Smart Pointers

Object-Oriented Programming with C++

Zhaopeng Cui

std smart pointers

- Standard library holder for raw pointers on stack
- Releases resource when destroyed

```
template <class X> std::auto_ptr {
public:
    explicit auto_ptr(X* = 0) throw();
    auto_ptr(auto_ptr&) throw();
    auto_ptr& operator=(auto_ptr&) throw();
    ~auto_ptr();
    X& operator*() const throw();
    X* operator->() const throw();
    ...
};
```

std smart pointers

- Standard library holder for raw pointers on stack
  - std::auto_ptr (deprecated in C++11)
  - std::unique_ptr
  - std::shared_ptr
  - std::weak_ptr
  - …

See SmartPointerExample.cpp

Putting it all together

Templates

Inheritance

Reference Counting

Smart Pointers

Reference: *C++ Strategies and Tactics*, Robert Murray, 1993

Goals

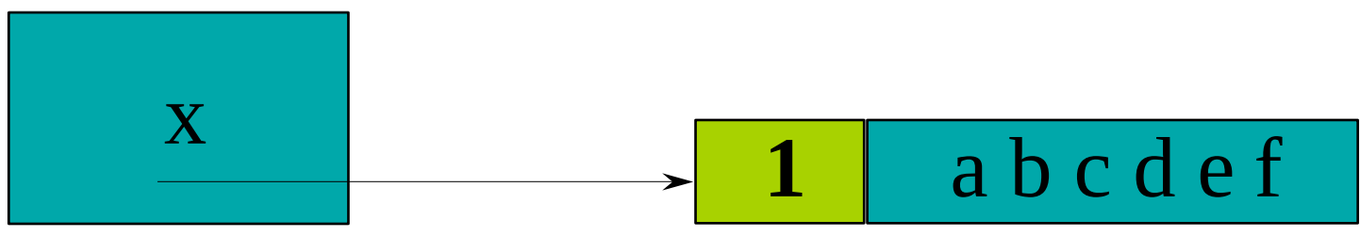
- Introduce the code for maintaining reference counts
  – A reference count is a count of the number of times an object is shared
  – Pointer manipulations have to maintain the count

- Class UCObject holds the count
  –"Use-counted object “

- UCPointer is a *smart pointer* to a UCObject
  – A smart pointer is an object defined by a class
  – Implemented using a template
  – Overloads operator-> and unary operator*

Reference counts in action

String x("abcdef");

