Inheritance

C++ Object Oriented Programming

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NTOUCS

Contents

- Basic Inheritance
  - Why inheritance
  - How inheritance works
  - Protected members
  - Constructors and destructors
  - Derivation tree
  - Function overriding and hiding
  - Example class hierarchy

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  - How inheritance works
  - Protected members
  - Constructors and destructors
  - Derivation tree
  - Function overriding and hiding
  - Example class hierarchy
- Inheritance Design
  - Exploring different inheritance structure
  - Direct solution to reuse code
  - Alternative solutions
  - Better design
  - Final solutions
  - Design rules (IS-A relationship, Proper inheritance)
  - Dubious designs

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  - The identification of the attributes and behaviours of these objects.
  - The identification of any super-classes.
  - The specification of the behaviours of the identified classes.

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Base class		**Derived class**
Super-class	vs.	**Sub-class**

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Base class		**Derived class**
Super-class	vs.	**Sub-class**
Parent class		**Child class**

Basic Inheritance

The Basic Problem: Extension

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Software entities (classes, modules, functions, etc.) should be open for extension, but closed for modification.

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- Also, a lot of redundancy.

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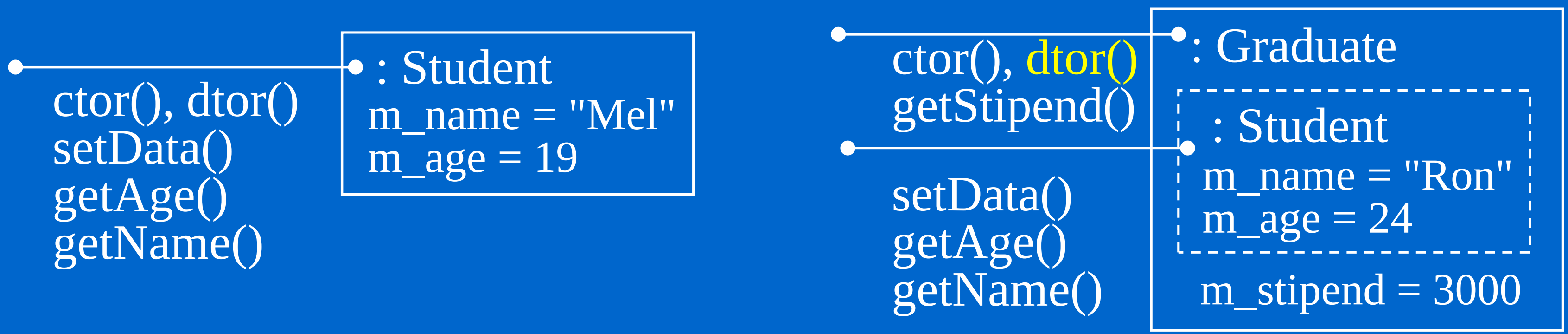

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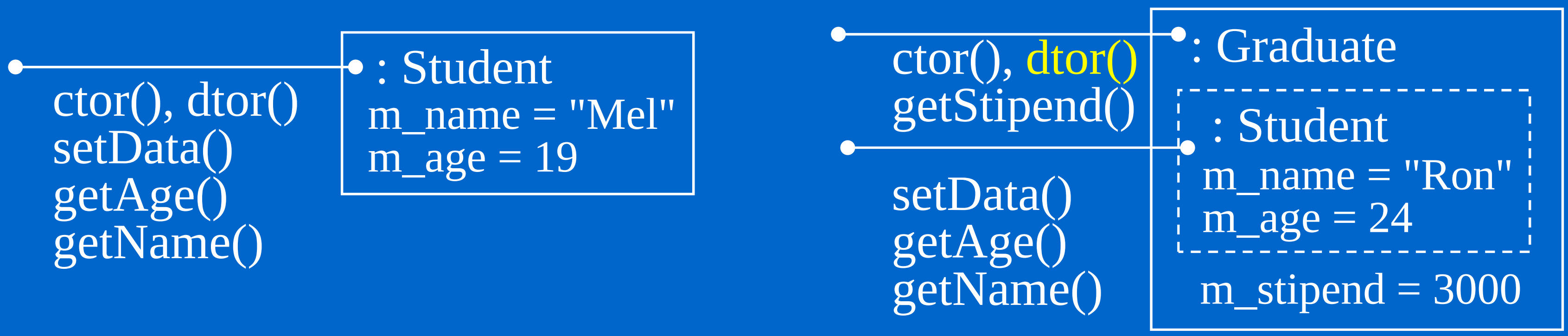


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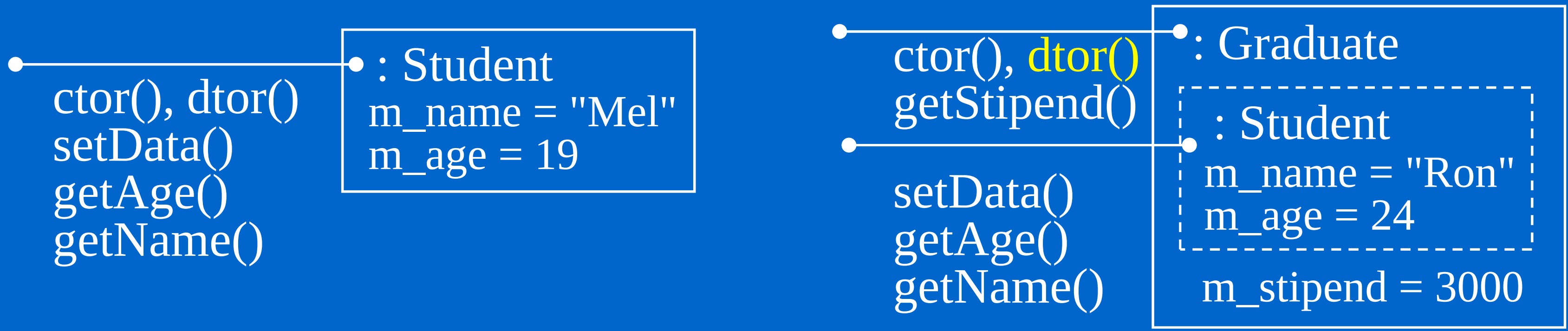


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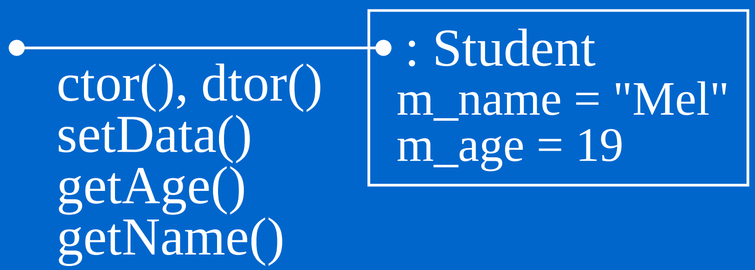

