UNIVERSITY
OF WOLLONGONG
AUSTRALIA

CSCI251
Advanced Programming
Week 7: Inheritance and Polymorphism

Outline

Object Oriented Programming in C++

Inheritance

1. What is it?
2. Multilevel Inheritance
3. Multiple Inheritance
4. Protected
5. Why inheritance?
6. Access specifiers and Inheritance modes

Polymorphism

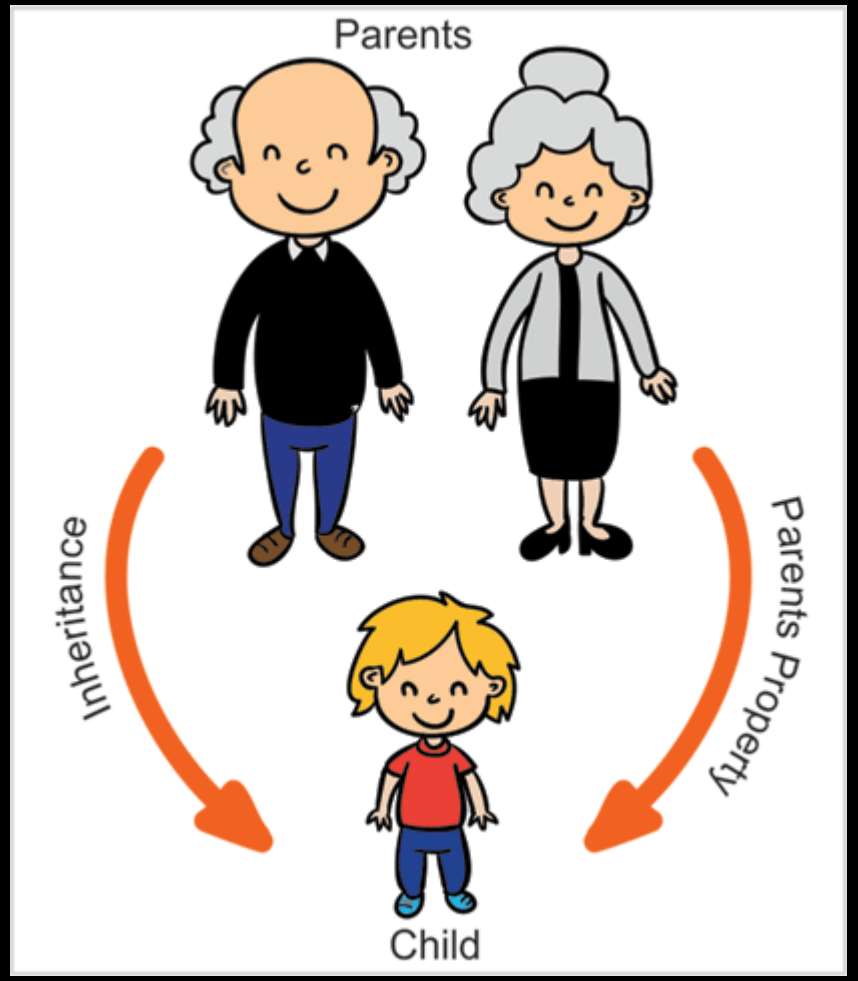
6. What is Polymorphism?
7. Virtual Functions

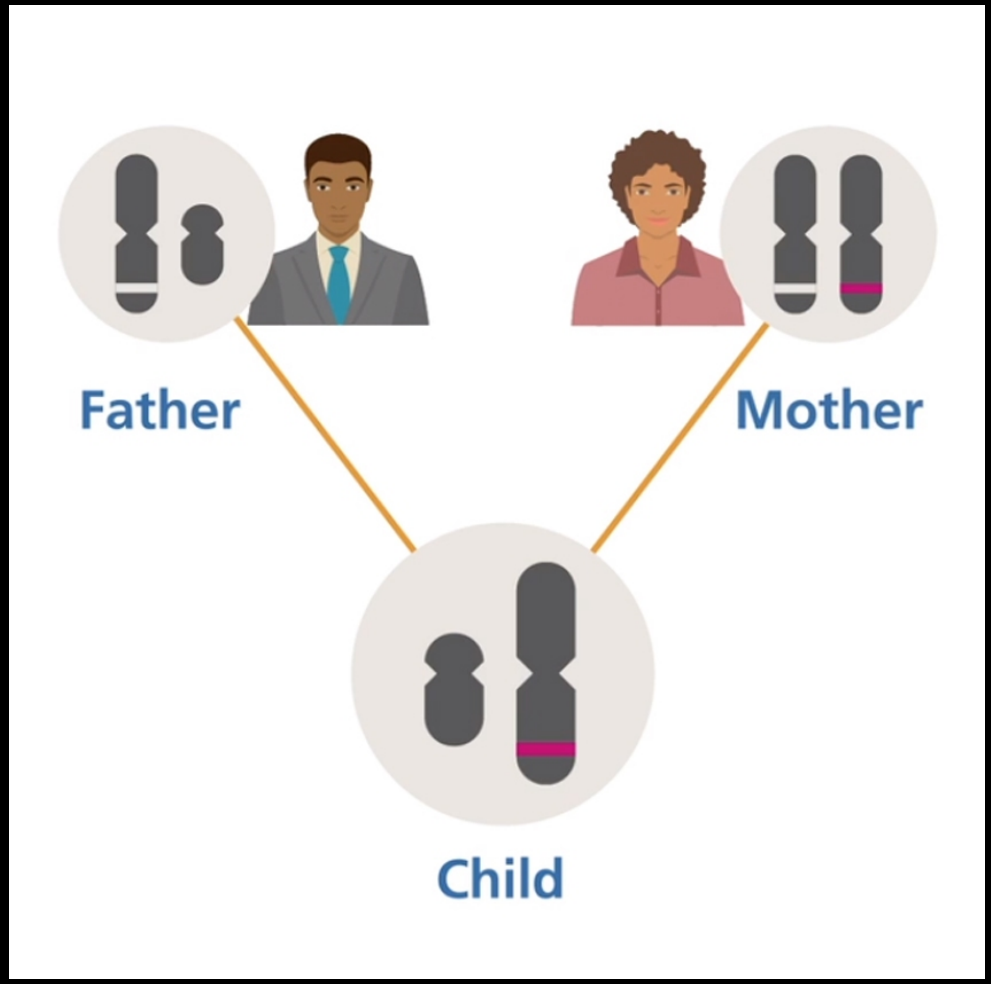
UML Language

8. What is UML?
9. Class/Object Relations

1. Inheritance

What is it?





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What is Inheritance?

Concept: Inheritance allows to us to define a child class that inherits all the methods and properties from a parent class.

We have two categories here:

Child (derived class): the class that inherits from another class

Parent (base class) : the class being inherited from

Source: https://www.w3schools.com

What is Inheritance?

Syntax: `class Child_Class: public Parent_Class{…};`

```
class White_Hacker: public Hacker {};
```

Source: https://www.w3schools.com

Inheritance

class Hacker:

Attributes:
name
level

Methods:
scan()
attack()

```
class White_Hacker: public Hac
ker
```

class White_Hacker:

Attributes:
name
Level

Methods:
scan()
attack()
defend()

Parent Class

Child Class

Code

```
#include <iostream>
using namespace std;
class Hacker {      // The class Hacker
public:           // Access specifier
    string name;    // Attribute (string variable)
    int level;      // Attribute (int variable)
    void scan(){    // Create function/method inside class
        cout << "I am scanning the target";
    };
};
class White_Hacker: public Hacker{
public:
    void defend(){
        cout << "----for defending!-----";
    }
};
int main(){
     White_Hacker w_Hacker; // an Object of White Hacker
     w_Hacker.name = "John";
     w_Hacker.level = 7;
     cout << "Hacker "<< w_Hacker.name << ", level: "<<w_Hacker.level<<"\n";
     w_Hacker.scan(); // Call the method
     w_Hacker.defend();
     return 0;
 }
```

Practice 1: Inheritance

- Do in Code:Block
- Create a class Gray_Hacker inherited from class Hacker with one method (use public: as access specifier)
  - void purpose()
  - print to screen “---for YOUR WORDs-----”
- In main() function:
  - Create an object gray_Hacker of class Gray_Hacker
  - Call the method scan()
  - Call the method purpose()

Multilevel Inheritance

Multilevel Inheritance?

Concept: A class can also be derived from one class, which is already derived from another class.

```
Child_Hacker is derived from class
White_Hacker, which is derived from
class Hacker
```

Code

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

class Hacker {      // The class Hacker
public:           // Access specifier
    string name;    // Attribute (string variable)
    int level;      // Attribute (int variable)
    void scan(){    // Create function/method inside class
        cout << "I am scanning the target";
    };
};
class White_Hacker: public Hacker{
public:
    void defend(){
        cout << "----for defending!-----\n";
    }
};
class Child_Hacker: public White_Hacker {
public:
    void whoiam(){
        cout << "I am a child of a white Hacker";
    }
};
 int main(){
     Child_Hacker ch_Hacker; // Create an Object of Child Ha
cker
     ch_Hacker.scan();
     ch_Hacker.defend();
     ch_Hacker.whoiam();
     return 0;
 }
```

Practice 2: Multilevel Inheritance

- Do in Code:Block
- Create a class Child_Hacker inherited from class Gray_Hacker with one method (use public: as access specifier)
  - void whoiam()
  - print to screen “I am a child of a Gray Hacker”
- In main() function:
  - Create an object ch_Haker of class Child_Hacker
  - Call the method scan()
  - Call the method purpose()
  - Call the method whoiam()

Multiple Inheritance

Multiple Inheritance?

Concept: A class can also be derived from more than one base class, using a comma-separated list.

