

מודלים לפיתוח מערכות תוכנה

Software Systems Modeling

קורס 12003

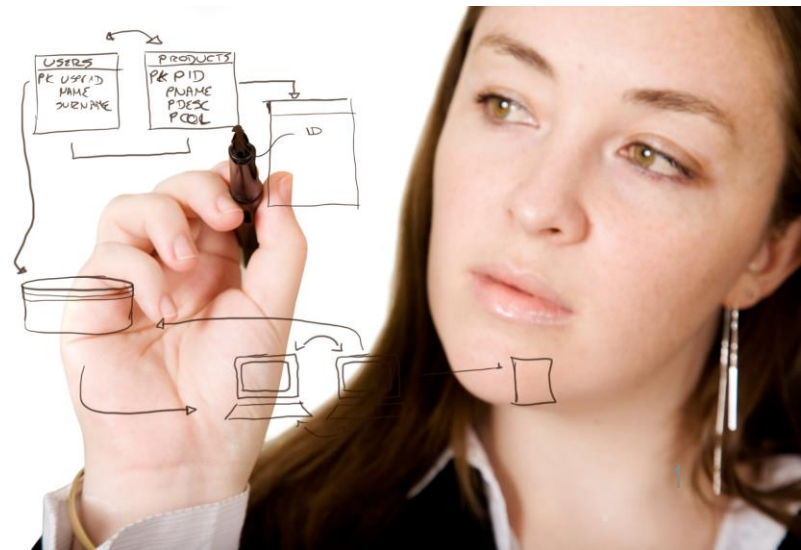
סמסטר ב' תשע"ה

5. Object Constraint Language (OCL)

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הפעם

- UML

- שימוש בתבניות תיכון

- סיכום

- OCL

- תאוריה

- כלים + הדגמה

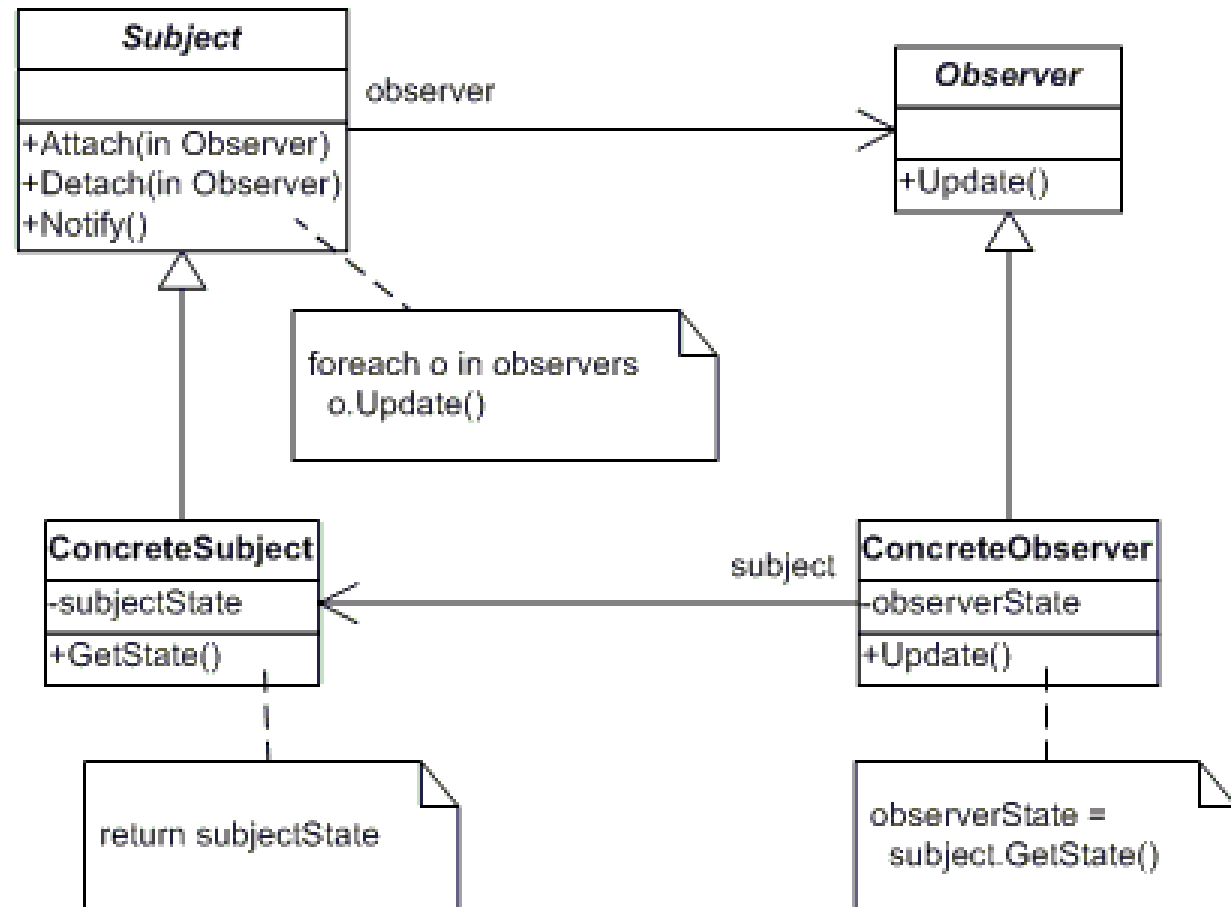
- תרגיל 1 חלק ג'

מקורות

- [RIT Class](#) Wei Le
- Eclipse, Open Model CourseWare
<https://eclipse.org/gmt/omcw/>
- JCE SE Course, Design Patterns
<http://jce-il.github.io/se-class/lecture/se-11-patterns.pdf>
- OCL
 - Jos Warmer and Anneke Kleppe – The Object Constraint Language – Second Edition
 - Object Management Group (OMG); *Object Constraint Language OMG Available Specification Version 2.4*, Feb. 2014
<http://www.omg.org/spec/OCL/>
 - “Object Constraint Language (OCL): a Definitive Guide”
<http://modeling-languages.com/> ([paper](#), [slides](#), [youtb](#))

