

# Class Diagram with Constraints

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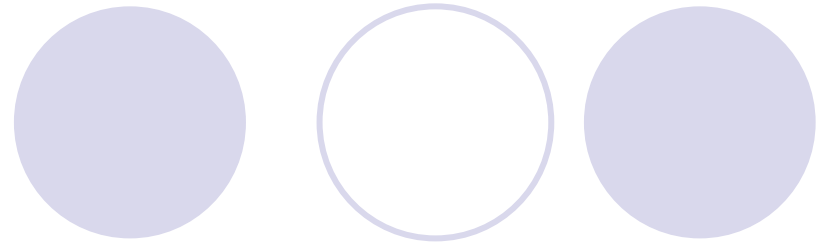
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**McGill**

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# Topics Outline



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

# Motivation



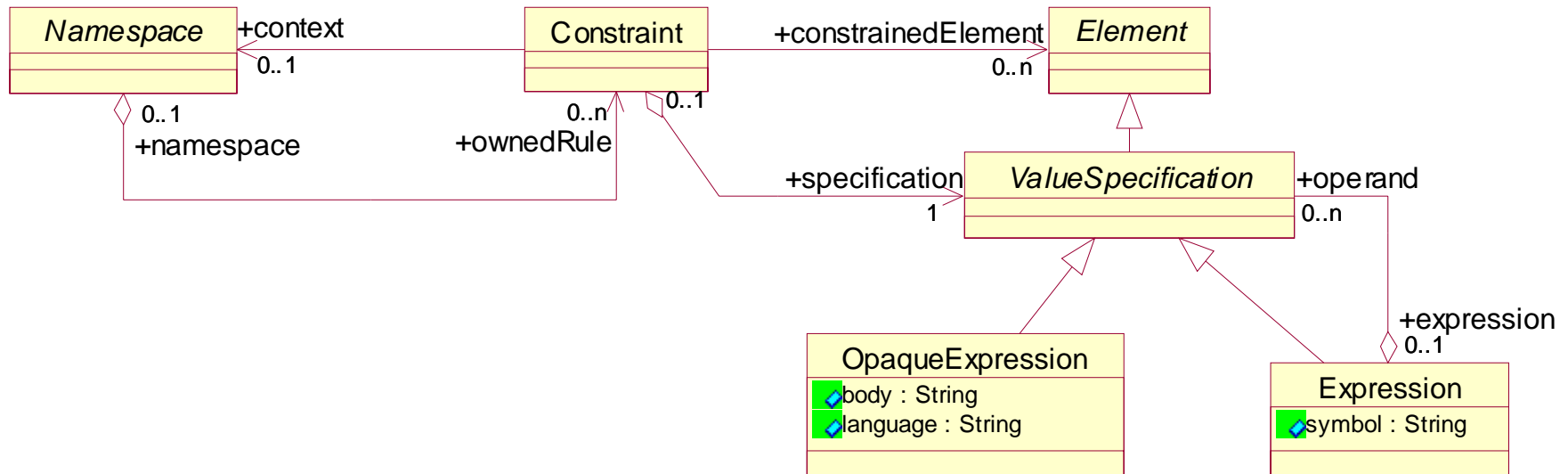
- MOF/UML:

- 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

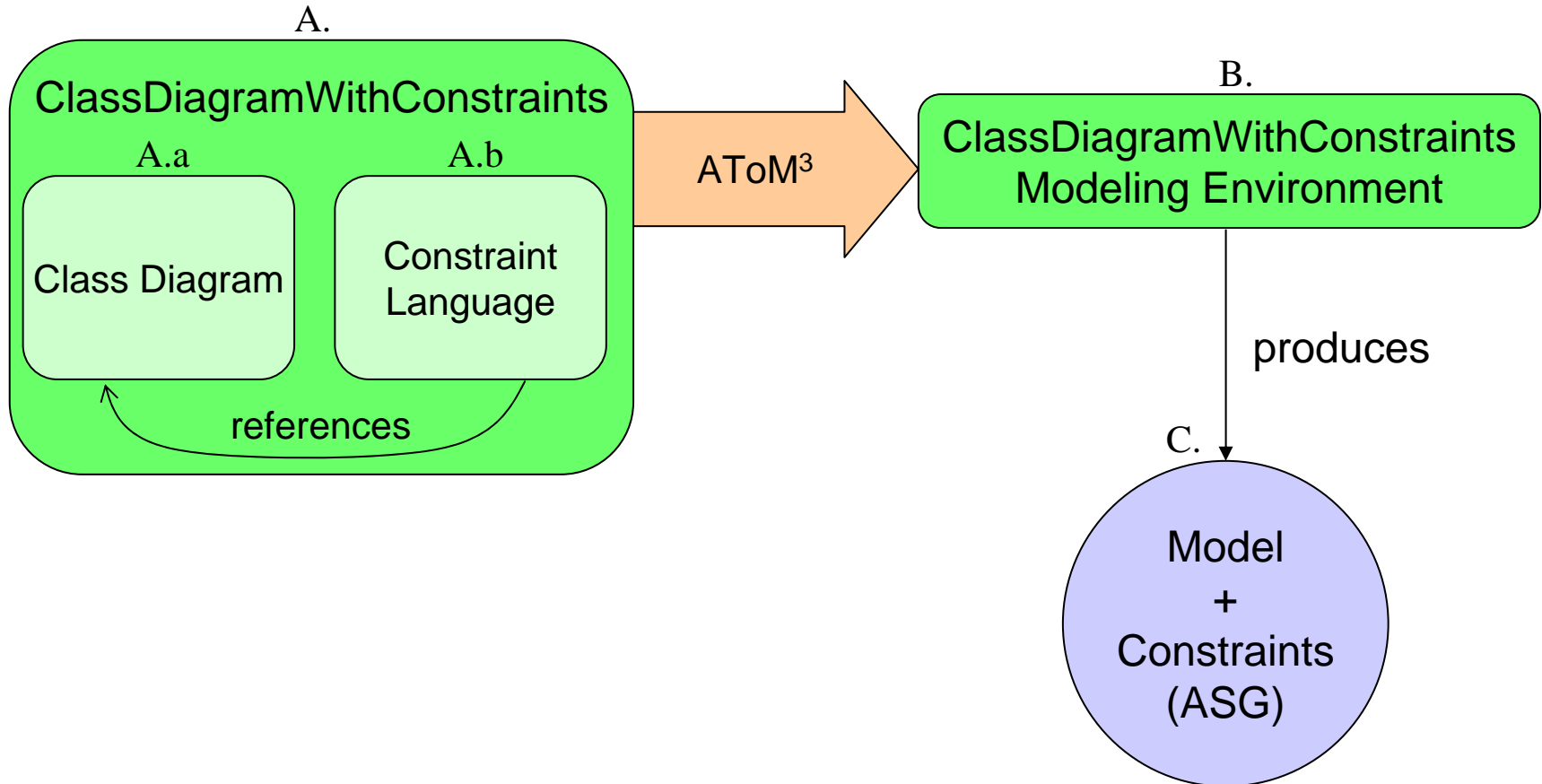


- The constraint specification is a **ValueSpecification**
  - A **ValueSpecification** identifies values in a model
  - Can be an **Expression** (e.g.  $a + b = 3$ )
  - Can be an **OpaqueExpression** (e.g. an OCL statement)
- Where does it go from there?

