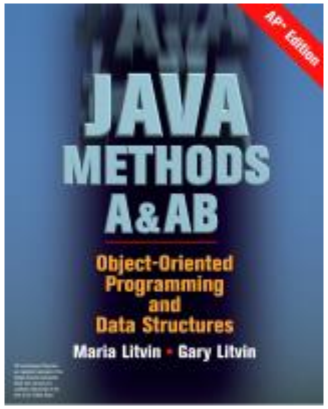

AP* Edition
JAVA
METHODS
A&AB
Object-Oriented Programming and Data Structures
Maria Litvin · Gary Litvin

Java Methods

A & AB

Object-Oriented Programming and Data Structures

Maria Litvin ● Gary Litvin

```
Section[] chapter12 =
new Section[12]
```

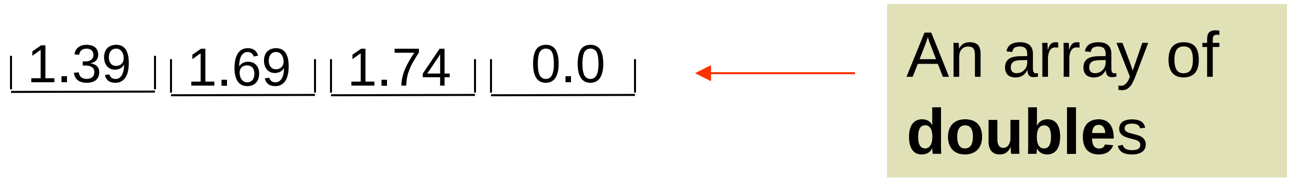
Arrays and ArrayLists

Objectives:

- Learn about arrays and when to use them
- Learn the syntax for declaring and initializing arrays and how to access array's size and elements
- Learn about the java.util.ArrayList class
- Discuss "for each" loops
- Learn simple array algorithms
- Understand two-dimensional arrays

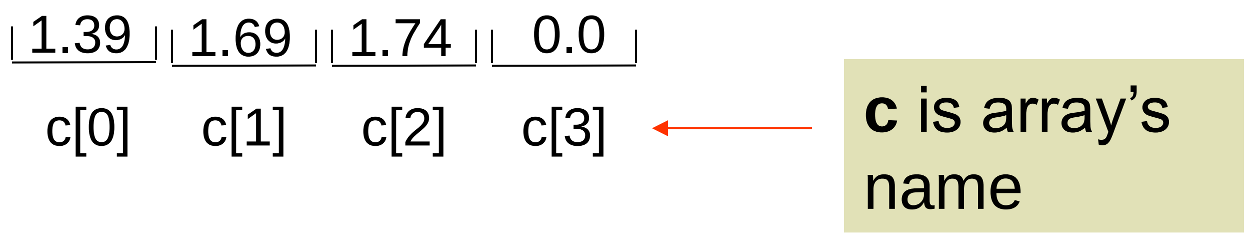
What is an Array

- An array is a block of consecutive memory locations that hold values of the same data type.
- Individual locations are called array’s *elements*.
- When we say “element” we often mean the value stored in that element.



What is an Array (cont’d)

- Rather than treating each element as a separate named variable, the whole array gets one name.
- Specific array elements are referred to by using array’s name and the element’s number, called *index* or *subscript*.



Indices (Subscripts)

- In Java, an index is written within square brackets following array's name (for example, a[k]).
- Indices start from 0; the first element of an array a is referred to as a[0] and the *n*-th element as a[n−1].
- An index can have any int value from 0 to array's length − 1.

Indices (cont'd)

- We can use as an index an int variable or any expression that evaluates to an int value. For example:

```
a [3]
a [k]
a [k – 2]
a [ (int) (6 * Math.random()) ]
```

Indices (cont'd)

- In Java, an array is declared with fixed length that cannot be changed.
- Java interpreter checks the values of indices at run time and throws ArrayIndexOutOfBoundsException if an index is negative or if it is greater than the length of the array – 1.

Why Do We Need Arrays?

- The power of arrays comes from the fact that the value of a subscript can be computed and updated at run time.

No arrays:

```
int sum = 0;
sum += score0;
sum += score1;
…
sum += score999;
```

1000 times!

With arrays:

```
int n = 1000;
int sum = 0, k;

for (k = 0;  k < n;  k++)
    sum += scores[k];
```

Why Arrays? (cont'd)

- Arrays give <u>direct access</u> to any element — no need to scan the array.

No arrays:

1000 times!

```
if (k == 0)
    display (score0);
else if (k == 1)
    display (score1);
else
…  // etc.
```

With arrays:

```
display (scores[k]);
```

Arrays as Objects

- In Java, an array is an object. If the type of its elements is *anyType*, the type of the array object is *anyType*[ ].
- Array declaration:

```
anyType [ ]  arrName;
```

Arrays as Objects (cont'd)

- As with other objects, the declaration creates only a reference, initially set to null. An array must be created before it can be used.
- One way to create an array:

```
arrName = new anyType [length] ;
```

Brackets, not parens!

Declaration and Initialization

- When an array is created, space is allocated to hold its elements. If a list of values is not given, the elements get the default values. For example:

```
scores = new int [10] ;

words = new String [10000];
```

length 10, all values set to 0

length 10000, all values set to **null**

Initialization (cont’d)

- An array can be declared an initialized in one statement. For example:

```
int [ ] scores = new int [10] ;

private double [ ] gasPrices = { 3.05, 3.17, 3.59 };

String [ ] words = new String [10000];

String [ ] cities = {"Atlanta", "Boston", "Cincinnati" };
```

Initialization (cont'd)

- Otherwise, initialization can be postponed until later. For example:

```
String [ ] words;                 ← Not yet initialized

...
words = new String [ console.readInt() ];

private double[ ] gasPrices;      ← Not yet initialized
…
gasPrices = new double[ ]  { 3.05, 3.17, 3.59 };
```

Array’s Length

- The length of an array is determined when that array is created.
- The length is either given explicitly or comes from the length of the {…} initialization list.
- The length of an array arrName is referred to in the code as arrName.length.
- length is like a public field (not a method) in an array object.

