Analyzing inheritance hierarchies through Formal Concept Analysis

A 22-years walk in a landscape of conceptual structures

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Motivation

Class models, inheritance hierarchies

- Capture domain knowledge
- Focus on classification and reuse

Normal form

- No redundancy
- All abstractions are created
- All specialization links are present
- Most compact structure with these properties

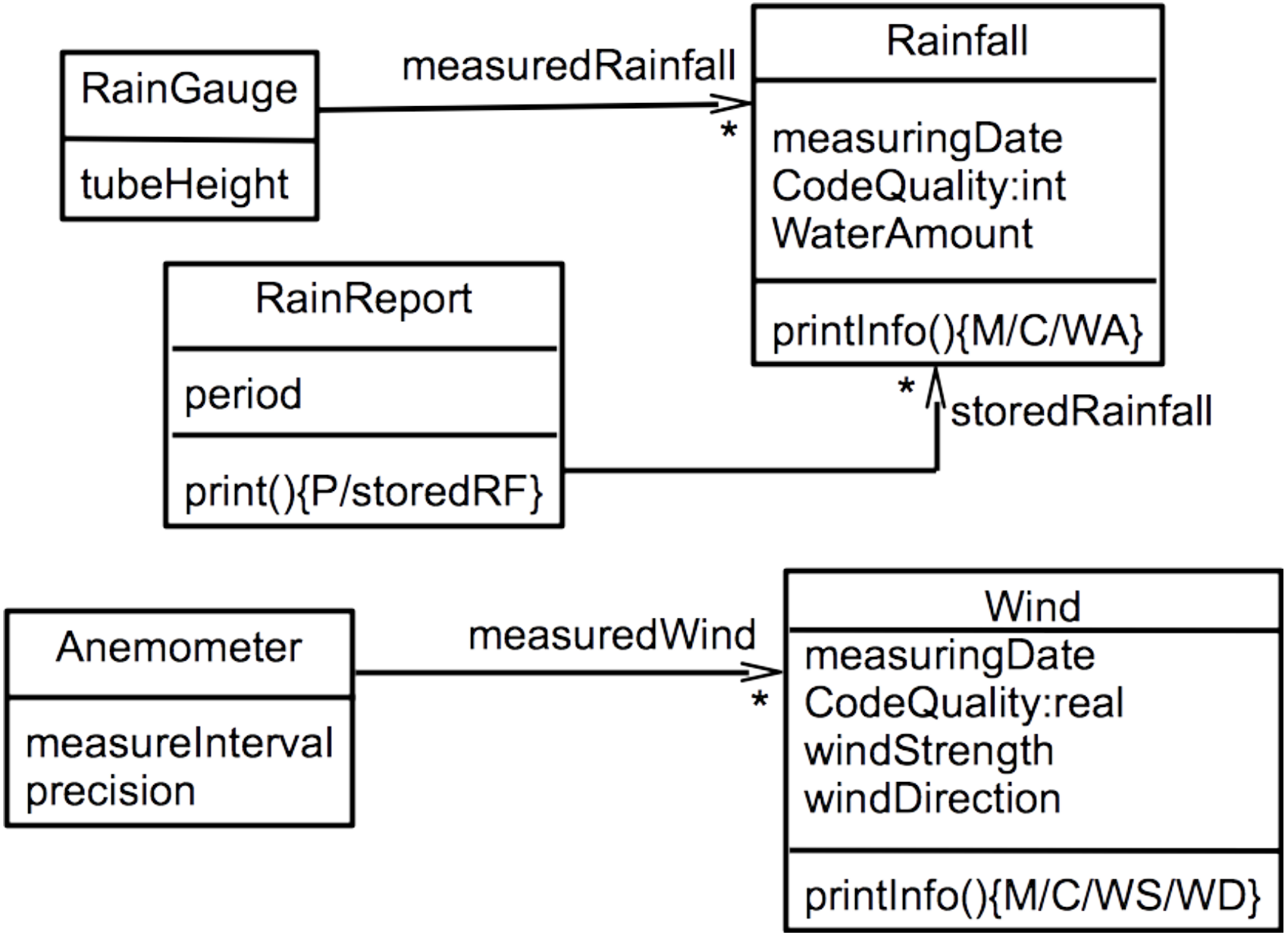
→ To restructure the current model or just to analyze it

Show historical steps in normalization

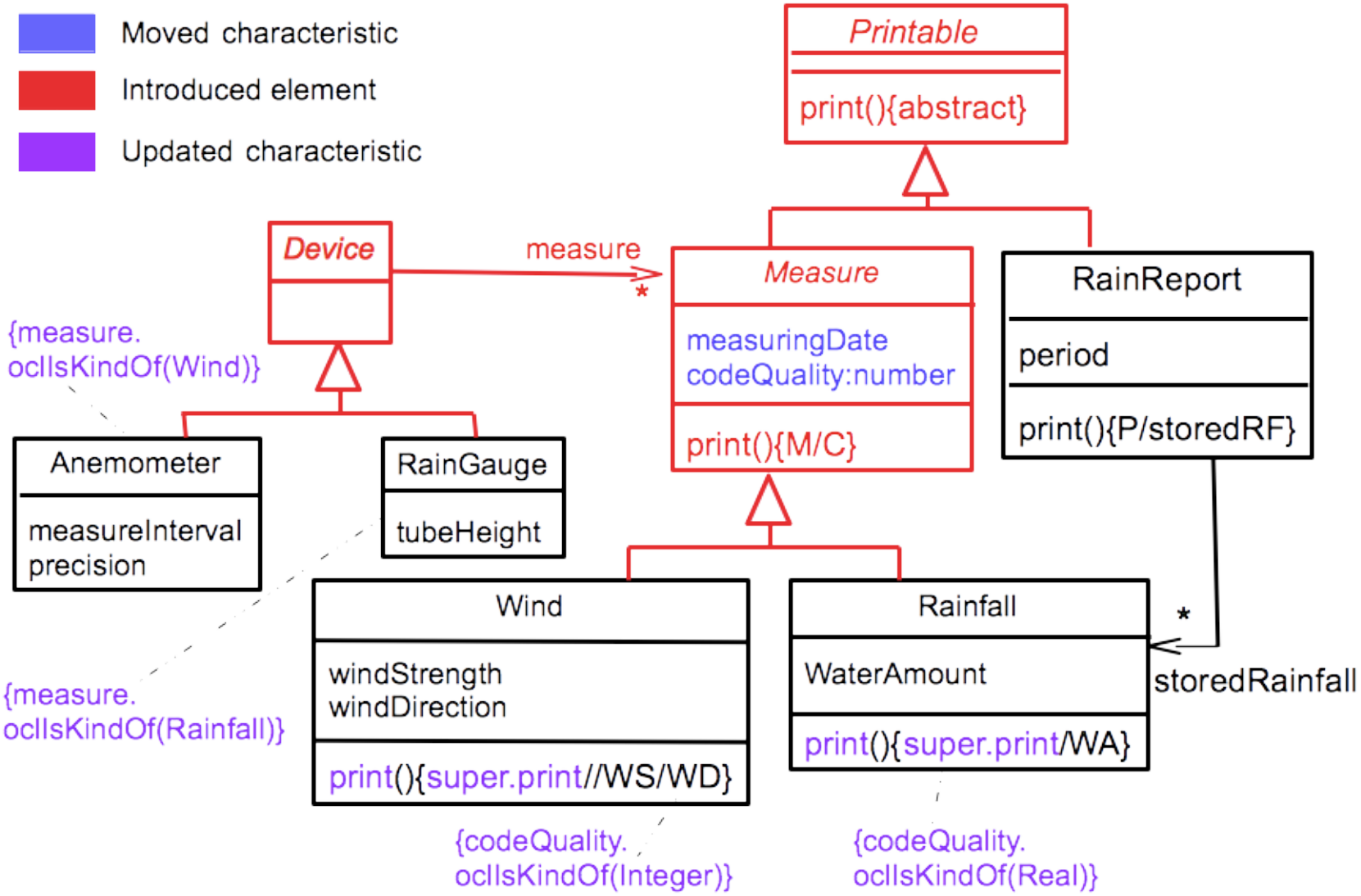
Outline

- Normalization illustration
- Formal Concept Analysis *(Ganter and Wille 1999)*
  Galois lattices *(Barbut and Monjardet 1970)*
  - Flat characteristics *(Godin et al., 1993)*
  - Hierarchical characteristics *(Godin et al., 1993)*
- Relational Concept Analysis *(Huchard et al. 2007)*
  - Reified characteristics *(Roume et al. 2004)*
  - Clustered reified characteristics *(unpublished)*
- Ongoing work (terms, exploration)