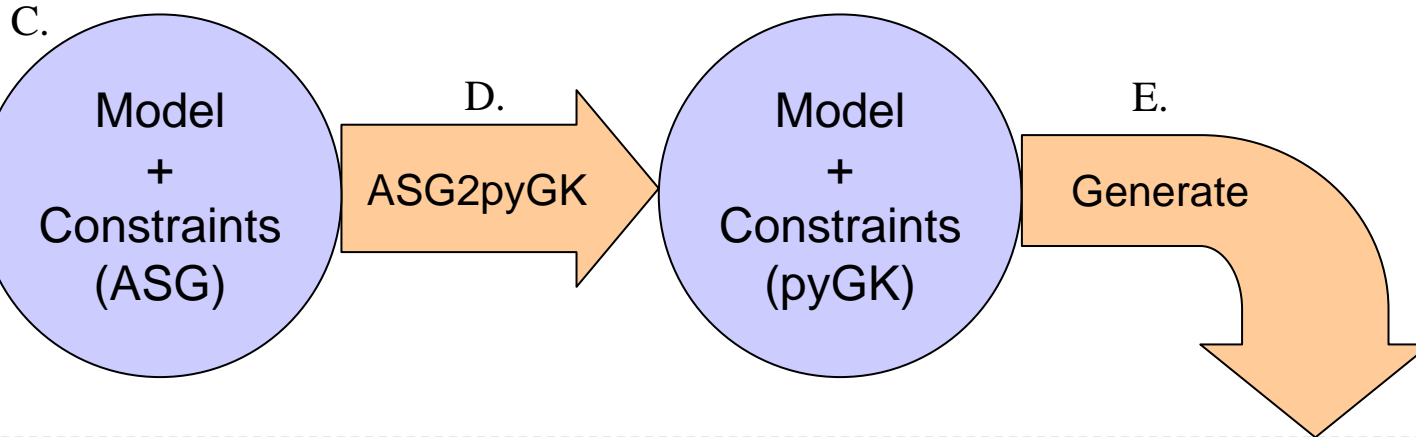
# Motivation: Goals

- 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)



# Solution: General Approach (2)



```
model_pyGK_MDL.py  
def model_pyGK_MDL():
```

E.a

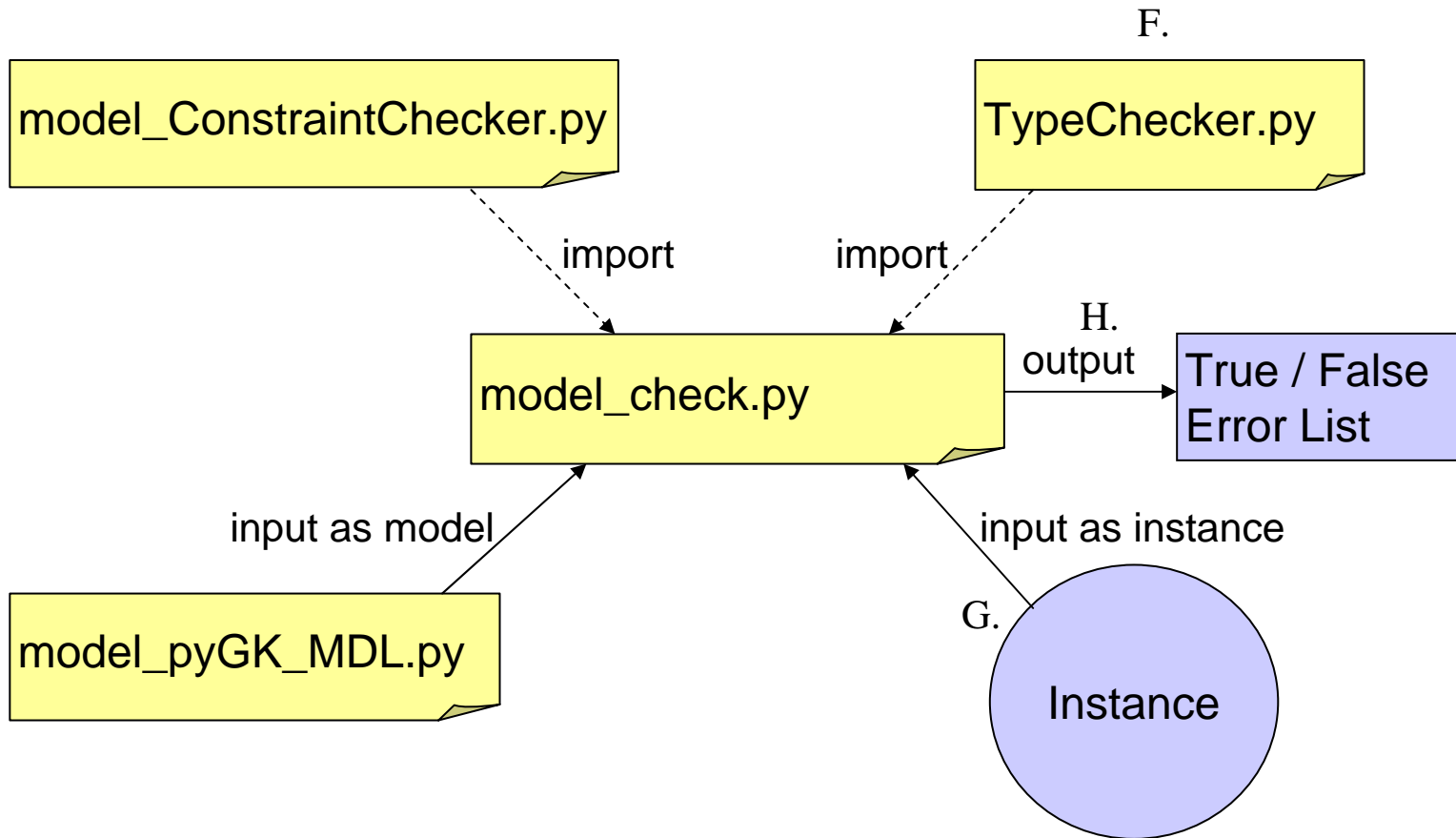
```
model_ConstraintChecker.py  
self._model  
  
def constraint1(context):  
def constraint2(context):  
...  
def check(instance):
```

