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TOWARDS AUTOMATING THE **ANALYSIS OF INTEGRITY CONSTRAINTS** IN MULTI-LEVEL MODELS

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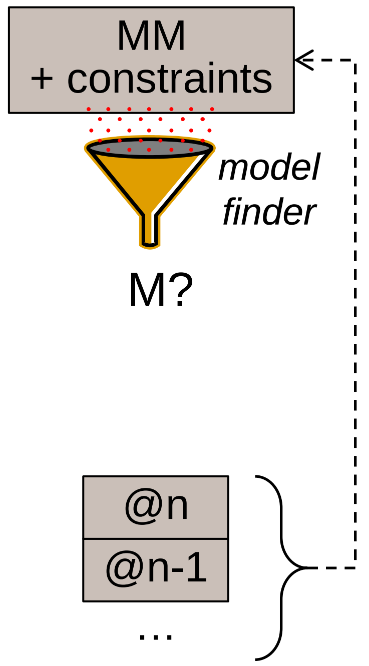
GOAL

- analysis of correctness properties in multi-level models
- starting with a basic correctness property: satisfiability

  "given a meta-model with (ocl) integrity constraints,
  is there a valid model that satisfies all constraints?"

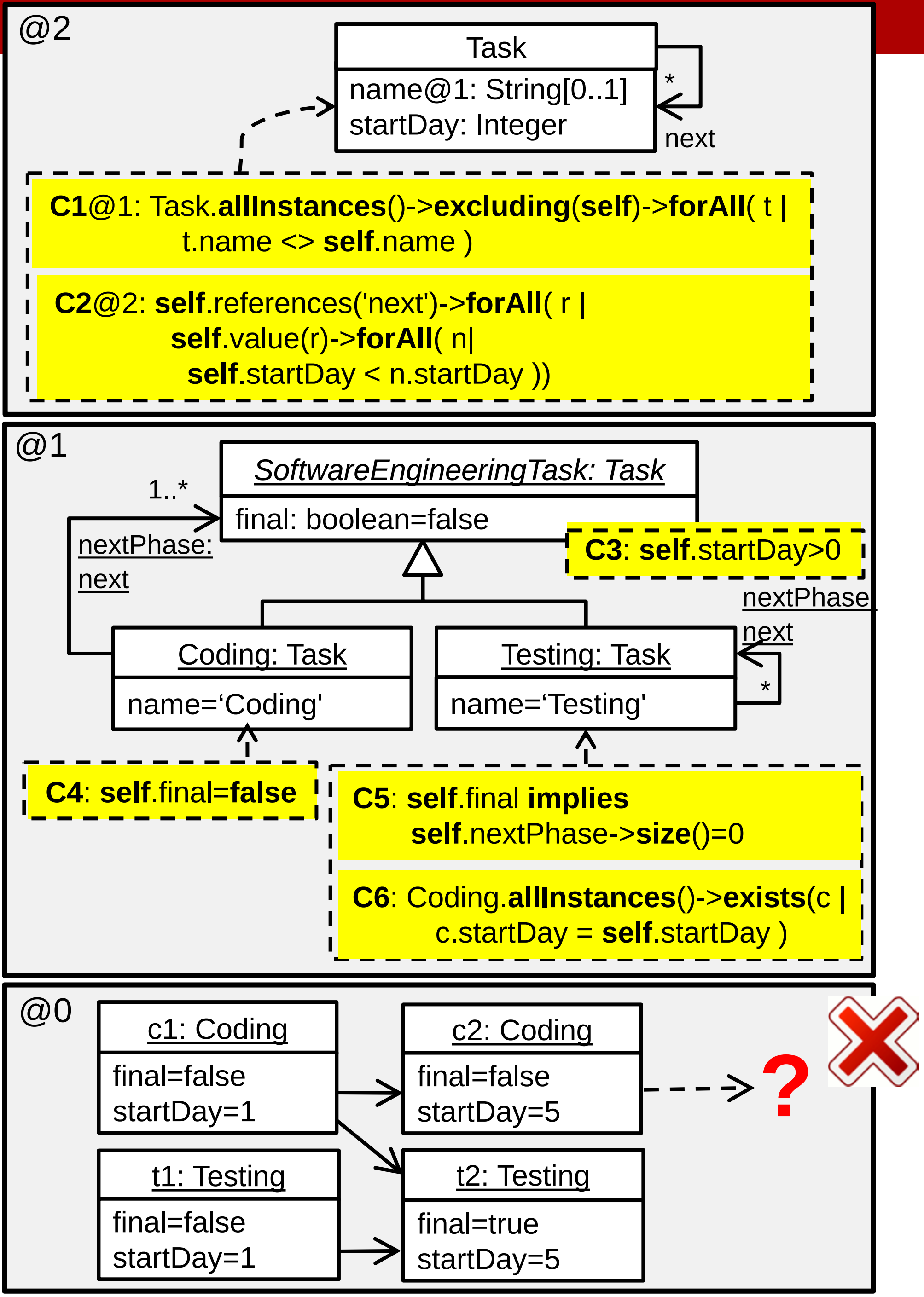
2-LEVELS

- constraints defined in MM, and evaluated in M
- analysis by means of *off-the-shelf* model finders



MULTI-LEVEL MODELLING

- constraints defined at any meta-level
- constraints evaluated *n* meta-levels below
- contribution: how to use standard model finders to analyse multi-level models



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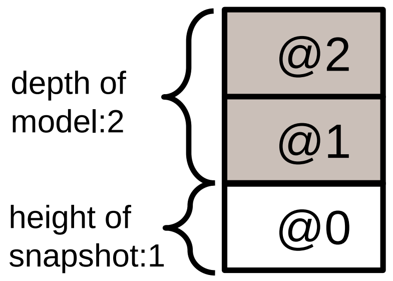
metaDepth

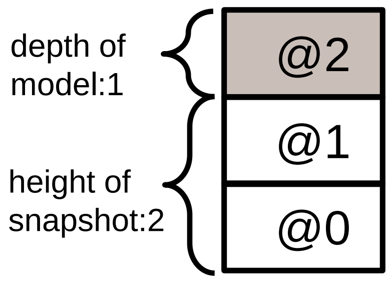
http://astreo.ii.uam.es/~jlara/metaDepth/

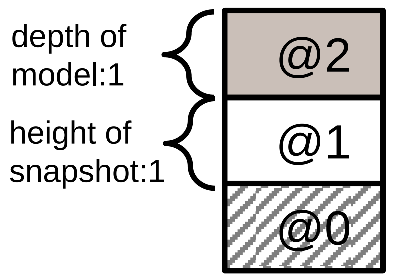
- multi-level textual framework
- constraints defined in any meta-level
- **potency**: meta-level of instantiation (or constraint evaluation)
- **reflection**: useful for constraints to be evaluated >1 meta-levels below
  - *references(r)*: name of references that instantiate reference *r*
  - *value(r)*: content of reference with name *r*

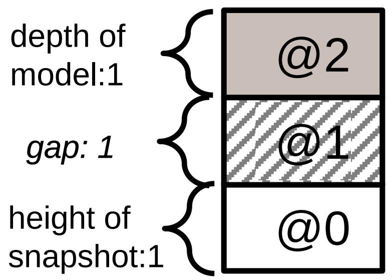
can this model be completed?