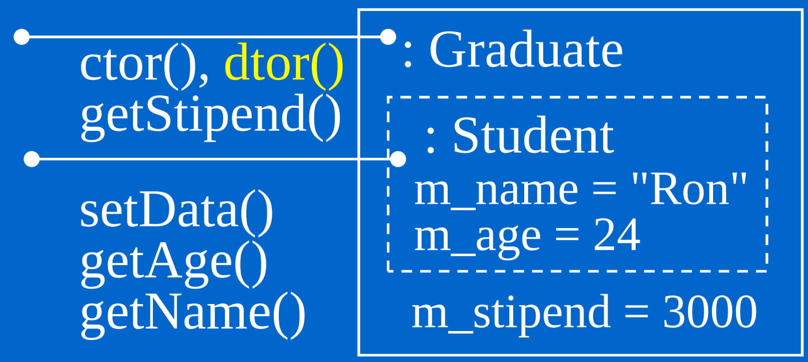


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  Did you edit student.h or student.cpp?

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- Can we give the derived class access to "private" data of base class?

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- Who can access protected fields?
  - base class and friends of base class

Protected Data and Functions

- Can we give the derived class access to "private" data of base class?

```
class Student {
public:
   Student();
   ~Student();
   void setData(char *name, int
   age);
   int getAge() const;
   const char *getName() const;
protected:
   char *m_name;
   int m_age;
};
```

- The following is now legal

```
int Graduate::getStipend() const {
   if (m_age > 30)
      return 0;
   return m_stipend;
}
```

- Who can access protected fields?
  - base class and friends of base class
  - derived class and friends of derived classes

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- The following is now legal

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int Graduate::getStipend() const {
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```

Note: the encapsulation perimeter is enlarged a great deal with "protected" in your design

- Who can access protected fields?
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Basic Inheritance (cont'd)

- Most of the member functions of the base class are implicitly inherited by the derived class except

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Basic Inheritance (cont'd)

- Most of the member functions of the base class are implicitly inherited by the derived class except
  - The constructor (including copy ctor)
  - The assignment operator
  - The destructor
- They are synthesized by the complier again if not explicitly defined. The synthesized ctor, dtor, and assignment operator would chain automatically to the function defined in the base class.

Inheritance and Constructors

- Rewrite Student using constructor

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class Student {
public:
    Student(char *name, int age);
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    m_name = new char[strlen(name)+1];
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```
Graduate::Graduate(char *name, int age, int stipend)
              : m_age(age), m_stipend(stipend)
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Inheritance and Ctors (cont'd)

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```

error C2614: 'Graduate' : illegal member initialization: 'm_age' is not a base or member

- Base class guarantee

  The base class will be fully constructed before the body of the derived class constructor is entered

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- Copy constructor is also a constructor. Member objects and base class **must** be initialized through **initialization list**

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- For example:

```
class Derived: public Base {
public:
    …
    Derived(Derived &src);
    …
private:
    Component m_obj;
};
```

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- For example:

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class Derived: public Base {
public:
    …
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    …
private:
    Component m_obj;
};
Derived::Derived(Derived &src): Base(src), m_obj(src.m_obj) {
    …
}
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   Derived(Derived &src);
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private:
   Component m_obj;
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If you do not define a copy ctor, the compiler would generate one exactly like this.

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    …
    Derived(Derived &src);
    …
private:
    Component m_obj;
};
Derived::Derived(Derived &src): Base(src), m_obj(src.m_obj) {
    …
}
```

Note:

```
Derived::Derived(Derived &src):
        m_obj(src.m_obj)
{
    …
}
```

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- For example:

Compiler adds **Base()** invocation automatically

```
class Derived: public Base {
public:
   …
   Derived(Derived &src);
   …
private:
   Component m_obj;
};
```

Note:

```
Derived::Derived(Derived &src):
      m_obj(src.m_obj)
{
   …
}
```

```
Derived::Derived(Derived &src): Base(src), m_obj(src.m_obj) {
   …
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Inheritance and Destructors

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Student::Student(char *name, int age) : m_age(age) {
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   strcpy(m_name, name);
   cout << "In Student ctor\n";
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Student::~Student() {
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```
Graduate::Graduate(char *name, int age, int stipend, char *address)
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    m_address = new char[strlen(address)+1];
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Graduate::~Graduate() {
    delete[] m_address;
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```

Inheritance and Dtors (cont'd)

- What happens in main()

Inheritance and Dtors (cont'd)

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```
void main() {
   Graduate student("Michael", 24, 6000, " 8899 Storkes Rd.");
   cout << student.getName() << " is " << student.getAge() << " years old and "
         << "has a stipend of " <, student.getStipend() << "dollars.\n"
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Inheritance and Dtors (cont'd)

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Michael is 24 years old and has a stipend of 6000 dollars.
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The output is:

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chaining

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- The compiler automatically calls each dtor when the object dies.

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- The compiler automatically calls each dtor when the object dies.
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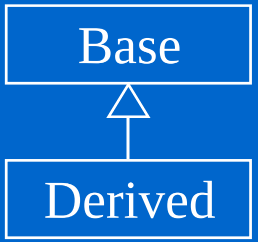
  - In destructing the derived object, the base object is still in scope and functioning correctly.

Chaining of Assignment Operator

- By default, the compiler adds a "**bit-wise copy**" assignment operator for every class which you do not define an assignment operator

Chaining of Assignment Operator

- By default, the compiler adds a "**bit-wise copy**" assignment operator for every class which you do not define an assignment operator
- If you have a class hierarchy where a class Derived inherits from a class Base. There are 4 possibilities in defining their assignment operators:



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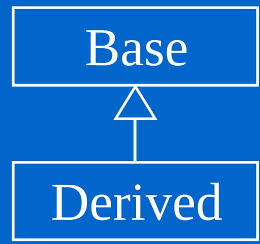

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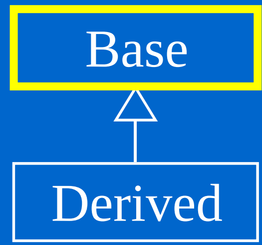

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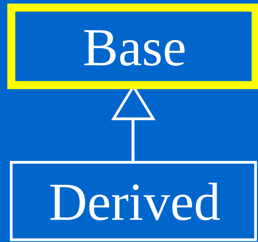

1. If both classes do not have assignment operator: both are bit-wise copy
2. If you define Base& Base::operator=(Base &) but not Derived& Derived::operator=(Derived &), then compiler synthesizes

```
Derived& Derived::operator=(Derived &rhs) {
    Base::operator=(rhs); // calling your function
        ….
    return *this;
}
```

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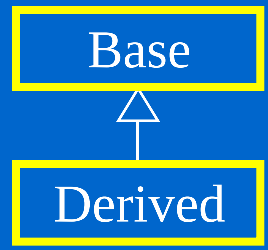