Initializing Elements

- Unless specific values are given in a {…} list, all the elements are initialized to the default value: 0 for numbers, false for booleans, null for objects.
- If its elements are objects, the array holds references to objects, which are initially set to null.
- Each object-type element must be initialized before it is used.

Initializing Elements (cont'd)

- Example:

```
Color[ ] pens;
...
pens = new Color [ 3 ];
...
pens [0] = Color.BLUE;
pens [1] = new Color (15, 255, 255);
pens [2] = g.getColor();
```

Array not created yet

Array is created; all three elements are set to **null**

Now all three elements are initialized

Passing Arrays to Methods

- As other objects, an array is passed to a method as a reference.
- The elements of the original array are not copied and are accessible in the method's code.

```
//  Swaps a [ i ] and a [ j ]
public void swap (int [ ] a, int  i, int  j)
{
    int temp = a [ i ];
    a [ i ] = a [ j ];
    a [ j ] = temp;
}
```

Returning Arrays from Methods

- As any object, an array can be returned from a method.
- The returned array is usually constructed within the method or obtained from calls to other methods.
- The return type of a method that returns an array with *someType* elements is designated as *someType*[ ].

Returning Arrays from Methods (cont'd)

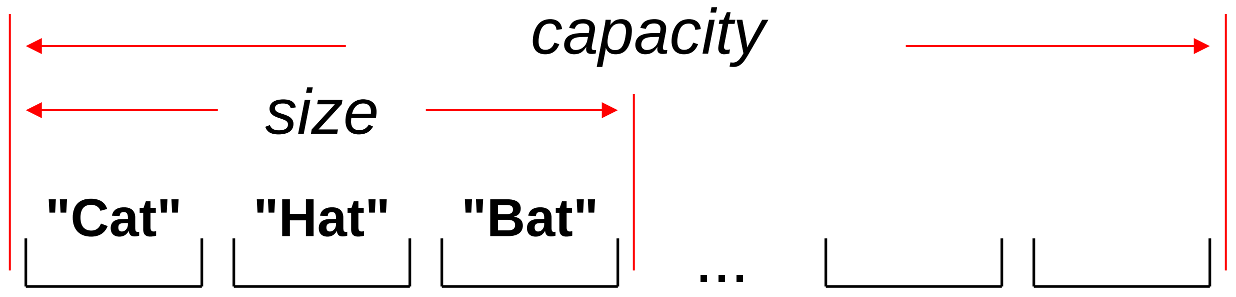
```
public double[ ] solveQuadratic
    (double a, double b, double c)
{
  double d = b * b – 4 * a * c;
  if (d < 0) return null;

  d = Math.sqrt(d);

  double[ ] roots = new double[2];
  roots[0] = (–b – d) / (2*a);
  roots[1] = (–b + d) / (2*a);
  return roots;
}
```

Or simply:

```
  return new double[ ]
    { (–b – d) / (2*a),
      (–b + d) / (2*a) };
```

java.util.ArrayList<*E*>

- Implements a list using an array.
- Can only hold objects (of a specified type), not elements of primitive data types.
- Keeps track of the list *capacity* (the length of the allocated array) and list *size* (the number of elements currently in the list)



ArrayList — Generics

- Starting with Java 5, ArrayList and other collection classes hold objects of a specified data type.
- The elements' data type is shown in angle brackets and becomes part of the ArrayList type. For example:

```
ArrayList<String> words = new ArrayList<String>();

ArrayList<Integer> nums = new ArrayList<Integer>();
```

ArrayList<E> Constructors

Java docs use the letter ***E*** as the type parameter for elements in generic collections

```
ArrayList<E> ( )

ArrayList<E> (int capacity)
```

Creates an empty **ArrayList<*E*>** of default capacity (ten)

Creates an empty **ArrayList<*E*>** of the specified capacity

ArrayList<*E*> Methods (a Subset)

```
int size()
boolean isEmpty ()
boolean add (E obj)
void add (int i, E obj)
E set(int i, E obj)
E get(int i)
E remove(int i)
boolean contains(E obj)
int indexOf(E obj)
```

returns **true**

inserts **obj** as the **i**-th value; **i** must be from 0 to **size()**

i must be from 0 to **size() –1**

use **equals** to compare objects

ArrayList Example

```
ArrayList<String> names =
                    new ArrayList<String>( );
names.add("Ben");
names.add("Cat");
names.add(0, "Amy");
System.out.println(names);
```

Output

```
[Amy, Ben, Cat]
```

ArrayList’s **toString** method returns a string of all the elements, separated by commas, within **[ ]**.

ArrayList<*E*> Details

- Automatically increases (doubles) the capacity when the list runs out of space (allocates a bigger array and copies all the values into it).
- get(i) and set(i, obj) are efficient because an array provides random access to its elements.
- Throws IndexOutOfBoundsException when

  $i < 0$ or $i \geq$ size()

  (or $i >$ size() in add (i, obj))

ArrayList<*E*> Autoboxing

- If you need to put ints or doubles into a list, use a standard Java array or convert them into Integer or Double objects
- In Java 5, conversion from int to Integer and from double to Double is, in most cases, automatic (a feature known as *autoboxing* or *autowrapping*); the reverse conversion (called *autounboxing*) is also automatic.

