UCLA Samueli Computer Science

CS32: Introduction to Computer Science II

Discussion Week 2

Yichao (Joey)

April 10, 2020

Credit: Carey Nachenberg, Junheng Hao

Hello, CS32!

UCLA Samueli Computer Science

- Course website: http://web.cs.ucla.edu/classes/spring20/cs32/
- CS32 Discussion 1j
  - Time and place: 2:00-3:50pm, Friday
  - Discussion sessions on week 2-10
- TA: Yichao(Joey) Zhou
  - Email: yichao.joey.zhou@gmail.com
  - Office Hours: Wednesdays 10:30-11:30am & 4:30-6:30pm & Fridays 8:30-9:30am
- LA:
  - Email:
  - Office Hours:
- Discussion Website: https://yz-joey.github.io/teaching/

  (Slides will be posted here!)

About me

UCLA Samueli Computer Science

- I am a third-year PhD candidate at ScAi Data Mining Lab, Department of Computer Science, working with Prof. Wei Wang and Prof. Kai-Wei Chang.
- Other courses I taught: CS145 (Intro to data mining) CS146 (Intro to machine learning), CS30
- Research Interests:
  - Natural Language Processing
    - Language Understanding
  - Data Mining
    - Information Extraction, Text Mining
  - Healthcare + AI

More about my research

UCLA Samueli Computer Science

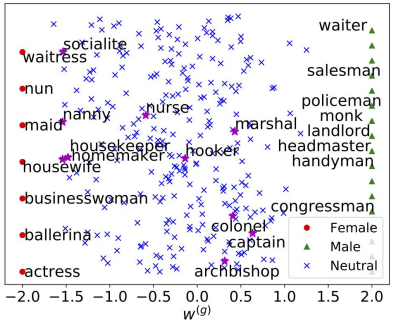
→ Natural Language Understanding

Pun Recognition and Generation

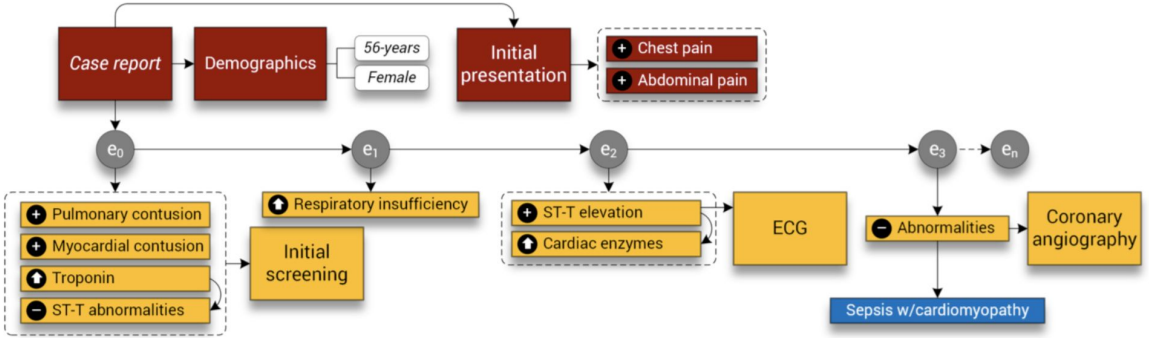
	Homographic Puns
1.	Did you hear about the guy whose whole left side was cut off? He's **all right** now.
2.	I'd tell you a chemistry joke but I know I wouldn't get a **reaction**.
	Heterographic Puns
1.	The boating store had its best **sail (sale)** ever.
2.	I lift weights only on Saturday and Sunday because Monday to Friday are **weak (week)** days.

Table 1: Examples of homographic and heterographic puns.

Gender-neutral Embedding



→ Health Care + AI



Research Opportunities at ScAi

UCLA Samueli Computer Science

- Start your research experiences in AI/Data mining/NLP areas ***EARLY***!
- Ask yourself:
  - Your background on programming (python preferred), math & statistics (linear algebra, probability, calculus) and machine learning/data mining knowledge
  - Your past project/research experiences
  - How many hours per week (on average) can you contribute to research? Balance your coursework and other activities.