SCENARIOS in the analysis of multi-level models









APPLICATIONS

model completion, satisfiability of new constraints at level 1	satisfiability at any meta-level, of a language definition	standard two-level scenario	existence of models@0 with certain features, assess potencies

CHALLENGES

flatten two meta-levels into one, which will be input to the finder	emulate the generation of several meta-levels within one	remove constraints with potency > 1	particular case of second scenario

► Flattened model (@2+@1) is used to search models at level 0

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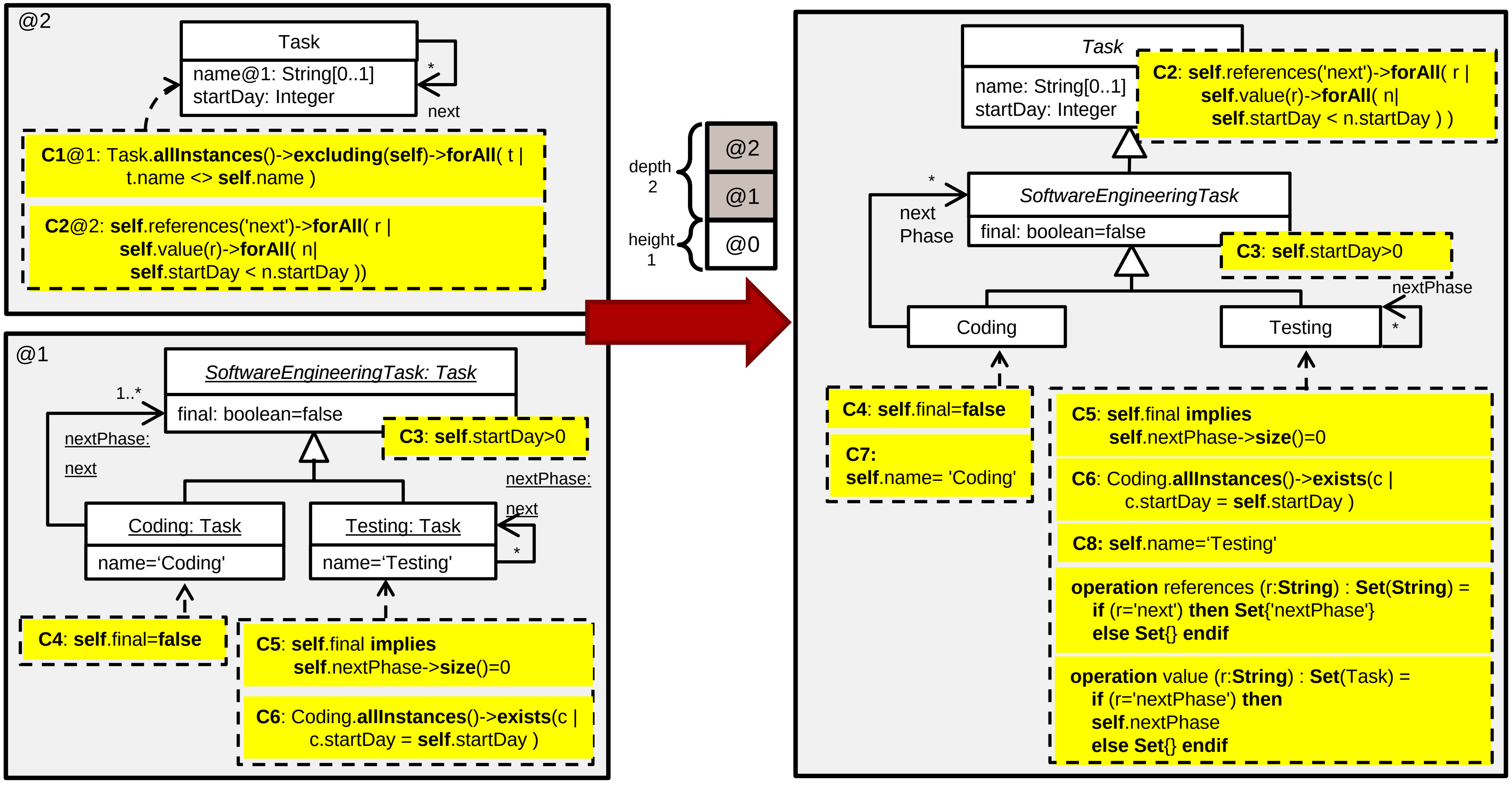
5. Attribute slots at level 1 (*name*) are removed, their value is given as constraints
6. Emulate built-in operations (*reference*, *value*)



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        t.name <> self.name )

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        self.value(r)->forAll( n|
          self.startDay < n.startDay ))

C3: self.startDay>0

C4: self.final=false

C5: self.final implies
        self.nextPhase->size()=0

C6: Coding.allInstances()->exists(c |
        c.startDay = self.startDay )
```

```
C2: self.references('next')->forAll( r |
        self.value(r)->forAll( n|
          self.startDay < n.startDay ) )

C3: self.startDay>0

C4: self.final=false

C7:
self.name= 'Coding'

C5: self.final implies
        self.nextPhase->size()=0

C6: Coding.allInstances()->exists(c |
        c.startDay = self.startDay )

C8: self.name='Testing'

operation references (r:String) : Set(String) =
    if (r='next') then Set{'nextPhase'}
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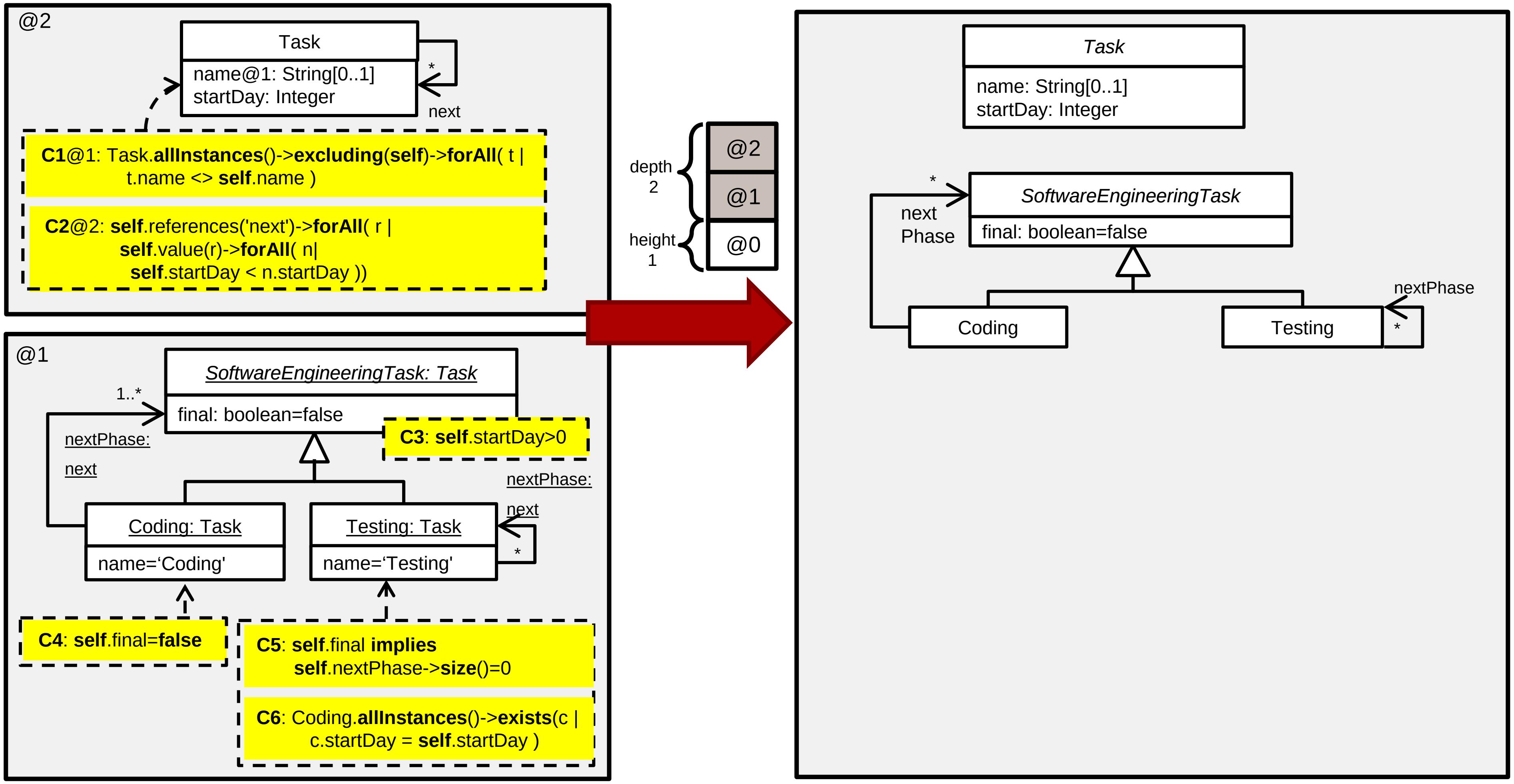