Normalization objective: initial class model



Normalization objective: normal form



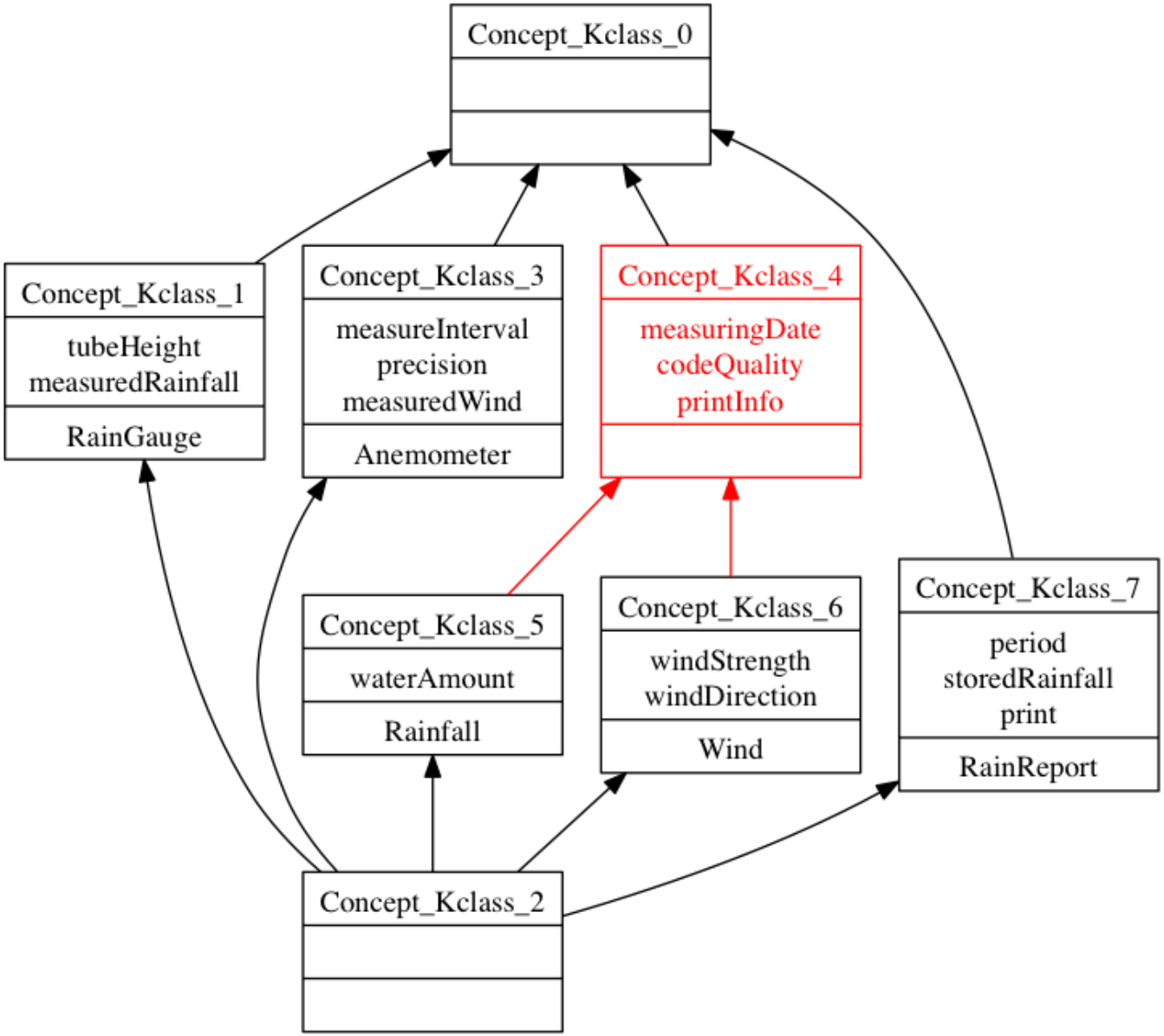
Flat characteristics: Formal context (Godin and Mili, 1993)

Kclass	tubeHeight	measureInterval	precision	measuringDate	codeQuality	waterAmount	windStrength	windDirection	period	measuredRainfall	measuredWind	storedRainfall	print	printInfo
RainG.	×									×				
Anem.		×	×								×			
Rainf.				×	×	×								×
Wind				×	×		×	×						×
RainR.									×			×	×	

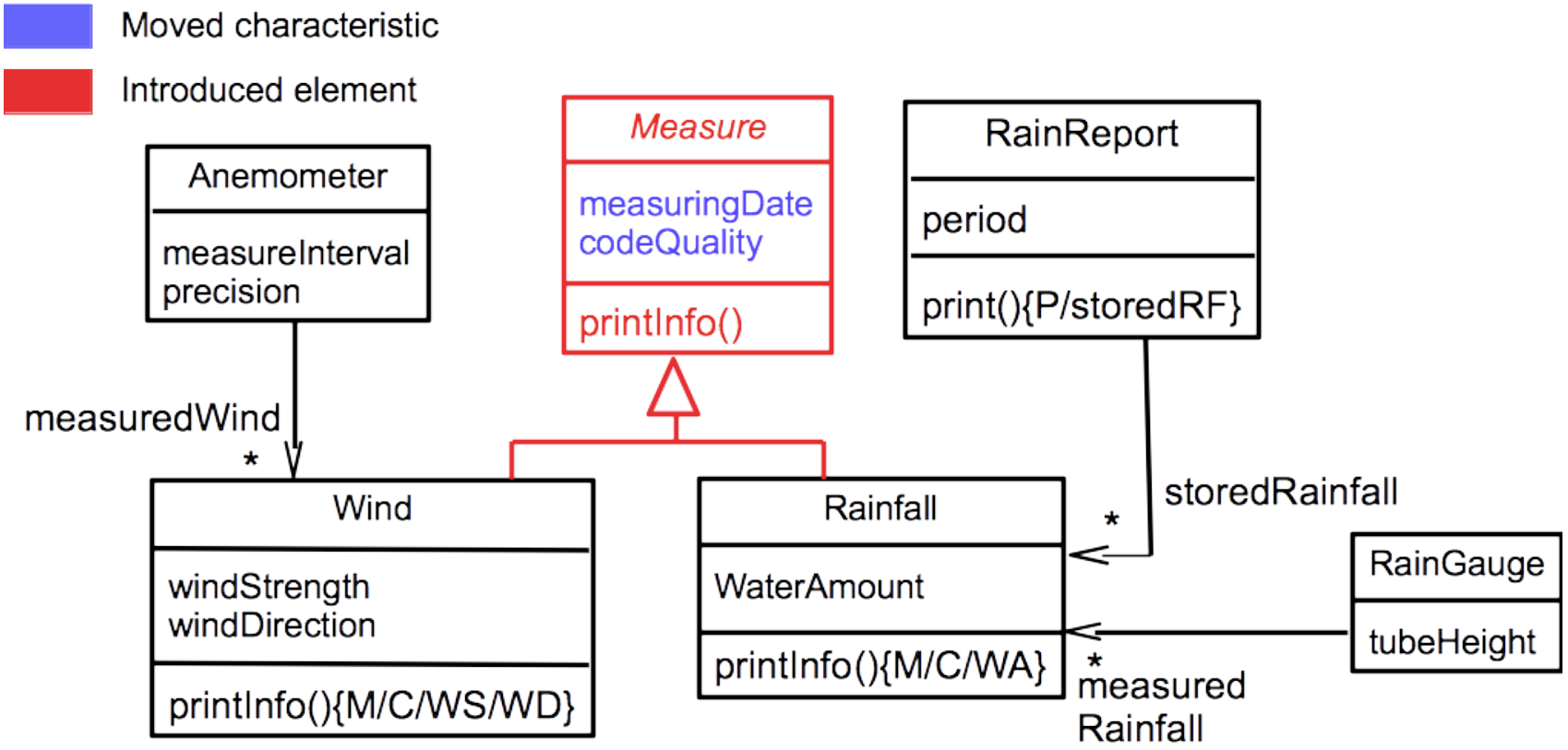
Flat characteristics: Concept

Kclass	tubeHeight	measureInterval	precision	measuringDate	codeQuality	waterAmount	windStrength	windDirection	period	measuredRainfall	measuredWind	storedRainfall	print	printInfo
RainG.	×									×				
Anem.		×	×								×			
Rainf.				×	×	×								×
Wind				×	×		×	×						×
RainR.									×			×	×	

