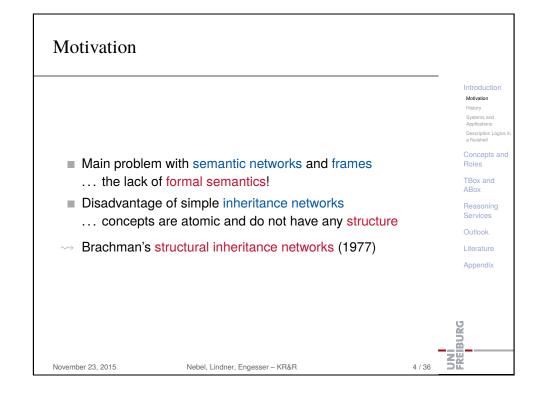
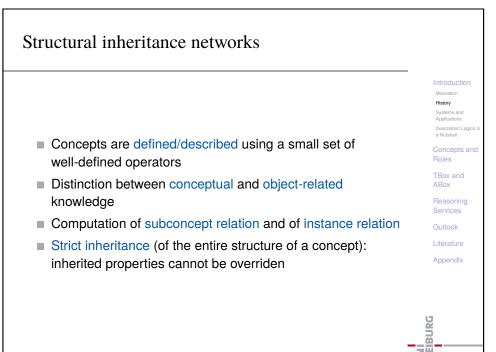
Principles of Knowledge Representation and Reasoning Semantic Networks and Description Logics II: Description Logics – Terminology and Notation

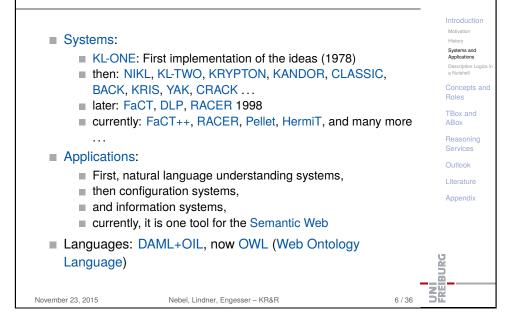


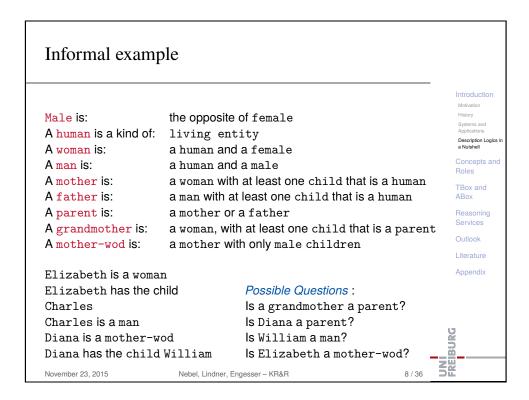
1 Introduction		
<ul> <li>Motivation</li> <li>History</li> <li>Systems and</li> <li>Description L</li> </ul>	Applications .ogics in a Nutshell	Introduction Motivation History Systems and Applications Description Logics in a Nutshell Concepts and Roles TBox and ABox Reasoning Services Outlook Literature Appendix
November 23, 2015	Nebel, Lindner, Engesser – KR&R	3/36

