# Chapter 11:
# Object Design 3 (Specifying Interfaces)

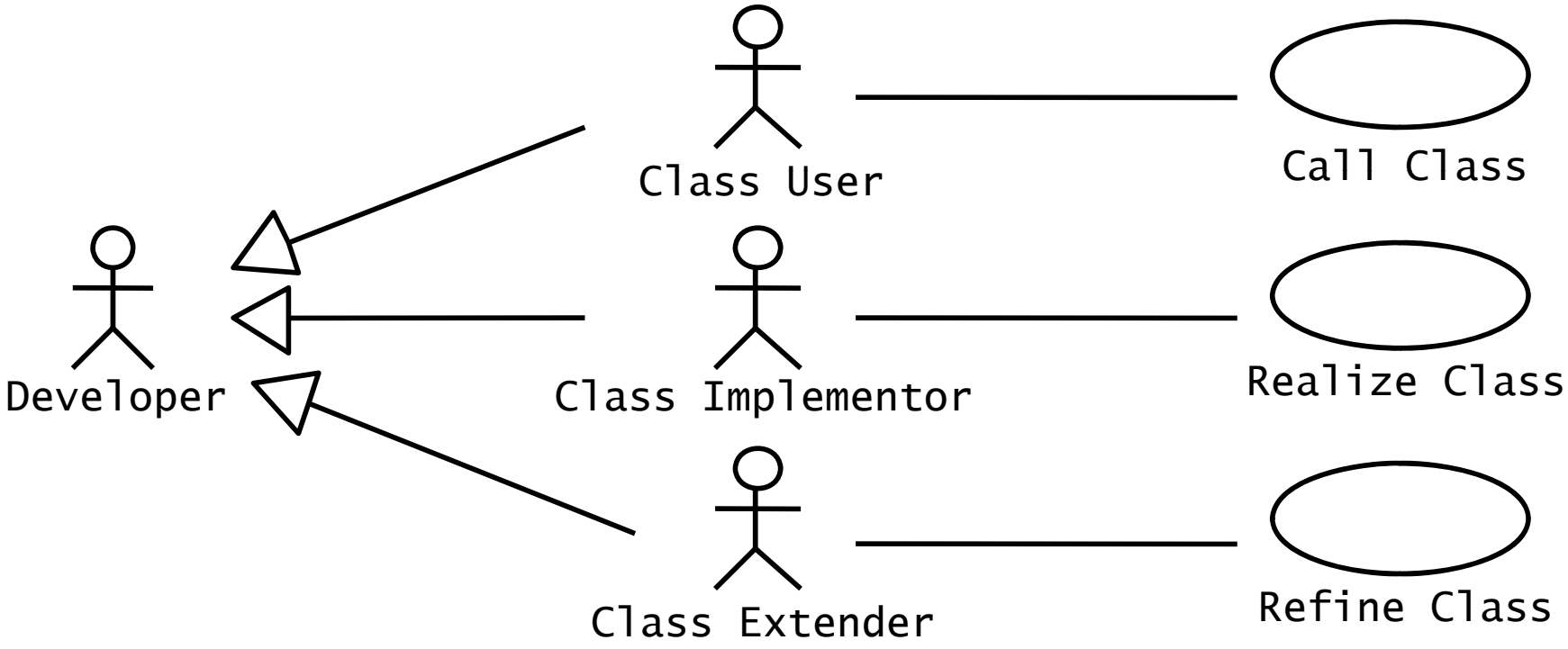
**O**bject-**O**riented
**S**oftware**C**onstruction

Armin B. Cremers, Tobias Rho, Daniel Speicher & Holger Mügge
(based on Bruegge & Dutoit)

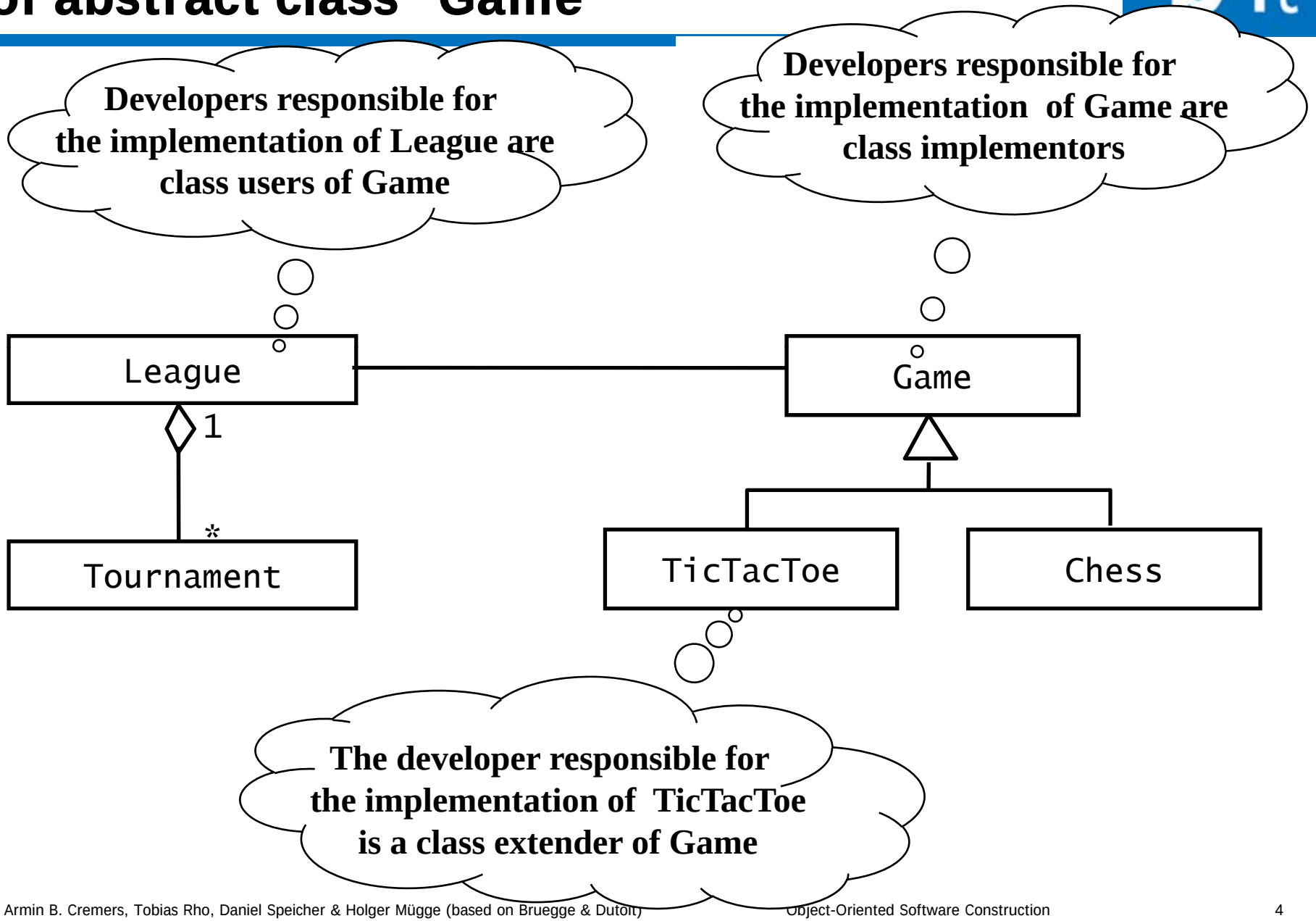
# Object Design – Interface Design


- Requirements analysis activities
  - Identifying first attributes and operations without specifying their types or their parameters.
- Goal of Interface Design:
  - Describe the Interface of each object precisely enough so that objects realized by individual developers fit together with minimal Integration problems
- Activities:
  - Identify missing attributes and operations from analysis object and subsystem service
  - Specify Visibility and Signatures
  - Specify Contracts (main focus in this lecture)

