Advanced Modeling with UML

- Part 1: Model Management
- Part 2: Extension Mechanisms and Profiles
- Part 3: Object Constraint Language (OCL)

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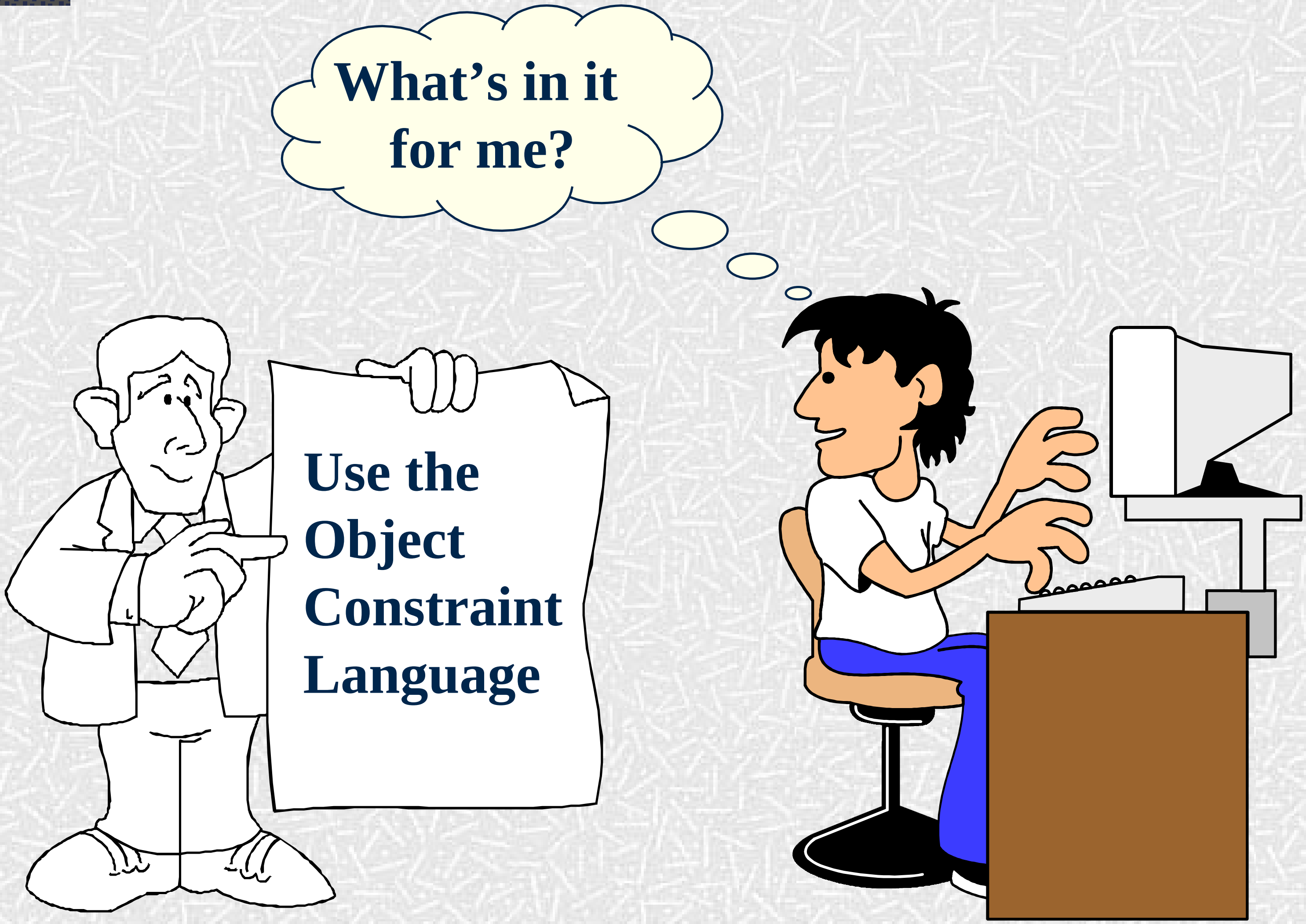
Overview

- What are constraints
- Core OCL Concepts
- Advanced OCL Concepts
- Wrap up

Why use OCL ?



That’s why !!