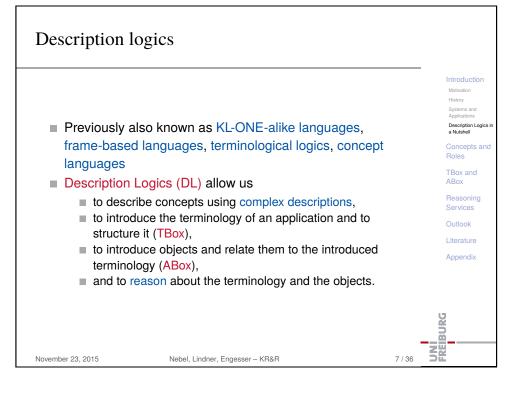


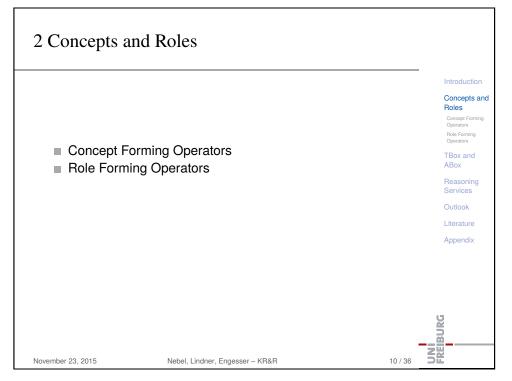
November 23, 2015

## Systems and applications

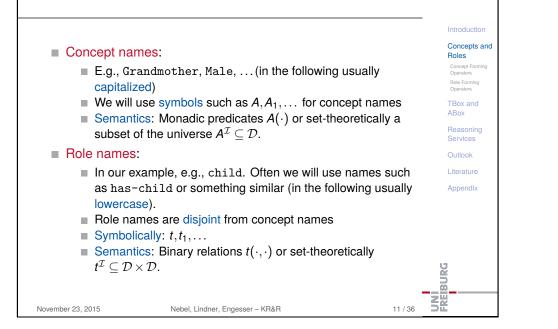


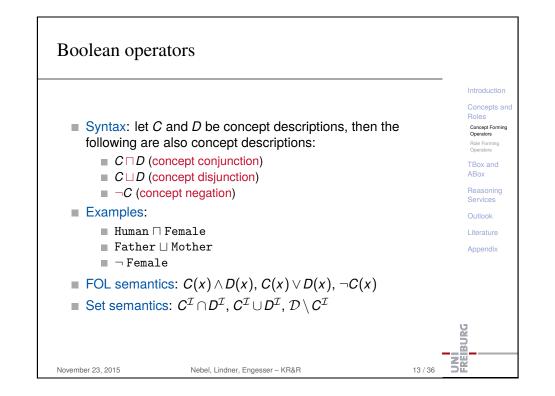






#### Atomic concepts and roles

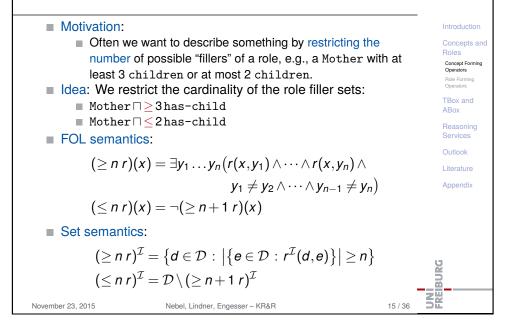


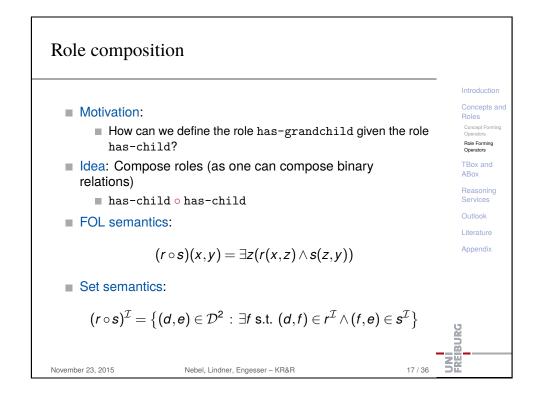


Concept and role description	
<ul> <li>From (atomic) concept and role names, complex concept and role descriptions can be created</li> <li>In our example, e.g., "Human and Female."</li> </ul>	Introduction Concepts and Roles Concept Forming Operators
Symbolically: C for concept descriptions and r for role descriptions	Role Forming Operators TBox and ABox
Which particular constructs are available depends on the chosen description logic!	Reasoning Services Outlook
<ul> <li>FOL semantics: A concept description <i>C</i> corresponds to a formula <i>C</i>(<i>x</i>) with the free variable <i>x</i>. Similarly with role descriptions <i>r</i>: they correspond to formulae <i>r</i>(<i>x</i>,<i>y</i>) with free variables <i>x</i>,<i>y</i>.</li> <li>Set semantics:</li> </ul>	Literature Appendix