```
Child_Hacker is derived from class
Ethical, and White_Hacker, which is
derived from class Hacker
```

Code

```cpp
#include <iostream>
using namespace std;
class Hacker {      // The class Hacker
public:           // Access specifier
    string name;    // Attribute (string variable)
    int level;      // Attribute (int variable)
    void scan(){    // Create function/method inside class
        cout << "I am scanning the target";
    };
};
class White_Hacker: public Hacker{
public:
    void defend(){
        cout << "----for defending!-----\n";
    }
};
// Another class
class Blue {
public:
    void blue(){
        cout << "I am also doing in a Blue Team";
    }
};
// Multiple Class
class Child_Hacker: public White_Hacker, public Blue {
public:
    void whoiam(){
        cout << "I am a child of a white Hacker\n";
    }
};
 int main(){
     Child_Hacker ch_Hacker; // Create an Object of Child Hacke
r
     ch_Hacker.scan();
     ch_Hacker.defend();
     ch_Hacker.whoiam();
     ch_Hacker.blue();
     return 0;
 }
```

Practice 3: Multiple Inheritance

- Do in Code:Block
- Create a class Red with one method red() print out is “I am also doing in a Red Team”
- Create a class Child_Hacker inherited from class Gray_Hacker and Red class
- In main() function:
  - Create an object ch_Haker of class Child_Hacker
  - Call the method scan()
  - Call the method purpose()
  - Call the method whoiam()
  - Call the method red()

Access Specifier:

protected

Access Specifier - protected

Recall: To modify the access feature of attributes and methods, we have 3 different types of access specifiers:

- Public can be directly accessed from outside the object.
- Private can only be directly accessed by internal methods.
- Protected can be directly accessed by objects of subclasses (inheriting class), but not by arbitrary external objects.

Access Specifier - protected

- Protected is similar to private, but it can also be accessed in the derived class (subclass).

Code

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

class Hacker {      // The class Hacker
protected:           // Access specifier
    int level;      // Attribute (int variable)
};
class White_Hacker: public Hacker{
public:
    int upgrade_Level;
    void setLevel(int l){
        level=l;
    }
    int getLevel(){
        return level;
    }
};
 int main(){
     White_Hacker w_Hacker; // Create an Object of White Hacker
     w_Hacker.setLevel(7);
     w_Hacker.upgrade_Level = 2;
     // Print to the screen the values
     cout << "White hacker has level: "<< w_Hacker.getLevel()<<"\n";
     cout << "now increase " << w_Hacker.upgrade_Level << " levels\n";
     cout << "The level now is " << w_Hacker.getLevel() + w_Hacker.upgrade_L
evel;
     return 0;
 }
```

Why we use Inheritance?

- Code reusability:
  - reuse attributes and methods of an existing class when you create a new class.

Access specifiers and Inheritance modes

C++ classes have access specifiers for data and methods which have three different types:

- **Public** can be directly accessed from outside the object.
- **Private** can only be directly accessed by internal methods.
- **Protected** can be directly accessed by objects of subclasses.

We can also use access specifiers to specify different inheritance modes:

- **Public inheritance** makes public members of the base class **remain public** respectively in the derived class.
- **Protected inheritance** makes public members of the base class **protected** in the derived class.
- **Private inheritance** makes public and protected members of the base class **private** in the derived class.

Access specifier table for members

Access	Public	Protected	Private
Same class			
Derived classes			
Outside classes			

Here, we assume subclasses to be derived from public inheritance.

Access specifier table for members

Access	Public	Protected	Private
Same class	YES	YES	YES
Derived classes	YES	YES	NO
Outside classes	YES	NO	NO

Here, we assume subclasses to be derived from public inheritance.

Different Inheritance modes

```
class Base {
  public:
    int x;
  protected:
    int y;
  private:
    int z;
};

class PublicDerived: public Base {
  // x is public
  // y is protected
  // z is not accessible from PublicDerived
};

class ProtectedDerived: protected Base {
  // x is protected
  // y is protected
  // z is not accessible from ProtectedDerived
};

class PrivateDerived: private Base {
  // x is private
  // y is private
  // z is not accessible from PrivateDerived
};
```

Practice 4


2. Polymorphism

Polymorphisms in C++

Compile-time polymorphism (early binding): determine function call during the compile-time.

- Function overloading
- Operator overloading

Run-time polymorphism (late binding): determine function call at the run-time. It usually happens with inheritance (to be introduced later).

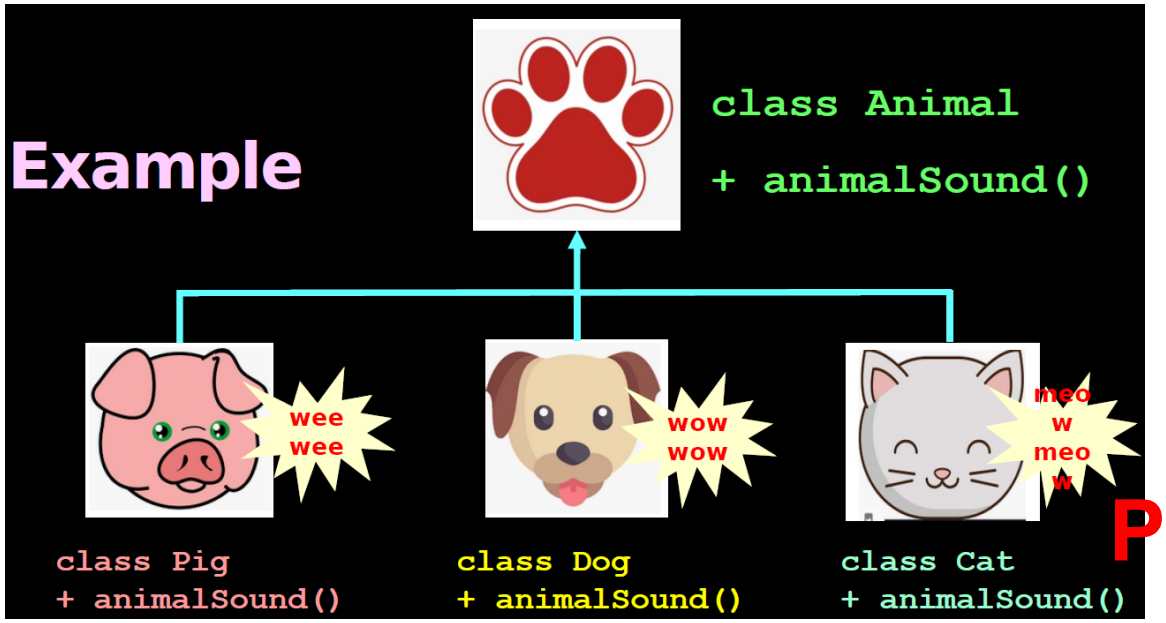
- Function overriding
- Virtual function

Run-time Polymorphism

Run-time polymorphism

Determine function call at the run-time. It usually happens with inheritance (to be introduced later).

- Function overriding: re-define the same function as defined in its base class.
- Virtual function: a ‘variant’ of function overriding; allow you to invoke derived class functions through a base class pointer or reference..



Practice 2

Function overriding

Code

```
The animal makes a sound
The pig says: wee wee
The dog says: wow wow
The cat says: meow meow

Process returned 0 (0x0)
Press any key to continue.
```

```cpp
#include <iostream>
using namespace std;
// Base class
class Animal {
  public:
    void animalSound(){cout << "The animal makes a sound \
n" ;}
};
// Derived class
class Pig : public Animal {
  public:
    void animalSound() {cout << "The pig says: wee wee \
n" ;}
};
class Dog : public Animal {
  public:
    void animalSound() {cout << "The dog says: wow wow \
n" ;}
};
class Cat : public Animal {
  public:
    void animalSound() {cout << "The cat says: meow meow \
n" ;}
};
int main() {
  Animal myAnimal;
  Pig myPig; Dog myDog; Cat myCat;
  myAnimal.animalSound();
  myPig.animalSound();
  myDog.animalSound();
  myCat.animalSound();
```

Virtual Function

Virtual function

Runtime polymorphism.
Ensure the correct function is called, regardless of the type of the pointer.

```
The pig says: wee wee
The dog says: wow wow
```

```cpp
#include <iostream>
using namespace std;
// Base class
class Animal {
  public:
    virtual void animalSound(){cout << "The animal makes a
sound \n" ;}
};
// Derived class
class Pig : public Animal {
  public:
    void animalSound() {cout << "The pig says: wee wee \
n" ;}
};
class Dog : public Animal {
  public:
    void animalSound() {cout << "The dog says: wow wow \
n" ;}
};
class Cat : public Animal {
  public:
    void animalSound() {cout << "The cat says: meow meow \
n" ;}
};
int main() {
  Animal *ptr=new Pig();
  ptr->animalSound();
  ptr=new Dog();
 ptr->animalSound();
```

Abstract class & Pure virtual function

An abstract class: it cannot be instantiated; it is a base class to be inherited; it must have at least one **pure** virtual function.