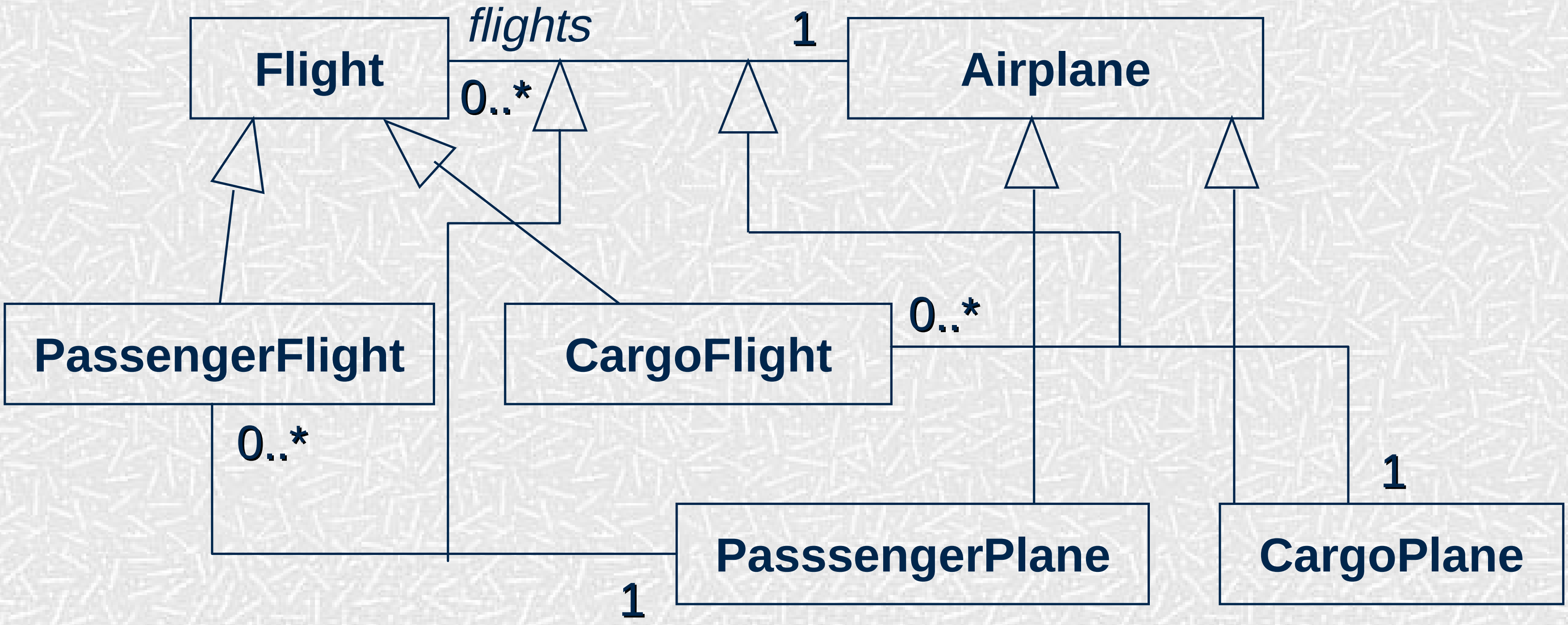
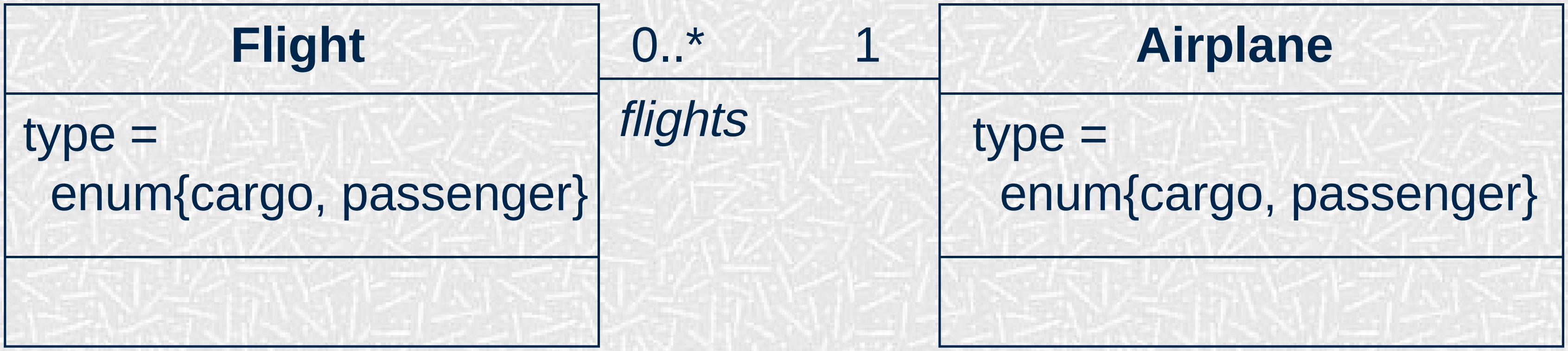

Flight
flights
1
Airplane
0..*
PassengerFlight
CargoFlight
0..*
0..*
1
PasssengerPlane
CargoPlane
1

Diagram with invariants



Flight

type =
enum{cargo, passenger}

0..*

flights

1

Airplane

type =
enum{cargo, passenger}

context Flight
inv: type = #cargo implies airplane.type = #cargo
inv: type = #passenger implies airplane.type = #passenger

Definition of constraint

- “A constraint is a restriction on one or more values of (part of) an object-oriented model or system.”

Different kinds of constraints

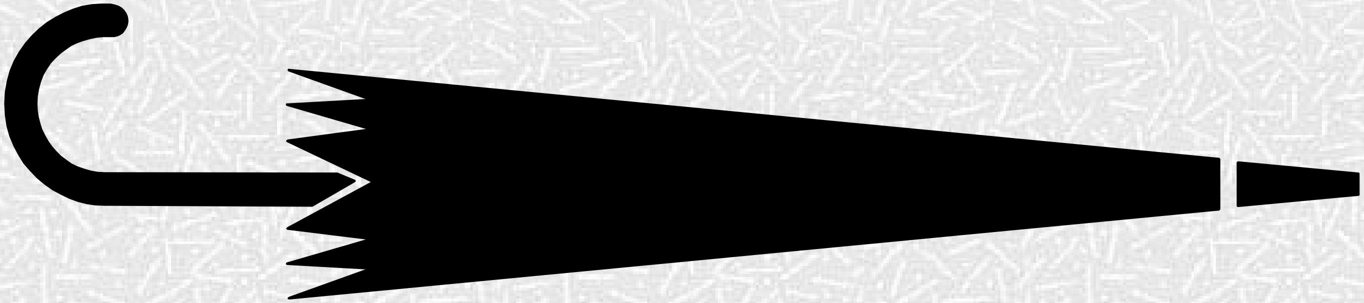
- Class invariant
  - a constraint that must always be met by all instances of the class
- Precondition of an operation
  - a constraint that must always be true BEFORE the execution of the operation
- Postcondition of an operation
  - a constraint that must always be true AFTER the execution of the operation

Constraint stereotypes

- UML defines three standard stereotypes for constraints:
  - invariant
  - precondition
  - postcondition

What is OCL?

