ontology & conceptual
modeling research group

Assessing Ontologies via Simulation

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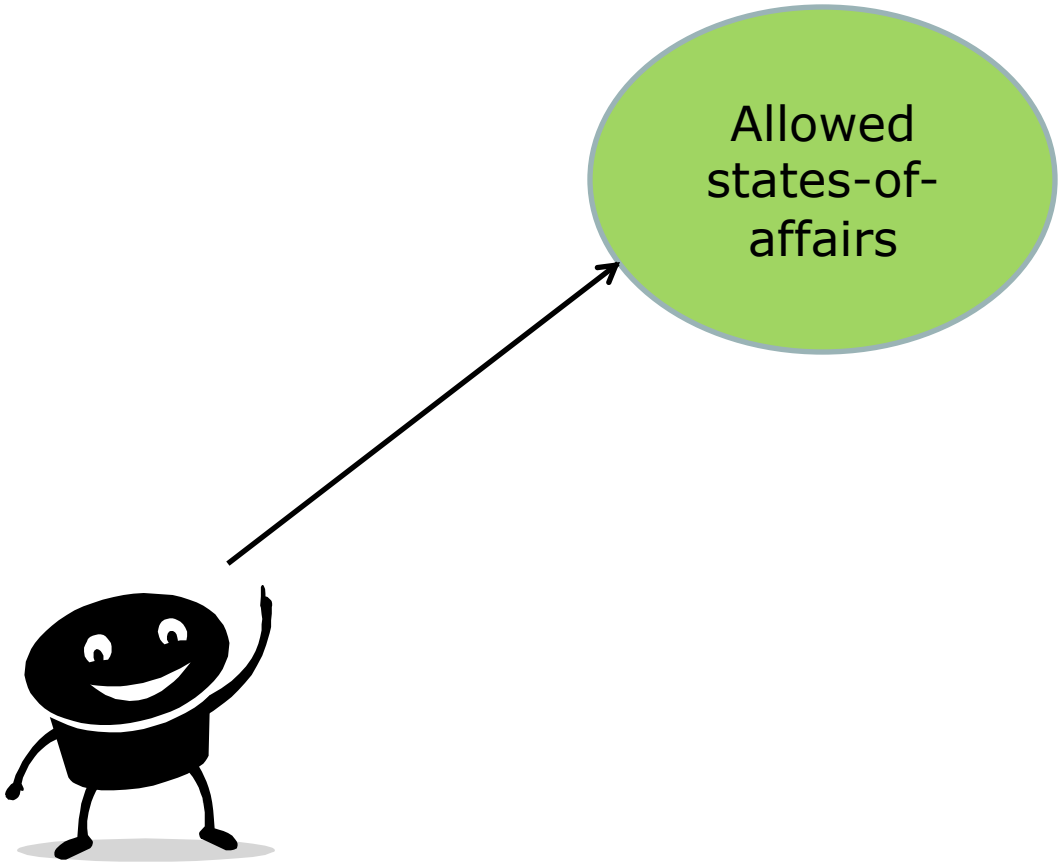
Motivation

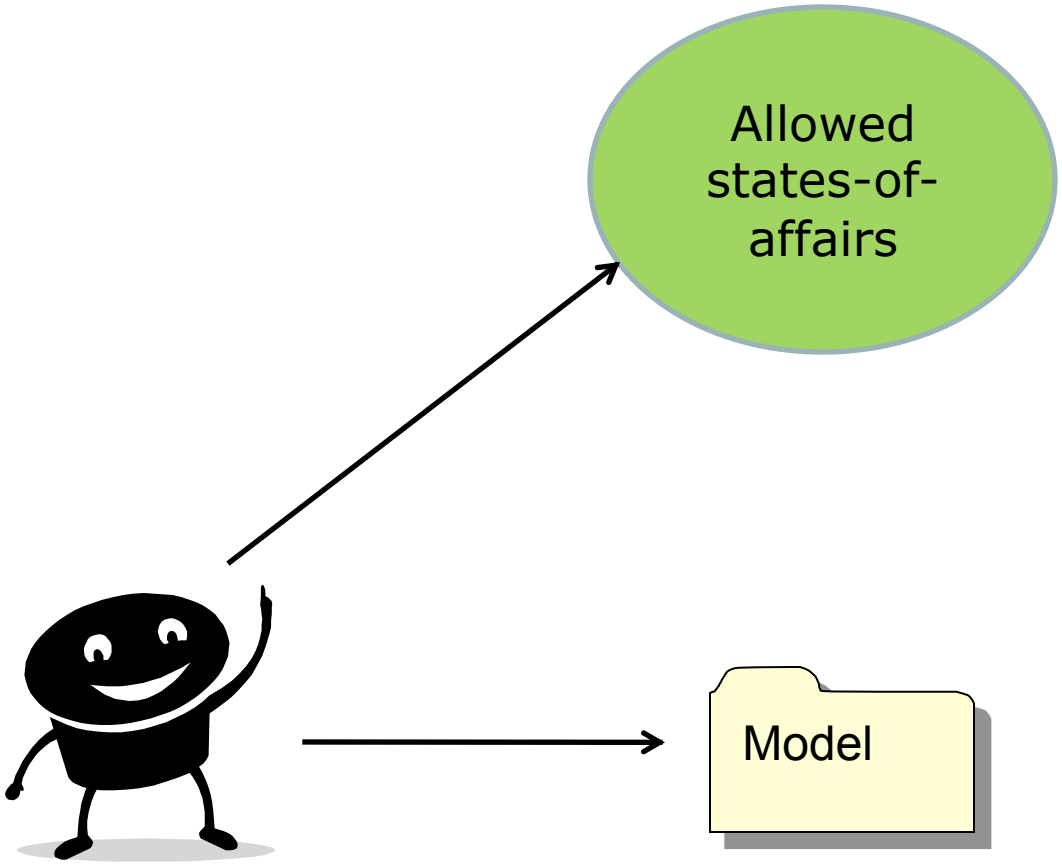
- We see conceptual models as a means to represent the categories that modelers (or subject matter experts) perceive in some portion of the physical and/or social world
  - **represent the modeller's intended conceptualization**
- The model should ideally:
  - **describe all states of affairs that are deemed admissible and**
  - **rule out those deemed inadmissible**
  - (according to the conceptualization)
- Assessing the quality of conceptual models is key to ensure that conceptual models can be used effectively as a basis for understanding, agreement and construction of information systems.

Conceptualization

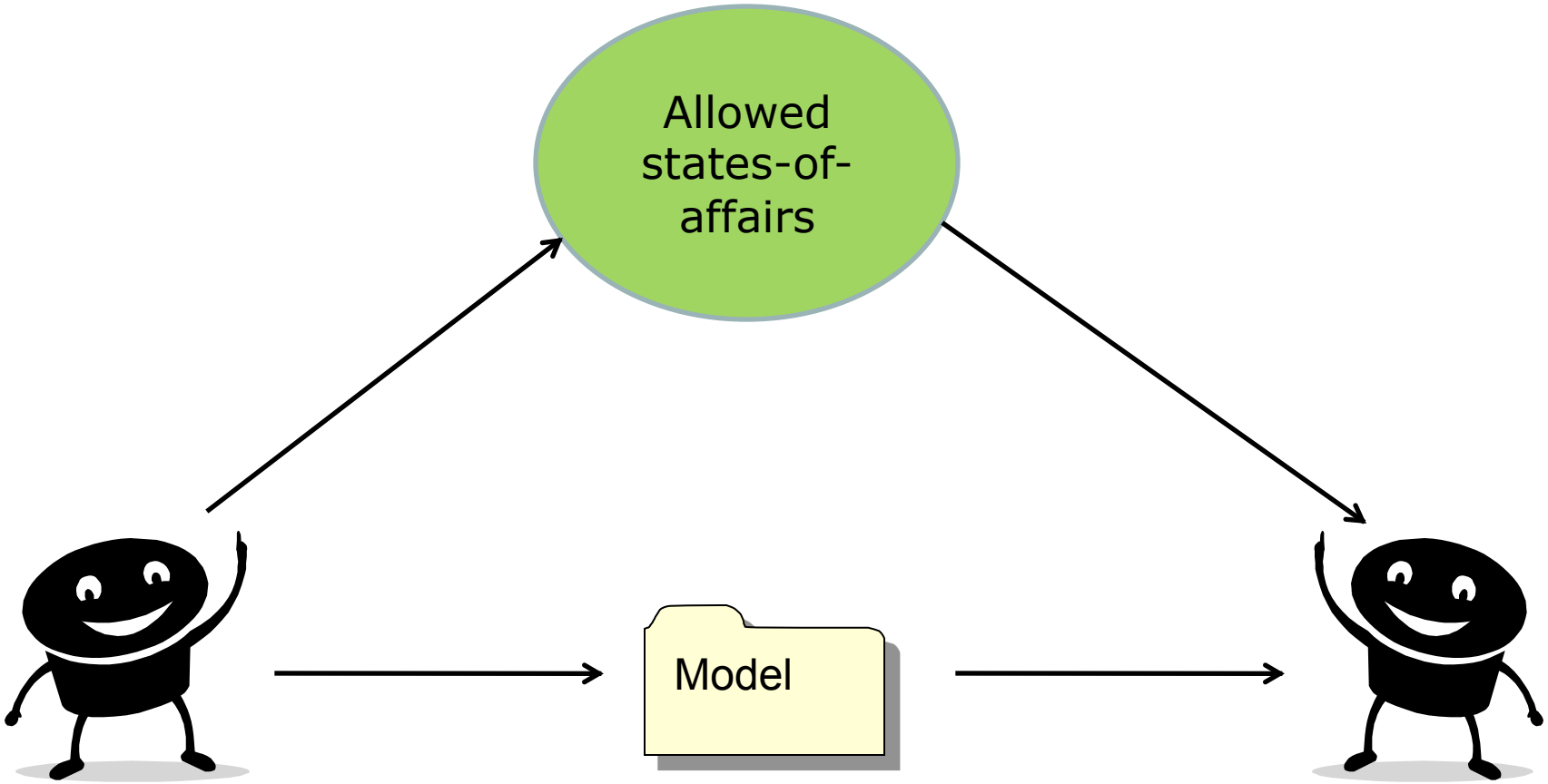
(entities that are allowed to exist, their properties and relations, ...)