$\begin{array}{l} \mathcal{C}^{\mathcal{I}} = \{ d \in \mathcal{D}  :  \mathcal{C}(d) \text{ "is true in" } \mathcal{I} \} \\ r^{\mathcal{I}} = \{ (d,e) \in \mathcal{D}^2  :  r(d,e) \text{ "is true in" } \mathcal{I} \} \\ & \text{November 23, 2015} & \text{November . KR&R} \end{array} $	FREIBURG

Role restrictions	
Motivation:	Introduction
Often we want to describe something by restricting the	Concepts and Roles
possible "fillers" of a role, e.g. Mother-wod.	Concept Forming Operators
Sometimes we want to say that there is at least a filler of a	Role Forming Operators
particular type, e.g. Grandmother	TBox and
Idea: Use quantifiers that range over the role-fillers	ABox
■ Mother □ ∀has-child.Man	Reasoning Services
Woman T has-child.Parent	Outlook
FOL semantics:	Literature
$(\exists r.C)(x) = \exists y(r(x,y) \land C(y))$	Appendix
$(\forall r.C)(x) = \forall y (r(x,y) \rightarrow C(y))$	
Set semantics:	
$(\exists r. \mathcal{C})^\mathcal{I} = ig\{ d \in \mathcal{D}  :   ext{there ex. some } e \;  ext{s.t.} \; (d, e) \in r^\mathcal{I} \wedge e \in \mathcal{C} \}$	<sup>ז</sup> }ע
$(orall r.\mathcal{C})^\mathcal{I} = \left\{ oldsymbol{d} \in \mathcal{D}  :   ext{for each } oldsymbol{e}   ext{ with } (oldsymbol{d},oldsymbol{e}) \in oldsymbol{r}^\mathcal{I},  oldsymbol{e} \in oldsymbol{C}^\mathcal{I}  ight\}$	
November 23, 2015 Nebel, Lindner, Engesser – KR&R 14 / 36	NH