- OCL is
  - a textual language to describe constraints
  - the constraint language of the UML
- Formal but easy to use
  - unambiguous
  - no side effects



Constraints and the UML model

- OCL expressions are always bound to a UML model

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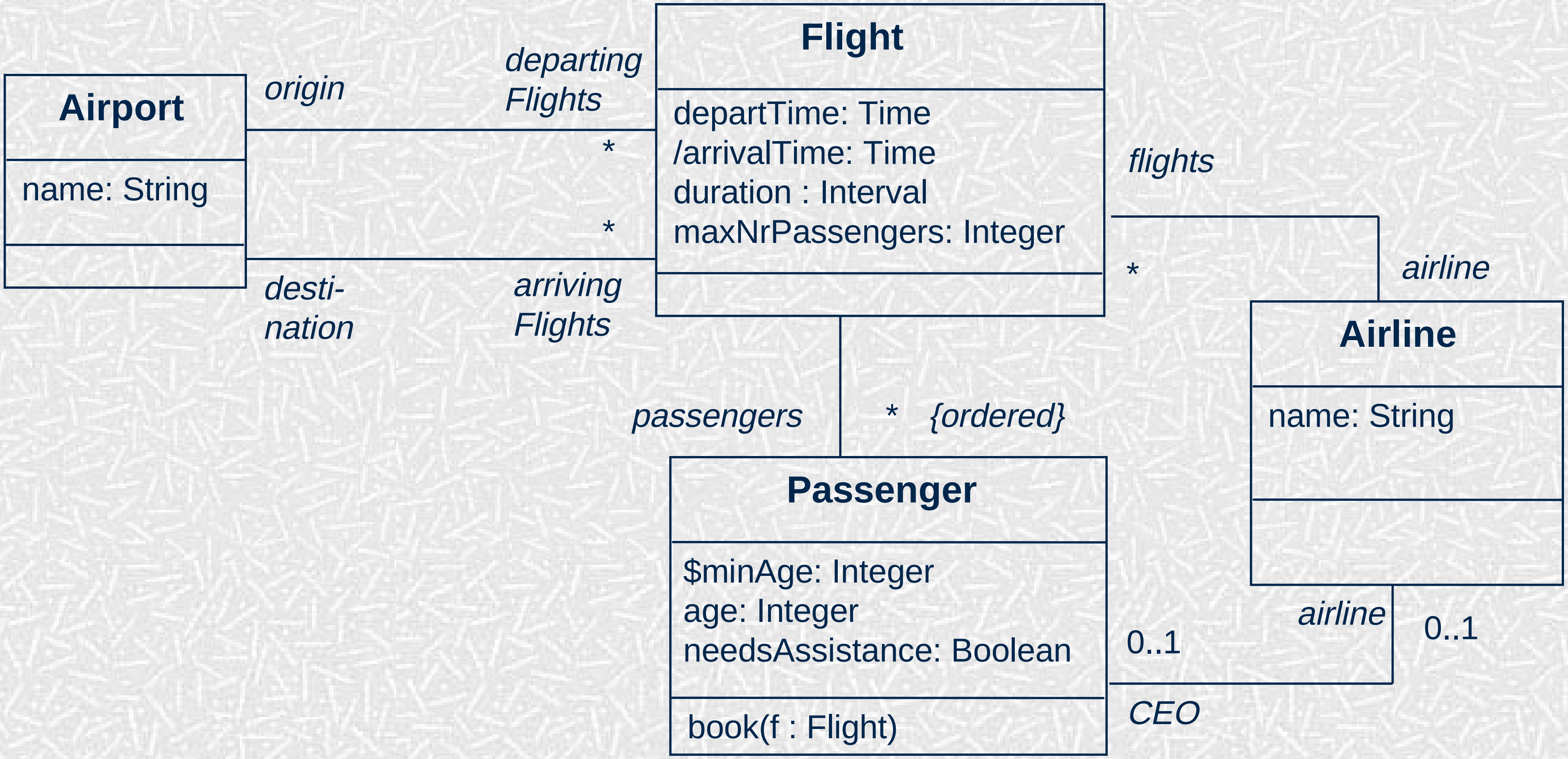
Example model



Constraint context and self

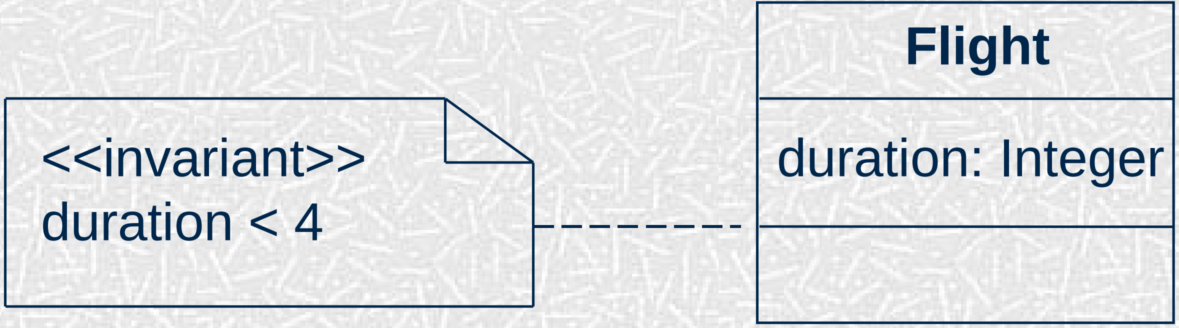
- Every OCL expression is bound to a specific context.
- The context may be denoted within the expression using the keyword 'self'.

Notation

- Constraints may be denoted within the UML model or in a separate document.
  - the expression:

    context Flight inv: self.duration < 4
  - is identical to:

    context Flight inv: duration < 4
  - is identical to:



Elements of an OCL expression

- In an OCL expression these elements may be used:
  - basic types: String, Boolean, Integer, Real.
  - classifiers from the UML model and their features
    - attributes, and class attributes
    - query operations, and class query operations
  - associations from the UML model

Example: OCL basic types

```
context Airline inv:
name.toLower = ‘klm’

context Passenger inv:
age >= ((9.6 - 3.5)* 3.1).floor implies
mature = true
```

