Data Structures

C++ Review

CS 225
Brad Solomon

August 27, 2025

UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN

Department of Computer Science

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Scan for:

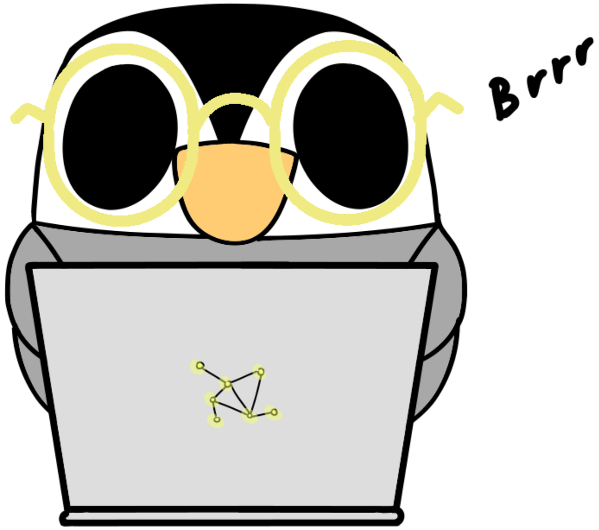
- Website
- Application
- Interest form

(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

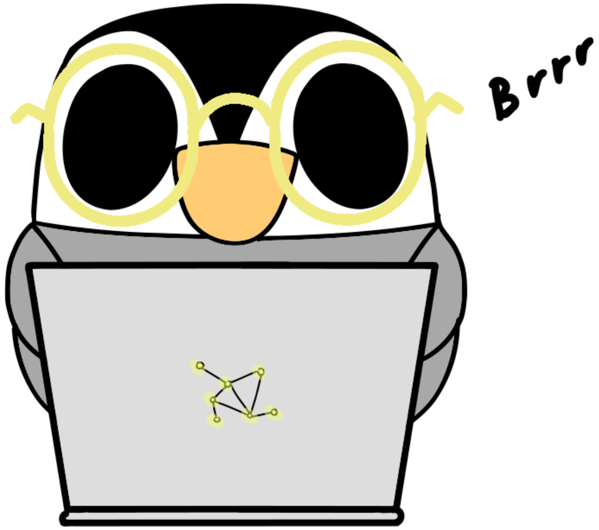
For now, please use Discord or Piazza

You can also stop by faculty office hours!

Thursday, 11 AM — 12 PM

Siebel 2233

See the website for Harsha's and Mattox's



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/fa2025/exams/

Learning Objectives

A brief high level review of C++

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

Brainstorm the List Abstract Data Types (ADT)

Encapsulation - Classes

Abstraction / organization separating:

Internal Implementation	**External Interface**

Brainstorming a ‘Library’ class

```
class Library {
public:










private:







};
```

Memory Management — Ownership

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

```
class Library{
public:
    void addBook(Book * book);
    void removeBook(std::string title);
    void returnBook(Book * book);

private:
    std::vector<Book*> in;
    std::vector<Book*> out;
};

```

Memory Management — Ownership

Join Code: 225

Imagine I have a Library class:

```
class Library{
public:
    void addBook(Book * book);
    void removeBook(std::string title);
    void returnBook(Book * book);

private:
    std::vector<Book*> in;
    std::vector<Book*> out;
};

```

Pretest: Does Library class ‘own’ the Books it is storing?