ArrayList<*E*> Autoboxing Example

```
ArrayList<Integer> counts =
                    new ArrayList<Integer>( );

counts.add(17);
...
int count = counts.get(0);
```

Autoboxing: compiled as **counts.add(new Integer(17));**

Autounboxing: **count** gets the value 17

ArrayList Pitfalls

```
// Remove all occurences
// of "like" from words:

int i = 0;

while (i < words.size())
{
  if ("like".equals(words.get(i))
    words.remove(i);
  else
    i++;
}
```

Caution: when you remove elements, a simple **for** loop doesn't work:

```
~~for (int i  = 0; i < words.size();
                                  i++)
{
   if ("like".equals(words.get(i))
     words.remove(i);
 }~~
```

Shifts all the elements after the **i**-th to the left and decrements the size

“For Each” Loop

- Introduced in Java 5
- Works both with standard arrays and ArrayLists
- Convenient for *traversing*
- Replaces iterators for collections (Chapter 19)

“For Each” Loop: Example 1

```
int [ ] scores = { ... };
...
int sum = 0;

for (int s : scores)
{
    sum += s;
}
...
```

Basically the same as:

```
for (int i = 0;
           i < scores.length;  i++)
{
    int s = scores[i];
    sum += s;
}
```

“For Each” Loop: Example 2

```
ArrayList<String> words = new ArrayList<String>();
...
for (String str : words)
{
    System.out.println(str);    // process  str
}
```

Basically the same as:

```
for (int i = 0;
             i < words.size();  i++)
{
    String str = words.get(i);
    System.out.println(str);
}
```

“For Each” Loop (cont’d)

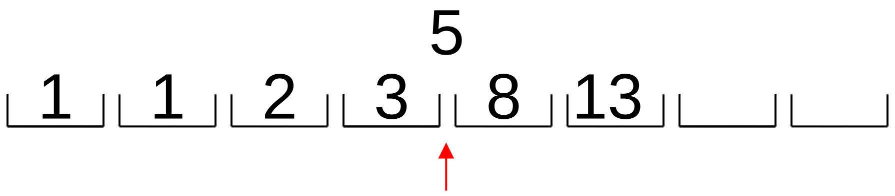
- You cannot add or remove elements within a “for each” loop.
- You cannot change elements of primitive data types or references to objects within a “for each” loop.

Inserting a Value into a Sorted Array

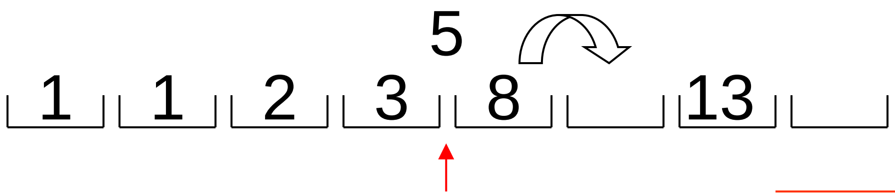
- Given: an array, sorted in ascending order. The number of values stored in the array is smaller than array's length: there are some unused elements at the end.
- Task: insert a value while preserving the order.

Inserting a Value (cont'd)

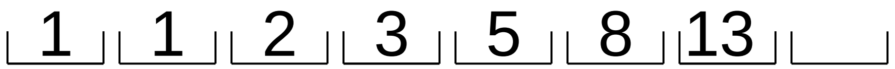
1. Find the right place to insert:



2. Shift elements to the right, starting from the last one:



3. Insert the value in its proper place:



Can be combined together in one loop: look for the place to insert while shifting.

Inserting a Value (cont'd)

```
//  Returns true if inserted successfully, false otherwise
public boolean insert(double[ ] arr, int count, double value)
{
    if (count >= arr.length)
        return false;

    int k = count – 1;
    while ( k >= 0  && arr [ k ] > value )
    {
        arr [ k + 1 ] = arr [ k ];
        k––;
    }
    arr [ k + 1] = value;

    return true;
}
```