# Developers play different Roles during Object Design



# Example for the relationship from viewpoint of abstract class “Game”

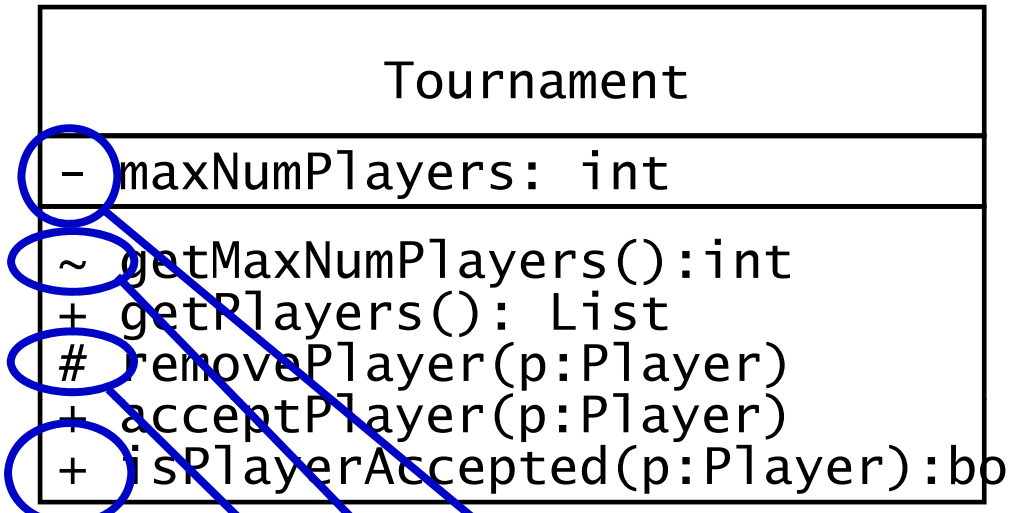


# Add Visibility Information


UML defines four levels of visibility:

- Private (Class implementor):
  - A private attribute can be accessed only by the class in which it is defined.
  - A private operation can be invoked only by the class in which it is defined.
  - Private attributes and operations cannot be accessed by subclasses or other classes.
- Protected (Class extender):
  - A protected attribute or operation can be accessed by the class in which it is defined and on any descendent (subclass) of the class.
- Public (Class user):
  - A public attribute or operation can be accessed by any class.
- Package (Class user)
  - A package attribute or operation can be accessed only a by class, which is part of the same package (Java)

# Implementation of UML Visibility in Java




```
public class Tournament {
    private int maxNumPlayers;

    public Tournament(League l, int maxNumPlayers)
    int getMaxNumPlayers() {…};
    protected void removePlayer(Player p) {…};
    public List getPlayers() {…};
    public void acceptPlayer(Player p) {…};
    public boolean isPlayerAccepted(Player p) {…};
```

# Information Hiding Heuristics


- Carefully define the public interface for classes as well as subsystems (façade)
- Always apply the “Need to know” principle.
  - Only if somebody needs to access the information, make it publicly available, but then only through well defined channels, so you always control and verify the access.
- The fewer an operation knows
  - the less likely it will be affected by any changes
  - the easier the method can be changed
- Information hiding is not a major issue during analysis, however during design it is an issue.

# Information Hiding Design Principles

- Only the operations of a class are allowed to manipulate its attributes
  - Access attributes only via operations.

```
// Can be accessed directly
public Object myAttr = … ;
```

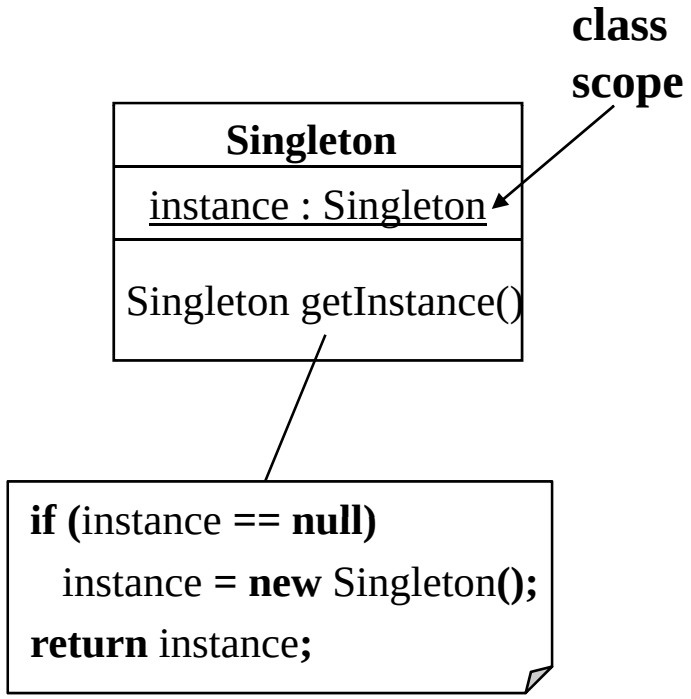
```
// Can't be accessed directly
private Object myAttr = … ;
public Object getMyAttr(){
   return this.myAttr;
}
public void setMyAttr( Object attr ){
  doCheck( attr ) ; …
  this.myAttr = attr;
}
```

- Advantage of get and set methods: error checking

# Information Hiding Design Principles

- Sometimes a variable should be restricted to one single instance available in the system over all time (Java: virtual machine).
- Application of Singleton Pattern [Gamma, 1995]
- Sample Code (Java, usage of class fields):

```
public class Singleton {
  private static Singleton instance = null;
  public Singleton() { }
  public static Singleton getInstance() {
     if (instance == null) {
           instance = new Singleton();
     }
     return instance;
   }
}
```