About the course

UCLA Samueli Computer Science

What you will learn in this course…

More about C++ and data structures. Well, that's a lot. And very important.

- Review of C++
- **Object-oriented programming:** Data abstraction, Inheritance and Polymorphism, Recursion, …
- **Data structures:** Arrays, Lists, Trees, Graphs, Hash tables, …
- **Algorithms** (eg. sorting) **and complexity analysis**

CS32 is the most beneficial course for your future job interview if you apply for Software Development Engineers (SDE).

About the discussion

UCLA Samueli Computer Science

- Part 1: Review lectures
  - Review some topics, questions and examples based on last week's lectures
  - Some extended topics from lectures
  - Some typical questions & examples
  - Homework & projects
- Part 2: Exercise
  - Hands-on exercise questions (from worksheets) in groups

Tell me what you'd like to do in the discussion!

- If you have conceptual questions or problems about lectures, ...
- If you find some problems (not limited in worksheets) are particularly difficult for you, ...
- Then, write emails about it to me with **keyword "`CS32-DisQ`"** !

Announcements

UCLA Samueli Computer Science

- Homework 1 is due on
- Project 2 is due on

Special Notes

UCLA Samueli Computer Science

Important: Special notes about homework and projects!

1. Check projects & homework requirements first! You may **get 0** if you do not follow these guidelines and restrictions!
2. When debugging, check your error message! Search Google or Stackoverflow for similar error and find possible reasons.
3. Do **NOT** let you TAs or LAs debug through emails (almost impossible actually)!
4. Others...

Outline Today

UCLA Samueli Computer Science

- Dynamic memory allocation in C++
- Constructor, destructor, copy constructors, and assignment operators
- Data structure: Arrays & Linked Lists (probably just start)

Dynamic memory allocation

- Let's first compare with *Static Memory Allocation*!
- If we want to type in a paragraph and save it into a C-string,

```
#define MAXLENGTH 10000
char s[MAXLENGTH+1];
cin.getline(s);
```

- What if the paragraph is extremely long? → Out-of-bound
- What if the paragraph has only five words? → Overallocated Memory (Waste)

Dynamic memory allocation

`new` in C++

UCLA Samueli Computer Science

What if we want to fit the paragraph into a C-string with right the sufficient size?

```
<type> *<name> = new <type>[<#elements>];
char *article = new char[length];
```

int variable

`new` will dynamically allocate the sequential memory space for the requested data type and size and return the starting address of the allocated memory space.

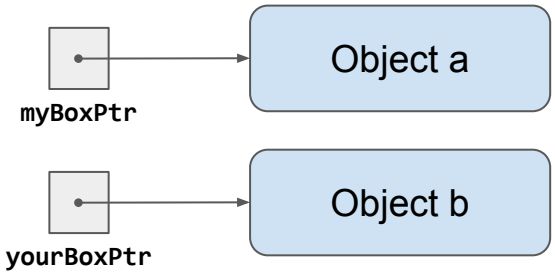
Variables allocated with `new` will remain in the memory unless we manually delete it which means dynamic allocation has to be deleted once we no longer use it.

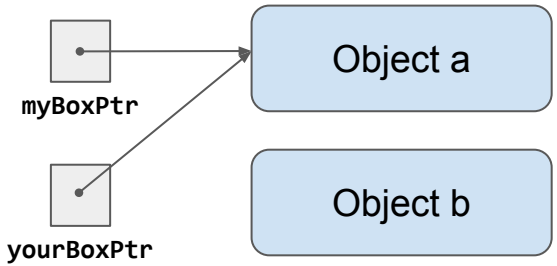
```
delete [] article
```

Dynamic memory allocation

Memory Leak

UCLA Samueli Computer Science






```
// Create first object
MagficBox* myBoxPtr = new MagficBox

// Create second object
MagficBox* yourBoxPtr = new MagficBox

// Assignment causes an inaccessible object (b)
yourBoxPtr =  myBoxPtr
```

