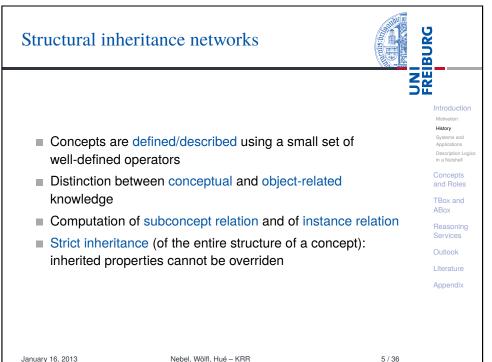
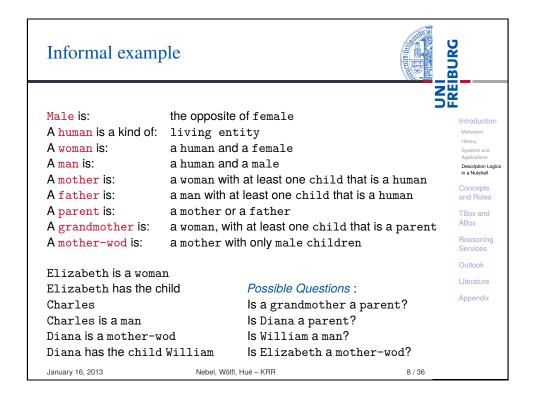


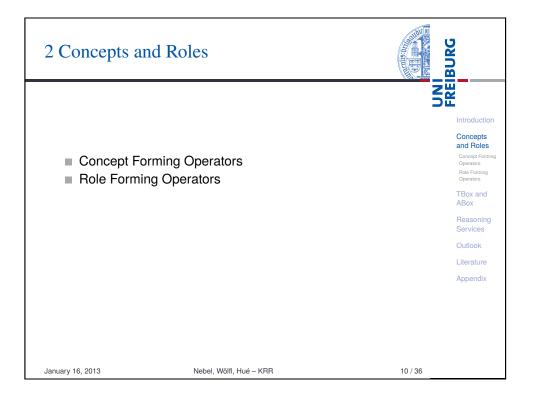
1 Introduction	n	
-	nd Applications Logics in a Nutshell	Introduction Motivation History Systems and Applications Description Logics in a Nutshell Concepts and Roles TBox and ABox Reasoning Services Outlook Literature Appendix
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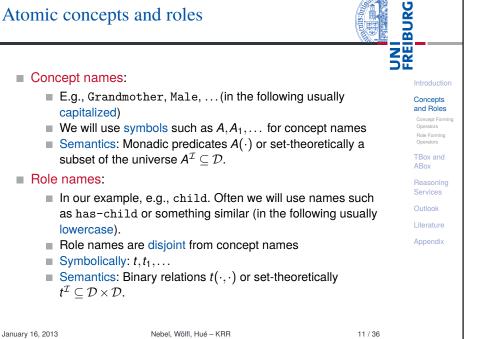
⊐ IC,	Introduction Motivation History Systems and Applications Description Logic
IC,	Motivation History Systems and Applications Description Logic
IC,	Systems and Applications Description Logic
IC,	Applications Description Logic
	in a Nutshell
	Concepts and Roles
	TBox and
	ABox
	Reasoning
	Services
	Outlook
	Literature
	Appendix

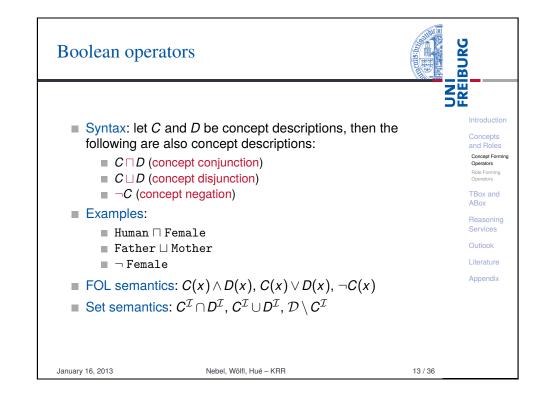


Description logics		NN REBURG
frame-based langua languages Description Logics to describe con to introduce the structure it (TBc to introduce obj terminology (AE	cepts using complex descriptions, terminology of an application and to (x), ects and relate them to the introduced	Concepts and Roles TBox and ABox Reasoning Services Outlook Literature
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Atomic concepts and roles