Lab: *Index Maker*

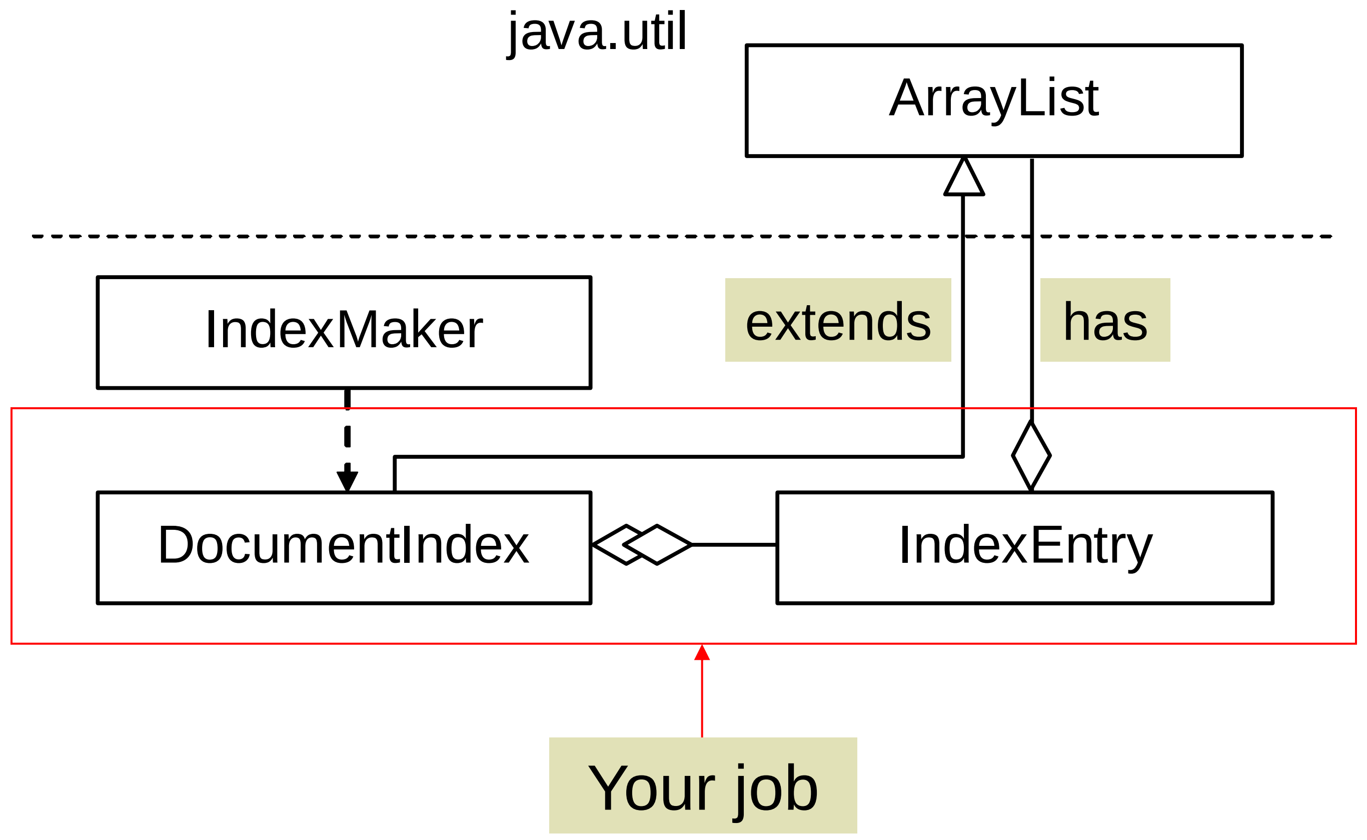
fish.txt

```
One fish
Two fish
Red fish
Blue fish.

Black fish
Blue fish
Old fish
New fish.

This one has
a little star.

This one has a little car.
Say! What a lot
of fish there are.
```

fishIndex.txt

```
A 12, 14, 15
ARE 16
BLACK 6
BLUE 4, 7
CAR 14
FISH 1, 2, 3, 4, 6, 7, 8, 9, 16
HAS 11, 14
LITTLE 12, 14
LOT 15
NEW 9
OF 16
OLD 8
ONE 1, 11, 14
RED 3
SAY 15
STAR 12
THERE 16
THIS 11, 14
TWO 2
WHAT 15
```

Index Maker (cont'd)



Two-Dimensional Arrays

- 2-D arrays are used to represent tables, matrices, game boards, images, etc.
- An element of a 2-D array is addressed using a pair of indices, “row” and “column.” For example:

```
board [ r ] [ c ] = 'x';
```

2-D Arrays: Declaration

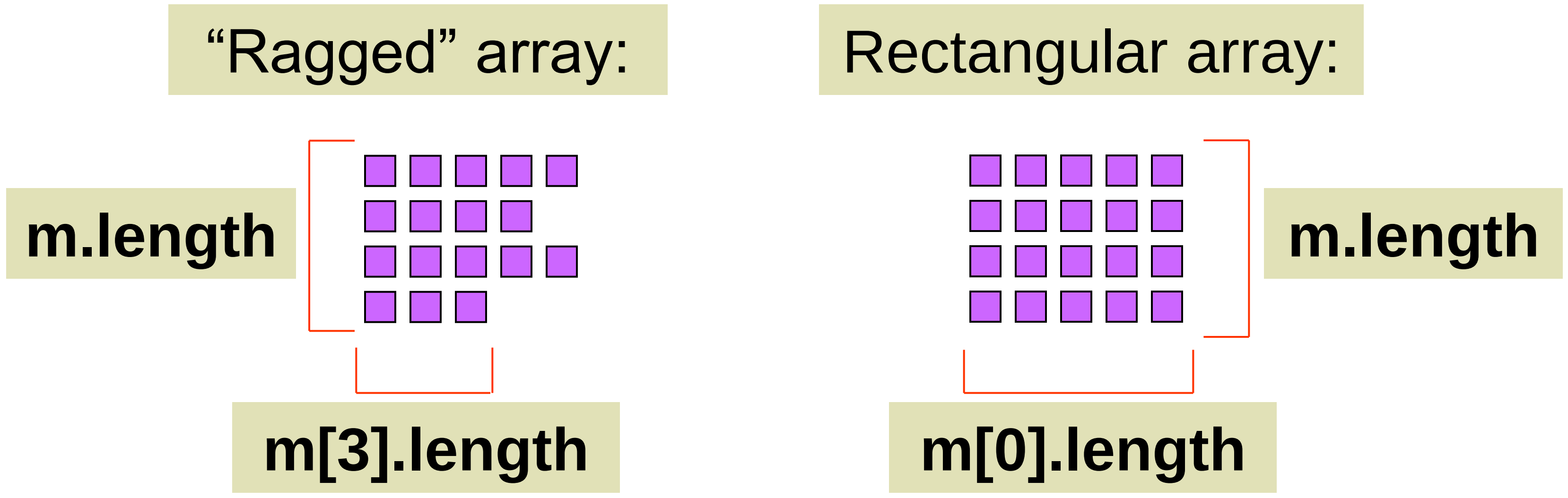
```
// 2-D array of char with 5 rows, 7 cols:
char[ ] [ ] letterGrid = new char [5][7];

// 2-D array of Color with 1024 rows, 768 cols:
Color[ ] [ ] image = new Color [1024][768];

// 2-D array of double with 2 rows and 3 cols:
double [ ] [ ] sample =
    { { 0.0, 0.1, 0.2 },
      { 1.0, 1.1, 1.2 } };
```

2-D Arrays: Dimensions

- In Java, a 2-D array is basically a 1-D array of 1-D arrays, its rows. Each row is stored in a separate block of consecutive memory locations.
- If m is a 2-D array, then m[k] is a 1-D array, the *k*-th row.
- m.length is the number of rows.
- m[k].length is the length of the k-th row.