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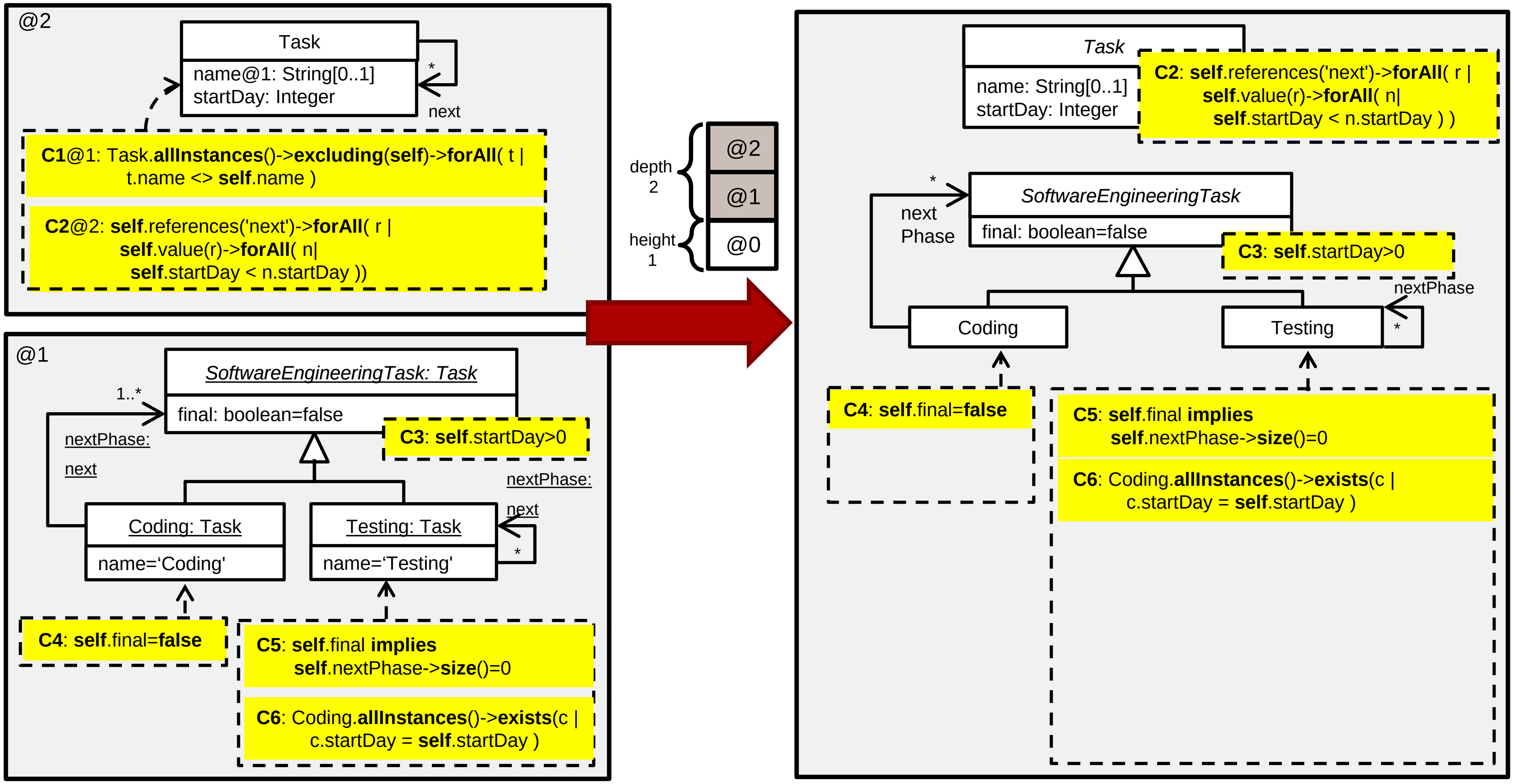

@2
Task
name@1: String[0..1]
startDay: Integer
*
next
C1@1: Task.allInstances()->excluding(self)->forAll(t | t.name <> self.name)
C2@2: self.references('next')->forAll(r | self.value(r)->forAll(n| self.startDay < n.startDay))
@1
SoftwareEngineeringTask: Task
final: boolean=false
1..*
nextPhase: next
C3: self.startDay>0
nextPhase: next
*
Coding: Task
name='Coding'
Testing: Task
name='Testing'
C4: self.final=false
C5: self.final implies self.nextPhase->size()=0
C6: Coding.allInstances()->exists(c | c.startDay = self.startDay)
depth 2
height 1
@2
@1
@0
Task
name: String[0..1]
startDay: Integer
C2: self.references('next')->forAll(r | self.value(r)->forAll(n| self.startDay < n.startDay))
*
next Phase
SoftwareEngineeringTask
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nextPhase
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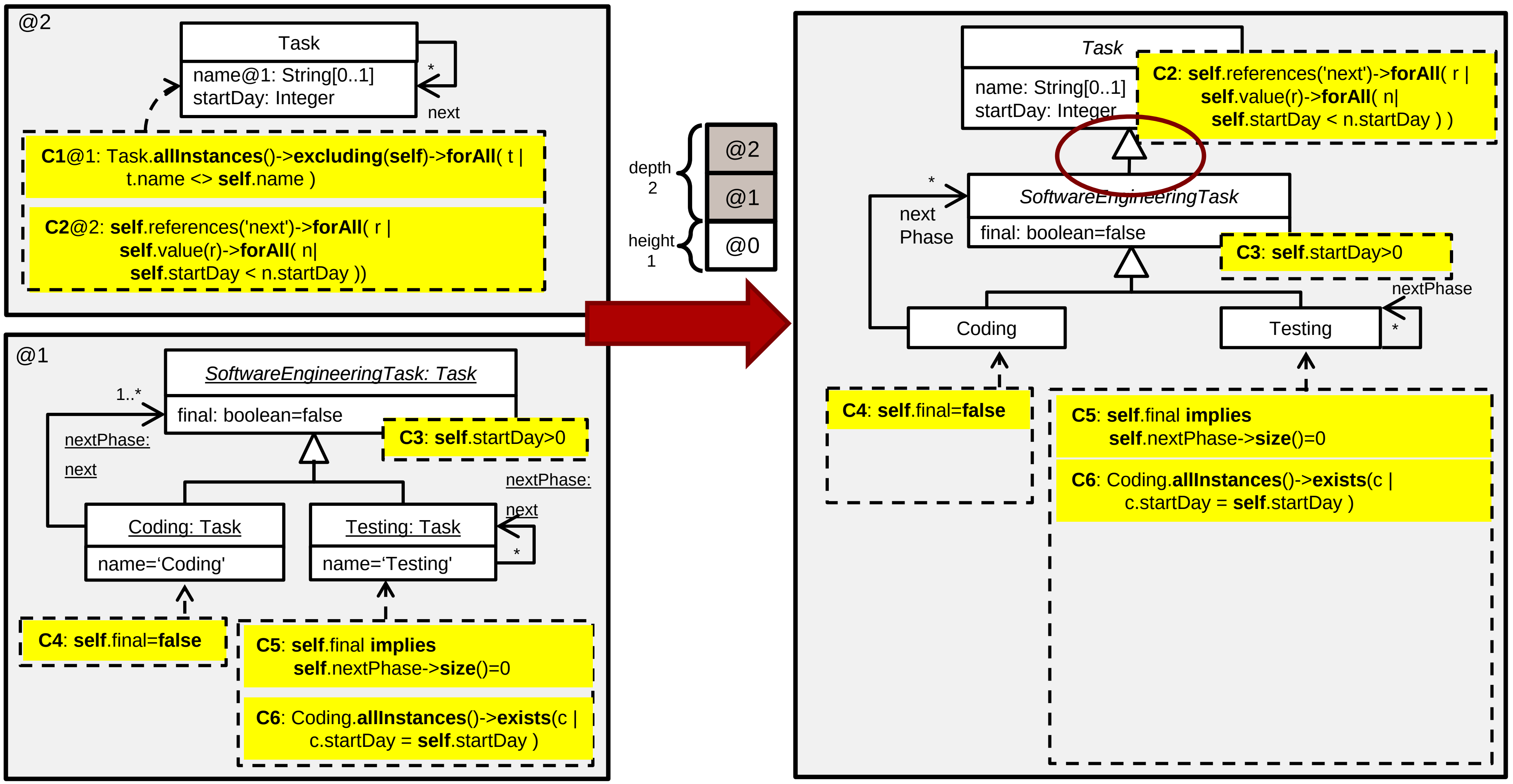

