Class Diagrams with Constraints

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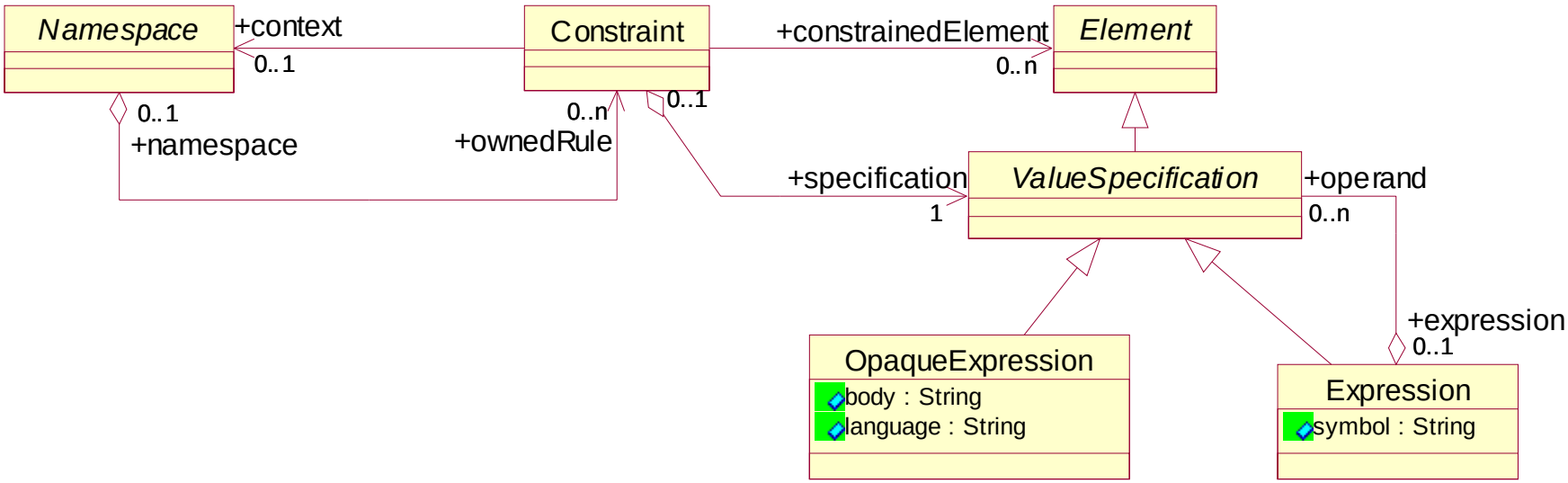
Topics Outline

- Motivation
- Solution
  - Metamodel
  - Code Generation
  - Type Checker
  - Constraint Checker
- Validation
  - Order System Example
- Future Work
- Conclusion

Motivation

- MOF/UML:
  - Use OCL and natural language to constrain the metamodel
- Are OCL and natural language constraints included in the metamodel itself?
- True bootstrapping would assume so…

