Module 30: Programming in C++

Dynamic Binding (Polymorphism): Part 5

Partha Pratim Das

Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

ppd@cse.iitkgp.ernet.in

Tanwi Mallick
Srijoni Majumdar
Himadri B G S Bhuyan

Module Objectives

- Understand design with class hierarchy

Module Outline

- Staff Salary Processing
    - C Solution
    - C++ Solution
        - Non-Polymorphic Hierarchy
        - Polymorphic Hierarchy
        - Polymorphic Hierarchy (Flexible)

Staff Salary Processing: Problem Statement: RECAP (Module 29)

- An organization needs to develop a salary processing application for its staff
- At present it has an engineering division only where Engineers and Managers work. Every Engineer reports to some Manager. Every Manager can also work like an Engineer
- The logic for processing salary for Engineers and Managers are different as they have different salary heads
- In future, it may add Directors to the team. Then every Manager will report to some Director. Every Director could also work like a Manager
- The logic for processing salary for Directors will also be distinct
- Further, in future it may open other divisions, like Sales division, and expand the workforce
- **Make a suitable extensible design**

C Solution: Engineer + Manager: RECAP (Module 29)

- How to represent Engineers and Managers?
  - `struct`
- How to initialize objects?
  - Initialization functions
- How to have a collection of mixed objects?
  - Array of `union`
- How to model variations in salary processing algorithms?
  - `struct`-specific functions
- How to invoke the correct algorithm for a correct employee type?
  - Function switch
  - Function pointers

C Solution: Advantages and Disadvantages RECAP (Module 29)

Advantages:

- Solution exists!
- Code is well structured – has patterns

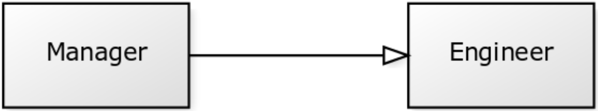
Disadvantages:

- Employee data has scope for better organization
    - No encapsulation for data
    - Duplication of fields across types of employees – possible to mix up types for them (say, `char *` and `string`)
    - Employee objects are created and initialized dynamically through `Init...` functions. How to release the memory?
- Types of objects are managed explicitly by `E_Type`:
    - Difficult to extend the design – addition of a new type needs to:
        - Add new type code to `enum E_Type`
        - Add a new pointer field in `struct Staff` for the new type
        - Add a new case (`if-else`) based on the new type
    - Error prone – developer has to decide to call the right processing function for every type (`ProcessSalaryManager` for `Mgr` etc.)

Recommendation:

- Use classes for encapsulation on a hierarchy

C++ Solution: Non-Polymorphic Hierarchy Engineer + Manager



Manager

Engineer

- How to represent Engineers and Managers?
  - Non-Polymorphic `class` hierarchy
- How to initialize objects?
  - Constructor / Destructor
- How to have a collection of mixed objects?
  - `array` of base class pointers
- How to model variations in salary processing algorithms?
  - Member functions
- How to invoke the correct algorithm for a correct employee type?
  - Function switch
  - Function pointers

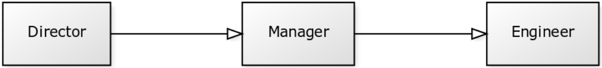
C++ Solution: Non-Polymorphic Hierarchy Engineer + Manager

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

typedef enum E_TYPE { Er, Mgr };
class Engineer { protected: string name_; E_TYPE type_;
public: Engineer(const string& name, E_TYPE e = Er) : name_(name), type_(e) {}
    E_TYPE GetType() { return type_; }
    void ProcessSalary() { cout << name_ << ": Process Salary for Engineer" << endl; }
};
class Manager : public Engineer { Engineer *reports_[10];
public: Manager(const string& name, E_TYPE e = Mgr) : Engineer(name, e) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Manager" << endl; }
};
int main() { Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib");
    Engineer *staff[] = { &e1, &m1, &m2, &e2, &e3 };

    for (int i = 0; i < sizeof(staff) / sizeof(Engineer*); ++i) {
        E_TYPE t = staff[i]->GetType();
        if (t == Er) staff[i]->ProcessSalary();
        else if (t == Mgr) ((Manager *)staff[i])->ProcessSalary();
        else cout << "Invalid Staff Type" << endl;
    }
    return 0;
}
```

C++ Solution: Non-Polymorphic Hierarchy Engineer + Manager