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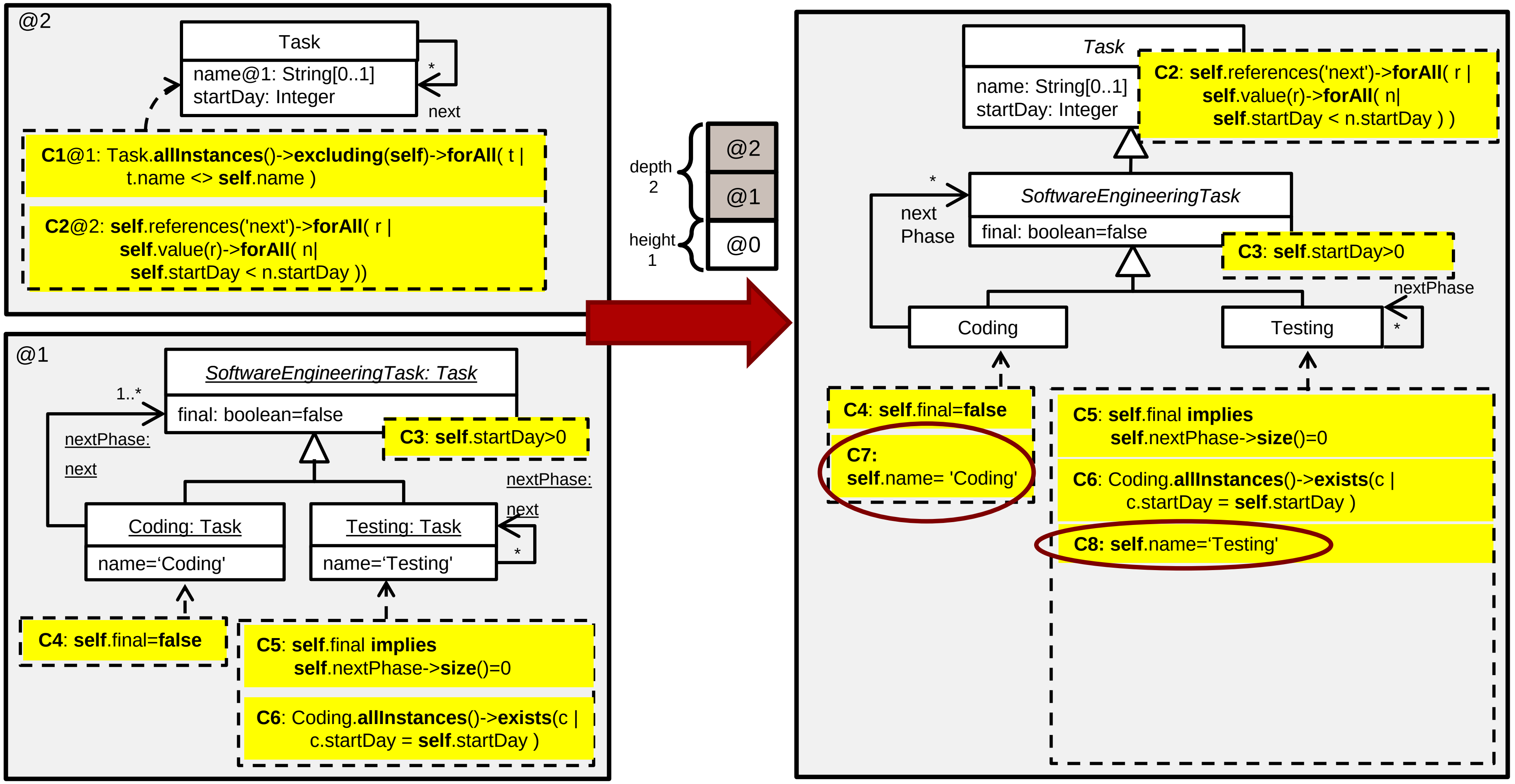

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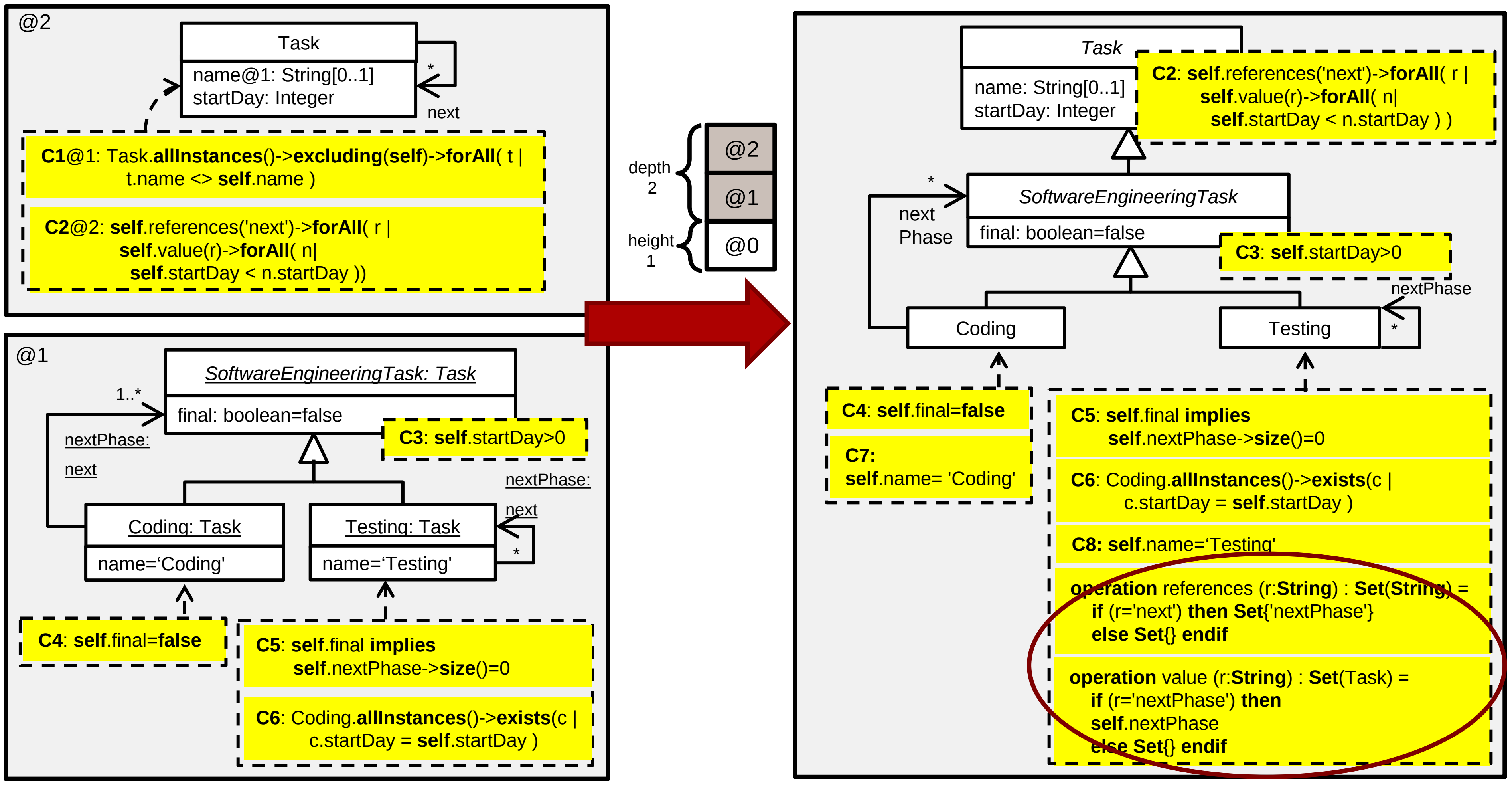