A pure virtual function: it is declared with *a pure specifier (=0).*

Indication*: we must have subclasses to inherit the abstract base class; these subclasses must override the pure virtual function; subclasses are still abstract if they do not override the pure virtual function.*

```cpp
// C++ Program to illustrate the abstract class and virtual
// functions
#include <iostream>
using namespace std;

class Base {
    // private member variable
    int x;

public:
    // pure virtual function
    virtual void fun() = 0;

    // getter function to access x
    int getX() { return x; }
};

// This class inherits from Base and implements fun()
class Derived : public Base {
    // private member variable
    int y;

public:
    // implementation of the pure virtual function
    void fun() { cout << "fun() called"; }
};

int main(void)
{
    // creating an object of Derived class
    Derived d;

    // calling the fun() function of Derived class
    d.fun();

    return 0;
}
```

Practice 3


3. UML

What is UML?

UML stands for “Unified Modelling Language”

- It is an industry-standard graphical language for specifying, visualizing, constructing, and documenting the artifacts of software systems
- The UML uses mostly graphical notations to express the OO analysis and design of software projects.
- Simplifies the complex process of software design

Type of UML

- Use Case Diagram
- Class Diagram
- Sequence Diagram
- Collaboration Diagram
- State Diagram

Class Diagram

- Provide a conceptual model of the system in terms of classes and their relationships between them.
- Used for requirement capture, end-user interaction.
- Detailed class diagrams are used by developers.

Class Representation

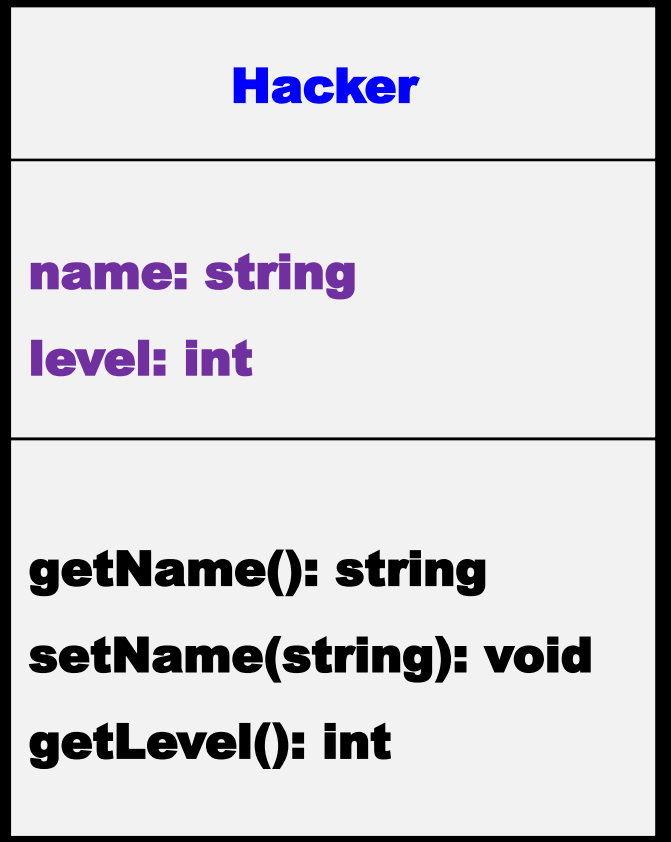
- Each class is represented by a rectangle subdivided into three compartments
  - Name
  - Attributes
  - Operations
- Modifiers are used to indicate visibility of attributes and operations.
  - '+' is used to denote Public visibility (everyone)
  - '#' is used to denote Protected visibility (friends and derived)
  - '-' is used to denote Private visibility (no one)
- By default, attributes are hidden and operations are visible.

Class Visualisation

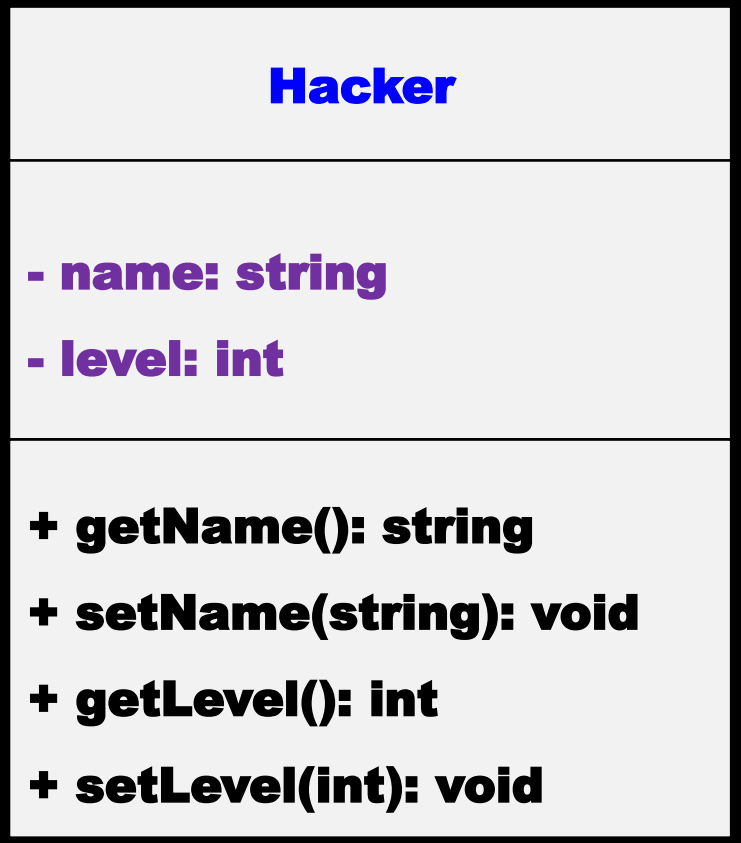
class name

attributes

methods



Class Visualisation

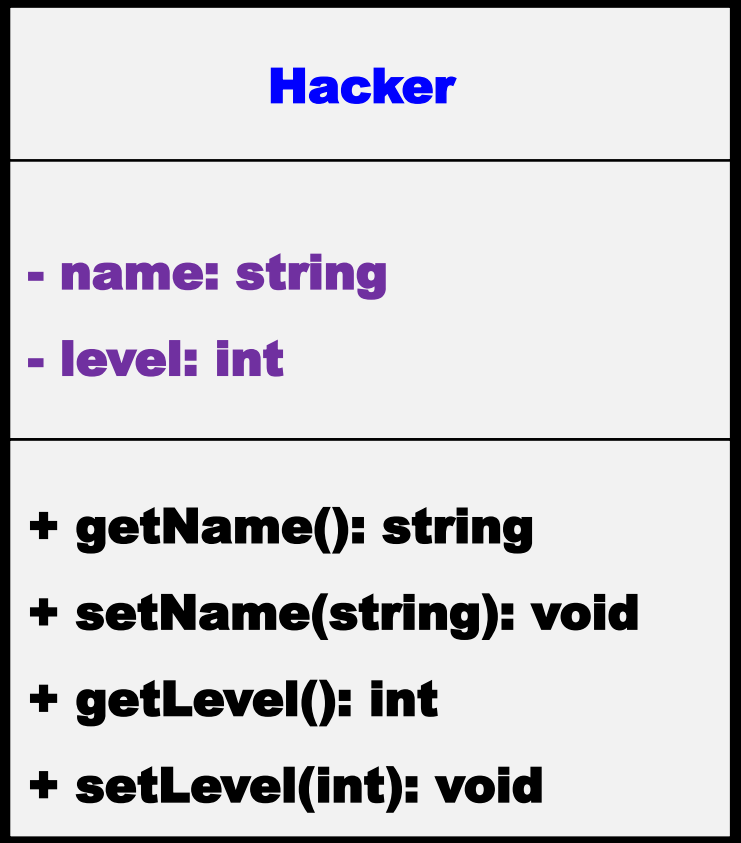


‘+’ public

‘#’ protected

‘-’ private

Class Visualisation

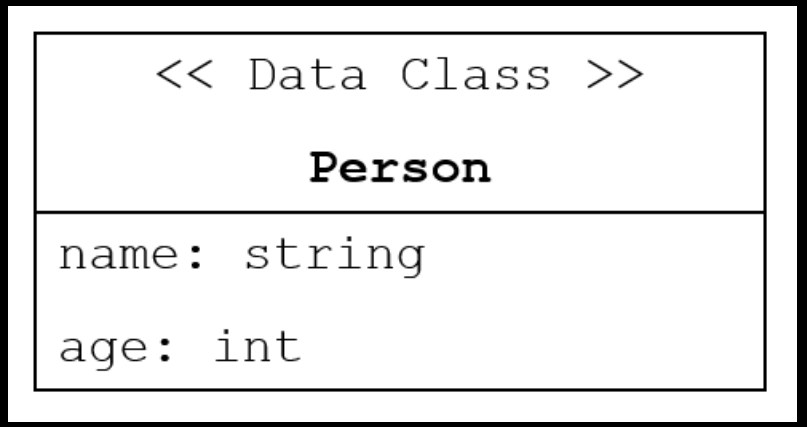



```
class Hacker {
  private:
        string name;
        int level;
    public:
        string getName(){…}
        void setName(String){…}
        int getLevel(){…}
        void setLevel(int){…}
};
```

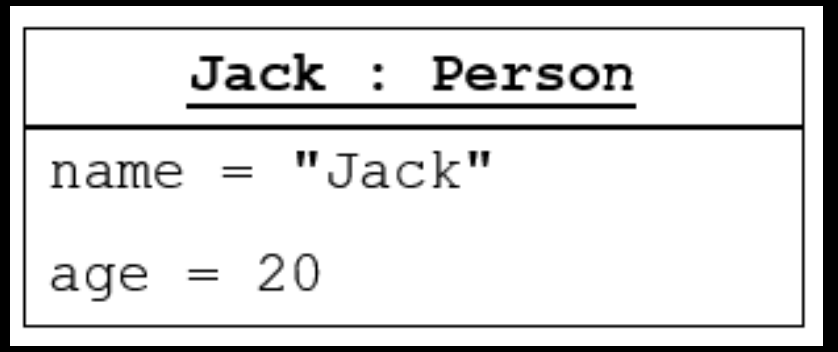
Object Diagram

- The building block is the object symbol, each based on a class symbol.

