Data Structures

C++ Review

CS 225

Brad Solomon

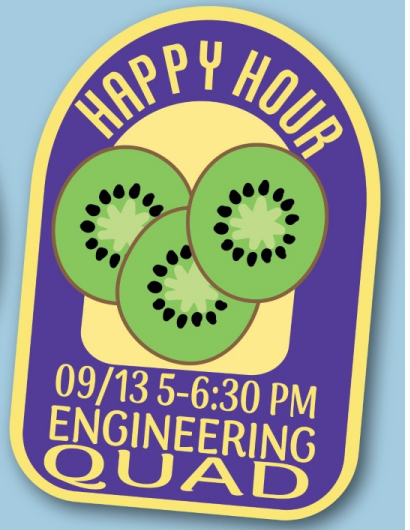
August 28, 2023

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Department of Computer Science

Theta Tau Fall Rush 2024

Freshly Theta Tau!



·····09/14 & 09/15 10 AM-1 PM: INTERVIEWS (ONLINE)·····

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Quad Day

August 25th 12PM-4PM
Main Quad

Business Quad Day

August 27th 3:30PM-6PM
South Quad

Info Nights

August 29th 6PM-7PM
Location TBA

September 3rd 7PM-8PM
Location TBA

Meet & Greet and Case Training

September 4th 7PM-9PM
Location TBA

Please dress business casual for Info Nights, Meet & Greet, and Case Training

Application Deadlines

1. August 30th @ 11:59pm
2. September 6th @ 11:59pm

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- ☑ Resume Booster

student run

apply for fall

Scan for:

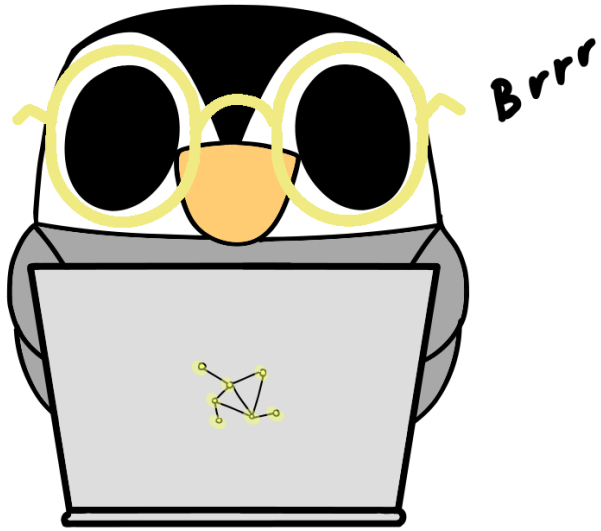
- Website
- Application
- Interest form

(Optional) Open Lab This Week

This week's lab is open office hours

Focus is making sure your machine is setup for semester

Installation information available on website



Office Hours

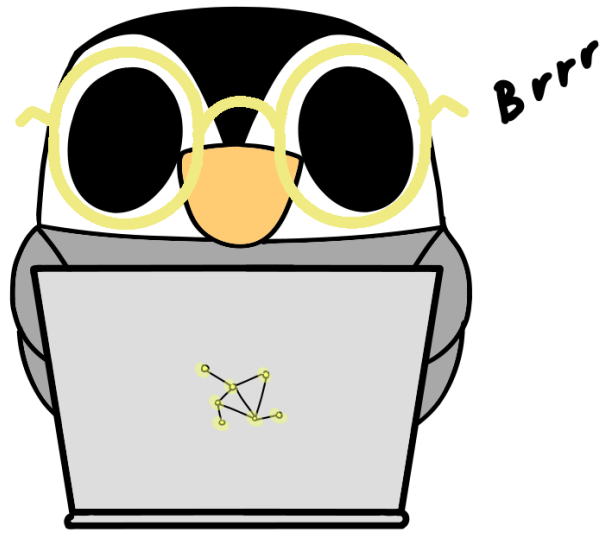
The office hour calendar will be populated next week

For now, please use Discord or Piazza

You can also stop by my regular office hours!

Thursday, 11 AM — 12 PM

Siebel 2233



Testing a 'Clicker' Set-up!

Have you signed up to take exam 0?

A) Yes!

B) No!