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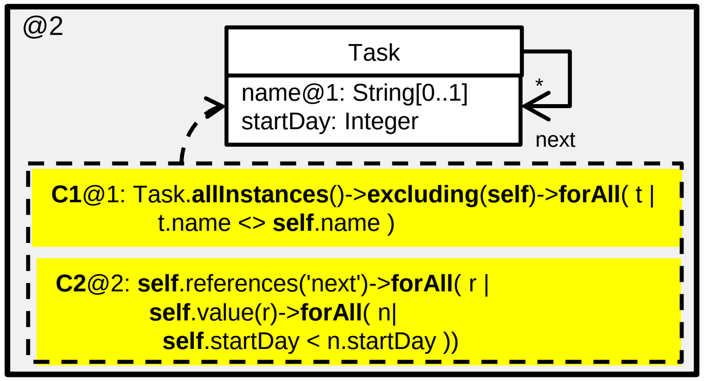

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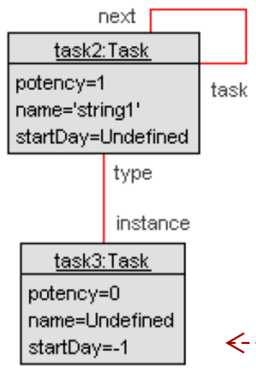

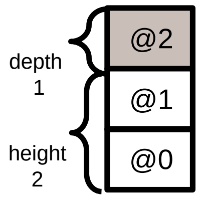

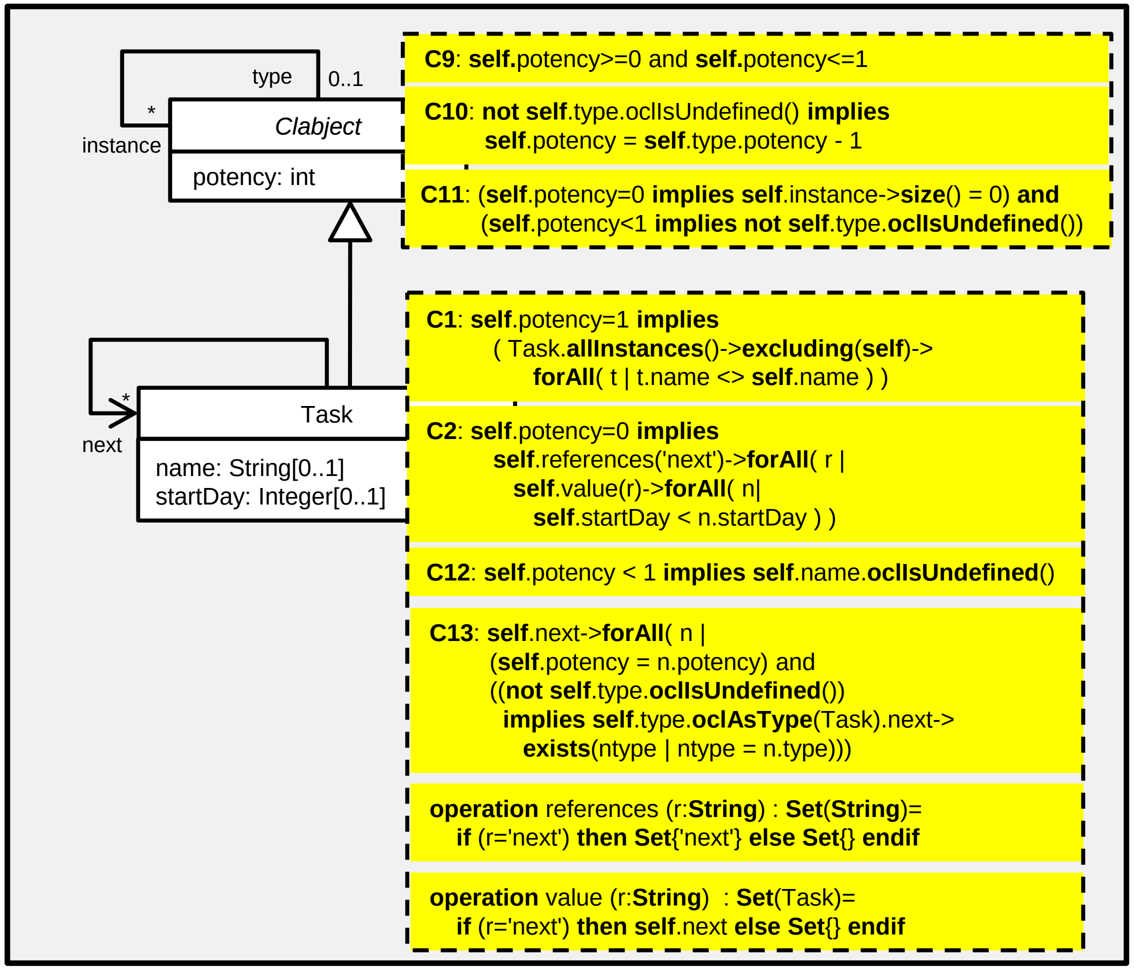

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C10: not self.type.oclIsUndefined() implies
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C11: (self.potency=0 implies self.instance->size() = 0) and
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C12: self.potency < 1 implies self.name.oclIsUndefined()

