OWL

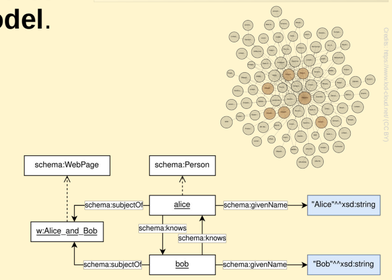
Web **O**ntology **L**anguage

Data (ABox)

Knowledge is expressed on the Web in the Resource Description Framework (RDF), a **graph data model**.

RDF Model		
Node	URI	Universally named resource
	Blank node	Anonymous resource
	Literal	String, number, date, etc.
Triple	3-tuple of the form (subject, predicate, object)	
Graph	Set of RDF triples	

The Linked Open Data (LOD) cloud is a collection of more than 1,5k interlinked RDF graphs.



representation in the Chowlk visual notation

A. Hogan *et al.*, *Knowledge Graphs*, Morgan & Claypool, 2021.

chapters 3 and 4 about OWL

Schema (TBox)

Web ontologies are made of a **vocabulary** and logical **axioms** over that vocabulary. The underlying formalism of OWL is a Description Logics (DL) called SROIQ.

Vocabulary	
Class	Set of resources
Object property	Relation between two resources
Datatype property	Relation between a resource and a literal
Named individual	Same as URI node

Class Expressions	**Prop. Expressions**
C, D	p, q
`owl:Thing`, `owl:Nothing`	**inverse** p
not C, C **and** D, C **or** D	p **o** q
p **some** C, p **only** C	
p (**min** | **max** | **exactly**) n C	
p **value** i	
p **Self**	
{i, j, k, ...}	

defs. given in the OWL Manchester syntax

Axioms
C **SubClassOf:** D
p **Domain**: C p **Range**: D
p **SubPropertyOf**: q

1M+ classes and properties can be found in the Linked Open Vocabulary (LOV) cloud and in OntoPortal repositories.

F. Baader, D. Calvanese, D. L. McGuinness, D. Nardi, P. F. Patel-Schneider (Eds.), *The Description Logic Handbook : Theory, Implementation and Applications*, 2nd edition, Cambridge University Press, 2010.

with chapter 1 as quick overview

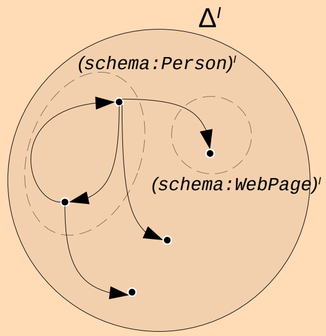
Sebastian Rudolph, *Foundations of Description Logics*, 2011.

Semantics

OWL has model-theoretic semantics: terms defined in the vocabulary map to a domain of **interpretation**, whose structure is constrained by ontological axioms.

Interpretation Function ($\cdot^I$)	
`owl:Thing`	Δ^I
`owl:Nothing`	$\varnothing$
(**not** C)^I	$\Delta^I \setminus C^I$
(C **and** D)^I	$C^I \cap D^I$
(C **or** D)^I	$C^I \cup D^I$
(p **some** C)^I	$\{ r_1 \mid \exists.r_2, (r_1, r_2) \in p^I \text{ and } r_2 \in C^I \}$
(p **only** C)^I	$\{ r_1 \mid \forall.r_2, (r_1, r_2) \notin p^I \text{ or } r_2 \in C^I \}$
(p **value** i)^I	$\{ r_1 \mid \exists.i^I (r_1, i^I) \in p^I \}$
(p **Self**)^I	$\{ r \mid (r, r) \in p^I \}$
({i, j, k, ...})^I	$\{i^I, j^I, k^I, ...\}$
(**inverse** p)^I	$\{ (r_1, r_2) \mid (r_2, r_1) \in p^I \}$
(p **o** q)^I	$\{ (r_1, r_3) \mid (r_1, r_2) \in p^I \text{ and } (r_2, r_3) \in p^I \}$

full def. in Rudolph (p. 20)



$\mathcal{I} \models \alpha$ can read either as 'I models axiom α' or as 'I satisfies axiom α'

Satisfiability	
$\mathcal{I} \models$ (C **SubClassOf**: D)	$C^I \subseteq D^I$
$\mathcal{I} \models$ (p **Domain**: C)	$r_1 \in C^I$ for all $(r_1, r_2) \in p^I$
$\mathcal{I} \models$ (p **Range**: D)	$r_2 \in D^I$ for all $(r_1, r_2) \in p^I$
$\mathcal{I} \models$ (p **SubPropertyOf**: q)	$p^I \subseteq q^I$

full def. in Rudolph (p. 22)

Horn logic / Datalog

Knowledge is often expressed in a **rule langage** such as Datalog. Such langages are all based on the properties of Horn clauses.

The intersection of Horn logic and SROIQ is called DL rules. Rules beyond this fragment are however commonly used in Web ontologies via the Semantic Web Rule Language (SWRL). SWRL rules must be DL-safe.

Rule-based inference

Reasoning with rules is generally fast. Reasoning procedures are referred to as consequence-based reasoning and consist in applying a small set of rewriting rules until a **fixed point** is reached.

Modal logics

OWL can be seen as a notational variant of various modal logics. The domain of interpretation then corresponds to a set of **possible worlds** and binary relations express **transitions** across possible worlds (e.g. over time).

Tableaux algorithm

The most common reasoning procedure for OWL consists in **constructing a model** of a knowledge graph (with axioms) until a trivial contradiction is found or the model satisfies all axioms.

Other procedures based on **automata** have also been devised.

Reasoners

Several well-known OWL reasoners are being commercially used.

Subsets of SROIQ, identified as OWL profiles, have desired properties w.r.t. reasoning complexity.

Profile	**Reasoner**
DL (SROIQ)	Pellet
	HermiT
	FaCT++
RL (Rule language)	RDFox
EL (Existential language)	ELK
	CEL
QL (Query language)	ontop

more reasoners on the OWL@Manchester website

All DL fragments, with reasoning properties, are listed on Evgeny Zolin's website.