

# DLs, from FL to OWL

For CMCS498w

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# DL Parts

- The Concept/Class Expression Language (CL)
  - Concept constructors (&, v...)
  - Gives names to DLs (e.g., ALC, SHIF, SHION)
- The TBox
  - Relations between class names and expressions
  - Identified as “the Ontology”
- The ABox
  - The “fact base” or “KB”
- The Rbox
  - Describes relations between and properties of roles

# The Class Expression language

- Concept Names (C, D, E...)
- Concept constructors
  - Boolean (&, v, ~)
  - Quantifiers ( $\forall$ ,  $\exists$ )
  - Numeric quantifiers (min/max cardinality)
- Class expression == Universally quantified proposition with one free variable
  - $C \ \& \ D == (\forall x)(Cx \ \& \ Dx)$
  - $C \ \& \ \exists P.D == (\forall x)(Cx \ \& \ (\exists y)(P(x,y) \ \& \ Dy))$
  - $\exists P.(D \ \& \ \forall P.C) ==$ 
    - $(\forall x)((\exists y)(P(x,y) \ \& \ Dy \ \& \ \forall z(P(y,z) \rightarrow Cz))$
- Expressions can be nested and composed, applied to individuals, and appear in concept inclusion axioms

# The ABox

- The “assertional” box
- Claims about *individuals*
  - Class membership
  - Relations to other individuals
- (Mostly) *ground* propositions
  - $b:C$ ,  $c:(D \ \& \ C)$ ,  $d:\forall P.C$
  - $R(b, c)$ ,  $P(d, e)$
- Typically very inexpressive

# The TBox

- The “terminological” box
- CEs can only appear:
  - In concept assertions (a:C)
  - In concept axioms (C subClassOf D)
- Definitions
  - *like* equivalentClass, but where
    - lhs is atomic
    - TBox is definitorial
- Partial axioms (subClassOf)
  - Specializations
  - General Concept Inclusion (GCI) axioms
  - With GCIs, definitions reduced to pairs of inclusions

# The RBox

- Property inclusion axioms
- Inverse and Transitivity (I and R+)
- Role constructors
  - $\&$ ,  $\vee$ ,  $\sim$ , identity, transitive closure
  - Not common, very expressive
  - Remember! Just 2-place predicates
    - Thus, normal propositional connectives work

# $FL_0, FL^-, AL$

- $FL_0$ 
  - Atomic concepts (C, D, E)
  - Conjunction and universal quantification ( $\&$ ,  $\forall$ )
- $FL^-$ 
  - Existential quantification (min1,  $\exists$ )
- $AL$ 
  - Atomic negation ( $\sim$ )
  - Top and Bottom (Thing and Nothing)
    - Bottom is easy:  $C \ \& \ \sim C$

# From AL to ALC

- E, U, & C
  - Existential *restriction* ( $\exists P.C$ )
  - Disjunction (Union,  $\vee$ )
  - Full negation
    - EU if C
      - $C \vee D$  iff  $\sim(\sim C \ \& \ \sim D)$
      - $\exists P.C$  iff  $\sim \forall P.\sim C$
    - C if EU
      - $\sim \forall P.C$  iff  $\exists P.\sim C$  and  $\sim \exists P.C$  iff  $\forall P.\sim C$
      - $\sim(C \ \& \ D)$  iff  $\sim C \ \vee \ \sim D$  and  $\sim(C \ \vee \ D)$  iff  $\sim C \ \& \ \sim D$
- N: Number restrictions
  - What are the 8 distinct AL[U][E][N] languages?

# From ALC to OWL-Lite/DL

- Concept Expression Language
  - Lite (SHIF(D))
    - S == ALCR+ (transitive roles)
    - H == Role hierarchy
      - H & R+ yeilds General TBoxes
    - I == Inverse
    - F == Functional Roles (min/max/card 0-1)
    - (D) DatatypeProperties
  - DL (SHION(D))
    - N == Number restrictions
    - O == Nominals (oneOf/hasValue)
  - DAML+OIL (SHIOQ(D))
    - Q == Qualified Number Restrictions
- TBox
  - General TBoxes/inclusion axioms

# Reasoning

- Concepts
  - C is satisfiable (or not)
  - C is subsumed by D
- Individuals
  - The ABox is (in)consistent
  - Instance check
- Core Services
  - Concept subsumption & satisfiability
  - Abox/KB consistency & instance checking
  - Retrieval
  - Realization
  - (On the SemWeb) Entailment

# Reasoning Procedures

- Structural Subsumption
  - Incomplete for all but most inexpressive DLs
- Tableau
  - Sound, complete, decidable, optimizable for a wide range of DLs
  - Exploit modal logic research
  - Composable, understandable, comes out of the semantics
- Resolution
  - Much less common for specialized DL reasoners
  - Highly optimized FOL resolution engines
  - Inexpressive Datalogy/Rule/Horn Clause engines

# Reading

- DLHB Chapter 2:
  - <http://www.cs.man.ac.uk/~franconi/dl/course/dlhb/dlhb-02.pdf>
  - Review prior sections
  - Sections 2.2.4 (2.2.4.4 is important, but tricky, and not immediate critical path. 2.3.1 (skim), 2.3.2 (study))
- From SHIQ and RDFS to OWL
  - <http://www.cs.man.ac.uk/~horrocks/Publications/download/2003/HoPH03a.pdf>
  - Section 7.2 (the semantics)
  - We'll be discussing the rest as well, but not next time!