Join Code: 225

You can participate by going to website:

https://clicker.cs.illinois.edu/

Exam 0 (9/4 — 9/6)

An introduction to CBTF exam environment / expectations

Quiz on foundational knowledge from all pre-reqs

Practice questions can be found on PL

Topics covered can be found on website

Registration started August 22

https://courses.engr.illinois.edu/cs225/fa2024/exams/

Learning Objectives

A brief high level review of C++

- Fundamentals of Objects / Classes
- Memory Management and Ownership
- Pointers and Const

Brainstorm the List Abstract Data Types (ADT)

Encapsulation - Classes

Abstraction / organization separating:

Internal Implementation **External Interface**

Brainstorming a ‘Library’ class

```
 1 class Library {
 2 public:
 3
 4
 5
 6
 7
 8
 9
10
11
12
13 private:
14
15
16
17
18
19
20
21 };
```

Memory Management — Ownership

Imagine I have a Library class (and hidden Book class):

```
1  class Library{
2  public:
3      void addBook(Book book);
4      void removeBook(std::string title);
5
6  private:
7      std::vector<Book> in;
8      std::vector<Book> out;
9  };
```

Memory Management — Ownership

Imagine I have a Library class:

```
1  class Library{
2  public:
3      void addBook(Book book);
4      void removeBook(std::string title);
5
6  private:
7      std::vector<Book> in;
8      std::vector<Book> out;
9  };
```

Join Code: 225

Does my Library class 'own' the Books it is storing?

A) **Yes!** B) **No!** C) **Not sure**

Memory Management

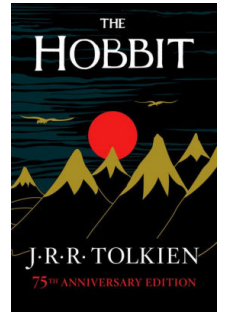
Stack: Local variable storage

Ex: `int x = 5;`

Heap: Dynamic storage

Ex: `int* x = new int[5];`

Memory Management - Parameters



Pass by **Value:** A local copy of the original

Ex: `addBook(Book book)`

Pass by **Pointer to Value:** An address on the heap

Ex: `addBook(Book* book)`

Pass by **Reference:** An *alias* to an existing variable

Ex: `addBook(Book& book)`

Memory Management - Parameters

Which implementation is 'best'? Why?

```
1  class Library {
2  public:
3      int numBooks;
4      std::string * titles;
5  };
6
7  // *** Function A ***
8  std::string getFirstBook(Library l){
9      return (l.numBooks > 0) ? l.titles[0] : "None";
10 }
11
12 // *** Function B ***
13 std::string getFirstBook(Library * l){
14     return(l->numBooks > 0) ? l->titles[0] : "None";
15 }
16
17 // *** Function C ***
18 std::string getFirstBook(Library & l){
19     return (l.numBooks > 0) ? l.titles[0] : "None";
20 }
21
22
23
24
```

Memory Management

Local memory on the stack is managed by the computer

Heap memory allocated by **new** and freed by **delete**

Pass by value makes a copy of the object

Pass by pointer can be dereferenced to modify an object

Pass by reference modifies the object directly

Memory Management — Ownership

```
1  class Library{
2  public:
3
4      void addBook(Book book);
5
6
7      void removeBook(std::string title);
8
9
10 private:
11
12     std::vector<Book> in;
13
14
15     std::vector<Book> out;
16
17
18 };
```

Does Library 'own' Books?

A) **Yes!**

B) **No!**

C) **Not sure**

Does my destructor need to delete them?

Memory Management — Ownership

```
1  class Library{
2  public:
3      // Implemented to store on heap
4      void addBook(Book book);
5
6
7      void removeBook(std::string title);
8
9
10 private:
11
12     std::vector<Book*> in;
13
14
15     std::vector<Book*> out;
16
17
18 };
```

Does Library 'own' Books?

A) **Yes!**

B) **No!**

C) **Not sure**

Does my destructor need to delete them?

Memory Management — Ownership

```
1  class Library{
2  public:
3
4      void addBook(const Book& book);
5
6
7      void removeBook(std::string title);
8
9
10 private:
11
12     std::vector<Book*> in;
13
14
15     std::vector<Book*> out;
16
17
18 };
```

Does Library 'own' Books?

A) **Yes!**

B) **No!**

C) **Not sure**

Does my destructor need to delete them?

The Rule of Three

If it is necessary to **define any one** of these three functions in a class, it will be necessary to **define all three** of these functions:

1. Destructor — Called when we delete object

2. Copy Constructor — Make a new object as a copy of an existing one

3. Copy assignment operator — Assign value from existing X to Y

‘The Rule of Zero'

A corollary to Rule of Three

Classes that **declare** custom destructors, copy/move constructors or copy/move assignment operators should deal exclusively with ownership. Other classes **should not declare** custom destructors, copy/move constructors or copy/move assignment operators

— Scott Meyers

Memory Management — Ownership

If I don’t have to allocate things, I should not allocate them!

Try to always use an existing class that handles ownership!