Model classes and attributes

- “Normal” attributes

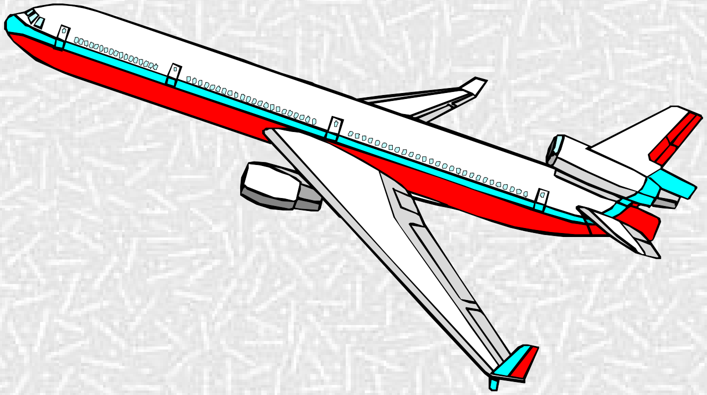
  context Flight inv:

  self.maxNrPassengers <= 1000

- Class attributes

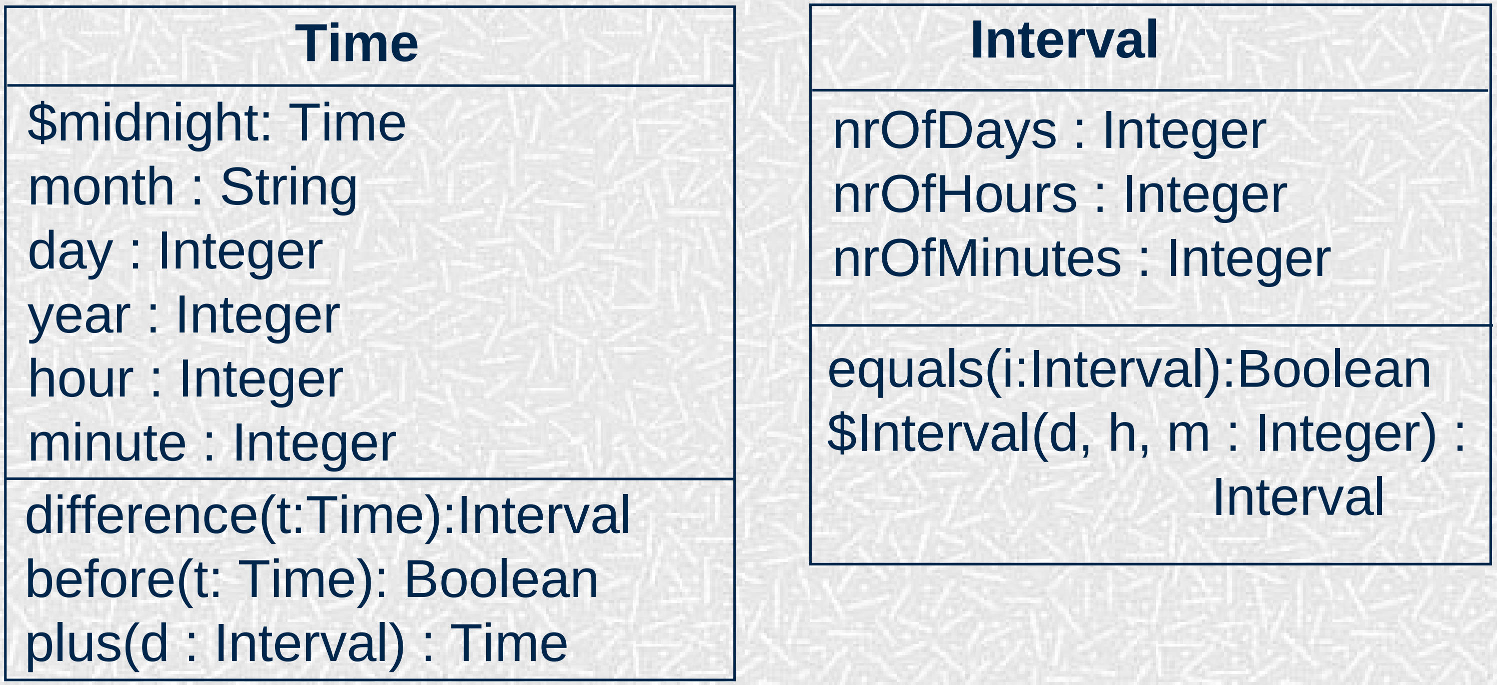
  context Passenger inv:

  age >= Passenger.minAge



Example: query operations

```
context Flight inv:
self.departTime.difference(self.arrivalTime)
                                   .equals(self.duration)
```



Time

$midnight: Time
month : String
day : Integer
year : Integer
hour : Integer
minute : Integer

difference(t:Time):Interval
before(t: Time): Boolean
plus(d : Interval) : Time

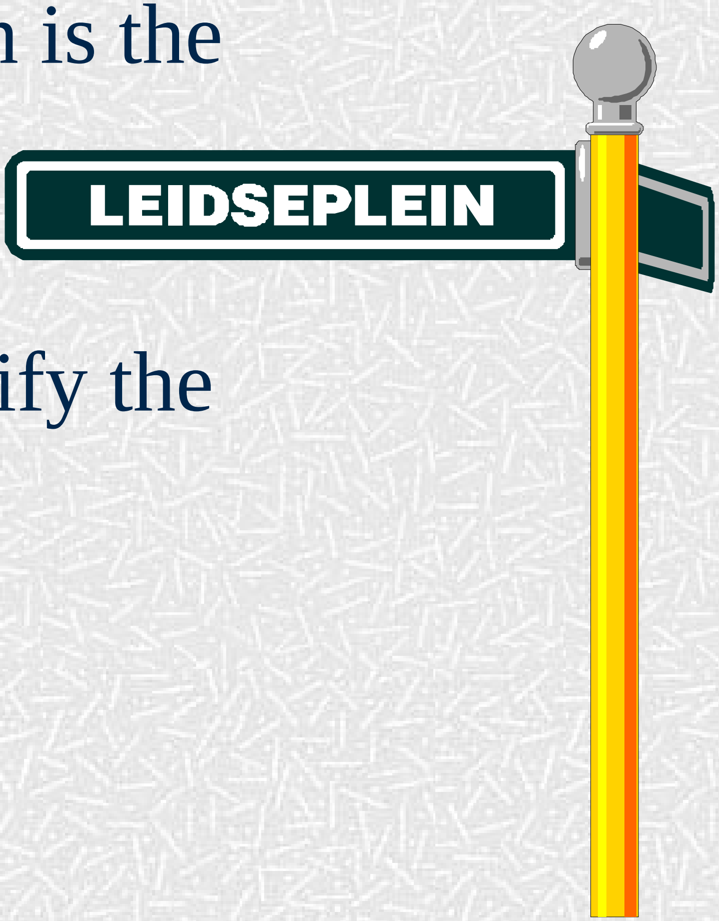
Interval

nrOfDays : Integer
nrOfHours : Integer
nrOfMinutes : Integer

equals(i:Interval):Boolean
$Interval(d, h, m : Integer) :
Interval

Associations and navigations

- Every association is a navigation path.
- The context of the expression is the starting point.
- Role names are used to identify the navigated association.



