Inheritance & Polymorphism

CMSC 240 Software Systems Development

Today

- Inheritance
- Polymorphism
- Virtual functions
- Pure virtual functions and abstract classes

RICHMOND

Today

- Inheritance
- Polymorphism
- Virtual functions
- Pure virtual functions and abstract classes

RICHMOND

Inheritance

- Suppose you will define classes to model **`cats`**, **`dogs`**, and **`birds`**
- These classes have many common features
- What is the best way to design these classes to avoid redundancy?

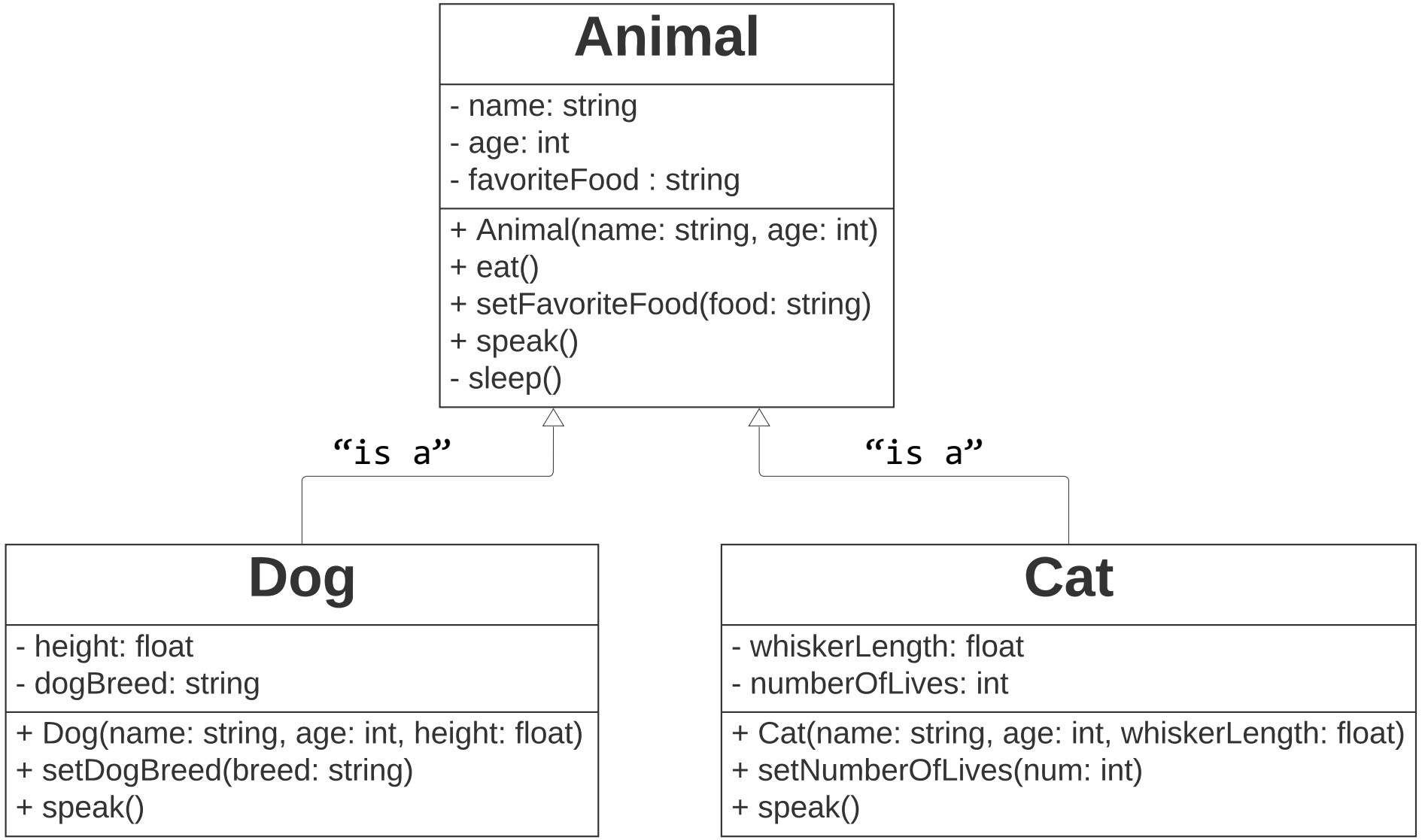
- Object-oriented programming allows you to define new classes from existing classes
- This is called **inheritance**