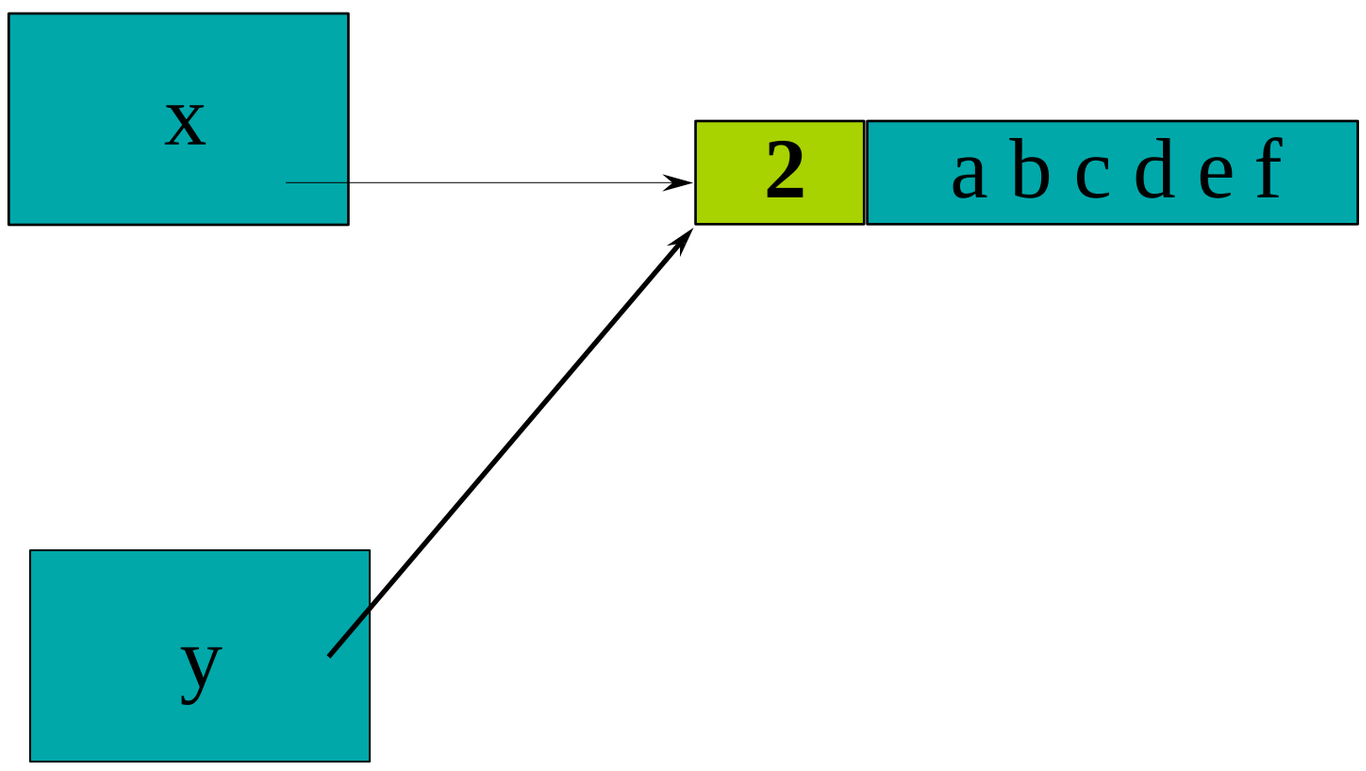


Shared memory maintains a count of how many times it is shared

Reference counts in action

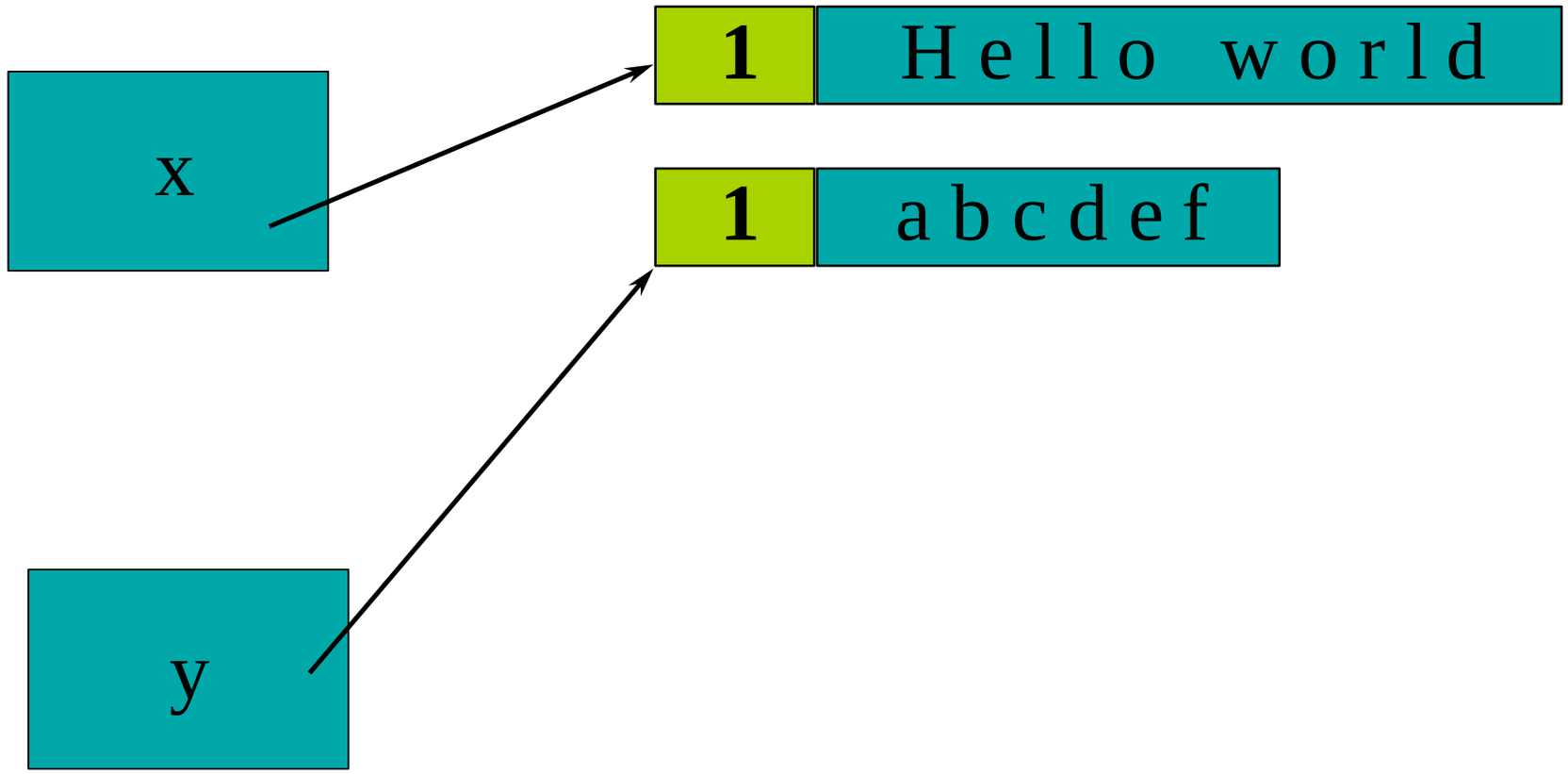
String x("abcdef");