# Design by Contract

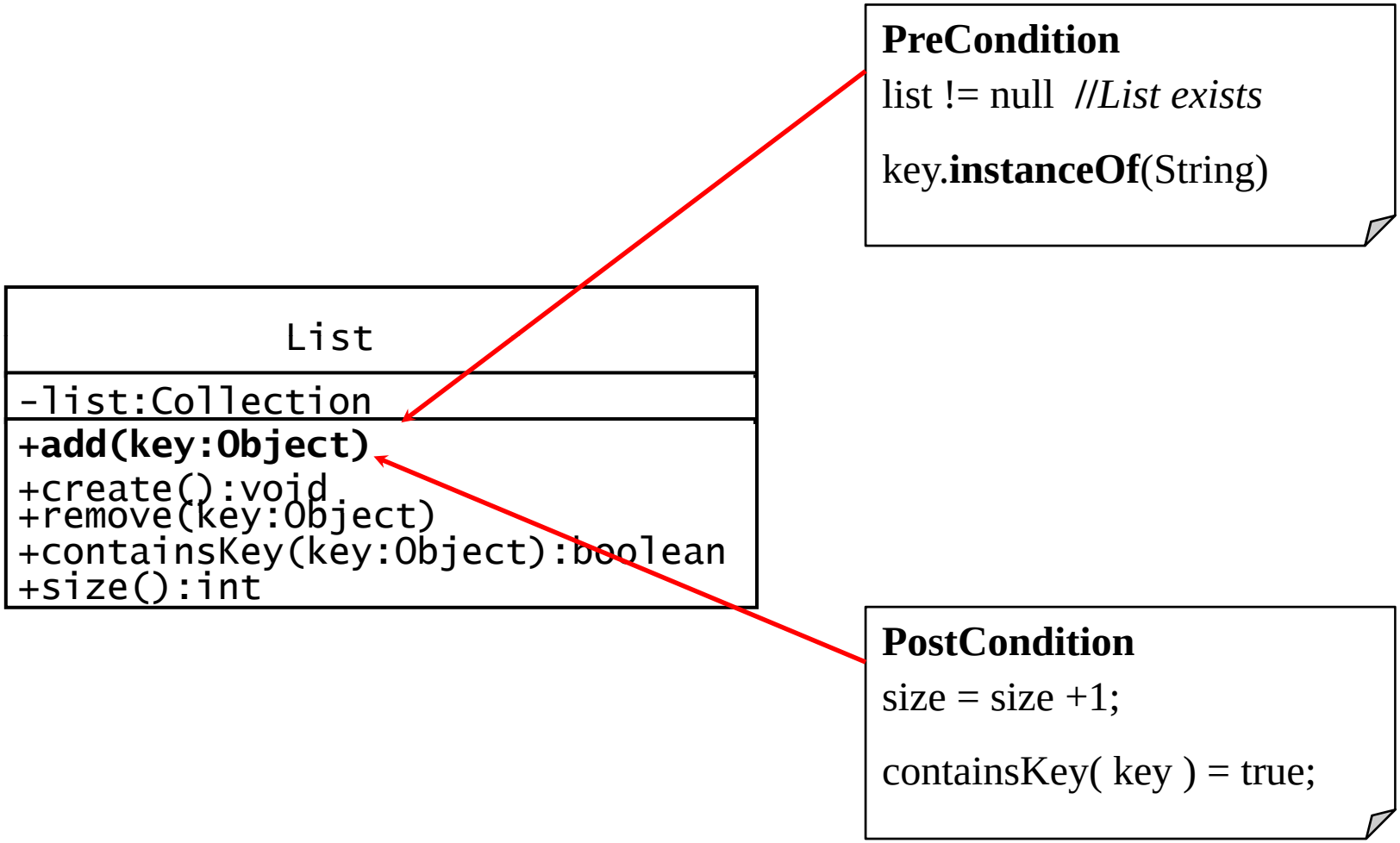

- Idea: Contracts on a class enable caller (client) and callee (class itself) to share the same assumptions (semantics) about the class.
- Problem: Accurate Semantics cannot be added to standard UML models discussed so far
- Solution/Realization: **Design By Contract** by Betrand Meyer ("Object-Oriented Software Construction", Prentice Hall)
  - Process of developing software based on the notion of contracts between objects
  - Contracts are expressed as assertions (predicates) that make assumptions on the *cases*, a method can handle
  - Assertions comprise preconditions, postconditions and invariants

# Types of Assertions

- Precondition:
  - Preconditions are predicates associated with a specific operation and must be true *before* the operation is invoked.
  - Preconditions are used to specify constraints that a caller must meet before calling an operation.

- Postcondition:
  - Postconditions are predicates associated with a specific operation and must be true *after* an operation is invoked.
  - Postconditions are used to specify constraints that the object (callee) must ensure after the invocation of the operation.

# Examples of Assertions
## Assertion of List method “add”



# Design by Contract


- Parties in the contract: class and client
  - PreCondition binds clients
  - PostCondition binds class
- A precondition expresses what the class requires of its calling client
- A postcondition expresses what the class guarantees to the calling code upon return
- Contract important for Class User (Client) and Class Implementor (class)
- Contract entails benefits and obligations for both parties

# Example

| Contract for add of class List | Obligations | Benefits |
|---|---|---|
| **Class User** | Ensure that list exists but is not full before add() is called | Can retrieve item by containsKey( ); |
| **Class Implementor** | Make sure that key is in the List; List has increased by one | Does not need to care about cases, where List is full or not created |

# Class invariants and class correctness


- Preconditions and postconditions describe properties of individual methods
- Need for global properties of instances which must be preserved by all routines
- Examples (List)
  - Size of List must not be negative
  - Size of List must be lower than 1000 entries
  - The number of elements must be even

# Class invariants and class correctness


- A class invariant is an assertion to be satisfied by all instances of the class at all “stable” times:
  - on instance creation
  - before and after every remote call to a routine
  - may be violated during call
- A class invariant only applies to public methods; private methods are not required to maintain the invariant.

# Invariant Rule

- An assertion *I* is a correct class invariant for a class *C* iff the following two conditions hold:
  - The constructor of *C*, when applied to arguments satisfying the constructor's precondition in a state where the attributes have their default values, yields a state satisfying *I*.
  - Every public method of the class, when applied to arguments and a state satisfying both *I* and the method's precondition, yields a state satisfying *I*.

# Design by Contract
## Inheritance


- What does inheritance mean in relation to Design by Contract?

  ➔ Overridden methods must conceptually do the same job!

- Contract Inheritance

- Rule of Thumb: Demand no more, promise no less.

# Design by Contract
## Inheritance

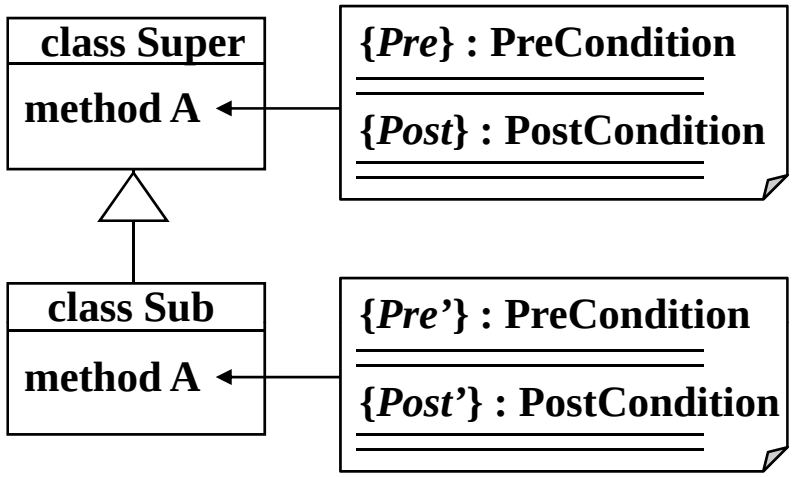
Demand no more:

- A method of a subclass is allowed to **weaken** the **precondition** of the method it overrides
- An overridden method with a weaker precondition can handle more generic cases (i.e. at least the same or even more cases) than its superclass

Promise no less:

- A method of a subclass is allowed to **strengthen** the **postcondition** of the method it overrides
- An overridden method with a stronger postcondition ensures more specific cases (i.e. at most the same or even less cases) to the client upon return