C13: self.next->forAll( n |
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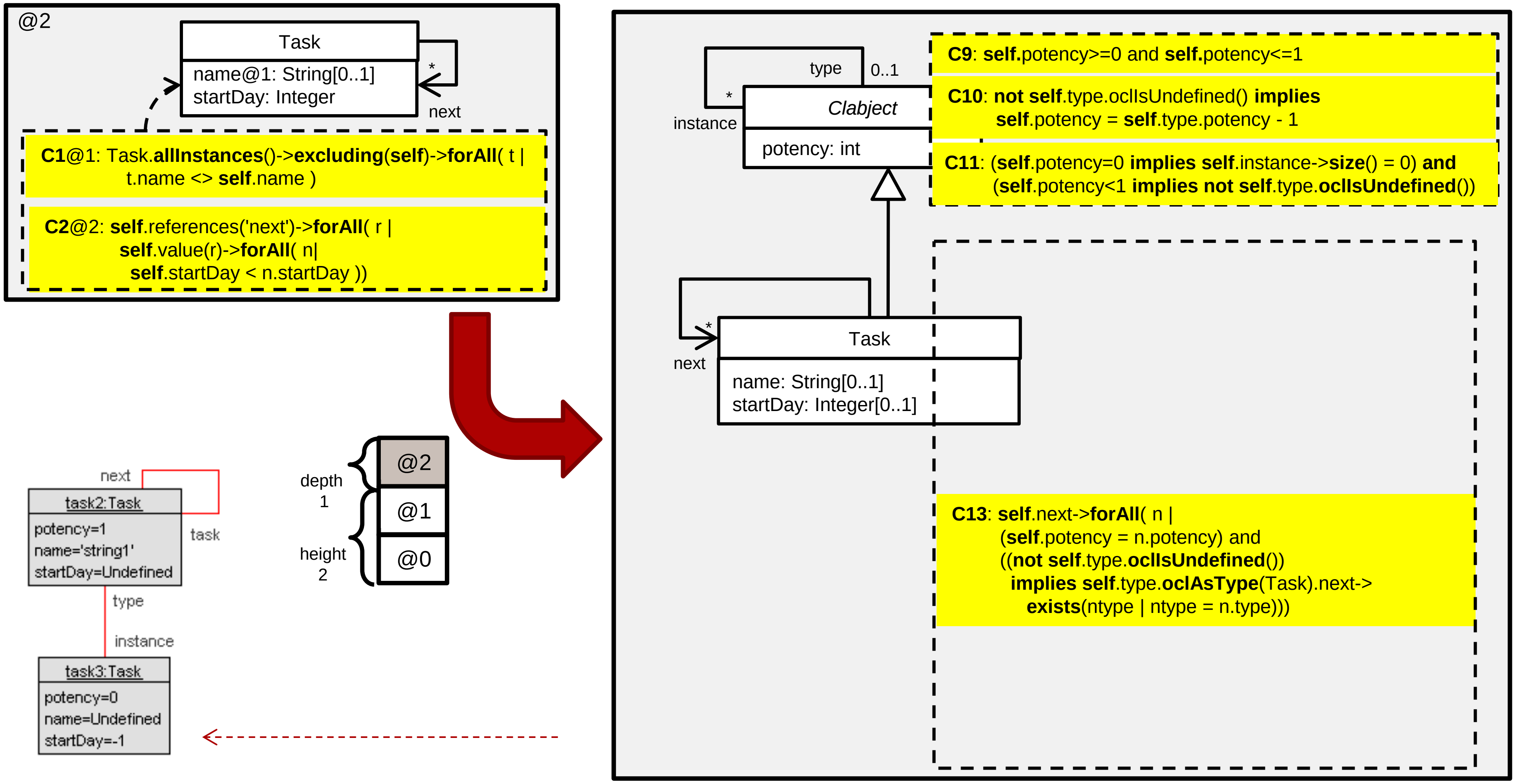

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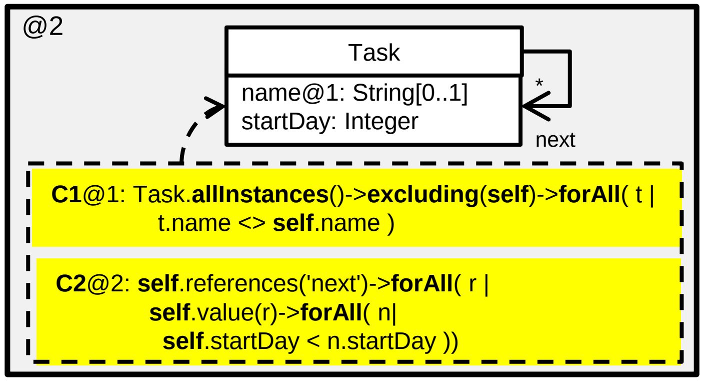

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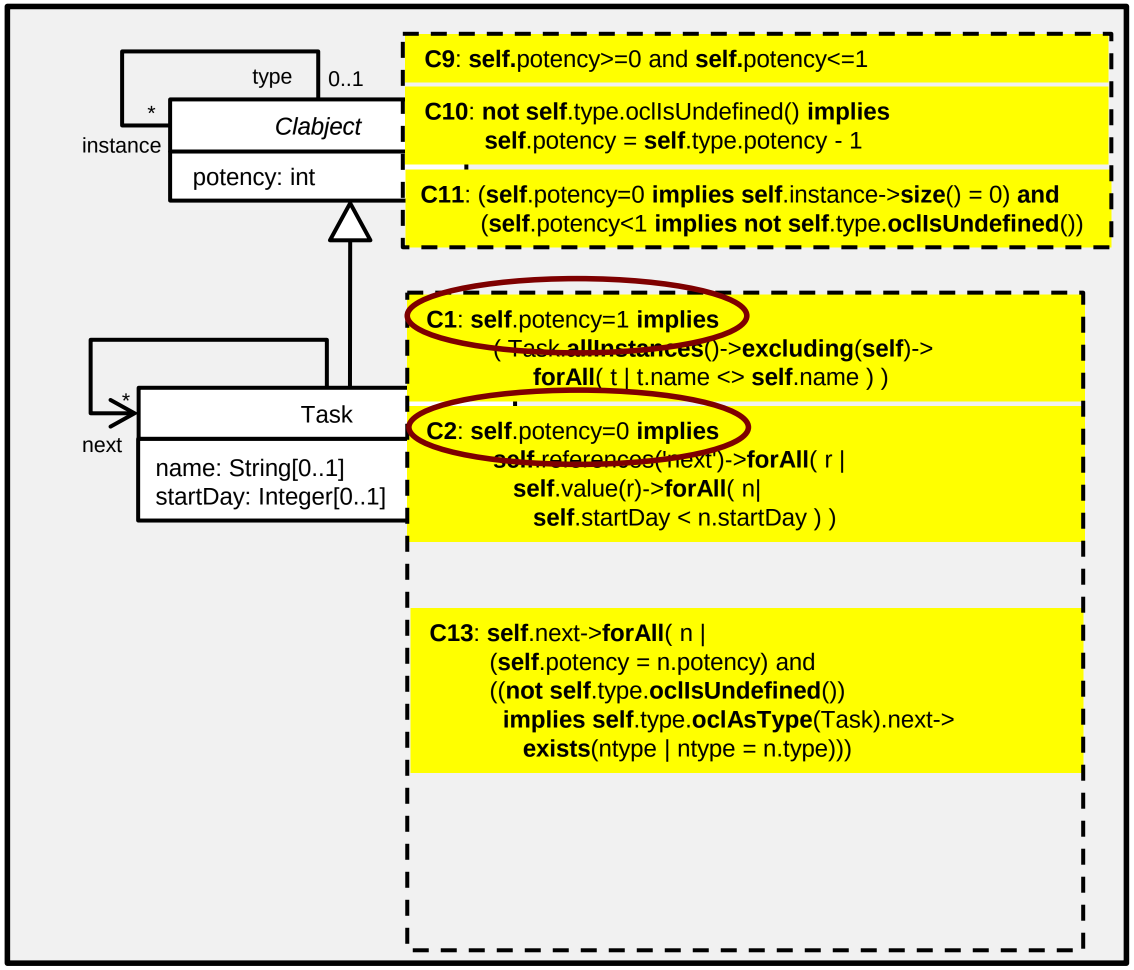