Motivation: Current Situation in MOF 2.0

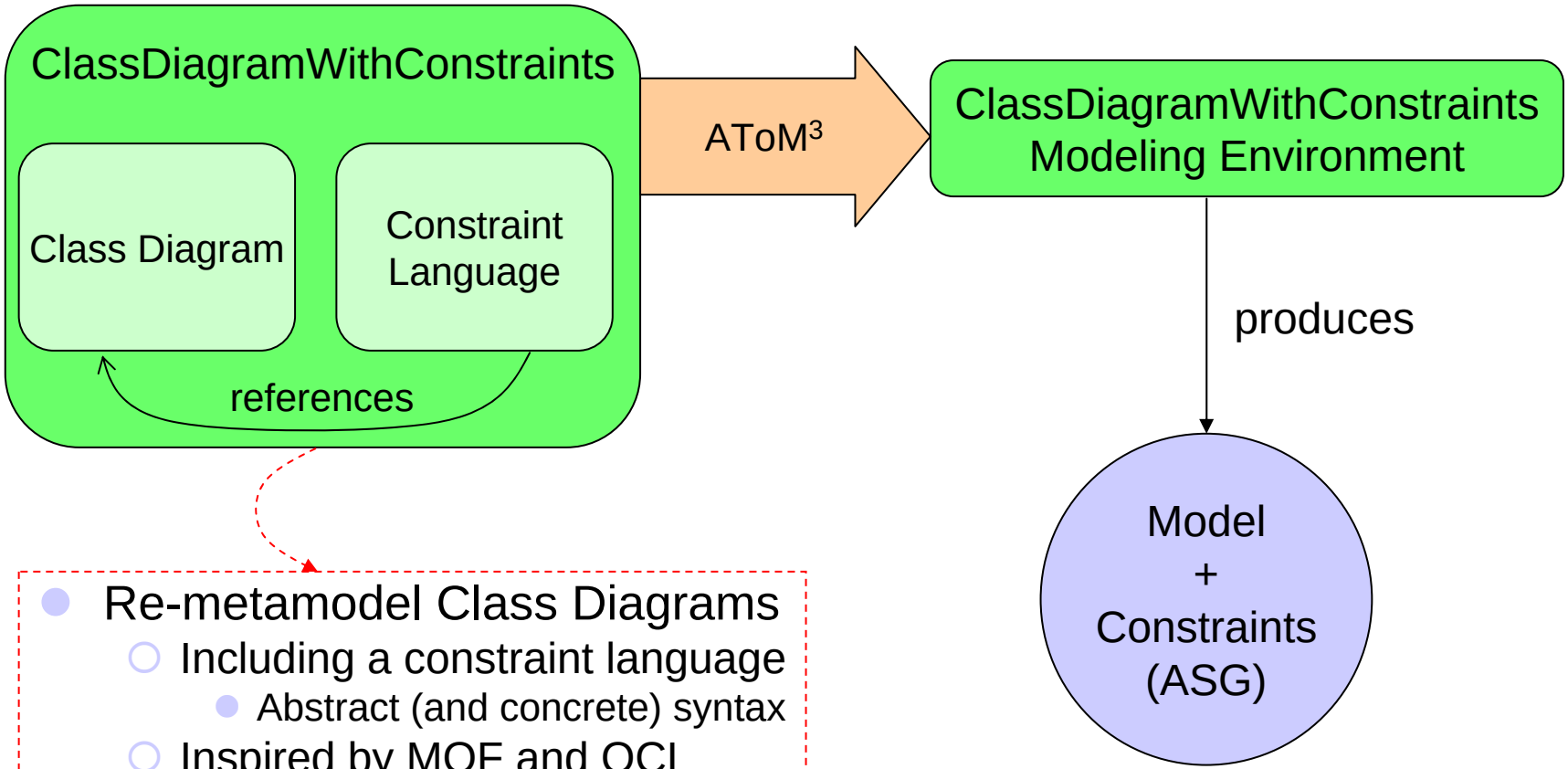


- The constraint specification is a ValueSpecification
  - A ValueSpecification identifies values in a model
  - Can be an Expression (e.g. a + b = 3)
  - Can be an OpaqueExpression (e.g. an OCL statement)
- Where does it go from there?