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Derived& Derived::operator=(Derived &rhs) {
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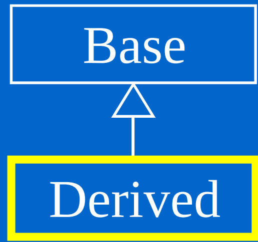

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class Student {
public:
    Student(char *name, int age);
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};
```

```
class ForeignGraduate: public Graduate {
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   ForeignGraduate(char *name, int age,
                   int stipend,
                   char *nationality);
   ~ForeignGraduate()
   const char *getNationality();
private:
   char *m_nationality;
};
```

```
class Graduate: public Student {
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Layers of Inheritance (cont'd)

Student

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- **ctor of Student**

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Student::Student(char *name, int age) : m_age(age) {
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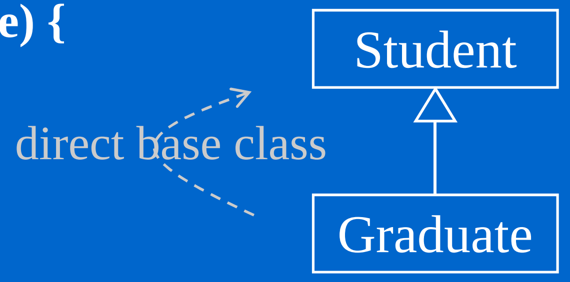

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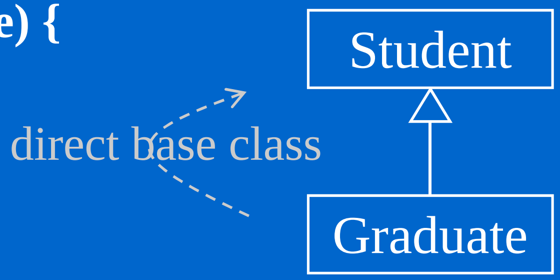

- **ctor of Graduate invokes the ctor of its direct base class - Student**

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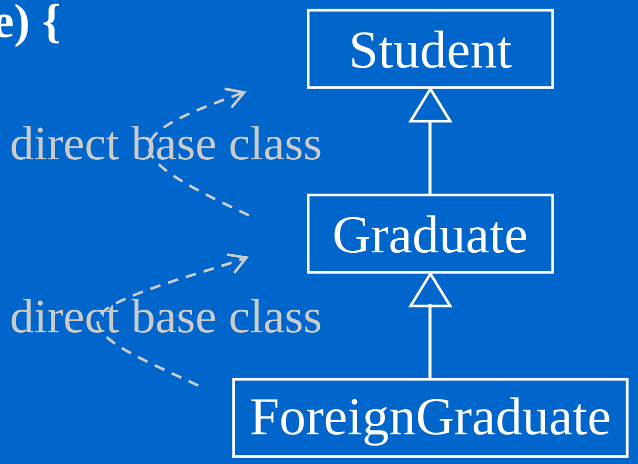

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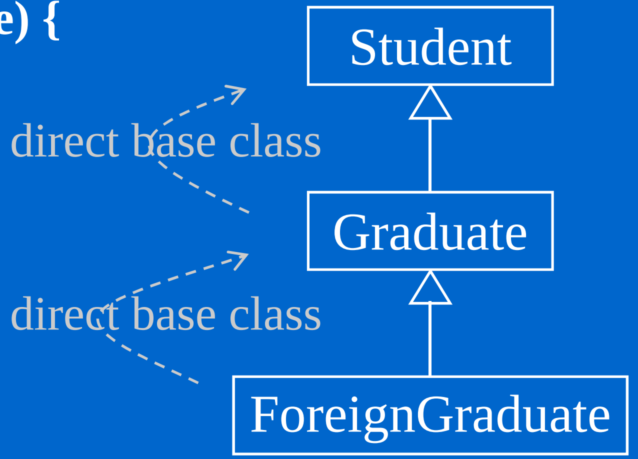

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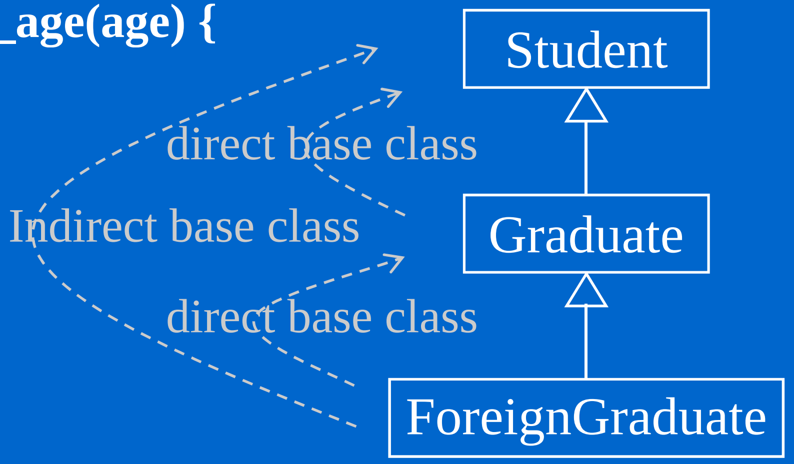

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- Note: **function signature** is exactly the same as in the base class.

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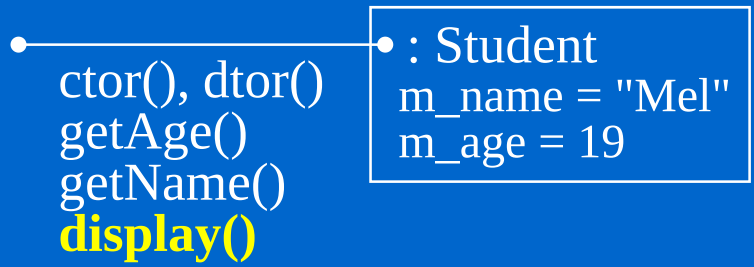