Dynamic memory allocation

A Problematic Code (1)

UCLA Samueli Computer Science

```
#include <iostream>
#include <string>
using namespace std;

class Node{
public:
    Node(int id){
        cout << "Constructor:" << id << endl;
        this->id = id;
    }
    ~Node(){
        cout << "Destructor:" << this->id << endl;
    }
private:
    int id;
};

int main(){
    Node node1(31);
    Node* node2 = new Node(32);
    // do something
    return 0;
}
```

Q: What is the output of this simple “node” program?

```
Constructor:31
Constructor:32
Destructor:31
```

Node(32) does not deconstruct!

Dynamic memory allocation

A Problematic Code (2)

UCLA Samueli Computer Science

Let's check it by Valgrind!

```cpp
#include <iostream>
#include <string>
using namespace std;

class Node{
public:
    Node(int id){
        cout << "Constructor:" << id << endl;
        this->id = id;
    }
    ~Node(){
        cout << "Destructor:" << this->id << endl;
    }
private:
    int id;
};

int main(){
    Node node1(31);
    Node* node2 = new Node(32);
    // do something
    return 0;
}
```

```
jeffhao@jeffhao:~/Desktop/CS32_example/memleak$ valgrind --leak-check=yes ./node_prog
==10005== Memcheck, a memory error detector
==10005== Copyright (C) 2002-2015, and GNU GPL'd, by Julian Seward et al.
==10005== Using Valgrind-3.11.0 and LibVEX; rerun with -h for copyright info
==10005== Command: ./node_prog
==10005==
Constructor:31
Constructor:32
Destructor:31
==10005==
==10005== HEAP SUMMARY:
==10005==     in use at exit: 72,708 bytes in 2 blocks
==10005==   total heap usage: 3 allocs, 1 frees, 73,732 bytes allocated
==10005==
==10005== 4 bytes in 1 blocks are definitely lost in loss record 1 of 2
==10005==    at 0x4C2E0EF: operator new(unsigned long) (in /usr/lib/valgrind/vgpreload_memcheck-amd64
-linux.so)
==10005==    by 0x400ACA: main (in /home/jeffhao/Desktop/CS32_example/memleak/node_prog)
==10005==
==10005== LEAK SUMMARY:
==10005==    definitely lost: 4 bytes in 1 blocks
==10005==    indirectly lost: 0 bytes in 0 blocks
==10005==      possibly lost: 0 bytes in 0 blocks
==10005==    still reachable: 72,704 bytes in 1 blocks
==10005==         suppressed: 0 bytes in 0 blocks
==10005== Reachable blocks (those to which a pointer was found) are not shown.
==10005== To see them, rerun with: --leak-check=full --show-leak-kinds=all
==10005==
==10005== For counts of detected and suppressed errors, rerun with: -v
==10005== ERROR SUMMARY: 1 errors from 1 contexts (suppressed: 0 from 0)
```

Dynamic memory allocation

Good memory example from textbook

UCLA Samueli Computer Science

```
/** @file GoodMemory.cpp */
# include “GoodMemory.h”

GoodMemory::GoodMemory() : someBoxPtr(nullPtr)
{
} // end default constructor

GoodMemory::~GoodMemory()
{
     delete someBoxPtr;
} // end constructor

void GoodMemory::unleakyMethod(const double& someItem)
{
     someBoxPtr = new ToyBox<double>();
     someBoxPtr->setItem(someItem)
} // end unleakyMethod
```

Construction & Destruction

Class Composition

UCLA Samueli Computer Science

Class composition is when a class contains one or more member variables that are objects.

Order of construction:

- Member variables are constructed in order.
- Then the current class constructor is executed.

Order of destruction:

- The current class destructor is executed first.
- The member variables are destructed in the reverse order.

Summary:

- Constructor: Inside -> Outside (In-order)
- Destructor: Outside -> Inside (Reverse Order)

Construction & Destruction

UCLA Samueli Computer Science

Question: For classes containing members of a class type, what is the order of construction and destruction?

What is the output?