Writing a model



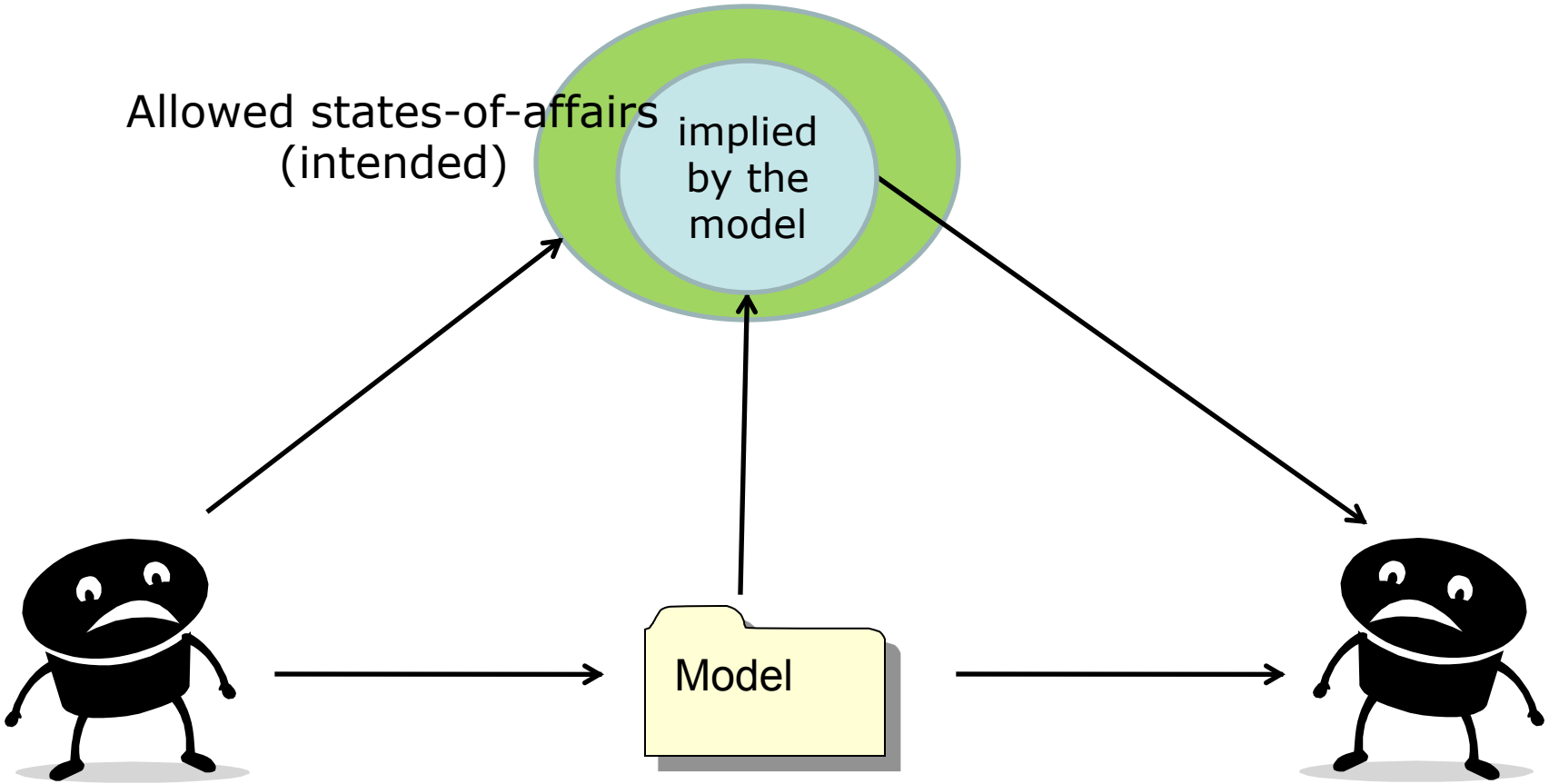
Interpreting a model



Intended x Modeled States-of-Affairs

Model is overconstrained

A mistake of the modeller?

