Programming Abstractions

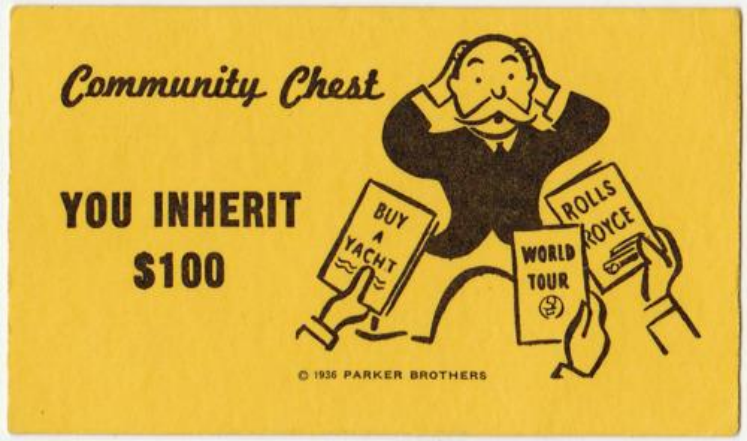
CS106B

Cynthia Lee

Inheritance Topics

Inheritance

- The basics
  - Example: Stanford GObject class
- Polymorphism



Inheritance

What? Why? How?

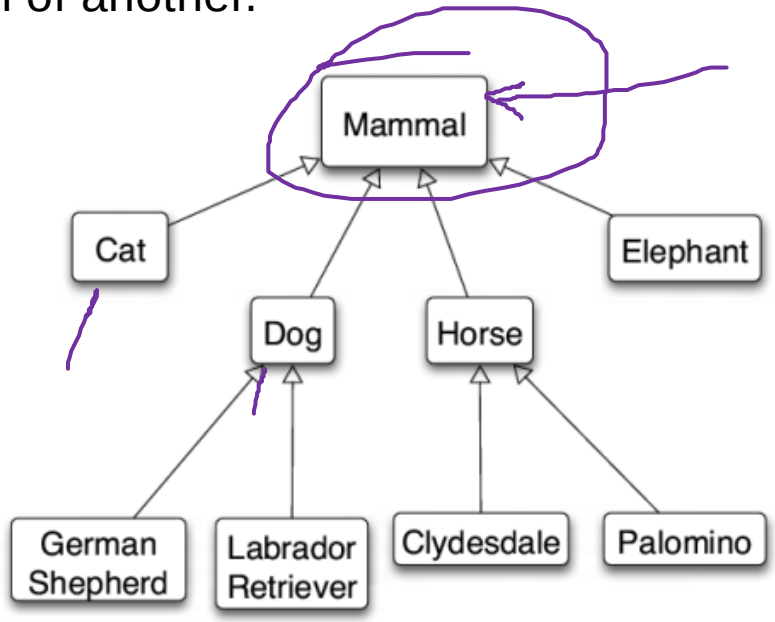
Inheritance: what?

is-a relationship: A hierarchical connection where one category can be treated as a specialized version of another.

- every rectangle *is a* shape
- every lion *is an* animal

type hierarchy: A set of data types connected by is-a relationships that **can share common code**.

- Re-use!



Inheritance: why?

- Remember the #1 rule of computer scientists:
  - Computer scientists are super lazy
  - …in a good way!

- We want to reuse code and work as much as possible
- You've already seen this going back to the very start of your CS education:
  - Loops and Functions *(instead of copy&paste to repeat code)*
  - Arrays *(instead of copy&paste to make 100 named variables)*
  - Data structures *(same idea as arrays but more expressive)*

- Inheritance is another way of organizing smart reuse of code

Inheritance: how?