Answer:

A(444)
A(888)
B()
~B()
~A(888)
~A(444)

```
#include <iostream>
#include <string>
using namespace std;

class A
{
public:
        A(){cout << "A()" << endl;}
        A(int x){cout << "A(" << x << ")" << endl; this->id = x;}
        ~A(){cout << "~A("<< this->id <<")" << endl;}
private:
        int id;
};

class B
{
public:
        B():a1(888),a2(444){cout << "B()" << endl;}
        ~B(){cout << "~B()" << endl;}
private:
        A a2;
        A a1;
};

int main()
{
        B b;
        return 0;
}
```

Construction & Destruction

UCLA Samueli Computer Science

Note: There is a difference between class composition and class inheritance. → Will be explained in later lectures.

```cpp
#include <iostream>
#include <string>
using namespace std;

class A
{
public:
    A(){cout << "A()" << endl;}
    A(int x){cout << "A(" << x << ")" << endl;}
    ~A(){cout << "~A()" << endl;}
};

class B
{
public:
    B():a1(1),a2(2){cout << "B()" << endl;}
    ~B(){cout << "~B()" << endl;}
private:
    A a2;
    A a1;
};

int main()
{
    B b;
    return 0;
}
```

```cpp
#include <iostream>
#include <string>
using namespace std;

class A
{
public:
    A(){cout << "A()" << endl;}
    A(int x){cout << "A(" << x << ")" << endl;}
    ~A(){cout << "~A()" << endl;}
};
class B : public A
{
public:
    B():a1(1),a2(2){cout << "B()" << endl;}
    ~B(){cout << "~B()" << endl;}
private:
    A a2;
    A a1;
};

int main()
{
    B b;
    return 0;
}
```

Initializer List (Must)

UCLA Samueli Computer Science

For initialization of non-static const data members

```
#include<iostream>
using namespace std;

class Test {

public:
    Test(int x):t(x)  {}  //Initializer list must be used
    int getT() { return t; }
private:
    const int t;
};

int main() {
    Test t1(10);
    cout<<t1.getT();
    return 0;
}
```

Initializer List (Must)

UCLA Samueli Computer Science

For initialization of reference members

Reference members must be initialized using Initializer List. In the following example, “t” is a reference member of Test class and is initialized using Initializer List.

```
#include<iostream>
using namespace std;
class Test {
public:
    Test(int &t):t(t) {}  //Initializer list must be used
    int getT() { return t; }
private:
     int &t;
};

int main() {
    int x = 20;
    Test t1(x);
    cout<<t1.getT()<<endl;
    x = 30;
    cout<<t1.getT()<<endl;
    return 0;
}
```

Initializer List (Must)

UCLA Samueli Computer Science

For initialization of member objects which do not have default constructor

In the following example, an object “a” of class “A” is data member of class “B”, and “A” doesn’t have default constructor. Initializer List must be used to initialize “a”.

```
#include <iostream>
using namespace std;

class A {
public:
    A(int arg){
    i = arg;
    cout << "A's Constructor
called: Value of i: " << i
<< endl;
};
private:
    int i;
};
```

```
// Class B contains object
of A
class B {
public:
    B(int x):a(x) {
//Initializer list must be
used
    cout << "B's
Constructor called";
};
private:
    A a;
};
```

```
int main() {
    B obj(10);
    return 0;
}
```

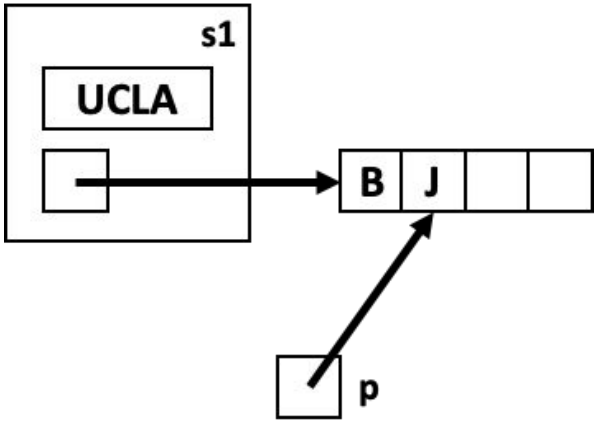
Copy Constructors

Motivation

UCLA Samueli Computer Science

Consider an example of UCLA and its students:

```
Student st1("Brian");
Student st2("John");
School s1("UCLA");
s1.addStudent(st1);
s1.addStudent(st2);
Student *p = s1.getStudent("John");
```