Motivation: Goals

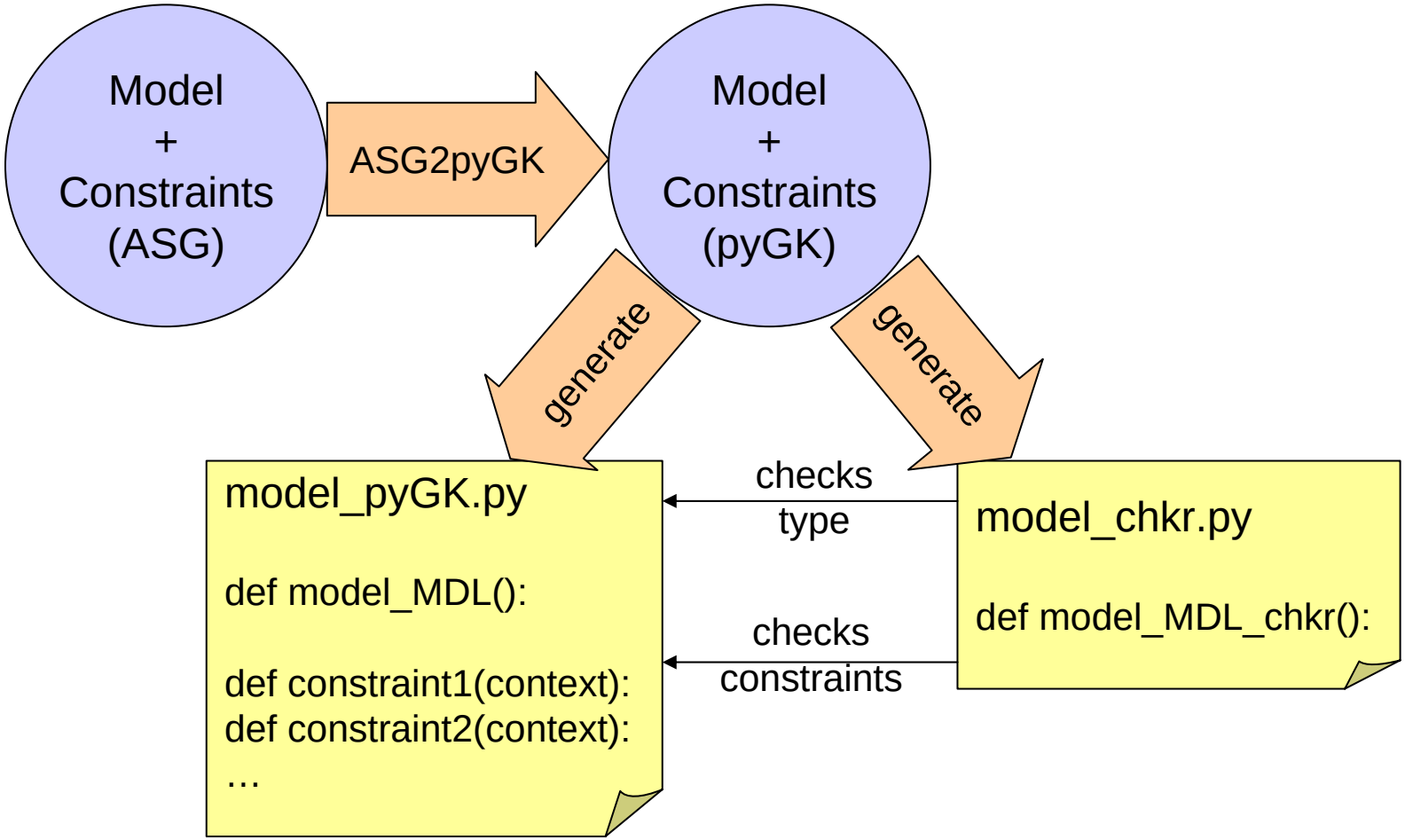
- Define a metamodel for Class Diagrams in which constraints are also metamodeled
- Be able to check a model instance against a model defined in this “new” formalism
- Start using pyGK

Solution: General Approach (1)