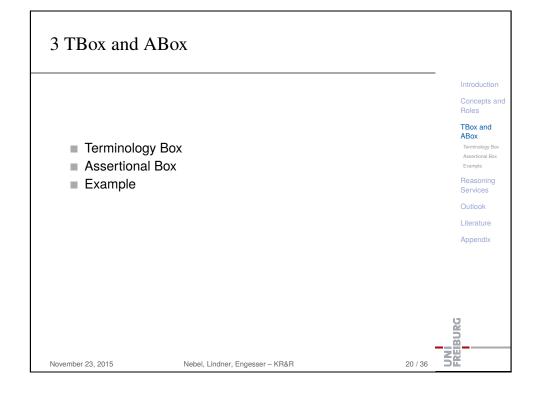
## Cardinality restriction

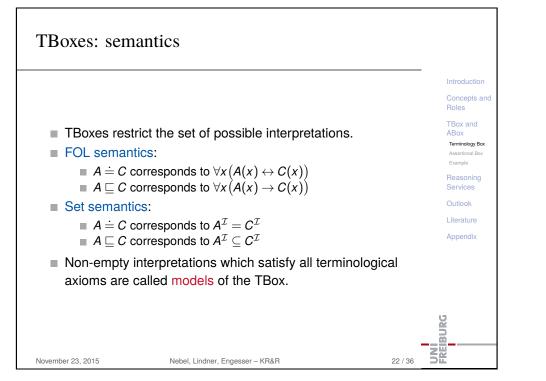


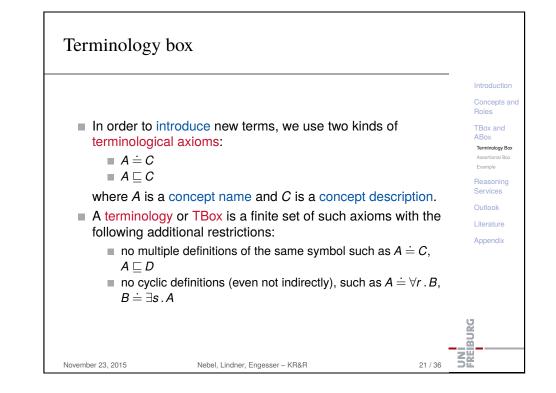


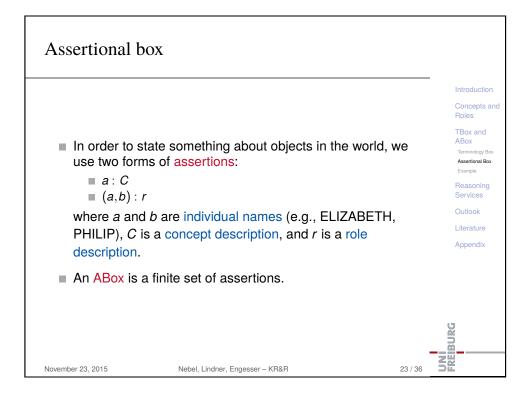
#### Inverse roles Motivation: Roles How can we describe the concept "children of rich parents"? Concept Formin Idea: Define the "inverse" role for a given role (the converse Role Formina Operators relation) TBox and ABox ■ has-child<sup>-1</sup> Reasoning ■ Example: ∃has-child<sup>-1</sup>.Rich Services FOL semantics: Literature Appendix $r^{-1}(x,y) = r(y,x)$ Set semantics: $(r^{-1})^{\mathcal{I}} = \{(d, e) \in \mathcal{D}^2 : (e, d) \in r^{\mathcal{I}}\}$ BURG **NN** Nebel, Lindner, Engesser - KR&R 16/36 November 23, 2015

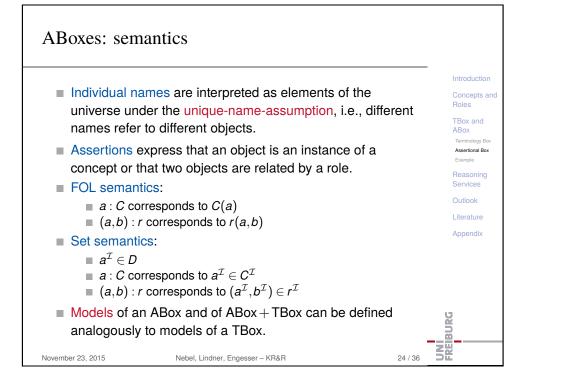
Role value m	aps				
friends ■ Idea: Relate	<ul> <li>Motivation:</li> <li>How do we express the concept "women who know all the friends of their children"</li> <li>Idea: Relate role filler sets to each other</li> <li>Woman □ (has-child ∘ has-friend ⊑ knows)</li> </ul>				
	$(r \sqsubseteq s)(x) = \forall y (r(x,y) \rightarrow s(x,y))$ ics: Let $r^{\mathcal{I}}(d) = \{e : r^{\mathcal{I}}(d,e)\}.$		Services Outlook Literature Appendix		
Note: Role	$(r \sqsubseteq s)^{\mathcal{I}} = \left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \subseteq s^{\mathcal{I}}(d)  ight\}$ value maps lead to undecidability of satisfing oncept descriptions!	ability	BURG		
November 23, 2015	Nebel, Lindner, Engesser - KR&R	18 / 36	FRE		



