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

Chapter 8, Object Design: Object Constraint Language

Outline of the Lecture

- OCL
- Simple predicates
- Preconditions
- Postconditions
- Contracts
- Sets, Bags, and Sequences

OCL Basic Concepts

- OCL expressions
  - Return **True** or **False**
  - Are evaluated in a specified context, either a class or an operation
  - All constraints apply to all instances.

OCL Simple Predicates

Example:

```
context Tournament inv:
  self.getMaxNumPlayers() > 0
```

In English:

"The maximum number of players in any tournament should be a postive number."

Notes:

- "self" denotes all instances of "Tournament"
- OCL uses the same dot notation as Java.

OCL Preconditions

Example:

```
context Tournament::acceptPlayer(p) pre:
  not self.isPlayerAccepted(p)
```

In English:

"The acceptPlayer(p) operation can only be invoked if player p has not yet been accepted in the tournament."

Notes:

- The context of a precondition is an operation
- isPlayerAccepted(p) is an operation defined by the class Tournament.

OCL Postconditions

Example:

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

In English:

"The number of accepted player in a tournament increases by one after the completion of acceptPlayer()"

Notes:

- self@pre denotes the state of the tournament before the invocation of the operation.
- Self denotes the state of the tournament after the completion of the operation.

OCL 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
```

OCL 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
```

JavaDoc

- Add documentation comments to the source code.
- A doc comment consists of characters between **/**** and ***/**
- When JavaDoc parses a doc comment, leading * characters on each line are discarded. First, blanks and tabs preceding the initial * characters are also discarded.
- Doc comments may include HTML tags
- Example of a doc comment:

```
/**
* This is a <b> doc </b> comment
*/
```

More on Java Doc

- Doc comments are only recognized when placed immediately before class, interface, constructor, method or field declarations.
- When you embed HTML tags within a doc comment, **you should not use heading tags such as <h1> and <h2>**, because JavaDoc creates an entire structured document and these structural tags interfere with the formatting of the generated document.

Java Implementation of Tournament class (Contract as a set of JavaDoc comments)

```
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() {…}
```