Example: navigations

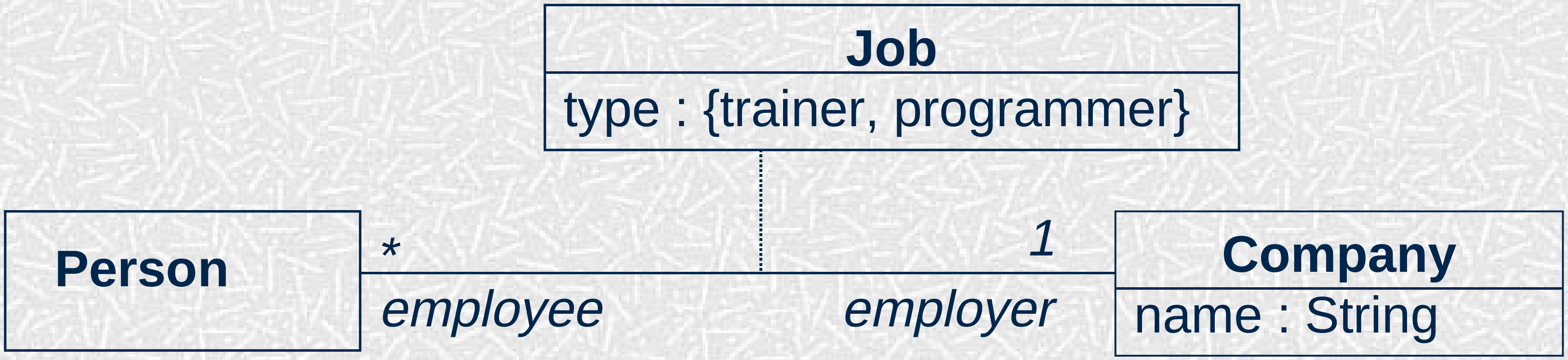
- Navigations

```
context Flight
inv: origin <> destination
inv: origin.name = ‘Amsterdam’

context Flight
inv: airline.name = ‘KLM’
```

Association classes

```
context Person inv:
if employer.name = ‘Klasse Objecten’ then
  job.type = #trainer
else
   job.type = #programmer
endif
```



The OCL Collection types

- What are constraints
- Core OCL Concepts
  - Collections
- Advanced OCL Concepts
- Wrap up

Three subtypes to Collection

- Set:
  - arrivingFlights(from the context Airport)
- Bag:
  - arrivingFlights.duration (from the context Airport)
- Sequence:
  - passengers (from the context Flight)

Collection operations

- OCL has a great number of predefined operations on the collections types.

- Syntax:

collection->operation

The collect operation

- Syntax:

  ```
  collection->collect(elem : T | expr)
  collection->collect(elem | expr)
  collection->collect(expr)
  ```

- Shorthand:

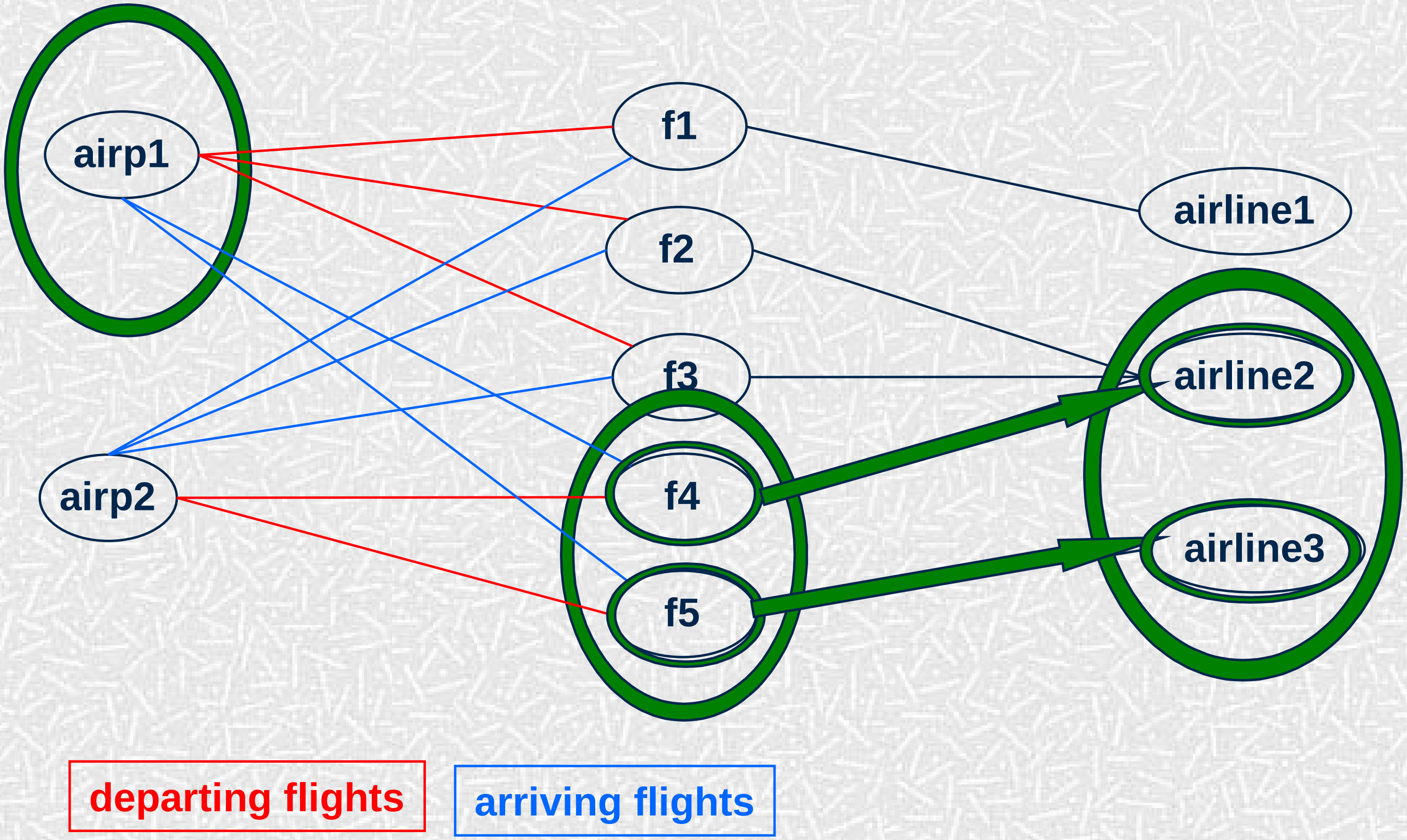
  ```
  collection.expr
  ```

- The *collect* operation results in the collection of the values resulting evaluating *expr* for all elements in the *collection*

Example: collect operation

context Airport inv:

self.arrivingFlights->collect(airLine)->notEmpty



The select operation

- Syntax:

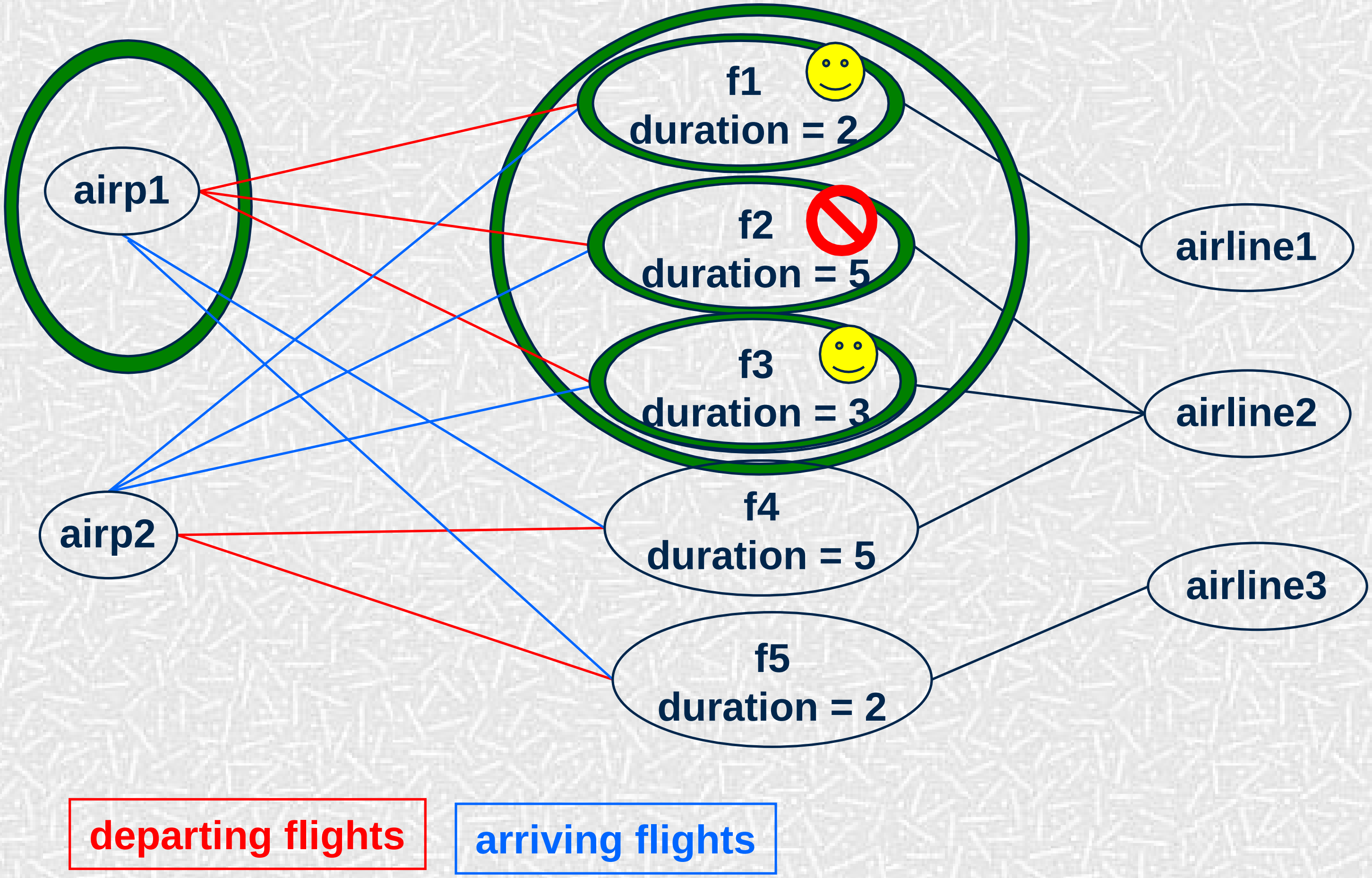
```
collection->select(elem : T | expression)
collection->select(elem | expression)
collection->select(expression)
```

- The *select* operation results in the subset of all elements for which *expression* is true

Example: collect operation

context Airport inv:

self.departingFlights->select(duration<4)->notEmpty



The forAll operation

- Syntax:

```
collection->forAll(elem : T | expr)
collection->forAll(elem | expr)
collection->forAll(expr)
```

- The *forAll* operation results in true if *expr* is true for all elements of the collection