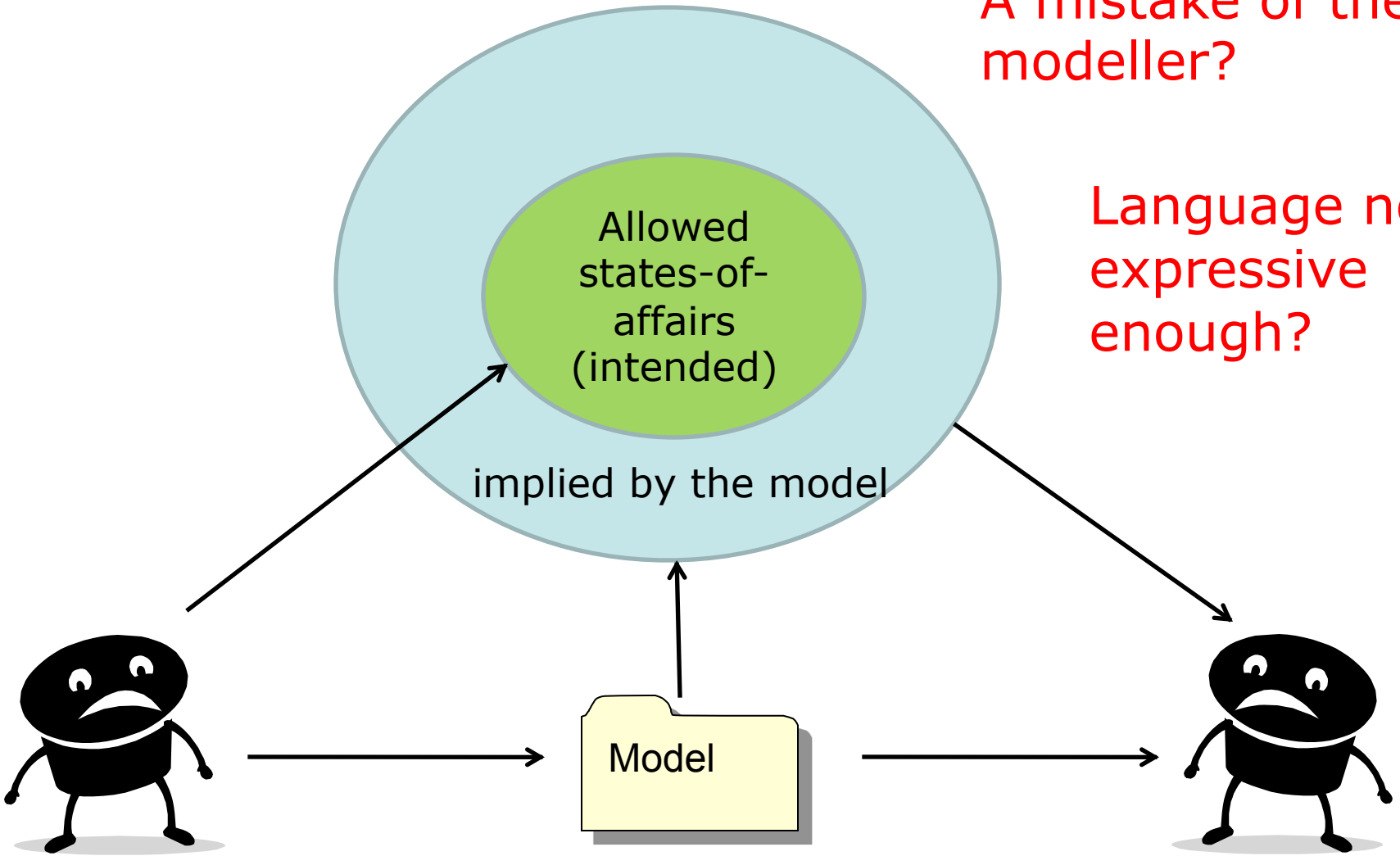


Intended x Modeled States-of-Affairs

Model is underconstrained

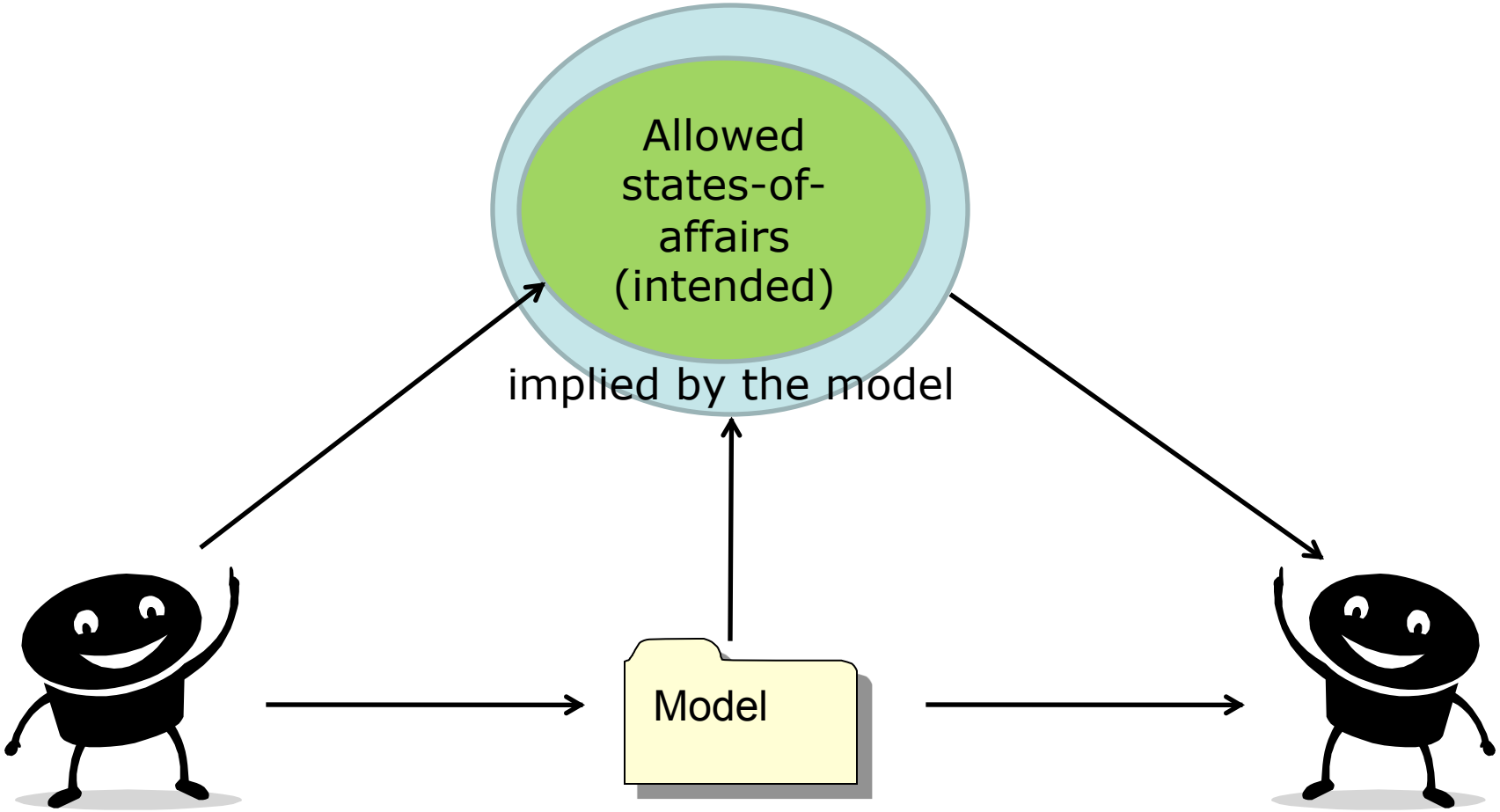
A mistake of the modeller?

Language not expressive enough?

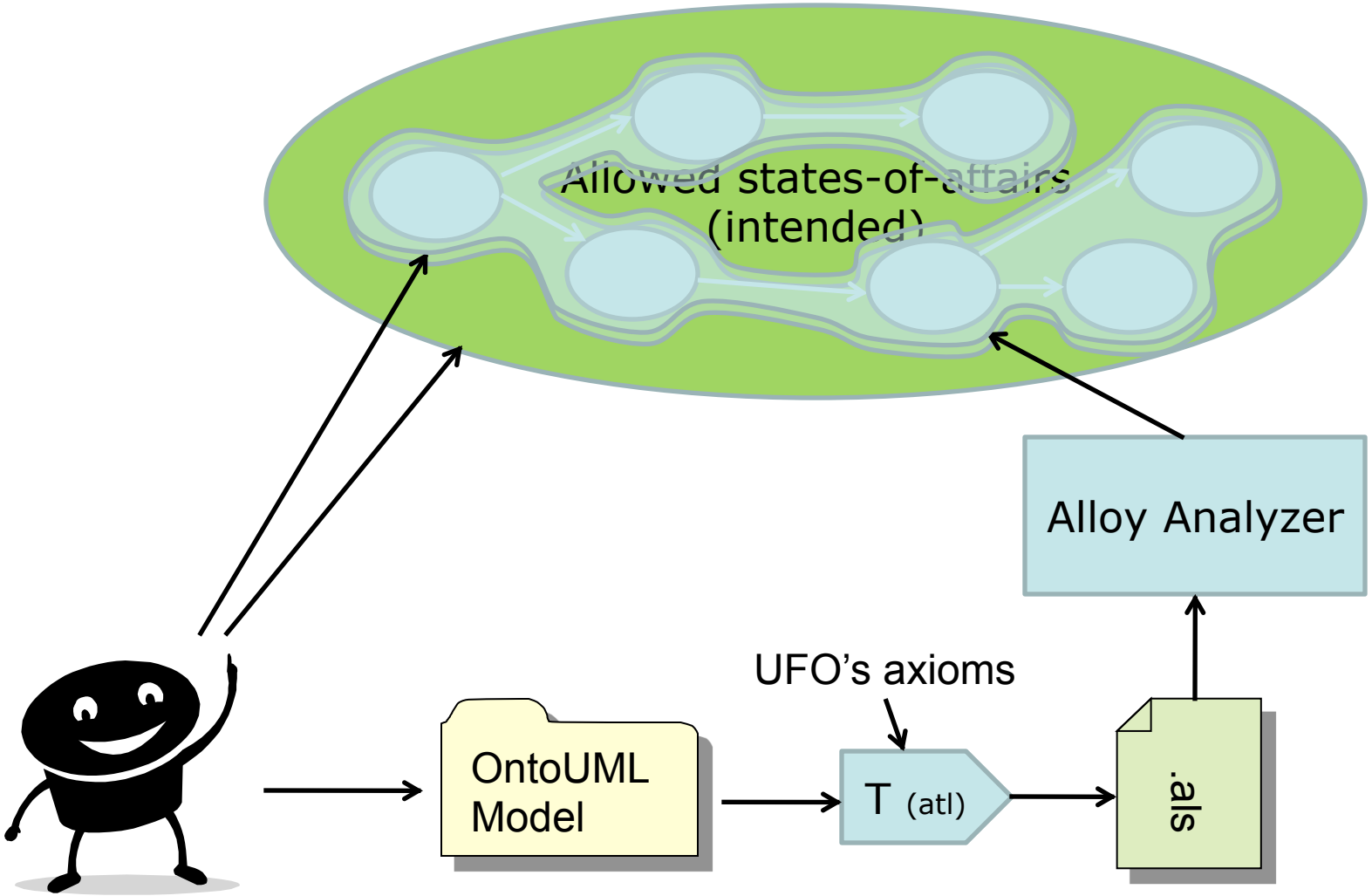


Intended x Modeled States-of-Affairs

High precision
And coverage



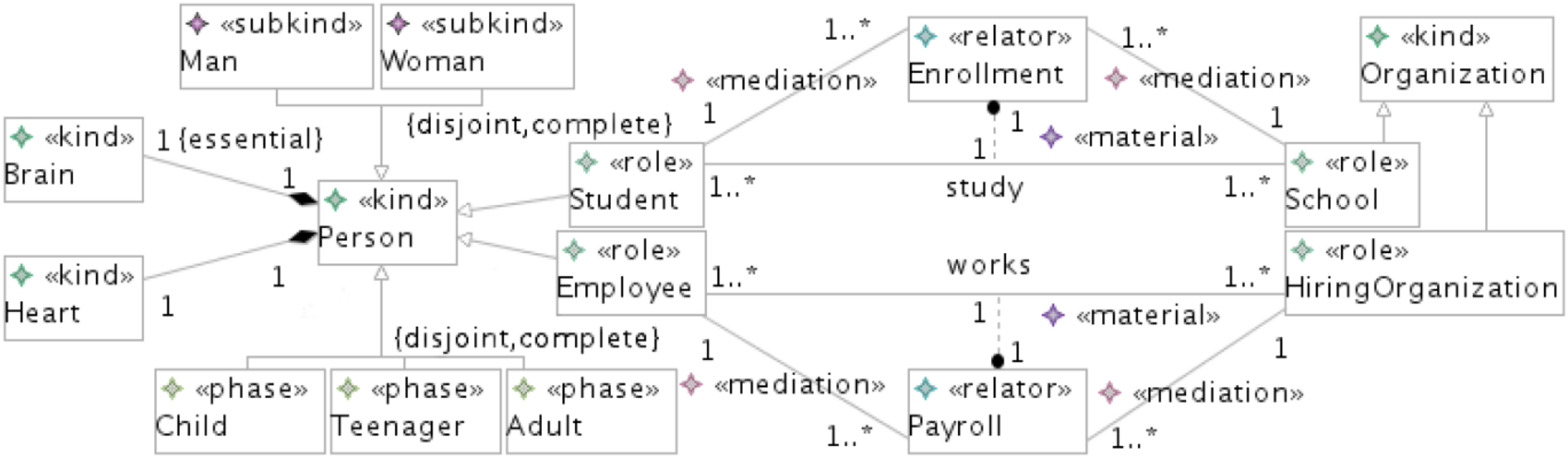
Our Approach: Transform OntoUML Model into Logic-Based Alloy for Simulation