Flat characteristics: concept lattice



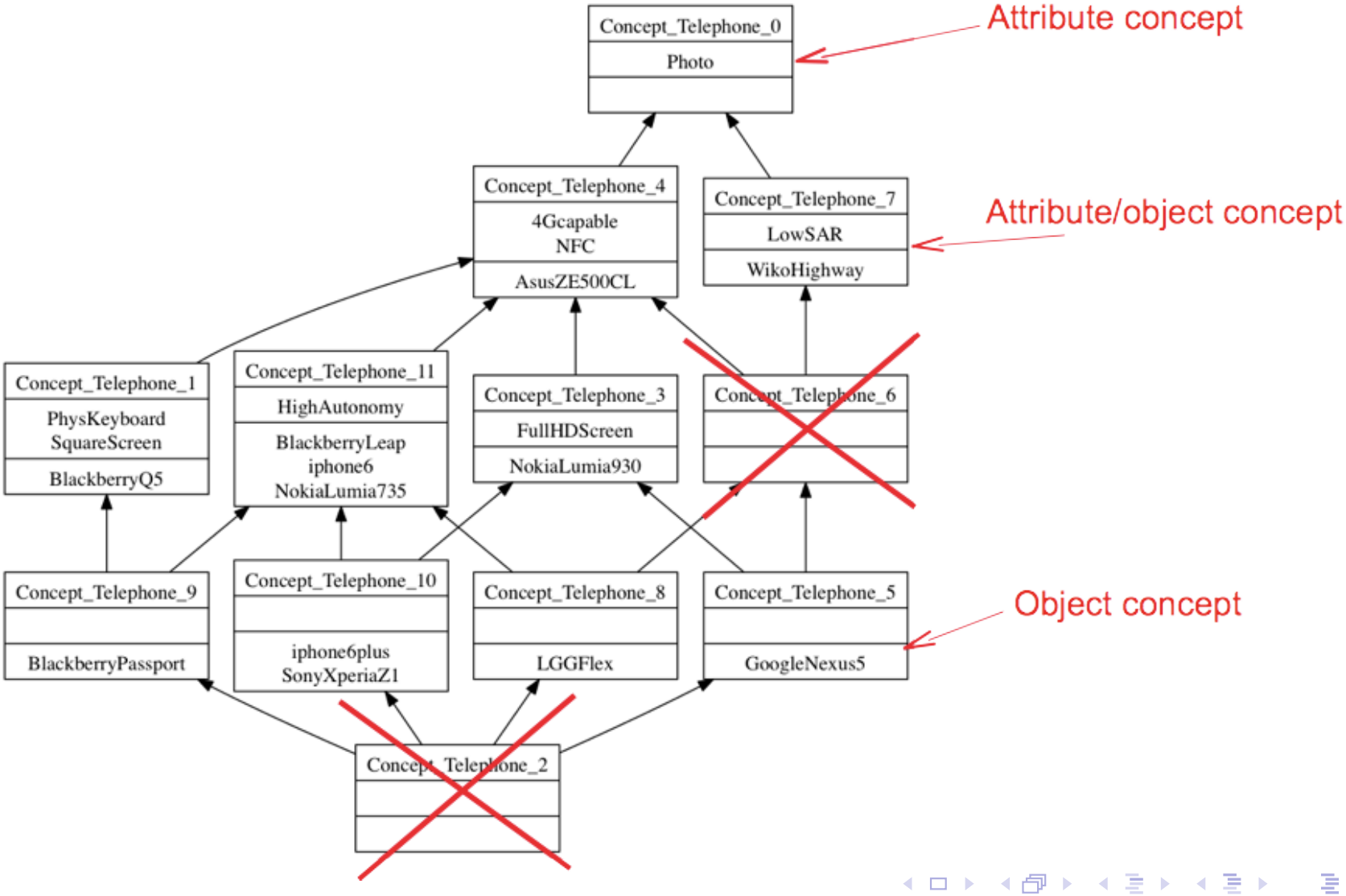
Flat characteristics: revisited model



Parenthesis: AOC-poset (Telephone classification)

With O the described entities, A the characteristics

#concepts in lattice $\leq 2^{min(|O|,|A|)}$, #concepts in AOC-posets $\leq |O| + |A|$



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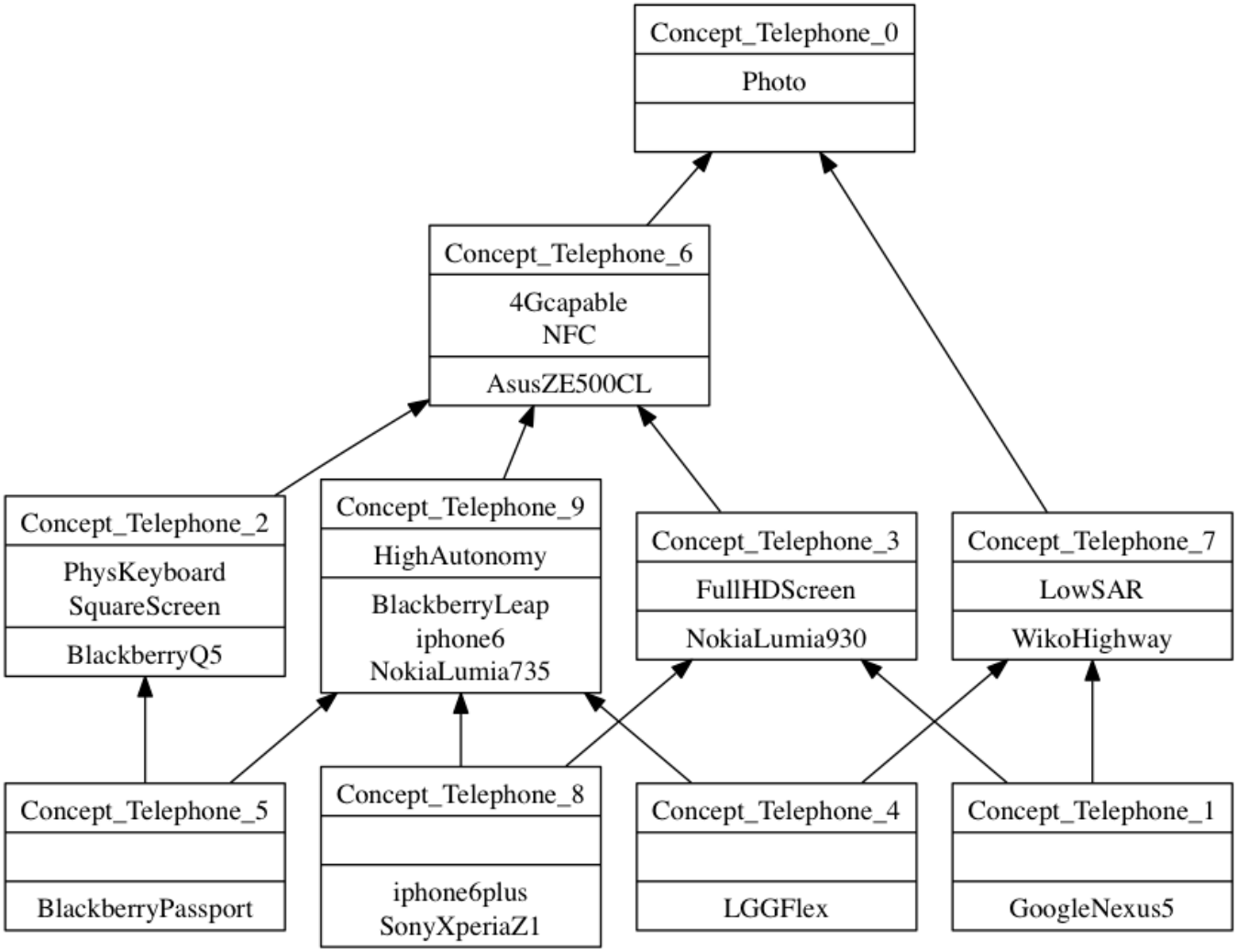
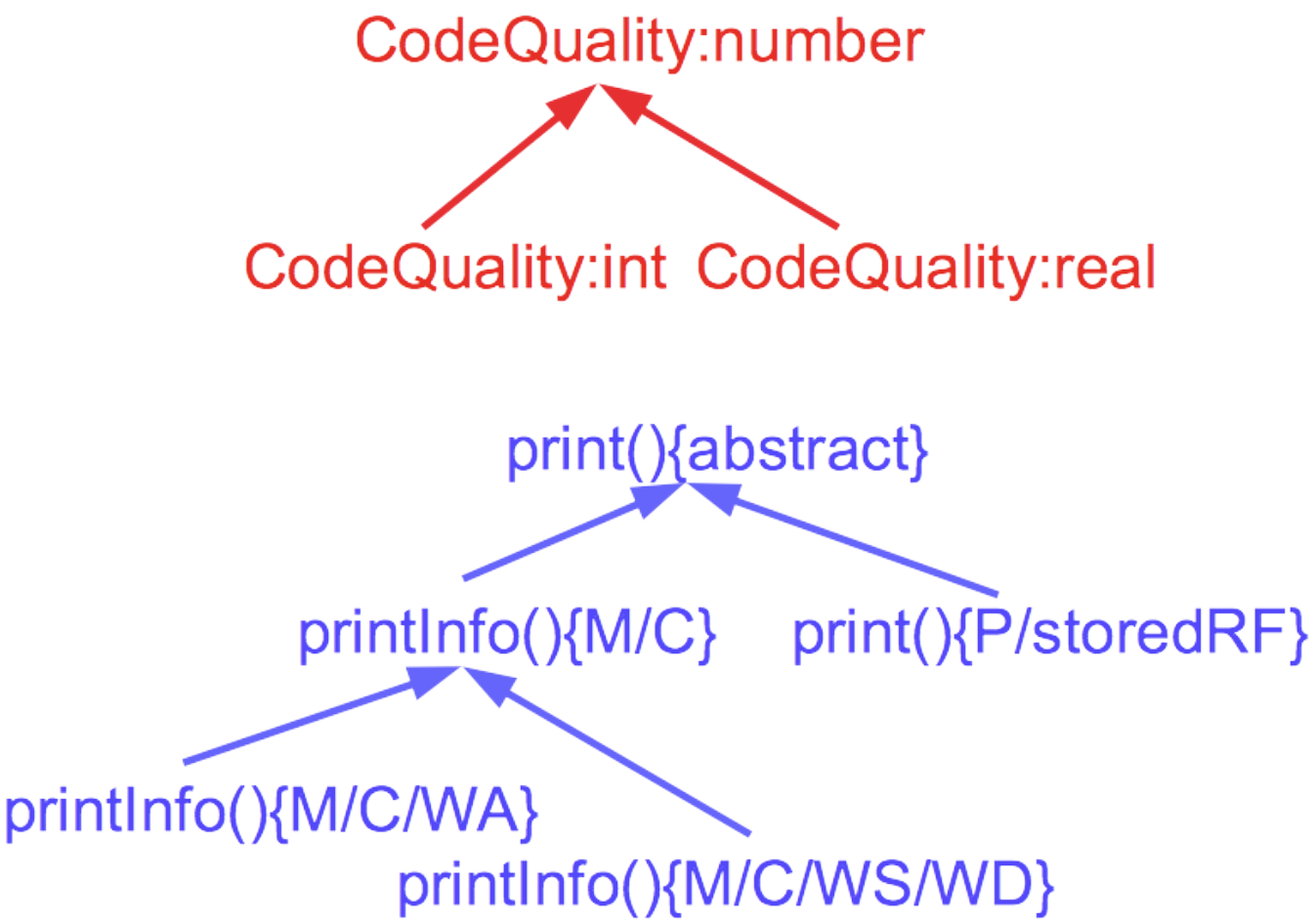


