Lecture 6a: Interfaces and Iterators

CS 70: Data Structures and Program Development

Tuesday, February 26, 2019

Reading Types

The “Inside Out” (or “Right-to-Left”) Rule

Start “on the inside” at the variable name, and spiral outwards

1. `int x`
2. `Cow barn[10]`
3. `Cow* v`
4. `const int * w1`
5. `int * const w2`
6. `int *z[5]`
7. `int (*y)[4]`
8. `const Cow (* const (*q)[4])[6]`

Interfaces

Interface for a Stack data structure?

const Member Function

In stringstack.hpp

```
class StringStack {
public:
    size_t size() const;
    ...
};
```

Function `size` can't change members of the object it is called upon.

const Member Function

In stringstack.hpp

```
class StringStack {
public:
    size_t size() const;
    ...
};
```

Function `size` can't change members of the object it is called upon.

In stringstack.cpp

```
size_t StringStack::size() const {
    return size;
}
```

Which Member Functions should be `const`?

```
class StringStack {
public:
    void push(const std::string& pushee);
    bool empty();
    std::string& top();     // access top element
    void pop();             // discard top element
private:  ...
};
```

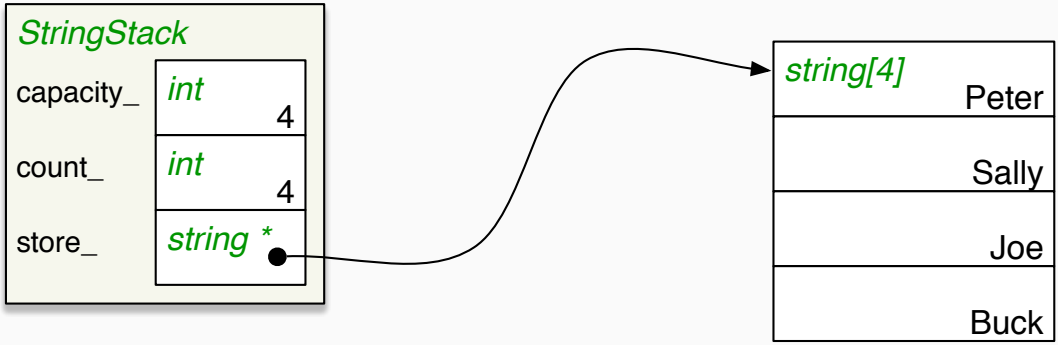
Improved version

```
class StringStack {
public:
    void push(const std::string& pushee);
    bool empty() const;
    std::string& top();
    const std::string& top() const;
    void pop();
private: ...
};
```

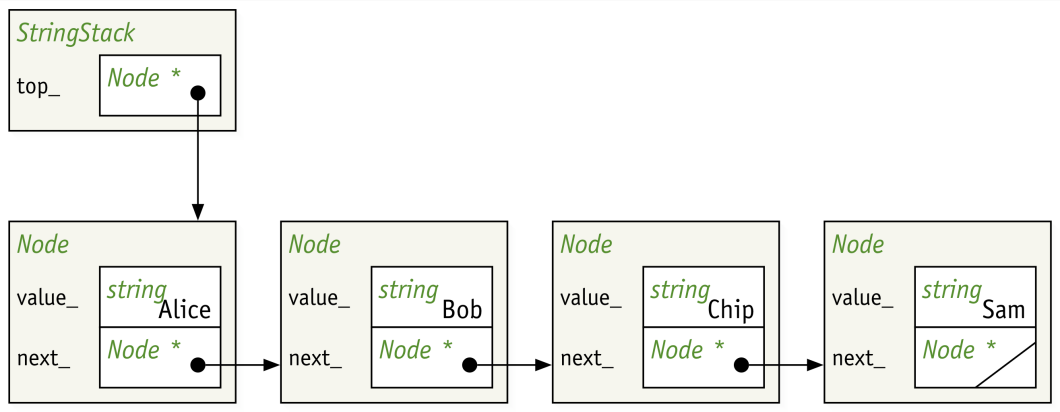
const Member Functions in Practice

```
void stackTest(StringStack& s, const StringStack& cs) {
    s.push("Hi!");
    cs.push("Hello?"); //compiler error: push is not const

    std::string& x = s.top();
    x = "Hey!"; //changes the top element of s
    s.top() = "Hiya!"; //changes the top element of s

    std::string& y = cs.top(); //compiler error
    cs.top() = "Howdy!"; //compiler error
    const std::string& z = cs.top(); //ok
}
```

Implementation 1: Dynamic Array



Implementation 2: Linked Lst



Extending the interface

Suppose we want to access all elements of a `StringStack`?

- Print the current stack elements for debugging
- Check whether the stack contains a particular string
- Check whether the stack contains two copies of the same string
- ...

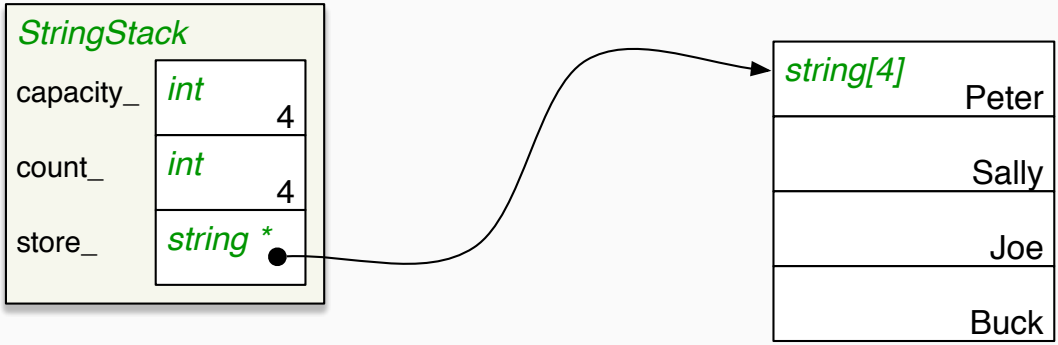
Option 1. Strengths and weaknesses?

```
class StringStack {
public:
    void push(const std::string& pushee);
    ...etc...

    void print() const;
    bool hasString(const std::string& searchee) const;
    bool hasDuplicates() const;
    ...etc...
};
```

