathcal{A} \sqcap \neg$**(<a,b>:R)**

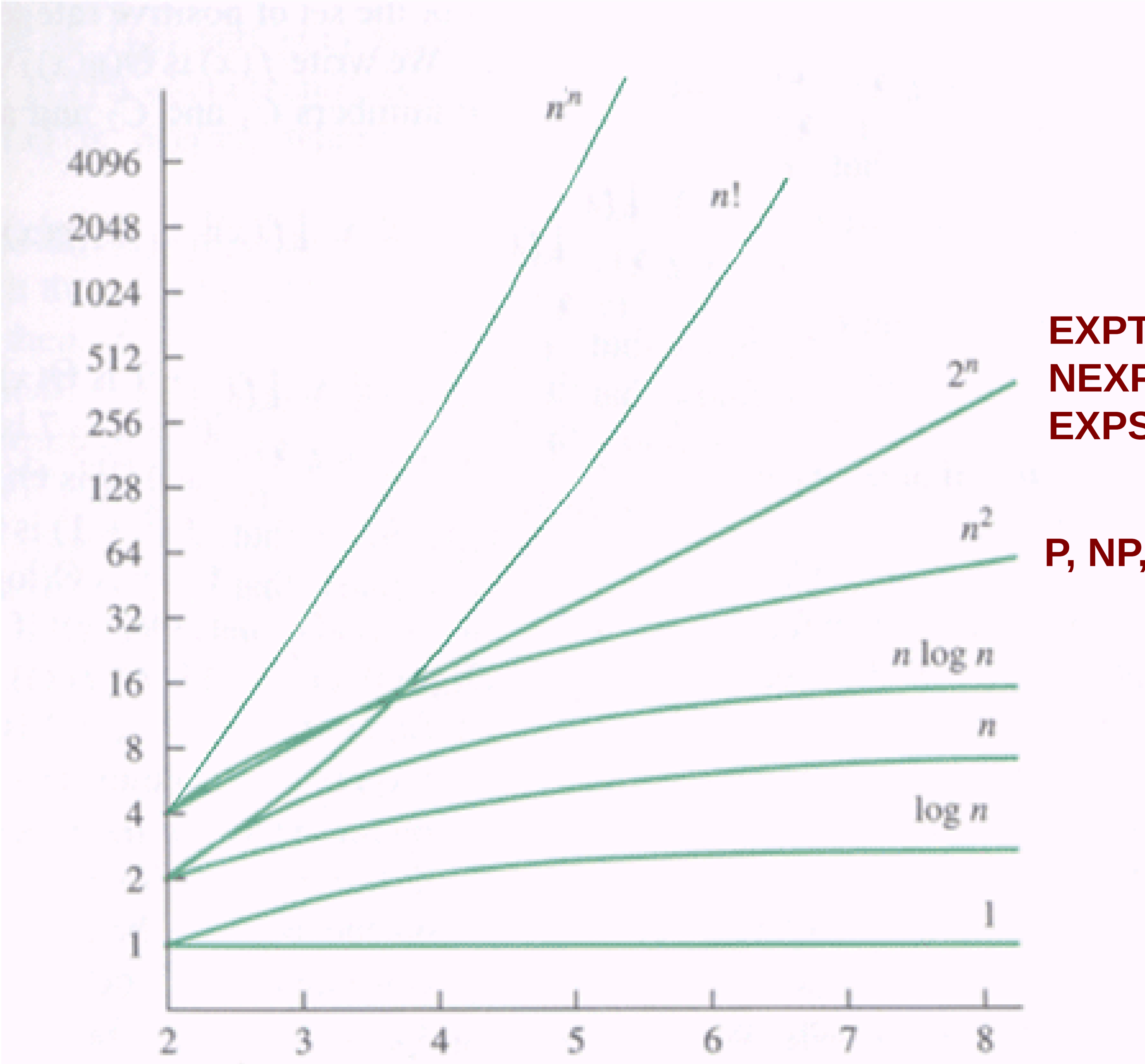
    is individual ***a*** ***R****-related to individual* ***b****?*
  - classifications (not yes/no):

    to which classes/concepts does **a** belong?

    all individuals of class/concept **C**?
- *Everything boils down to consistency checking for ABoxes*
  - ...under certain (rather weak) conditions

Complexity

- Decidability is often necessary
  - but not enough
  - we also want a decision “in reasonable time”
  - different DL-variants have different *complexity*
  - many different *complexity classes*
    - polynomial (**P**), exponential (**EXP**)...
    - ...in time and space
- *Tractable* (or *feasible*) complexity
  - acceptable complexity for large knowledge bases
  - typically *polynomial* complexity (**P**)
  - complexity grows $O(n^c)$ of problem size n



EXPTIME,
NEXPTIME,
EXPSPACE

P, NP, PSPACE

DL-complexity

- We have presented many DL-notations
  - *do not* use all at the same time!
  - that gives high complexity
  - which is why we have different OWL Profiles
- Complexity calculator on the net:
  - *Complexity of reasoning in Description Logics* http://www.cs.man.ac.uk/~ezolin/dl/