Superclasses and Subclasses

- Inheritance enables you to define a general class (i.e., a superclass) and later extend it to more specialized classes (i.e., subclasses)
- A subclass inherits from a superclass
  - For example, both a dog and a cat are animals
    - **`Animal`** is a superclass
    - **`Dog`** is a subclass of **`Animal`**
    - **`Cat`** is a subclass of **`Animal`**
- This is an example of an **is-a** relationship
  - **`Dog`** **is-a** **`Animal`**
  - **`Cat`** **is-a** **`Animal`**

Superclass

Subclasses



Superclasses and Subclasses

- A subclass inherits accessible data fields and methods from its superclass and may also add new data fields and methods
  - A subclass is not a subset of its superclass
  - A subclass usually contains more information and methods
- For example
  - **`Animal`** has a name, age, and favorite food
  - **`Cat`** also has whisker length, and number of lives
  - **`Dog`** also has height, and a dog breed

Superclasses and Subclasses

- A superclass is also called a “parent class” or “base class”
- A subclass is also called a “child class” or “derived class”

- A child class inherits from a parent class

- A subclass extends a superclass

- A derived class derives from a base class

Superclasses and Subclasses

- Remember, a class defines a type
- A type defined by a subclass is called a *subtype*, and a type defined by its superclass is called a *supertype*
- For example
  - **`Cat`** is a subtype of **`Animal`**, and
  - **`Animal`** is a supertype of **`Dog`**

Inheritance

```
class BaseClass
{
    // ... code for the base class
};

class DerivedClass : access_specifier BaseClass
{
    // ... code for the derived class
};
```

Access Control with Inheritance

Public Inheritance

- **public members** of the base class
  - become public members of the derived class
- **protected members** of the base class
  - become protected members of the derived class
- **private members** of the base class are
  - not accessible directly from the derived class

Access Control with Inheritance

Protected Inheritance

- **both public and protected members** of the base class
  - ➢become protected members of the derived class

- **private members** of the base class are
  - ➢not accessible directly from the derived class

Access Control with Inheritance

Private Inheritance

- **both public and protected members** of the base class
  - ➢become private members of the derived class

- **private members** of the base class are
  - ➢not accessible directly from the derived class

Constructor and Destructor in Inheritance

- When creating an object of the derived class, the base class's constructor is called first, followed by the derived class's constructor

- Conversely, when the object is destroyed, the derived class's destructor is called first, followed by the base class's destructor

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

class Parent
{
public:
    Parent()
    {
        cout << "1. Parent class under construction." << endl;
    }
};

class Child : public Parent   // Child inherits from the Parent
{
public:
    Child()
    {
        cout << "2. Child class under construction." << endl;
    }
};

int main()
{
    // Create a new instance of the child class.
    Child childInstance;
}
```

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

class Parent
{
public:
    Parent()
    {
        cout << "1. Parent class under construction." << endl;
    }
};

class Child : public Parent   // Child inherits from the Parent
{
public:
    Child()
    {
        cout << "2. Child class under construction." << endl;
    }
};

int main()
{
    // Create a new instance of the child class.
    Child childInstance;
}
```

```
1. Parent class under construction.
2. Child class under construction.
```

Ask a question

Today

- ~~Inheritance~~
- Polymorphism
- Virtual functions
- Pure virtual functions and abstract classes

RICHMOND

Polymorphism

- Polymorphism is a foundational concept in object-oriented programming that enables objects of different classes to be treated as objects of a common super class

- The term "polymorphism" is derived from Greek and means "having multiple forms"

- At its core, polymorphism allows one interface to represent **many different types** of objects or methods

Polymorphism

- Remember, a class defines a type
- A type defined by a subclass is called a subtype, and a type defined by its superclass is called a supertype
- For example
  - **`Dog`** is a subtype of **`Animal`**, and
  - **`Animal`** is a supertype for **`Cat`**
- Polymorphism means that a variable of a supertype can refer to a subtype object
  - For example, an **`Animal`** could be used to refer to a **`Cat`** or **`Dog`**

Polymorphism

- An object of a subtype can be used wherever its supertype value is required

For example: the **`animals`** vector is a list of pointers to **`Animal`** types. But we load it with **`Dog`** and **`Cat`** types.

```
// Create a dog and a cat.
Dog woofer{"Woofer", 3, 36.4};
Cat cheddar{"Cheddar", 5, 3.1};

// Create a vector of animal pointers.
vector<Animal*> animals;

// Add addresses to a dog and a cat.
animals.push_back(&woofer);
animals.push_back(&cheddar);
```