String y = x; // shallow copy of x



Reference counts in action

```
String x("abcdef");
String y = x; // shallow copy of x
x = "Hello world";  // copy on write
```



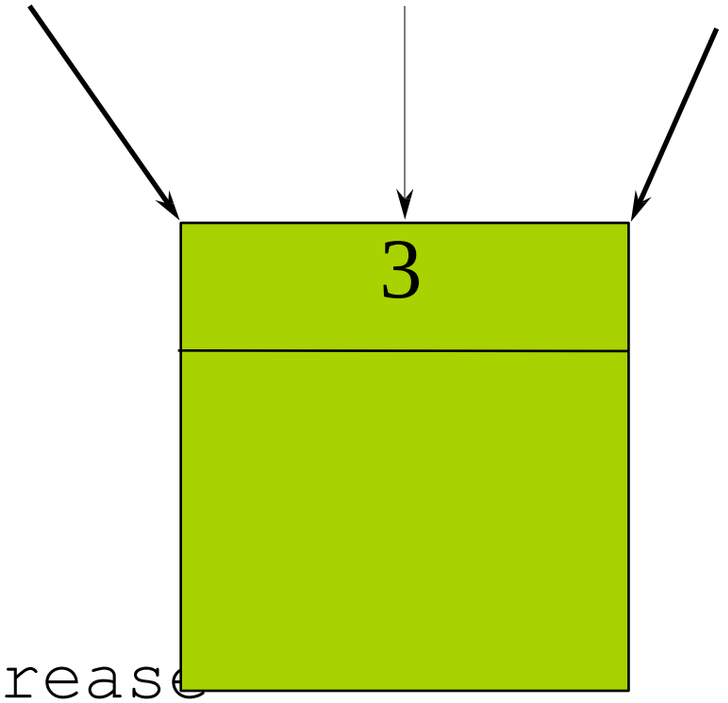
Reference counting

- Each shareable object has a counter
- Initial value is 0
- Whenever a pointer is assigned:

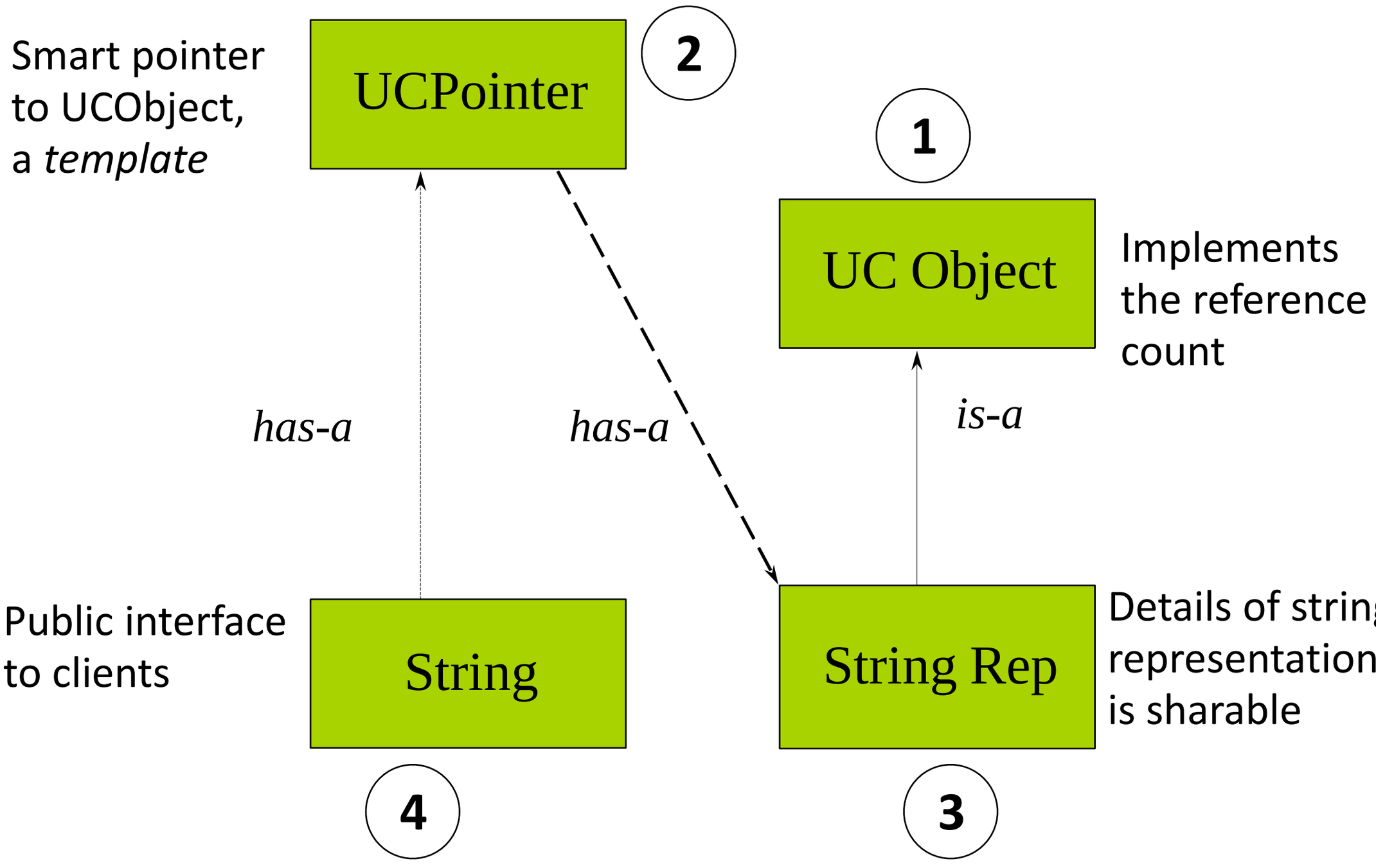
  p = q;

- Have to do the following

```
p->decrement(); // p's count will decrease
p = q;
p->increment(); // q/p's count will increase
```



The four classes involved



Reusing reference counting

```
#include <assert.h>
class UCObject {
public:
    UCObject() : m_refCount(0) { }
    virtual ~UCObject() { assert(m_refCount == 0); }
    UCObject(const UCObject&) : m_refCount(0) { }
    void incr() { m_refCount++; }
    void decr();
    int references() { return m_refCount; }
private:
    int m_refCount;
};
```

UCObject continued

```
inline void UCObject::decr(){
   m_refCount -= 1;
   if (m_refCount == 0) {
      delete this;
   }
}
```

- “delete this” is legal
  - But don't use this afterward

Class UCPointer

```
template <class T>
class UCPointer {
private:
     T* m_pObj;
     void increment() { if (m_pObj) m_pObj->incr(); }
     void decrement() { if (m_pObj) m_pObj->decr(); }
public:
     UCPointer(T* r = 0): m_pObj(r) { increment(); }
     ~UCPointer() { decrement(); }
     UCPointer(const UCPointer<T> & p);
     UCPointer& operator=(const UCPointer<T> &);
     T* operator->() const;
     T& operator*() const { return *m_pObj; }
};
```

UCPointer copy ctor

```
template <class T>
UCPointer<T>::UCPointer(const UCPointer<T> & p) {
   m_pObj = p.m_pObj;
   increment();
}
```

UCPointer assignment

```
template <class T>
UCPointer<T>&
UCPointer<T>::operator=(const UCPointer<T>& p) {
   if (m_pObj != p.m_pObj) {
      decrement();
      m_pObj = p.m_pObj;
      increment();
   }
   return *this;
}
```