Concept and role description	BURG
 From (atomic) concept and role names, complex concept and role descriptions can be created In our example, e.g., "Human and Female." Symbolically: <i>C</i> for concept descriptions and <i>r</i> for role descriptions 	Introduction Concepts and Roles Concept Forming Operators Role Forming
Which particular constructs are available depends on the chosen description logic!	Operators TBox and ABox Reasoning
 FOL semantics: A concept description C corresponds to a formula C(x) with the free variable x. Similarly with role descriptions r: they correspond to formulae r(x,y) with free variables x,y. Set semantics: 	Services Outlook Literature Appendix
$\begin{aligned} \mathcal{C}^{\mathcal{I}} &= \{ d \in \mathcal{D} : \mathcal{C}(d) \text{ "is true in" } \mathcal{I} \} \\ r^{\mathcal{I}} &= \big\{ (d, e) \in \mathcal{D}^2 : r(d, e) \text{ "is true in" } \mathcal{I} \big\} _{\text{Nebel, Wölfl, Hué - KRR}} &= 12/36 \end{aligned}$	

Role restriction	S		
Motivation:		N	
Often we w	ant to describe something by restr	ricting the	Introduction
	llers" of a role, e.g. Mother-wod.		Concepts
	s we want to say that there is at lea	ist a filler of a	Concept Forming Operators
	ype, e.g. Grandmother htifiers that range over the role-f	illers	Role Forming Operators
	/has-child.Man		TBox and
■ Woman 🗆 🗄	nas-child.Parent		ABox Reasoning
FOL semantics	:		Services
(3	$\exists r.C)(x) = \exists y(r(x,y) \land C(y))$		Outlook
	$\forall r.C)(x) = \forall y (r(x,y) \rightarrow C(y))$		Literature
($(I,C)(x) \equiv \forall y (I(x,y) \rightarrow C(y))$		Appendix
Set semantics:			
$(\exists r.C)^{\mathcal{I}} = ig d$	$\in \mathcal{D}$: there ex. some <i>e</i> s.t. (<i>d</i> , <i>e</i>	$(e) \in r^{\mathcal{I}} \land e \in \mathcal{C}^{\mathcal{I}} \}$	
$(orall r. \mathcal{C})^\mathcal{I} = ig d$ e	$\in \mathcal{D}$: for each $m{e}$ with $(m{d},m{e})\in r^2$	$^{\mathcal{I}},~oldsymbol{e}\in \mathcal{C}^{\mathcal{I}}ig\}$	
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Cardinality restriction	BURG
Motivation:	i i i i i i i i i i i i i i i i i i i
 Often we want to describe something by restricting the number of possible "fillers" of a role, e.g., a Mother with at 	Introduction Concepts
 least 3 children or at most 2 children. Idea: We restrict the cardinality of the role filler sets: 	and Roles Concept Forming
Mother □ ≥ 3 has-child Mother □ ≤ 2 has-child	Operators Role Forming Operators
FOL semantics:	TBox and ABox
$(\geq n r)(x) = \exists y_1 \dots y_n(r(x,y_1) \wedge \dots \wedge r(x,y_n) \wedge$	Reasoning Services
$y_1 \neq y_2 \wedge \cdots \wedge y_{n-1} \neq y_n$	Outlook
$(\leq n r)(x) = \neg(\geq n+1 r)(x)$	Literature Appendix
Set semantics:	
$(\geq n r)^{\mathcal{I}} = \left\{ \boldsymbol{d} \in \mathcal{D} : \left \left\{ \boldsymbol{e} \in \mathcal{D} : r^{\mathcal{I}}(\boldsymbol{d}, \boldsymbol{e}) \right\} \right \geq n ight\}$	
$(\leq n r)^{\mathcal{I}} = \mathcal{D} \setminus (\geq n+1 r)^{\mathcal{I}}$	

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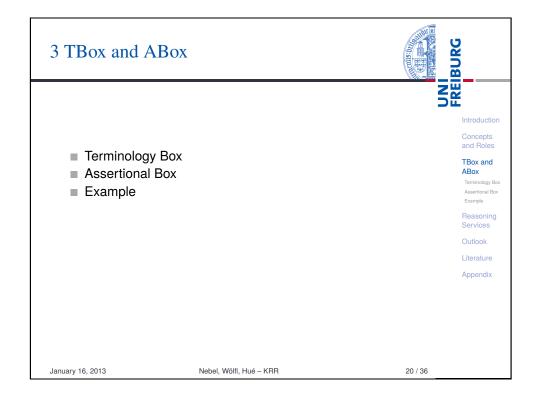
Nebel, Wölfl, Hué – KRR