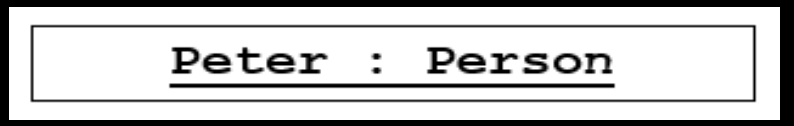
A class with attributes



object name class name underline



A specific value for each attribute



Simplified representation

- Object diagrams can represent a 'snapshot' of the system at a given moment, …
- … although we may leave out the attributes to obtain a time-invariant object symbol.

Class/Object Relations

- Class symbols by themselves provides quite limited information about the system.
- A system will often have multiple classes related in various ways, and a model of the system should reflect such relationship.
- UML defines the following relationship types:
  - Inheritance
  - Dependency.
  - Association.
  - Aggregation.
  - Composition.

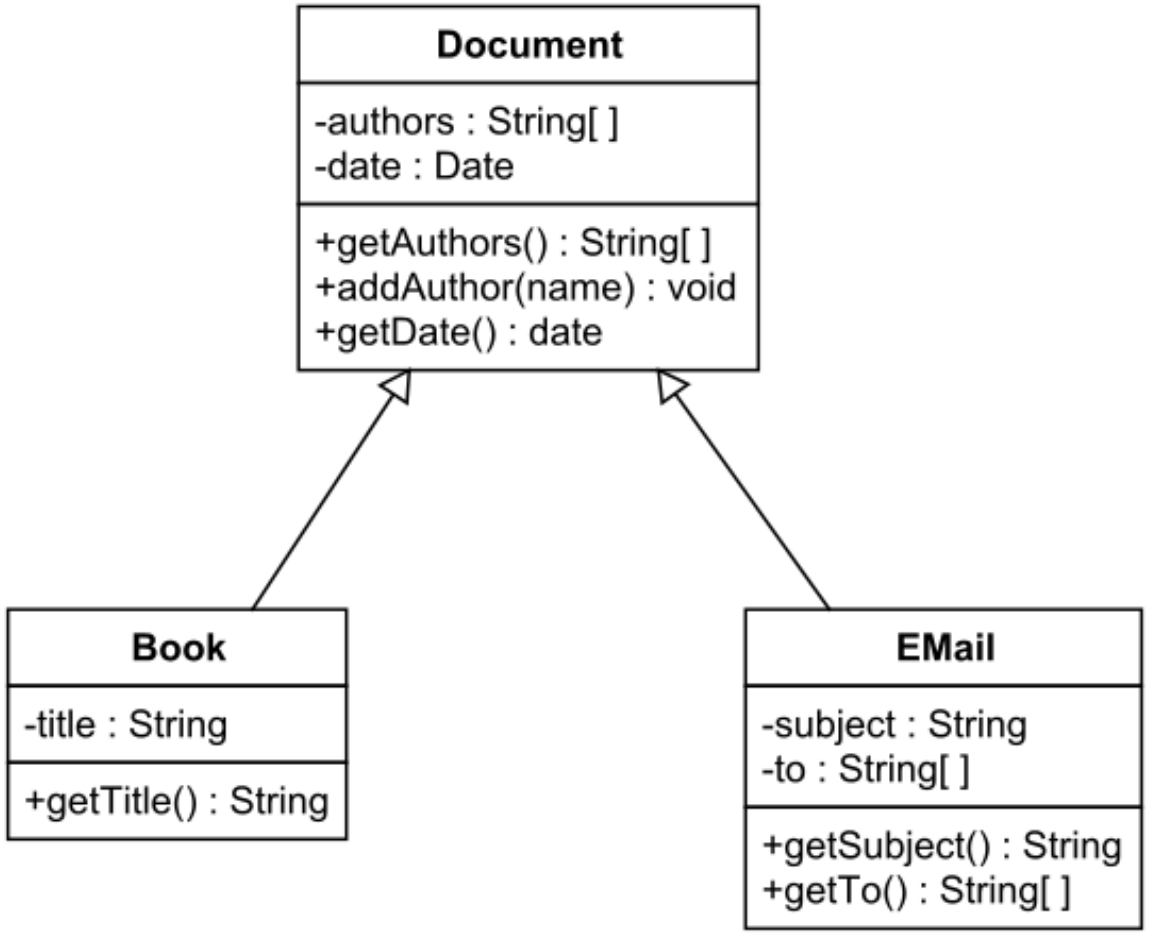
http://www.uml-diagrams.org/

Class/Object Relations

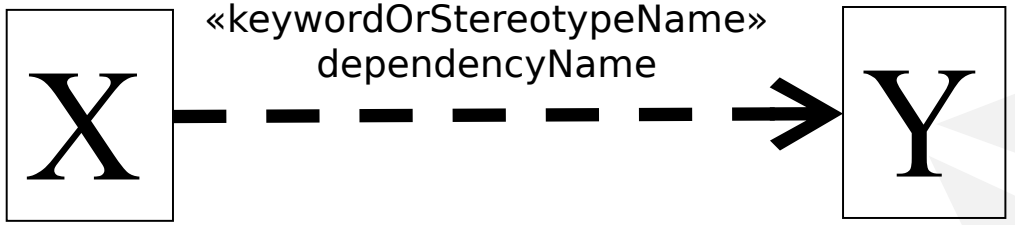
- The nature of the relationship can significantly impact how changes we make to one class, or to objects of that class, impact other classes or objects.
- In a certain sense those relations are in order of binding strength.

http://www.uml-diagrams.org/

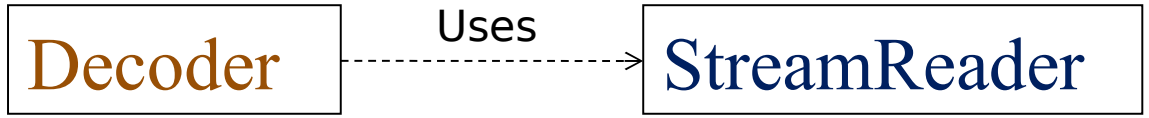
Inheritance



Dependency



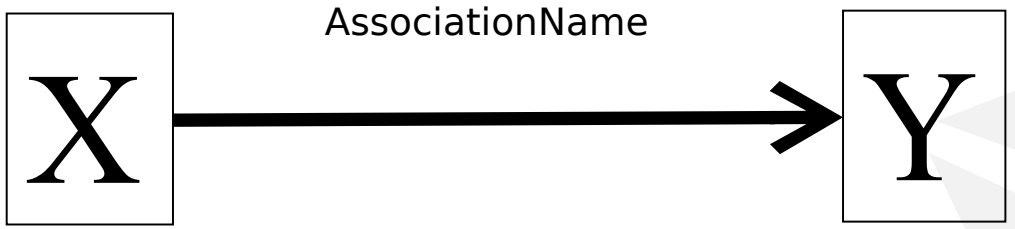
- Very general, one directional relationship indicating that one class uses another class, or depends on it in someway.
  - X uses (or depends on) Y but Y isn't influenced by X.



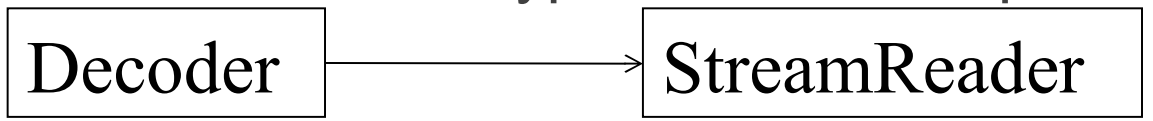

```
class Decoder {
 private:
    .  .  .
 public:
   void readStream( StreamRd
   *stR )
   { stR->getStream(); … }
   ...
};
```

```
class StreamRd{
   private:
      .  .  .
   public:
      void getStream();
   ...
};
```

Association



- One class retains a relationship with another class.
  - Often a collection of object links.
  - The illustration is one directional but these are often bi-directional and then a line without arrows is used.
- Association can be described as a “has a” type of relationship.