E.b

```
model_check.py  
def model_check(instance):
```

E.c

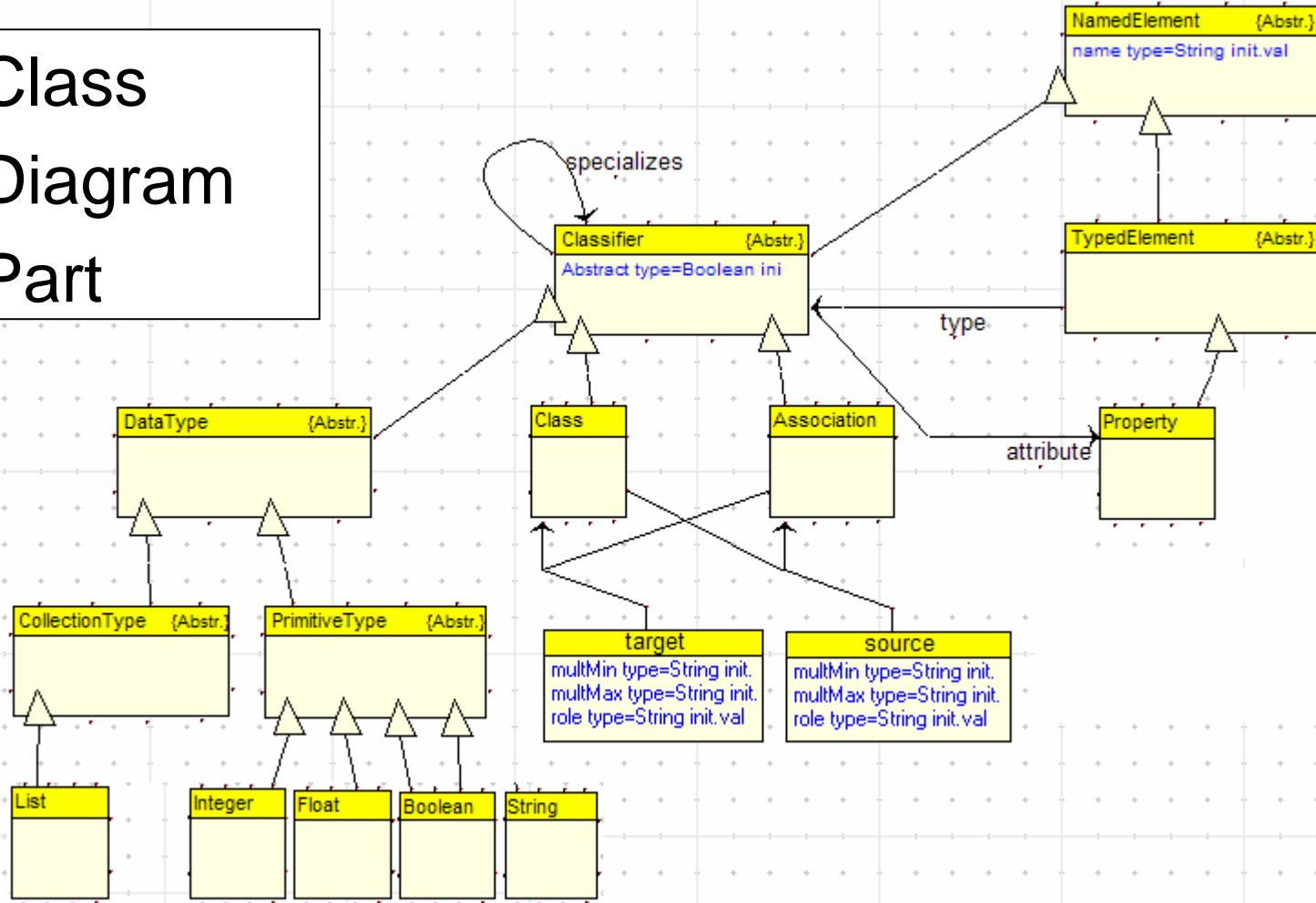
# Solution: General Approach (3)