The UCPointer `operator->`

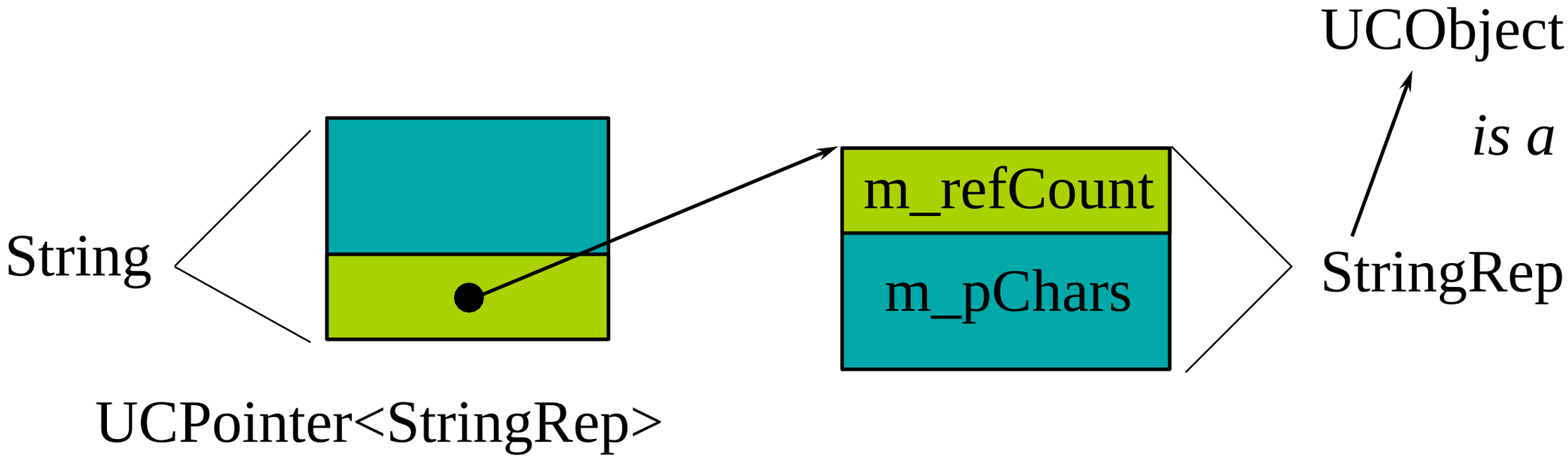
```
template<class T>
T* UCPointer<T>::operator->() const {
    return m_pObj;
}
```

- Example: Shape inherits from UCObject.

```
Ellipse *pEll = new Ellipse(200F, 300F);
UCPointer<Shape> p(pEll);
p->render(); // calls Ellipse::render() on
elly!
```

Envelope and Letter

- Envelope provides protection
- Letter contains the contents



Class String

```
class String {
public:
    String(const char *);
    ~String();
    String(const String&);
    String& operator=(const String&);
    int operator==(const String&) const;
    String operator+(const String&) const;
    int length() const;
    operator const char*() const;
private:
    UCPointer<StringRep> m_rep;
};
```

Class StringRep

```
class StringRep : public UCObject {
public:
    StringRep(const char *);
    ~StringRep();
    StringRep(const StringRep&);
    int length() const{ return strlen(m_pChars); }
    int equal(const StringRep&) const;
private:
    char *m_pChars;
};
```

StringRep implementation

```
StringRep::StringRep(const char *s) {
    if (s) {
        int len = strlen(s) + 1;
        m_pChars = new char[len];
        strcpy(m_pChars , s);
    } else {
        m_pChars = new char[1];
        *m_pChars = '\0';
    }
}
StringRep::~StringRep() {
    delete [] m_pChars ;
}
```

StringRep implementation

```
StringRep::StringRep(const StringRep& sr) {
   int len = sr.length();
   m_pChars = new char[len + 1];
   strcpy(m_pChars , sr.m_pChars );
}

int StringRep::equal(const StringRep& sp)
const {
   return (strcmp(m_pChars, sp.m_pChars) == 0);
}
```

String implementation

```
String::String(const char *s)
    : m_rep(new StringRep(s)) {}

String::~String() {}

// Again, note constructor for rep in list.
String::String(const String& s) : m_rep(s.m_rep) {}

String&
String::operator=(const String& s) {
    m_rep = s.m_rep; // let smart pointer do work!
    return *this;
}
```

String implementation

```
int
String::operator==(const String& s) const {
    // overloaded -> forwards to StringRep
    return m_rep->equal(*s.m_rep); // smart ptr *
}
```

```
int
String::length() const {
    return m_rep->length();
}
```

Critique

- UCPointer maintains reference counts
- UCObject hides the details of the count, String is very clean
- StringRep deals only with string storage and manipulation
- UCObject and UCPointer are reusable
- Slower than raw pointers
- Intrusive design
  - see `std::shared_ptr` for non-intrusive design