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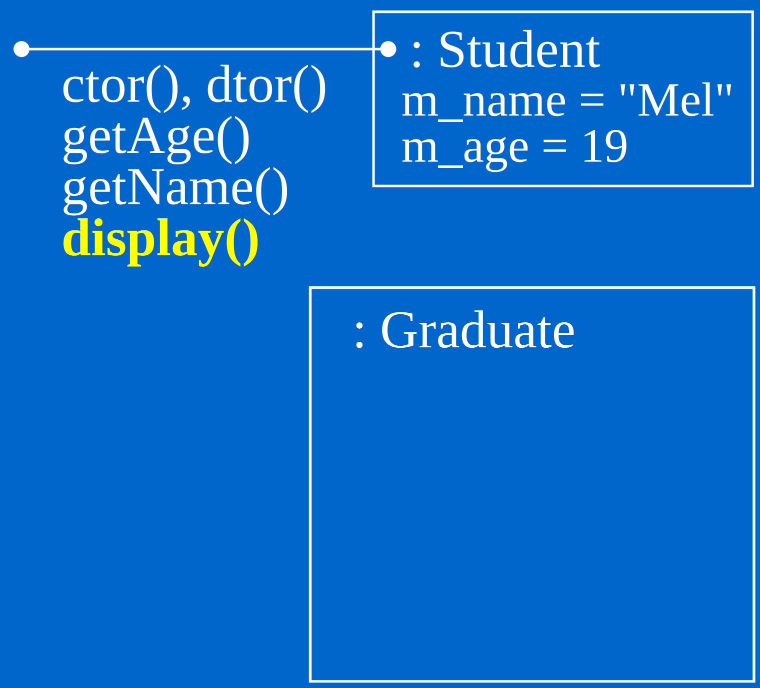

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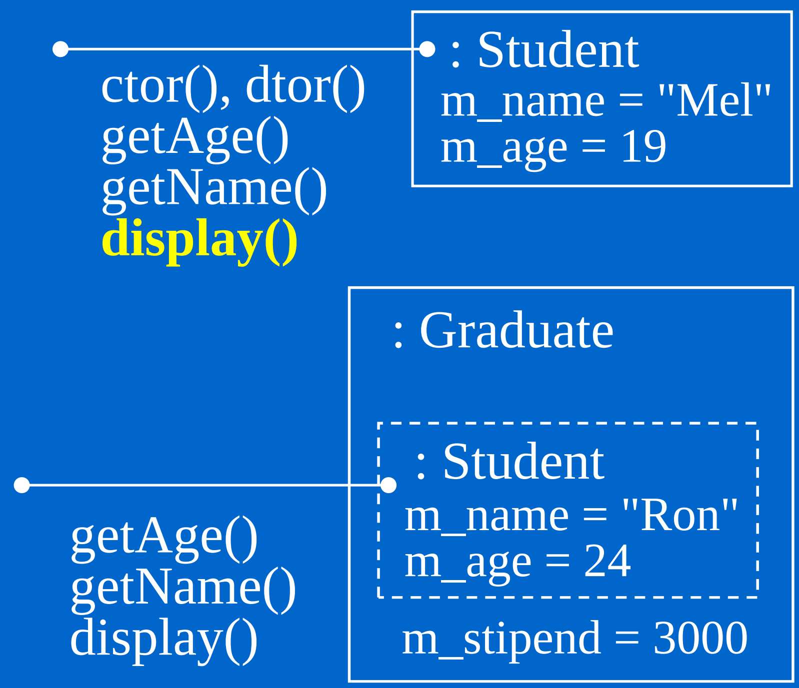

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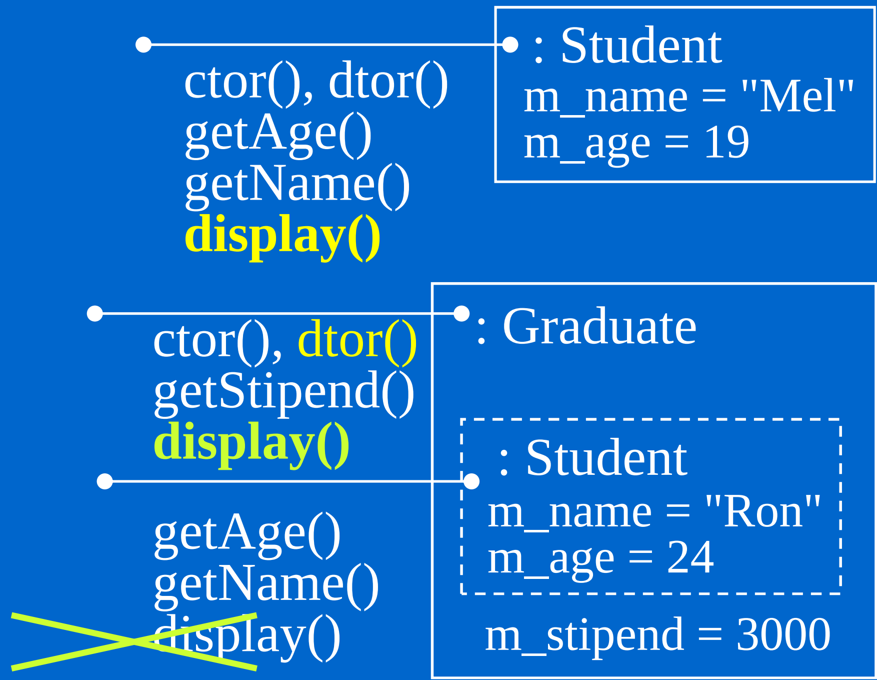

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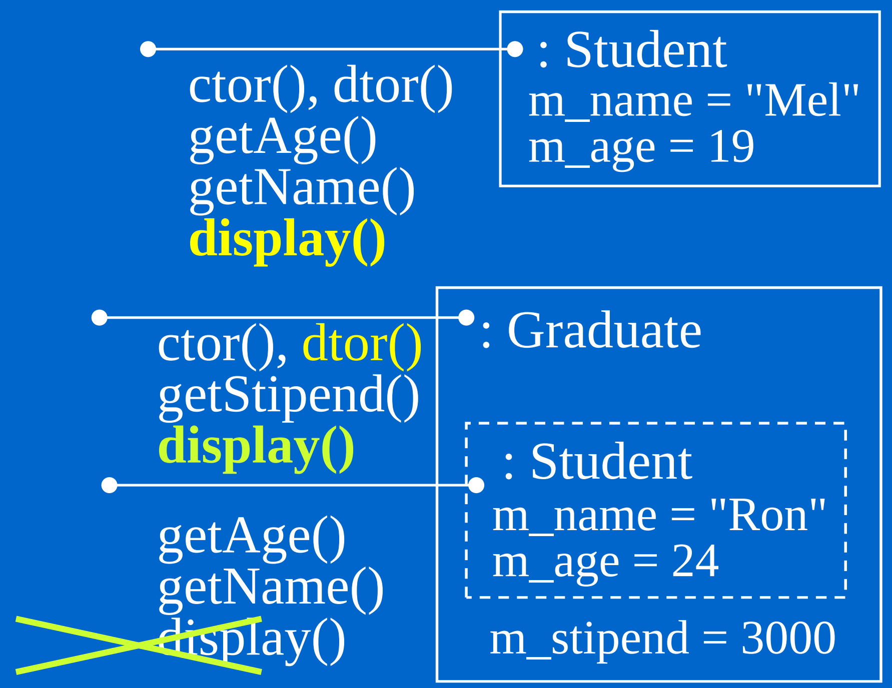