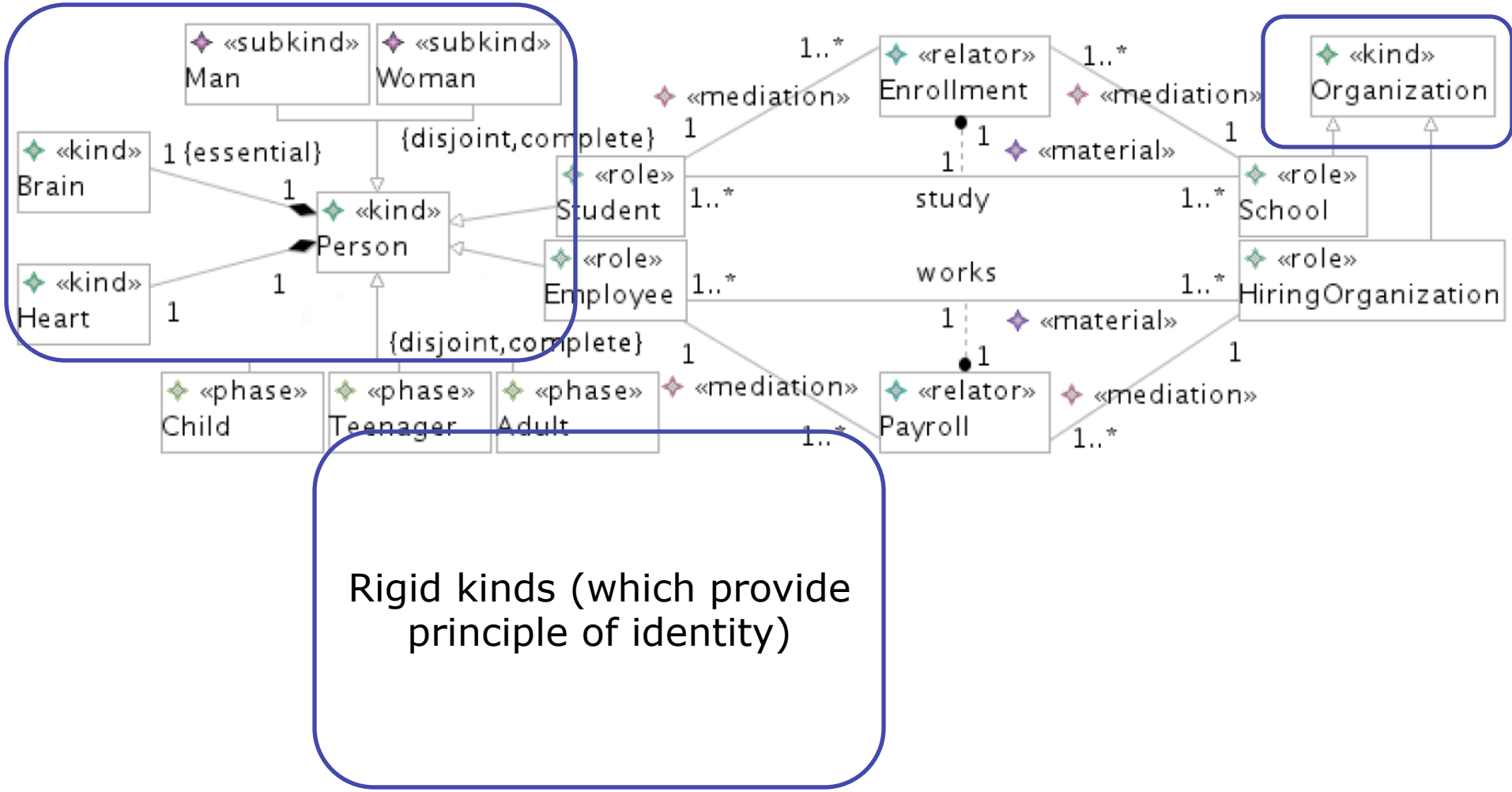
OntoUML

- UML profile that incorporates the theory in the UFO foundational ontology
  - **finer-grained distinctions between different types of classes and different types of part-whole relations**
  - **rich syntactic constraints**
  - Incorporates advances from DOLCE & OntoClean, GFO & GOL
- Modal meta-properties for object classifiers
  - Distinguishing rigid, semi-rigid and anti-rigid classifiers
    - (and therefore distinguish properties that apply necessarily to objects from those that apply contingently)
- Meta-properties for part-whole relations
  - mandatory, essential, inseparable and immutable parts, and immutable wholes

An Example

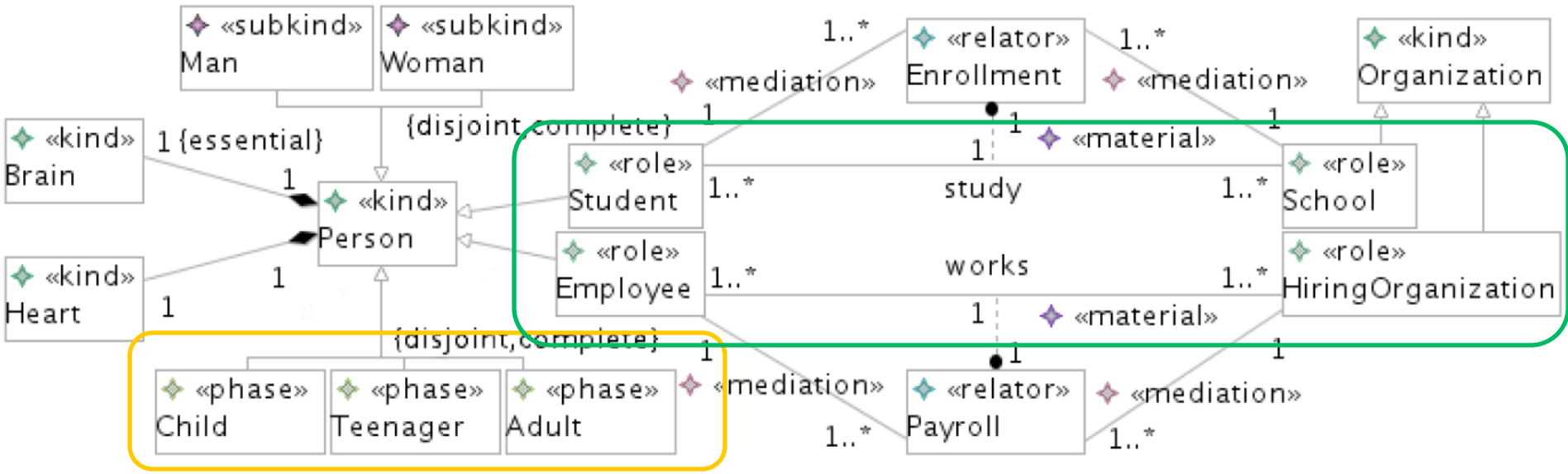

«subkind»
Man
«subkind»
Woman
{disjoint,complete}
«kind»
Brain
1 {essential}
1
«kind»
Person
«kind»
Heart
1
1
«role»
Student
«role»
Employee
{disjoint,complete}
«phase»
Child
«phase»
Teenager
«phase»
Adult
1..*
«mediation»
1
«relator»
Enrollment
1..*
«mediation»
1
«material»
1
1..*
study
1..*
«role»
School
«kind»
Organization
1..*
works
1..*
«role»
HiringOrganization
1
«material»
1
1
«mediation»
1..*
«relator»
Payroll
1..*
«mediation»
1

An Example: Rigid Universals



Rigid kinds (which provide principle of identity)