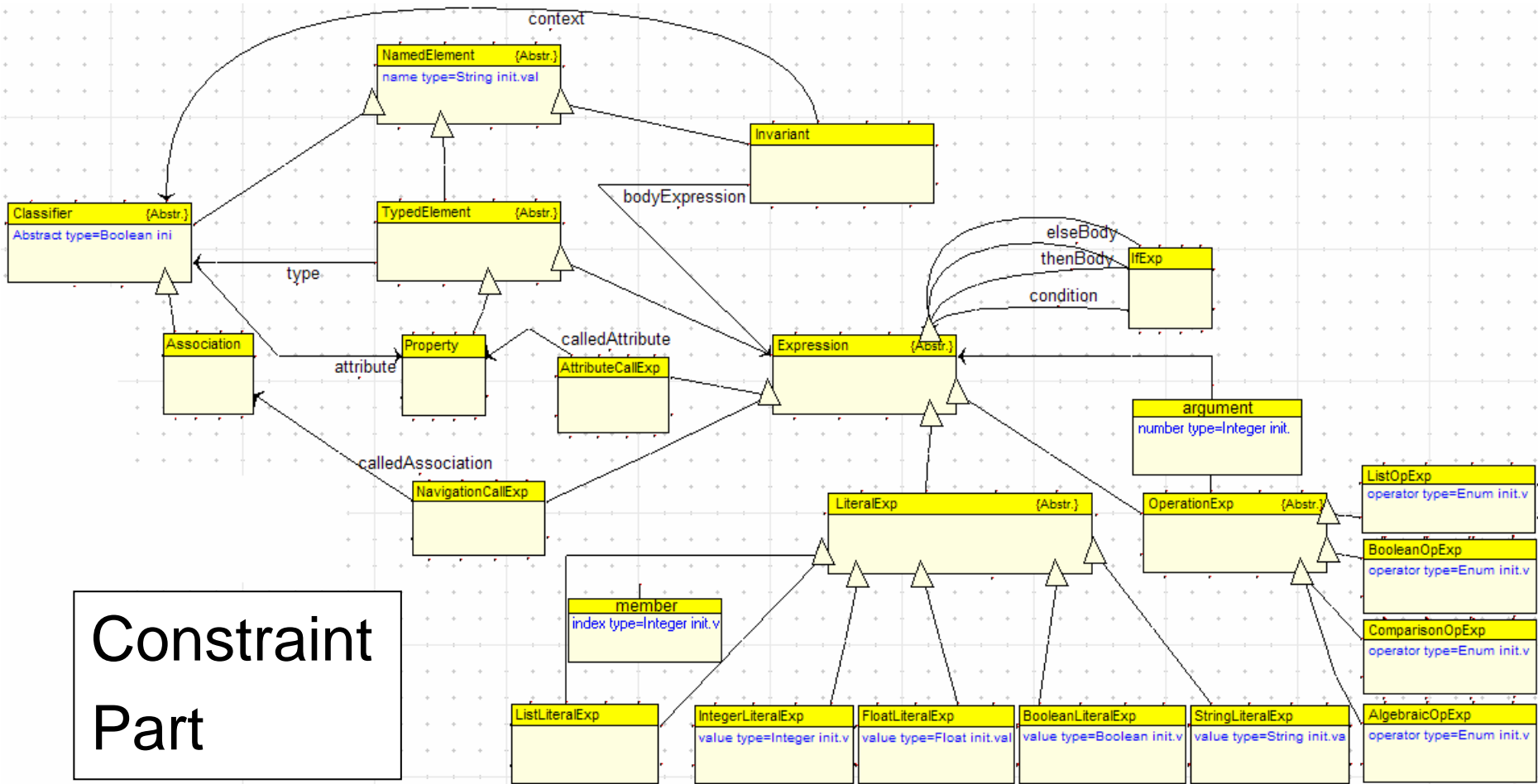


# Solution: ClassDiagramsWithConstraints (1)

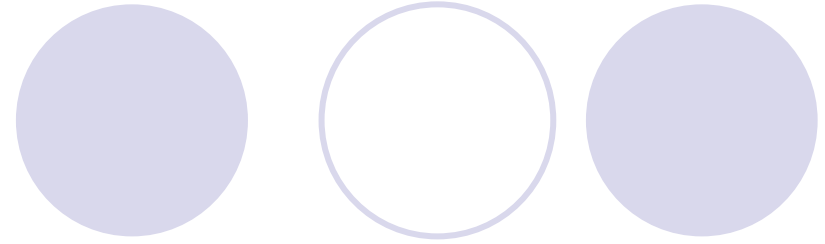
Class  
Diagram  
Part



# Solution: ClassDiagramsWithConstraints (2)



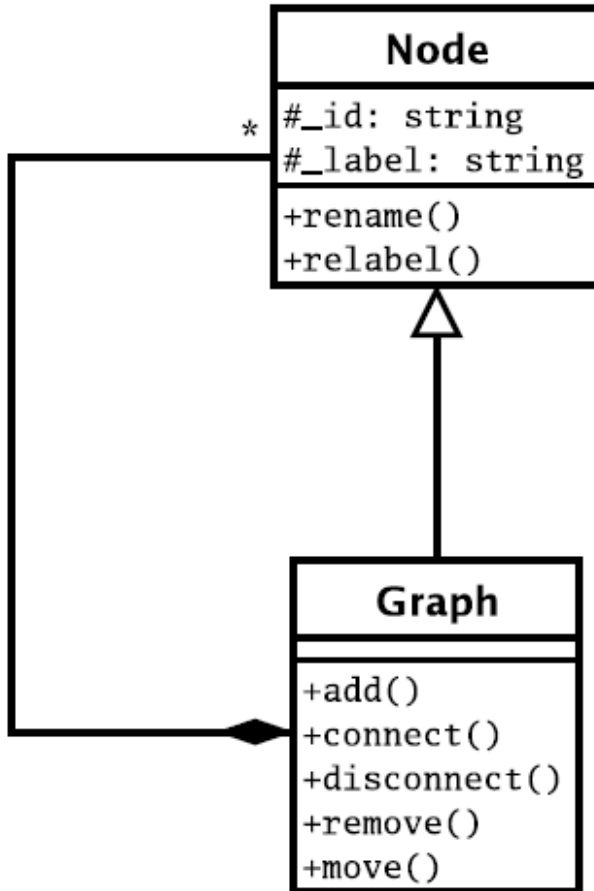
# Solution: Overview of pyGK (1)



- The **Python Graph Kernel**
- Developed by Marc Provost
