Intro to C++

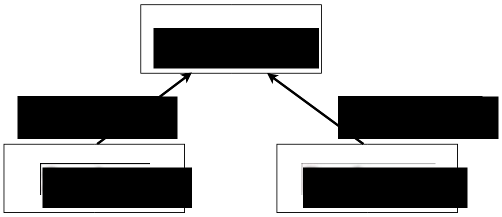
Lecture Topics

- Inheritance and polymorphism

These notes are taken from Eunsuk Kang & JeanYang @ MIT.

Inheritance

- A class defines a set of objects, or a type, e.g., all *University people*
- Some objects are distinct from others in some ways, e.g., *University students* vs. *University professors*, but they all are still *University people*
    - o *University* professor and student are subtypes of *University* people



- o What characteristics/behaviors do people at *University* have in common?
    - ▪ name, ID, address, …
    - ▪ change address, display profile, …
- o What things are special about students?
    - ▪ course number, classes taken, year, …
- o What things are special about professors?
    - ▪ course number, classes taught, rank (assistant, etc.), …
    - ▪ add a class taught, promote, …

- Inheritance means that a subtype inherits characteristics and behaviors of its base type
    - o e.g. Each *University* student has
        - ▪ Characteristics that it inherits from *University* person: name, ID, address
        - ▪ Methods that it inherits from *University* person: display profile, etc.
- Base Type: Person

```
#include <string>

using namespace std;

class Person
{
 protected:
    int id;
    string name;
    string address;
 public:
    Person(int id, string name, string address);
    ~Person();
    void displayProfile();
    void changeAddress(string newAddress);
};
```

```
Person::Person(int id, string name, string address)
{
    this->id = id;
    this->name = name;
    this->address = address;
}

Person::~Person() { }

void Person::displayProfile()
{
    cout << "-----------------------------\n";
    cout << "Name: " << name << " ID: " << id <<;
    cout << " Address: " << address << "\n";
    cout << "-----------------------------\n";
}
```

- Subtype: Student

```
class Student : public Person
{
 protected:
    int course;
    int year; // 1 = freshman, 2 = sophomore, etc.
    //vector<int*> classesTaken; // dynamic array, part of
                               // C++ standard library
 public:
    Student(int id, string name, string address, int course, int
year);
    void displayProfile();
    void updateYear(int newyear) { this->year = newyear; }
    //void changeCourse(int newCourse);
};
```

- Constructing an object of subclass

```
Student::Student(int id, string name, string address, int course,
int year) : Person(id, name, address)
            // call to the base constructor
{
    this->course = course;
    this->year = year;
}
```

- Creating an object

```
Student* james = new Student(971232, “James Lee”, “32 Lincoln
Ave.”, 6, 2);
```

  - From base class
    - name = “James Lee”
    - ID = 971232 person
    - address = “32 Lincoln Ave.”

    - from derived class (subclass)
        - course number = 6
        - year = 2
- Overriding a method in base class
    - Both Person and Student have a method `void displayProfile();`
        - The method defined in Student will overwrite the method defined in Person

```
void Student::displayProfile()
{
    cout << "--------------------------" << endl;
    cout << "Name: " << name << ", ID: " << id;
    cout << ", Address: " << address << endl;
    cout << "Course: " << course << ", year: " << year << endl;
    cout << "--------------------------" << endl;

}
```

```
Person* john = new Person(901289, “John Doe”, “500 University
Ave.”);

Student* james = new Student(971232, “James Lee”, “32 Lincoln
Ave.”, 6, 2);

james->addClassTaken(220);
john->displayProfile();
james->displayProfile();
```

Polymorphism

- Ability of type A to appear as and be used like another type B
    - e.g., a Student object can be used in place of an Person object
- Actual type vs. declared type
    - Every variable has a *declared type* at compile-time
    - But during runtime, the variable may refer to an object with an *actual type* (either the same or a subclass of the declared type)

```
Person* john = new Person(901289, “John Doe”, “500
University Ave.”);

Person* steve = new Student(911923, "Steve", "99 Lincoln
Ave.", 18, 3);
```

    - What are the declare types of john and steve?

```
steve->displayProfile();

Name: Steve ID: 911923 Address: 99 Lincoln Ave.
```

- Why doesn't it display the course number and classes taken?
  - Because steve 's declared class is Person and thus its Person::displayProfile is invoked.
  - To ensure that a function from the actual class is called, the overridden method must be declared as virtual.