Dimensions (cont'd)

- Java allows "ragged" arrays, in which different rows have different lengths.
- In a rectangular array, m[0].length can be used to represent the number of columns.



2-D Arrays and Nested Loops

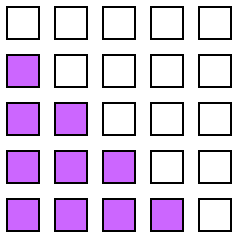
- A 2-D array can be traversed using nested loops:

```
for (int  r = 0;  r < m.length;  r++)
{
    for (int  c = 0;  c < m[0].length;  c++)
    {
        ...   //  process m[ r ][ c ]
    }
}
```

“Triangular” Loops

- “Transpose a matrix” idiom:

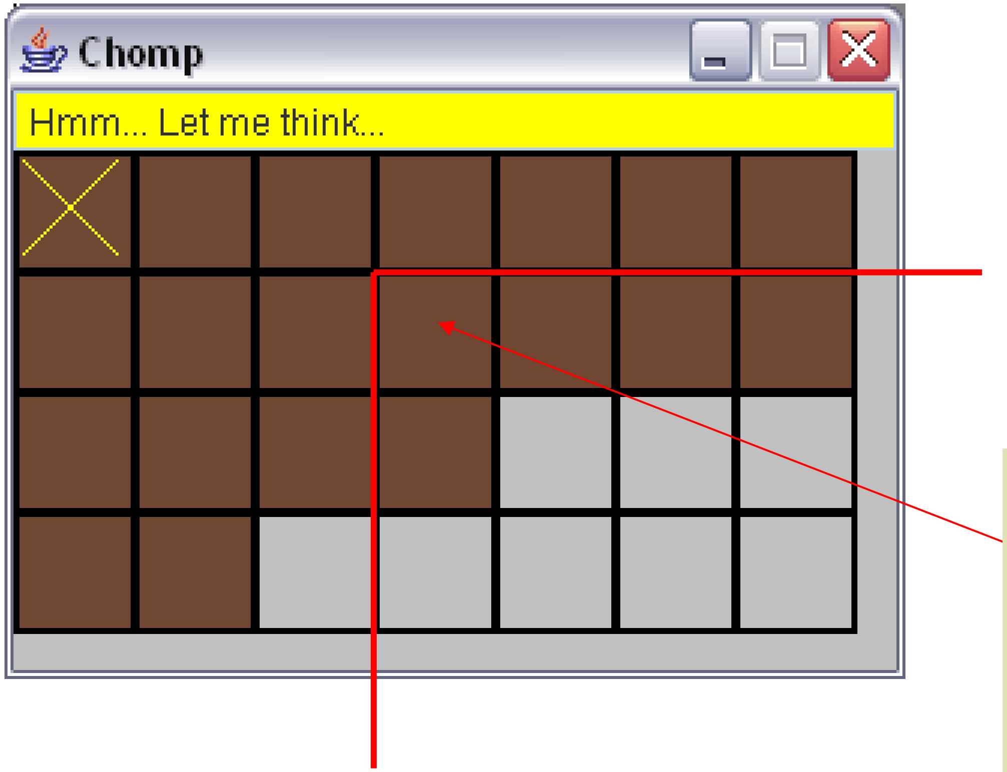
```
int  n = m.length;

for (int  r = 1;  r < n;  r++)
{
    for (int  c = 0;  c < r;  c++)
    {
        double temp = m [ r ][ c ];
        m [ r ][ c ] = m [ c ][ r ];
        m [ c ][ r ] = temp;
    }
}
```



The total number of iterations through the inner loop is:

