

Algorithms and Analysis

Lesson 7: *Iterate*



Array iteration, iterators

Outline

1. **Iterators**
2. The C++ Iterator Pattern
3. Linked-List Iterators
4. Generic Programming



Iterators

- One common task you want to do on a collection of objects is to iterate through each component
- If we have a standardised method for all collections then it is much easier to remember what to do
- But we can also write code that works for any collection that follows this pattern
- This pattern is known as the **iterator pattern**
- The pattern was first developed in C++, but is commonly used in many other languages

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Iterating Over C Arrays

- In C we would typically use a for-loop to iterate over an array

```
int n = 10;                                // size of array
int* begin = malloc(n*sizeof(10));         // malloc returns beginning of array
int* end = begin + n;                      // address past end of array

int sum = 0;
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C++ Iterator Pattern

- The C++ iterator pattern says for every `container<T>` we create a nested class called

`container::iterator`

which acts as a pointer (for arrays this could just be a pointer to the array)

- The class should implement

- ★ a dereferencing operator `T operator* ()`

- ★ an increment operator `operator++ ()`

- ★ a not equal function

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A Beginning and an Ending

- In addition the container should have two methods

- ★ `begin()`

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- Wow! That seems awfully complicated
- Don't panic! **We can hack this**

Minimal Iterator

```
template <typename>
class Container<T> {
private:

    class iterator {    // this is a nested class
public:
    iterator() {...}    // constructor
    iterator operator++() {...} // increment
    T& operator*() {...} // dereference
    friend bool operator!=(const iterator&, const iterator&){
        // code to determine inequality
    }
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public:

    iterator begin() {...}    // return begin iter
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Array-based iterators

- For array based containers such as vector we don't actually need to create an iterator class as we can just use the normal pointer

```
template <typename T>
class Array {
private:
    T *data;
    unsigned length;
    unsigned capacity;

public:
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    typedef T* iterator;           // iterator is pseudonym for T*
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- That's all we need

Using Array Iterators

```
main() {  
  
    Array<string> elements(4): {"earth", "water", "wind", "fire"};  
  
    for(Array::iterator it=elements.begin(); it!=elements.end(); ++it) {  
        cout << *it << endl;  
    }  
  
    for(auto it=elements.begin(); it!=elements.end(); ++it) {  
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    for(string& element: elements) { // range-based loop  
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- To use the iterator we need to implement the iterator class
- The object instantiated from the class should represent the position we are in the linked list