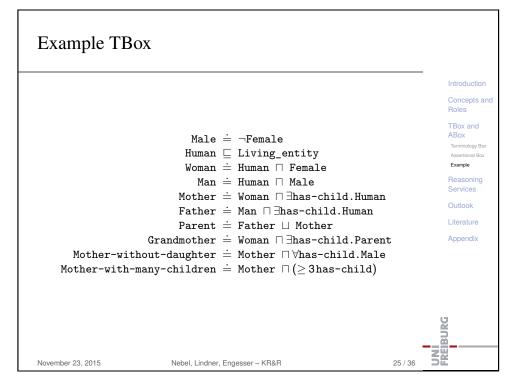


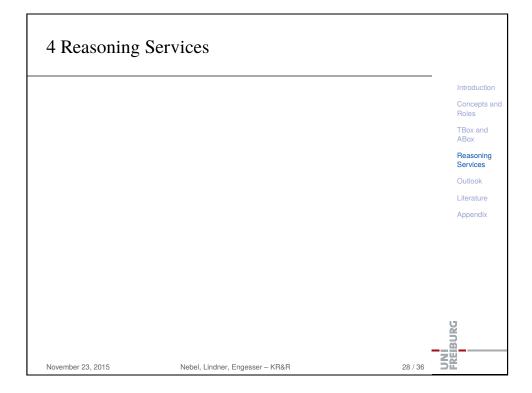


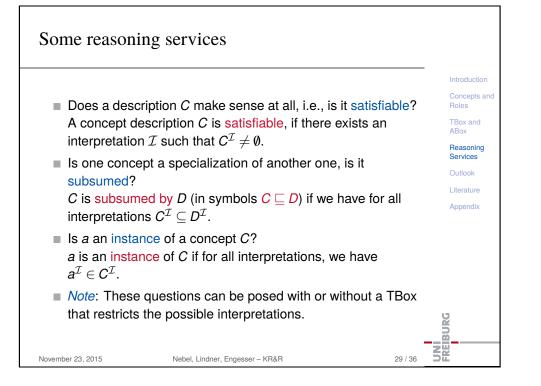


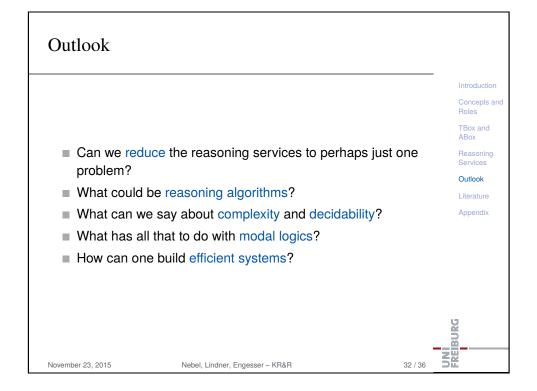


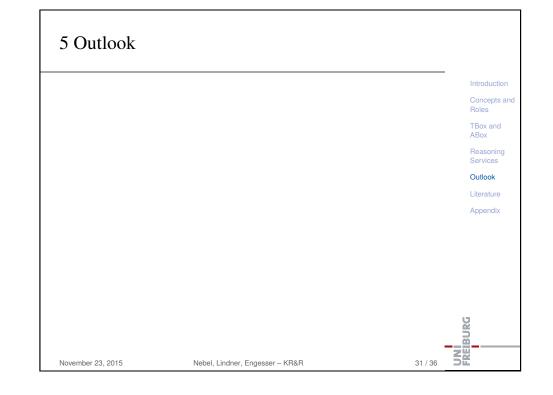
Example ABo	X		
			Introduction Concepts and Roles TBox and
CHARLES: Man EDWARD: Man ANDREW: Man		DIANA: Woman ELIZABETH: Woman	ABox Terminology Box Assertional Box Example
	-without-daughter		Reasoning Services
(ELIZABETH, CHAR			Outlook
(ELIZABETH, EDWA (ELIZABETH, ANDR			Literature
(DIANA, WILLIAM) (CHARLES, WILLIAM)	: has-child		Appendix
			telburg