Polymorphism

- An object of a subtype can be used wherever its supertype value is required

Actual types

Declared type

```
// Create a dog and a cat.
Dog woofer{"Woofer", 3, 36.4};
Cat cheddar{"Cheddar", 5, 3.1};

// Create a vector of animal pointers.
vector<Animal*> animals;

// Add addresses to a dog and a cat.
animals.push_back(&woofer);
animals.push_back(&cheddar);
```

Today

- ~~Inheritance~~
- ~~Polymorphism~~
- Virtual functions
- Pure virtual functions and abstract classes

RICHMOND

Virtual Functions

- The **`virtual`** keyword plays a crucial role in enabling polymorphic behavior
  - When a function is declared as **`virtual`** in a base class, it indicates that this function can be overridden by a derived class
  - When a pointer to the base class type points to an object of a derived class, a call to a virtual function will invoke the most derived version of that function for the actual object being pointed to

- With the **`virtual`** keyword, the function call is dynamically bound to the appropriate version at runtime

```
1   #ifndef ANIMAL_H
2   #define ANIMAL_H
3   #include <string>
4
5   class Animal
6   {
7   public:
8       Animal(std::string name, int age);
9       void eat();
10      void setFavoriteFood(std::string favorite);
11      virtual void speak();
12  private:
13      std::string name;
14      int age;
15      std::string favoriteFood;
16      void sleep();
17  };
18
19  #endif
```

Today

- ~~Inheritance~~
- ~~Polymorphism~~
- ~~Virtual functions~~
- Pure virtual functions and abstract classes

RICHMOND

Pure Virtual Function

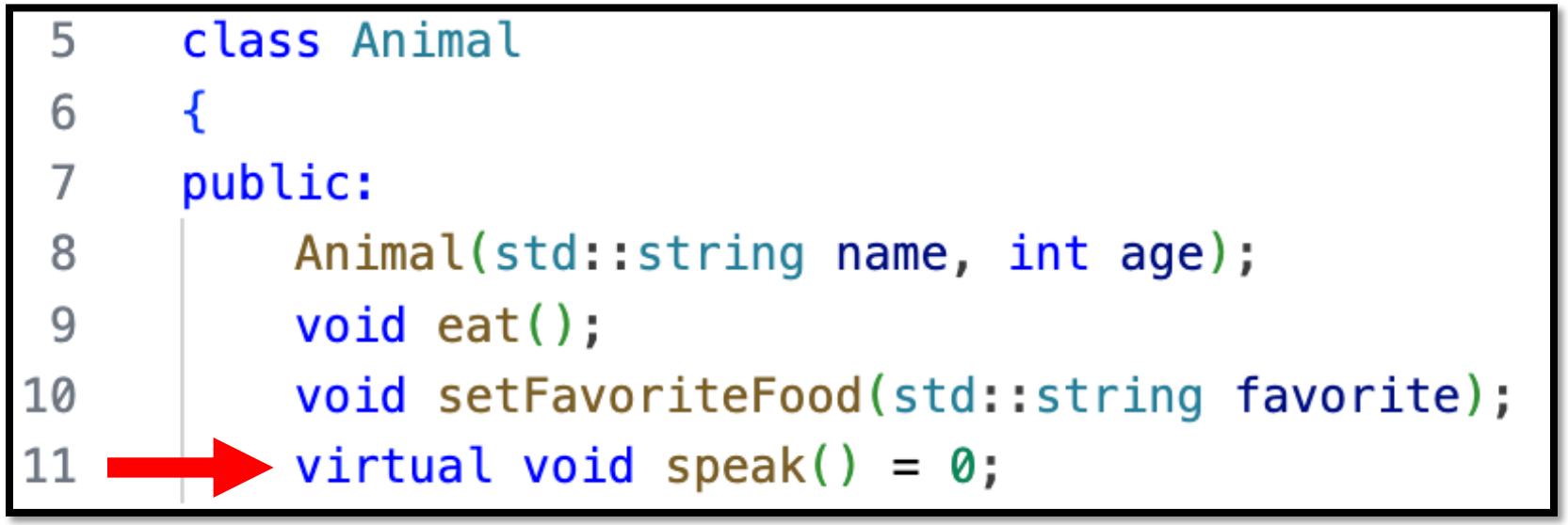
pure virtual function

- a virtual function with an `= 0` assignment
- indicating that there is no implementation for that function
- any concrete derived class must provide an implementation

```
 5    class Animal
 6    {
 7    public:
 8        Animal(std::string name, int age);
 9        void eat();
10        void setFavoriteFood(std::string favorite);
11        virtual void speak() = 0;
```

Abstract Class

- An **abstract class** is a class that either defines or inherits at least one function for that is pure virtual
- **You can not create an instance of an abstract class**



Ask a question