Linked-List Iterators

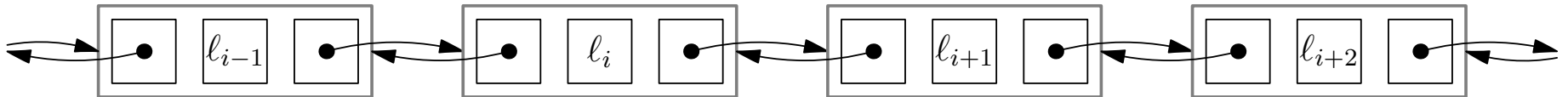
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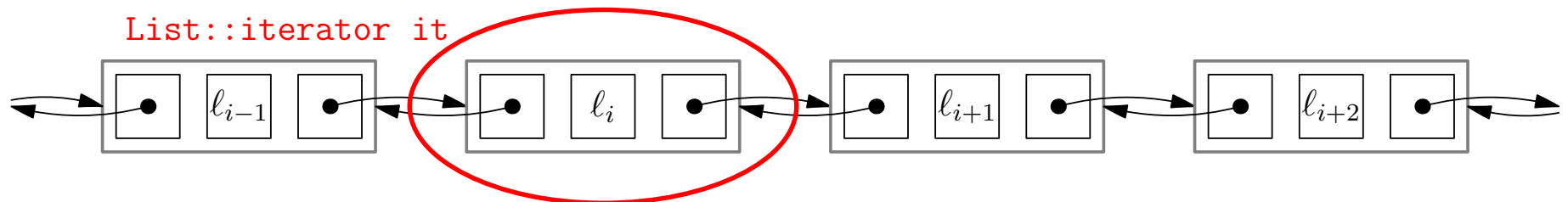
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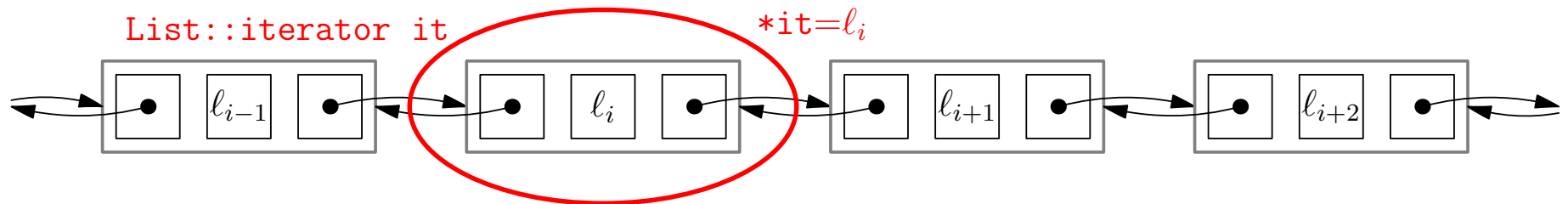
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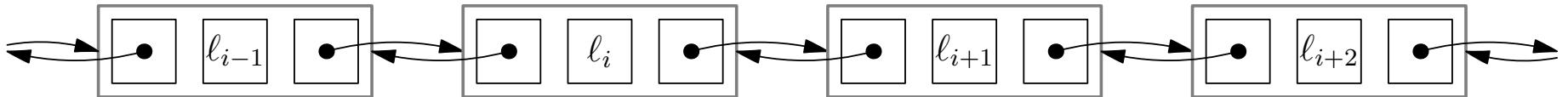
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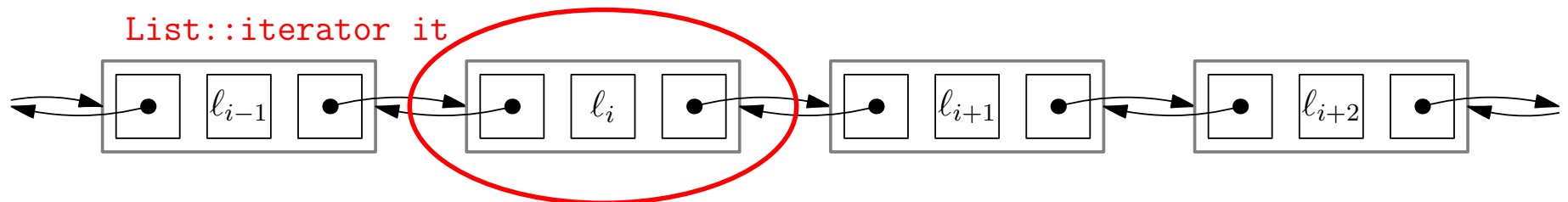
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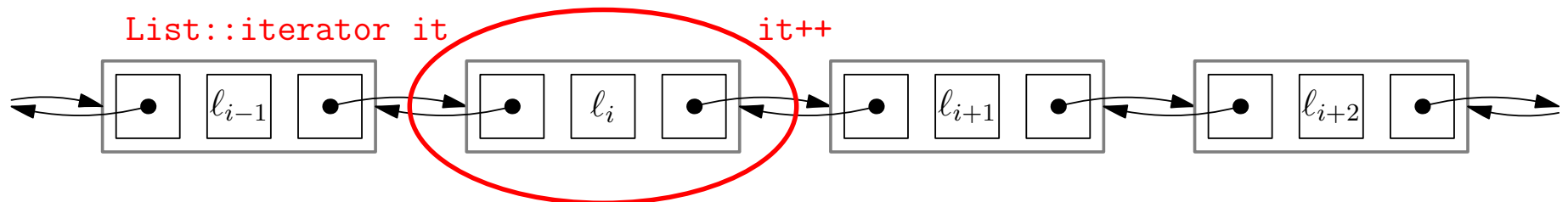
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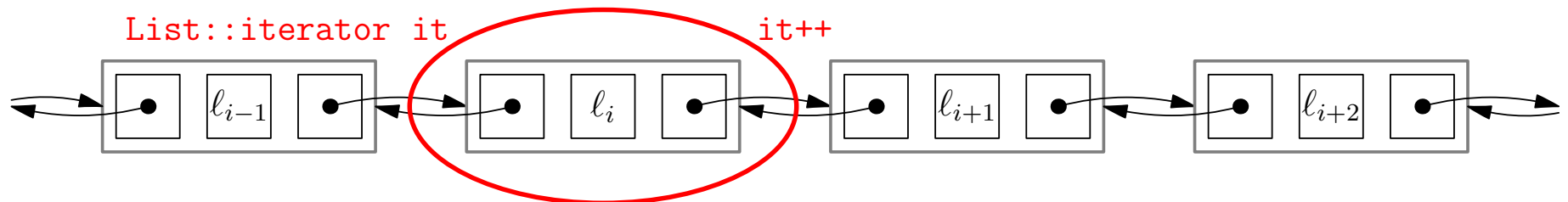