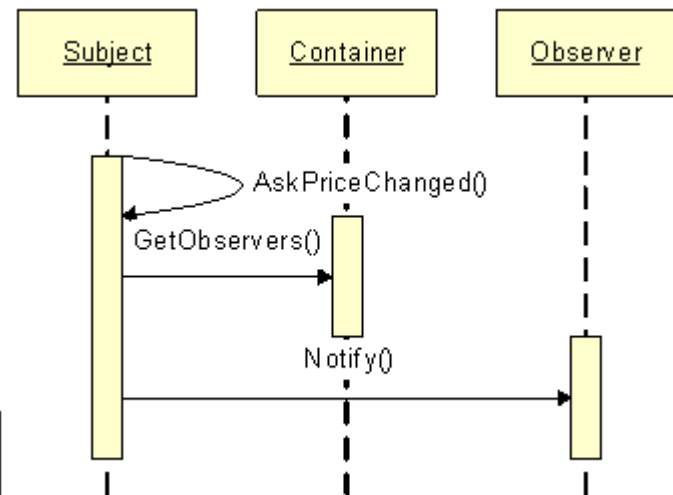
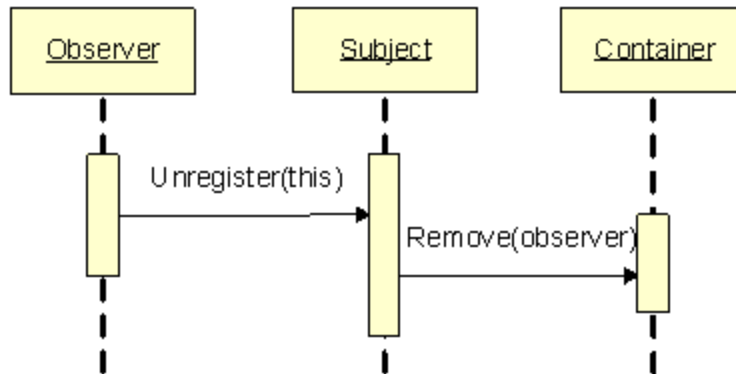
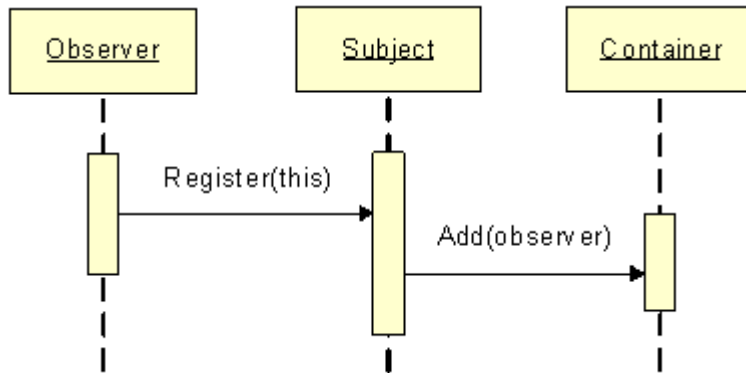
Observer

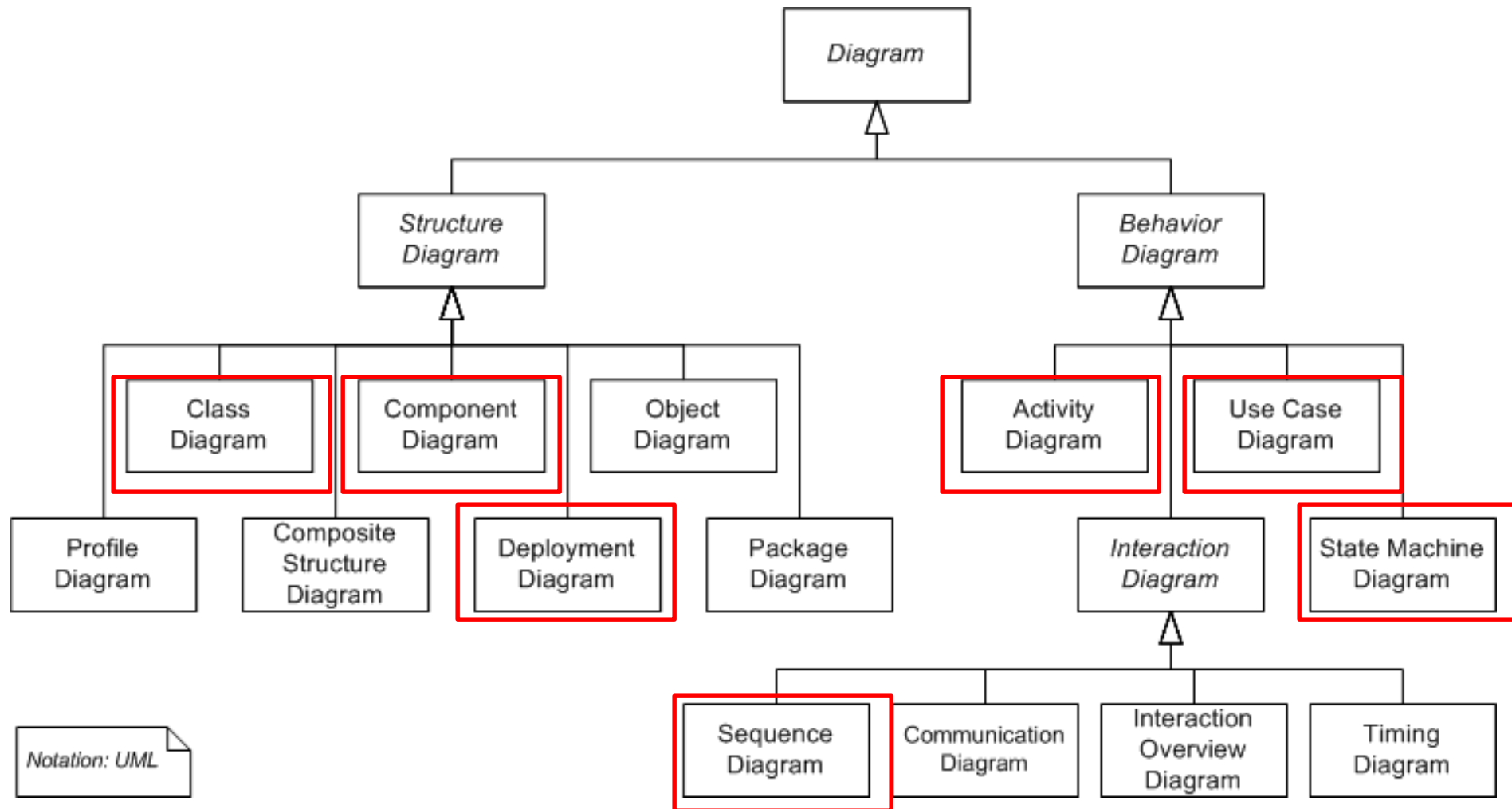
Example



Observer

• תרשימי רצף:





UML Summary

- UML: a graphical language for modeling and designing software
- Semi-formal models using syntax and semantics
- UML 2.0 standard
- 3 stages of design before coding: business modeling (initiation), requirement analysis (what to do), architecture (how to do it)
- UML as a family of languages: extensibility - UML for real-time systems, e.g., meta-class, constraints
- Best open source UML tools: <http://apps.open-libraries.com/best-OPEN-source-uml-tools/>

UML Diagrams Summary

- Use Case Diagram: actor and use cases
 - 2 usage: mainly for requirement (sometimes business modeling), a communication between users, customers, designers
 - 4 elements: actor, system boundary, use cases, association
 - 4 rules to write good use case diagram: less ambiguity, complete, consistent, no design details - cross check with text requirement
 - 3 use case relations: include, extend, generalization/specialization
 - 4 key elements in use cases: name, actor, pre/post conditions, flow (main, alternative flows), sometimes relations with other use cases

UML Diagrams Summary

- Sequence diagram: object interactions
 - Requirement analysis – describe use cases, find more objects
 - 4 elements: objects (actor), lifetime, activation, messages

UML Diagrams Summary

- Class Diagram: class and class relations
 - Requirement and architecture design
 - 3 elements: name, attribute (optional), operation (optional)
 - 2 types of class relations: association (aggregation/composition), generalization/specialization – inheritance
 - Identify names in the requirement as classes

UML Diagrams Summary

- Activity diagram: capture an activity/action -- unit of executable functionality
 - Business modeling, requirement - both data and control flow, concurrent modeling
 - 2 types of elements
 1. Activity nodes
 - Parameter nodes
 - Action nodes
 - Control nodes: decision/merge, join/fork, initial/final/flow final
 - Object nodes (pin): value pin, exceptional pin
 2. Activity edges
 - Direct, Weight (optional) - the minimum number of tokens that must traverse the edge at the same time
 - Control /object edges

UML Object Constraint Language

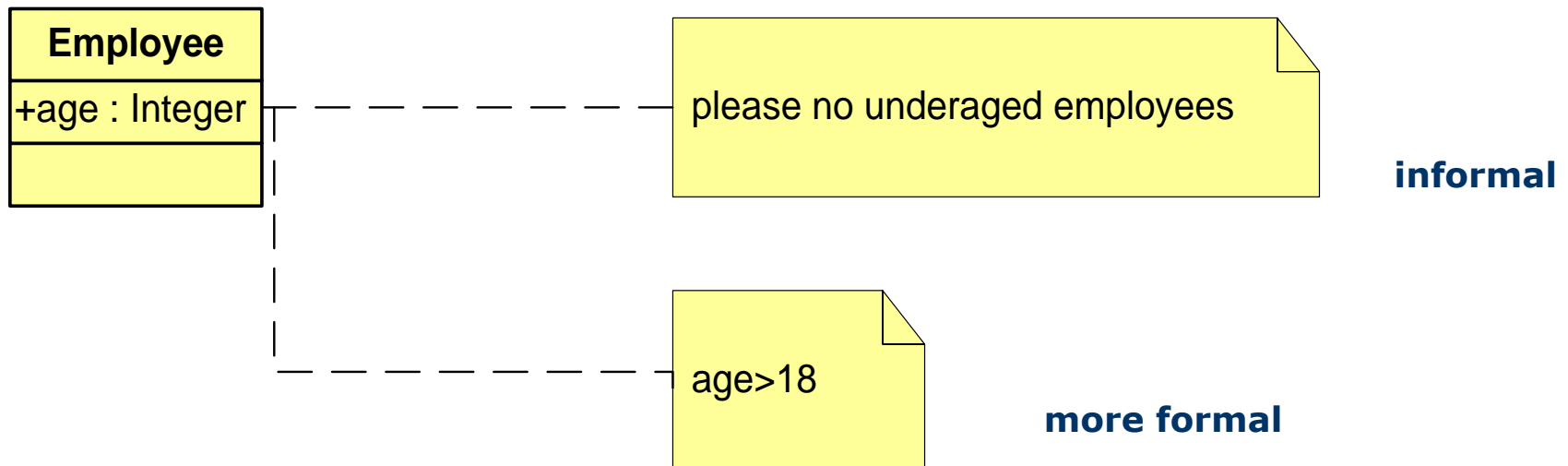


Overview

- Motivation and short history
- OCL
 - structure of an OCL constraint
 - basic types
 - accessing objects and their properties
 - collections

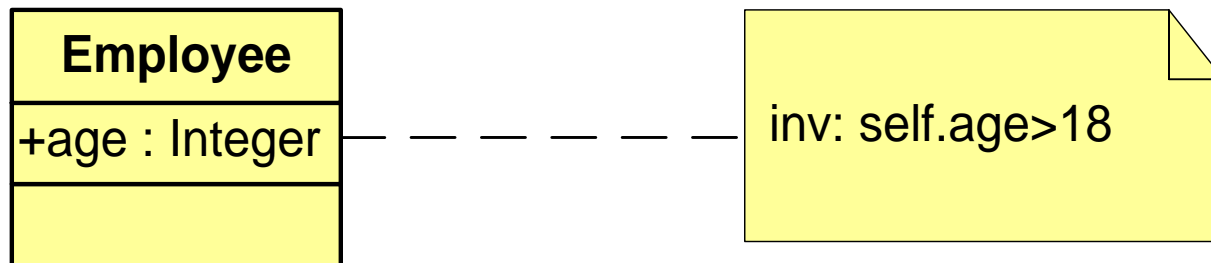
Motivation

- Graphic specification languages such as UML can describe often only partial aspects of a system
- Constraints are often (if at all) described as marginal notes in natural language
 - almost always ambiguous
 - imprecise
 - not automatically realizable/checkable
- Formal Languages are better applicable



Motivation 2

- Traditional formal languages (e.g. Z) require good mathematical understanding from users
 - mostly applied in academic world, not in industry
 - hard to learn, too complex in application
- The *Object Constraint Language* (OCL) has been developed to achieve the following goals:
 - formal, precise, unambiguous
 - applicable for a large number of users (business or system modeler, programmers)
 - Specification language
 - not a Programming language



History

- Developed in 1995 from IBM's Financial Division
 - original goal: business modeling
 - Insurance department
 - derived from S. Cook's „Syntropy“
- Belongs to the UML Standard since Version 1.1 (1997)
- *OCL 2.0 Final Adopted Specification* (ptc/03-10-14) October 2003
- developed parallel to UML 2.0 and MOF 2.0
 - core OCL (basic or essential OCL)