$1 + 2 + 3 + ... + n{-}1 =$ $\boldsymbol{n\ (n - 1)\ /\ 2}$

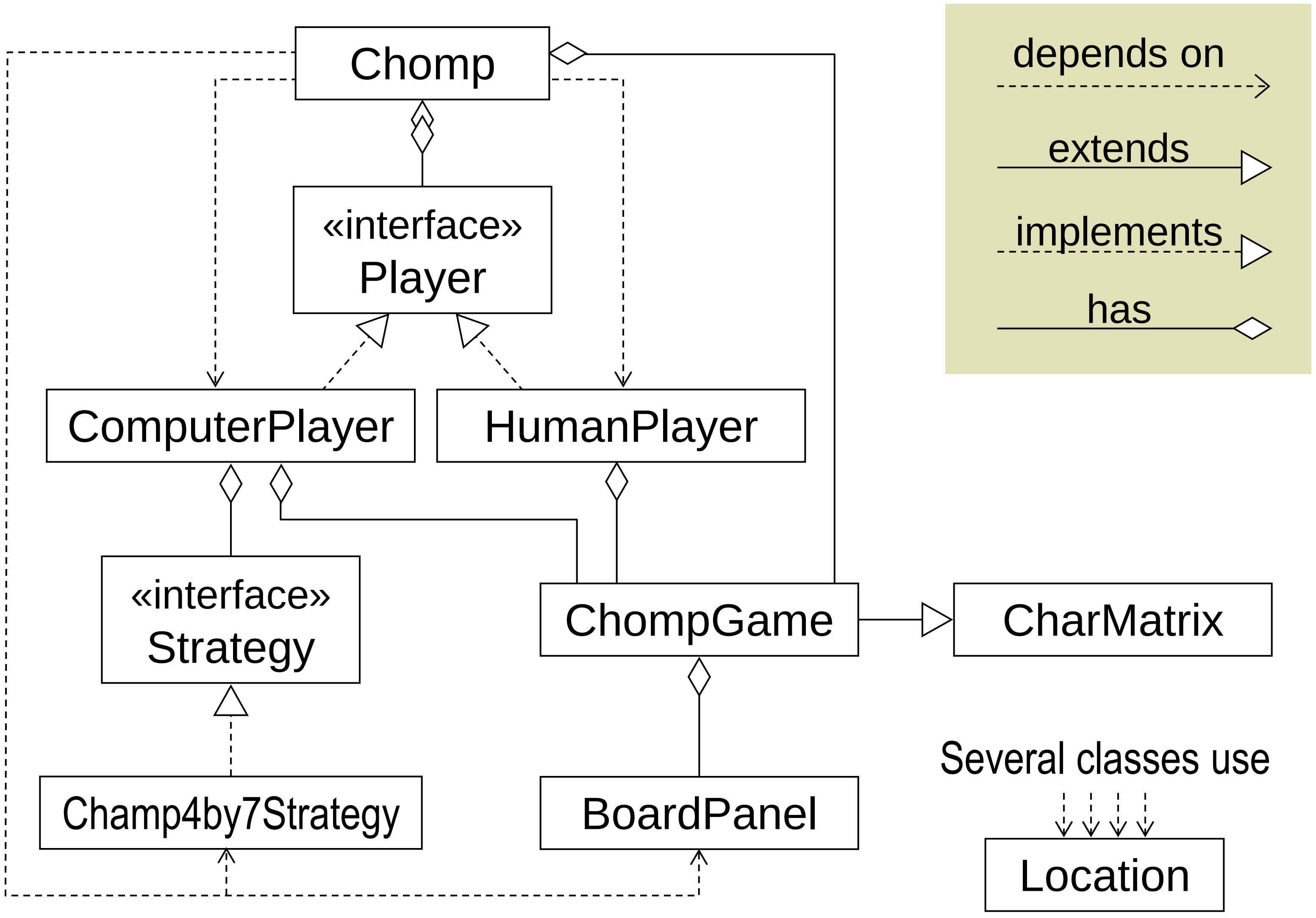
Case Study: *Chomp*



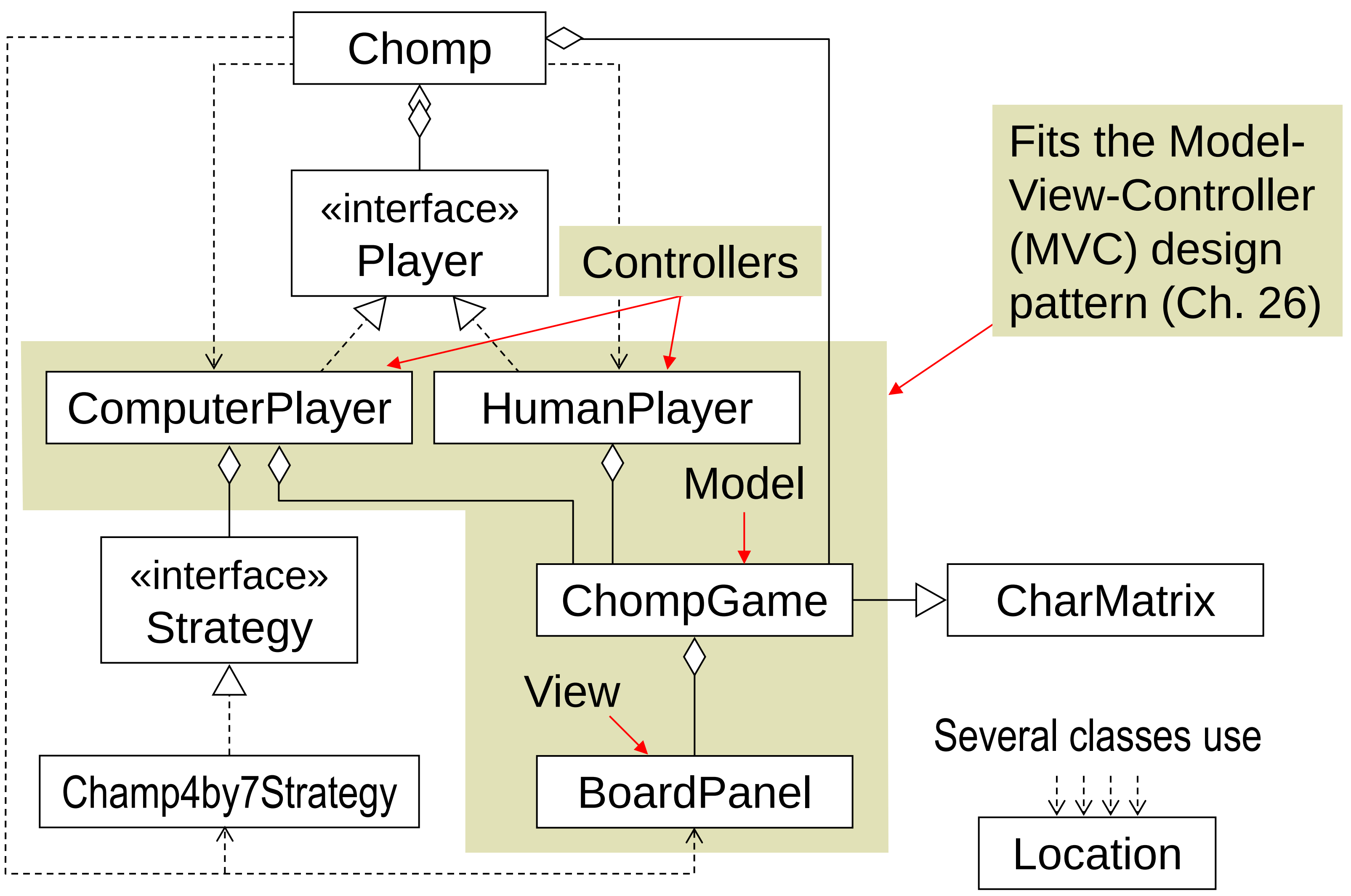
Hmm... Let me think...