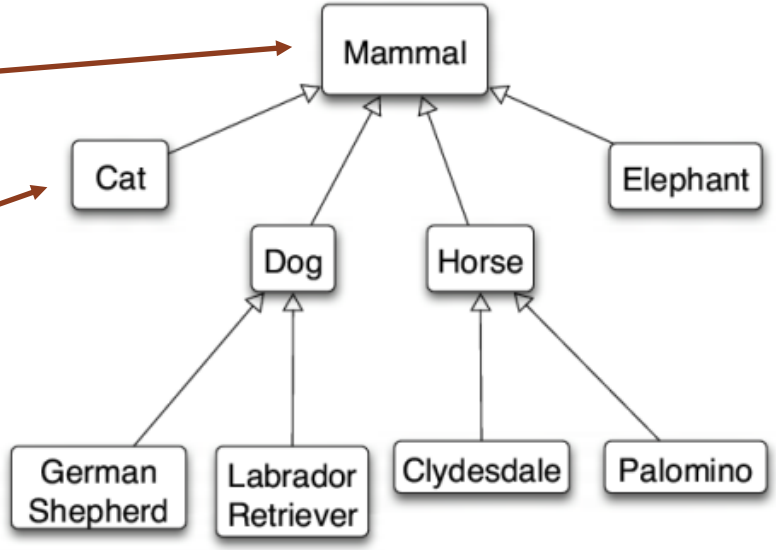
inheritance: A way to form new classes based on existing classes, taking on their attributes/behavior.

- a way to group related classes
- a way to share code between two or more classes

One class can *extend* another, absorbing its data/behavior.

Inheritance vocab

- **superclass** (base class): Parent class that is being extended.
- **subclass** (derived class): Child class that inherits from the superclass.
  - Subclass gets a copy of every field and method from superclass.
  - Subclass can add its own behavior, and/or change inherited behavior.