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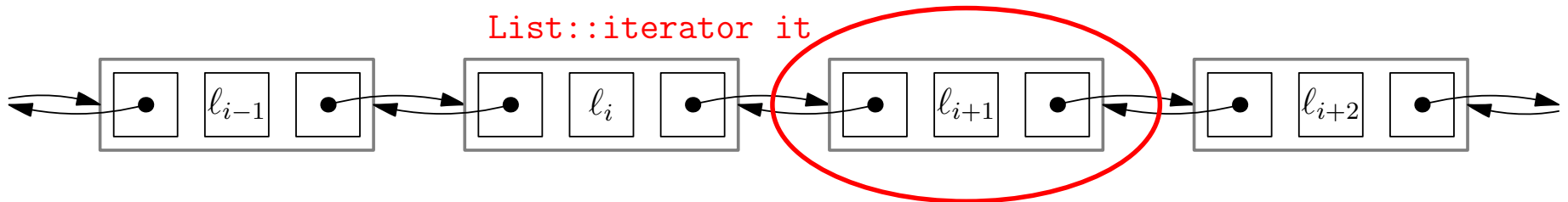
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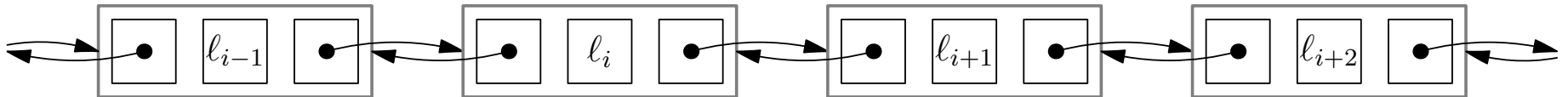
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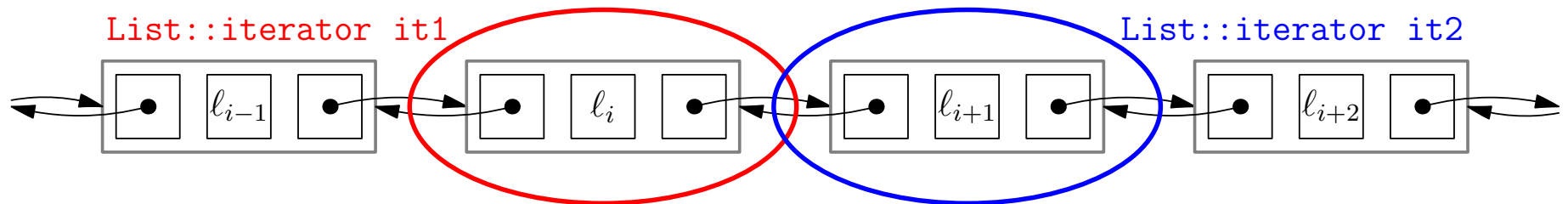
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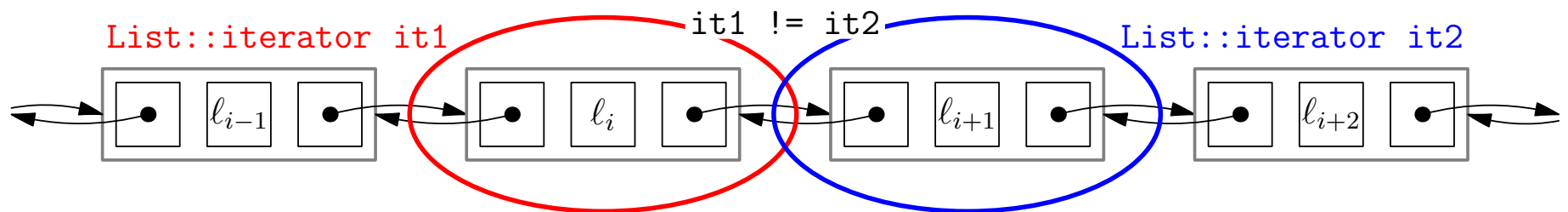
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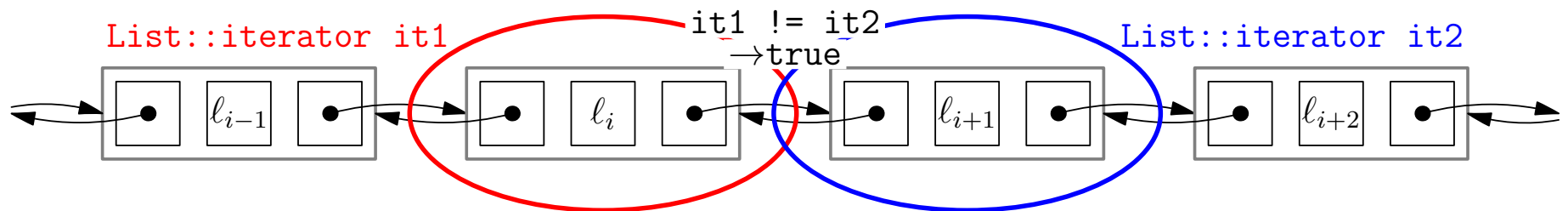
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    iterator end() {return nullptr;}
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Increment Operators