Next move: the five remaining squares inside the angle will be "eaten"

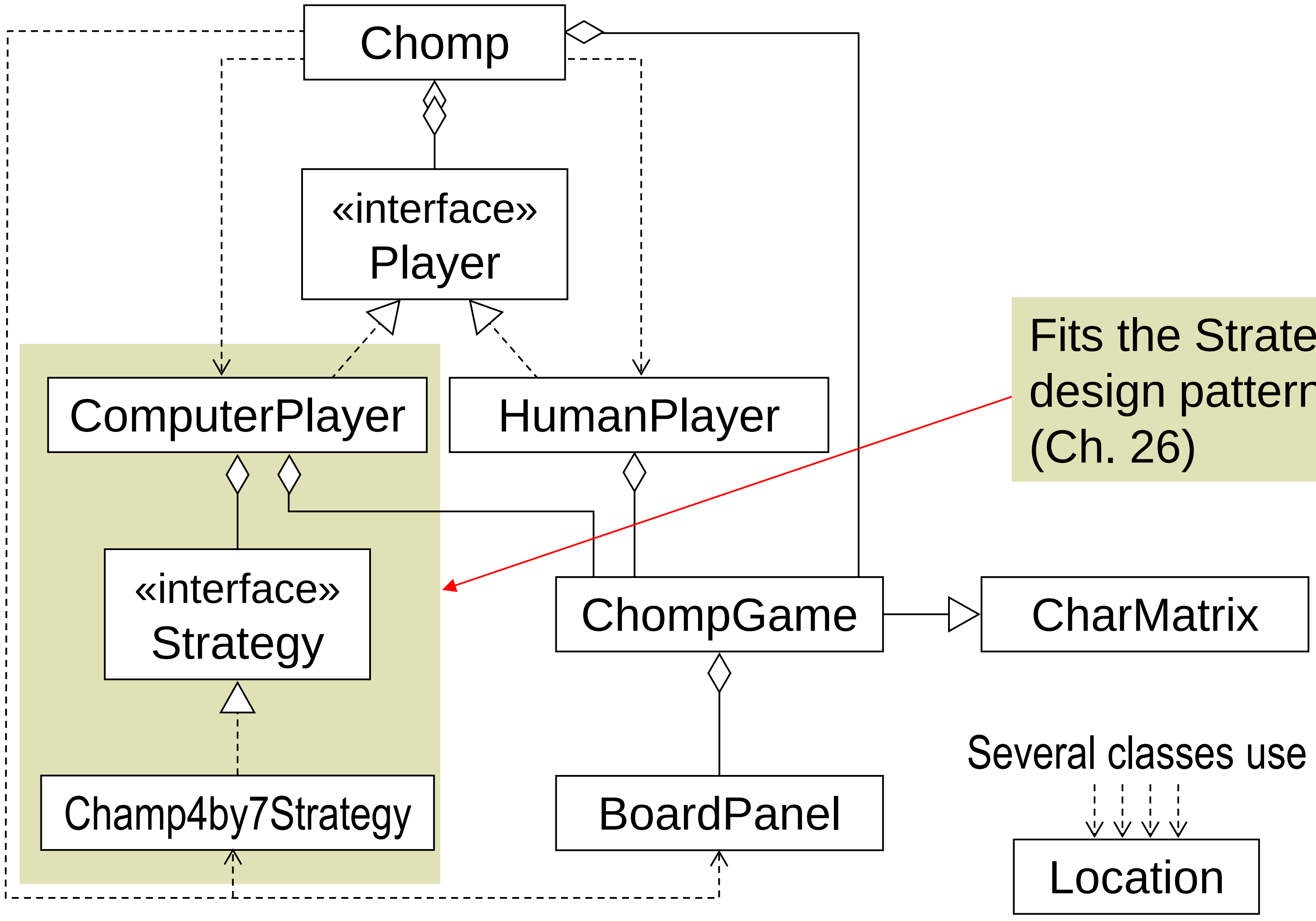
Chomp Design



Chomp Design (cont'd)



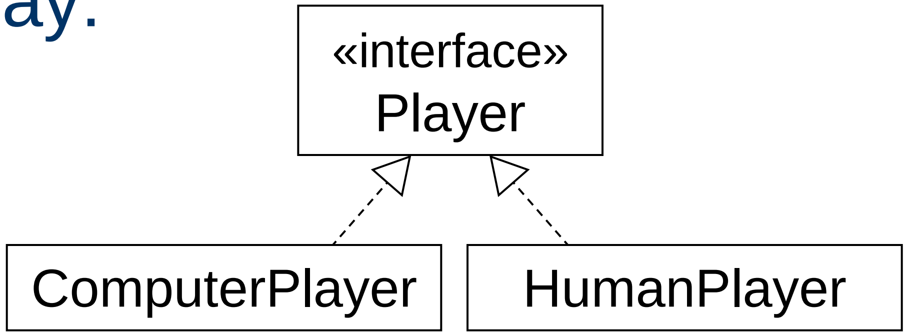
Chomp Design (cont'd)