- Virtual functions
  - Declare overridden methods as virtual in the base

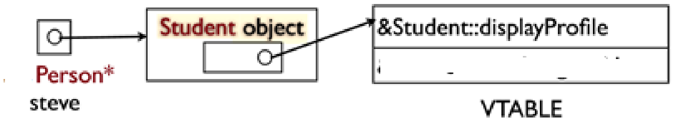
```
class Person
{
 …
    virtual void displayProfile();
};
```

  - Calling a virtual function

```
Person* steve = new Student(911923, "Steve", "99 Lincoln
Ave.", 18, 3);
steve->displayProfile();

Name: Steve ID: 911923 Address: 99 Lincoln Ave.
Course: 18
Classes taken
```

  - What goes on under the hood?
    - Virtual table
      - stores pointers to all virtual functions
      - created per each class
      - lookup during the function call



  - Should destructors in a base class be declared as virtual?
    - Yes, we must always clean up the mess created in the subclass (otherwise, risks for memory leaks!)
  - Can we declare a constructor as virtual?
    - No, not in C++. To create an object, you must know its exact type.
    - The VPTR has not even been initialized at this point.

- Type casting
  - What will happen?

```
Person* steve = new Student(911923, "Steve", "99 Lincoln
Ave.", 18, 3);
steve-> updateYear(4);  // will not work!
```

        - Can only invoke methods of the declared type!
        - “updateYear” is not a member of Person
    - Use “dynamic_cast<...>” to downcast the pointer

```
Person* steve = new Student(911923, "Steve", "99 Lincoln
Ave.", 18, 3);
Student* steve2 = dynamic_cast<Student*>(steve);
steve2->updateYear(4); // OK
```

- Static vs. dynamic casting
    - Can also use “static_cast<...>”

```
Student* steve2 = static_cast<Student*>(steve);
```

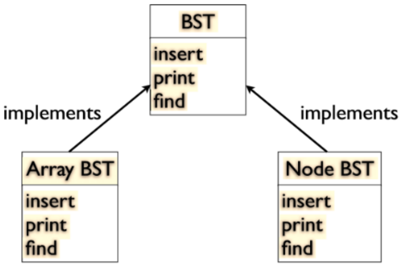
        - Cheaper but dangerous because there is no runtime check

```
Person* p = Person(...);
Student* s1 = static_cast<Student*>(p); // s1 is not checked!
Student* s2 = dynamic_cast<Student*>(p); // s2 is set to NULL
```

    - Use “static_cast<...>” only if you know what you are doing!

Abstract base class

- Abstract methods
    - Sometimes you want to inherit only declarations, not definitions
    - A method without an implementation is called an abstract method
    - Abstract methods are often used to create an interface
- Example: Binary search tree
    - Can provide multiple implementations to BST
    - Decouples the client from the implementations



- Defining abstract methods in C++
    - Use pure virtual functions

```
class BST
{
 public:
   virtual ~BST() = 0;
   virtual void insert(int val) = 0;
   virtual bool find(int val) = 0; // “find” is pure
   virtual void print_inorder() = 0; };
};
```

        - Here `virtual` “says” that the methods are virtual and `=0` “says” that they are pure, i.e., no implementation is provided at this point.

- Abstract base class in C++
    - A class with one or more pure virtual functions
    - Cannot be instantiated

```
int main()
{
    BST *bst = new BST(); // cannot do this
}
```

    - Its subclass must implement all of the pure virtual functions:

```
class NodeBST : public BST
{
   protected:
    Node *root;

   public:
    NodeBST();
    ~NodeBST();

   void insert(int val);
   void print();
   bool find(int val);

};

void NodeBST:insert(int val)
{
   if (root == NULL) { root = new Node(val); }
   else { ... }
}
```

    - Does it make sense to define a constructor since the class will never be instantiated?
        - Yes, the constructor is still needed to initialize its members, since they will be inherited by its subclass.
    - Does it make sense to define a destructor since the class will never be created in the first place?
        - Yes, a destructor must be defined as virtual so that the destructor of its subclass is called.
        - Destructor can also be defined as pure, but its body must still be provided.