- C++ has a pre-increment operator `++a` and a post-increment operator `a++`

- The pre-increment operator increments *a* and returns the incremented version, e.g.

```
T& operator++() {++count; return *this;} // defines ++a
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- The post-increment operator copies *a* increments it and returns the copy, e.g.

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T operator++(int) {T b=a; ++count; return b;} // defines a++
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Const Iterators

- C++ uses the compiler to test whether functions change their argument or not

```
func1(Class obj)    // obj is copied so will only modify copy  
func2(Class& obj)   // passed by reference, might change obj  
func3(const Class& Obj) // will not change obj
```

- func3 will only call methods of Obj that are const

```
class Class {  
    void method() const;    // won't change the object  
    void change();         // might change the object  
}
```

- We want to declare a const iterator so need to define

```
const T& operator*() const // const dereferencing operator
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Const Iterators

- C++ uses the compiler to test whether functions change their argument or not

```
func1(Class obj)    // obj is copied so will only modify copy
func2(Class& obj)   // passed by reference, might change obj
func3(const Class& Obj) // will not change obj
```

- func3 will only call methods of Obj that are const

```
class Class {
    void method() const; // won't change the object
    void change();       // might change the object
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Bidirectional Iterators

- For the linked list we have implemented a **forward iterator**
- This is the only iterator possible for a singly linked list
- For a doubly linked list we can implement a **bidirectional iterator**
- This requires us to implement the decrement operators

```
T& operator--();           // implements --obj  
T operator--(int);         // implements obj--
```

- There also exist **random-access iterators** that implements methods including

```
T& operator[int i]         // returns i'th element  
operator+=[int i]          // move forward i places
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Outline

1. Iterators
2. The C++ Iterator Pattern
3. Linked-List Iterators
4. **Generic Programming**



Range-Based For Loop

- C++ allows you to iterate over collections elegantly

```
Collection<string> collection;
```

```
for (string& element: collection) {  
    print(element); // or whatever function you want  
}
```

- This is syntactic sugar! The compiler just replaces this with

```
for(auto& it=collection.begin(); it!=collection.end(); ++it) {  
    print(*it);  
}
```

- This works for any class that has an iterator
- **auto** just works out the correct type

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- **auto** just works out the correct type
- By being pretty it reduces bugs in code

Generic Algorithms

- Iterators allow us to write generic functions
- E.g. summing elements

```
template <typename Iter, typename T>
T accum(It it, It end, T init) {
    for(; it != end; ++it)
        init += *it;
    return init;
}
```

- This will sum many collections

```
int array[20];
vector<double> v[5];
set<int> s;
```

```
cout << "array_sum=" << accum(&array[0], &array[20], 0) << endl;
cout << "vector_sum=" << accum(v.begin(), v.end(), 0.0) << endl;
cout << "set_sum=" << accum(s.begin(), s.end(), 0) << endl;
```