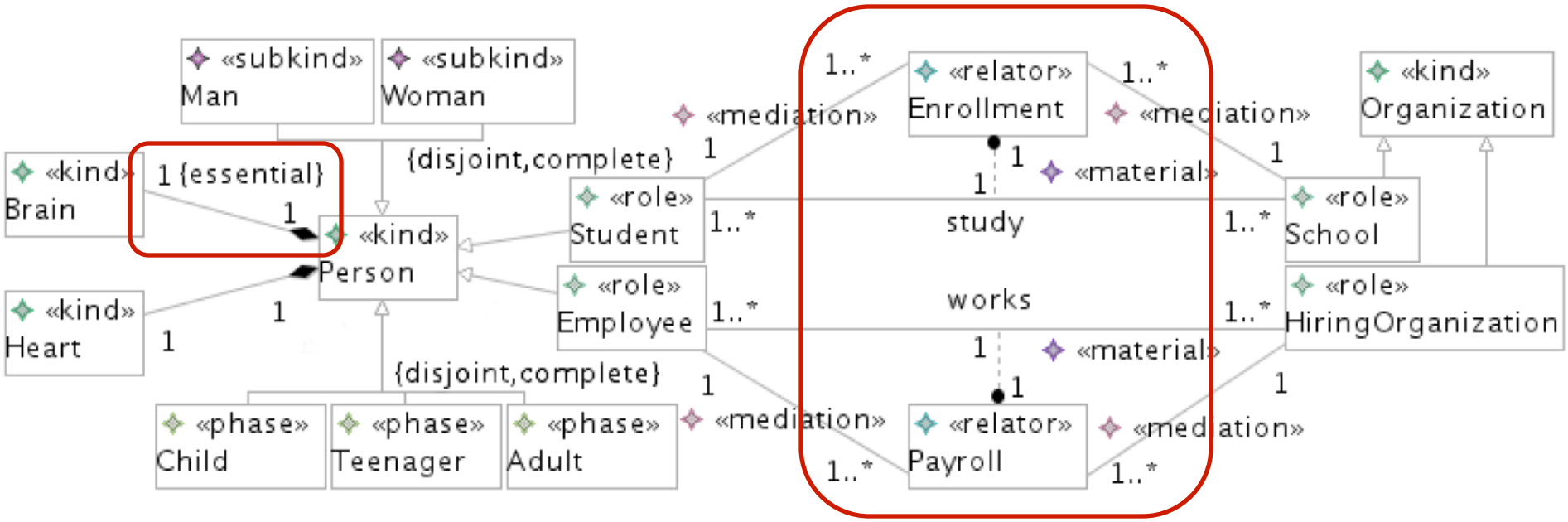
An Example: Anti-Rigid Universals



Anti-rigid, defined by intrinsic properties

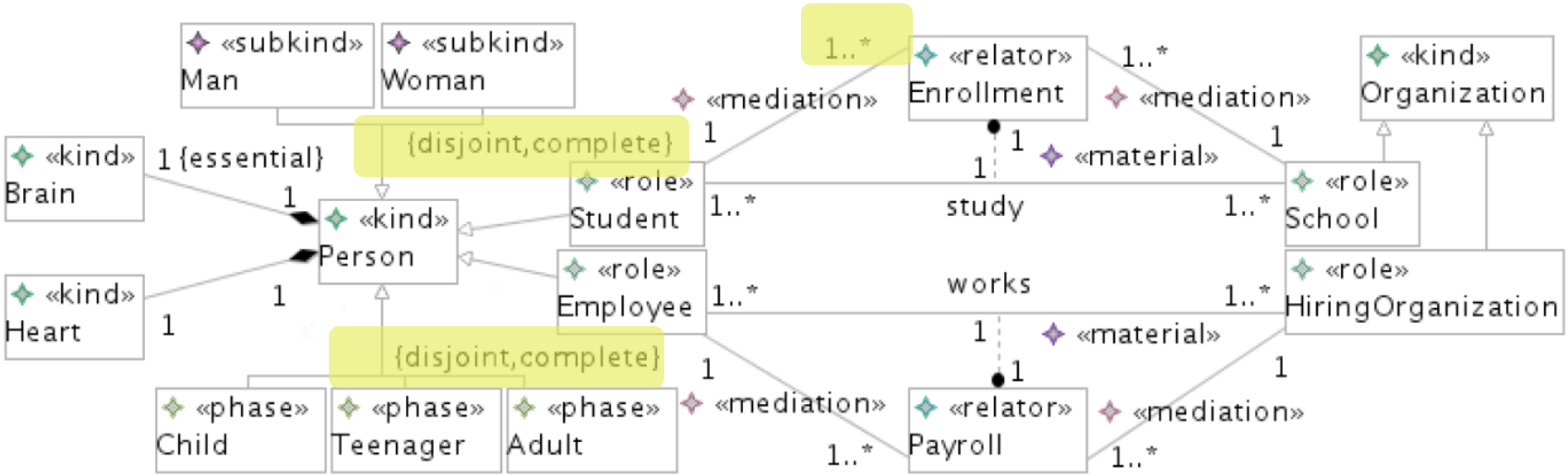
Anti-rigid, relationally dependent

An Example: Existential Dependence

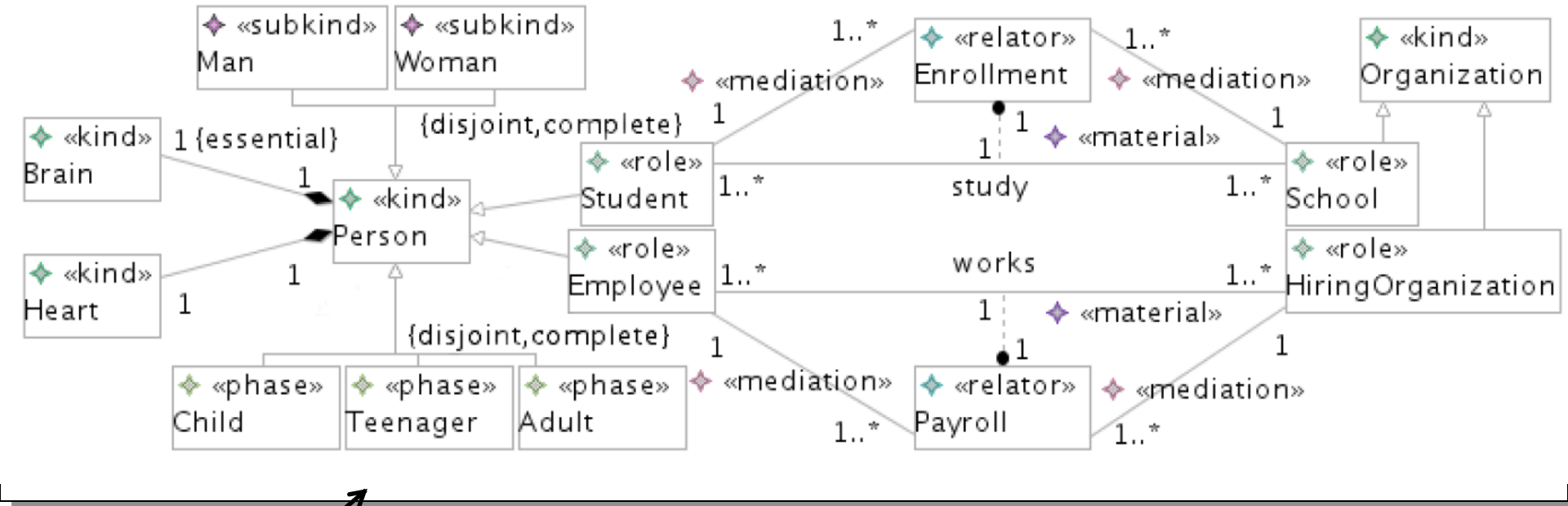


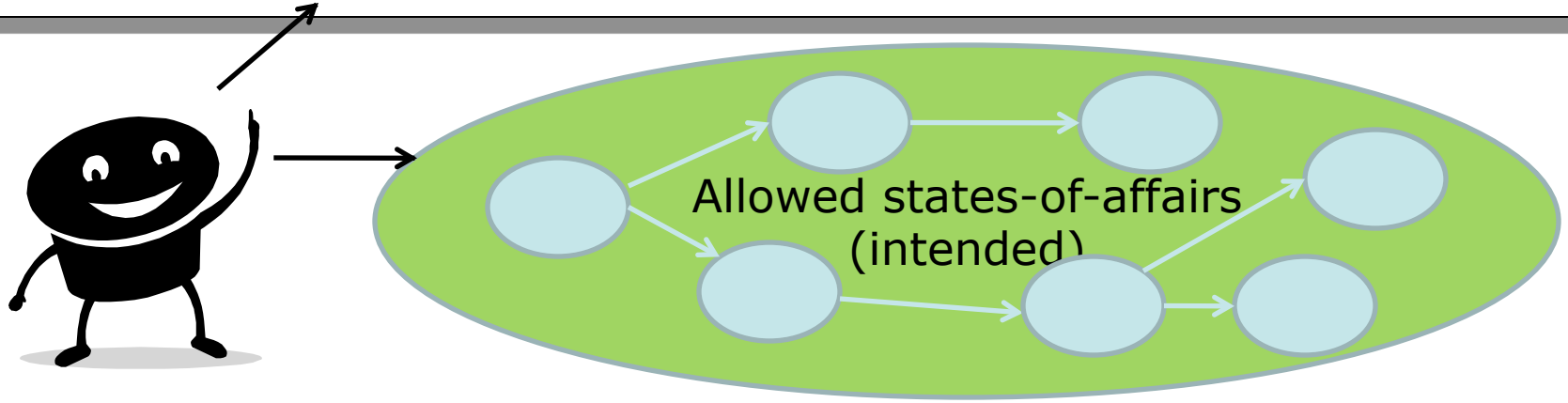
Existential dependence

An Example: Additional constraints...