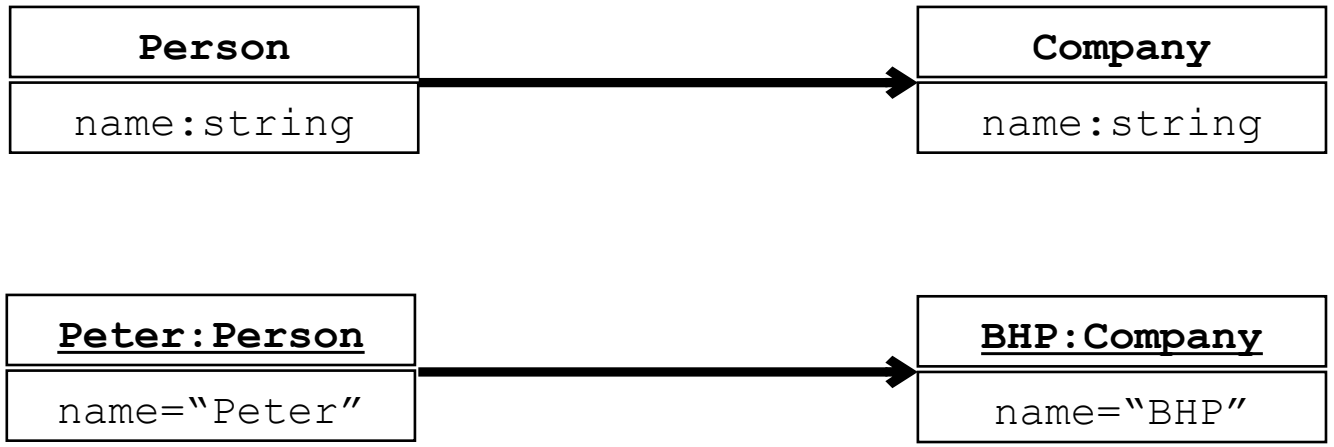

```
class Decoder {
 private:
   StreamRd *stR;
 public:
   Decoder();
   Decoder( StreamRd *stream )
   { stR = stream; … }
   ...
};
```

```
class StreamRd{
   .   .   .
};
```

- In the association implementation we have an object of one type *being* in another class, as opposed to the object being based in a function of the class as seen in the dependency.
- Association, aggregation, and composition all typically have this property; the distinction between them is based around the type of connection.
  - With a dependency it's more like using the functionality of another class instance.
    - cout, an instance of ostream, is an example of dependency.

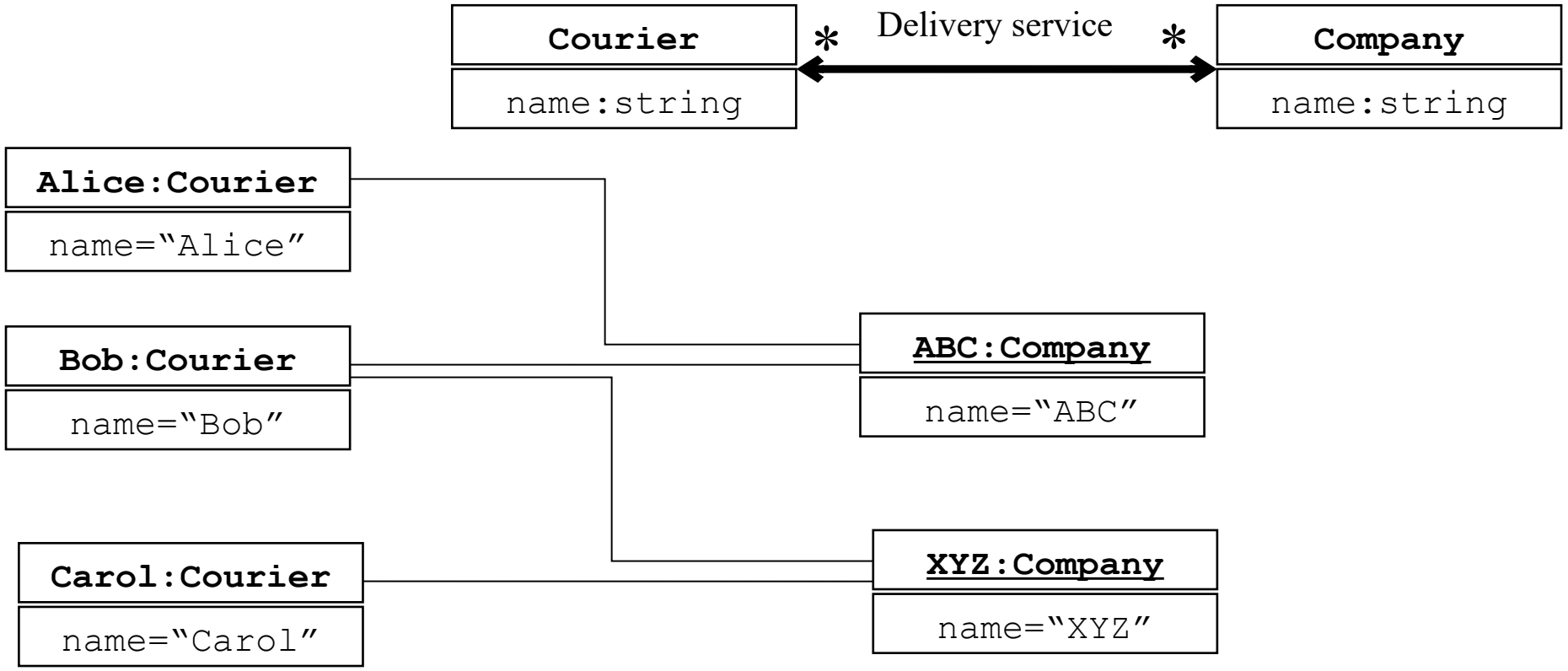
Object links and Class associations

- An association in a class diagram is represented by links between objects in an object diagram, showing that the objects are related/communicate with each other.
  - You can link objects together so long as there is a relationship between their classes.
- The links reflect only a static view of the interaction between objects.

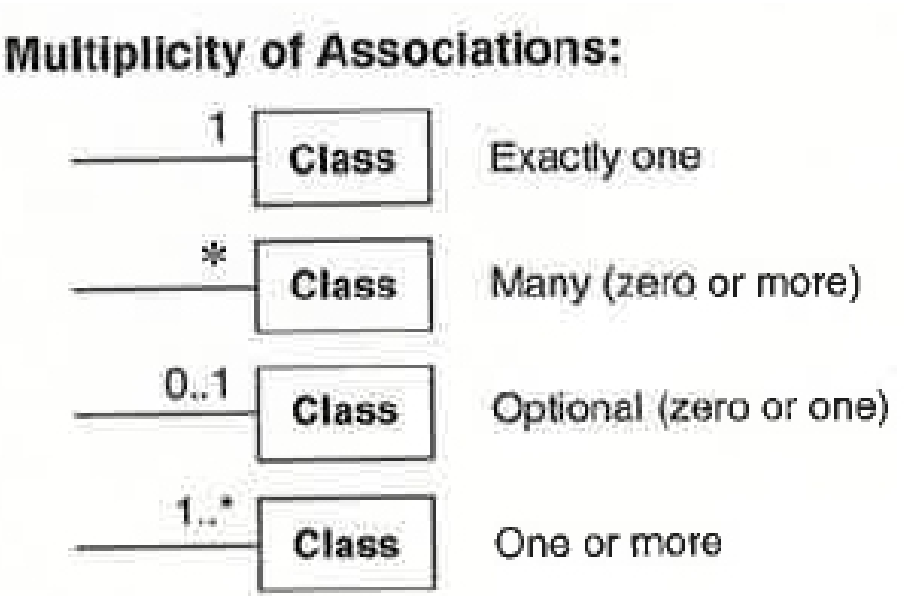


Linking multiple objects

- Sometimes we want to link multiple objects from one class to an object of another.
  - ➢ We illustrate this in a UML diagram using the multiplicity, represented by a *.



- From Blaha & Rumbaugh:

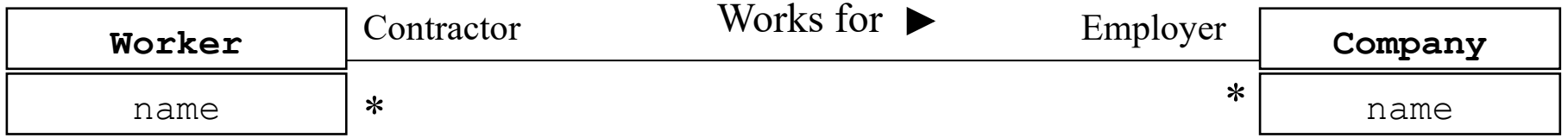


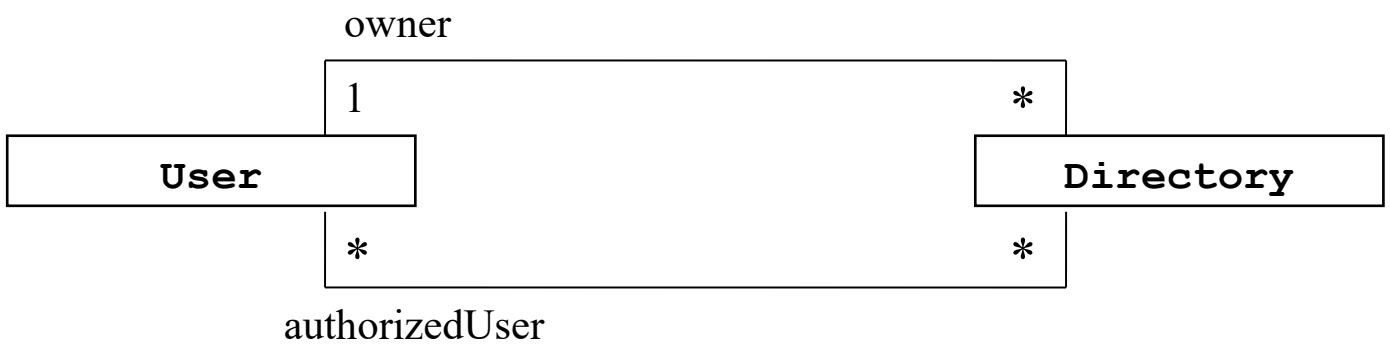
- For example:

- Actually some countries have more than one capital.
- Countries have many cities, and we can use this to illustrate a range of values allowed for a multiplicity, in general “a..b”.