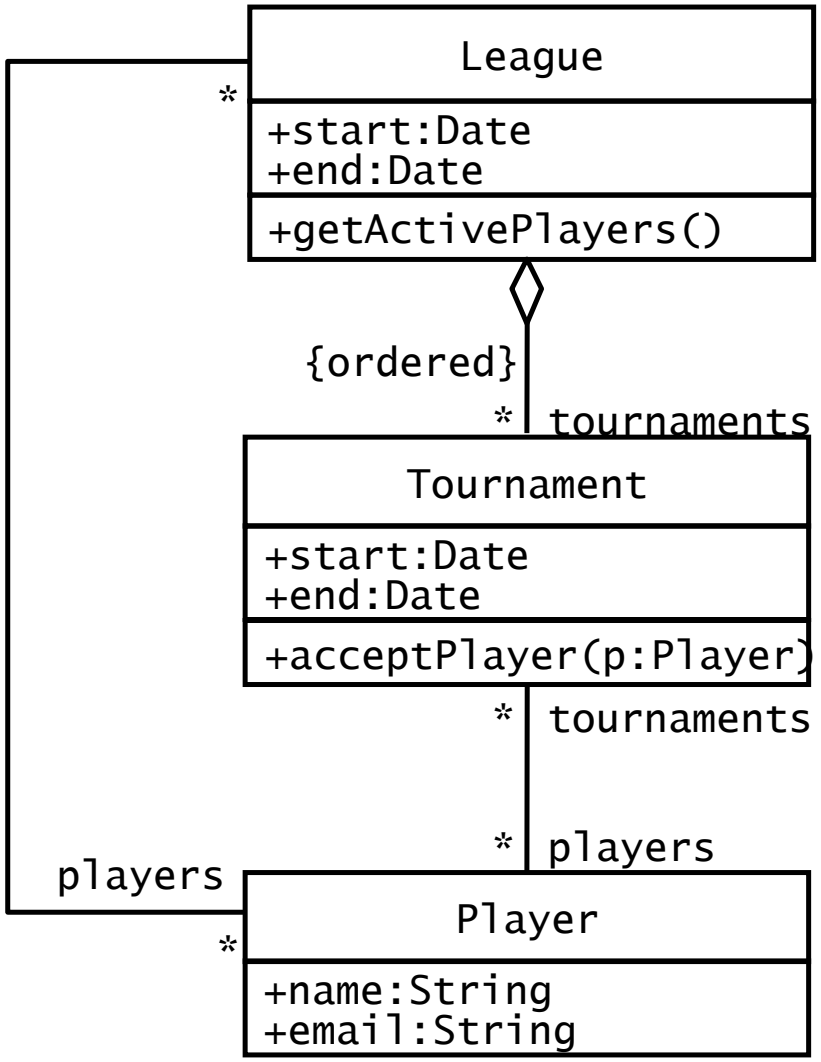
```
/** The acceptPlayer() operation
 * assumes that the specified
 * player has not been accepted
 * in the Tournament yet.
 * @pre !isPlayerAccepted(p)
 * @pre getNumPlayers()<maxNumPlayers
 * @post isPlayerAccepted(p)
 * @post getNumPlayers() =
 *     @pre.getNumPlayers() + 1
 */
public void acceptPlayer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

How do we specify constraints on on a group of classes?

Starting from a specific class in the UML class diagram, we navigate the associations in the class diagram to refer to the other classes and their properties (attributes and Operations).

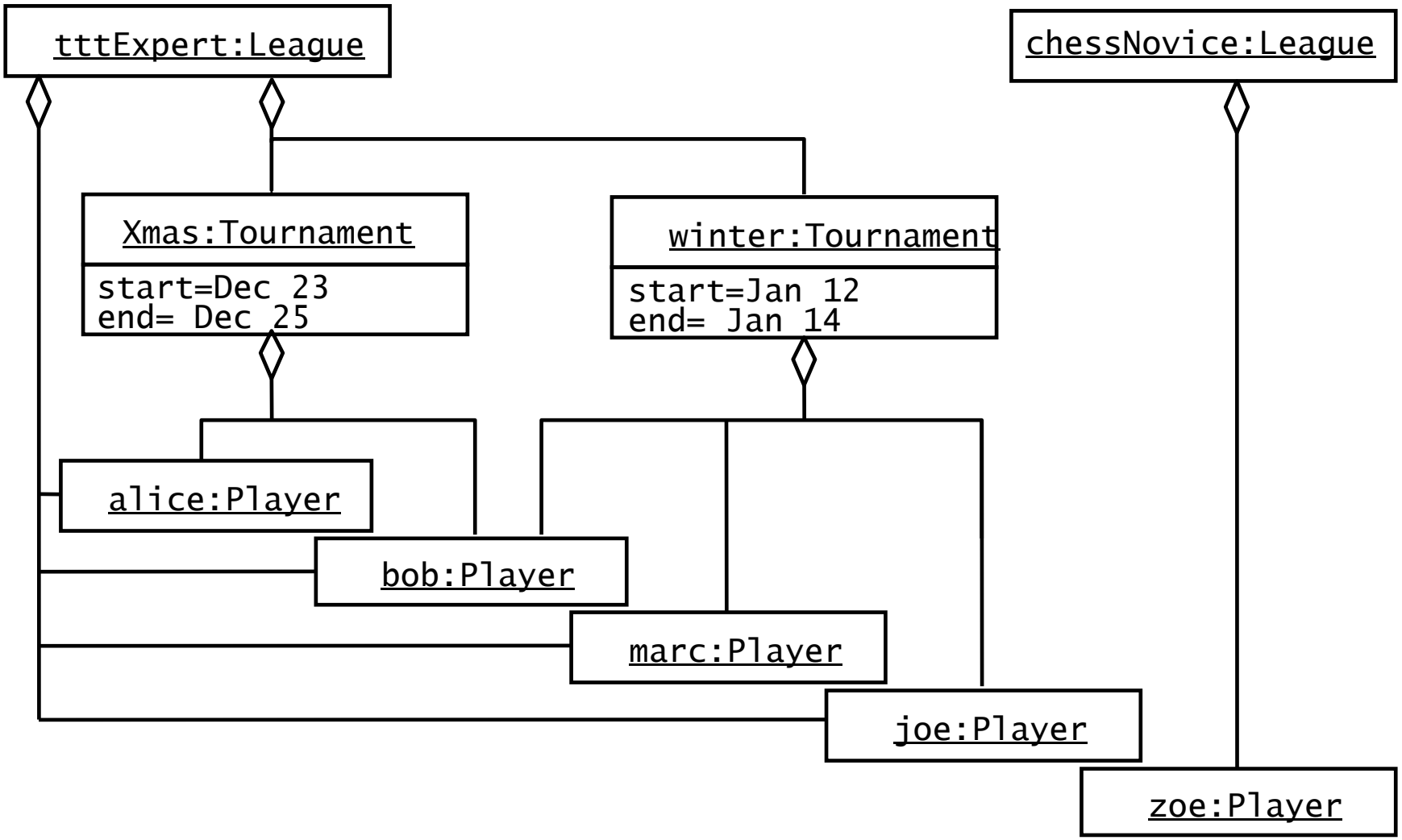