We want to create a new School called s2, with exactly the same content as s1. In other words, we want to clone s1.

```
School s2(""); s2=s1; // Is this correct?
```

Copy Constructors

Shallow copy problem

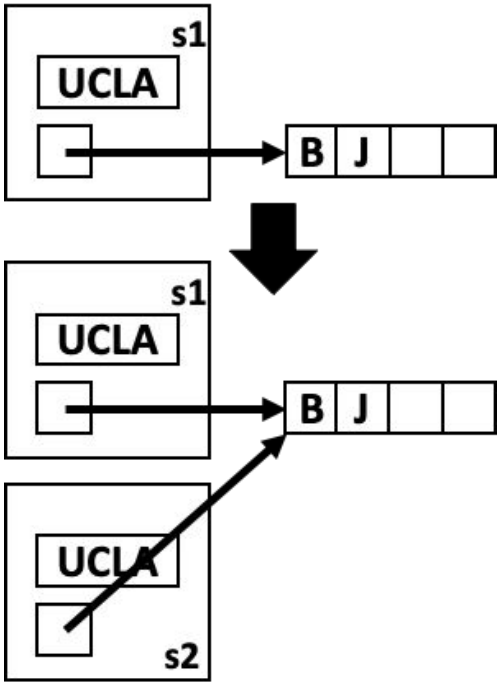
UCLA Samueli Computer Science

We want to create a new School called s2, with exactly the same content as s1. In other words, we want to clone s1.

```
School s2(“”); s2=s1; // Definitely not! Why?
```

What if grab values out of s1 and manually copy them into s2?

```
School s2(“”);
s2.setName(s1.getName( ));
… // copy all members and properties
```



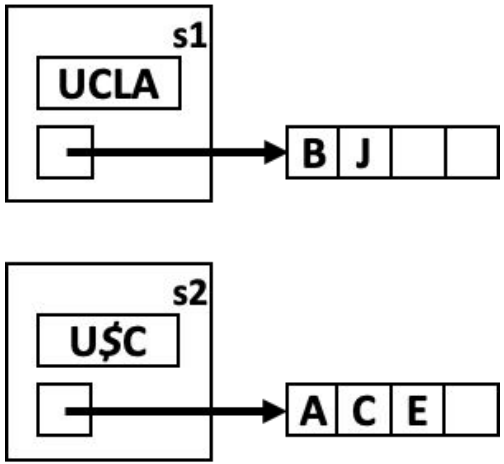
Copy Constructors

Example

UCLA Samueli Computer Science

Immutable. We don't change the object we're copying from.

```
School::School(const School &aSchool){
    m_name = aSchool.m_name;
    m_numStudents = aSchool.m_numStudents;
    m_students = new Students[m_numStudents];
    for (int i = 0; i < m_numStudents; ++i)
        m_students[i] = aSchool.m_students[i];
}
```