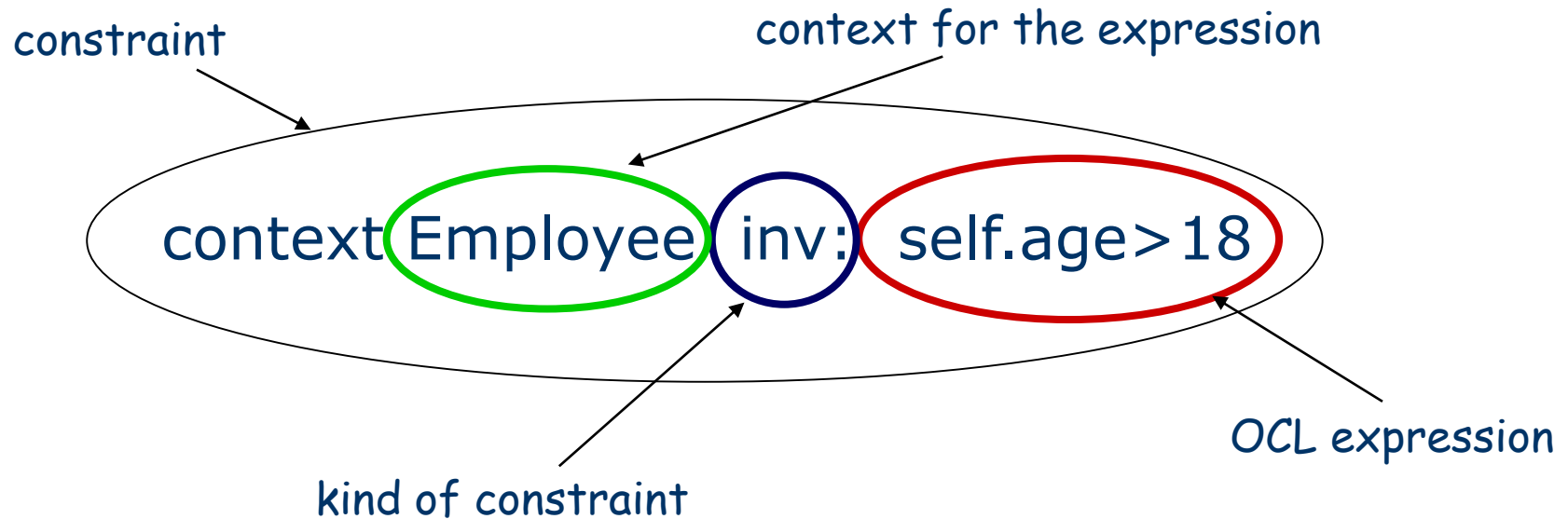
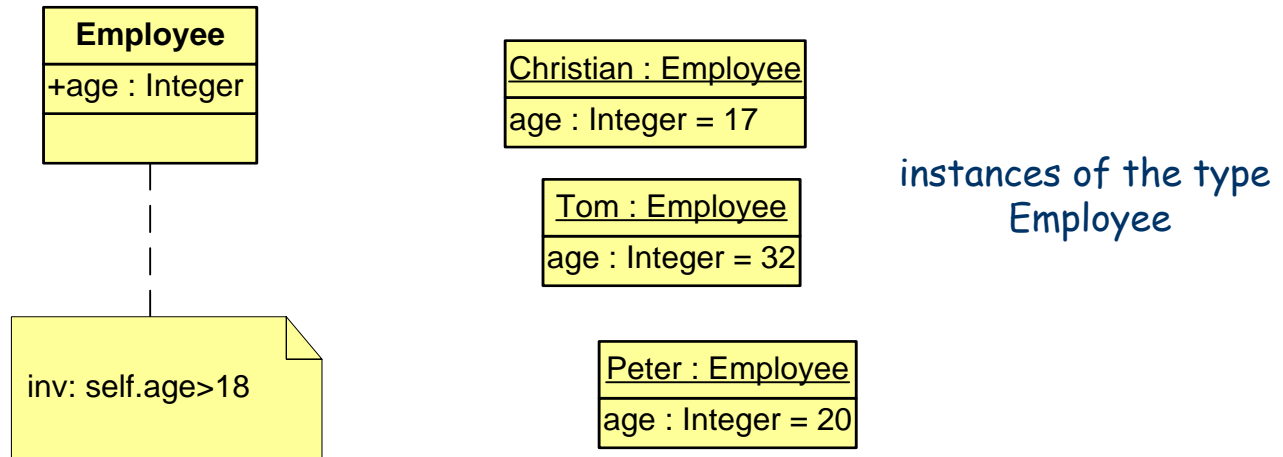
Language features

- Specification language without side effects
- Evaluation of an OCL expression returns a value - the model remains unchanged! (even though an OCL expression maybe used to specify a state change (e.g., post-condition) the state of the system will never change)
- OCL is not a programming language (no program logic or flow control, no invocation of processes or activation of non-query operations, only queries)
- OCL is a typed language, each OCL expression has a type. It is not allowed to compare Strings and Integers
- Includes a set of predefined types
- The evaluation of an OCL expression is instantaneous, the states of objects in a model cannot change during evaluation

Where to use OCL

- Constraints specification for model elements in UML models
 - Invariants
 - Pre- and post conditions (Operations and Methods)
 - Guards
 - Specification of target (sets) for messages and actions
 - initial or derived values for attributes & association ends
- As „query language“
- Constraints specification in metamodels based on MOF or Ecore
 - metamodels are also models
 - possible kinds of constraints
 - invariants, pre- and post conditions, initial or derived values

OCL Constraint



kind of constraints (Invariants)

Employee
age : Integer wage : Integer
raiseWage(newWage : Integer)

- **inv** invariant: constraint must be true
 - for all instances of constrained type at any time
 - Constraint is always of the type Boolean

```
context Employee
  inv: self.age > 18
```

kind of constraints 2 (Pre- and Postconditions)

Employee
age : Integer wage : Integer
raiseWage(newWage : Integer)

- **pre** precondition: constraint must be true, before execution of an Operation
- **post** postcondition: constraint must be true, after execution of an Operation
 - `self` refers to the object on which the operation was called
 - `return` designates the result of the operation (if available)
 - The names of the parameters can also be used

```
context Employee::raiseWage(newWage:Integer)
  pre: newWage > self.wage
  post: wage = newWage
```

kind of constraints 3 (others)