Labelling and multiple associations

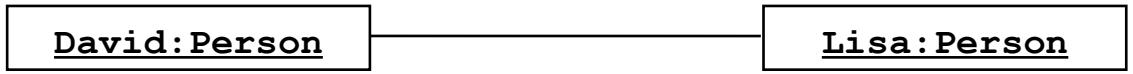
- Sometimes the association name may not clearly describe the relationship between classes
  - We can label the association roles to make things clearer.



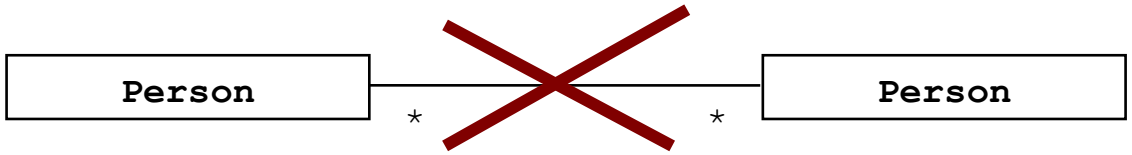


Self association

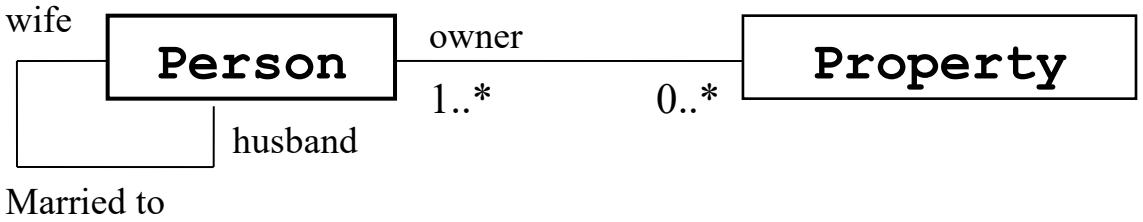
- Linked objects can be from the same class.



  - However, the class diagram below is confusing.



  - So, if a class can be associated to itself, only one class symbol should be shown.

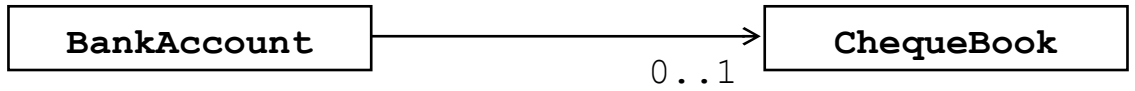


Some Implementation Examples

- Optional one-way Association:

  Example: A Cheque Book may be issued for use with a Bank Account, but some account holders may not be interested.

  The ChequeBook "doesn't exist" independent of the BankAccount.

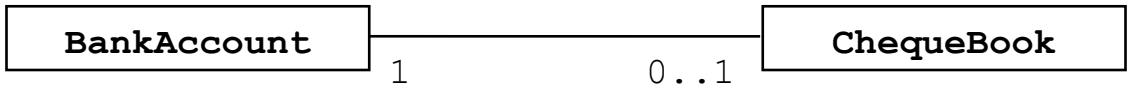



```
class BankAccount {
   private:
       ChequeBook *chBook;
   public:
      BankAccount(CheckBook *cP);
   ...
};
```

```
class ChequeBook {


   ...
};
```

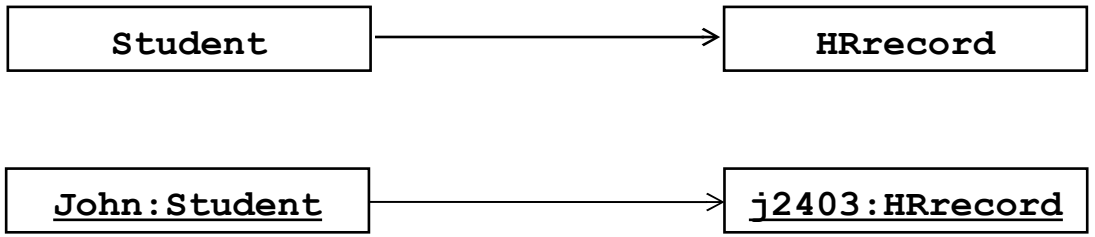
- You need to keep track of whether a `ChequeBook` exists or not, if it doesn't the `chBook` would effectively be nullptr.

- Bi-directional Association (one-to-optional):
  - We could have a Cheque Book for the Bank Account, as before, but…
  - … the Cheque Book has to be linked to a Bank Account.




```
class BankAccount {
   private:
      ChequeBook *chBook;
   . . .
};

class ChequeBook {
   private:
      BankAccount *account;
   . . .
};
```

- One way link between objects



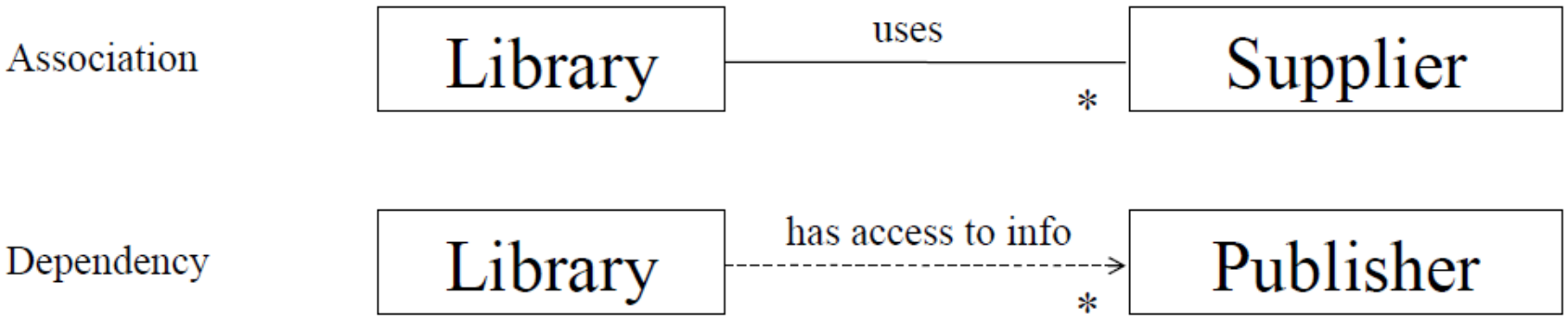
Class diagram

Object diagram

```
class HRrecord{
  . . .
};

class Student{
  HRrecord *record;
  . . .
};

. . .
HRrecord *j2403 = new HRrecord();
Student *John = new Student();

John->addRecord( j2403 );
```

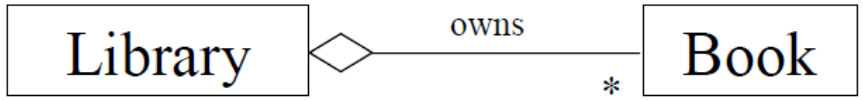
Association, Aggregation and Composition

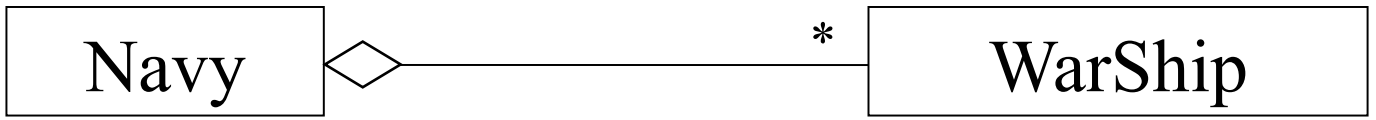
- Aggregation and composition are subsets of association, and reflect "owns" relationship
- Aggregation implies that the two associated classes can exist independently.
- Composition implies that the two associated classes cannot exist independently.
- The association below does not indicate ownership.



Aggregation

– Examples: Class and Student, Parent and Child, Library and Book, Navy and WarShip





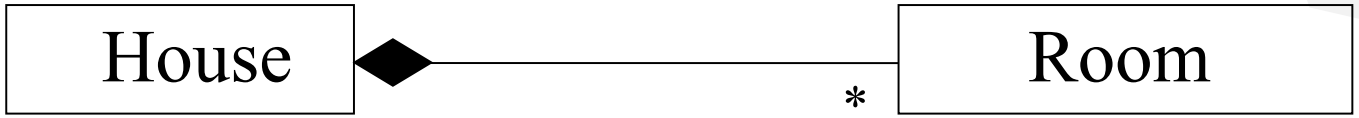

```
class Navy {
 private:
   int currentlyInService;
   WarShip *ships; // array of ships
 public:
   void addnewShip( WarShip *nShip );
   void decommissionShip( WarShip *nShip );
   ...
};
```

```
class WarShip{
   .   .   .
};
```

The implementation of aggregation is similar to association, it's a special case.