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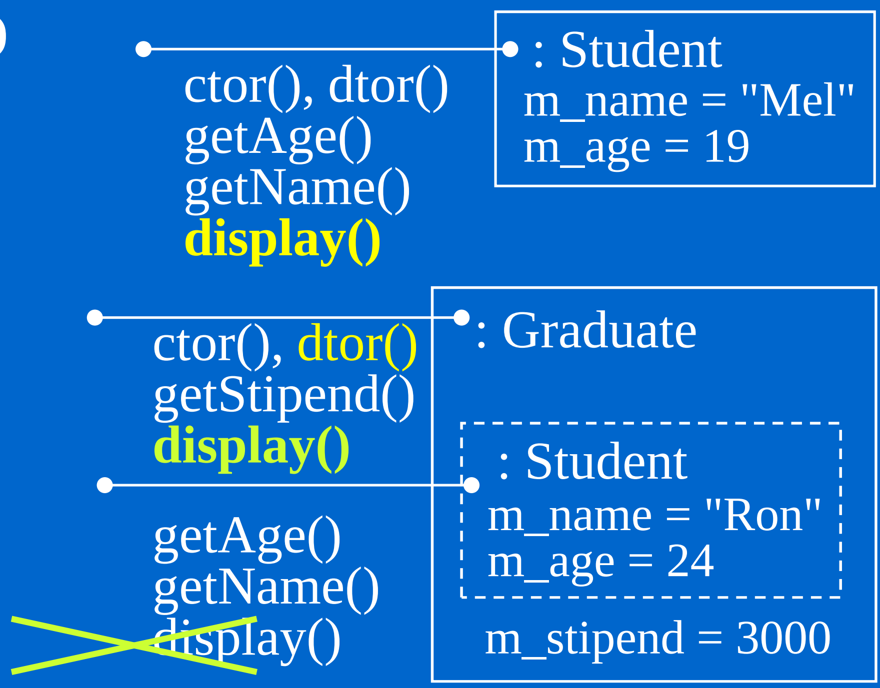

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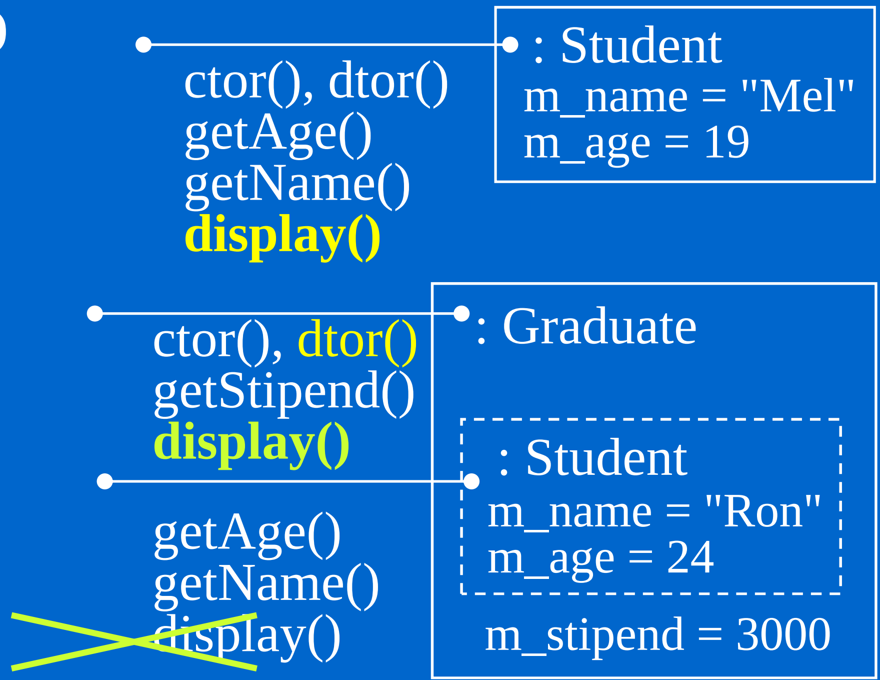

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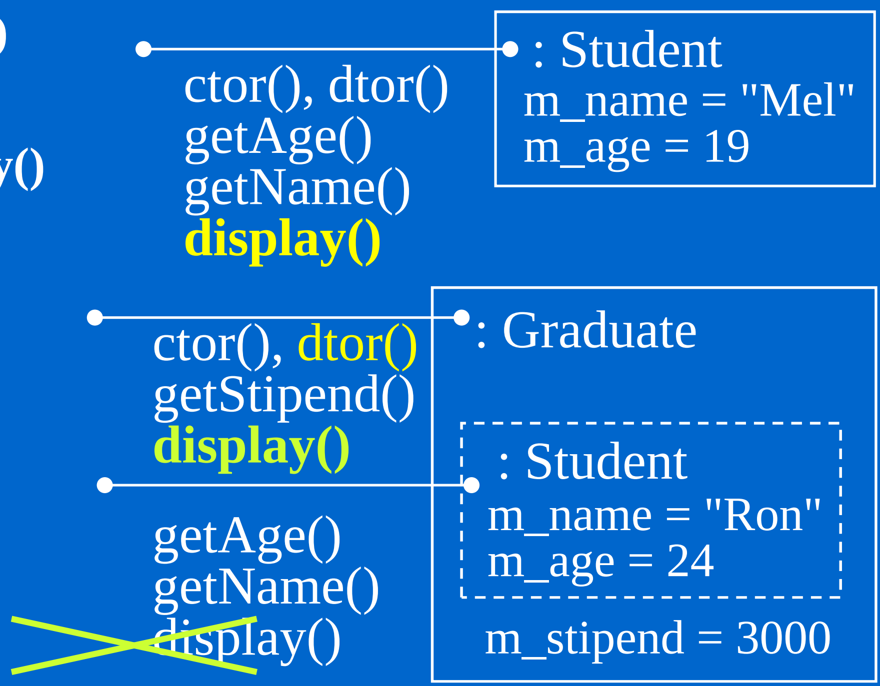