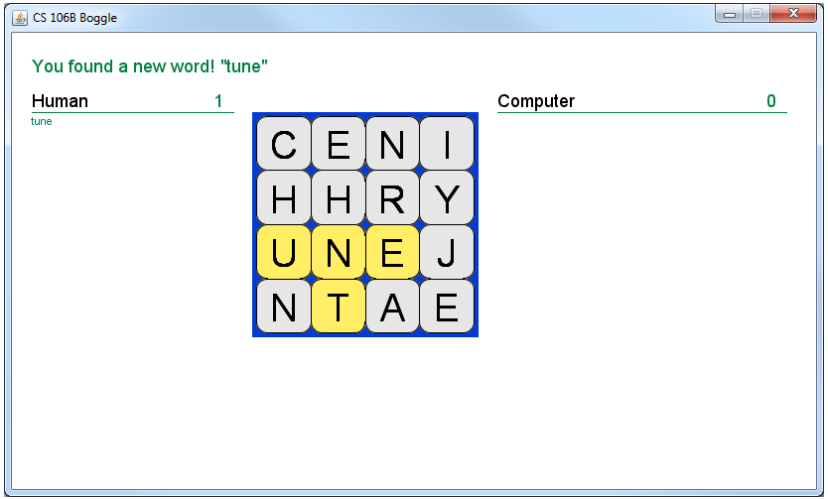


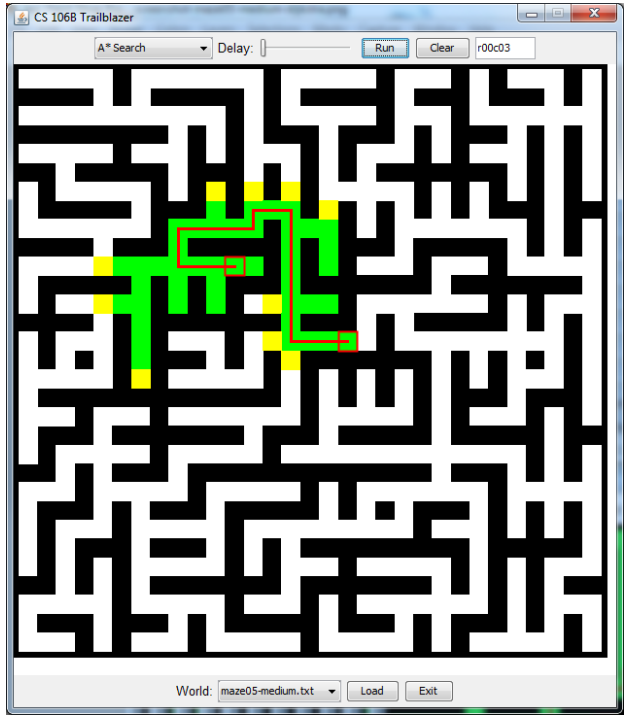
Inheritance Example

Stanford Library G-Object family of classes

Behind the scenes…

- We've always told you not to worry about the graphics parts of your assignments.
  - "Just call this BoggleGUI function…"
- Now you can go ahead and take a look!

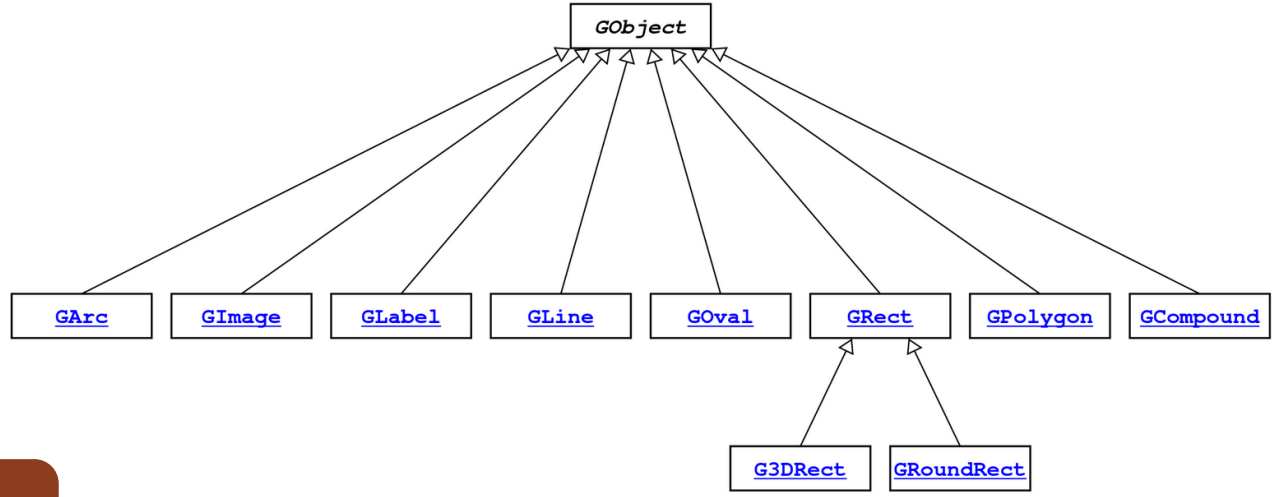




GObject hierarchy

The Stanford C++ library contains a hierarchy of graphical objects based on a common base class named `GObject`.

- `GArc`
- `GImage`
- `GLabel`
- `GLine`
- `GOval`
- `GPolygon`
- `GRect`
- `G3DRect`
- `GRoundRect`



GObject members

GObject defines the state and behavior common to all shapes:

- contains(*x*, *y*)
- get/setColor()
- getHeight(), getWidth()
- get/setLocation(), get/setX(), get/setY()
- move(*dx*, *dy*)
- setVisible(*visible*)

```
double x;
double y;
double lineWidth;
std::string color;
bool visible;
```

The subclasses add state and behavior unique to them:

GLabel	GLine	GPolygon	GOval
get/setFont	get/setStartPoint	addEdge	getSize
get/setLabel	get/setEndPoint	addVertex	get/setFillColor
		get/setFillColor	
...	...	...	...