Before you use keyword ‘new’, try everything else.

```
 1 class Library {
 2 public:
 3     int numBooks;
 4     std::string * titles;
 5     ~Library();
 6     Library( int num, std::string* list );
 7 };
 8
 9 Library::~Library(){
10    delete titles;
11    titles = nullptr;
12 }
13
14 Library::Library(int num, std::string* list){
15     numBooks = inNum;
16     titles = new std::string[ inNum ];
17     std::copy(inList, inList + inNum, titles);
18 }
19
20 int main(){
21    std::string myBooks[3] = {"A", "B", "C"};
22    Library L1( 3, myBooks );
23    Library L2( L1 );
24    return 0;
25 }
```

```
1  class Library {
2  public:
3      int numBooks;
4      std::string * titles;
5      ~Library();
6      Library( int num, std::string* list );
7  };
8
9  Library::~Library(){
10    delete titles;
11    titles = nullptr;
12 }
13
14 Library::Library(int num, std::string* list){
15     numBooks = inNum;
16     titles = new std::string[ inNum ];
17     std::copy(inList, inList + inNum, titles);
18 }
19
20 int main(){
21    std::string myBooks[3] = {"A", "B", "C"};
22    Library L1( 3, myBooks );
23    Library L2( L1 );
24    return 0;
25 }
```

Whats wrong with this code?

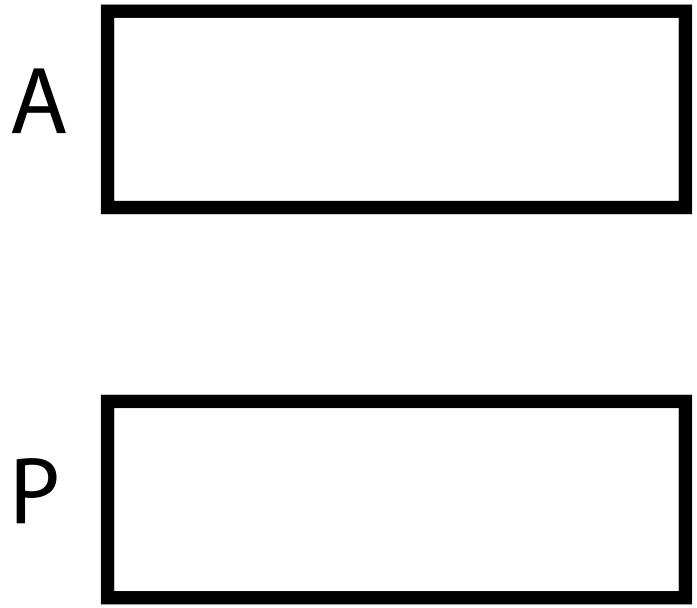
A. Can't create L2 Library obj

B. Don't delete either Library

C. Deleting L1 deletes L2

Pointers

```
1 int a = 3;
2
3 int *p = &a; // Value: 0xfffffc6216cc
4
5
6
7
8
9
```



Pointers

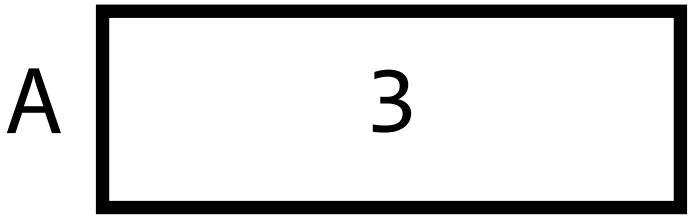
```
1 int a = 3;
2
3 int *p = &a; // Value: 0xfffffc6216cc
4
5 (*p)++;
6
7
8
9
```

Pointers

```
1 int a = 3;
2
3 int *p = &a; // Value: 0xfffffc6216cc
4
5 (*p)++;
6
7 p++;
8
9
```

Pointers

```
1 int a = 3;
2
3 int *p = &a; // Value: 0xfffffc6216cc
4
5 (*p)++;
6
7 p++;
8
9 int *b;
```



Pointer-to-const vs constant pointer

```
 1 int x = 3;
 2 int y = 2;
 3 // *** A ***
 4 const int* a = &x;
 5
 6 a = &y;
 7
 8 // *** B ***
 9 const int* b = &x;
10
11 *b = y;
12
13 // *** C ***
14 int* const c = &y;
15
16 c = &x;
17
18 // *** D ***
19 int* const d = &y;
20
21 *d = x;
```

(const int)* a = &x;

X

(int)* const c = &y;