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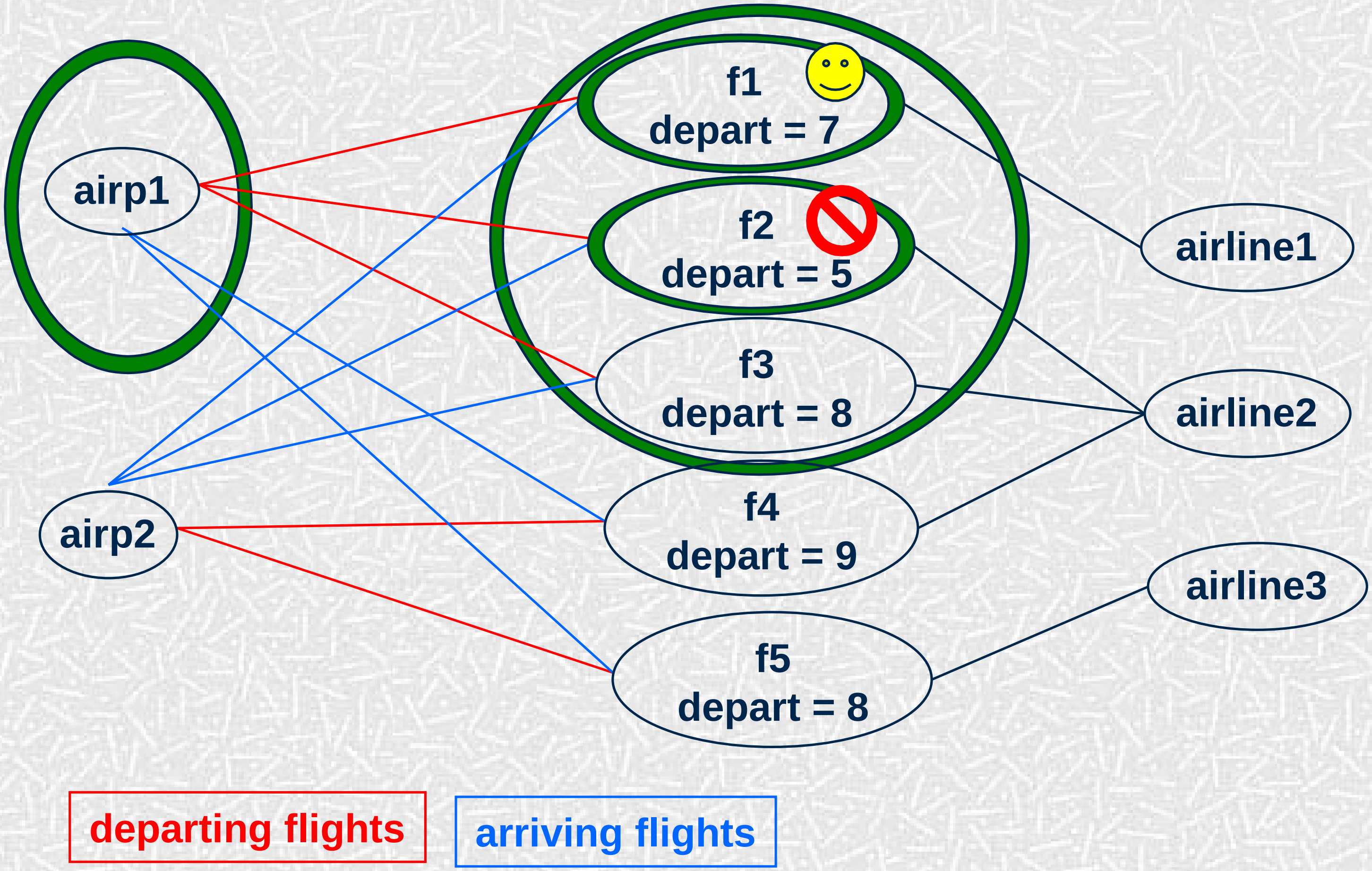
Example: forAll operation

context Airport inv:

self.departingFlights->forAll(departTime.hour>6)



The exists operation

- Syntax:

```
collection->exists(elem : T | expr)
collection->exists(elem | expr)
collection->exists(expr)
```

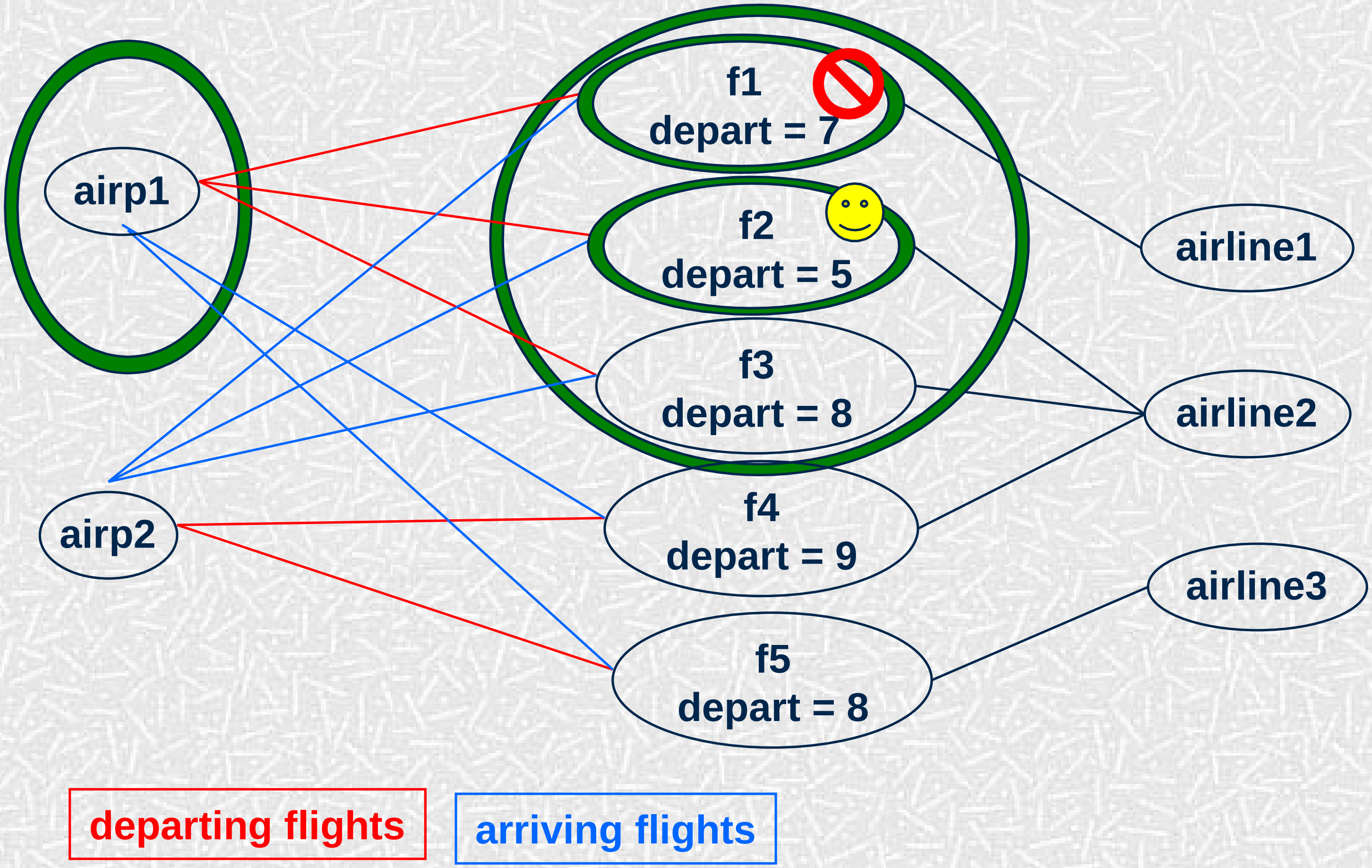
- The *exists* operation results in true if there is at least one element in the collection for which the expression *expr* is true.