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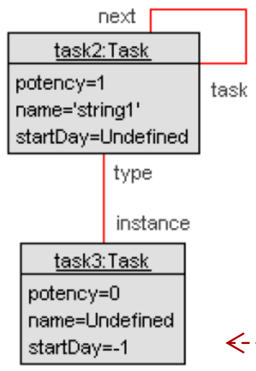

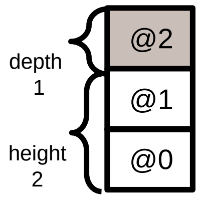

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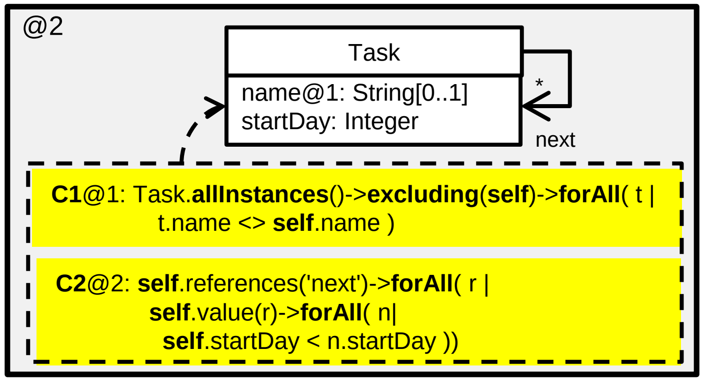

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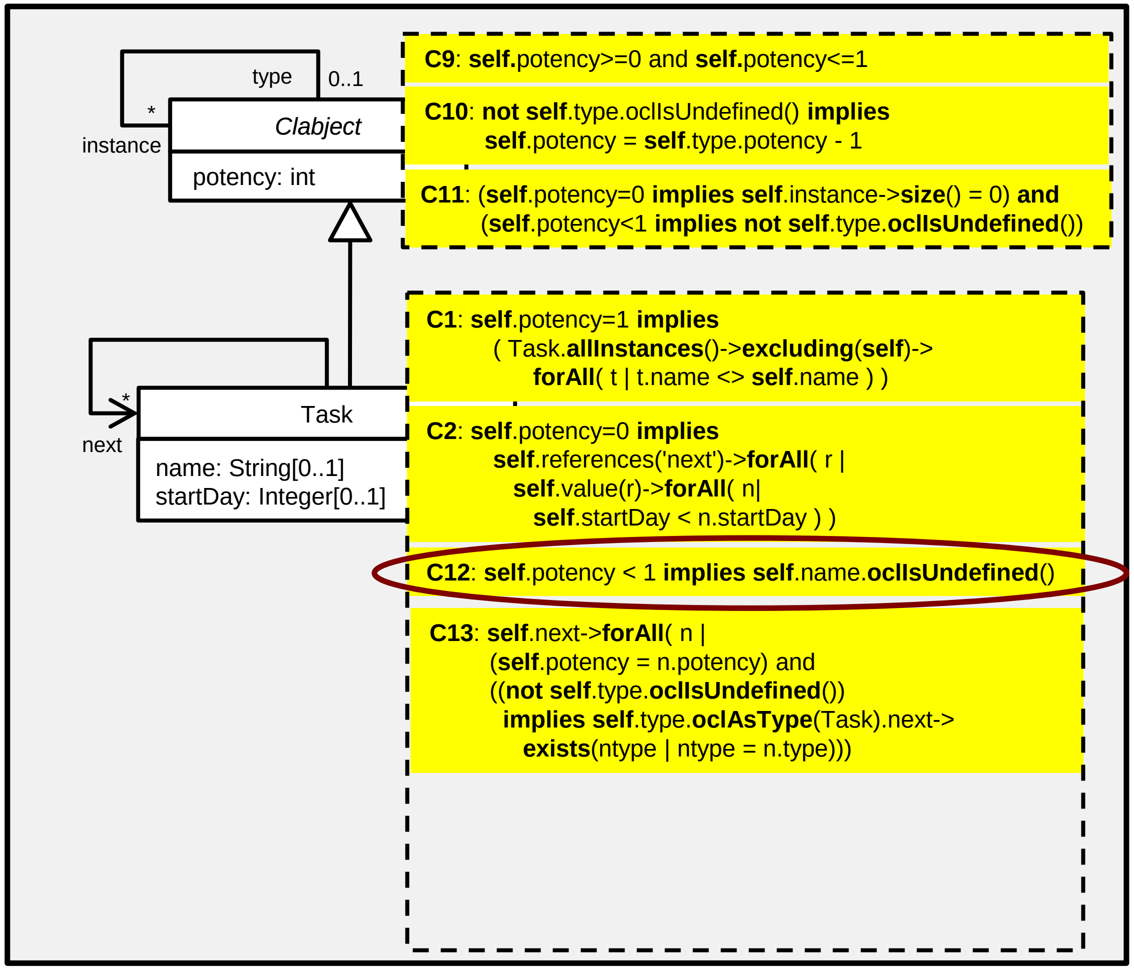

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C12: self.potency < 1 implies self.name.oclIsUndefined()

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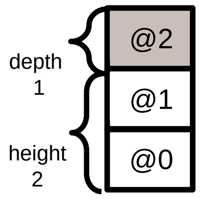