```
    Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib");
    Engineer *staff[] = { &e1, &m1, &m2, &e2, &e3 };

Output:
Rohit: Process Salary for Engineer
Kamala: Process Salary for Manager
Rajib: Process Salary for Manager
Kavita: Process Salary for Engineer
Shambhu: Process Salary for Engineer
```

C++ Solution: Non-Polymorphic Hierarchy Engineer + Manager + Director



- How to represent Engineers, Managers, and Directors?
  - Non-Polymorphic `class` hierarchy
- How to initialize objects?
  - Constructor / Destructor
- How to have a collection of mixed objects?
  - `array` of base class pointers
- How to model variations in salary processing algorithms?
  - Member functions
- How to invoke the correct algorithm for a correct employee type?
  - Function switch
  - Function pointers

C++ Solution: Non-Polymorphic Hierarchy Engineer + Manager + Director

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

typedef enum E_TYPE { Er, Mgr, Dir };
class Engineer { protected: string name_; E_TYPE type_;
public: Engineer(const string& name, E_TYPE e = Er) : name_(name), type_(e) {}
    E_TYPE GetType() { return type_; }
    void ProcessSalary() { cout << name_ << ": Process Salary for Engineer" << endl; }
};
class Manager : public Engineer { Engineer *reports_[10];
public: Manager(const string& name, E_TYPE e = Mgr) : Engineer(name, e) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Manager" << endl; }
};
class Director : public Manager { Manager *reports_[10];
public: Director(const string& name) : Manager(name, Dir) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Director" << endl; }
};
int main() { Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib"); Director d("Ranjana");
    Engineer *staff[] = { &e1, &m1, &m2, &e2, &e3, &d };

    for (int i = 0; i < sizeof(staff) / sizeof(Engineer*); ++i) {
        E_TYPE t = staff[i]->GetType();
        if (t == Er) staff[i]->ProcessSalary();
        else if (t == Mgr) ((Manager *)staff[i])->ProcessSalary();
        else if (t == Dir) ((Director *)staff[i])->ProcessSalary();
        else cout << "Invalid Staff Type" << endl;
    }
    return 0;
}
```

C++ Solution: Non-Polymorphic Hierarchy Engineer + Manager + Director

```
    Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib"); Director d("Ranjana");
    Engineer *staff[] = { &e1, &m1, &m2, &e2, &e3, &d };

Output:
Rohit: Process Salary for Engineer
Kamala: Process Salary for Manager
Rajib: Process Salary for Manager
Kavita: Process Salary for Engineer
Shambhu: Process Salary for Engineer
Ranjana: Process Salary for Director
```

C++ Solution: Non-Polymorphic Hierarchy: Advantages and Disadvantages

Advantages:

- Data is encapsulated
- Hierarchy factors common data members
- Constructor / Destructor to manage lifetime
- `struct`-specific functions made member function (overridden)
- `E_Type` subsumed in `class` – no need for `union`
- Code reuse evidenced

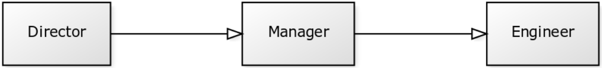
Disadvantages:

- Types of objects are managed explicitly by `E_Type`:
  - Difficult to extend the design – addition of a new type needs to:
    - Add new type code to `enum E_Type`
    - Application code need to have a new case (`if-else`) based on the new type
  - Error prone because the application programmer has to cast to right type to call `ProcessSalary`

Recommendation:

- Use a polymorphic hierarchy with dynamic dispatch

C++ Solution: Polymorphic Hierarchy Engineer + Manager + Director



- How to represent Engineers, Managers, and Directors?
  - Polymorphic `class` hierarchy
- How to initialize objects?
  - Constructor / Destructor
- How to have a collection of mixed objects?
  - `array` of base class pointers
- How to model variations in salary processing algorithms?
  - Member functions
- How to invoke the correct algorithm for a correct employee type?
  - Virtual Functions