- **body** specifies the result of a query operation
 - The expression has to be conformed to the result type of the operation

```
context Employee::getWage() : Integer
```

```
body: self.wage
```

- **init** specifies the initial value of an attribute or association end

- Conformity to the result type + Multiplicity

```
context Employee::wage
```

```
init: wage = 900
```

Employee
age : Integer wage : Integer
raiseWage(newWage : Integer) getWage() : Integer

- **derive** specifies the derivation rule of an attribute or association end

```
context Employee::wage
```

```
derive : wage = self.age * 50
```

- **def** enables reuse of variables/operations over multiple OCL expressions

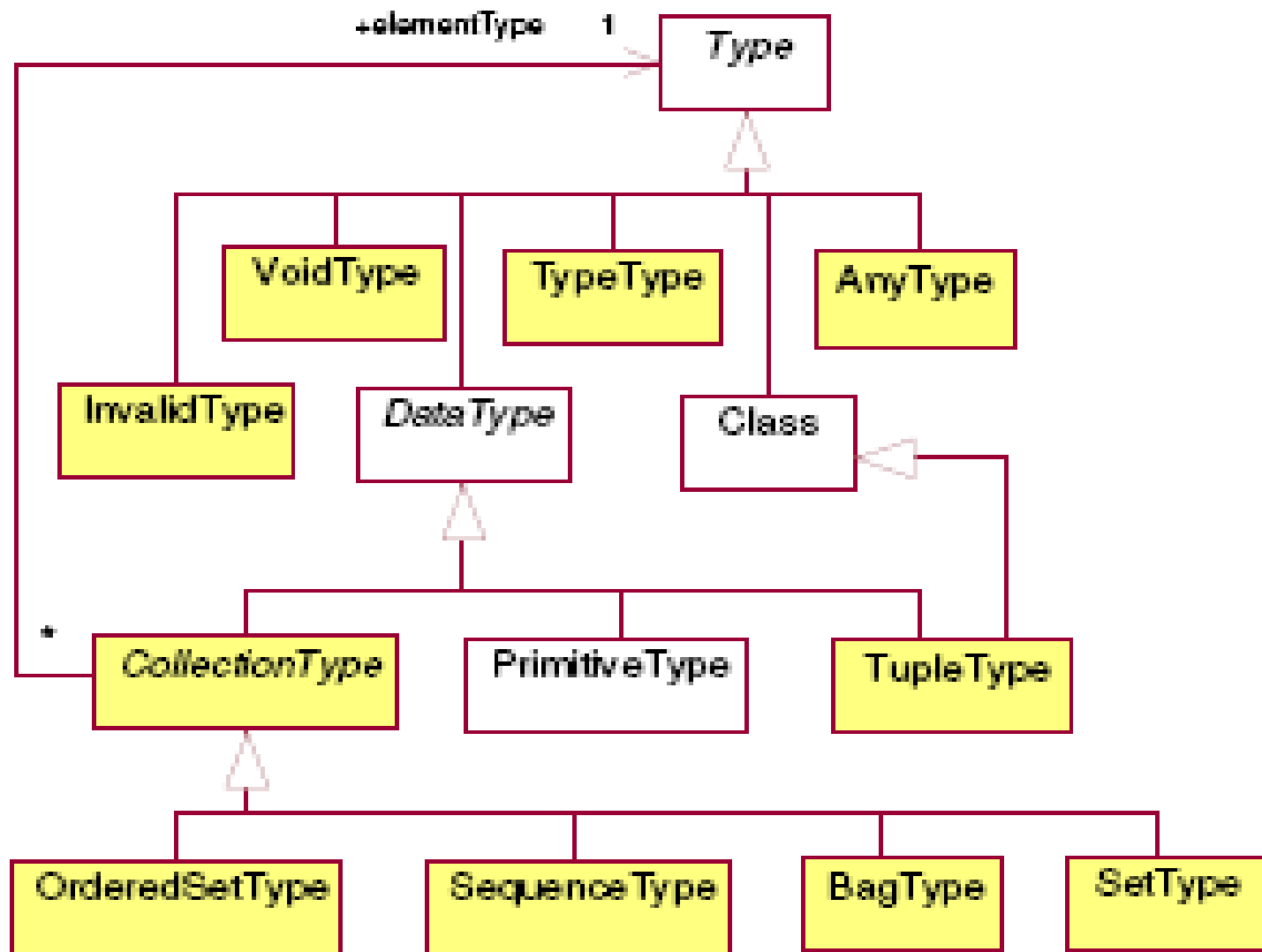
```
context Employee
```

```
def: annualIncome : Integer = 12 * wage
```

OCL Metamodel

- OCL 2.0 has MOF Metamodel
- The Metamodel reflects OCL's abstract syntax
- Metamodel for OCL Types
 - OCL is a typed language
 - each OCL expression has a type
 - OCL defines additional to UML types:
 - CollectionType, TupleType, OclMessageType,....
- Metamodel for OCL Expressions
 - defines the possible OCL expressions

OCL Types Metamodel



OCL Types

- Primitive Types
 - Integer, Real, Boolean, String
 - OCL defines a number of operations on the primitive types
 - $+$, $-$, $*$, $/$, $\min()$, $\max()$, ... , for Integer or Real
 - $\text{concat}()$, $\text{size}()$, $\text{substring}()$, ... , for String
- OCLModelElementTypes
 - All Classifiers within a model, to which OCL expression belongs, are types
- Collection Types
 - CollectionType is abstract, has an element type, which can be CollectionType again
 - Set: contains elements without duplicates, no ordering
 - Bag: may contain elements with duplicates, no ordering
 - Sequence: ordered, with duplicates
 - OrderedSet: ordered, without duplicates

OCL Types 2

- TupleType

- Is a "Struct" (combination of different types into a single aggregate type)
- is described by its attributes, each having a name and a type

- VoidType

- Is conform to all types

Basic constructs for OCL expressions

- **Let, If-then-else**

```
context Employee inv:
```

```
let annualIncome : Integer = wage * 12 in
```

```
if self.isUnemployed then
```

```
    annualIncome < 5000
```

```
else
```

```
    annualIncome >= 5000
```

```
endif
```

Employee
+age : Integer
+wage : Integer
+isUnemployed : Boolean

- **Let** expression allows to define a (local) variable

- **If-then-else** construct (complete syntax)

```
if <boolean OCL expression>
```

```
then <OCL expression>
```

```
else <OCL expression>
```

```
endif
```

Accessing objects and their properties (Features)

Employee
+age : Integer
+wage : Integer
+isUnemployed : Boolean
+getWage() : Integer

