**Object-Oriented Software Engineering**
Using UML, Patterns, and Java

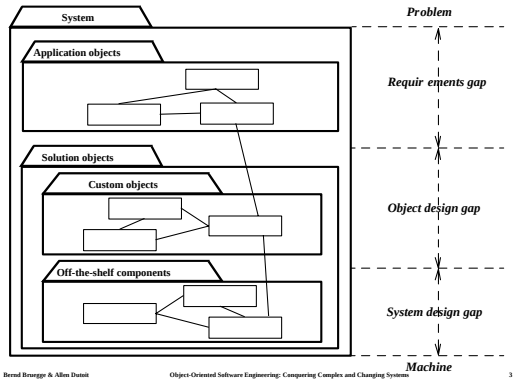
# Chapter 9, Object Design: Specifying Interfaces

## *Object Design*

- Object design is the process of adding details to the requirements analysis and making implementation decisions
- The object designer must choose among different ways to implement the analysis model with the goal to minimize execution time, memory and other measures of cost.
  - **Requirements Analysis: The functional model and the dynamic model deliver operations for the object model**
  - **Object Design: We decide on where to put these operations in the object model**
- Object design serves as the basis of implementation

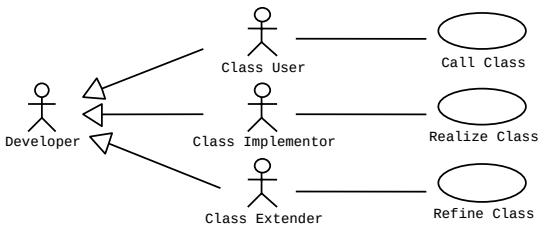


## *Object Design: Closing the Gap*



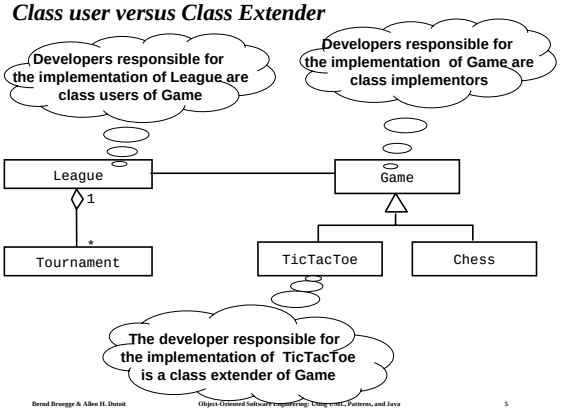



## *Developers play different Roles during Object Design*






## *Class user versus Class Extender*






## *Specifying Interfaces*

- Requirements analysis activities
  - **Identifying attributes and operations without specifying their types or their parameters.**
- Object design: Three activities
  1. **Add visibility information**
  2. **Add type signature information**
  3. **Add contracts**

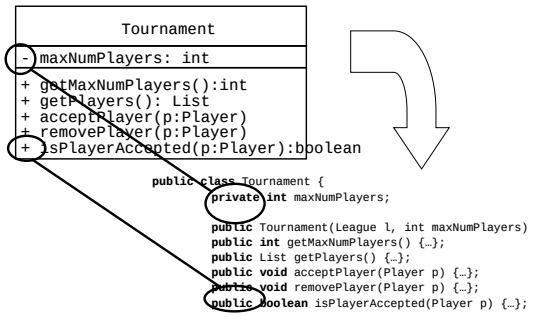
## *1. Add Visibility Information*

UML defines three 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 of the class.**
- Public (Class user):
  - **A public attribute or operation can be accessed by any class.**



## *Implementation of UML Visibility in Java*






## *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 possible, but then only through well defined channels, so you always know the access.**
- The fewer an operation knows
  - **the less likely it will be affected by any changes**
  - **the easier the class can be changed**
- Trade-off: Information hiding vs efficiency
  - **Accessing a private attribute might be too slow (for example in real-time systems or games)**

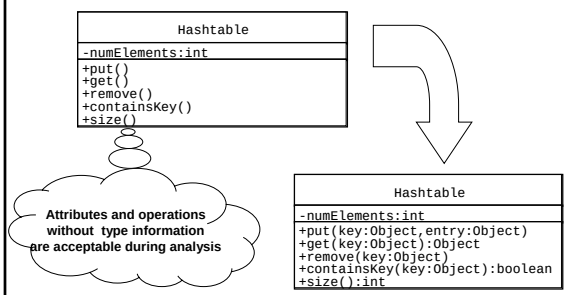


## *Information Hiding Design Principles*

- Only the operations of a class are allowed to manipulate its attributes
  - **Access attributes only via operations.**
- Hide external objects at subsystem boundary
  - **Define abstract class interfaces which mediate between system and external world as well as between subsystems**
- Do not apply an operation to the result of another operation.
  - **Write a new operation that combines the two operations.**



## *2. Add Type Signature Information*






## *Team Activity: Visibility and Signatures*

- Description: Select one of your classes. Complete the visibility and signature for that class.
- Process:
  - Work in teams
  - You have about 10 minutes.