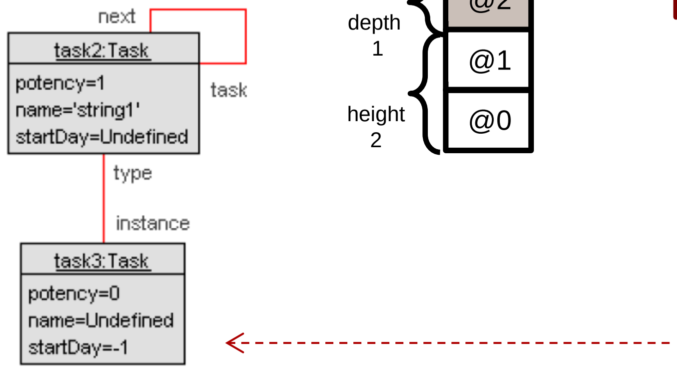

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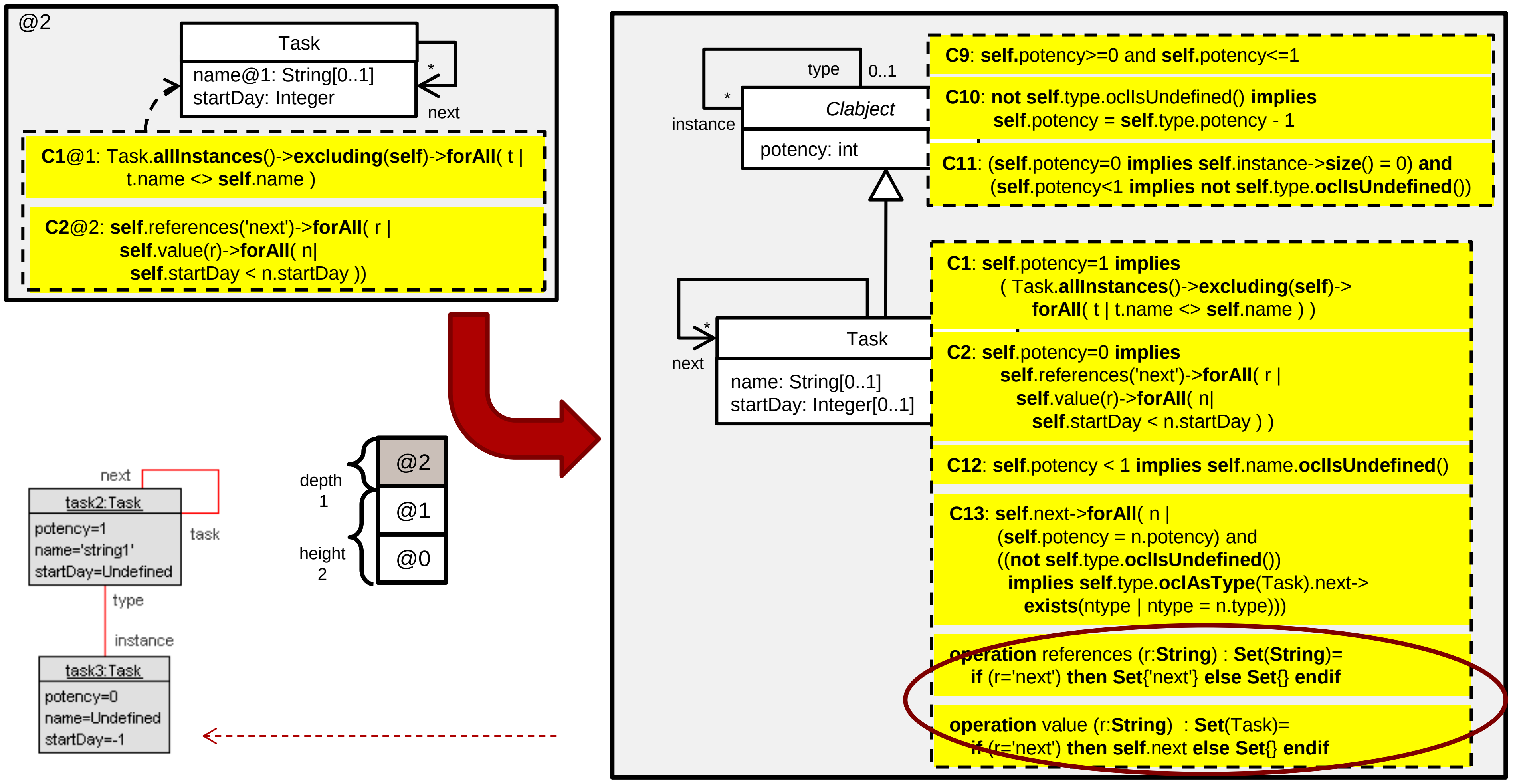

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          self.startDay < n.startDay ) )

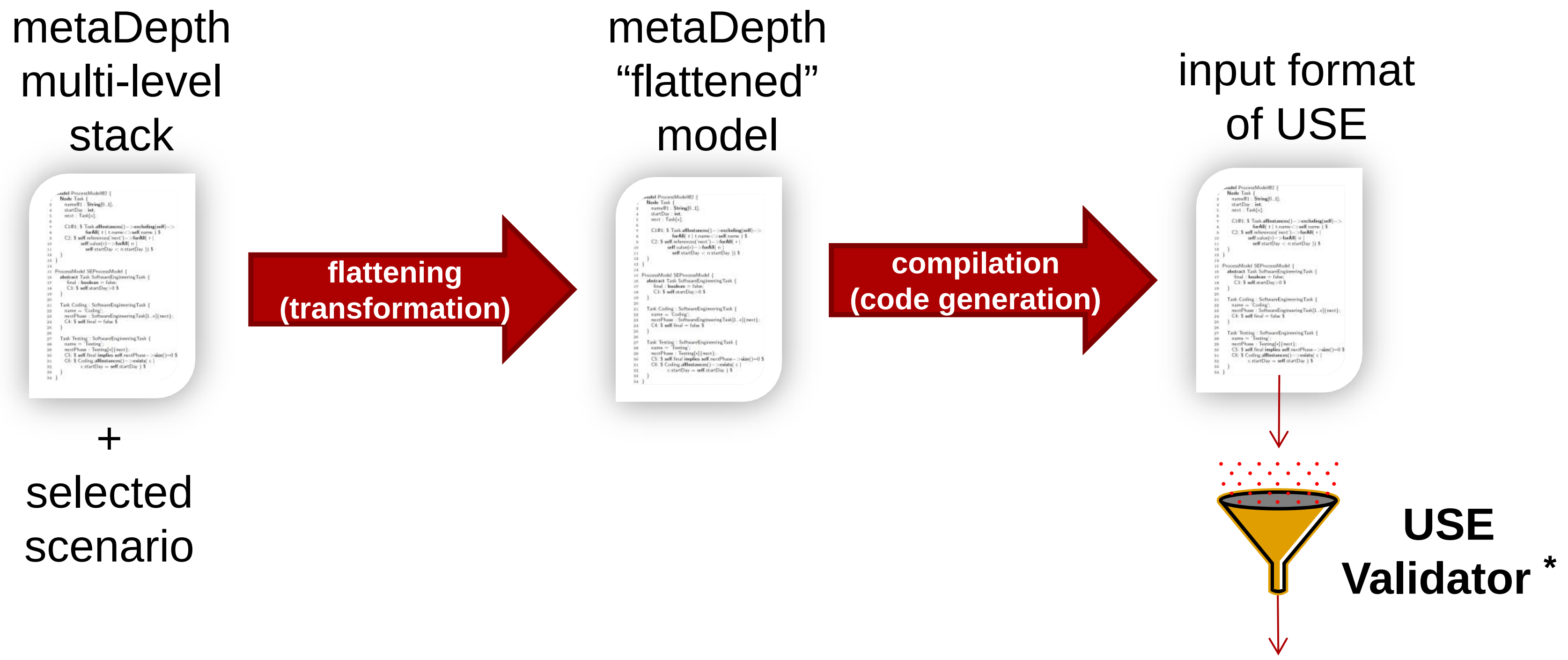
C12: self.potency < 1 implies self.name.oclIsUndefined()

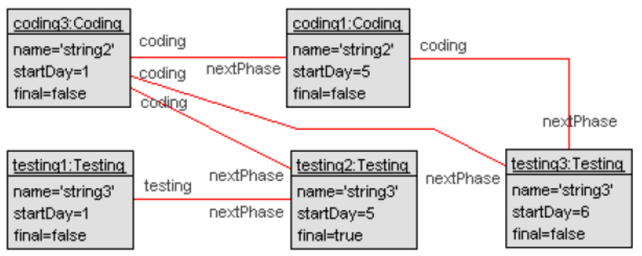
C13: self.next->forAll( n |
       (self.potency = n.potency) and
       ((not self.type.oclIsUndefined())
        implies self.type.oclAsType(Task).next->
          exists(ntype | ntype = n.type)))

operation references (r:String) : Set(String)=
  if (r='next') then Set{'next'} else Set{} endif

operation value (r:String)  : Set(Task)=
  if (r='next') then self.next else Set{} endif
```

Tool Support


metaDepth multi-level stack
+
selected scenario
flattening (transformation)
metaDepth "flattened" model
compilation (code generation)
input format of USE
USE Validator *



* M. Kuhlmann, L. Hamann, M. Gogolla. Extensive validation of OCL models by integrating SAT solving into USE. In TOOLS (49), LNCS 6705, pp.: 290-306.

SUMMARY

- Analysis of integrity constraints in multi-level models
  - flattening of multi-model according to analysis scenario
  - use of standard model finders to check satisfiability

FUTURE WORK

- Analysis of other correctness properties
- Tighter integration of MetaDepth and USE Validator
  - translate USE results back to MetaDepth
  - commands to e.g. complete a model
  - …

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TOWARDS AUTOMATING THE ANALYSIS OF INTEGRITY CONSTRAINTS IN MULTI-LEVEL MODELS

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