Example from ARENA: League, Tournament and Player



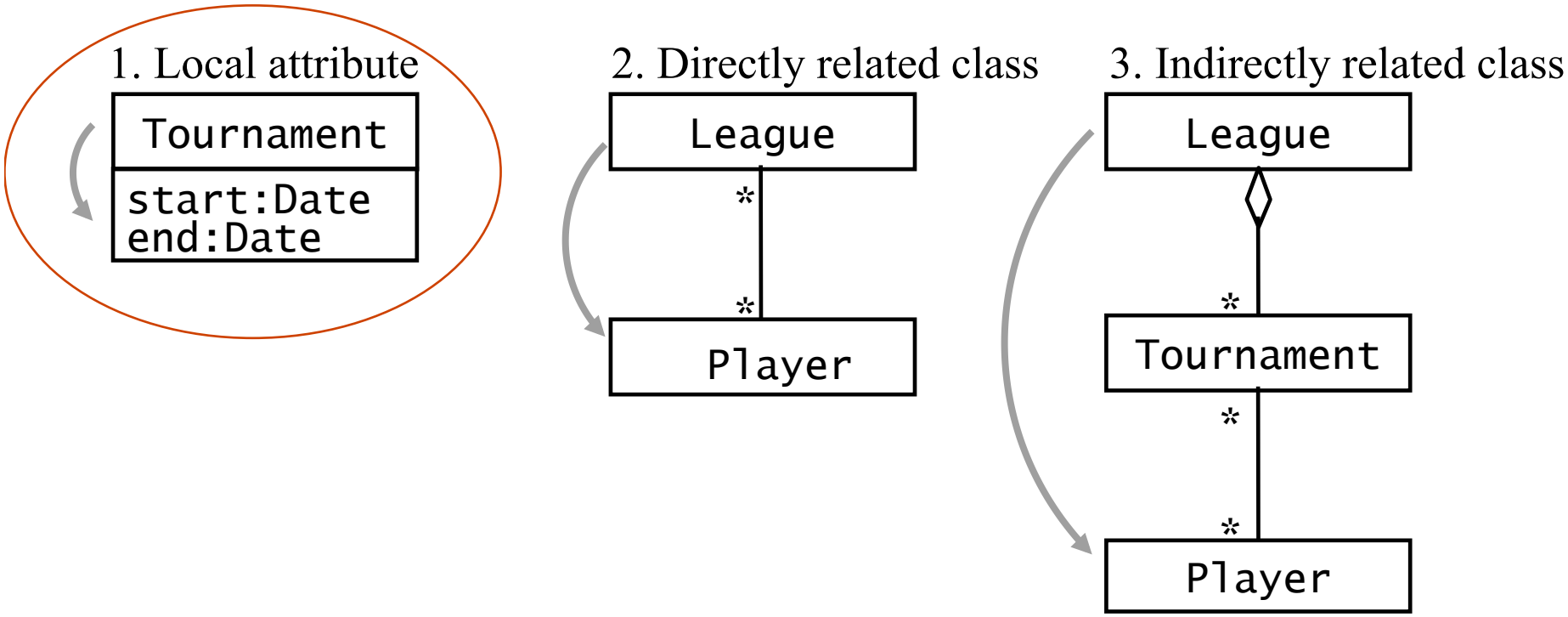
Constraints:

1. A Tournament's planned duration must be under one week.
2. Players can be accepted in a Tournament only if they are already registered with the corresponding League.
3. The number of active Players in a League are those that have taken part in at least one Tournament of the League.

Instance Diagram: 2 Leagues, 5 Players, 2 Tournaments



3 Types of Navigation through a Class Diagram



Any constraint for an arbitrary UML class diagram can be specified using only a combination of these 3 navigation types!

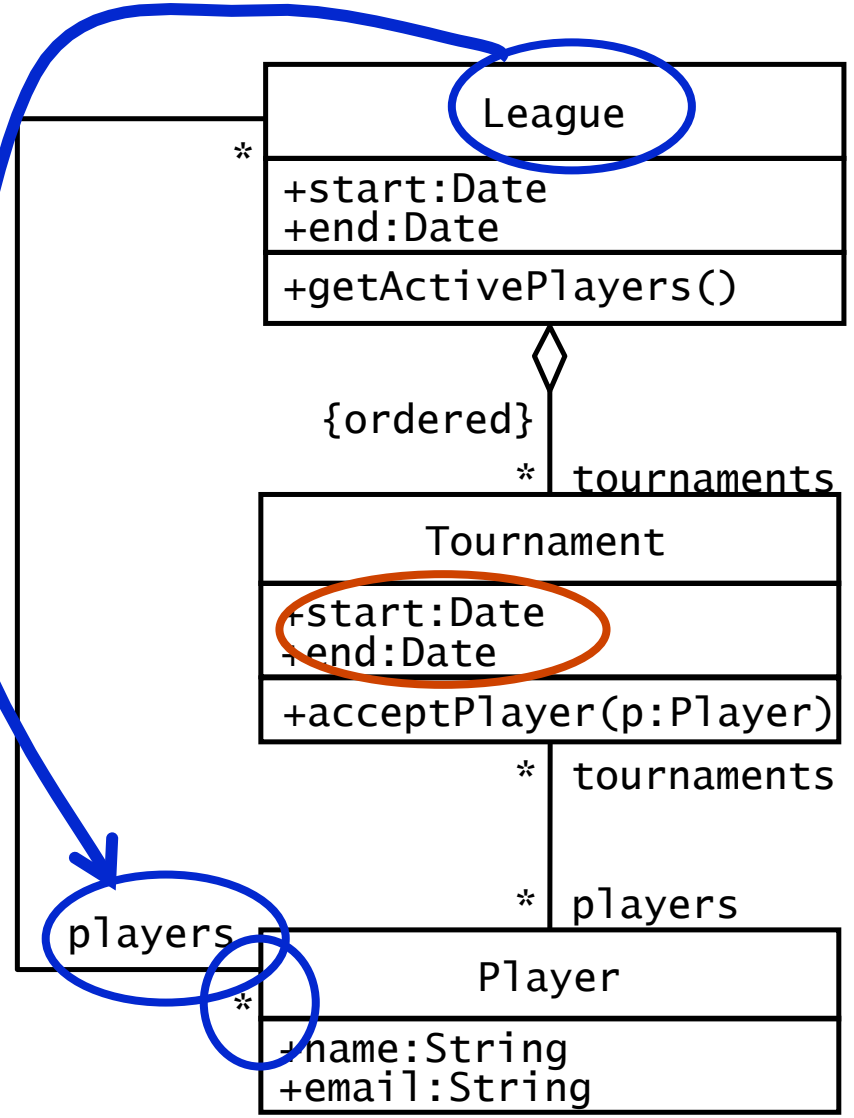
Specifying the Model Constraints in OCL

Local attribute navigation