A) **Yes!**

B) **No!**

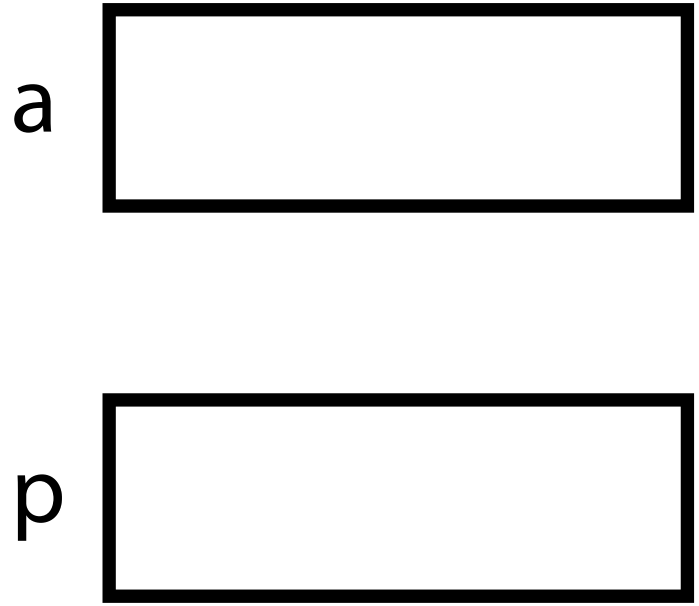
C) **Not sure**

Pointers

Pointers store memory addresses

```
int a = 3;

int *p = &a;
```



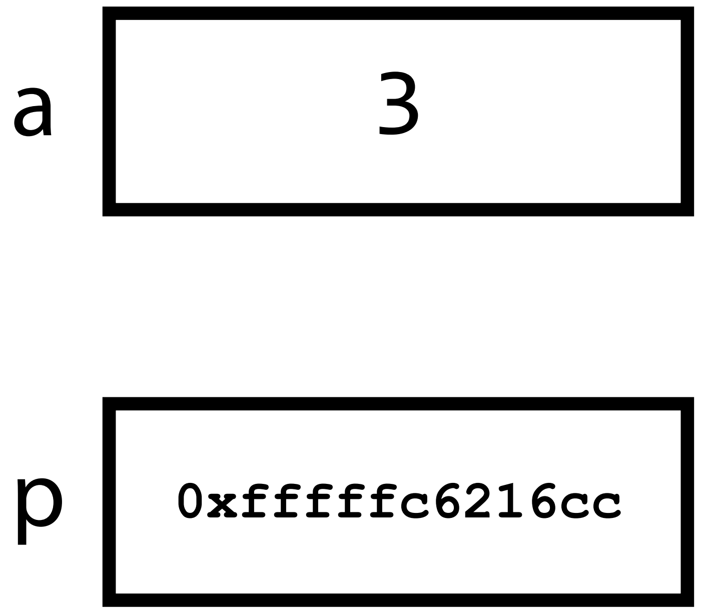
Pointers

Pointers store memory addresses

```
int a = 3;

int *p = &a;

p++;
```



Does a change? Does p?

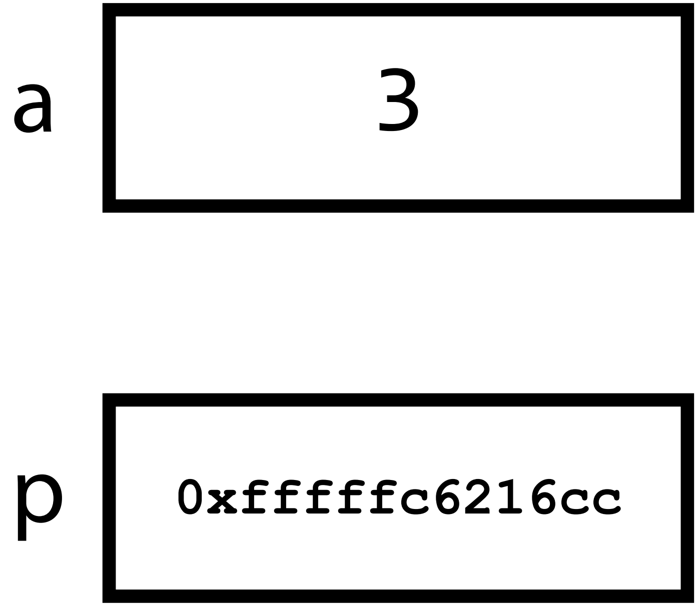
Pointers

Pointers store memory addresses

```
int a = 3;

int *p = &a;

(*p)++;
```



a

3

p

0xfffffc6216cc

Does a change? Does p?