# Design by Contract
## How to check pre and post conditions

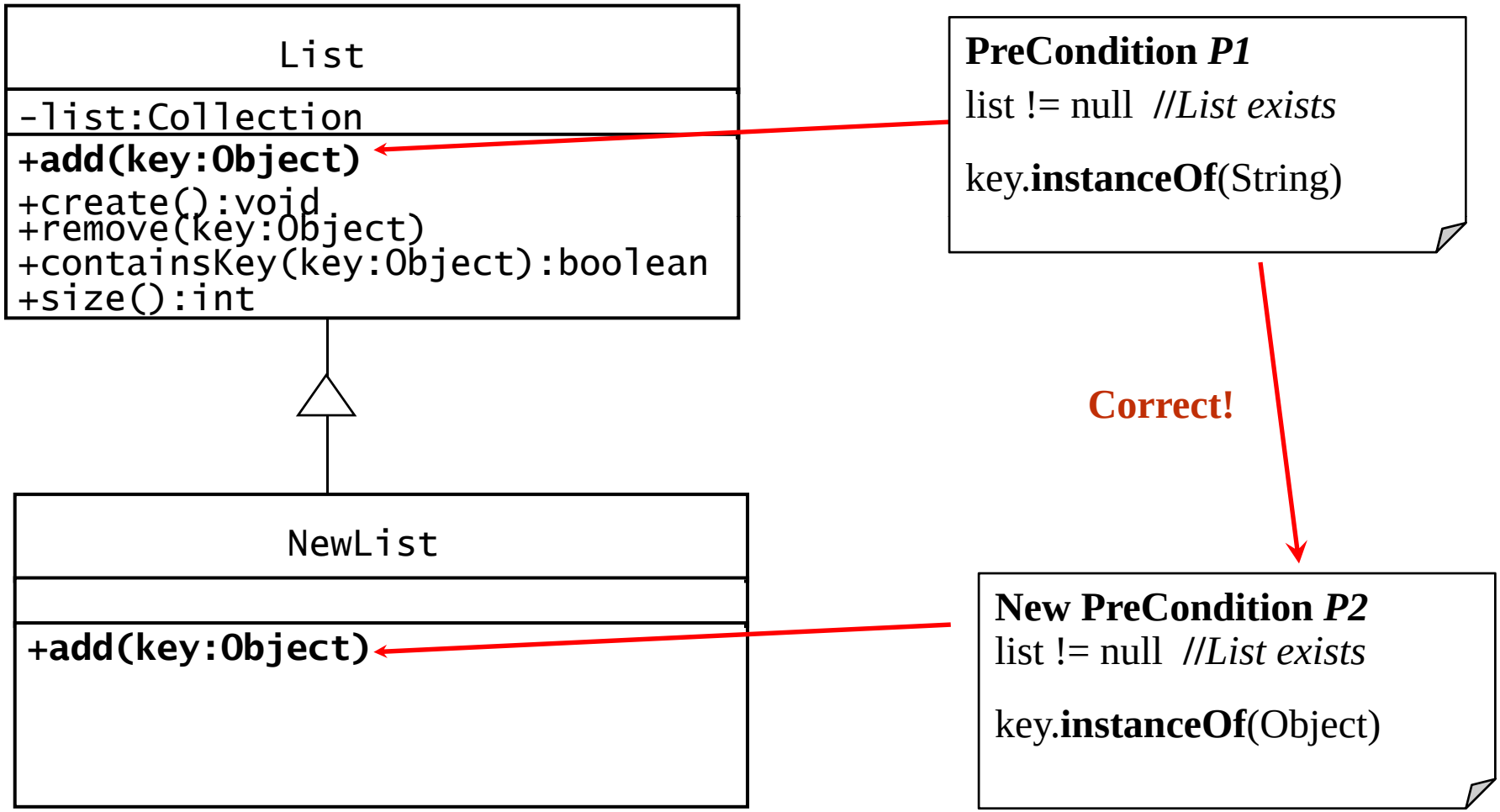



**{A.*Pre'*} is weaker than {A.*Pre*} <==> A.*Pre* => A.*Pre'***

**{A.*Post'*} is stronger than {A.*Post*} <==> A.*Post'* => A.*Post***

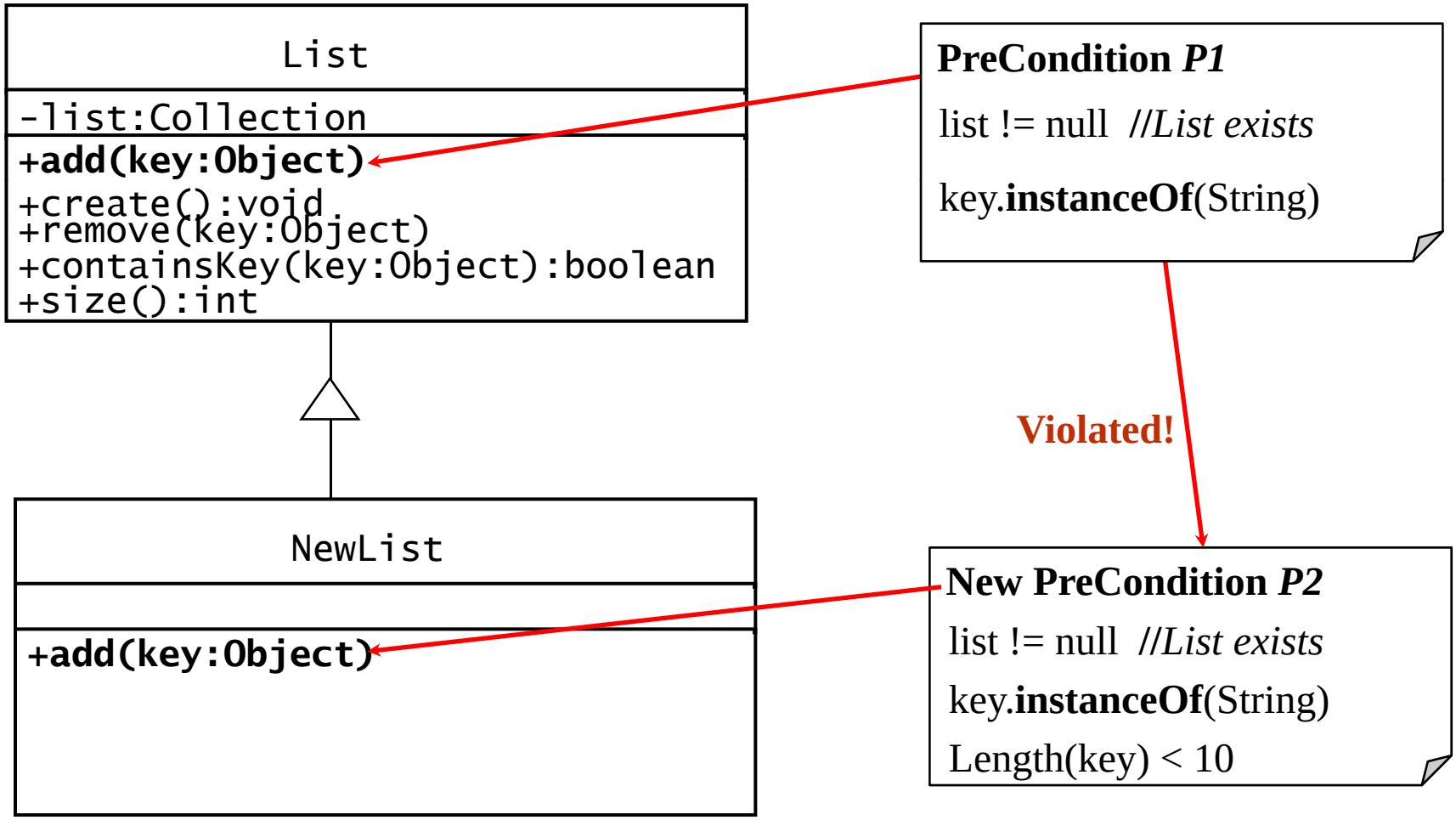
# Design by Contract
## Inheritance – Example 1

- A method of subclass is allowed to weaken the **preconditions** of the method it overrides. Example (1)