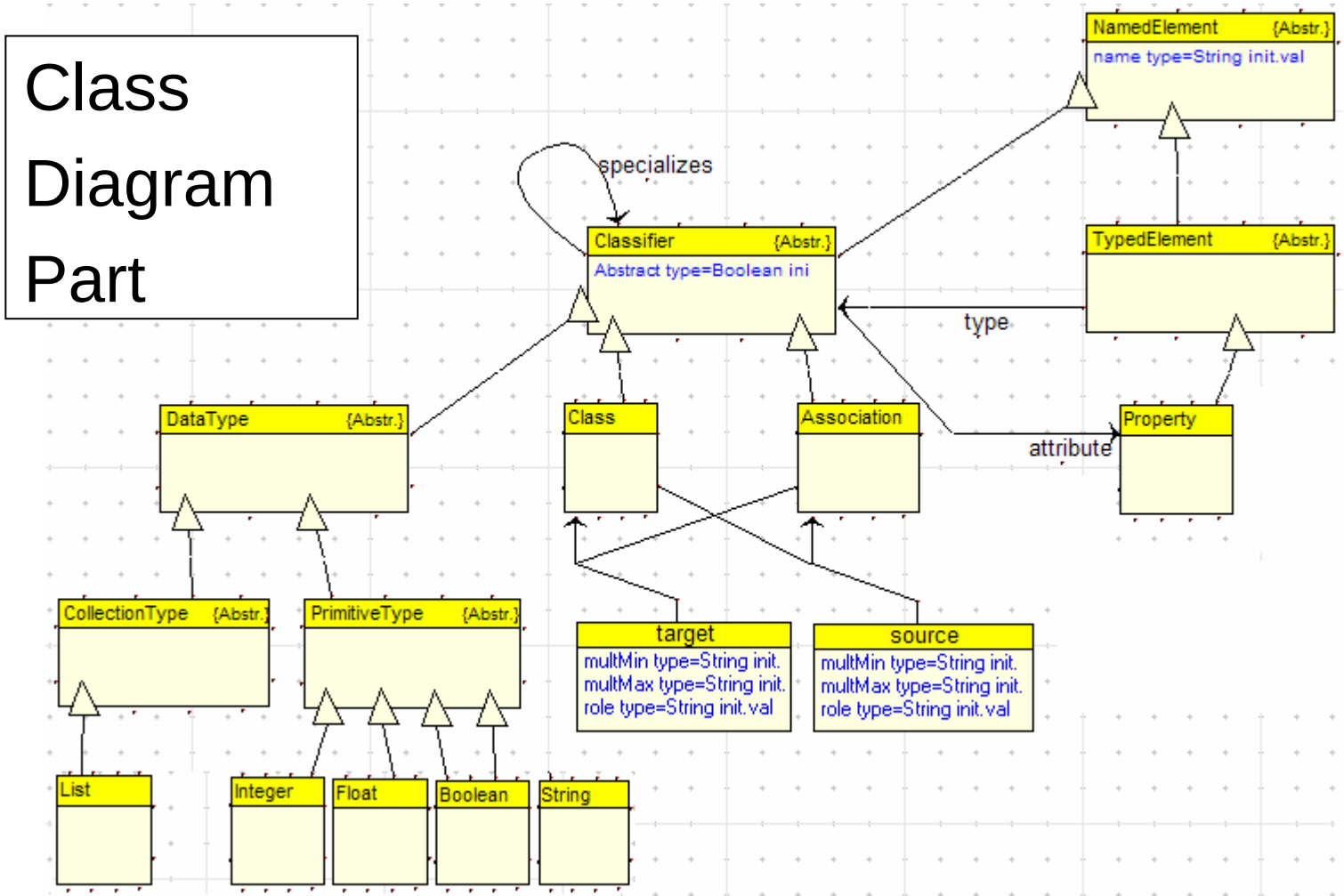
- Re-metamodel Class Diagrams
  - Including a constraint language
    - Abstract (and concrete) syntax
  - Inspired by MOF and OCL

Solution: General Approach (2)