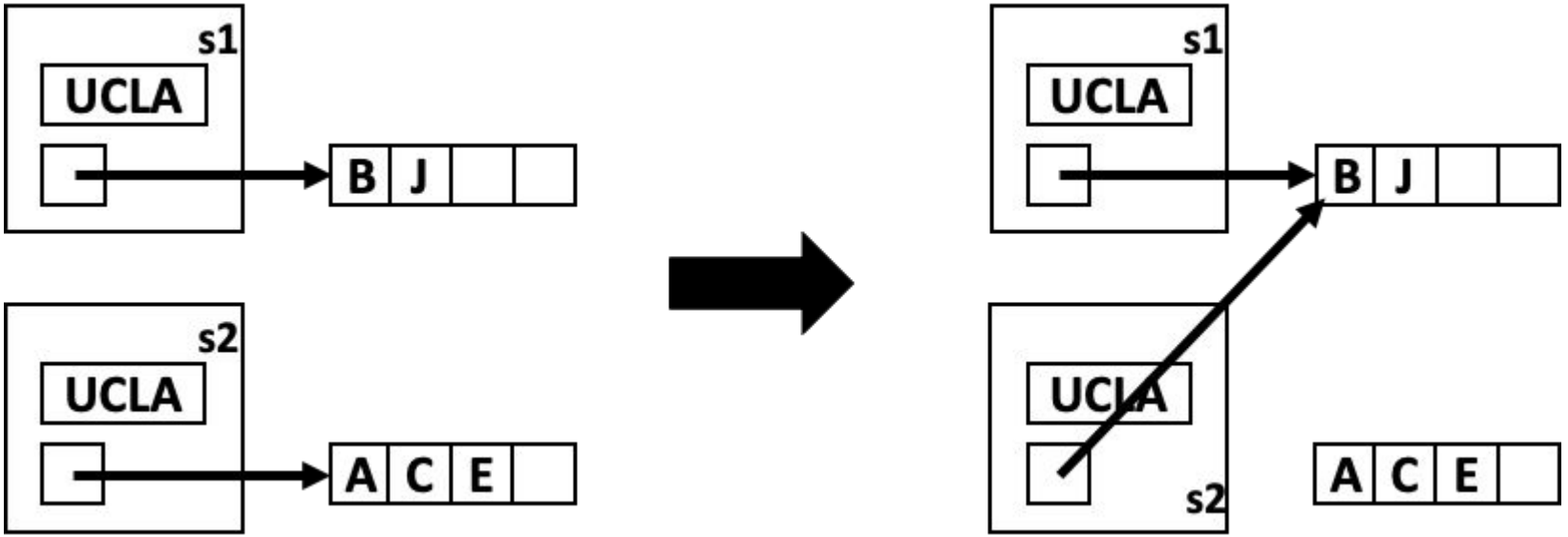
Now you can do: `School s2(s1);`

Assignment Operator

Motivation

UCLA Samueli Computer Science

What if `s2 = s1`?



Assignment Operator

Example

UCLA Samueli Computer Science

Assignment operator

- Overload the operator (in this case, we overload the assignment operator).

```
String& String::operator=(const String& rhs)
{
        delete [] m_text;
        m_len = rhs.m_len;
        m_text = new char[m_len+1];
        strcpy(m_text, rhs.m_text);
        return *this;
}
```

*Do not forget *this!*
Return the existing object so we can chain this operator

Assignment Operator

Example

UCLA Samueli Computer Science

Assignment operator

- Overload the operator (in this case, we overload the assignment operator).

```
String& String::operator=(const String& rhs)
{
        delete [] m_text;
        m_len = rhs.m_len;
        m_text = new char[m_len+1];
        strcpy(m_text, rhs.m_text);
        return *this;
}
```

What if it's a self-assignment?
String sa[100];
…
sa[i] = sa[j]; // i == j

Assignment Operator

Example

UCLA Samueli Computer Science

Assignment operator

- Overload the operator (in this case, we overload the assignment operator).

```
String& String::operator=(const String& rhs)
{
        delete [] m_text;
        m_len = rhs.m_len;
        m_text = new char[m_len+1];
        strcpy(m_text, rhs.m_text);
        return *this;
}
```

* Then sa[i] = sa[j], which the compiler turns into sa[i].operator=(sa[j]), calls String::operator= with the _this_ pointer pointing to the same string object that rhs is a reference to.
* So the delete [] text; gets rid of the dynamic array with the text of the string,
* So rhs.m_text is a dangling pointer, yielding undefined behavior for strcpy.