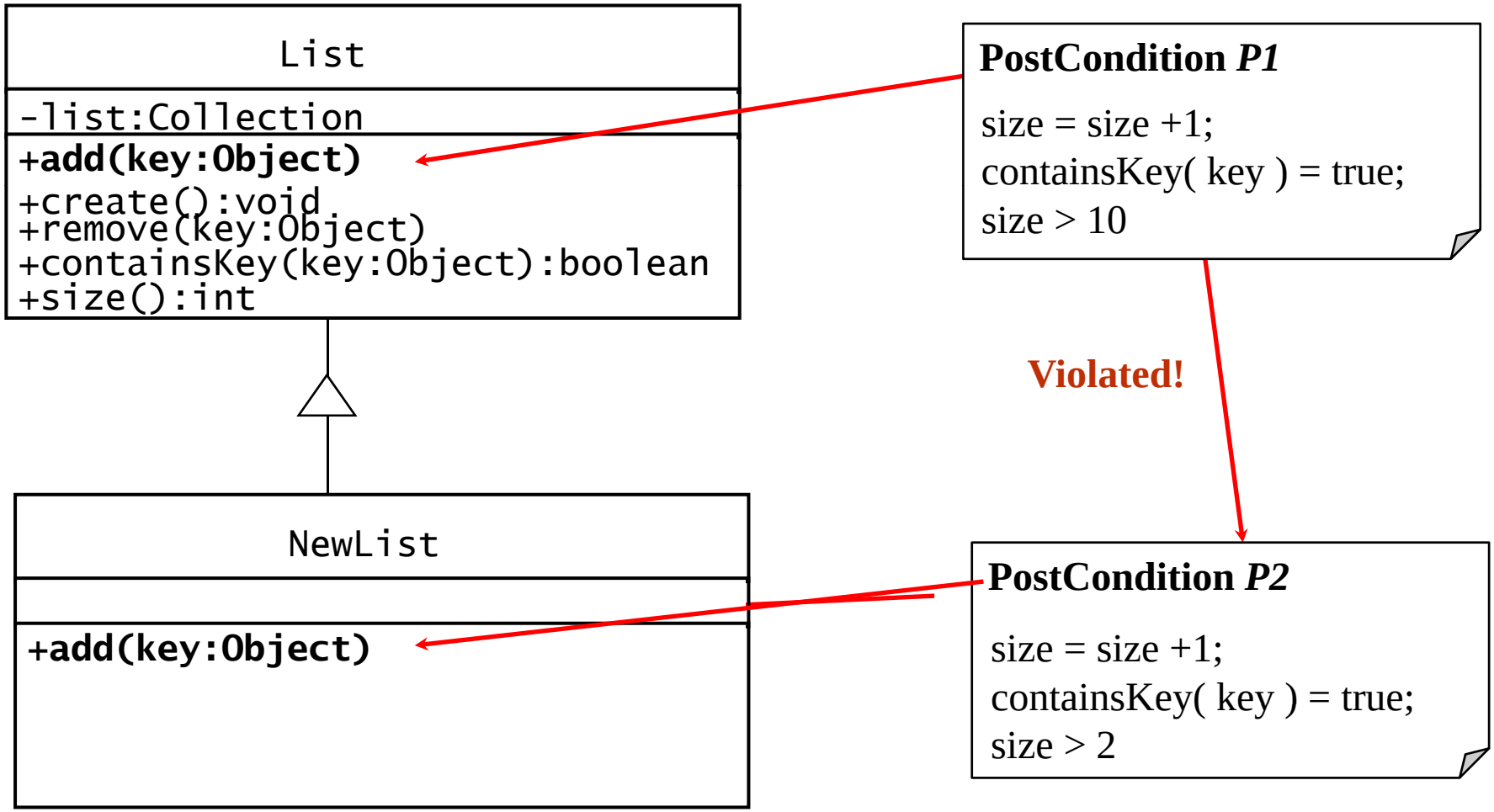
# Design by Contract
## Inheritance – Example 2

- A method of subclass is allowed to weaken the **preconditions** of the method it overrides. Example (2)



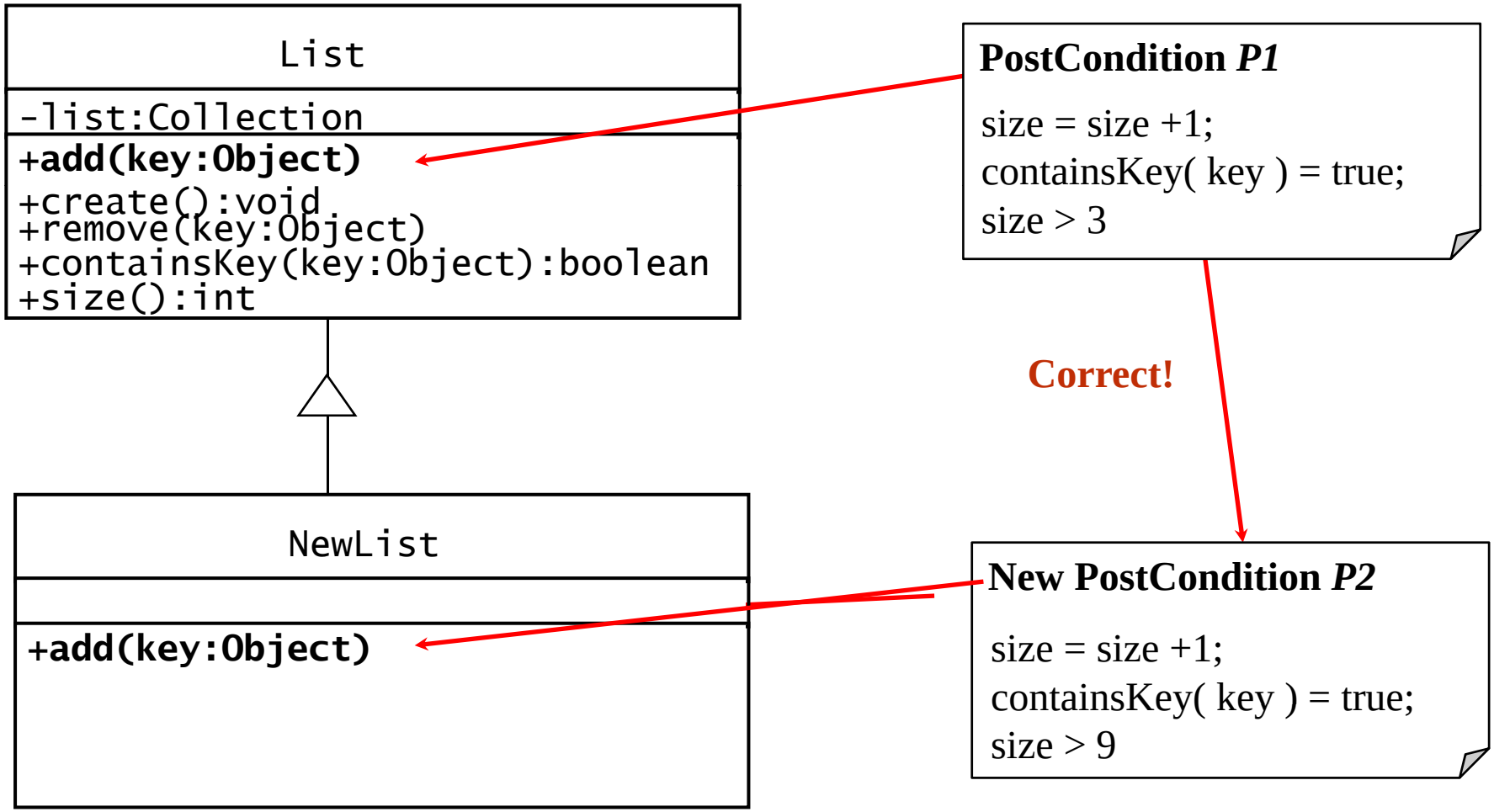
# Design by Contract
## Inheritance – Example 4