- An easy to use API for graph representation

# Solution:

## Overview of pyGK (2)



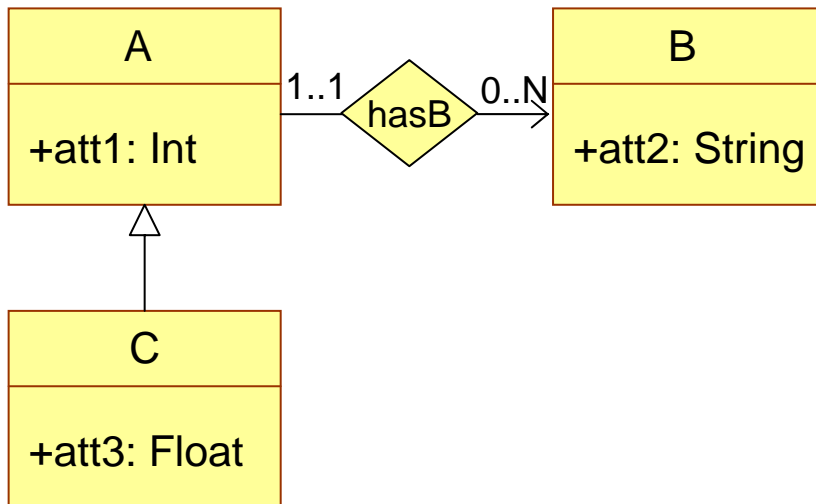
- `_id`: unique identifier
- `_label`: “type”
- PrimitiveTypes:
  - Int, Float, Bool, String, List
  - SymbolTable / AttrNode
- Straightforward functions to:
  - Construct a graph:
    - `add()`, `connect()`
  - Traverse a graph:
    - BFS, DFS