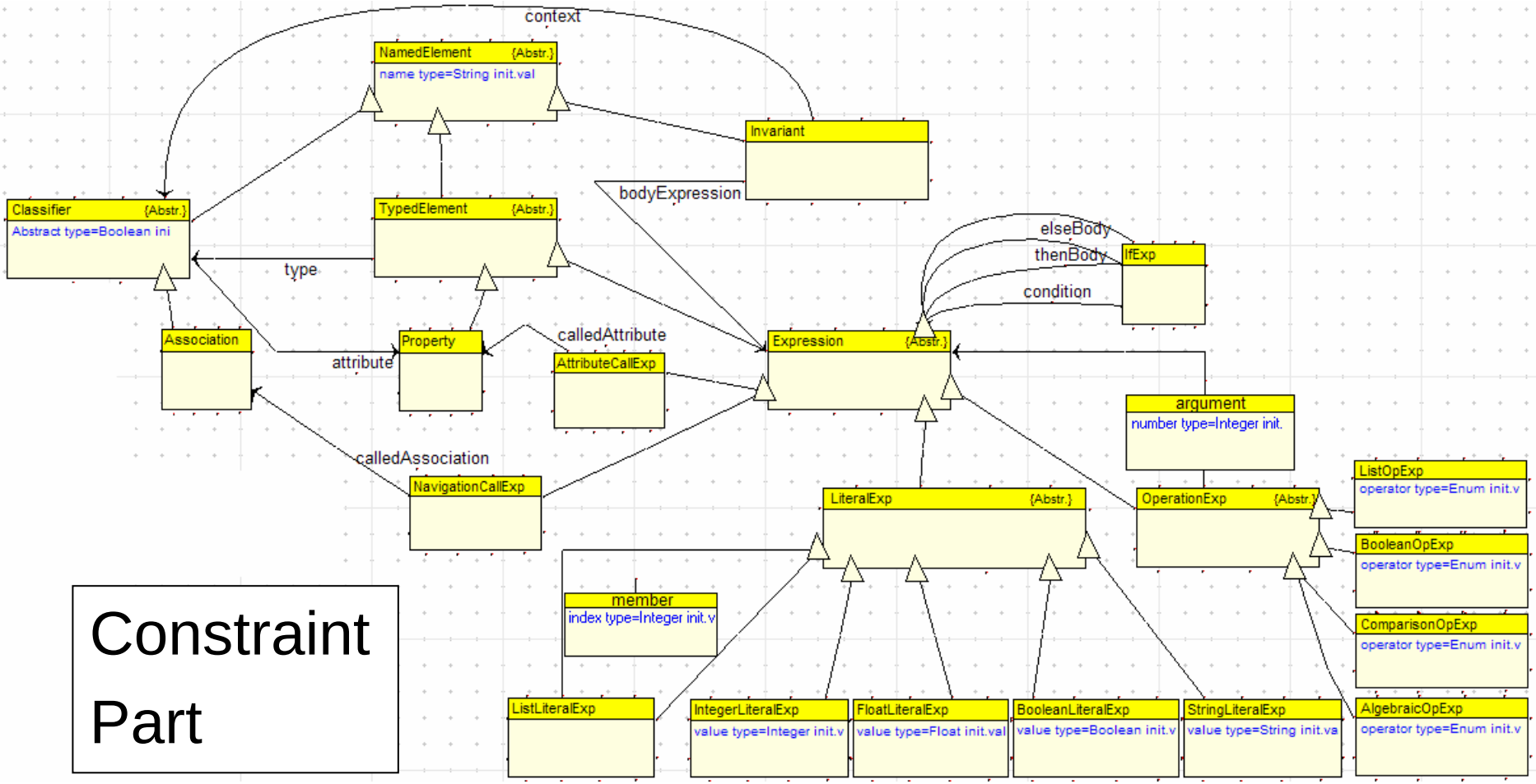


Solution: ClassDiagramsWithConstraints (1)

Class Diagram Part



Solution: ClassDiagramsWithConstraints (2)