- A method must ensure a stronger **postcondition** as the method it overrides: Example:



# Design by Contract
## Inheritance – Example 3

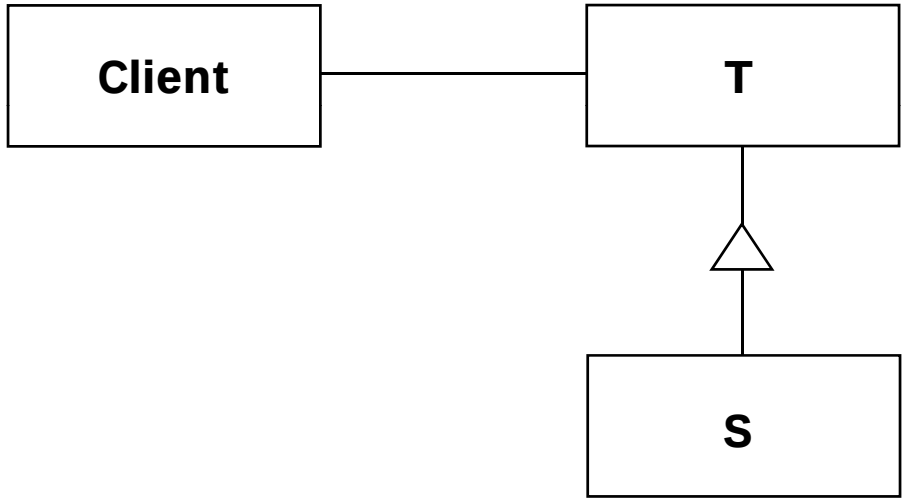
- A method must ensure a stronger **postcondition** as the method it overrides: Example:



# Application of Design by Contract

## The Liskov Substitution Principle:

- "If an object of type S can be substituted in all places where an object of Type T is expected, then S is a subtype of T"




- If all preconditions of the methods of type S are weakened and all postconditions of the methods of type S are stronger than the methods of type T, then S is a subtype of type T
- Client do not has to change its code, if object T is substituted by S

# Advantages of Design By Contract

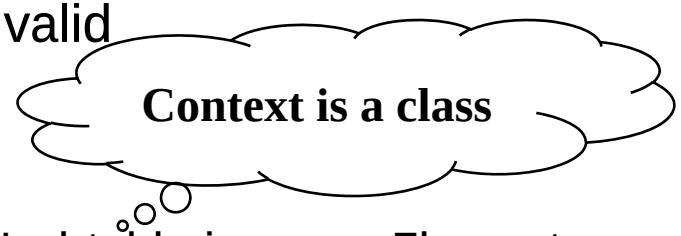

- Improves the reliability of programs
- Assertions provide accurate documentation for the implemented classes so that a programmer knows how to use the classes and what to expect from them;
- Assertions provide a way of controlling inheritance (substitutability)
- Assertions can be an important aid to developing critical systems.

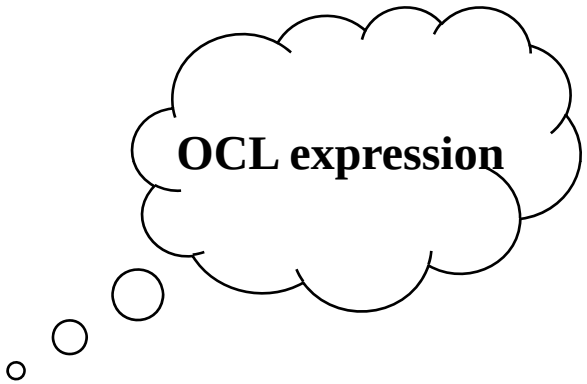
# Expressing constraints in UML Models


- OCL 2.0 (Object Constraint Language) is part of UML 2.0
- OCL allows constraints to be formally specified on single model elements (attributes, operations, classes) or groups of model elements (associations and participating classes)
- A constraint is expressed as an OCL expression returning the value true or false.
- OCL is not a procedural language (cannot constrain control flow).
- More Info:
  - Introduction of OCL for Together
    - http://bdn1.borland.com/devcon05/article/1,2006,33187,00.html
  - Tutorial of University of Koblenz
    - http://www.uni-koblenz.de/~beckert/Lehre/Praktikum-Formale-Entwicklung/oclIntro.pdf

# Expressing constraints in UML Models

- OCL expressions for Hashtable operation put():
  - The **context** keyword indicates the object to which the expression is valid

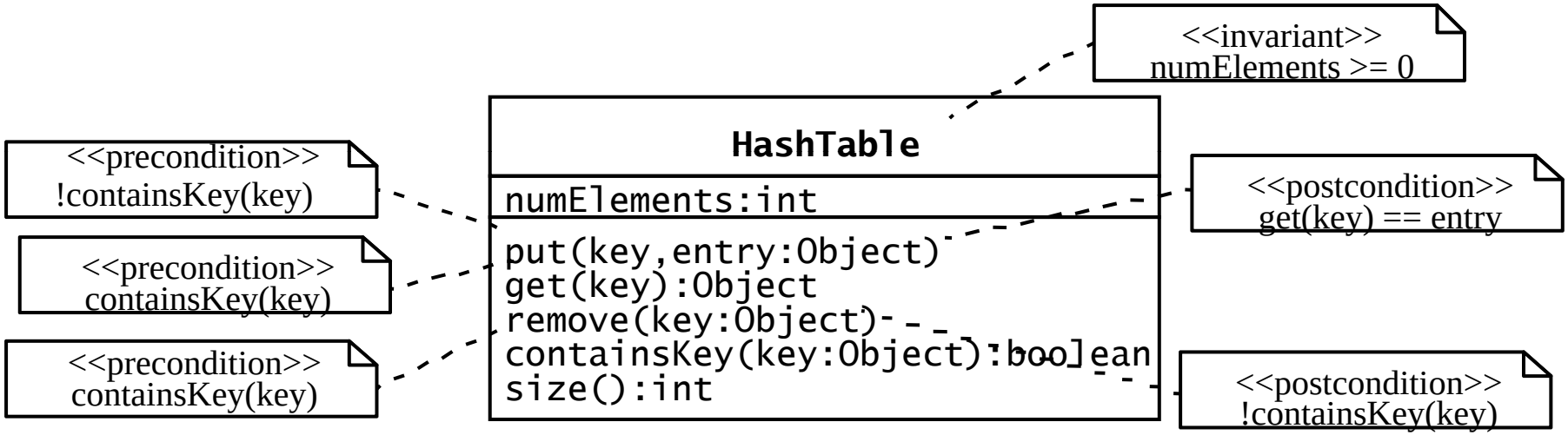



  - Invariant:
    - **context** Hashtable inv: numElements >= 0
  - Precondition:
    - **context** Hashtable::put(key, entry) pre:!containsKey(key)
  - Post-condition:
    - **context** Hashtable::put(key, entry) post: containsKey(key) and get(key) = entry