- **Attribute:**

```
context Employee inv: self.age > 18
```

```
context Employee inv: self.wage < 10000
```

```
context Employee inv: self.isUnemployed
```

- **Operations:**

```
context Employee inv: self.getWage() > 1000
```

Accessing objects and their properties (Features) 2

Employee
+age : Integer
+wage : Integer
+isUnemployed : Boolean
+position : Position
+getWage() : Integer

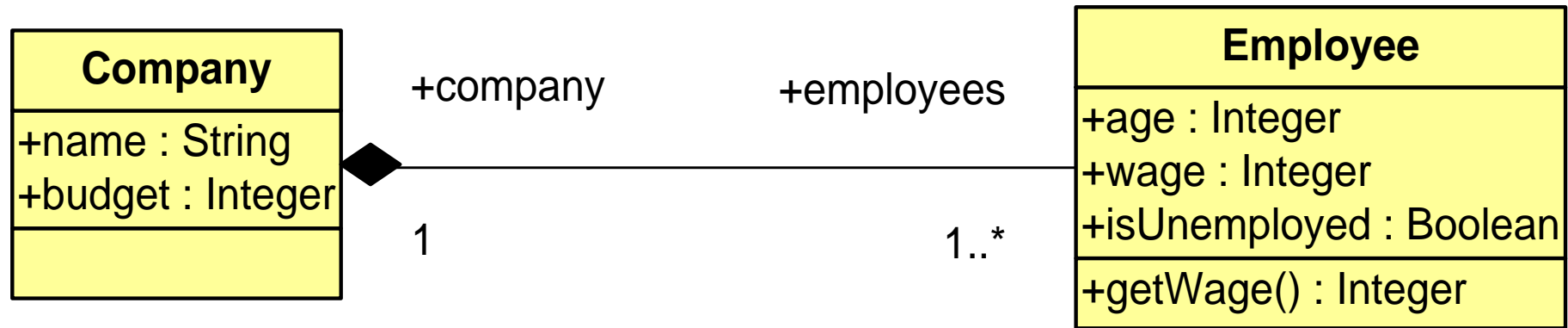
«Enumeration» Position
+CTO
+CEO
+JUNIOR_MANAGER
+SENIOR_MANAGER
+STUDENT
+TRAINEE

● Accessing enumerations with ' :: '

context Employee inv:

self.position=Position::TRAINEE implies self.wage<500

Accessing objects and their properties (Features) 3



● Association ends:

- allow navigation to other objects
- result in Set
- result in OrderedSet, when association ends are ordered

```

context Company inv: if self.budget<50000
then self.employees->size() < 31
else true
endif
  
```

Collections Operations (Iterations)

- some defined operations for collections
 - isEmpty(), size(), includes(),...
- Iteration operations
 - Select/Reject
 - Collect
 - ForAll
 - Exists
 - Iterate

Collections Operations (Iterations) 2

- **select** and **reject** create a subset of a collection
 - (result: Collection)

```
context Company inv:
```

```
self.employees->select (age < 18) -> isEmpty()
```

- Expression will be applied to all elements within the collection, context is then the related element

```
context Company inv:
```

```
self.employees->reject (age>=18) -> isEmpty()
```


Collections Operations (Iterations) 3

- **collect** specifies a collection which is derived from some other collection, but which contains different objects from the original collection (resulttype: Bag or Sequence)

```
context Company inv: self.employees->collect(wage)
    ->sum()<self.budget
-- collect returns a Bag of Integer
```

- Shorthand notation

```
self.employees.age
```

- Applying a property to a collection of elements will automatically be interpreted as a *collect* over the members of the collection with the specified property

Collections Operations (Iterations) 4

- **forAll** specifies expression, which must hold for all objects in a collection (resulttype: Boolean)

```
context Company inv: self.employees->forAll(age > 18)
```

- Can be nested

```
context Company inv:
self.employees->forAll (e1 |
    self.employees->forAll (e2 |
        e1 <> e2 implies e1.pnum <> e2.pnum))
```

Employee
+age : Integer
+wage : Integer
+isUnemployed : Boolean
+position : Position
+pnum : Integer
+getWage() : Integer

- **exists** returns true if the expression is true for at least one element of collection (resulttype: Boolean)

```
context Company inv:
self.employees->exists(e|e.pnum=1)
```

Collections Operations (Iterations) 5

- **iterate** is the general form of the Iteration, all previous operations can be described in terms of iterate

```
collection->iterate( elem : Type; acc : Type =
    <expression> | expression-with-elem-and-acc )
```

- **elem** is the iterator, variable **acc** is the accumulator, which gets an initial value **<expression>**.
- Example **SELECT** operation:

```
collection-> select(iterator | body)
```

-- is identical to:

```
collection->iterate(iterator; result : Set(T) = Set{} |
if body
then result->including(iterator)
else result
endif )
```

Predefined Operations

- OCL defines several Operations that apply to all objects

- **oclIsTypeOf (t:OclType) : Boolean**

- results is true if the type of self and t are the same

context Employee inv:

self.oclIsTypeOf(Employee) -- is true

self.oclIsTypeOf(Company) -- is false

- **oclIsKindOf (t:OclType) : Boolean**

- determines whether t is either the direct type or one of the supertypes of an object

- **oclIsNew () : Boolean**

- only in postcondition: results is true if the object is created during performing the operation