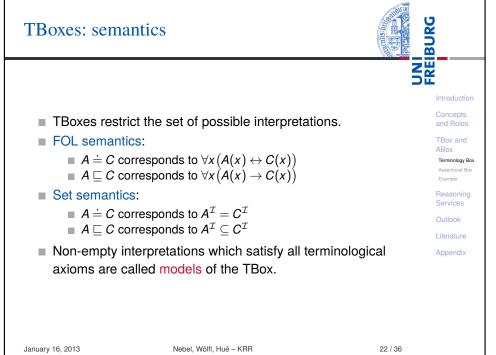
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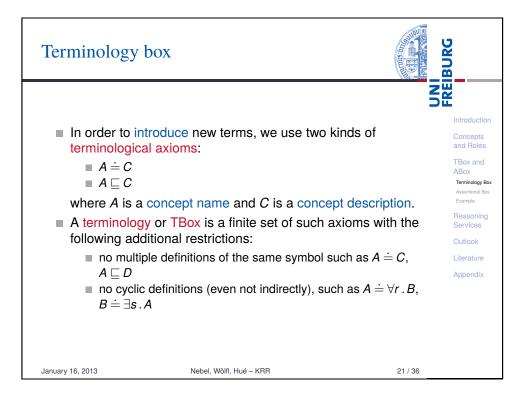
Role composi	tion	aurc
		L. S.
Motivation:		
How can has-chi	we define the role has-grandchil ld?	d given the role Concepts and Roles
Idea: Compo	se roles (as one can compose bi	nary relations)
∎ has-chi	ld • has-child	TBox and ABox
FOL semanti	cs:	Reasoning Services
	$(\pi - 1)(\pi + 1) = \neg - (\pi(\pi - 1) + \pi(\pi - 1))$	Outlook
	$(r \circ s)(x,y) = \exists z(r(x,z) \land s(z,y))$	Literature
Set semantic	s:	Appendix
$(r \circ s)^{\mathcal{I}} = \{$	$f((d,e) \in \mathcal{D}^2 : \exists f \text{ s.t. } (d,f) \in r^{\mathcal{I}} \land$	$(f, e) \in s^{\mathcal{I}} \}$
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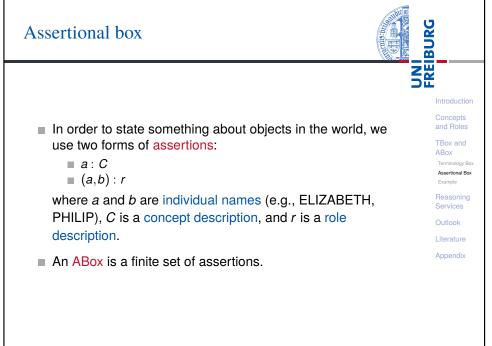
Inverse roles		BURG	
- Mativation		FRN	
Motivation:			duction
How can	we describe the concept "children of	of rich parents"?	epts
Idea: Define relation)	the "inverse" role for a given role	(Ine converse	
, ∎ has-chi	1d ⁻¹	Role F Opera	orming tors
	as-child ⁻¹ .Rich	TBox ABox	
FOL semanti	cs:	Reas	oning ices
	1	Outlo	ook
	$r^{-1}(x,y)=r(y,x)$	Litera	ature
Set semantic	S:	Арре	endix
(/	$(\mathcal{L}^{-1})^{\mathcal{I}} = \left\{ (d, e) \in \mathcal{D}^2 : (e, d) \in r \right\}$	\mathcal{I}	
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Role value map	S		BURG
Motivation:		S S	
How do we	express the concept "women w	ho know all the	Introduction
	neir children"		Concepts and Boles
Idea: Relate ro	le filler sets to each other		Concept Formir Operators
■ Woman 🗆 (h	has-child \circ has-friend \sqsubseteq kn	lows)	Role Forming Operators
FOL semantics	:		TBox and ABox
(<i>r</i>	$\sqsubseteq s)(x) = \forall y(r(x,y) \rightarrow s(x,y))$	y))	Reasoning Services
		.,	Outlook
Set semantics:	Let $r^{\mathcal{I}}(d) = \{e : r^{\mathcal{I}}(d, e)\}.$		Literature
(r 🗆	$(\mathbf{z},\mathbf{s})^\mathcal{I} = \left\{ \mathbf{d} \in \mathcal{D} : \mathbf{r}^\mathcal{I}(\mathbf{d}) \subseteq \mathbf{s}^\mathcal{I} \right\}$	$(d)\}$	Appendix
	e maps lead to undecidability	y of satisfiability	
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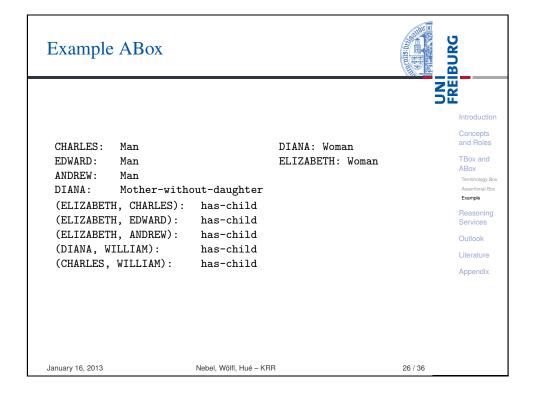