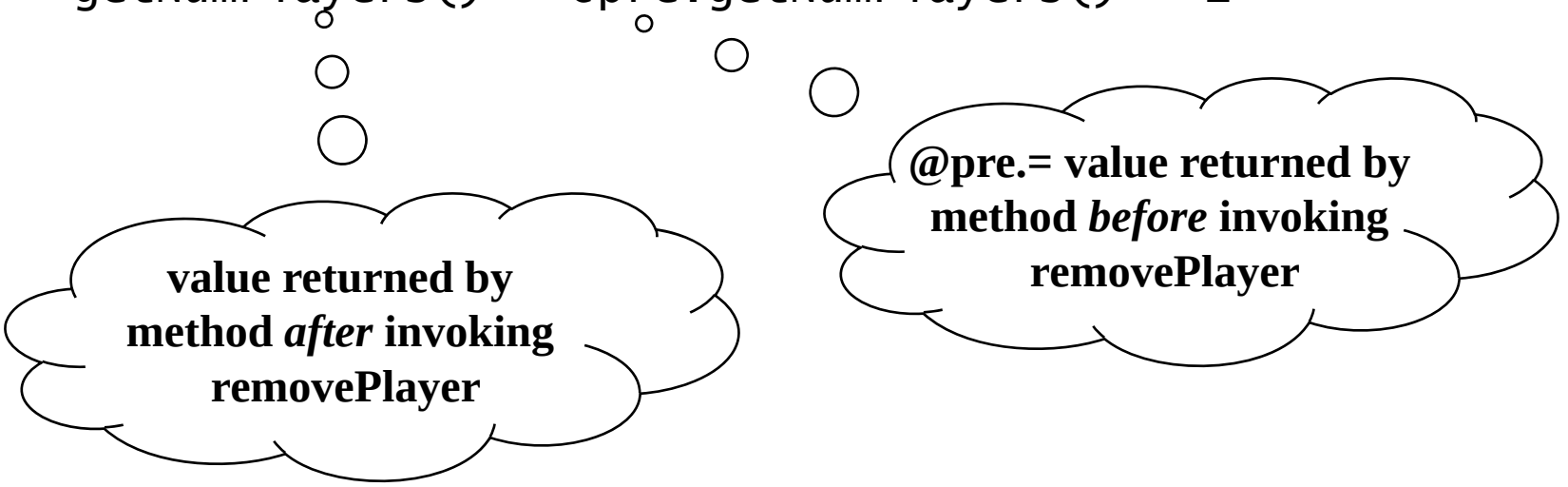
# Expressing constraints in UML Models

- A constraint can also be depicted as a note attached to the constrained UML element by a dependency relationship.



# Contract for acceptPlayer in Tournament

```
context Tournament::removePlayer(p) pre:
  isPlayerAccepted(p)

context Tournament::removePlayer(p) post:
  not isPlayerAccepted(p)

context Tournament::removePlayer(p) post:
  getNumPlayers() = @pre.getNumPlayers() - 1
```



# OCL Annotations
## JavaDoc (iContract)

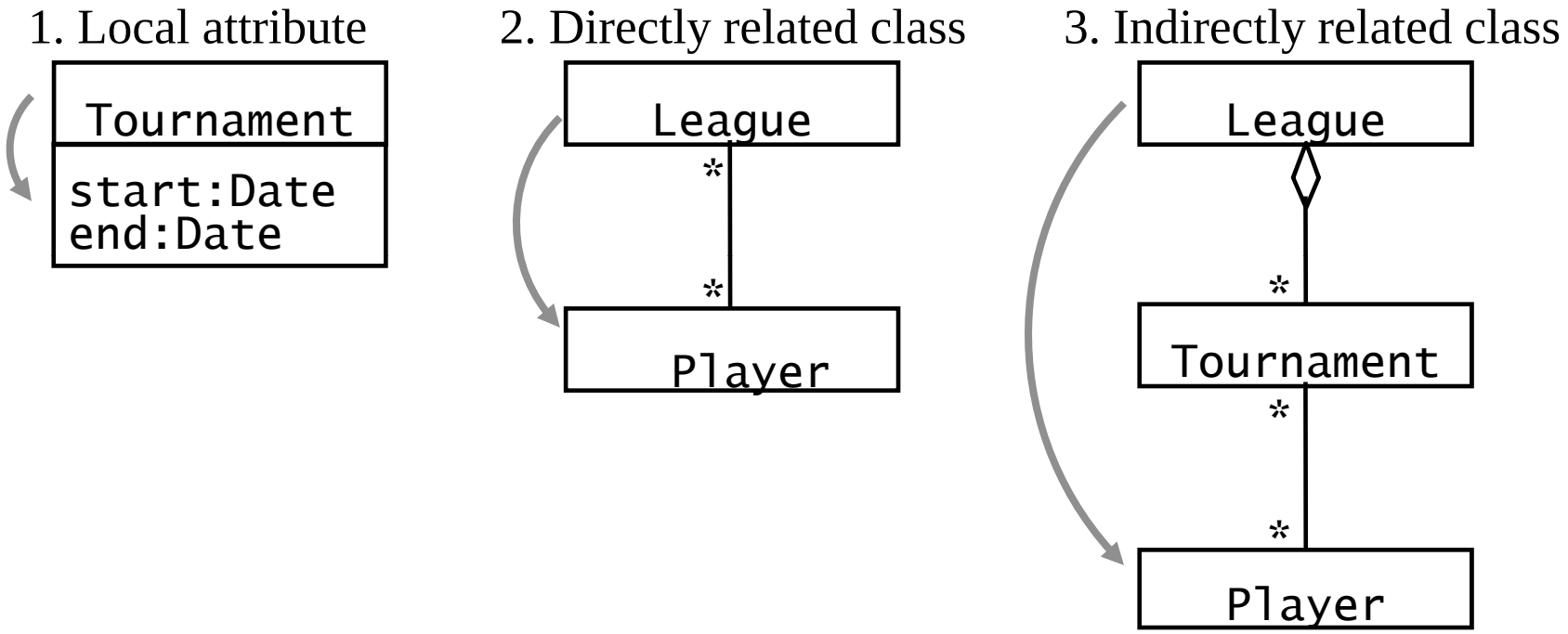

```
public class Tournament {
   /** The maximum number of players
    * is positive at all times.
    * @invariant maxNumPlayers > 0
    */
   private int maxNumPlayers;

   /** The players List contains
    * references to Players who are
    *  are registered with the
    * Tournament. */
   private List players;

   /** Returns the current number of
    * players in the tournament. */
   public int getNumPlayers() {…}

   /** Returns the maximum number of
    * players in the tournament. */
   public int getMaxNumPlayers() {…}
```

```
   /** The acceptPlayer() operation
    * assumes that the specified
    * player has not been accepted
    * in the Tournament yet.
    * @pre !isPlayerAccepted(p)
    * @pre getNumPlayers()<maxNumPlayers
    * @post isPlayerAccepted(p)
    * @post getNumPlayers() =
    *       @pre.getNumPlayers() + 1
    */
   public void acceptPlayer (Player p)
   {…}

   /** The removePlayer() operation
    * assumes that the specified player
    * is currently in the Tournament.
    * @pre isPlayerAccepted(p)
    * @post !isPlayerAccepted(p)
    * @post getNumPlayers() =
    *      @pre.getNumPlayers() - 1
    */
   public void removePlayer(Player p) {…}

}
```