An Example


«subkind» Man
«subkind» Woman
{disjoint,complete}
«kind» Brain
1 {essential}
«kind» Person
«kind» Heart
«role» Student
«role» Employee
«phase» Child
«phase» Teenager
«phase» Adult
{disjoint,complete}
«relator» Enrollment
«mediation»
«material»
study
«role» School
«kind» Organization
works
«role» HiringOrganization
«relator» Payroll
«mediation»
1..*
1


Allowed states-of-affairs
(intended)

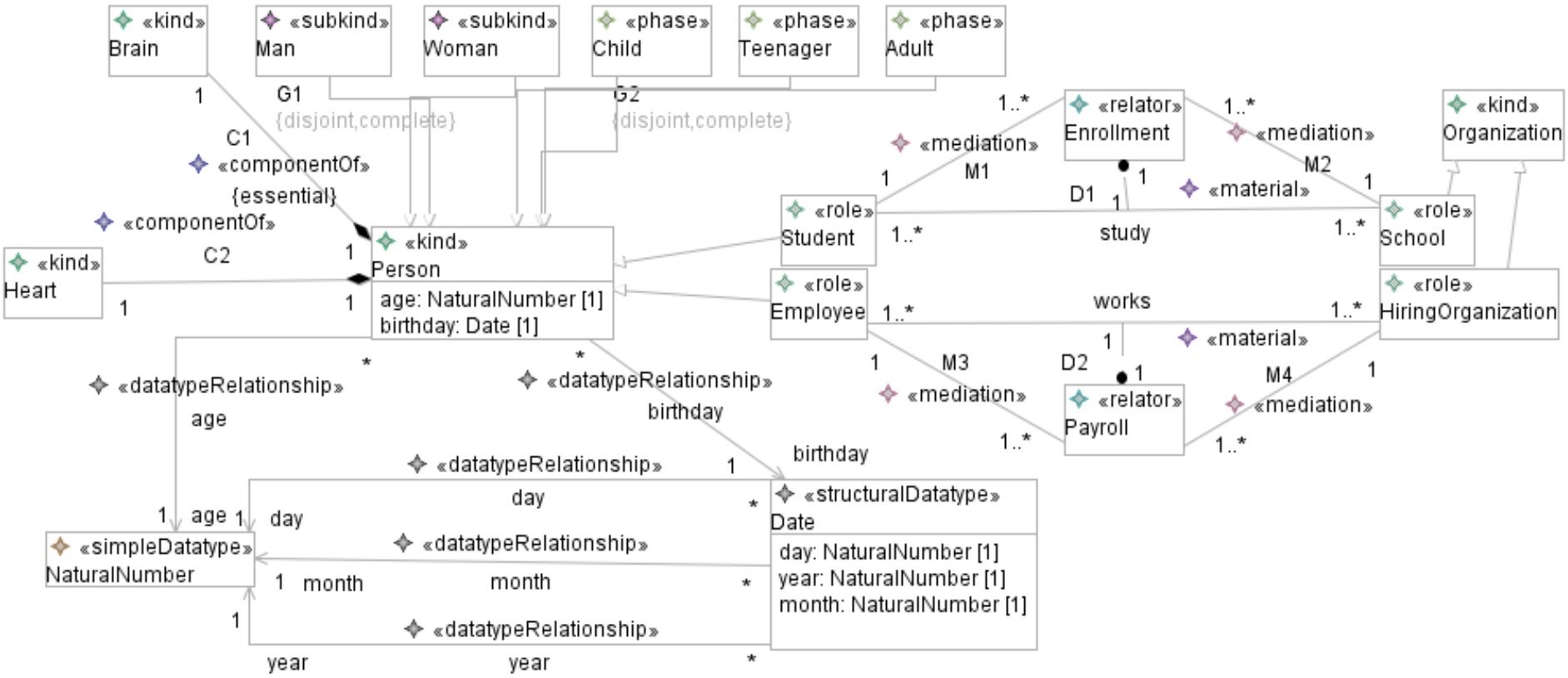
Alloy

- A model in Alloy consists of logical constraints which are captured in *signatures* and *fact declarations.*
- When a model is instantiated by the Alloy Analyzer, *atoms* are generated from signatures respecting the logical constraints in the model.
- Signatures can include field declarations, introducing relations between signatures.
- No notion of state change, dynamics or modality
- Analyzer can generate instances and produce counter-examples for predicates

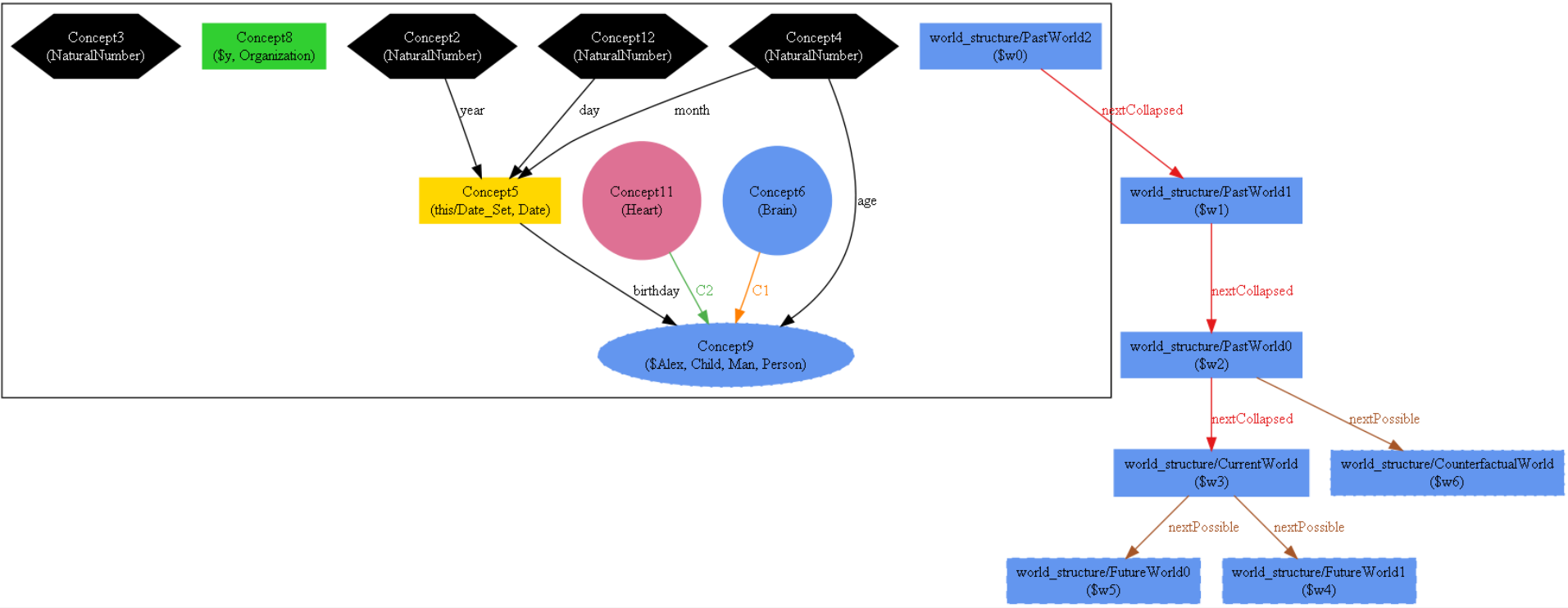
Transformation

- Reify worlds and acessibility relation in Alloy
- Branching-time Kripke structure
  - Past worlds, current world, future worlds & counterfactual worlds
- The characteristics of the OntoUML classes (e.g., rigidity, anti-rigidity) and the ones of the relationships (e.g., cardinality constraints, shareability, existential dependency and disjointness) are mapped into constraints in Alloy

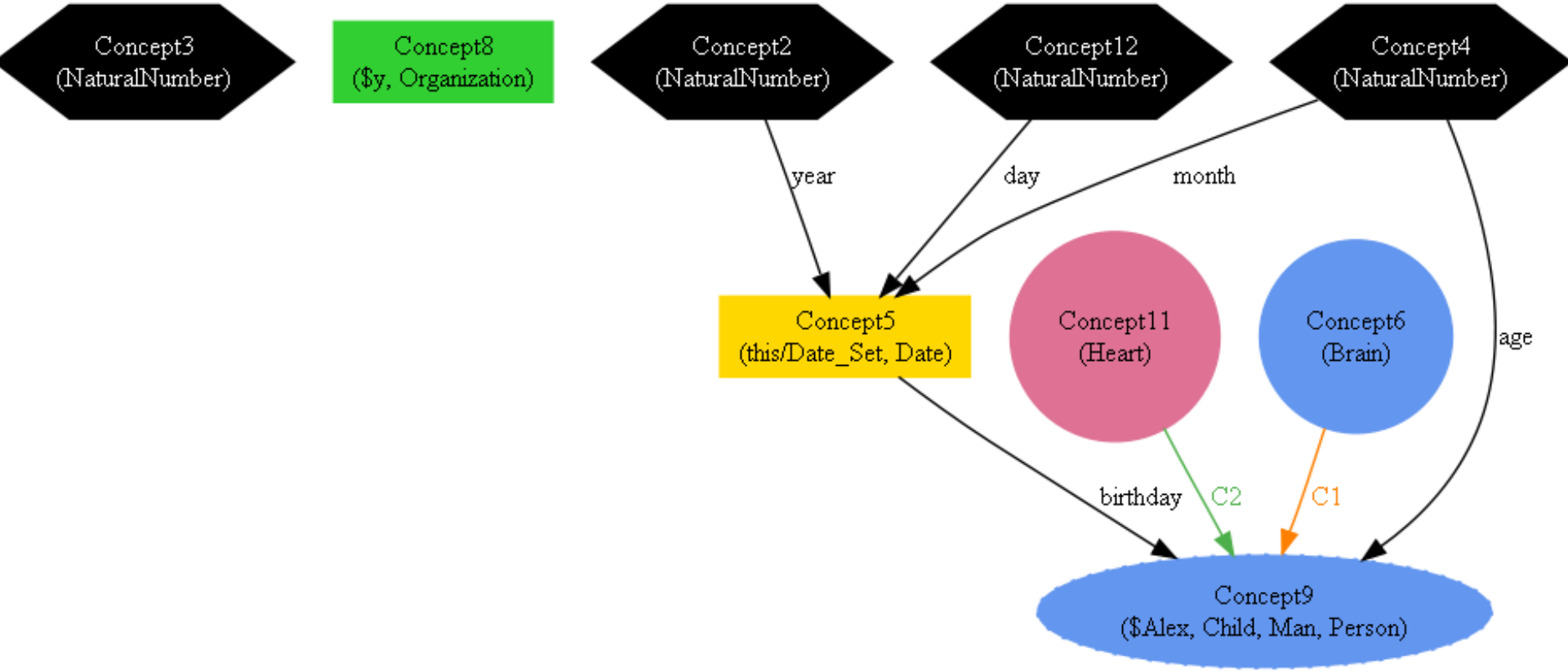
Example


«kind»
Brain
«subkind»
Man
«subkind»
Woman
«phase»
Child
«phase»
Teenager
«phase»
Adult
G1
{disjoint,complete}
G2
{disjoint,complete}
C1
«componentOf»
{essential}
«componentOf»
C2
«kind»
Heart
«kind»
Person
age: NaturalNumber [1]
birthday: Date [1]
«role»
Student
«role»
Employee
«mediation»
M1
«relator»
Enrollment
«mediation»
M2
«material»
D1
study
«role»
School
«kind»
Organization
works
«material»
D2
«mediation»
M3
«relator»
Payroll
«mediation»
M4
«role»
HiringOrganization
«datatypeRelationship»
age
«datatypeRelationship»
birthday
«simpleDatatype»
NaturalNumber
«datatypeRelationship»
day
«datatypeRelationship»
month
«datatypeRelationship»
year
«structuralDatatype»
Date
day: NaturalNumber [1]
year: NaturalNumber [1]
month: NaturalNumber [1]