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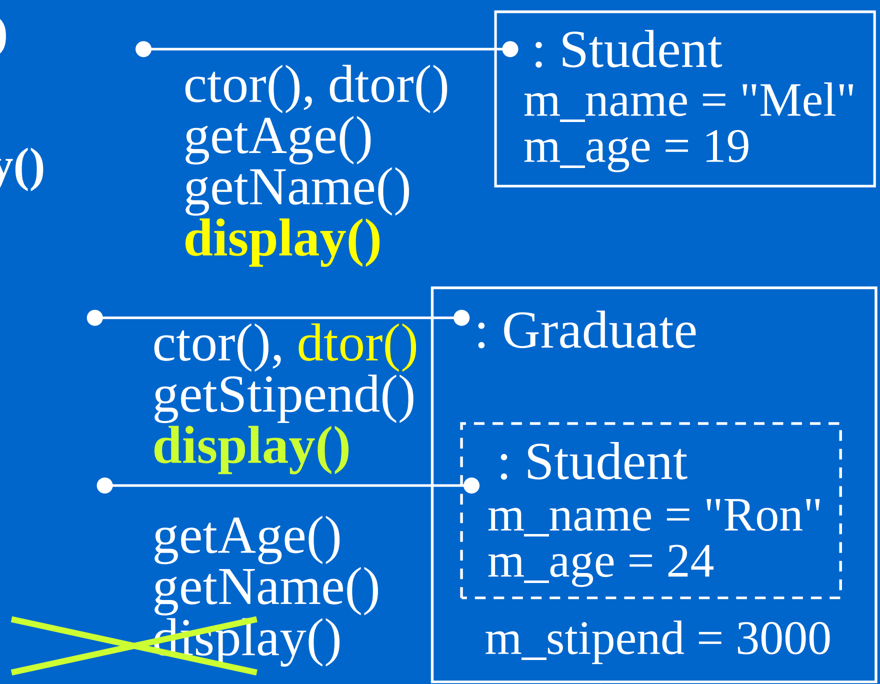

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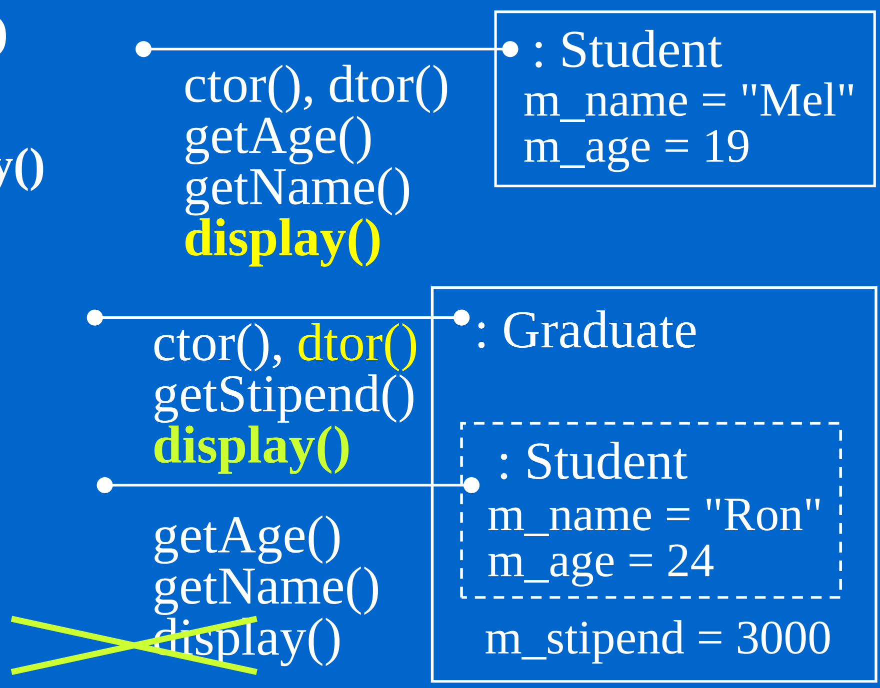

- Note: display() interface usually can enhance the encapsulation, replacing the functionality of trivial accessor functions

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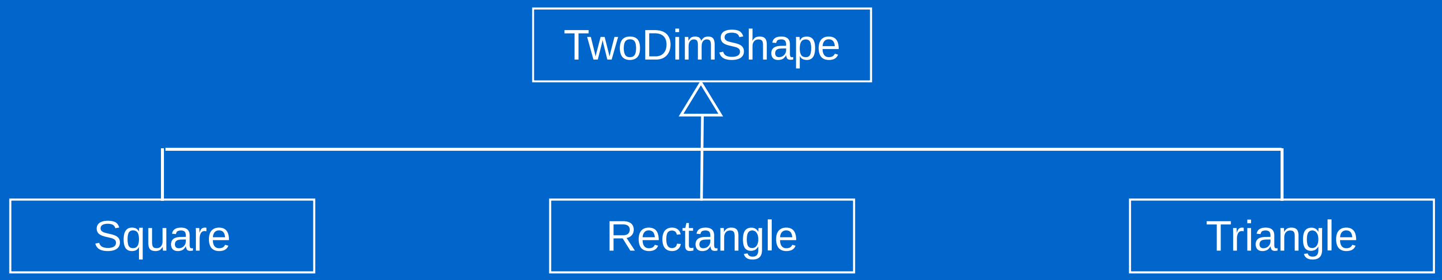

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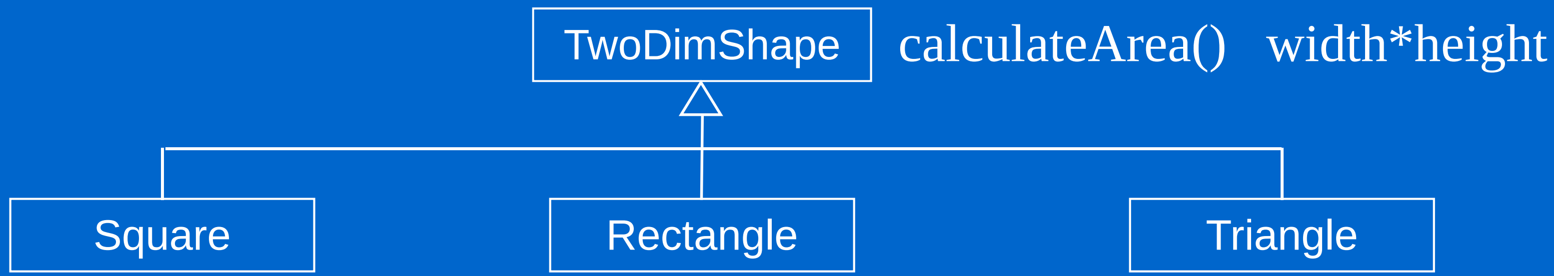