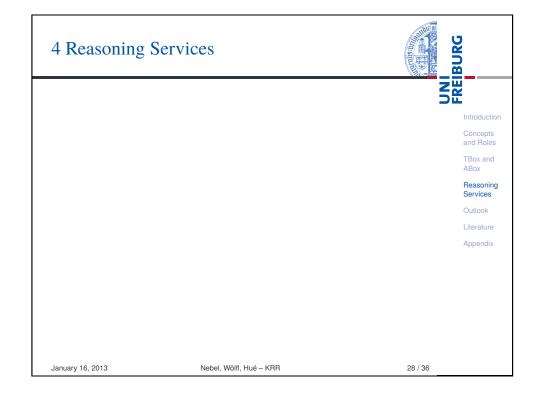


ABo

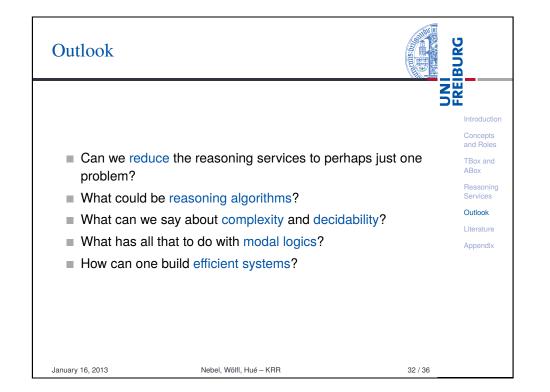
ABoxes: semantics		BURG
Individual names are interpreted as elements of the universe under the unique-name-assumption, i.e., different objects.	erent	Introduction Concepts and Roles
 Assertions express that an object is an instance of a concept or that two objects are related by a role. FOL semantics: a : C corresponds to C(a) (a,b) : r corresponds to r(a,b) 		TBox and ABox Terminology Box Assertional Box Example Reasoning Services
Set semantics: $a^{\mathcal{I}} \in D$ $a : C$ corresponds to $a^{\mathcal{I}} \in C^{\mathcal{I}}$ $(a,b) : r$ corresponds to $(a^{\mathcal{I}}, b^{\mathcal{I}}) \in r^{\mathcal{I}}$		Outlook Literature Appendix
 Models of an ABox and of ABox + TBox can be define analogously to models of a TBox. January 16, 2013 Nebel, Wölfl, Hué - KRR 	24 / 36	