Fits the Strategy design pattern (Ch. 26)

Chomp Design (cont'd)

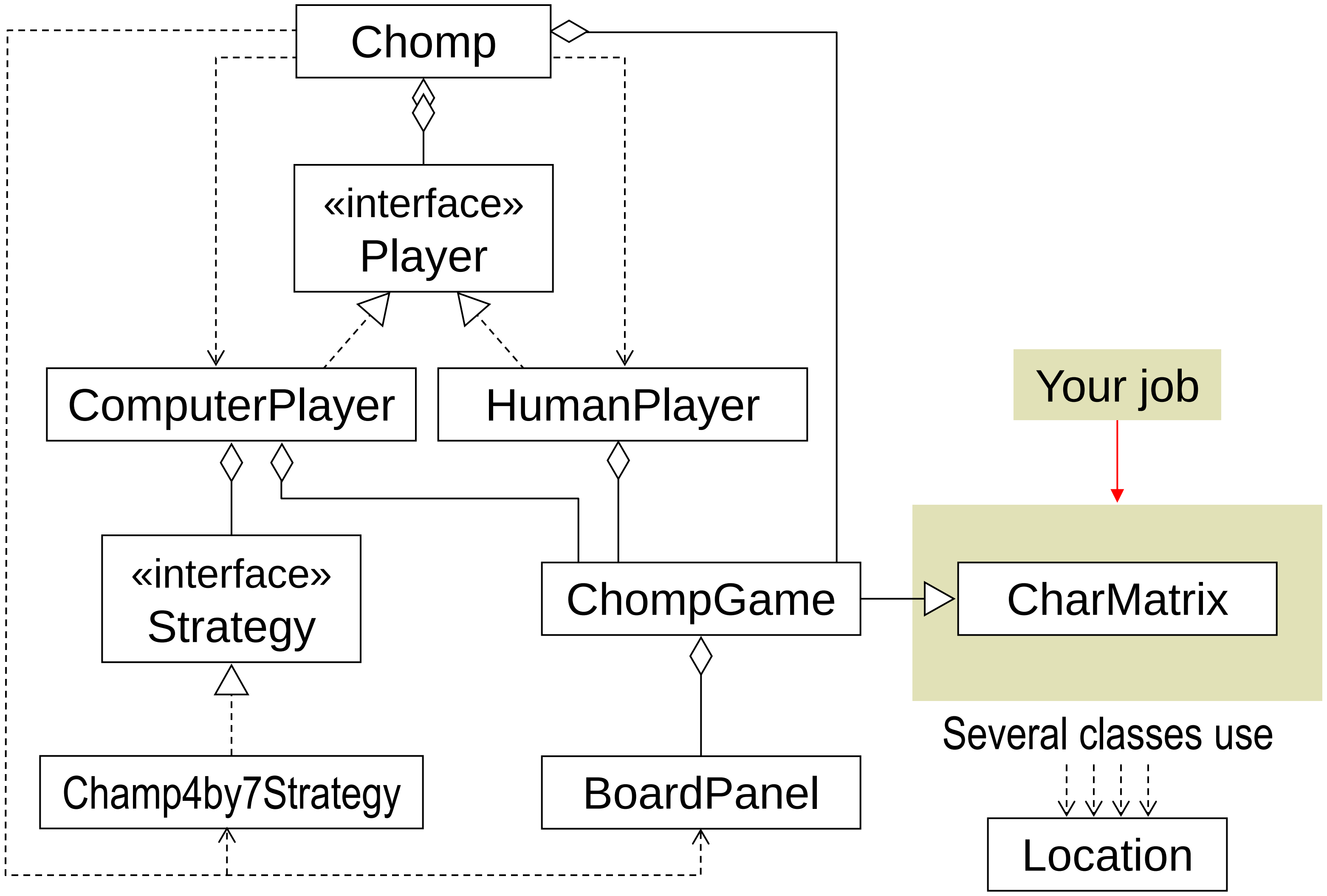
- The Player interface is introduced so that we can mix different types of players in the same array:



```
private Player[ ]  players;
...
    players = new Player[2];
    players[0] = new HumanPlayer(...);
    players[1] = new ComputerPlayer(...);
```

An array with elements of an interface type

Chomp (cont'd)


Chomp
«interface»
Player
ComputerPlayer
HumanPlayer
«interface»
Strategy
Champ4by7Strategy
ChompGame
BoardPanel
Your job
CharMatrix
Several classes use
Location

Review:

- Why are arrays useful?
- What types of elements can an array have?
- How do we refer to an array’s element in Java?
- What happens if an index has an invalid value?
- How do we refer to the length of an array?

Review (cont’d):

- Can we resize an array after it has been created?
- Are arrays in Java treated as primitive data types or as objects?
- What values do an array’s elements get when the array is created?
- Are the array’s elements copied when an array is passed to a method?
- Can a method return an array?

Review (cont'd):

- When is an ArrayList more convenient than an array?
- Explain the difference between the capacity and size in an ArrayList?
- What method returns the number of elements currently stored in an ArrayList?
- What method is used to insert an element into an ArrayList?

Review (cont’d):

- What is autoboxing?
- Can a double value be stored in an ArrayList<Double>?
- Can a “for each” loop be used with ArrayLists? Standard arrays?
- Describe an algorithm for inserting a value into a sorted array?
- Can a class extend ArrayList<String>?

Review (cont'd):

- Name a few applications of two-dimensional arrays.
- If m is a 2-D array of ints, what is the type of m[0]?
- How do we get the numbers of rows and cols in a 2-D array?