C++ Solution: Polymorphic Hierarchy Engineer + Manager + Director

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

class Engineer { protected: string name_;
public: Engineer(const string& name) : name_(name) {}
    virtual void ProcessSalary() { cout << name_ << ": Process Salary for Engineer" << endl; }
};
class Manager : public Engineer { Engineer *reports_[10];
public: Manager(const string& name) : Engineer(name) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Manager" << endl; }
};
class Director : public Manager { Manager *reports_[10];
public: Director(const string& name) : Manager(name) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Director" << endl; }
};
int main() { Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib"); Director d("Ranjana");
    Engineer *staff[] = { &e1, &m1, &m2, &e2, &e3, &d };

    for (int i = 0; i < sizeof(staff) / sizeof(Engineer*); ++i) staff[i]->ProcessSalary();

    return 0;
}
```

C++ Solution: Polymorphic Hierarchy Engineer + Manager + Director

```
    Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib"); Director d("Ranjana");
    Engineer *staff[] = { &e1, &m1, &m2, &e2, &e3, &d };

Output:
Rohit: Process Salary for Engineer
Kamala: Process Salary for Manager
Rajib: Process Salary for Manager
Kavita: Process Salary for Engineer
Shambhu: Process Salary for Engineer
Ranjana: Process Salary for Director
```

C++ Solution: Polymorphic Hierarchy: Advantages and Disadvantages

Advantages:

- Data is fully encapsulated
- Polymorphic Hierarchy removes the need for explicit `E_Type`
- Application code is independent of types in the system (virtual functions manage types through polymorphic dispatch)
- High Code reuse – code is short and simple

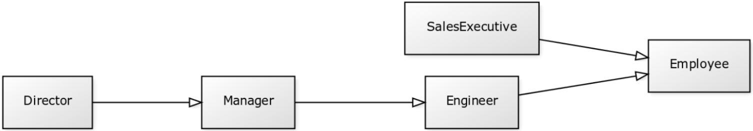
Disadvantages:

- Difficult to add an employee type that is not a part of this hierarchy (for example, employees of *Sales Division*

Recommendation:

- Use an abstract base class for employees

C++ Solution: Polymorphic Hierarchy (Flexible) Engineer + Manager + Director + Others



- How to represent Engineers, Managers, Directors, etc.?
  - Polymorphic `class` hierarchy with an Abstract Base Employee
- How to initialize objects?
  - Constructor / Destructor
- How to have a collection of mixed objects?
  - `array` of base class pointers
- How to model variations in salary processing algorithms?
  - Member functions
- How to invoke the correct algorithm for a correct employee type?
  - Virtual Functions (Pure in Employee)

C++ Solution: Polymorphic Hierarchy (Flexible) Engineer + Manager + Director + Others

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

class Employee { protected: string name_;
public: virtual void ProcessSalary() = 0;
};
class Engineer: public Employee { public: Engineer(const string& name) { name_ = name; }
    void ProcessSalary() { cout << name_ << ": Process Salary for Engineer" << endl; }
};
class Manager : public Engineer { Engineer *reports_[10];
public: Manager(const string& name) : Engineer(name) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Manager" << endl; }
};
class Director : public Manager { Manager *reports_[10];
public: Director(const string& name) : Manager(name) {}
    void ProcessSalary() { cout << name_ << ": Process Salary for Director" << endl; }
};
class SalesExecutive : public Employee { public:
    SalesExecutive(const string& name) { name_ = name; }
    void ProcessSalary() { cout << name_ << ": Process Salary for Sales Executive" << endl; }
};
int main() {
    Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib");   SalesExecutive s1("Hari"), s2("Bishnu");
    Director d("Ranjana");
    Employee *staff[] = { &e1, &m1, &m2, &e2, &s1, &e3, &d, &s2 };

    for (int i = 0; i < sizeof(staff) / sizeof(Employee*); ++i) staff[i]->ProcessSalary();
    return 0;
}
```

C++ Solution: Polymorphic Hierarchy (Flexible) Engineer + Manager + Director + Others

```
    Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib"); SalesExecutive s1("Hari"), s2("Bishnu");
    Director d("Ranjana");
    Employee *staff[] = { &e1, &m1, &m2, &e2, &s1, &e3, &d, &s2 };
```

```
Output:

Rohit: Process Salary for Engineer
Kamala: Process Salary for Manager
Rajib: Process Salary for Manager
Kavita: Process Salary for Engineer
Hari: Process Salary for Sales Executive
Shambhu: Process Salary for Engineer
Ranjana: Process Salary for Director
Bishnu: Process Salary for Sales Executive
```