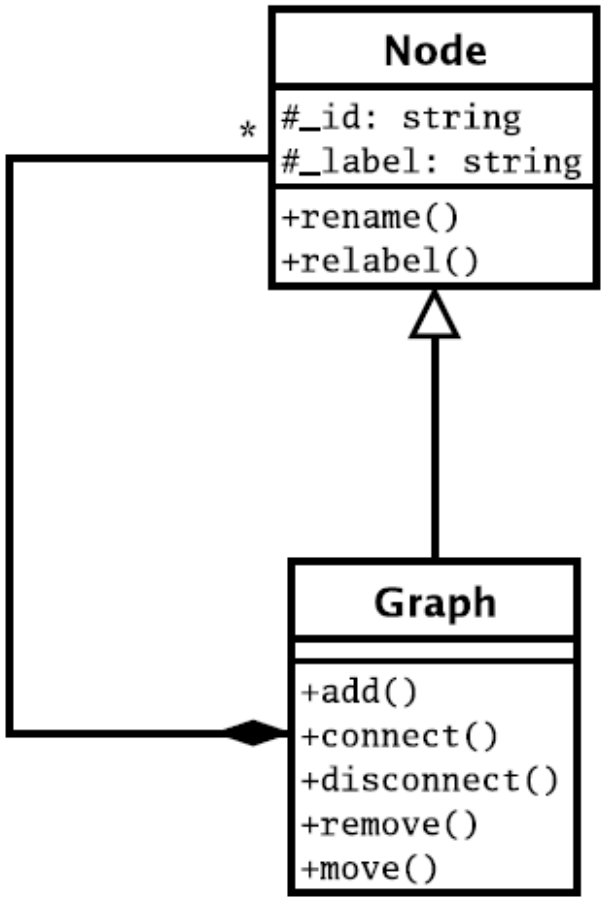


Constraint Part

Solution: Overview of pyGK (1)

- The **Py**thon **G**raph **K**ernel
- Developed by Marc Provost
- An easy to use API for graph representation

Solution: Overview of pyGK (2)



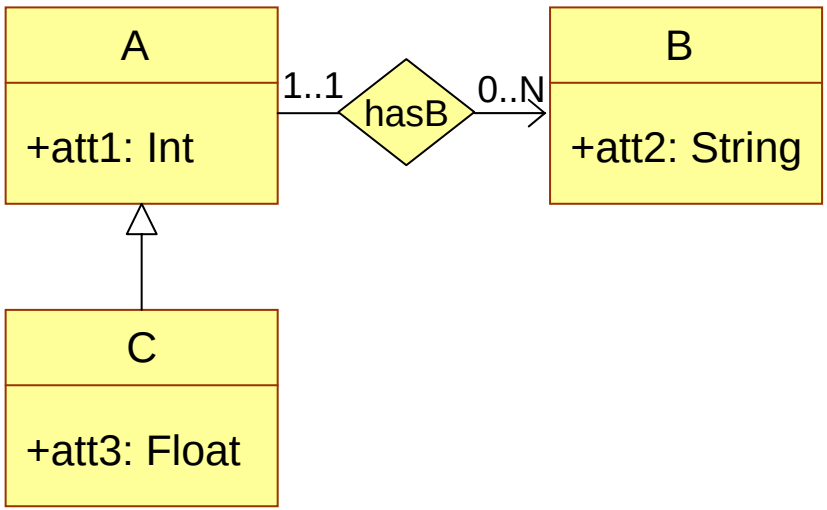
- _id: unique identifier
- _label: “type”
- PrimitiveTypes:
  - Int, Float, Bool, String, List
  - SymbolTable / AttrNode
- Straightforward functions to:
  - Construct a graph:
    - add(), connect()
  - Traverse a graph:
    - BFS, DFS

Ref: moncs.cs.mcgill.ca/MSDL/presentations/05.02.18.MarcProvost.pyGK/presentation.pdf

Solution: Converting ASG model to pyGK

- E.g.

Class Diagram in ASG format



Iterate through the ASGNodes and generate…

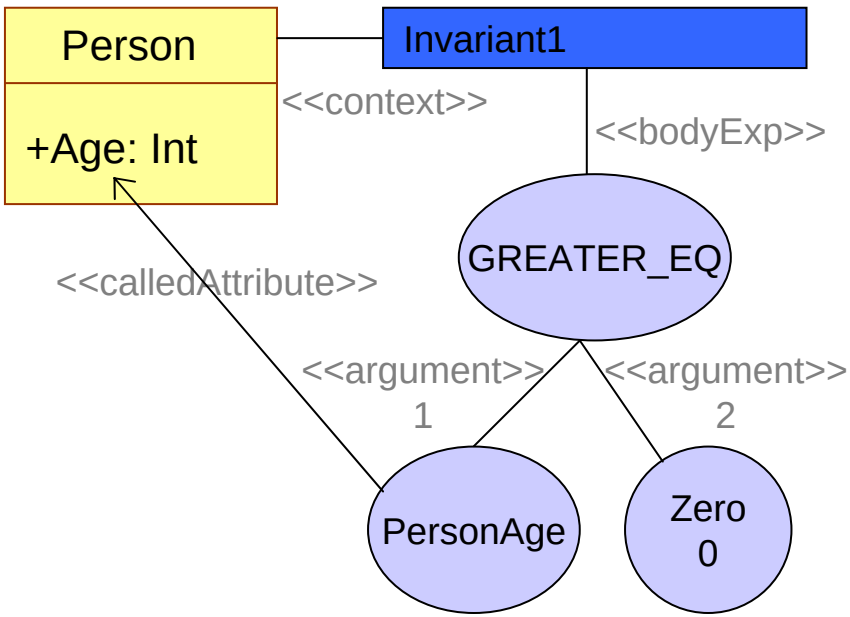
Class Diagram in pyGK format

```
model = Graph(ID="model", label="ClassDiagram")

A = AttrNode(ID="A", label="Class")
A["att1"] = Int()
B = AttrNode(ID="B", label="Class")
B["att2"] = String()
C = AttrNode(ID="C", label="Class")
C["att3"] = Float()
hasB = AttrNode(ID="hasB", label="Association")
hasB["srcMultMin"] = Int(value=1)
hasB["srcMultMin"] = Int(value=1)
hasB["trgMultMin"] = Int(value=0)
hasB["trgMultMin"] = String(value="N")
CInheritsB = AttrNode(ID="CInheritsB", label="Inherit")

// Add and connect nodes in model
```