Hierarchical characteristics (Godin and Mili, 1993)



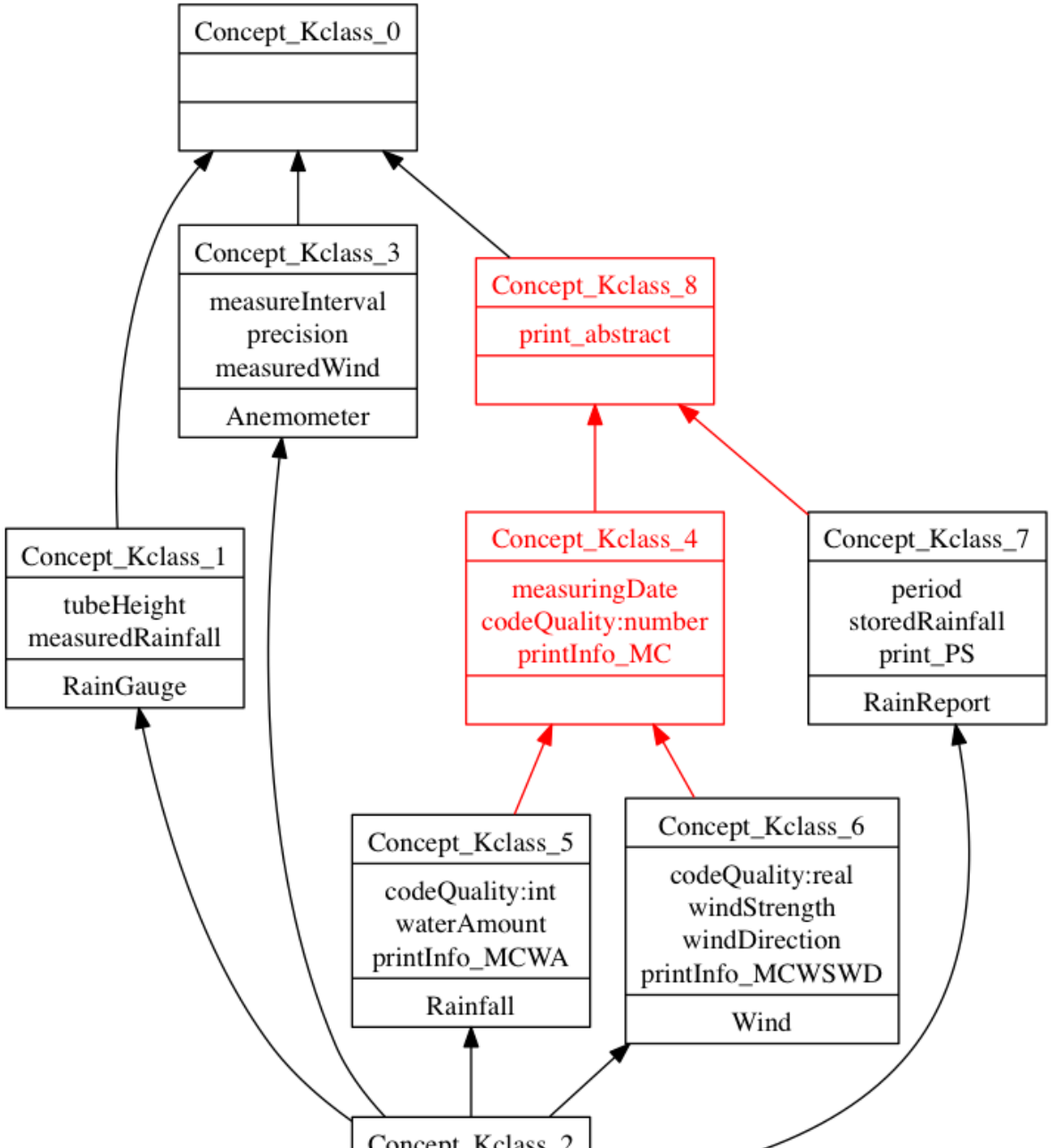
Hierarchical characteristics: Formal context (part 1)

Kclass	tubeHeight	measureInterval	precision	measuringDate	codeQuality:number	codeQuality:int	codeQuality:real	waterAmount	windStrength	windDirection	period	measuredRainfall	measuredWind
RainGauge	×											×	
Anemometer		×	×										×
Rainfall				×	×	×		×					
Wind				×	×		×		×	×			
RainReport											×		