OWL DL

Relation to OWL

- OWL DL and description logic are closely matched
  - everything in OWL DL has a DL-counterpart
  - most everything in DL can be expressed in OWL DL
- DL is a family of logic systems:
  - some of them correspond to particular OWL profiles
  - OWL1 DL: $\mathcal{SHOIN}^{(\mathcal{D})}$
  - OWL2 DL: $\mathcal{SROIQ}^{(\mathcal{D})}$

OWL profiles revisited

- OWL "1" (2002):
  - *OWL Full – "anything goes"*
  - OWL DL – fragment of OWL Full,
    - formal semantics through *description logic*
  - OWL Lite – simple fragment of OWL DL, not much used
- OWL 2 (2008):
  - *OWL2 Full – "anything goes"*
  - OWL2 DL – fragment of OWL2 full, extension of OWL DL
    - OWL2 EL – quick reasoning, fragment of OWL2 DL
    - OWL2 RL – rule language, fragment of OWL2 DL
      - OWL LD – linked data, fragment of OWL2 RL
    - OWL2 QL – query language, fragment of OWL2 DL

And there is more...

- A few other constructions
- Formal definitions of
  - syntax (rules for valid expressions, reasoning)
  - semantics (rules for interpreting expressions)
- Tools and techniques
- Lots of applications

Protege-OWL

Protege-OWL

- Extension of Protegé
  - ordinary Protegé supports *frames*
  - Protegé-OWL
    - reuses much of the Protege-Frames GUI

Old Protege-OWL (3.x and older)

- Supported OWL 1.1:
  - used *Jena* internally
  - wrapped Jena's API with a *Protege-OWL API*
    - uses Jena's graph metaphor
    - you “create the ontology as a graph”
  - many plug-ins:
    - SWRL, Jess, reasoning...
  - still available,
    - but not so actively developed

Protege-OWL 4 and later

- Supports OWL 2:
  - complete reimplementation of internals
  - *not* based on Jena
  - offers a dedicated *OWL API* (in Java)
    - description-logic metaphor
    - you "build the ontology from axioms"
  - more and more plug-ins
  - most OWL DL reasoners have moved to the OWL API

Manchester OWL syntax

Manchester OWL-syntax

- A simple DL notation without special symbols
  - used by Protege-OWL to construct classes
  - similar to DL syntax
- **Class: Woman**
  EquivalentTo: Human and Female
- **Class: Man**
  EquivalentTo: Human and not Female
- **Class: Parent**
  EquivalentTo: Mother or Father
- Can be used to *serialise* complete ontologies
  - ...we will look mostly at TBox expressions
- http://www.w3.org/TR/owl2-manchester-syntax/

Comparison

- DL:

  Male ≐ Human ⊓ ¬Female

- Machester OWL:

```
Class: Man
    EquivalentTo: Human and not Female
```

- TURTLE:

```
family:Man owl:equivalentClass
    owl:intersectionOf (
        family:Human
        [   a owl:Class ;
            owl:complementOf family:Woman
        ]
    ) .
```

Roles in Manchester OWL syntax

- **Class: Mother**
  EquivalentTo:
  Female and hasChild some owl:Thing
- **Class: Bachelor**
  EquivalentTo:
  Male and not hasSpouse some owl:Thing
- **Class: Uncle**
  EquivalentTo:
  Male and hasSibling some Parent
  - universal concept (top): **owl:Thing**
  - existential restriction: **some**

Null concept in Manchester OWL syntax

- **Class:** <class-name>
  EquivalentTo: Male and Female
  SubClassOf: owl:Nothing
  - null concept (bottom): **owl:Nothing**
  - subsumption (subconcept): **SubClassOf:**
  - equivalence: **EquivalentTo:**
    - ...used both for *definitions* and for *axioms*

More roles in Manchester OWL syntax

- ```
  Class: HappyFather
           EquivalentTo:
           Father and hasChild only Happy
  ```
  - value restriction: **only**
- ```
  Class: MotherOfOne
           EquivalentTo: Mother and
                            hasChild exactly 1
  ```
- ```
  Class: Bigamist
           EquivalentTo: hasSpouse min 2
  ```
  - number restriction: **exactly**, **min**, **max**
- ```
  Class: Narcissist
           EquivalentTo: loves some Self
  ```

Inverse, symmetric and transitive roles

- **Class: Child**
  ```
  EquivalentTo:
  Human and inverse hasChild some owl:Thing
  ```
- **Class: hasParent**
  ```
  EquivalentTo: inverse hasChild
  ```
- **ObjectProperty: hasSibling**
  ```
  Characteristic: Symmetric
  ```
- **ObjectProperty: hasAncestor**
  ```
  Characteristic: Transitive
  ```
- inverse role: **inverse**
  - symmetric role:
    Characteristic: SymmetricProperty
  - transitive role:
    Characteristic: TransitiveProperty