GObject members

`GObject` defines the state and behavior common to all shapes:

- `contains(`***x***`, `***y***`)`
- `get/setColor()`
- `getHeight(), getWidth()`
- `get/setLocation(), get/setX(), get/setY()`
- `move(`***dx***`, `***dy***`)`
- `setVisible(`***visible***`)`

```
double x;
double y;
double lineWidth;
std::string color;
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The subclasses add state and behavior unique to them:

`GLabel`	`GLine`	`GPolygon`	`GOval`
`get/setFont`	`get/setStartPoint`	`addEdge`	`getSize`
`get/setLabel`	`get/setEndPoint`	`addVertex`	`get/setFillColor`
		`get/setFillColor`	
`...`	`...`	`...`	`...`

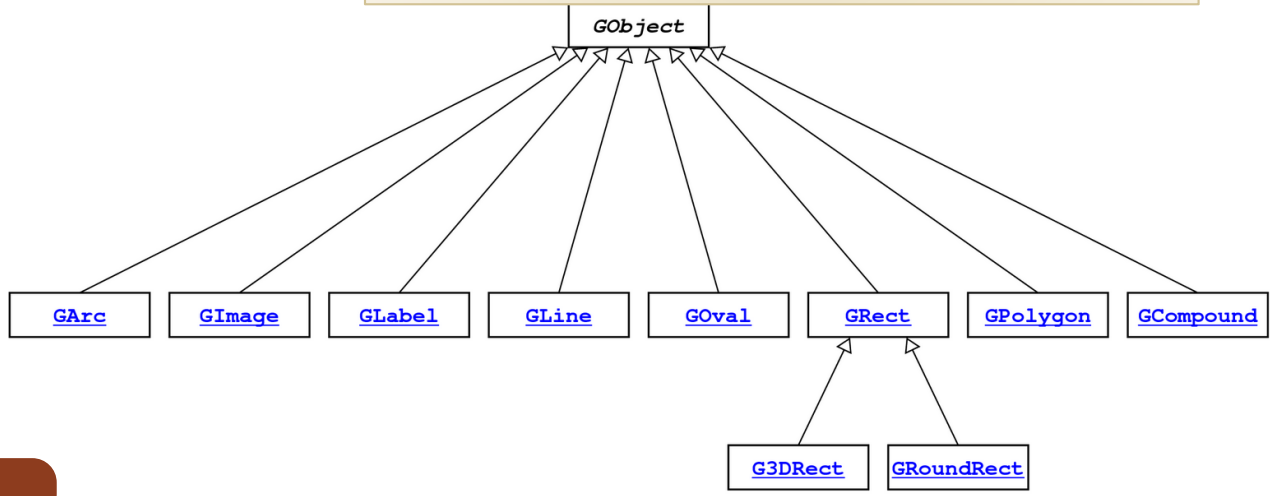
GObject hierarchy

The Stanford C++ library contains a h
objects based on a common base

- GArc
- GImage
- GLabel
- GLine
- GOval
- GPolygon
- GRect
- G3DRect
- GRoundRect

Q: Rectangle is-a Polygon, right?
Why doesn't it inherit from Polygon??

Although true in geometry, they don't share many fields and methods in this case.



Inheritance Example

Your turn: let's write an Employee family of classes

Example: Employees

Imagine a company with the following **employee regulations**:

- All employees work 40 hours / week
- Employees make $40,000 per year plus $500 for each year worked
  - Except for lawyers who get twice the usual pay, and programmers who get the same $40k base but $2000 for each year worked
- Employees have 2 weeks of paid vacation days per year
  - Except for programmers who get an extra week

Each type of employee has some unique behavior:

- **Lawyers** know how to sue
- **Programmers** know how to write code

Employee class