C++ Solution: Polymorphic Hierarchy (Flexible): Advantages and Disadvantages

Advantages:

- Data is fully encapsulated
- Flexible Polymorphic Hierarchy makes addition of any class possible on the hierarchy
- Application code is independent of types in the system (virtual functions manage types through polymorphic dispatch)
- Maximum Code reuse – code is short and simple

Disadvantages:

- Still needs to maintain employee objects in code and add them to the staff array - this is error prone

Recommendation:

- Use vector as a collection and insert staff as created

Edited on 04-Feb-2021

C++ Solution: Polymorphic Hierarchy (Flexible) Engineer + Manager + Director + Others

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

class Employee { protected:
    string name_;                       // Name of the employee
    vector<Employee*> reports_;         // Collection of reportees aggregated
public:
    virtual void ProcessSalary() = 0;   // Processing salary
    static vector<Employee*> staffs;    // Collection of all staffs
    void AddStaff(Employee* e) { staffs.push_back(e); };  // Add a staff to collection
};
class Engineer : public Employee { public:
    Engineer(const string& name) { name_ = name;    // Why init like name_(name) won’t work?
                               AddStaff(this); }    // Add the staff
    void ProcessSalary() { cout << name_ << ": Process Salary for Engineer" << endl; }
};
class Manager : public Engineer { public:
    Manager(const string& name) : Engineer(name) { }
    void ProcessSalary() { cout << name_ << ": Process Salary for Manager" << endl; }
};
class Director : public Manager { public:
    Director(const string& name) : Manager(name) { }
    void ProcessSalary() { cout << name_ << ": Process Salary for Director" << endl; }
};
class SalesExecutive : public Employee { public:
    SalesExecutive(const string& name) { name_ = name; AddStaff(this); }   // Add the staff
    void ProcessSalary() { cout << name_ << ": Process Salary for Sales Executive" << endl; }
};
```

Added on 04-Feb-2021

C++ Solution: Polymorphic Hierarchy (Flexible) Engineer + Manager + Director + Others

```
vector<Employee*> Employee::staffs;         // Collection of all staffs

int main() {
    Engineer e1("Rohit"), e2("Kavita"), e3("Shambhu");
    Manager m1("Kamala"), m2("Rajib");
    SalesExecutive s1("Hari"), s2("Bishnu");
    Director d("Ranjana");

    vector<Employee*>::const_iterator it;   // Iterator over staffs

    for (it = Employee::staffs.begin();     // Iterate on staffs
            it < Employee::staffs.end();
            ++it)
        (*it)->ProcessSalary();             // Process respective salary

    return 0;
}
```

```
Output:

Rohit: Process Salary for Engineer
Kavita: Process Salary for Engineer
Shambhu: Process Salary for Engineer
Kamala: Process Salary for Manager
Rajib: Process Salary for Manager
Hari: Process Salary for Sales Executive
Bishnu: Process Salary for Sales Executive
Ranjana: Process Salary for Director
```

Added on 04-Feb-2021

C++ Solution: Polymorphic Hierarchy (Flexible): Advantages and Disadvantages

Advantages:

- Data is fully encapsulated
- Flexible Polymorphic Hierarchy makes addition of any class possible on the hierarchy
- Application code is independent of types in the system (virtual functions manage types through polymorphic dispatch)
- Maximum Code reuse – code is short and simple
- Collection of staff encapsulated with creation
- vector and iterator increases efficiency and efficacy

Disadvantages:

- None in particular

Recommendation:

- Enjoy the solution

Added on 04-Feb-2021

Module Summary

- Completed design for a staff salary problem using hierarchy and worked out extensible C++ solution

Instructor and TAs

Name	**Mail**	**Mobile**
Partha Pratim Das, *Instructor*	ppd@cse.iitkgp.ernet.in	9830030880
Tanwi Mallick, *TA*	tanwimallick@gmail.com	9674277774
Srijoni Majumdar, *TA*	majumdarsrijoni@gmail.com	9674474267
Himadri B G S Bhuyan, *TA*	himadribhuyan@gmail.com	9438911655