Memory Management

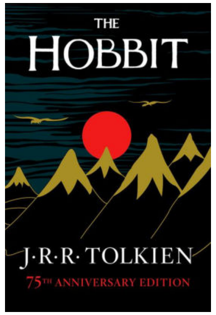
Stack: Local variable storage

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 do you prefer?

```cpp
class Library {
public:
    int numBooks;
    std::string * titles;
};

// *** Function A ***
std::string getFirstBook(Library l){
    return (l.numBooks > 0) ? l.titles[0] : "None";
}

// *** Function B ***
std::string getFirstBook(Library * l){
    return(l->numBooks > 0) ? l->titles[0] : "None";
}

// *** Function C ***
std::string getFirstBook(Library & l){
    return (l.numBooks > 0) ? l.titles[0] : "None";
}
```

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

What does **ownership** mean in C++?

Memory Management — Ownership

```
class Library{
public:
    void addBook(Book * book);


    void removeBook(std::string title);


    void returnBook(Book * book);
private:

    std::vector<Book*> in;


    std::vector<Book*> out;


};
```

Does Library ‘own’ Books?

A) **Yes!**

B) **No!**

C) **Not sure**

Memory Management — Ownership

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public:
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Are they destroyed when the Library destructor is called?

Memory Management — Ownership

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public:
    void addBook(Book book);


    void removeBook(std::string title);


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Memory Management — Ownership

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class Library{
public:
    void addBook(Book book);


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private:

    std::vector<Book> in;


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```

Does Library ‘own’ Books?

A) **Yes!**

B) **No!**

C) **Not sure**

Are they destroyed when the Library destructor is called?

Memory Management — Ownership

```
class Library{
public:
    void addBook(const Book& book);


    void removeBook(std::string title);


    void returnBook(const Book& book);
private:

    std::vector<Book*> in;


    std::vector<Book*> out;


};
```

Does Library ‘own’ Books?

A) **Yes!**

B) **No!**

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Are they destroyed when the Library destructor is called?

Memory Management — Ownership

The owner of an object is responsible for its resource management (particularly allocation / deallocation)

A ‘litmus test’ of ownership — who handles destruction?

If we are storing pointers or references, not our problem!

Vector’s consolation prize — vector handles destruction

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

```
class Library {
public:
    int numBooks;
    std::string * titles;
    ~Library();
    Library( int num, std::string* list );
};

Library::~Library(){
   delete titles;
   titles = nullptr;
}

Library::Library(int num, std::string* list){
    numBooks = inNum;
    titles = new std::string[ inNum ];
    std::copy(inList, inList + inNum, titles);
}

int main(){
   std::string myBooks[3] = {"A", "B", "C"};
   Library L1( 3, myBooks );
   Library L2( L1 );
   return 0;
}
```

```
class Library {
public:
    int numBooks;
    std::string * titles;
    ~Library();
    Library( int num, std::string* list );
};

Library::~Library(){
   delete titles;
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Library::Library(int num, std::string* list){
    numBooks = inNum;
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    std::copy(inList, inList + inNum, titles);
}

int main(){
   std::string myBooks[3] = {"A", "B", "C"};
   Library L1( 3, myBooks );
   Library L2( L1 );
   return 0;
}
```

Whats wrong with this code?

A. Can’t create L2 Library obj

B. Don’t delete either Library

C. Deleting L1 deletes L2

Templates

A way to write generic code whose type is determined during completion

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1. Templates are a recipe for code using generic types

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A way to write generic code whose type is determined during completion

1. Templates are a recipe for code using generic types

2. The compiler uses templates to generate C++ code **when needed**

```
template <typename T>
T sum(T a, T b){
...
}
```

template1.cpp

```cpp
template <typename T>
T max(T a, T b) {
  T result;
  result = (a > b) ? a : b;
  return result;
}

```

Templates are very useful!

List Abstract Data Type

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