Programming Paradigms

Control Flow (Part 4)

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Overview

- Expression Evaluation
- Structured and Unstructured Control Flow
- Selection
- Iteration ←
- Recursion

Iteration

- **Essential language construct**
  - Otherwise: Amount of work done is linear to program size
- **Two basic forms of loops**
  - Enumeration-controlled: Once per value in finite set
  - Logically controlled: Until Boolean expression is false

Enumeration-controlled Loops

- **Most simple form: Triple of**
  - Initial value
  - Bound
  - Step size

Fortran 90:

```
do i = 1, 10, 2
  ...
enddo;
```

Modula-2:

```
FOR i := 1 TO 10 BY 2 DO
  ...
END
```

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Iterations with i = 1, 3, 5, 7, 9

Semantic Variants

Different PLs offer different variants

- Can you leave the loop in the middle?
- Can you modify the loop variable?
- Can you modify the values used to compute the loop bounds?
- Can you read the loop variable in/after the loop?

Iterators

- **Special enumeration-controlled loop: Iterates through any kind of set/sequence of values**
  - E.g., nodes of a tree or elements of a collection
- **Decouples two algorithms**
  - How to enumerate the values
  - How to use the values
- **Three flavors**
  - “True” iterators, iterator objects, first-class functions

“True” Iterators

- Subroutine with **`yield`** statements
  - □ Each `yield` “returns” another element
- Popular, e.g., in Python, Ruby, and C#
- Used in a **`for`** loop
  - □ Example (Python):

```
# range is a built-in iterator
for i in range(first, last, step):
    ...
```

Example: Binary Tree

```
class BinTree:
    def __init__(self, data):
        self.data = data
        self.lchild = self.rchild = None

    # other methods: insert, delete lookup, ...

    def preorder(self):
        if self.data is not None:
            yield self.data
        if self.lchild is not None:
            for d in self.lchild.preorder():
                yield d
        if self.rchild is not None:
            for d in self.rchild.preorder():
                yield d
```

Iterator Objects

- **Regular object with methods for**
  - □ Initialization
  - □ Generation of next value
  - □ Test for completion
- **Popular, e.g., in Java and C++**
- **Used in `for` loop**

```
for (Iterator i = c.iterator(); i.hasNext(); ) {
    ... = i.next();
}
```

Iterator Objects

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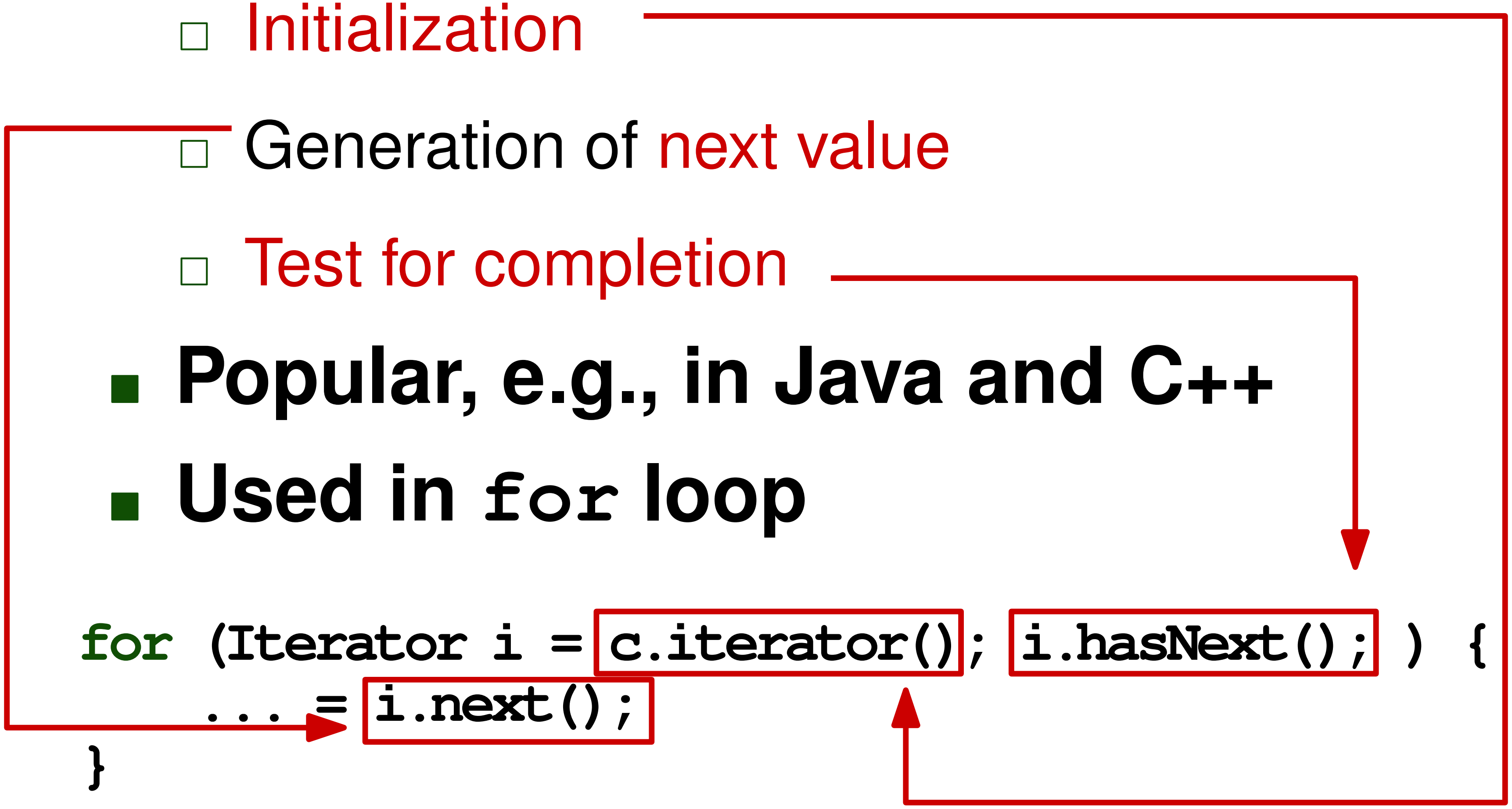