```
// Employee.h
class Employee {
public:
    Employee(string name,
             int years);
    virtual int hours();
    virtual string name();
    virtual double salary();
    virtual int vacationDays();
    virtual int years();

private:
    string m_name;
    int m_years;
};
```

```
// Employee.cpp
Employee::Employee(string name, int years) {
    m_name = name;
    m_years = years;
}

int Employee::hours() {
    return 40;
}

string Employee::name() {
    return m_name;
}

double Employee::salary() {
    return 40000.0 + (500 * m_years);
}

int Employee::vacationDays() {
    return 10;
}

int Employee::years() {
    return m_years;
}
```

Exercise: Employees

Exercise: Implement classes `Lawyer` and `Programmer`.

- A Lawyer remembers what **law school** he/she went to.
- Lawyers make twice as much **salary** as normal employees.
- Lawyers know how to **sue** people (unique behavior).
- Lawyers put ", Esq." at the end of their name.

- Programmers make the same base salary as normal employees, but they earn a **bonus of $2k/year** instead of $500/year.
- Programmers know how to write **code** (unique behavior).

Inheritance syntax

```
class Name : public SuperclassName {
```

- Example:

```
class Lawyer : public Employee {
    ...
};
```

By extending `Employee`, each `Lawyer` object now:

- receives a `hours`, `name`, `salary`, `vacationDays`, and `years` method automatically
- can be treated as an `Employee` by client code

Call superclass c'tor

```
SubclassName::SubclassName(params)
        : SuperclassName(params) {
    statements;
}
```

To call a superclass constructor from subclass constructor, use an *initialization list*, with a colon after the constructor declaration.

- Example:

```
Lawyer::Lawyer(string name, string lawSchool, int years)
        : Employee(name, years) {
    // calls Employee constructor first
    m_lawSchool = lawSchool;
}
```

Your turn: inheritance

```
string Lawyer::name() {
    ???
}
```

For adding ", Esq." to the name, which of the following could work?

A. `return m_name + ", Esq.";`
B. `return name() + ", Esq.";`
C. `return Employee::name() + ", Esq.";`
D. None of the above
E. More than one of the above

```
// Employee.h
class Employee {
public:
    Employee(string name,
             int years);
    int hours();
    string name();
    double salary();
    int vacationDays();
    string vacationForm();
    int years();

private:
    string m_name;
    int m_years;
};
```

Call superclass member

SuperclassName::*memberName*(*params*)

To call a superclass overridden member from subclass member.

- Example:

```
double Lawyer::salary() {          // paid twice as much
    return Employee::salary() * 2;
}
```

- **Note: Subclass *cannot* access private members of the superclass.**
- Note: You only need to use this syntax when the superclass's member has been overridden.
  - If you just want to call one member from another, even if that member came from the superclass, you don't need to write `Superclass::` .

Polymorphism

Start with *how*

Polymorphism

polymorphism: Ability for the **same code** to be used with **different types** of objects and **behave differently with each**.

- Templates provide a kind of *compile-time* polymorphism.
  - `Grid<int>` or `Grid<string>` will output different things for `myGrid[0][0]`, but we can predict at compile time which it will do

- Inheritance provides *run-time* polymorphism.
  - `someEmployee.salary()` will behave differently at runtime depending on what type of employee—may not be able to predict at compile time which it is

Polymorphism

A pointer of type *T* can point to any subclass of *T*.

```
Employee   *neha    = new Programmer("Neha", 2);
Employee   *diane   = new Lawyer("Diane", "Stanford", 5);
Programmer *cynthia = new Programmer("Cynthia", 10);
```

- Why would you do this?
  - Handy if you want to have a function that works on any Employee, but takes advantage of custom behavior by specific employee type:

```
void doMonthlyPaycheck(Employee *employee) {
    cout << "You are now $" << employee->salary()/12 << " wealthier!" << endl;
}
```

Polymorphism

A pointer of type *T* can point to any subclass of *T*.