```
context Tournament inv:
  end - start <= 7
```

Directly related class navigation

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



OCL-Collection

- The OCL-Type Collection is the generic superclass of a collection of objects of Type T
- Subclasses of Collection are
  - Set: Set in the mathematical sense. Every element can appear only once
  - Bag: A collection, in which elements can appear more than once (also called multiset)
  - Sequence: A multiset, in which the elements are ordered
- Example for Collections:
  - Set(Integer): a set of integer numbers
  - Bag(Person): a multiset of persons
  - Sequence(Customer): a sequence of customers

OCL Sets, Bags and Sequences

- Sets, Bags and Sequences are predefined in OCL and subtypes of Collection. OCL offers a large number of predefined operations on collections. They are all of the form:

```
collection->operation(arguments)
```

OCL-Operations for OCL-Collections (1)

`size: Integer`
Number of elements in the collection

`includes(o:OclAny): Boolean`
True, if the element `o` is in the collection

`count(o:OclAny): Integer`
Counts how many times an element is contained in the collection

`isEmpty: Boolean`
True, if the collection is empty

`notEmpty: Boolean`
True, if the collection is not empty

The OCL-Type **OclAny** is the most general OCL-Type.

OCL-Operations for OCL-Collections(2)

`union(c1:Collection)`
Union with collection **`c1`**

`intersection(c2:Collection)`
Intersection with Collection **`c2`** (contains only elements, which appear in the collection as well as in collection **`c2`** auftreten)

`including(o:OclAny)`
Collection containing all elements of the Collection and element **`o`**

`select(expr:OclExpression)`
Subset of all elements of the collection, for which the OCL-expression **`expr`** is true.

Other examples of OCL

(optional)

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))
```

Backup and Additional Slides

How do we get OCL-Collections?

- A collection can be generated by explicitly enumerating the elements from the UML model
- A collection can be generated by navigating along one or more 1-N associations in the UML model
  - Navigation along a single 1:n association yields a Set
  - Navigation along a couple of 1:n associations yields a Bag (Multiset)
  - Navigation along a single 1:n association labeled with the constraint {ordered} yields a Sequence