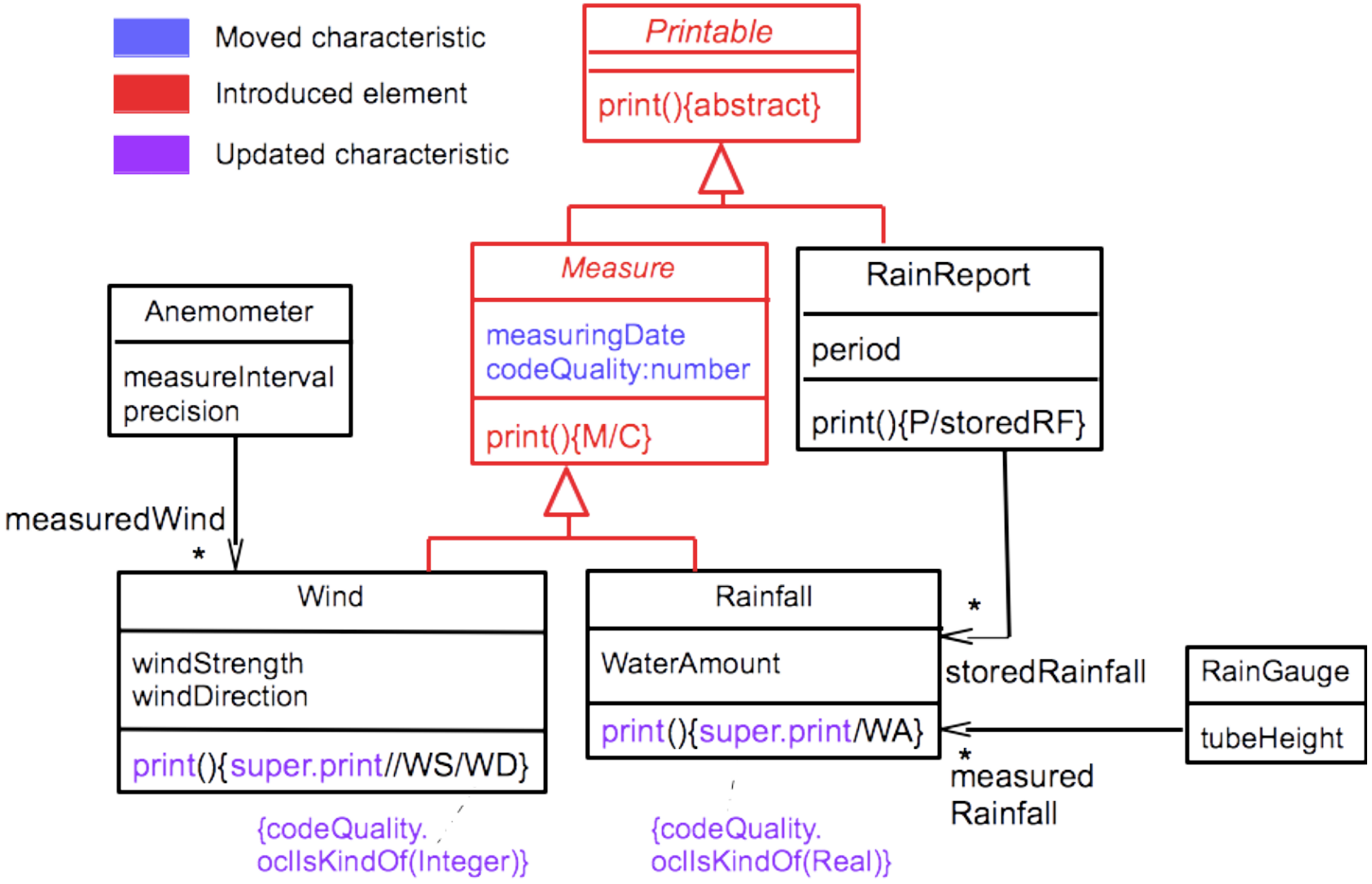
Hierarchical characteristics: Formal context (part 2)

Kclass	measuredWind	storedRainfall	print_abstract	printInfo_MC	printInfo_MCWA	printInfo_MCWSWD	print_PS
RainGauge							
Anemometer	×						
Rainfall			×	×	×		
Wind			×	×		×	
RainReport		×	×				×

Hierarchical characteristics: Concept Lattice



Hierarchical characteristics: revisited model



Relational Concept Analysis - going further with reification

Dataset

- Several entity categories (OA-contexts): classes, attributes, operations, roles
- Relations between entities (OO-contexts): hasAttribute, hasRole, hasOperation, hasTypeEnd

Principle

- Builds one concept lattice for each entity category
- Iterate on lattice construction and integration of relational attributes (encoding OO-contexts) in OA-contexts
- Until a fix-point

Reified characteristics: Object-Attribute contexts

Kclass
RainGauge
Anemometer
Rainfall
Wind
RainReport

Krole	measuredRainfall	measuredWind	storedRainfall
RG::measuredRainfall	×		
RR::storedRainfall			×
A::measuredWind		×	

Koperation	print	MC	MCWA	MCWSWD	PstoredRF
RR::print	×				×
R::printinfo	×	×	×		
W::printinfo	×	×		×	

Kattribute	tubeHeight	measureInterval	precision	measuringDate	codeQuality	waterAmount	windStrength	windDirection	period	number	int	real
RG::tubeHeight	×											
A::measureInterval		×										
A::precision			×									
R::measuringDate				×								
W::measuringDate				×								
R::codeQuality					×					×	×	
W::codeQuality					×					×		×
R::waterAmount						×						
W::windStrength							×					
W::windDirection								×				
RR::period									×			

Reified characteristics: Object-Object contexts

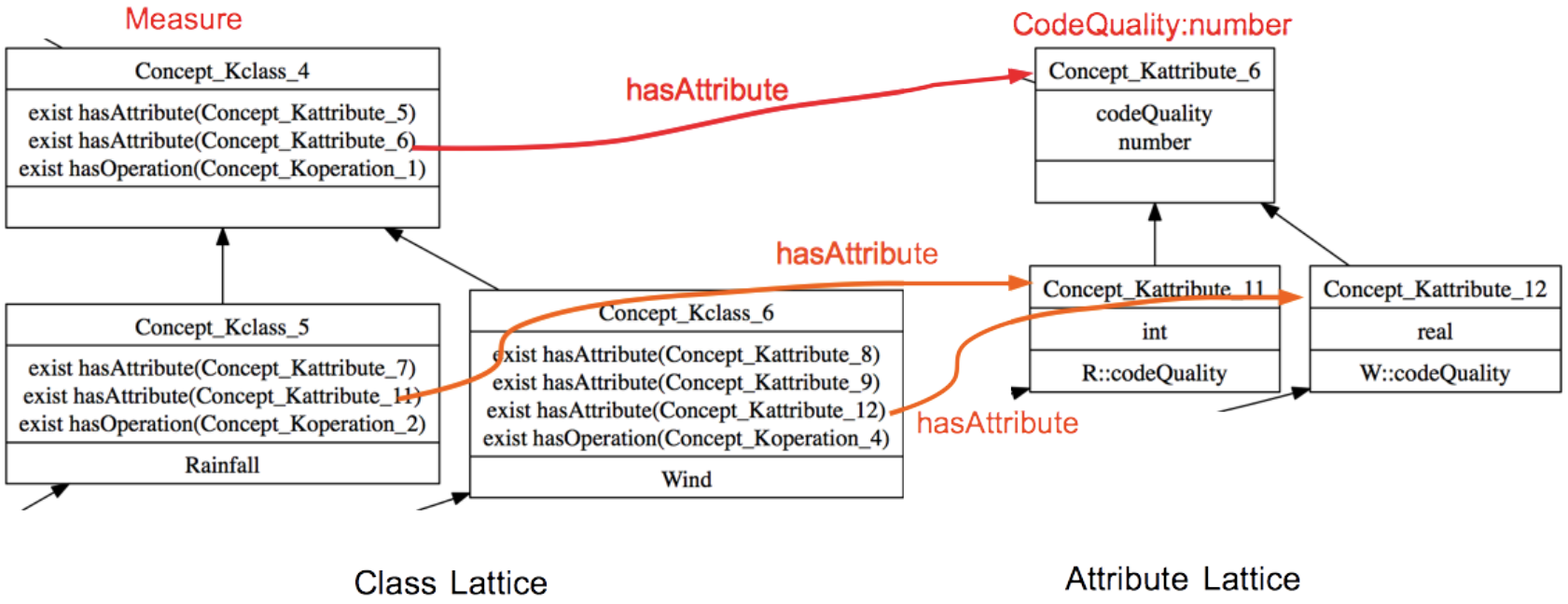
hasAttribute	RG::tubeHeight	A::measureInterval	A::precision	R::measuringDate	W::measuringDate	R::codeQuality	W::codeQuality	R::waterAmount	W::windStrength	W::windDirection	RR::period
RainGauge	×										
Anemometer		×	×								
Rainfall				×		×		×			
Wind					×		×		×	×	
RainReport											×

hasRole	RG::measuredRainfall	RR::storedRainfall	A::measuredWind
RainGauge	×		
Anemometer			×
Rainfall			
Wind			
RainReport		×	