Solution: Converting ASG constraint to pyGK

- E.g

Constraint expression in ASG format



Iterate through the ASGNodes and generate…

Constraint expression in pyGK fomrat

```
constraints = model(ID=“constraints”, label=“Constraints”)

Invariant1 = AttrNode(ID=“Invariant1”, label=“Invariant”)
comp1 = AttrNode(ID = "comp1", label = "ComparisonOp")
PersonAge = AttrNode(ID="PersonAge", label="AttributeCall")
PersonAge["calledAttributeType"] = Int()
PersonAge["calledAttributeName"] = String(value="Age")
PersonAge["owningClassifier"] = String(value="Person")
comp1["operator"] = String(value = "GREATER_EQ")
comp1[“argument1”] = PersonAge
comp1[“argument2”] = Int(value=0)
Invariant1[“bodyExp”] = comp1
Invariant1[“context”] = String(value=“Person”)

// Add and connect nodes in constraints
```

Solution: Saving to file (1)

- Define an API for constructing Python code:
  - A sort of an AST interface for Python
  - E.g. an Assignment Statement is

```
AssignmentStmt ::= LHS “ = ” RHS
LHS ::= LiteralStmt
RHS ::= LiteralStmt | OperationStmt
```

- Using this API, we can generate code constructs like *If* statements and function calls
- Also supports indentation for writing out Python code

Solution: Saving to file (2)

```
lit1 = LiteralStmt("a")
lit2 = LiteralStmt("in")
lit3 = LiteralStmt("c")
listLit = LiteralStmt("[0, 1, 2, 3]")
trueLit = LiteralStmt("True")
zeroLit = LiteralStmt("0")
imp1 = ImportStmt(LiteralStmt("pack"), LiteralStmt("mod"))
def1 = DefStmt(LiteralStmt("foo"), [lit2])
blk1 = BlockStmt([imp1])
blk1.appendReturnCarriage()
blk1.appendStmt(def1)
ass1 = AssignmentStmt(lit1, lit2)
plus1 = NaryOpStmt(LiteralStmt("+"), [lit1, lit2])
ass2 = AssignmentStmt(LHS=lit3, RHS=plus1)
eq1 = BinaryOpStmt(LiteralStmt("=="), [lit3, trueLit])
call1 = FunctionCallStmt(context=None, fnName=LiteralStmt("len"), arguments=[listLit])
less1 = BinaryOpStmt(LiteralStmt("<"), [call1, zeroLit])
if1 = IfStmt(eq1, BlockStmt([ReturnStmt(trueLit)]), BlockStmt([ReturnStmt(less1)]))
blk2 = BlockStmt([ass1, ass2, if1])

print blk1.toString(0)
print blk2.toString(1)
```

Output:

```
from pack import mod

def foo(in):
    a = in
    c = (a + in)
    if (c == True):
        return True
    else:
        return (len([0, 1, 2, 3]) < 0)
```