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```
for (Iterator i = c.iterator(); i.hasNext(); ) {
    ... = i.next();
}
```

Since Java 5

```
for (Element e : c) {
    ...
}
```

Example: Binary Tree

```
class BinTree<T> implements Iterable<T> {
    BinTree<T> left; BinTree<T> right; T val;

    // other methods: insert, delete, lookup

    public Iterator<T> iterator() {
        return new TreeIterator(this);
    }
    private class TreeIterator implements Iterator<T> {
        public boolean hasNext() {
            ... // check if there is another element
        }
        public T next() {
            ... // return the next element
        }
        public void remove() {
            throw new UnsupportedOperationException();
}}}
```

Iterating with First-Class Functions

- **Two functions**
  - □ One function about what to do for each element
  - □ Another function that calls the first function for each element
- **Example (Scheme):**

```
(define uptoby
  (lambda (low high step f)
    (if (<= low high)
      (begin
        (f low)
        (uptoby (+ low step) high step f))
       '())))
```

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Defines a function with four arguments

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Calls `f` with the next element

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Recursively calls `uptoby` to handle the remaining elements

Iterating with First-Class Functions (2)

- **Originally, proposed in functional languages**
- **Nowadays, available in many modern PLs through libraries**
  - E.g., Java

    ```
    mySet.stream().filter(e -> e.someProp > 5)
    ```

  - E.g., JavaScript

    ```
    myArray.filter(e => e.someProp > 5)
    ```

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```
mySet.stream().filter(e -> e.someProp > 5)
```

Iterates through all elements and returns a filtered subset

  - □ E.g., JavaScript

```
myArray.filter(e => e.someProp > 5)
```

Iterating with First-Class Functions (2)

- Originally, proposed in **functional languages**
- Nowadays, **available** in many modern PLs through **libraries**
  - □ E.g., Java

```
mySet.stream().filter(e -> e.someProp > 5)
```

Boolean function that decides which elements to keep

  - □ E.g., JavaScript

```
myArray.filter(e => e.someProp > 5)
```

Logically Controlled Loops

Whether to continue to iterate decided through a Boolean expression

- Pre-test:

```
while (cond) {
   ...
}
```

- Mid-test:

```
for (;;) {
   ...
   if (cond) break
}
```

- Post-test:

```
do {
   ...
} while (cond)
```

Quiz: Iteration

Which of the following statements is true?

- Iterators are a form of logically controlled loops.
- A “true” iterator yields one element each time it is called.
- Iterator objects have a method that yields another element each time it is called.
- Iterating with first-class functions does not require a for-loop.

Please vote in Ilias

Quiz: Iteration

Which of the following statements is true?

- ~~Iterators are a form of logically controlled loops.~~
- ~~A “true” iterator yields one element each time it is called~~.
- Iterator objects have a method that yields another element each time it is called.
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