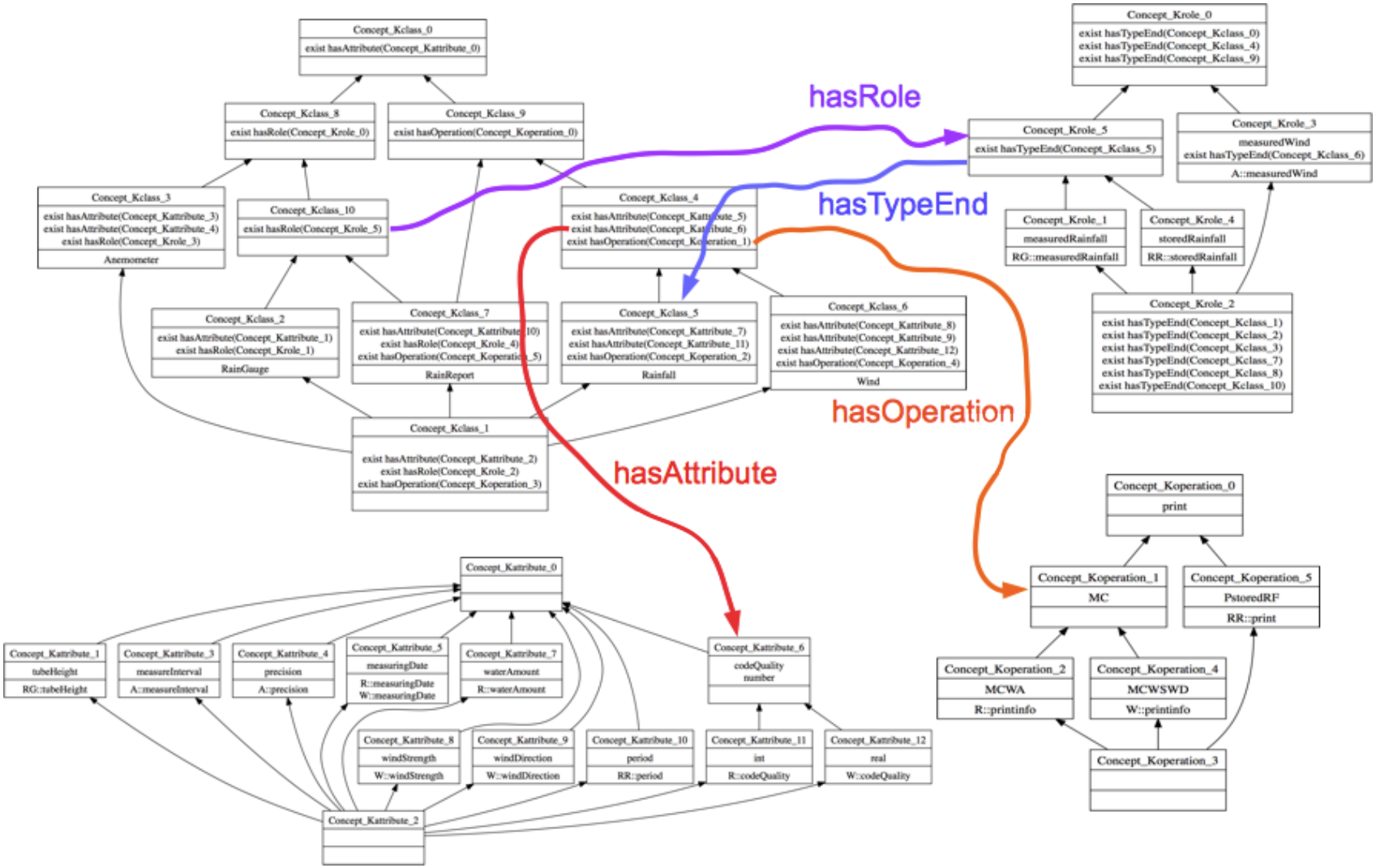
hasOperation	RR::print	R::printinfo	W::printinfo
RainGauge			
Anemometer			
Rainfall		×	
Wind			×
RainReport	×		

hasTypeEnd	Rainfall	Wind
RG::measuredRainfall	×	
RR::storedRainfall	×	
A::measuredWind		×

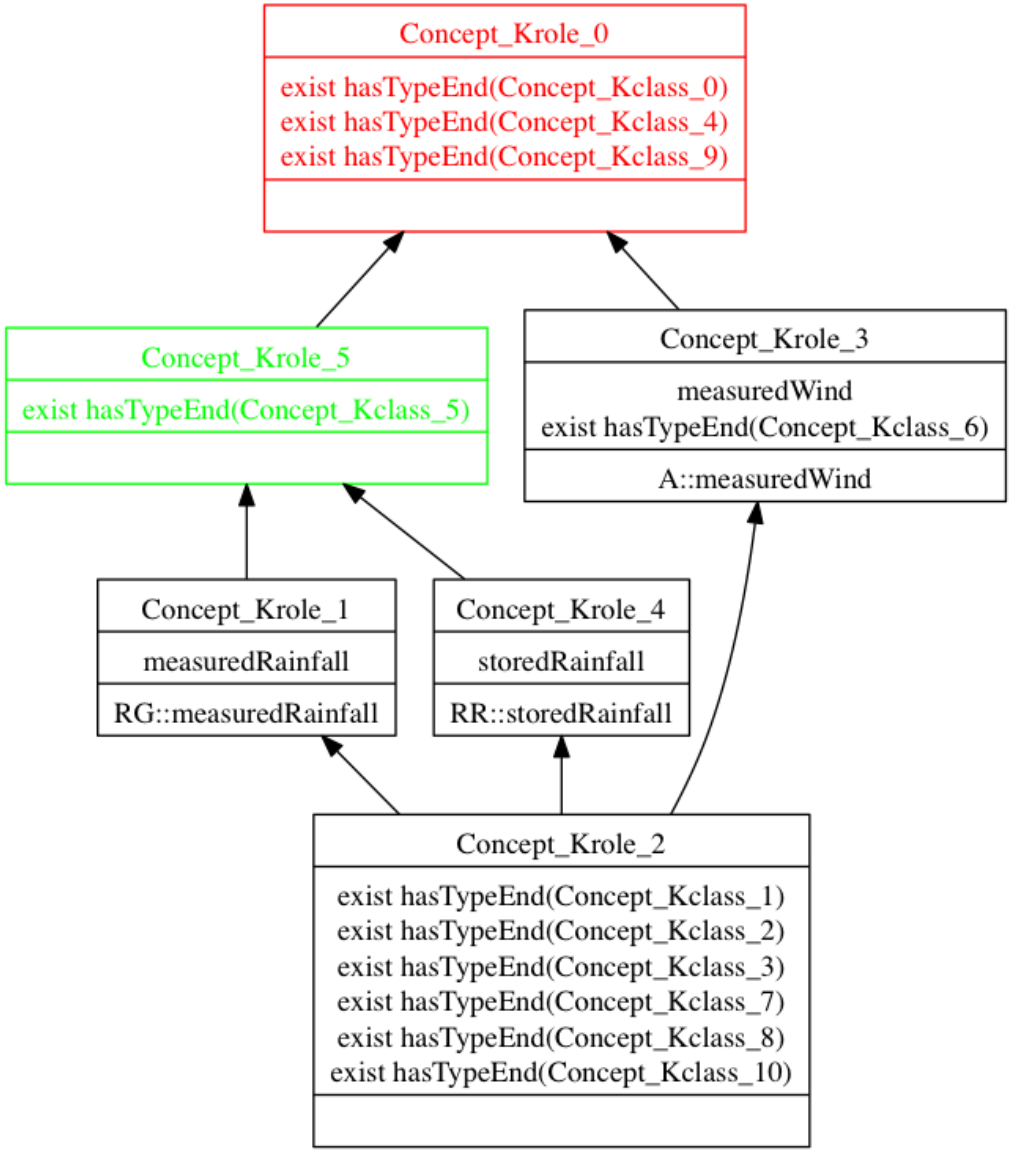
Reified characteristics: detail on class lattice and attribute lattice