Composition or composite aggregation

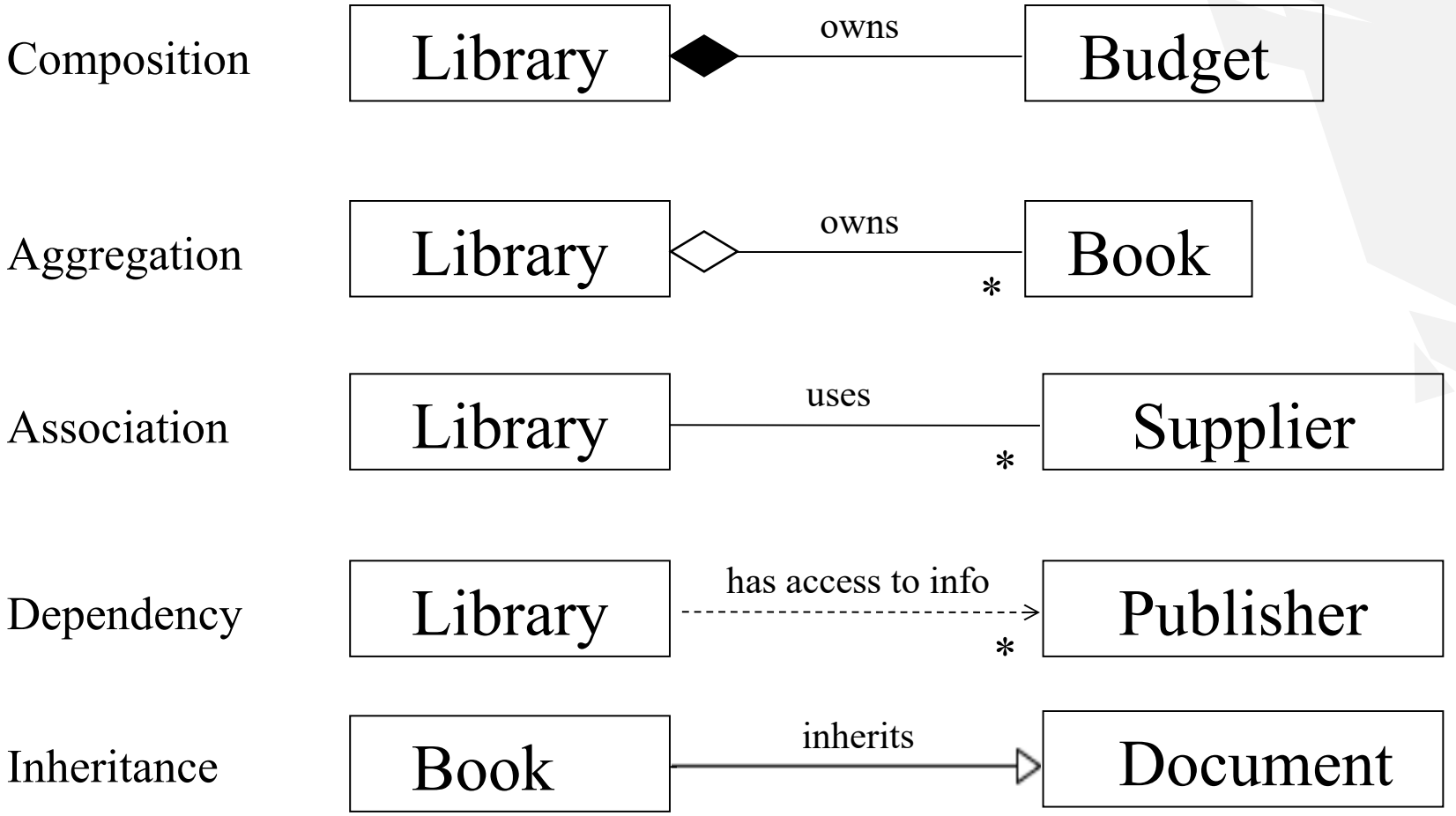
- Composition is the strongest version of Association
  - the owned object of a class cannot live on it's own. E.g., House owns rooms




```
class House {
 private:
   Room *rooms;
public:
   Cube() {
      rooms = new Room [2];   }
   ~Cube() {

      delete [] rooms;
   }
  ...
};
```

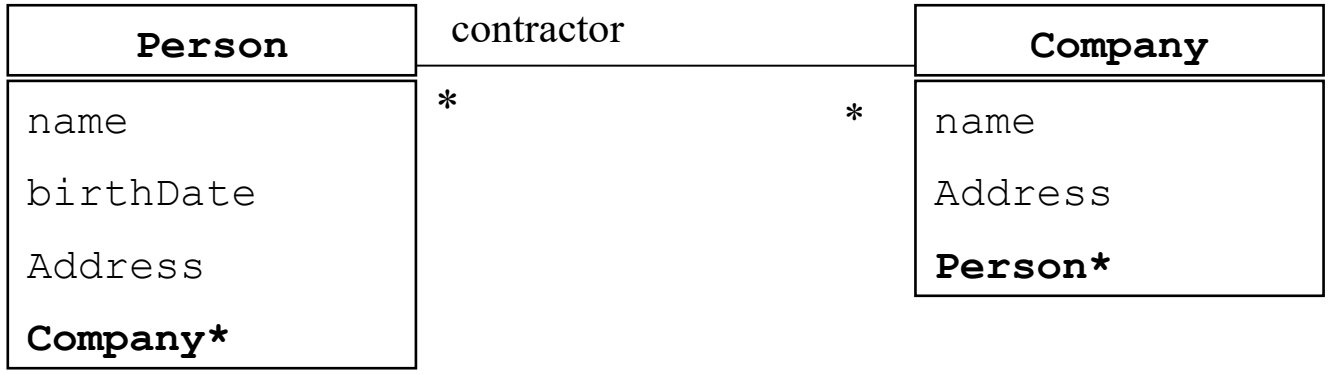
```
class Room{
   .   .   .
};
```

The relations to date …



Association classes

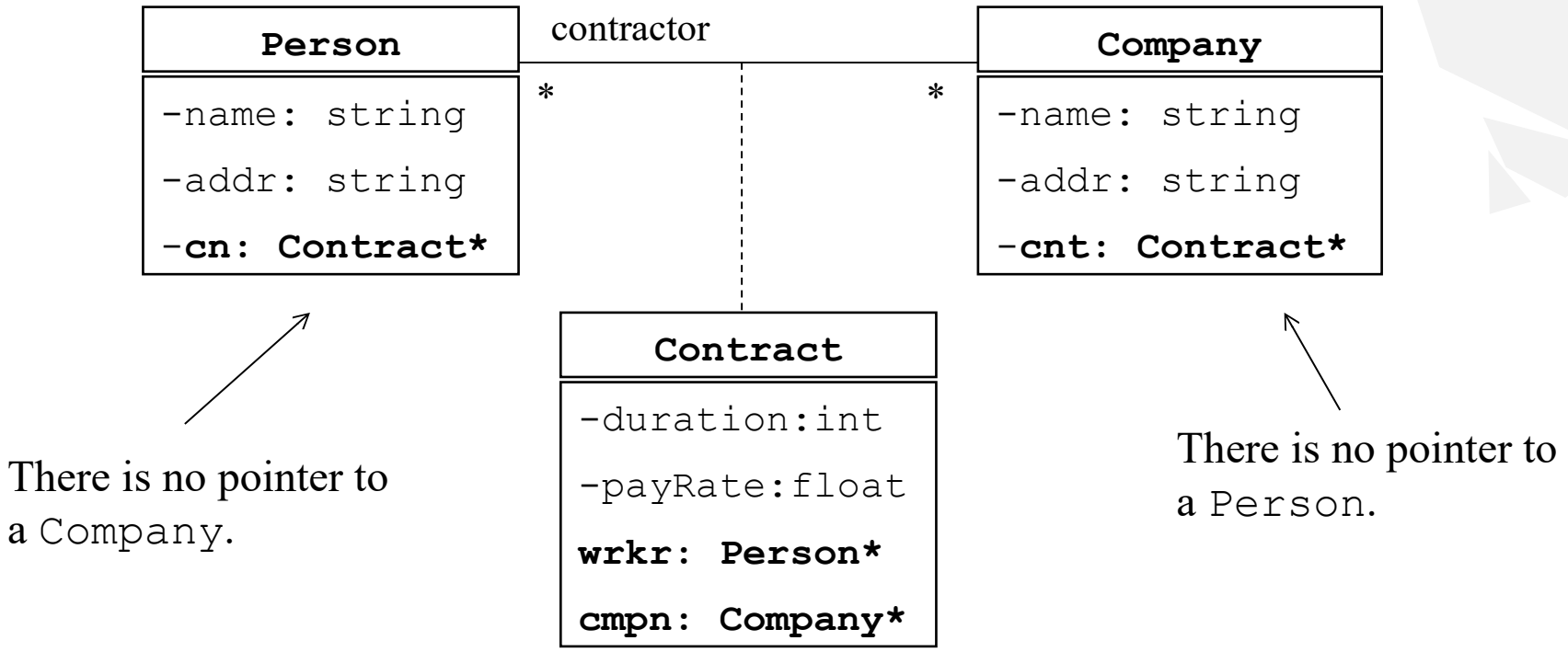
- Simple association can be implemented through pointers to objects as class data members.



- But if the association is implemented through a formal contract, where should the contract attributes be placed?
  - In the class `Person`?
  - In the class `Company`?
- How many contracts can a company have?
- Technically possible, but likely to be confusing and inefficient.

Association classes

- Complex associations can be modelled through classes.
- The notation for an association class is a class attached to an association by a dashed line.