Ref: [moncs.cs.mcgill.ca/MSDL/presentations/05.02.18.MarcProvost.pyGK/presentation.pdf](http://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")

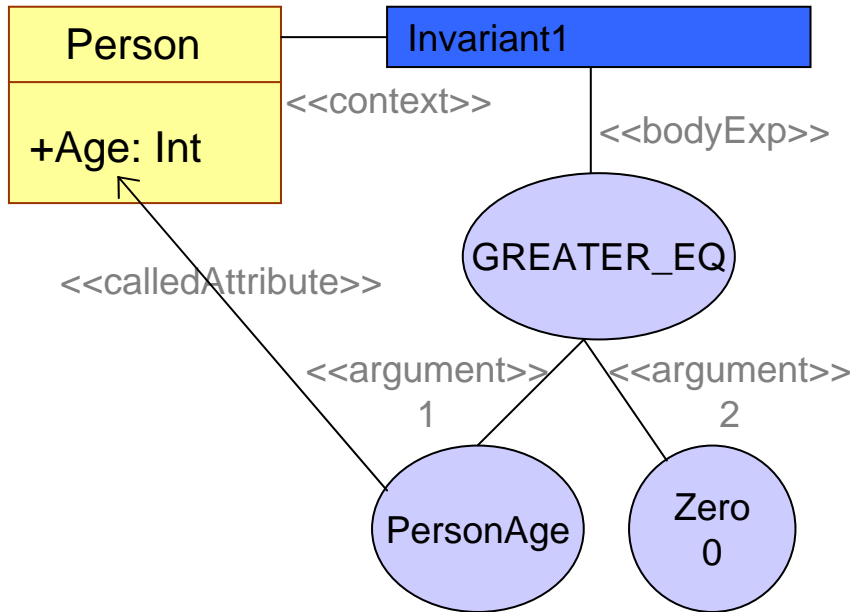
A = AttrNode(ID="A", label="Class")
A["att1"] = Int()
B = AttrNode(ID="B", label="Class")
B["att2"] = String()
C = AttrNode(ID="C", label="Class")
C["att3"] = Float()
hasB = AttrNode(ID="hasB", label="Association")
hasB["srcMultMin"] = Int(value=1)
hasB["srcMultMax"] = Int(value=1)
hasB["trgMultMin"]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

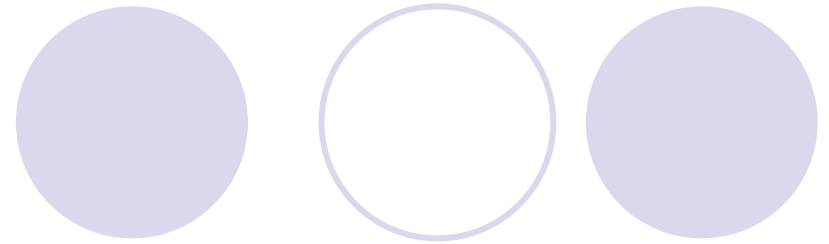
*Constraint expression in pyGK format*

```
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:

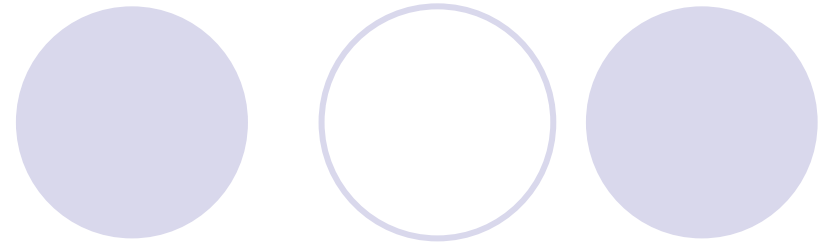
```
from pack import mod