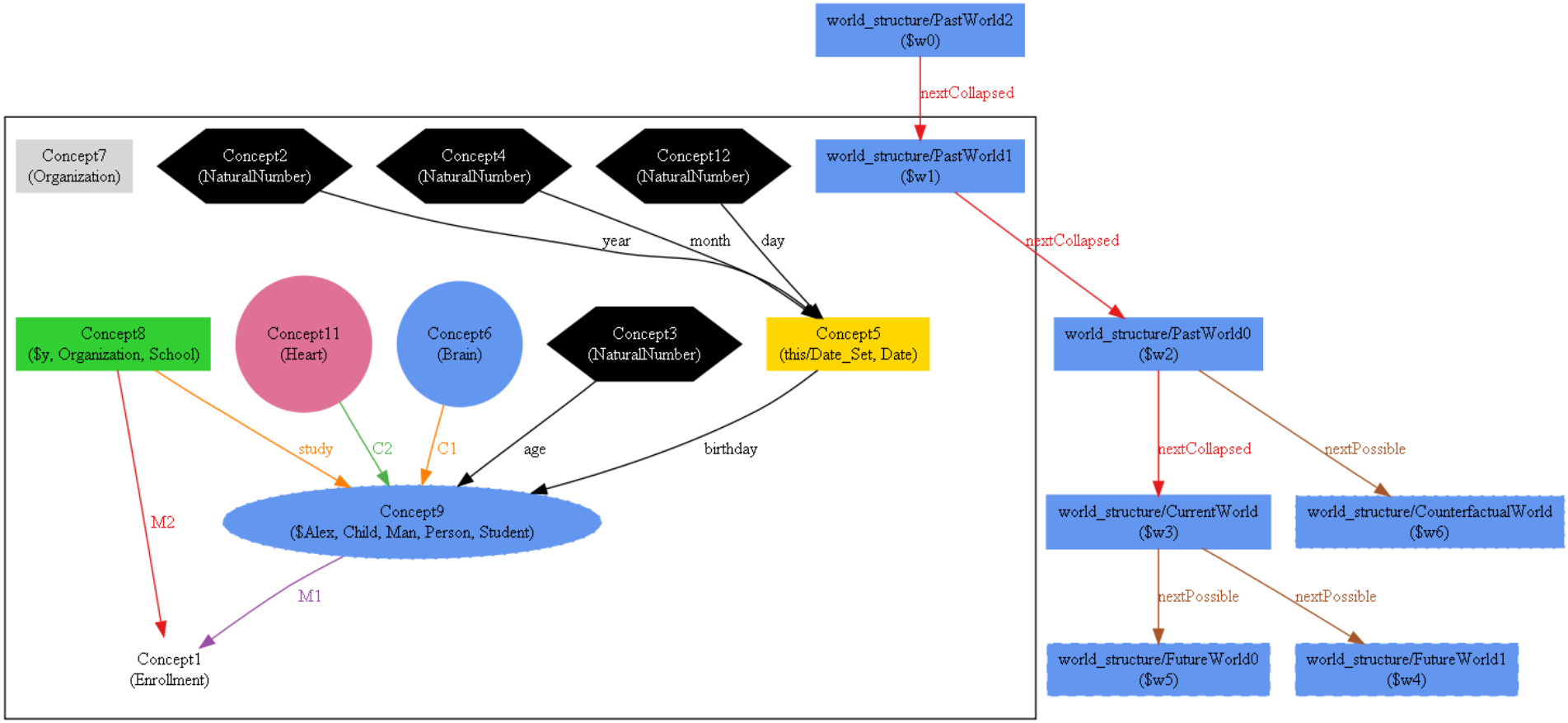
Example: PastWorld2
Alex is a Child



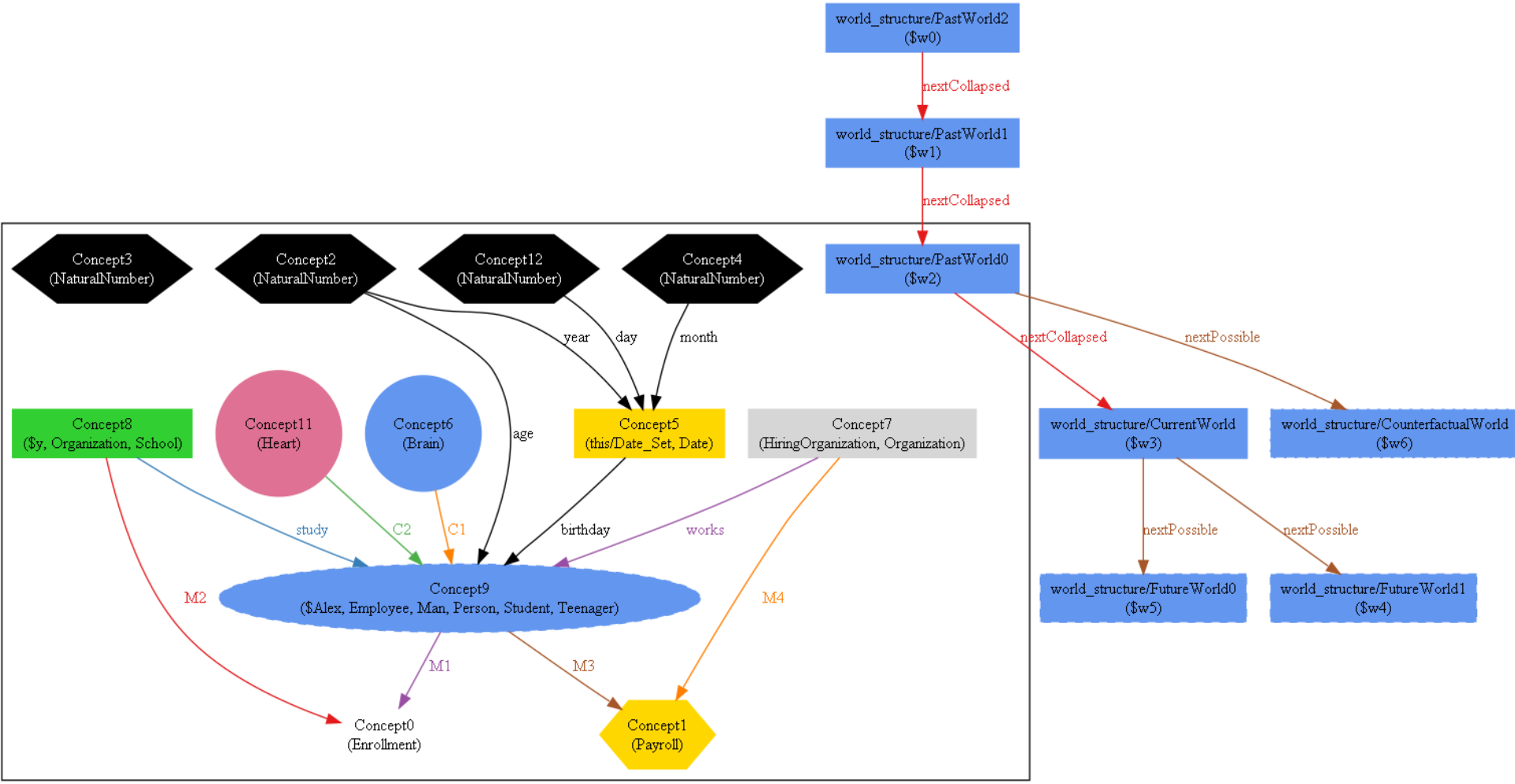
Example: PastWorld2
Alex is a Child



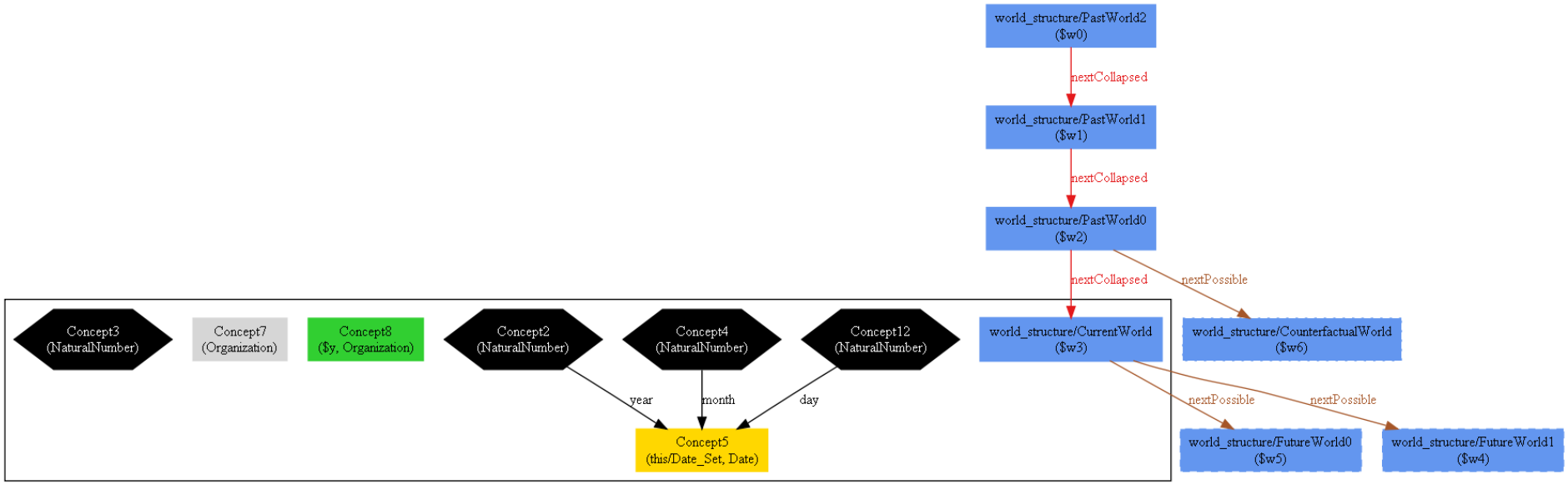
Example: PastWorld1
Alex changes age, becomes a Student, Concept8 is School, Organization appears

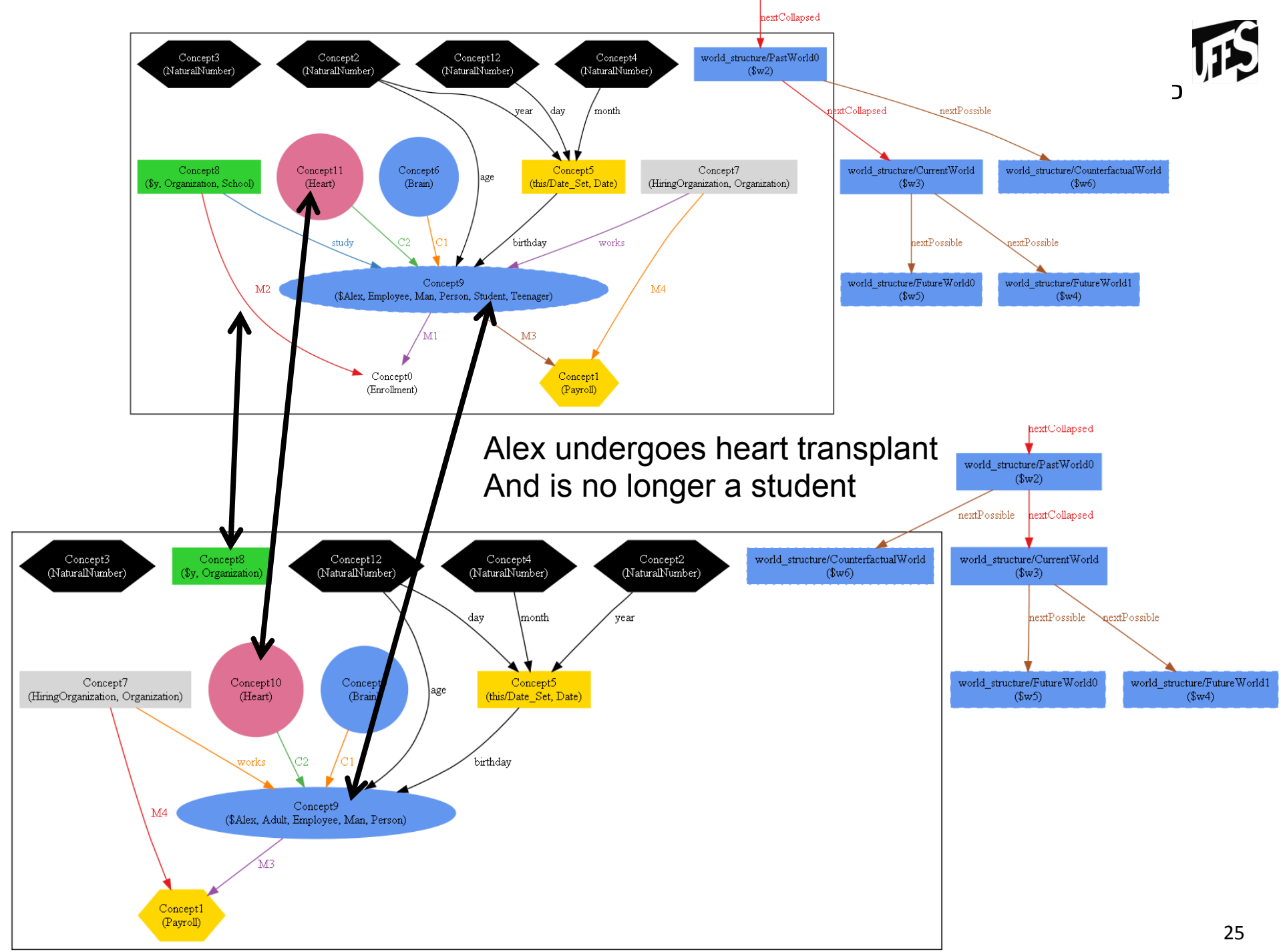


Example: PastWorld0
Alex is Employee (and still a Student), becomes Teenager



Example CurrentWorld: Alex no longer exists




nextCollapsed
Concept3
(NaturalNumber)
Concept2
(NaturalNumber)
Concept12
(NaturalNumber)
Concept4
(NaturalNumber)
world_structure/PastWorld0
($w2)
year
day
month
nextCollapsed
nextPossible
Concept8
($y, Organization, School)
Concept11
(Heart)
Concept6
(Brain)
age
Concept5
(this/Date_Set, Date)
Concept7
(HiringOrganization, Organization)
world_structure/CurrentWorld
($w3)
world_structure/CounterfactualWorld
($w6)
study
C2
C1
birthday
works
nextPossible
nextPossible
M2
Concept9
($Alex, Employee, Man, Person, Student, Teenager)
M4
world_structure/FutureWorld0
($w5)
world_structure/FutureWorld1
($w4)
M1
M3
Concept0
(Enrollment)
Concept1
(Payroll)
Alex undergoes heart transplant
And is no longer a student
nextCollapsed
world_structure/PastWorld0
($w2)
nextPossible
nextCollapsed
Concept3
(NaturalNumber)
Concept8
($y, Organization)
Concept12
(NaturalNumber)
Concept4
(NaturalNumber)
Concept2
(NaturalNumber)
world_structure/CounterfactualWorld
($w6)
world_structure/CurrentWorld
($w3)
day
month
year
nextPossible
nextPossible
Concept7
(HiringOrganization, Organization)
Concept10
(Heart)
Concept
(Brain)
age
Concept5
(this/Date_Set, Date)
world_structure/FutureWorld0
($w5)
world_structure/FutureWorld1
($w4)
works
C2
C1
birthday
M4
Concept9
($Alex, Adult, Employee, Man, Person)
M3
Concept1
(Payroll)

OCL constraints

- To guide the verification one may add invariants which can be checked for consistency
  - If examples can be produced, invariants are consistent
  - (it is possible to satisfy the invariant)
- Or add invariants which we believe are implied by the model