# Constraints can involve more than one class

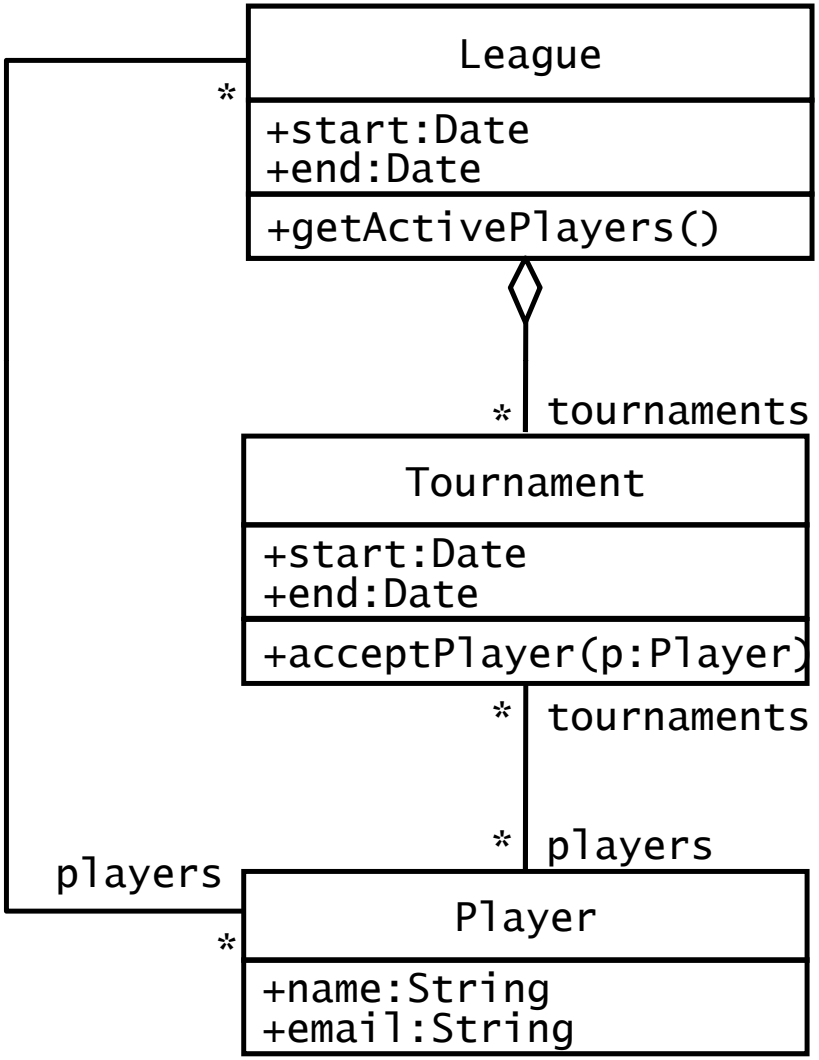

- Until now: Constraints are valid within a single class
- Often, Constraints are necessary to declare assertions across many classes
  - Make Assumptions about associations between classes
  - Definition of global invariants
- Expressions for navigating between classes are necessary
- Set-based operations

# Types of Navigation through a Class Diagram




Any OCL constraint for any class diagram can be built using only a combination of these three navigation types!

# Example: League, Tournament and Player

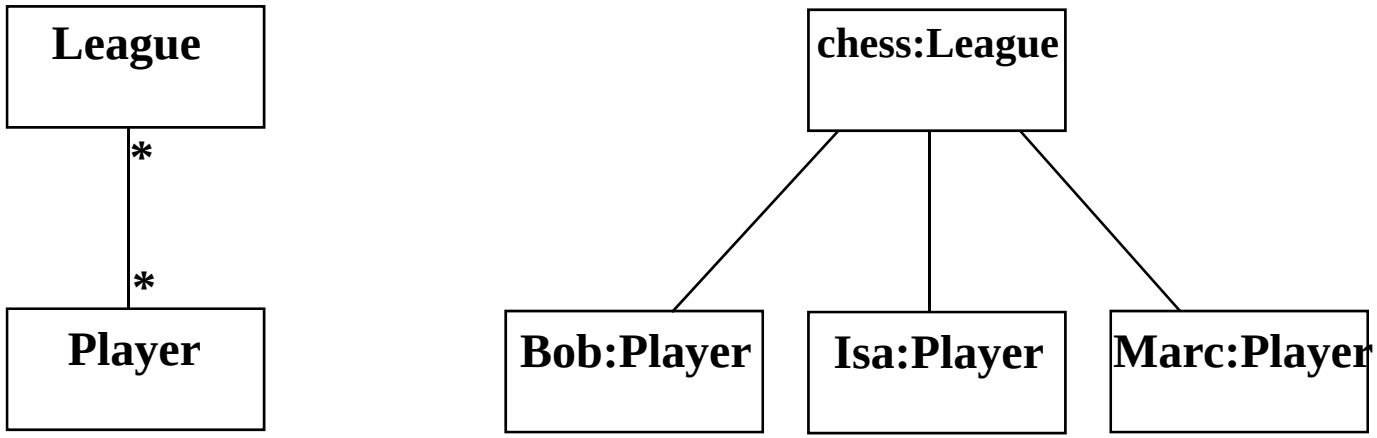


# Model Refinement with 2 additional Constraints


- A Tournament's planned duration must be under one week.
- Players can be accepted in a Tournament only if they are already registered with the corresponding League.

# OCL Collections

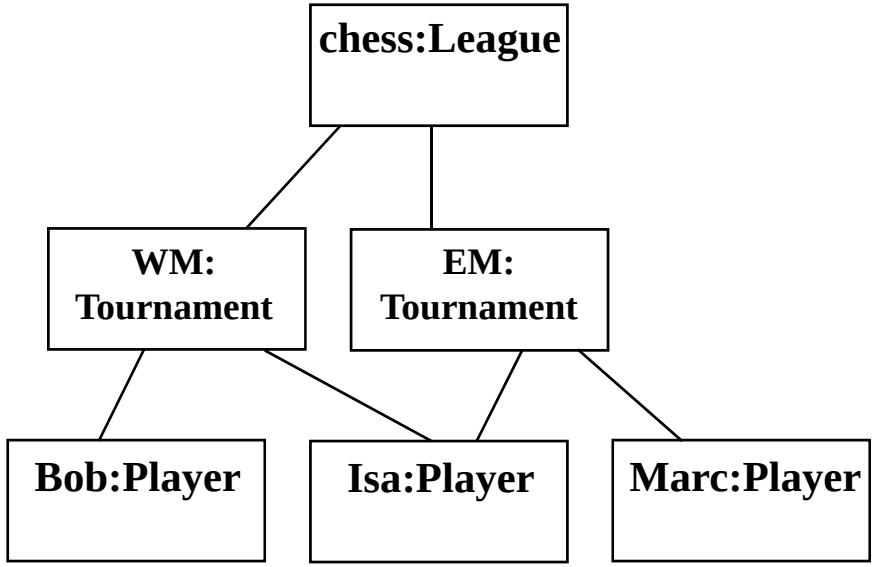
- Collections are data types used to navigate to associated classes within a constraint expression.
  - OCL Sets
    - Used to navigate a single (1:1, 1:n, or n:m) association




**league.player = {Bob, Isa, Marc}**

# OCL Collections

- Collections are data types used to navigate to associated classes within a constraint expression.
  - OCL Bags
    - Used to navigate through a series of at least two associations with one-to-many or many-to-many multiplicity


**league.tournament.player = {Bob, Isa, Marc,Isa}**

# OCL Collections

- OCL provides many operations for accessing collections (via Access Operator →). Examples:
  - includes(Object) – returns true if Object is in Collection
  - union(Collection) – returns a Collection containing elements from both the original collection and the collection specified as paramater
  - asSet(Collection) – returns a Set containing each element of the collection without any duplicate elements (as opposed to a bag)
- Examples:
  - {Bob, Isa, Marc}→includes( Timo ) = false;
  - league.tournament.player = {Bob, Isa, Marc,Isa}

    league.tournament.player→asSet = {Bob, Isa, Marc}

# Specifying the Model Constraints

## Local attribute navigation

```
context Tournament inv:
  end - start <= Calendar.WEEK
```

## Directly related class navigation

```
context
  Tournament::acceptPlayer(p)
  pre:
  league.players->includes(p)
```