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

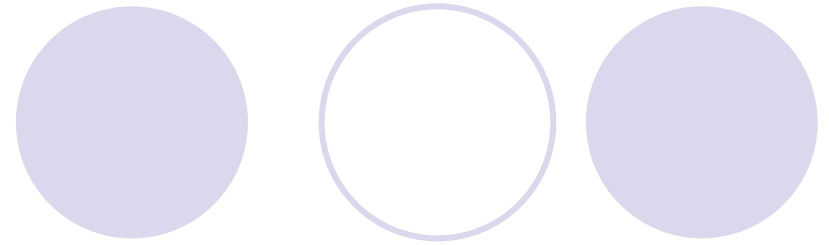
- Saving the constraints:

- 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:*

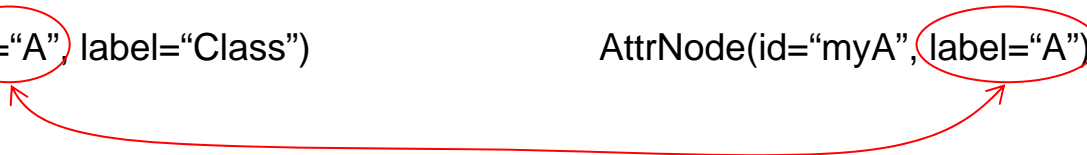
A
+att1: Int

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

*In instance:*

<u>myA</u> : A
+att1 = 0

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

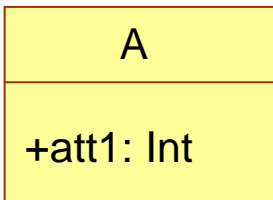


# ... every instance element owns only properties that its meta-element can own

- 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

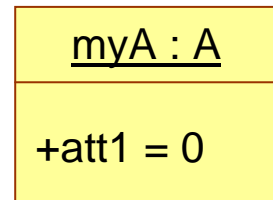
● E.g.

*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:
    - $\text{srcMultMin} \leq \# \text{ source instances} \leq \text{srcMultMax}$
    - $\text{trgMultMin} \leq \# \text{ target instances} \leq \text{trgMultMax}$

# 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 constraint against every instance of the constraint's context
    - Call the generated Python function
  - Don't forget sub types!

A decorative graphic at the top of the slide consists of two groups of three circles. The left group has a solid light purple circle on the left, a white circle with a light purple outline in the middle, and a white circle with a light purple outline on the right. The right group has a solid light purple circle on the left, a white circle with a light purple outline in the middle, and a solid light purple circle on the right.

# 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...
  - Constraint text editor that converts Expressions to the AST
- Expressiveness of the constraint language
  - Add more constructs like *select* operation (?)

# More Future Work



- Tests on bigger models
  - Performance issues?
- 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



## Special thanks to:

- Dr. Hans Vangheluwe
- Dr. Juan de Lara for ClassDiagram formalism in AToM<sup>3</sup>
- Marc Provost for help on pyGK and metamodeling

# References

1. Object Management Group, *UML 2.0 Infrastructure Final Adopted Specification*, Available Online, URL: <http://www.omg.org/docs/ptc/03-09-15.pdf>, September 2003
2. Object Management Group, *MOF 2.0 Core Final Adopted Specification*, Available Online, URL: <http://www.omg.org/docs/ptc/03-10-04.pdf>, October 2003
3. Object Management Group, *MOF-XMI Final Adopted Specification*, Available Online, URL: <http://www.omg.org/docs/ptc/03-11-04.pdf>, November 2003
4. Object Management Group, *UML 2.0 OCL Specification*, Available Online, URL: <http://www.omg.org/docs/ptc/03-10-14.pdf>, October 2003
5. C. Kiesner, G. Taentzer, J. Winkleman, *Visual OCL: A Visual Notation of Object Constraint Language*, Available Online, URL: <http://tfs.cs.tu-berlin.de/vocl/>, 2002