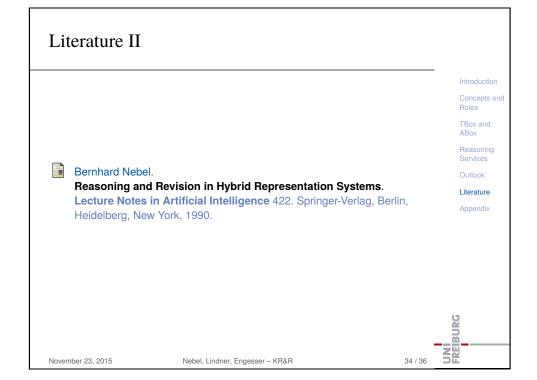








Lit	terature I			
				Introduction
		Ivanese, D. L. McGuinness, D. Nardi, and P.	F.	Concepts and Roles
	Patel-Schneider. The Description	Logic Handbook: Theory, Implementation	n,	TBox and ABox
	Applications, Cambridge Unive	ersity Press, Cambridge, UK, 2003.		Reasoning Services
	U U	nan and James G. Schmolze.		Outlook
		e KL-ONE knowledge representation system		Literature
		ce, 9(2):171–216, April 1985.	•	Appendix
		ans-Jürgen Bürckert, Jochen Heinsohn, Bern n Müller, Bernhard Nebel, Werner Nutt, and H		
	Terminological Kr terminological log	nowledge Representation: A proposal for a		
	0 0	c. International Workshop on Terminologic	al Logics	
	1991, DFKI Docu		ai Logios,	URG
Nover	nber 23, 2015	Nebel, Lindner, Engesser – KR&R	33 / 36	FREIE



 	le descripti		 Introduction
			Concepts and
			Roles TBox and ABox
Abstract	Concrete	Interpretation $t^{\mathcal{I}}$	Reasoning
t f	t f	$f^{\mathcal{I}}$ , (functional role)	Services
r r⊓s	(and <i>r s</i> )	$r^{\mathcal{I}} \cap s^{\mathcal{I}}$	Outlook
r  s	(or <i>r s</i> )	$r^{\mathcal{I}}   s^{\mathcal{I}}$	Literature
. ⊒o ¬r	(not <i>r</i> )	$\mathcal{D} \times \mathcal{D} - r^{\mathcal{I}}$	Appendix
r <sup>-1</sup>	(inverse r)	$\left\{ (d,d'): (d',d) \in r^{\mathcal{I}} \right\}$	
r  <sub>C</sub>	(restr r C)	$\left\{ \left(d,d'\right)\in r^{\mathcal{I}}:d'\in C^{\mathcal{I}} ight\}$	
<b>r</b> +	(trans r)	$(r^{\mathcal{I}})^+$	
<i>r</i> ∘ <i>s</i>	(compose r s)	$r^{\mathcal{I}} \circ s^{\mathcal{I}}$	
1	self	$\{(d,d):d\in\mathcal{D}\}$	
			U
			BURG