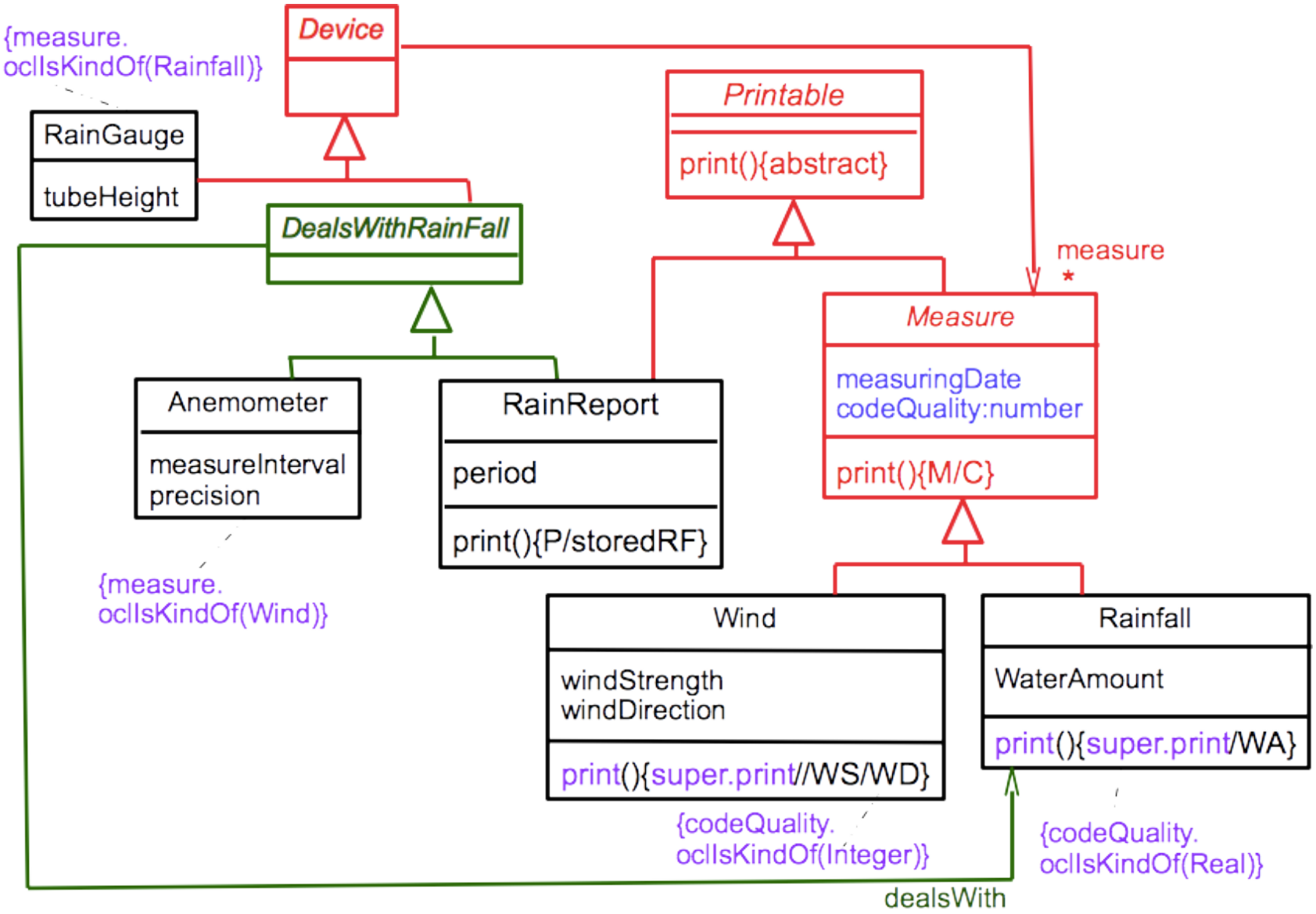
Reified characteristics: all lattices



Reified characteristics: Role lattices



Reified characteristics: revisited model



Clustered reified characteristics

Krole1	measuredRainfall	measuredWind
RG::measuredRainfall	×	
A::measuredWind		×

Krole2	storedRainfall
RR::storedRainfall	×

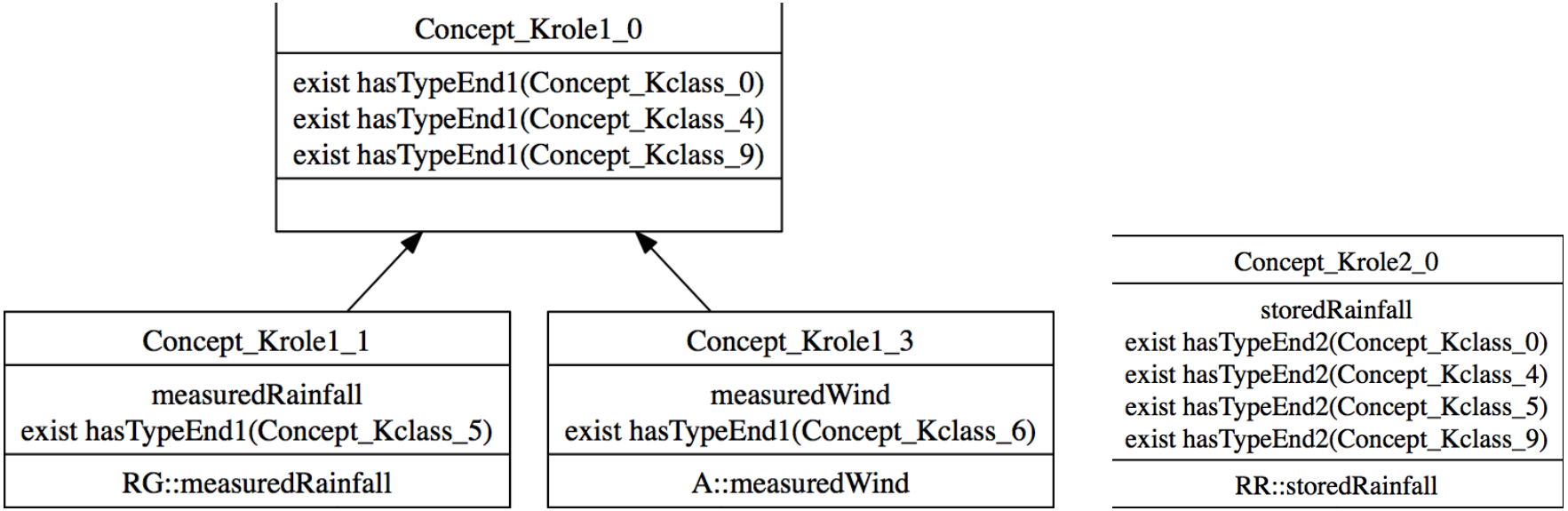
hasTypeEnd2	Rainfall	Wind
RR::storedRainfall	×	

hasRole1	RG::measuredRainfall	A::measuredWind
RainGauge	×	
Anemometer		×
Rainfall		
Wind		
RainReport		

hasRole2	RR::storedRainfall
RainGauge	
Anemometer	
Rainfall	
Wind	
RainReport	×

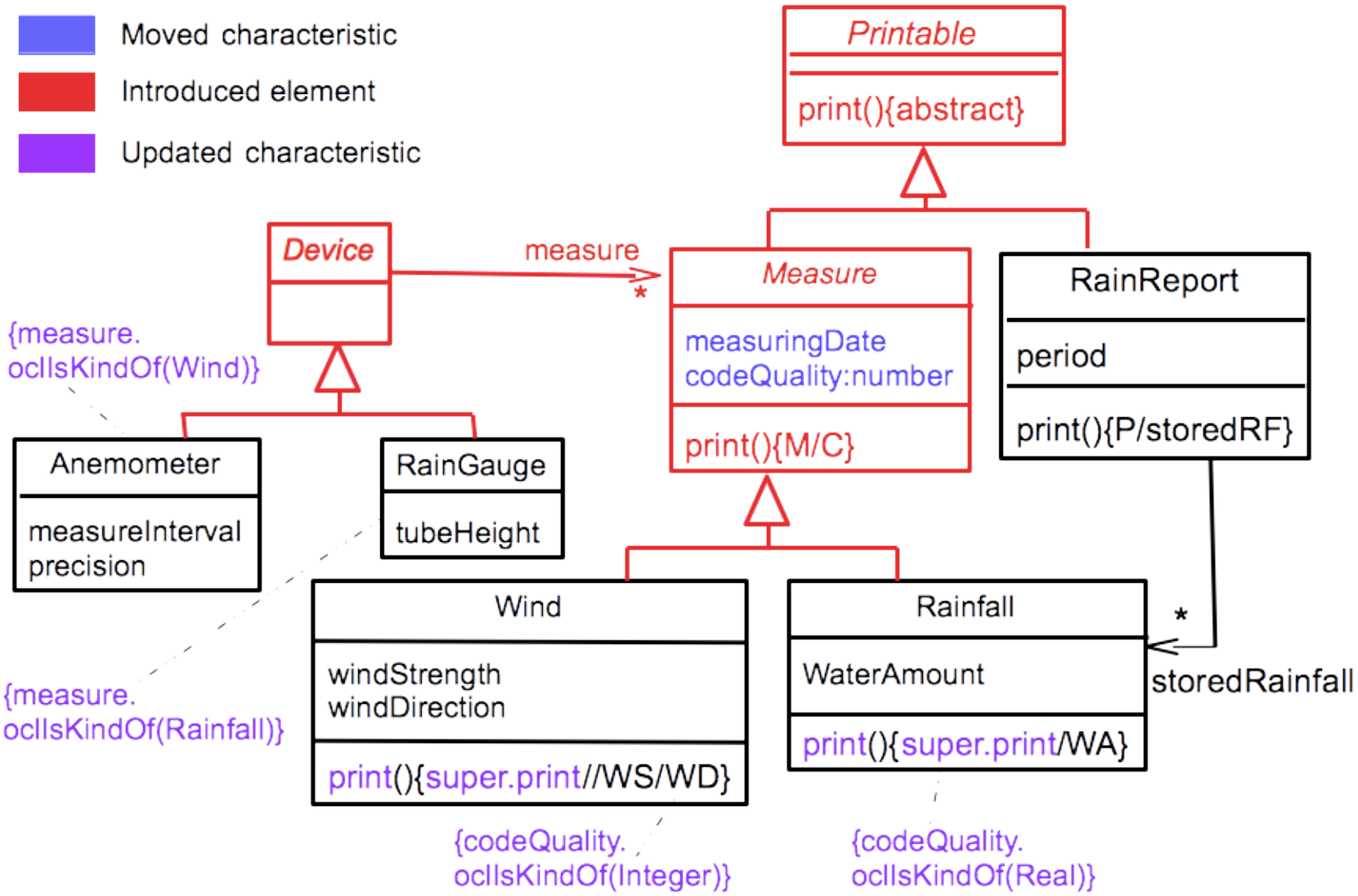
hasTypeEnd1	Rainfall	Wind
RG::measuredRainfall	×	
A::measuredWind		×