Solution: Saving to file (3)

- Saving the model:
  - Define a function:

    ```
    def <modelName>_MDL():
    ```

  - Spit out the pyGK statements that can rebuild the model

- Saving the constraints:
  - For each constraint, define a function:

    ```
    def <constraintName>(context):
    ```

  - Turn the pyGK format into Python code using the syntax API

Solution: Type Checking

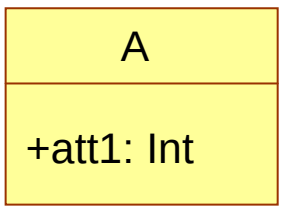
- Checks that a model instance conforms to a model
- It entails checking
  - That every instance element corresponds to a meta-element
  - That every instance element owns only properties that its meta-element can own
  - That every association in the model is respected

…every instance element corresponds to a meta-element

- For every (pyGK) Node in the instance,
  - Check that the model contains a Node whose id corresponds to the instance Node's label

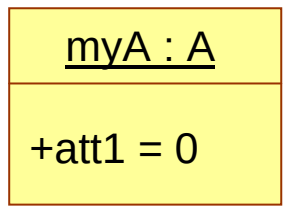
- E.g.

In model:



AttrNode(id="A", label="Class")

In instance:



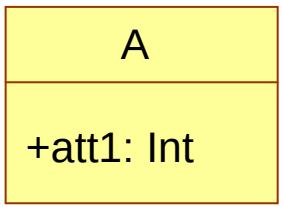
AttrNode(id="myA", label="A")

… every instance element owns only properties that its meta-element can own

- For each key in an AttrNode of the instance,
  - Check that the corresponding meta-element, or a super type of the meta-element, has the same key
  - Check that the values for the corresponding keys have the same type

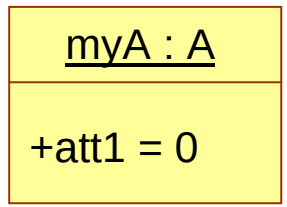
- E.g.

In model:



A = AttrNode(id="A", label="Class")
A["att1"] = Int()

In instance:



myA = AttrNode(id="myA", label="A")
myA["att1"] = Int(value=0)

…every association in the model is respected (1)

- Check that their instances attach the correct types, as permitted by the model
  - For every association,
    - Get the hierarchy of the source and built a list of IDs
    - Do the same for the target
    - Check that every instance connects
      - a source whose label is in the source ID list
      - a target whose label is in the target ID list
- Complexity: Inheritance

…every association in the model is respected (2)

- Check that their instances respect the multiplicities
  - Build a tuple table of all the instance links
  - Check:
    - srcMultMin <= # source instances <= srcMultMax
    - trgMultMin <= # target instances <= trgMultMax

Solution: Constraint Checking

- In type checking, the checker can be written offline
  - Applicable to any model
- For constraint checking, the checker is specific to the model
  - So, we need to generate something that will check each contraint against every instance of the constraint's context
    - Call the generated Python function
  - Don't forget sub types!

Validation

- So does all this work???
- Let us see the solution in action
- Order System Example

Validation: What do we have now?

- A constraint language that is included within the Class Diagram metamodel
- “Static” checking of model instances
  - A client application of the checker would input a model instance that is considered to be “stable” at that point
- A concrete application for pyGK

Validation: Limitations & Future Work

- What about operations?
- N-ary associations
- Visually surcharged models
  - But the abstract syntax tree will look something like that…
- Expressiveness of the constraint language
  - Add more constructs like *for* loop or *select* operation
- Tests on bigger models
  - Performance issues?

More Future Work

- Check multiplicities as constraints
  - So Type Checker would be a pure structural check
- Generation of modeling environment
  - Generate a modeling environment from ClassDiagramWithConstraints but without the constraint language
- Bootstrapping
  - Re-metamodel ClassDiagramWithConstraints in itself
    - Defining the constraints in the constraint language itself

Acknowledgements

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- Dr. Juan de Lara for ClassDiagram formalism in AToM^3
- Marc Provost for help on pyGK and metamodeling

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