Y

Const pointers vs const methods

```
1  struct BlackBox {
2      void update(const int & obj) {
3          myVal = obj;
4
5          obj++;
6      }
7
8
9      void update(int & obj) const {
10         myVal = obj;
11
12         obj++;
13     }
14
15
16     void update(const int & obj) const {
17         myVal = obj;
18
19         obj++;
20     }
21
22
23     int myVal;
24 };
25
```

A

B

C

The Const Keyword

Const means that an object cannot be modified

Variables: Can’t change value

Pointers: Cant change value OR can’t change pointer

Reference: Can’t change value (address always fixed)

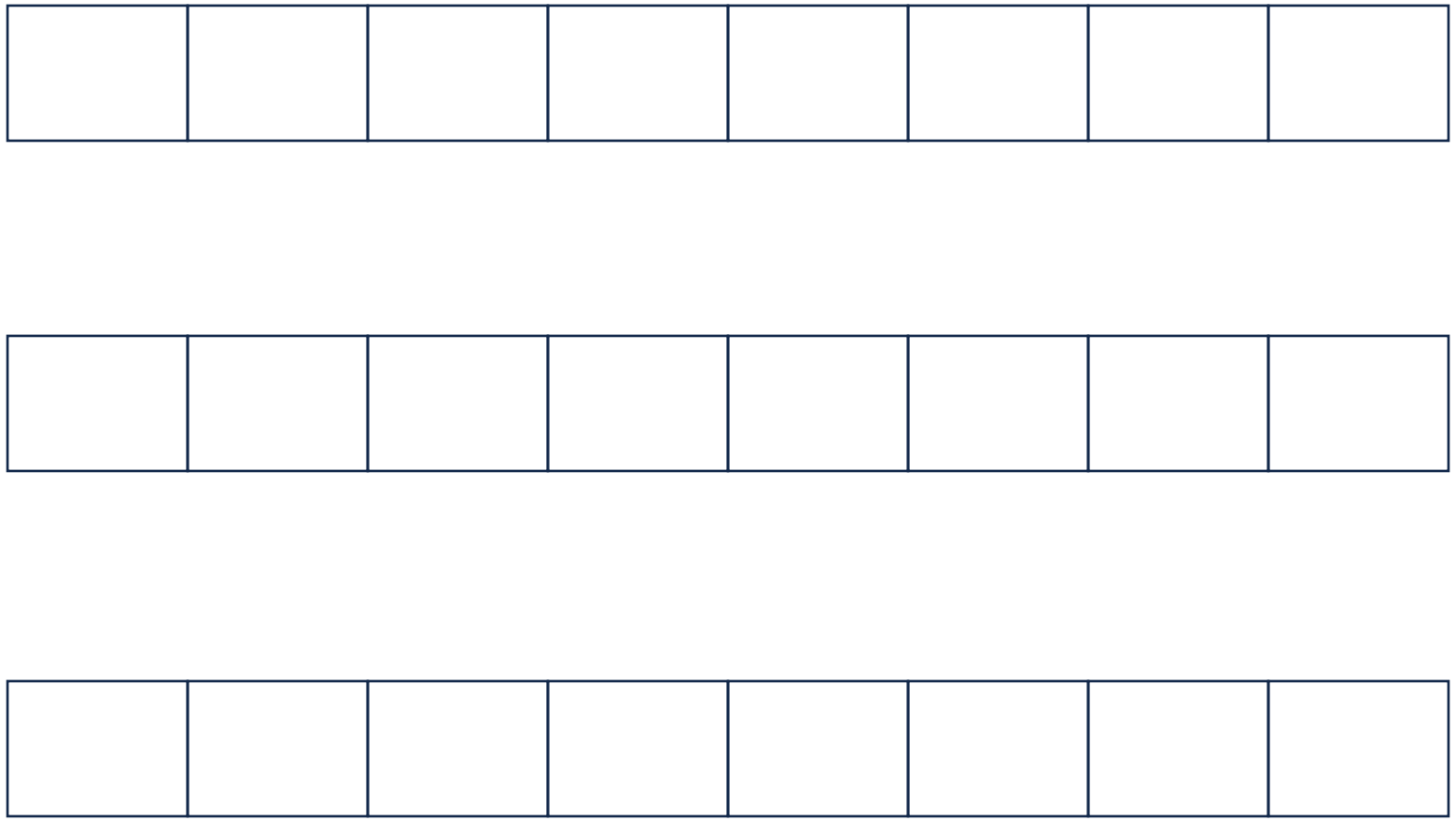
Method: Prevents non-mutable members from changing

Templates

template1.cpp

```
1
2
3  T maximum(T a, T b) {
4    T result;
5    result = (a > b) ? a : b;
6    return result;
7  }
```

Templates in the context of Lists



List Abstract Data Type

What is the expected **interface** for a list?