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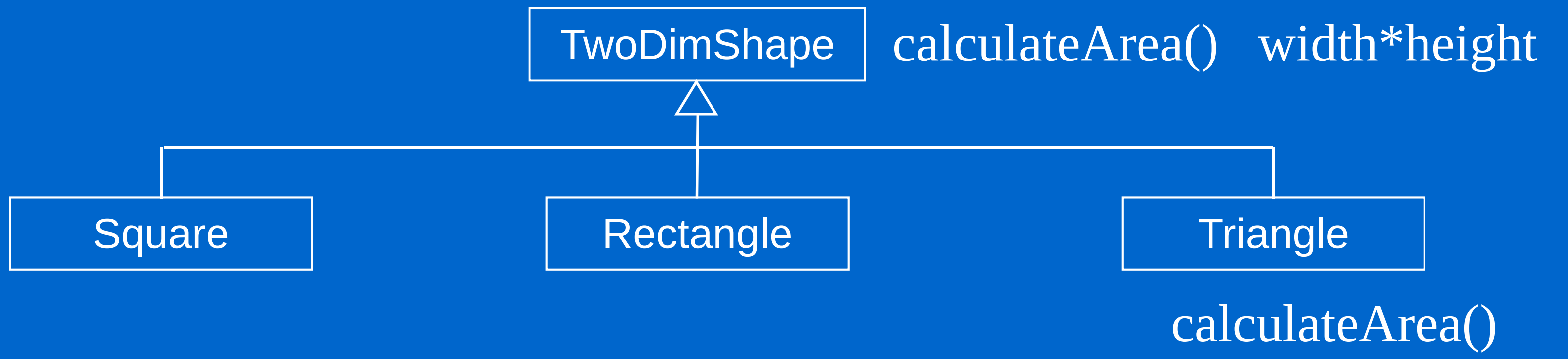

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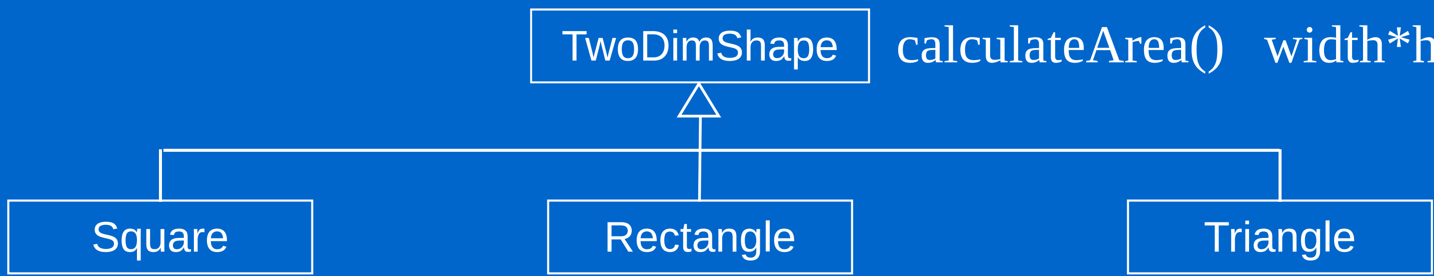

calculateArea() width*height

calculateArea()

1/2*TwoDimShape::calculateArea()

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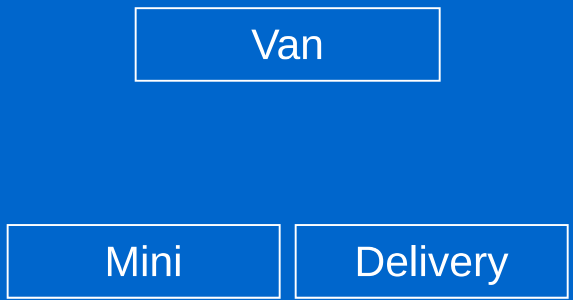

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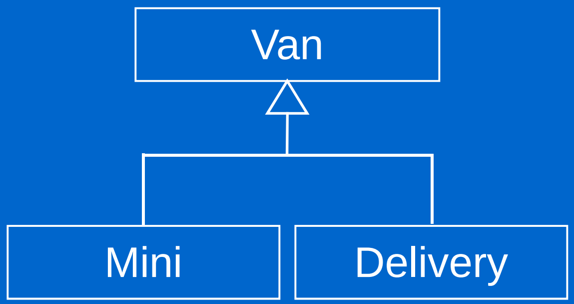

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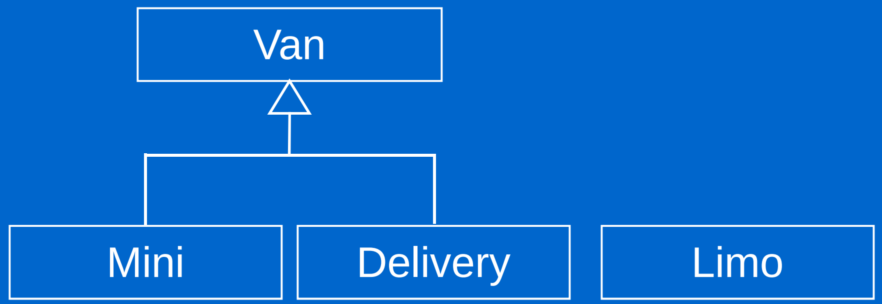

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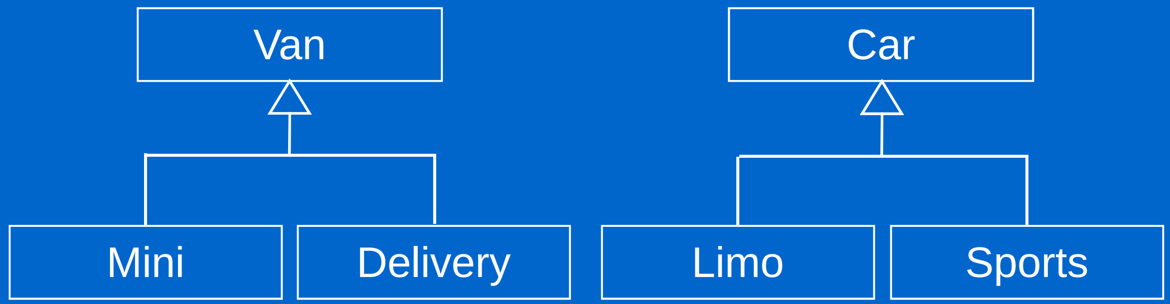

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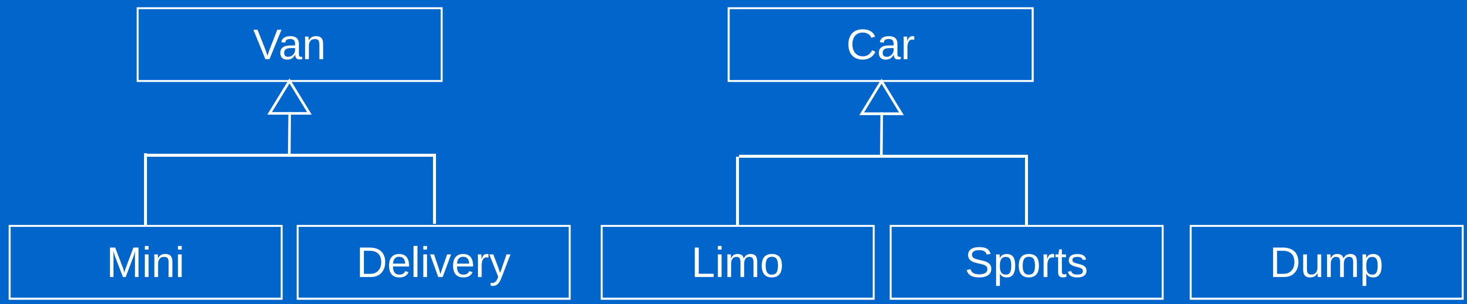