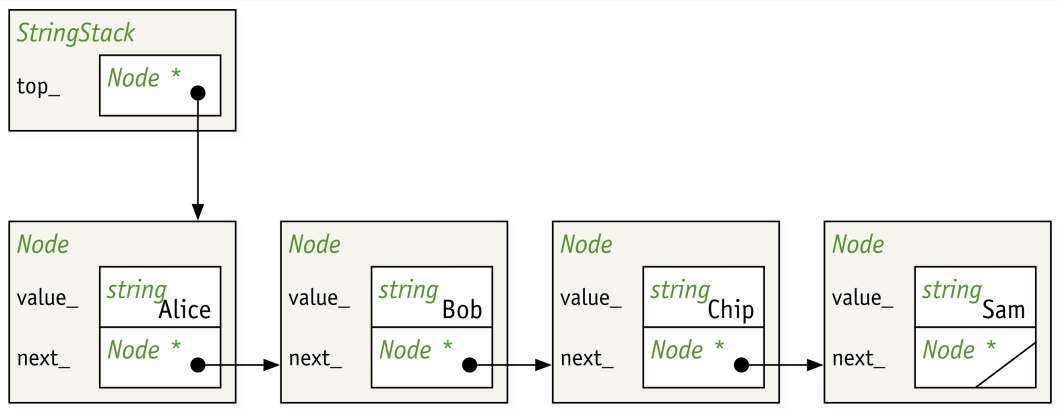
Option 2. Strengths and weaknesses?

```
class StringStack {
public:
    void push(const std::string& pushee);
    size_t size() const;
    ...etc...

    std::string& operator[](size_t index);
    const std::string& operator[](size_t index) const;

private:
    ...
};
```

Implementation 1: Dynamic Array



Implementation 2: Linked Lst



Printing a Stack

```
void printStack(const StringStack& ss) {
    for (size_t i = 0; i < ss.size(); ++i) {
        cout << ss[i] << " ";
    }
    cout << endl;
}
```

Printing a Stack

```
void printStack(const StringStack& ss) {
    for (size_t i = 0; i < ss.size(); ++i) {
        cout << ss[i] << " ";
    }
    cout << endl;
}
```

With dynamic array implementation: $\Theta(n)$

With linked list implementation: $\Theta(n^2)$

Iterators

Using Iterators Effectively ("Classic" C++)

```
// Print strings in StringStack
for (StringStack::iterator i = ss.begin(); i != ss.end(); ++i){
    cout << *i << endl;
}

// search for searchee in StringStack
bool found = false;
for (StringStack::iterator i = ss.begin(); i != ss.end(); ++i){
    if(*i == searchee){
        found = true;
    }
}
```

Using Iterators Effectively ("Classic" C++)

```
// Print the integers in vector<int> v
for (vector<int>::iterator i = v.begin(); i != v.end(); ++i)
    cout << *i << endl;

// Print characters of string s
for (string::iterator i = s.begin(); i != s.end(); ++i)
    cout << *i << endl;

// Print strings of set<string> t
for (set<string>::iterator i = t.begin(); i != t.end(); ++i)
    cout << *i << endl;

// Print booleans in list<bool> l
for (list<bool>::iterator i = l.begin(); i != l.end(); ++i)
    cout << *i << endl;
```

Arrays and pointer arithmetic

For a primitive array `data`, the following are equivalent:

```
for (size_t i = 0; i < DATA_LEN; ++i) {
  std::cout << data[i];
}

for (size_t i = 0; i < DATA_LEN; ++i) {
  std::cout << *(data+i);
}
```

Arrays and pointer arithmetic

The following are equivalent (if it's an array of `strings`)

```
for (size_t i = 0; i < DATA_LEN; ++i) {
  std::cout << data[i];
}

for (size_t i = 0; i < DATA_LEN; ++i) {
  std::cout << *(data+i);
}

for (std::string* p = data; p != data + DATA_LEN; ++p) {
  std::cout << *p;
}
```

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- The standard C++ iterator syntax is similar, and pointers are a nice metaphor to reason about the syntax of iterators.
- The iterator implementation can be wildly different under the hood.

What operations do we need to implement?

```
// Print strings in StringStack
for (StringStack::iterator i = ss.begin(); i != ss.end(); ++i){
    cout << *i << endl;
}

// search for searchee in StringStack
bool found = false;
for (StringStack::iterator i = ss.begin(); i != ss.end(); ++i){
    if(*i == searchee){
        found = true;
    }
}
```

Supporting Stack Iterators

```
class StringStack {
 public:
    ...push, pop, top, empty...

    class iterator {
     public:
       iterator(const iterator&) = default;
       bool         operator!=(const iterator& rhs) const;
       iterator&    operator++();
       std::string& operator*() const;
     private: ...
    };
    iterator begin();
    iterator end();
 private: ... };
```

Using iterators, how could we

1. Sum all the elements in a `StringStack`?
2. Count the number of `"moo"` contained in a `StringStack`?
3. Check if a `StringStack` is empty (without calling `.empty()`)?

Learning Targets

1. I can read complicated C++ types.
2. I can explain why iterators are useful in C++.
3. I can describe what functionality a class must support to have iterators.
4. I can write code that uses iterators to loop through collections.