```
Employee   *neha    = new Programmer("Neha", 2);
Employee   *diane   = new Lawyer("Diane", "Stanford", 5);
Programmer *cynthia = new Programmer("Cynthia", 10);
```

- When a member function is called on `diane`, it behaves as a `Lawyer`.
  - `diane->salary();`
  - (This is because all the employee functions are declared `virtual`.)
- You can *not* call any `Lawyer`-only members on `diane` (e.g. `sue`).
  - `diane->sue();` `// will NOT compile!`
- You *can* call any `Programmer`-only members on `cynthia` (e.g. `code`).
  - `cynthia->code("Java");` `// ok!`

Polymorphism examples

You can use the object's extra functionality by casting.

```
Employee   *diane   = new Lawyer("Diane", "Stanford", 5);
diane->vacationDays();                          // ok
diane->sue("Cynthia");                          // compiler error
((Lawyer*) diane)->sue("Cynthia");              // ok
```

Pro Tip: you should not cast a pointer into something that it is not!

- It will compile, but the code will crash (or behave unpredictably) when you try to run it.

```
Employee   *carlos  = new Programmer("Carlos", 3);
carlos->code();                                 // compiler error
((Programmer*) carlos)->code("C++");            // ok
((Lawyer*) carlos)->sue("Cynthia");             // No!!! Compiles but crash!!
```

Rules for “virtual”: runtime calls

DerivedType * obj = new DerivedType();

If we call a method like this: obj->method(), only one thing could happen:

1. DerivedType’s implementation of method is called

BaseType * obj = new DerivedType();

If we call a method like this: obj->method(), two different things could happen:

1. If method is **not virtual**, then BaseType’s implementation of method is called
2. If method is **virtual**, then DerivedType’s implementation of method is called

Rules for “virtual”: pure virtual

If a method of a class looks like this:

- `virtual returntype method() = 0;`
- then this method is a called “**pure virtual**” function
- and the class is called an “**abstract class**”
- Abstract classes are like Java interfaces
- You cannot do “= new Foo();” if Foo is abstract (just like Java interfaces)
- ALSO, you cannot do “= new DerivedFoo();” if DerivedFoo extends Foo and DerivedFoo does not implement *all* the pure virtual methods of Foo

```
class Mammal {
public:
  virtual void makeSound() = 0;
  string toString() { return “Mammal”; }
};
class Cat : public Mammal {
public:
  virtual void makeSound() { cout << “rawr” << endl; }
  string toString() { return “Cat”; }
};
class Siamese : public Cat {
public:
  virtual void makeSound() { cout << “meow” << endl; }
  string toString() { return “Siamese”; }
  virtual void scratchCouch() { cout << “scraaaatch” << endl; }
};
```

What is printed?

```
Siamese * s = new Mammal;
cout << s->toString();
```

(A) “Mammal”
(B) “Cat”
(C) “Siamese”
(D) Gives an error (identify compiler or crash)
(E) Other/none/more

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class Mammal {
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What is printed?

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  virtual void scratchCouch() { cout << “scraaaatch” << endl; }
};
```

What is printed?

```
Mammal * m = new Mammal;
cout << m->toString();
```

(A)“Mammal”
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(C)“Siamese”
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```

What is printed?

```
Mammal * m = new Siamese;
cout << m->toString();
```

(A)“Mammal”
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public:
  virtual void makeSound() { cout << “meow” << endl; }
  string toString() { return “Siamese”; }
  virtual void scratchCouch() { cout << “scraaaatch” << endl; }

};
```

What is printed?

```
Mammal * m = new Siamese;
m->scratchCouch();
```

(A)“Mammal”
(B)“Cat”
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public:
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  string toString() { return “Siamese”; }
  virtual void scratchCouch() { cout << “scraaaatch” << endl; }
};
```

What is printed?

```
Cat * c = new Siamese;
c->makeSound();
```

(A) “rawr”
(B) “meow”
(C) “Siamese”
(D) Gives an error (identify compiler or crash)
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