Predefined Operations 2

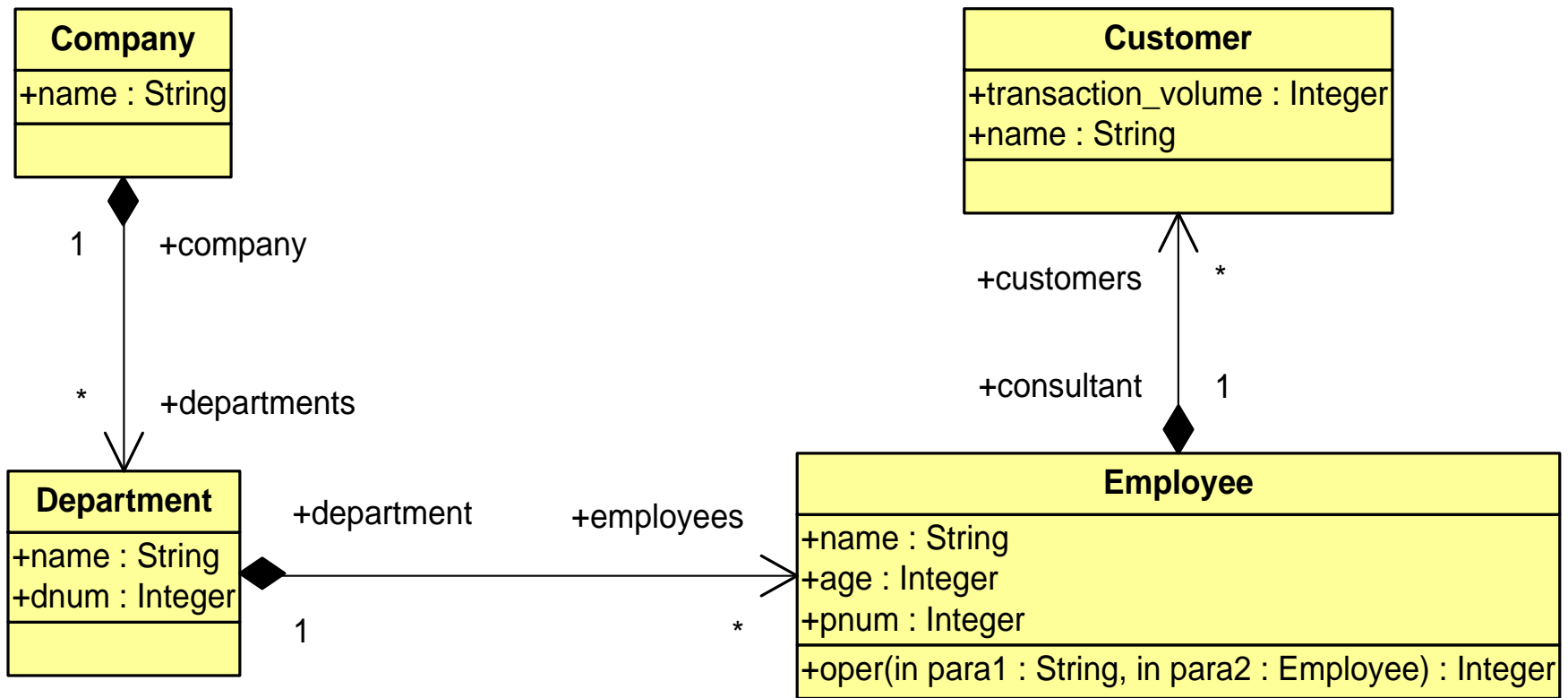
- **oclAsType (t:OclType) :T**
 - results in the same object, but the known type is the *OclType*
- **allInstances**
 - predefined feature on classes, interfaces and enumerations
 - results in the collection of all instances of the type in existence at the specific time when the expression is evaluated

context Company inv:

```
Employee.allInstances()->forall(p1|
  Employee.allInstances()->forall(p2|
    p1 <> p2 implies p1.pnum <> p2.pnum)
```

Employee
+age : Integer
+wage : Integer
+isUnemployed : Boolean
+position : Position
+pnum : Integer
+getWage() : Integer

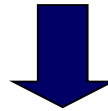
example model



Tips & Tricks to write better OCL (1/5)

- Keep away from complex navigation expressions!
 - a customer bonusprogram have to be funded if a customer exists which have a transaction volume more than 10000

```
context Company
inv: departments.employees.customers->exists(c|c.volume>10000)
    implies bonusprogram.isfunded
```



```
context Department
def: reachedVolume:Boolean = employees.customers->
    exists(c|c.volume>10000)
```

```
context Company
inv: departments->exists(d|d.reachedVolume) implies
    bonusprogram.isfunded
```

Tips & Tricks to write better OCL (2/5)

- Choose context wisely (attach an invariant to the right type)!



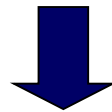
- two persons who are married are not allowed to work at the same company:

```
context Person
```

```
inv: wife.employers>intersection(self.employers)
```

```
->isEmpty() and husband.employers
```

```
->intersection(self.employers)->isEmpty()
```



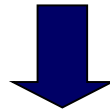
```
context Company
```

```
inv: employees.wife->intersection(self.employees)->isEmpty()
```


Tips & Tricks to write better OCL (3/5)

- Avoid *allInstances* operation if possible!
 - results in the set of all instances of the modeling element and all its subtypes in the system
 - problems:
 - the use of allInstances makes (often) the invariant more complex
 - in most systems, apart from database systems, it is difficult to find all instances of a class

```
context Person
inv: Person.allInstances->
  forAll(p| p. parents->size <= 2)
```

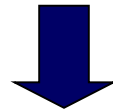


```
context Person
inv: parents->size <= 2
```

Tips & Tricks to write better OCL (4/5)

- Split complicated constraint into several separate constraints !
 - Some advantages:
 - each invariant becomes less complex and therefore easier to read and write
 - the simpler the invariant, the more localized the problem
 - maintaining simpler invariants is easier

```
context Company inv: self.employees.wage-> sum()<self.budget and
self.employees->forAll (e1 | self.employees ->forAll (e2 | e1 <> e2
implies e1.pnum <> e2.pnum)) and self.employees->forAll(e|e.age>20)
```



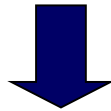
```
context Company
inv: self.employees.wage->sum()<self.budget
inv: self.employees->forAll (e1 | self.employees->forAll (e2|e1<>
    e2 implies e1.pnum <> e2.pnum))
inv: self.employees->forAll(e|e.age>20)
```

Tips & Tricks to write better OCL (5/5)

- Use the *collect* shorthand on collections!

```
context Person
```

```
inv: self.parents->collect(brothers) -> collect(children)->notEmpty()
```



```
context Person inv: self.parents.brothers.children->notEmpty()
```

- Always name association ends!
 - indicates the purpose of that element for the object holding the association
 - helpful during the implementation: the best name for the attribute (or class member) that represents the association is already determined