Assignment Operator

Example

UCLA Samueli Computer Science

Make it better:

```
String& String::operator=(const String& rhs)
{
        if (this != &rhs)
        {
                delete [] m_text;
                m_len = rhs.m_len;
                m_text = new char[m_len+1];
                strcpy(m_text, rhs.m_text);
        }
        return *this;
}
```

Since the goal of assignment is to make the left hand side object look like a copy of the right hand side object, if the two objects are the **same object**, the goal is immediately met, so the classic solution is to check for that:

Assignment Operator

Example

UCLA Samueli Computer Science

The classic way of implementing an assignment operator is problematic, and we don't like the duplication of code between the copy constructor and assignment operator, so try to have the assignment operator call the copy constructor.

One modern approach is the copy-and-swap idiom.

We give our class a swp function that swaps the values of two Strings by individually swapping each data member:

```
void String::swap(String& other)
{
        ... // exchange the m_len and other.m_len ints
        ... // exchange the m_text and other.m_text pointers
}
```

Assignment Operator

Example

UCLA Samueli Computer Science

It is essential that this function **does not** instead just swap the two Strings using String's assignment operator;
we **don't** do String temp(other); other = *this; *this = temp.

```
String& String::operator=(const String& rhs)
{
        if (this != &rhs)
        {
                String temp(rhs);
                swap(temp);
        }
        return *this;
}
```

Elegant!
Creating temp calls the copy constructor,
swap installs the copy of rhs in *this and puts the old value of *this into temp, and
when temp goes out of scope, the destructor gets rid of the old value.

http://web.cs.ucla.edu/classes/winter20/cs32/l2/string.txt

Assignment Operator

Example

UCLA Samueli Computer Science

```
#include<iostream>
using namespace std;

class Test
{
    public:
    Test() {}
    Test(const Test &t)
    {
        cout<<"Copy constructor called "<<endl;
    }
    Test& operator = (const Test &t)
    {
        cout<<"Assignment operator called "<<endl;
        return *this;
    }
};
```

```
int main()
{
    Test t1, t2;
    t2 = t1;
    Test t3 = t1;
}
```

Output:

Assignment operator called

Copy constructor called

Data Structure

Before we talk about doing things arrays, let's talk about data structure first!

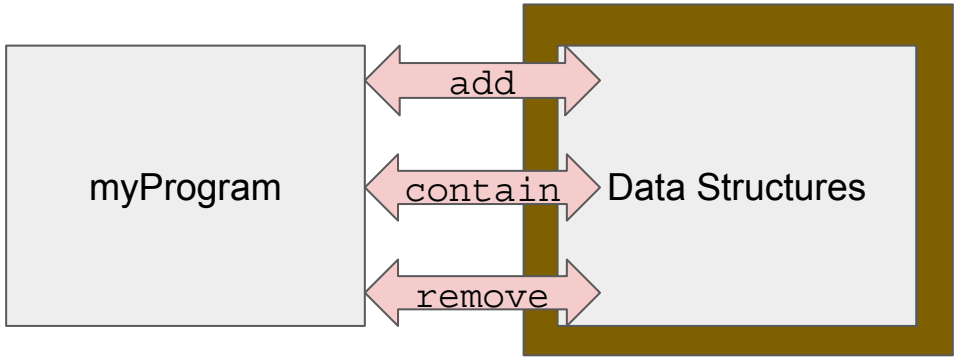
CS32 is not just to write code and run. It is more about organizing data. We call an organization scheme a data structure. For every structure, we define:

- How to **store/organize** the data items?
- Method to **add new data / remove data**
- Apply functions on data: most importantly, how to **search** data?

We also need to know pros and cons of each data structure as well as its efficiency or **complexity of algorithms** with these data structures.

Arrays (as an example)

- Most basic data structure and most important!



- Add / Contain / Remove → Complexity?
- More implementations: getIndexOf, getFrequencyOf, …
- More questions: Using array to implement Linked List? How to sort a array or maintain a sorted array?

Group Exercises: Worksheet 1

UCLA Samueli Computer Science

- Exercise problems from **Worksheet 1** (see “LA worksheet” tab in CS32 website). Answers will be posted after all discussions.
- Our LA will help you go through these problems.