## 3. Add Contracts

- Contracts on a class enable caller and callee to share the same assumptions about the class.
- Contracts include three types of constraints:
- Invariant:
  - **A predicate that is always true for all instances of a class. Invariants are constraints associated with classes or interfaces.**
- 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 must ensure after the invocation of the operation.**



## Expressing constraints in UML Models

- OCL (Object Constraint Language)
  - **OCL allows constraints to be formally specified on single model elements or groups of model elements**
  - **A constraint is expressed as an OCL expression returning the value true or false. OCL is not a procedural language (cannot constrain control flow).**
- OCL expressions for Hashtable operation put():
  - **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**

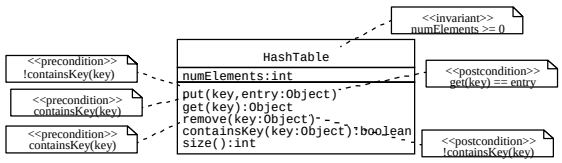
**OCL expression**

**Context is a class operation put**



## 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::acceptPlayer(p) **pre**:
not isPlayerAccepted(p)

**context** Tournament::acceptPlayer(p) **pre**:
getNumPlayers() < getMaxNumPlayers()

**context** Tournament::acceptPlayer(p) **post**:
isPlayerAccepted(p)

**context** Tournament::acceptPlayer(p) **post**:
getNumPlayers() = @pre.getNumPlayers() + 1



## Contract for removePlayer 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



## Annotation of Tournament class

```
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) {…}

}
```

## *Team Activity: Contracts*

- Description: Select one of your classes. Complete the contracts for that class.
- Process:
  - Work in teams
  - You have about 10 minutes.

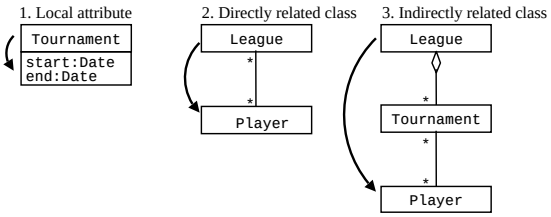


## *Constraints can involve more than one class*

**How do we specify constraints on more than one class?**



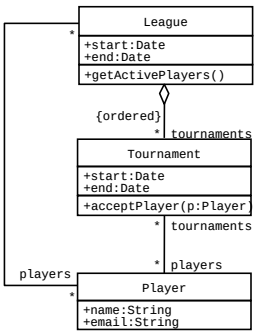
## *3 Types of Navigation through a Class Diagram*




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



## *ARENA Example: League, Tournament and Player*



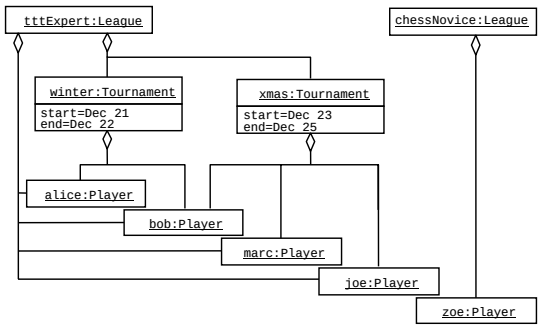



## *Model Refinement with 3 additional Constraints*

- 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.
- The number of active Players in a League are those that have taken part in at least one Tournament of the League.
- To better understand these constraints we instantiate the class diagram for a specific group of instances
  - **2 Leagues, 2 Tournaments and 5 Players**



## *Instance Diagram: 2 Leagues, 2 Tournaments, and 5 Players*



## *Specifying the Model Constraints*

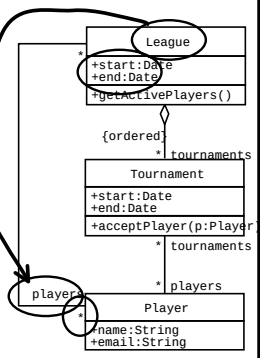
**Local attribute navigation**

**context** Tournament **inv:**

end - start <= Calendar.WEEK

**Directly related class navigation**

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






## *Specifying the Model Constraints*

**Local attribute navigation**

**context** Tournament **inv:**

end - start <= Calendar.WEEK

**Directly related class navigation**

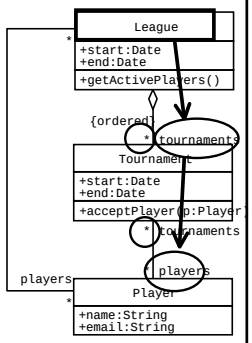
**context** Tournament::acceptPlayer(p) **pre:**

league.players->includes(p)

**Indirectly related class navigation**

**context** League::getActivePlayers **post:**

result = tournaments.players->asSet






## *OCL supports Quantification*

- OCL forall quantifier

/* All Matches in a Tournament occur within the Tournament's time frame */

**context** Tournament **inv**:
matches->forAll(m:Match |
m.start.after(t.start) and m.end.before(t.end))

- OCL exists quantifier

/* Each Tournament conducts at least one Match on the first day of the Tournament */

**context** Tournament **inv**:
matches->exists(m:Match | m.start.equals(start))



## *Summary*

- There are three different roles for developers during object design
  - **Class user, class implementor and class extender**
- During object design - and only during object design - we specify visibility rules
- Constraints are boolean expressions on model elements
- Contracts are constraints on a class enable class users, implementors and extenders to share the same assumption about the class ("Design by contract")
- OCL is a language that allows us to express constraints on UML models
- Complicated constratins involving more than one class, attribute or operation can be expressed with 3 basic navigation types.