  - If counterexamples are found than the intuition was wrong
  - (if counterexample is not found, then invariant is guaranteed to hold for all instances up to a certain size)

- We have implemented an OCL to Alloy transformation which allows us to express these invariants without knowledge of Alloy

Limitations

- Support models which are finitely instantiable
- Scope and scalability
  - Appeal to the “small scope hypothesis”
  - Exhaustive model checking becomes intractable with large number of instances

Conclusions

- A mature approach to conceptual modelling requires tools for modellers to gain confidence on the quality of the models they produce
- Our approach shows the possible dynamics of object creation, classification, association and destruction as defined in the conceptual model
- Snapshots confront the modeller with what he/she wrote
- Modalities are exercised in the generated world structure
- Verification of invariants with generation of counterexamples

- Tools available for download at http://nemo.inf.ufes.br

Future work

- Explore visualization techniques and perform empirical validation
- Support for temporal constraints
- Analysis and verification
  - What kinds of assertions are interesting for analysis?
  - A catalogue of patterns which reveal common mistakes (“warnings”)

Acknowledgements

- Giancarlo Guizzardi
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- John Guerson
- Tiago Prince Sales

References

- BENEVIDES, A. B. ; GUIZZARDI, G. ; BRAGA, B.F.B. ; ALMEIDA, J. P. A. . Validating Modal Aspects of OntoUML Conceptual Models Using Automatically Generated Visual World Structures. Journal of Universal Computer Science, v. 16, p. 2904-2933, 2011.
- BRAGA, B.F.B. ; ALMEIDA, J. P. A. ; GUIZZARDI, G. ; BENEVIDES, A. B. . Transforming OntoUML into Alloy: towards conceptual model validation using a lightweight formal method. Innovations in Systems and Software Engineering, Springer, v. 6, p. 1-13, 2010.

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