Example TBo	ЭХ	ZEBURG
	Male = ¬Female Human ⊑ Living_entity Woman = Human ⊓ Female Man = Human ⊓ Male Mother = Woman ⊓ ∃has-ch Father = Man ⊓ ∃has-ch Parent = Father ⊔ Mothe Grandmother = Woman ⊓ ∃has-ch hout-daughter = Mother ⊓ ∀has-ch many-children = Mother ⊓ (≥ 3ha	hild.Human Earpie Id.Human Reasoning Services er Outlook hild.Parent Literature
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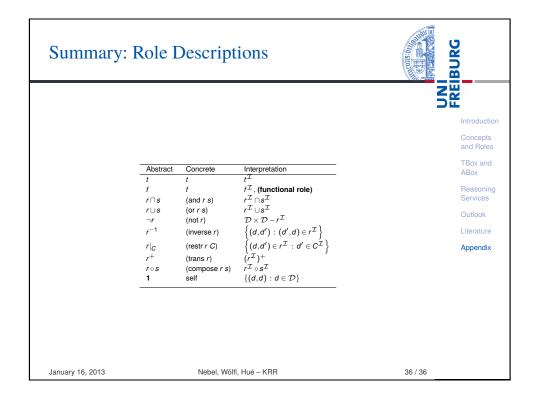
Some reasonin	g services	BURG
		FRE
Does a descri	ption C make sense at all, i.e., is	it satisfiable? Introduction
•	cription <i>C</i> is satisfiable, if there \mathfrak{C} such that $\mathcal{C}^{\mathcal{I}} \neq \emptyset$.	and Roles
Is one concep	t a specialization of another one	TBox and ABox
subsumed?		Reasoning Services
C is subsume interpretations	d by D (in symbols $C \sqsubseteq D$) if we $C^{\mathcal{I}} \subseteq D^{\mathcal{I}}$.	have for all Outlook Literature
	ce of a concept <i>C</i> ? ce of <i>C</i> if for all interpretations, w	Appendix /e have
	uestions can be posed with or w ne possible interpretations.	vithout a TBox
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5 Outlook		BURG
		FRE
		Introduction
		Concepts and Roles
		TBox and ABox
		Reasoning Services
		Outlook
		Literature
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Literature I		
Patel-Schneider. The Description Applications,	vanese, D. L. McGuinness, D. Nardi, Logic Handbook: Theory, Impleme rsity Press, Cambridge, UK, 2003.	Concepts
An overview of the	an and James G. Schmolze. • KL-ONE knowledge representation • 9(2):171–216, April 1985.	- Outlook
	ns-Jürgen Bürckert, Jochen Heinsoh Müller, Bernhard Nebel, Werner Nut	Appendix
terminological log	International Workshop on Termi	
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		Concepts and Roles
		TBox and ABox
	and Revision in Hybrid Representation Systems.	Reasoning Services
	es in Artificial Intelligence 422. Springer-Verlag, Ber	rlin, Outlook
Heidelberg, New	/ York, 1990.	Literature
		Appendix



 y. Conc	ept desc	criptions		2 C
			Z	
Abstract	Concrete	Interpretation	5	Introductio
A C ⊓ D C ⊔ D	A (and C D) (or C D)	$\begin{array}{c} A^{\mathcal{I}} \\ C^{\mathcal{I}} \cap D^{\mathcal{I}} \\ C^{\mathcal{I}} \cup D^{\mathcal{I}} \end{array}$		Concepts and Roles
¬C ∀r.C	(not <i>C</i>) (all <i>r C</i>)	$ \begin{array}{l} \mathcal{D} - \mathcal{C}^{\mathcal{I}} \\ \left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \subseteq \mathcal{C}^{\mathcal{I}} \right\} \end{array} $		TBox and ABox
∃r	(some r)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \neq \emptyset \right\}$		Reasoning
\geq n r	(atleast n r)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \geq n \right\}$		Services
$\leq nr$	(atmost n r)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \le n \right\}$		Outlook
∃r.C	(some r C)	$\left\{ \boldsymbol{d} \in \mathcal{D} : \boldsymbol{r}^{\mathcal{I}}(\boldsymbol{d}) \cap \boldsymbol{C}^{\mathcal{I}} \neq \boldsymbol{\emptyset} \right\}$		Literature
≥nr.C ≤nr.C	(atleast <i>n r C</i>) (atmost <i>n r C</i>)	$ \begin{cases} d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}} \ge n \\ d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}} \le n \end{cases} $		Appendix
$r \doteq s$	(eq r s)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) = s^{\mathcal{I}}(d) \right\}$		
$r \neq s$	(neq <i>r s</i>)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \neq s^{\mathcal{I}}(d) \right\}$		
$r \sqsubseteq s$	(subset r s)	$\left\{ oldsymbol{d} \in \mathcal{D} : r^\mathcal{I}(oldsymbol{d}) \subseteq oldsymbol{s}^\mathcal{I}(oldsymbol{d}) ight\}$		
$g \stackrel{.}{=} h$	(eq <i>g h</i>)	$\left\{ d \in \mathcal{D} : g^{\mathcal{I}}(d) = h^{\mathcal{I}}(d) eq \theta ight\}$		
g eq h	(neq <i>g h</i>)	$\left\{ oldsymbol{d} \in \mathcal{D} : \emptyset eq oldsymbol{g}^{\mathcal{I}}(oldsymbol{d}) eq oldsymbol{h}^{\mathcal{I}}(oldsymbol{d}) eq \emptyset ight\}$		
$\{i_1,i_2,\ldots,i_n\}$	(oneof <i>i</i> ₁ <i>i_n</i>)	$\{i_1^{\mathcal{I}}, i_2^{\mathcal{I}}, \dots, i_n^{\mathcal{I}}\}$		