Summary

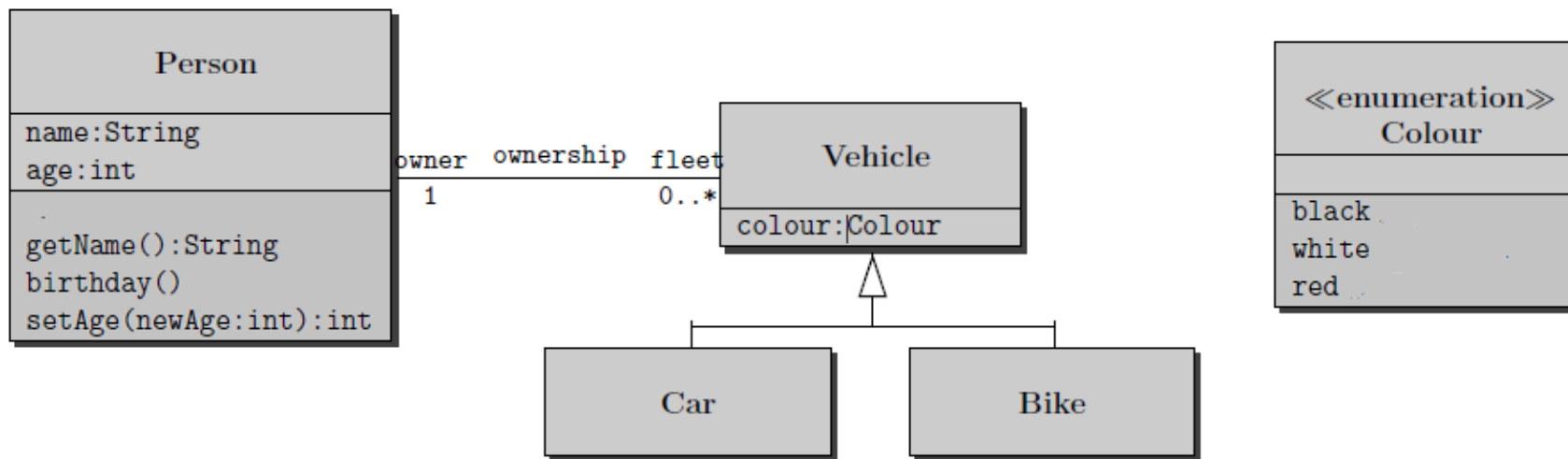
- focus was on the “core” part of OCL
- core OCL can be used for UML2 as well as MOF metamodels
- constraint for metamodels can be used for computing metrics or check design guidelines
- additional courseware about some of these topics is available

Demo / Tools

- Tools
 - Eclipse Modeling Tools
 - <http://www.eclipse.org/modeling/>
 - <http://www.eclipse.org/modeling/mdt/?project=uml2>
 - [Download Package](#)
 - Plugins: Papyrus, OCL Tools (alt.: UML2)
 - Alt: ArgoUML+Dresden OCL Toolkit
 - <http://argouml.tigris.org/>

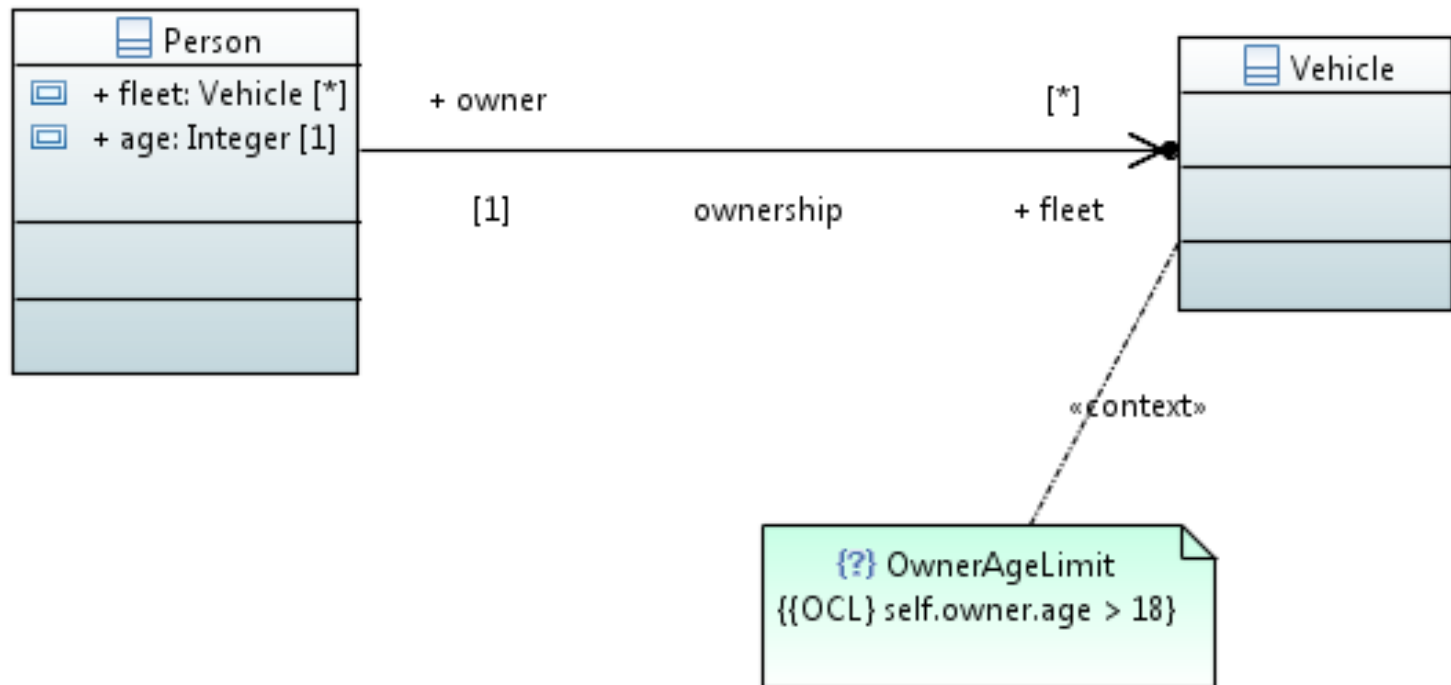
תרגיל כיתה- OCL

הוספת מספר אילוצים, בדומה לדוגמא:



Construct OCL constraints

1. A vehicle owner must be at least 18 years old
2. A car owner must be at least 18 years old
3. Nobody has more than 3 vehicles
4. All cars of a person are black
5. Nobody has more than 3 black vehicles
6. If `setAge(. . .)` is called with a non-negative argument then the argument becomes the new value of the attribute `age`
7. Calling `birthday()` increments the age of a person by 1
8. Calling `getName()` delivers the value of the attribute `name`



תרגיל בית – UML3

- הוספת חמישה אילוצים לדיאגרמות הקיימות מהחלק הקודם של התרגיל
 - כיסוי של שלשת הסוגים + קבוצה
- מומלץ בכלי, אך לא חובה
- הגשה באישיו כרגיל

סיכום

- OCL

– דוגמאות <https://github.com/jcabot/ocl-repository>

- הרחבות אפשריות לנושא UML:

– MDA/MDSE

– Eclipse Ecore/EMF

- בפעם הבאה: היבטי אריכטקטורה + פרויקט