# Summary: Concept descriptions

Concrete	Interpretation	-	Introduction
I	$A^{\mathcal{I}}$	-	Concepts and
and C D)	$\mathcal{C}^{\mathcal{I}} \cap \mathcal{D}^{\mathcal{I}}$		Roles
or C D)	$\mathcal{C}^{\mathcal{I}} \cup \mathcal{D}^{\mathcal{I}}$		TBox and ABox
not C)	$\mathcal{D} - \mathcal{C}^{\mathcal{I}}$		
all <i>r C</i> )	$\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \subseteq C^{\mathcal{I}}\}$		Reasoning Services
some r)	$\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \neq \emptyset\}$		Outlook
atleast <i>n r</i> )	$\left\{ d \in \mathcal{D} :  r^{\mathcal{I}}(d)  \ge n \right\}$		Literature
atmost <i>n r</i> )	$\left\{ d \in \mathcal{D} :  r^{\mathcal{I}}(d)  \leq n \right\}$		Appendix
some r C)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}} \neq \emptyset \right\}$		Appendix
atleast <i>n r C</i> )	$\left\{ d \in \mathcal{D} :  r^{\mathcal{I}}(d) \cap C^{\mathcal{I}}  \geq n \right\}$		
atmost <i>n r C</i> )	$\left\{ d \in \mathcal{D}  :    r^{\mathcal{I}}(d) \cap C^{\mathcal{I}}   \leq n \right\}$		
eq <i>r s</i> )	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) = s^{\mathcal{I}}(d) \right\}$		
neq r s)	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \neq s^{\mathcal{I}}(d) \right\}$		
subset <i>r s</i> )	$\left\{ d \in \mathcal{D} : r^{\mathcal{I}}(d) \subseteq s^{\mathcal{I}}(d) \right\}$		
eq <i>g h</i> )	$\{d \in \mathcal{D} : g^{\mathcal{I}}(d) = h^{\mathcal{I}}(d) \neq \emptyset\}$		
neq <i>g h</i> )	$\left\{ d \in \mathcal{D} : \emptyset \neq g^{\mathcal{I}}(d) \neq h^{\mathcal{I}}(d) \neq \emptyset \right\}$		JRG
one of $i_1 \dots i_n$ )			
Nebel, Lindner	, Engesser – KR&R	35 / 36	LA LA
	and $C D$ ) for $C D$ ) not $C$ ) all $r C$ ) some $r$ ) atleast $n r$ ) atmost $n r$ ) some $r C$ ) atleast $n r C$ ) atmost $n r C$ ) atmost $n r C$ ) atmost $n r C$ ) atmost $n r S$ ) subset $r s$ ) subset $r s$ ) eq $g h$ ) neq $g h$ ) photo $i_1 \dots i_n$ )	$A^{\mathcal{I}}$ and $C D$ ) $C^{\mathcal{I}} \cap D^{\mathcal{I}}$ for $C D$ ) $C^{\mathcal{I}} \cup D^{\mathcal{I}}$ for $C D$ ) $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \subseteq C^{\mathcal{I}}\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d)   \leq n\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}} \neq \emptyset\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}}   \geq n\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}}   \geq n\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) \cap C^{\mathcal{I}}   \leq n\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) = s^{\mathcal{I}}(d)\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) = s^{\mathcal{I}}(d)\}$ for $C D$ $\{d \in \mathcal{D} : r^{\mathcal{I}}(d) = s^{\mathcal{I}}(d)\}$ for $C D$ $\{d \in \mathcal{D} : g^{\mathcal{I}}(d) = h^{\mathcal{I}}(d) \neq \emptyset\}$ for $C D$ $\{d \in \mathcal{D} : \emptyset \neq g^{\mathcal{I}}(d) \neq h^{\mathcal{I}}(d) \neq \emptyset\}$ for $C D$ $\{d \in \mathcal{D} : \emptyset \neq g^{\mathcal{I}}(d) \neq h^{\mathcal{I}}(d) \neq \emptyset\}$	$ \begin{array}{c} A^{\mathcal{I}} \\ \text{and } C \ \mathcal{D} \\ C^{\mathcal{I}} \cap \mathcal{D}^{\mathcal{I}} \\ \text{or } C \ \mathcal{D} \\ \mathcal{D} \\ C^{\mathcal{I}} \cup \mathcal{D}^{\mathcal{I}} \\ \text{not } C \\ \mathcal{D} \\ \mathcal{D} \\ \mathcal{C} \\ \mathcal{C} \\ \mathcal{D} \\ \mathcal{C} \\ \mathcal{D} \\ \mathcal{C} \\ \mathcal{D} \\ \mathcal{D} \\ \mathcal{C} \\ \mathcal{C} \\ \mathcal{D} \\ \mathcal{D} \\ \mathcal{D} \\ \mathcal{C} \\ \mathcal{D} \\ D$