Clustered characteristics: Separated role lattices

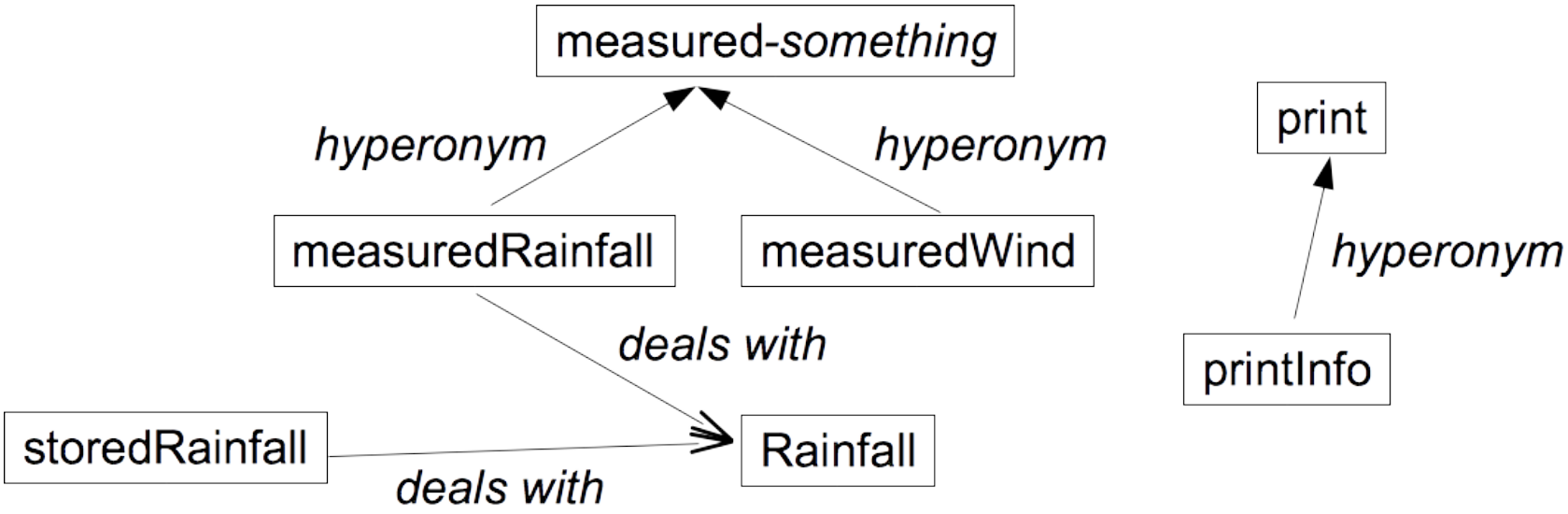


The same clustering has to be applied to attributes and operations to avoid "over-generalization"

Clustered characteristics: Normal form

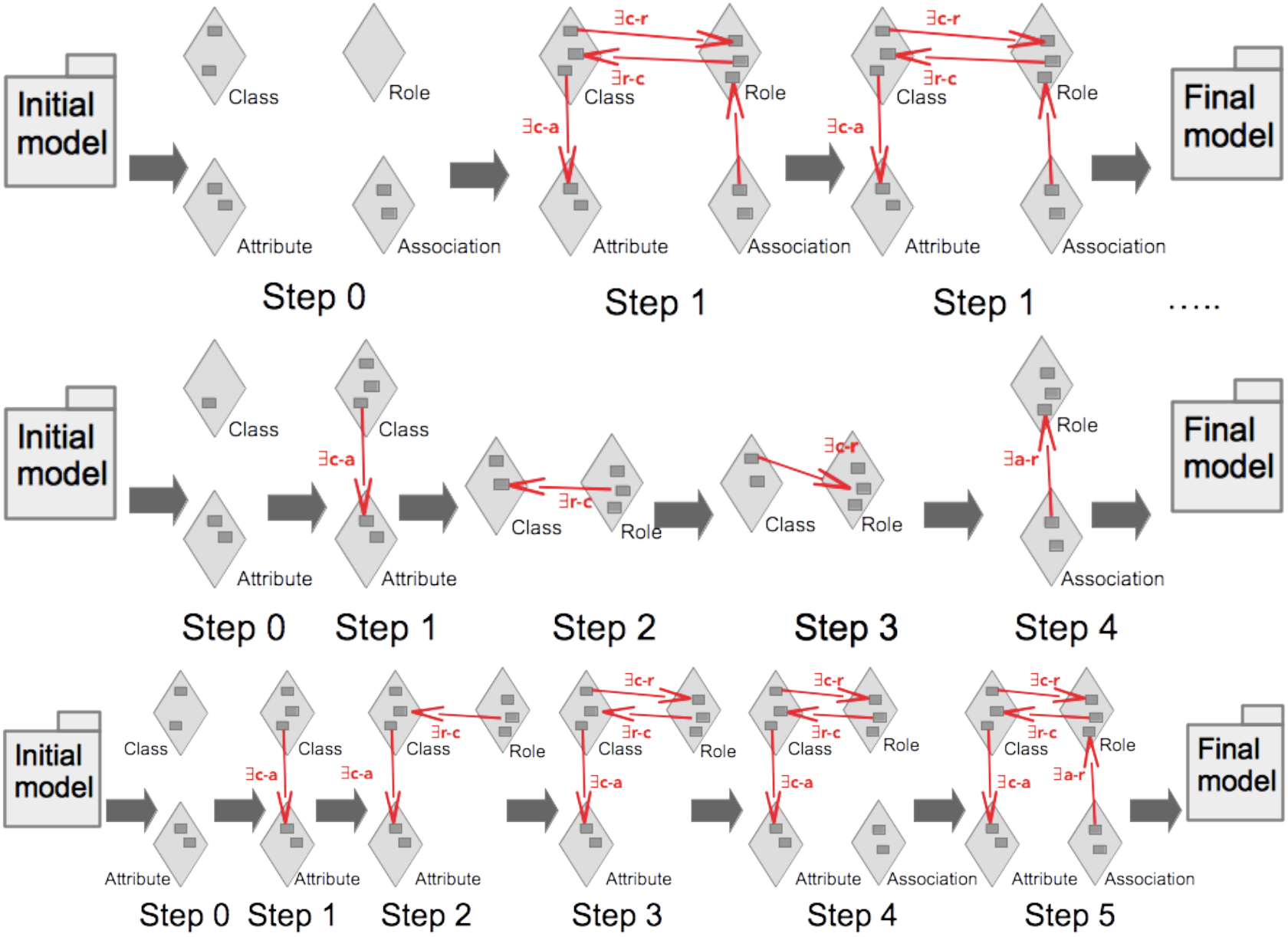


Ongoing work: Lexical resources (Falleri et al. 2010)



RCA input is tuned depending lexical resource

Ongoing work: Exploratory approaches (Miralles et al. 2015)



Conclusion/Perspectives

Conclusion

- A similar approach for restructuring ontologies [Valtchev et al.]
- RCA is used for other datasets and usages (data in environmental domain, software components/services classification, software analysis for extracting assets and feature models for product lines)

Perspectives

- Towards a unique, generic tool
- Improving lexical resource acquisition and analysis
- Work on methodological aspects (exploration, guiding metrics)

Questions?

Tools: Objecteering modules[1], RCAexplore[2], Talend workflow[3], Java packages

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[1] http://www.objecteering.com/
[2] http://dolques.free.fr/rcaexplore.php
[3] http://www.talend.com/