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

class Person;
class Contract;
class Company
{
    string name;
    string addresss;
    Contract *contract; //association via Contract class public:
    Company(string Name="") : name(Name), contract(NULL) {}
    string getName() const { return(name); }
    void setContract(Contract *cn) { contract = cn;}
    Contract *getContract() const { return( contract); }
};
```

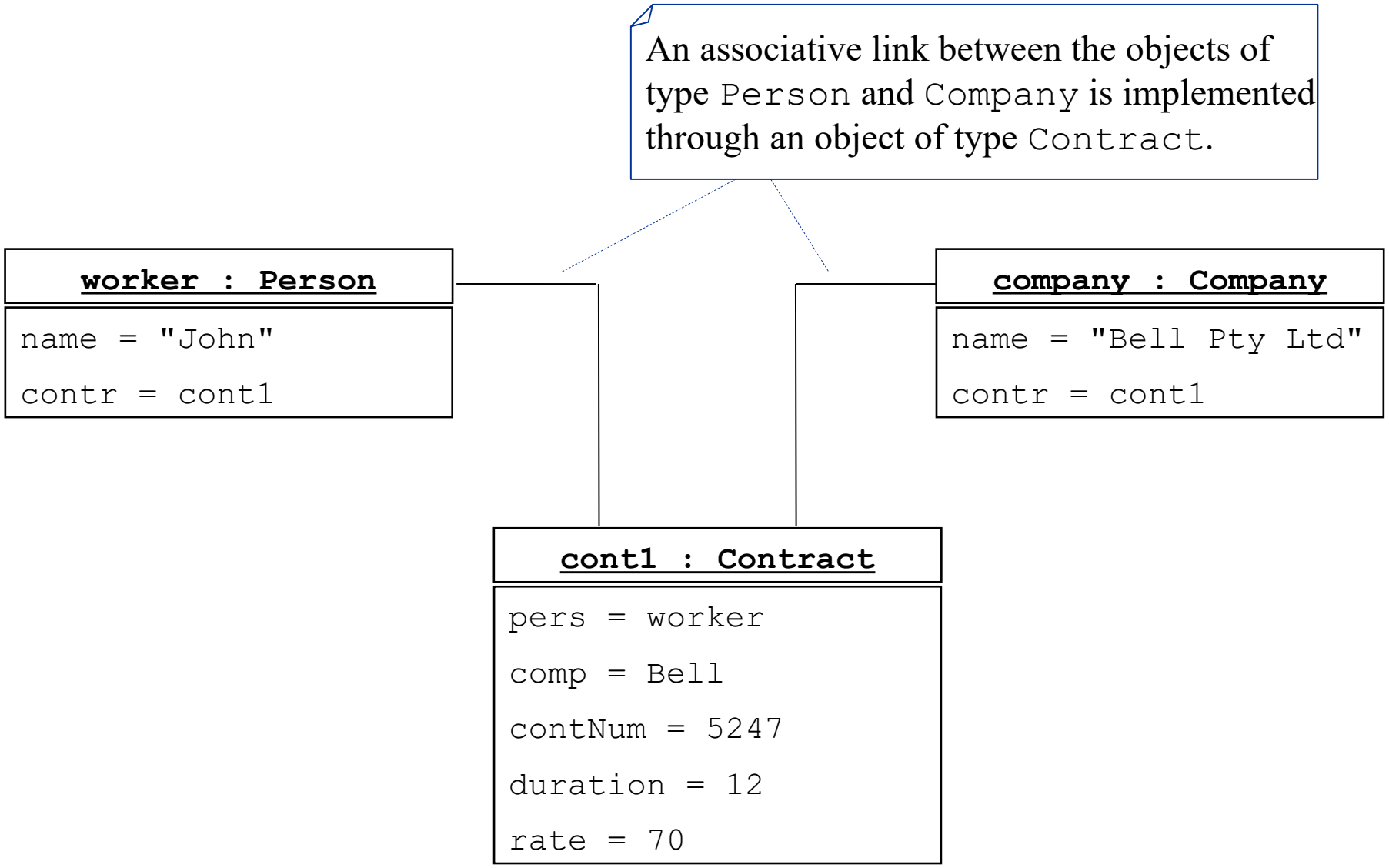
```
class Person
{
    string name;
    Contract *contract; //association via Contract class
  public:
    Person(string Name="") : name(Name), contract(NULL){}
    string getName() const  { return(name);}
    void setContract(Contract *cn) { contract = cn;}
    Contract *getContract() const { return( contract); }
};
```

```
class Contract
{
    Person *pers;  // association link to the class Person
    Company *comp; // association link to the class Company
    int contNum;
    int duration;
    static float rate;
  public:
    Contract( Person* worker, Company* empl, int cN, int dr )
    : pers(worker), comp(empl), contNum(cN), duration(dr)
    {
       worker->setContract( this ); // set a link Person->Contract
       comp->setContract( this );   // set a link Company->Contract
    }

    string getPersonName() const { return(pers->getName());}
    string getCompName() const { return(comp->getName()); }
    float getRate() const { return(rate); }
    int getDuration() const { return(duration); }
    int getContractNumber() const { return(contNum); }
};
float Contract::rate = 70.00;
```

```
int main()
{
  Person *worker = new Person( "John" );
  Company *company = new Company( "Bell Pty Ltd" );

  Contract *cont1 = new Contract(worker,company,5247,12);

  cout <<worker->getName()<<" has a contract number “
  << worker->getContract()->getContractNumber()
  << " with “ <<worker->getContract()->getCompName()
  << endl;

  cout<<"Duration: "
  << worker->getContract()->getDuration()
  << " months“ << endl;
  cout << "Rate: $“ << worker->getContract()->getRate()
  << "/hr " <<endl;
  return 0;
}
```

```
John has a contract number 5247 with Bell Pty Ltd
 Duration: 12 months
 Rate: 70 $/hr
```

- Here goes an object diagram representing the relationship.



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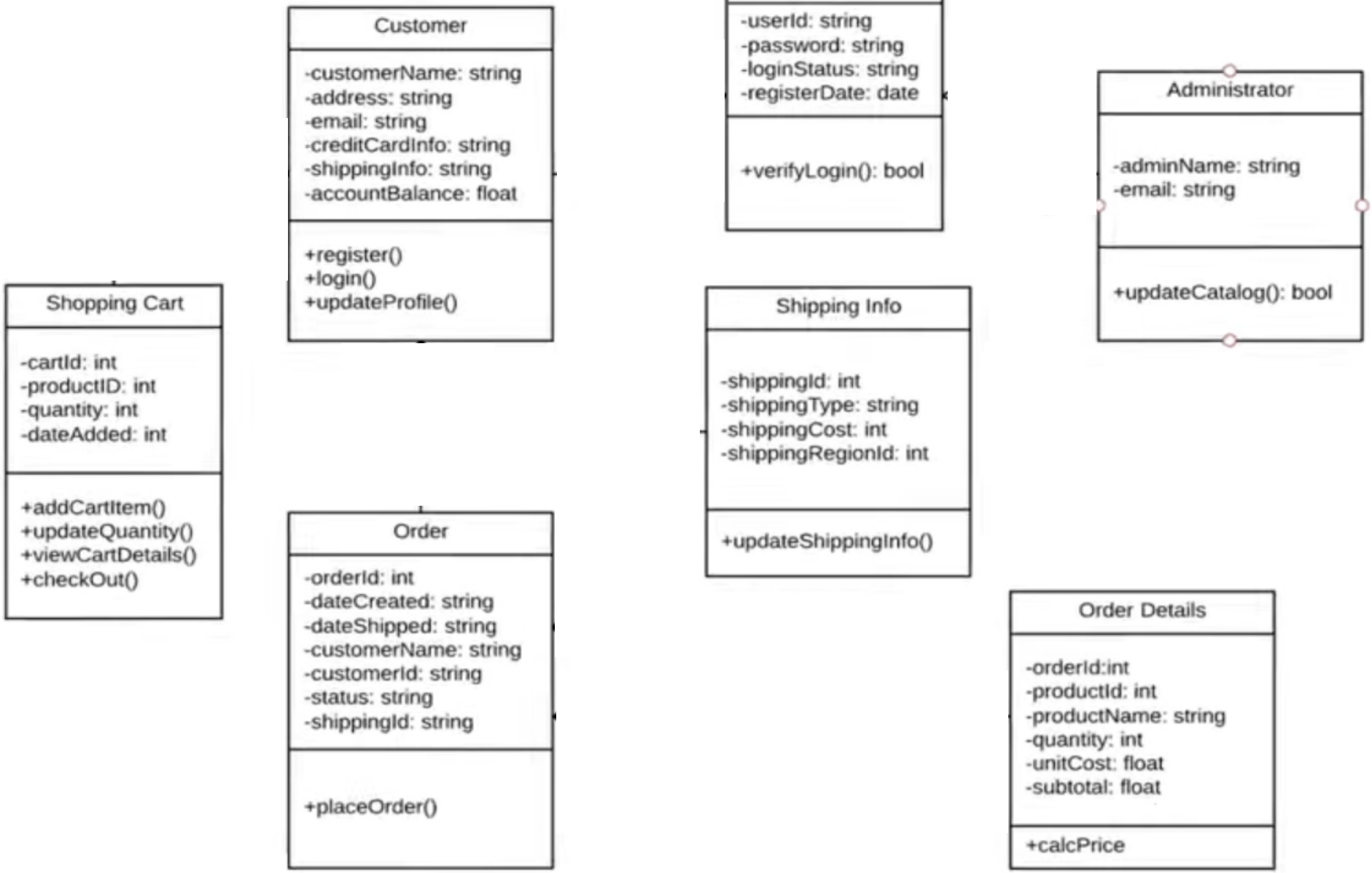

Online Shopping Cart