∃

Example: exists operation

context Airport inv:

self.departingFlights->exists(departTime.hour<6)



Example: exists operation

```
context Airport inv:
self.departingFlights ->
            exists(departTime.hour < 6)
```

Other collection operations

- *isEmpty*: true if collection has no elements
- *notEmpty*: true if collection has at least one element
- *size*: number of elements in collection
- *count(elem)*: number of occurences of elem in collection
- *includes(elem)*: true if elem is in collection
- *excludes(elem)*: true if elem is not in collection
- *includesAll(coll)*: true if all elements of coll are in collection

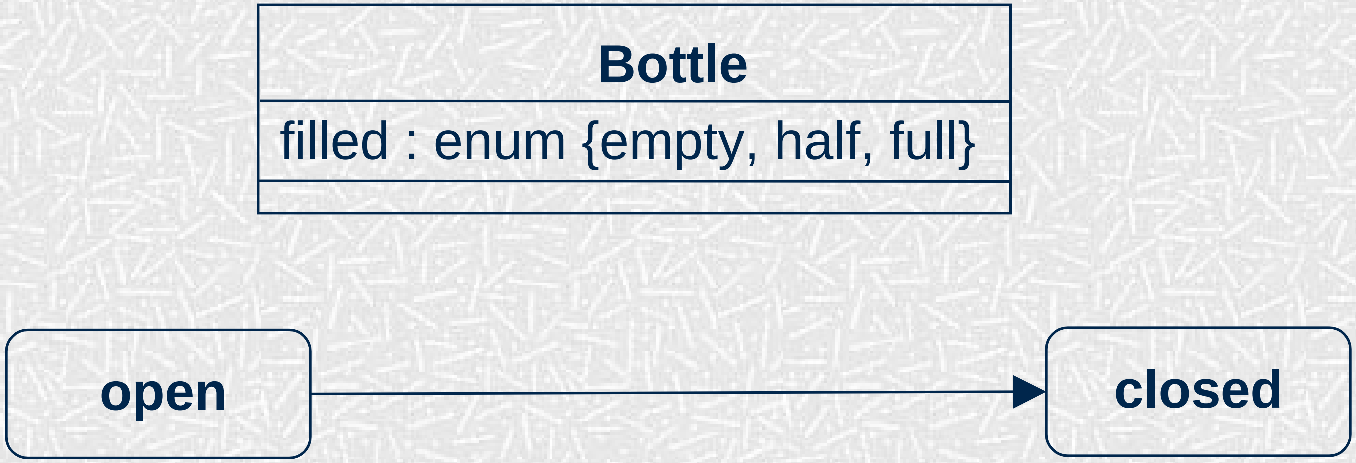
Result in postcondition

- Example pre and postcondition

```
context Airline::servedAirports() : Set(Airport)
pre :  -- none
post: result = flights.destination->asSet
```

Statechart: referring to states

- The operation *oclInState* returns true if the object is in the specified state.



context Bottle inv:
self.oclInState(closed) implies filled = #full

Local variables

- The Let construct defines variables local to one constraint:

```
Let var : Type = <expression1> in <expression2>
```

Iterate

- The *iterate* operation for collections is the most generic and complex building block.

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

Iterate example

- Example iterate:

```
context Airline inv:
flights->select(maxNrPassengers > 150)->notEmpty
```

- Is identical to:

```
context Airline inv:
flights->iterate(f : Flight; answer : Set(Flight) = Set{ } |
if f.maxNrPassengers > 150 then
   answer->including(f)
else answer endif )->notEmpty
```

Inheritance of constraints

- Guiding principle Liskovs Substitution Principle (LSP):
  - “Whenever an instance of a class is expected, one can always substitute an instance of any of its subclasses.”

Inheritance of constraints

- Consequences of LSP for invariants:
  - An invariant is always inherited by each subclass.
  - Subclasses may strengthen the invariant.

- Consequences of LSP for preconditions and postconditions:
  - A precondition may be weakened
  - A postcondition may be strengthened

Wrap up

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Current Developments

- Feedback from several OCL implementors handled in UML-RTF
  - e.g. the grammar has some loose ends
  - typical tool-related issues
- Development of OCL metamodel
  - currently concrete syntax only
  - will result in abstract syntax
- OCL Workshop with pUML group
  - formalization of OCL

OCL Tools

- Cybernetics
  - ww.cybernetic.org
- University of Dresden
  - www-st.inf.tu-dresden.de/ocl/
- Boldsoft
  - www.boldsoft.com
- ICON computing
  - www.iconcomp.com
- Royal Dutch Navy
- Others … …

Conclusions and Tips

- OCL invariants allow you to
  - model more precisely
  - stay implementation independent
- OCL pre- and postconditions allow you to
  - specify contracts (design by contract)
  - precisely specify interfaces of components
- OCL usage tips
  - keep constraints simple
  - always combine natural language with OCL
  - use a tool to check your OCL