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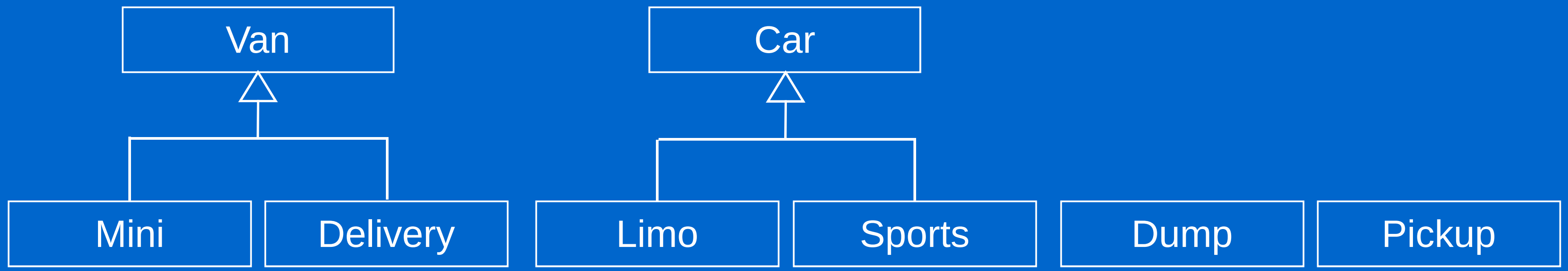

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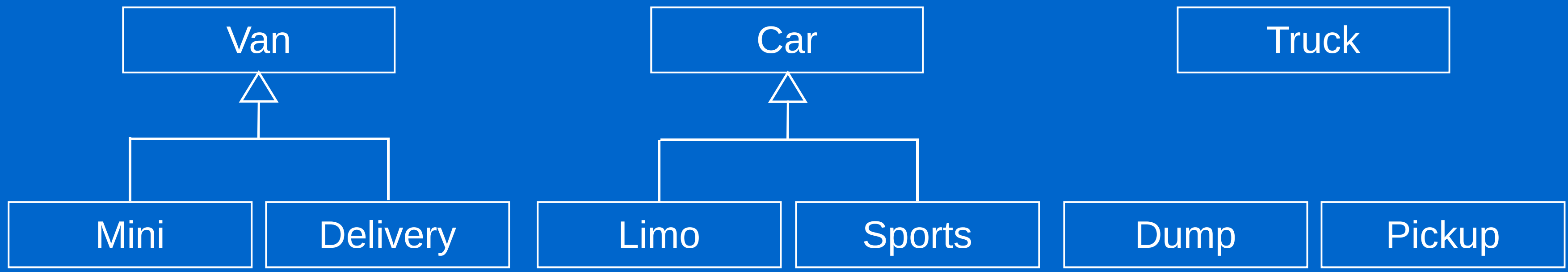

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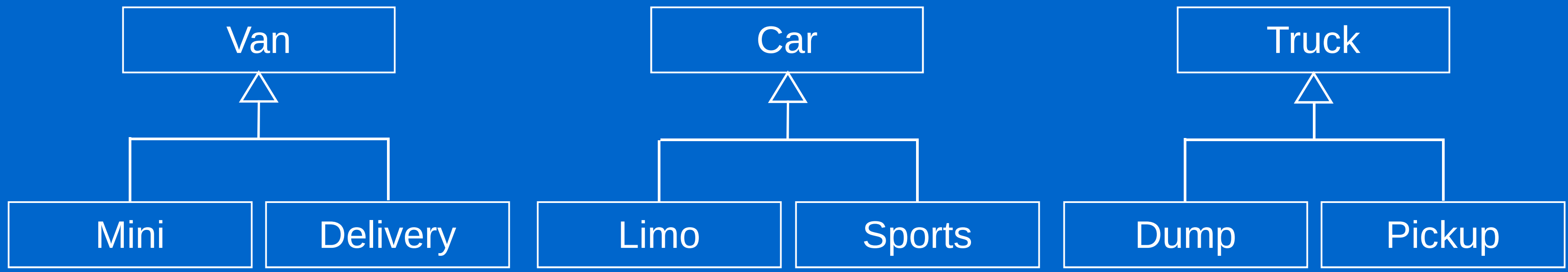

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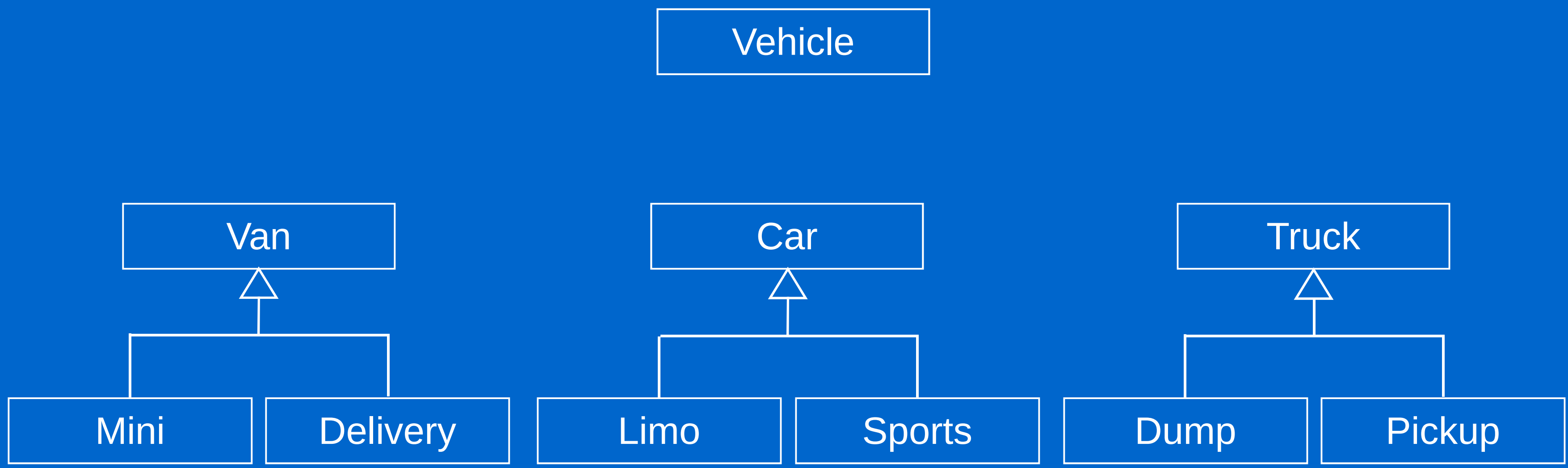

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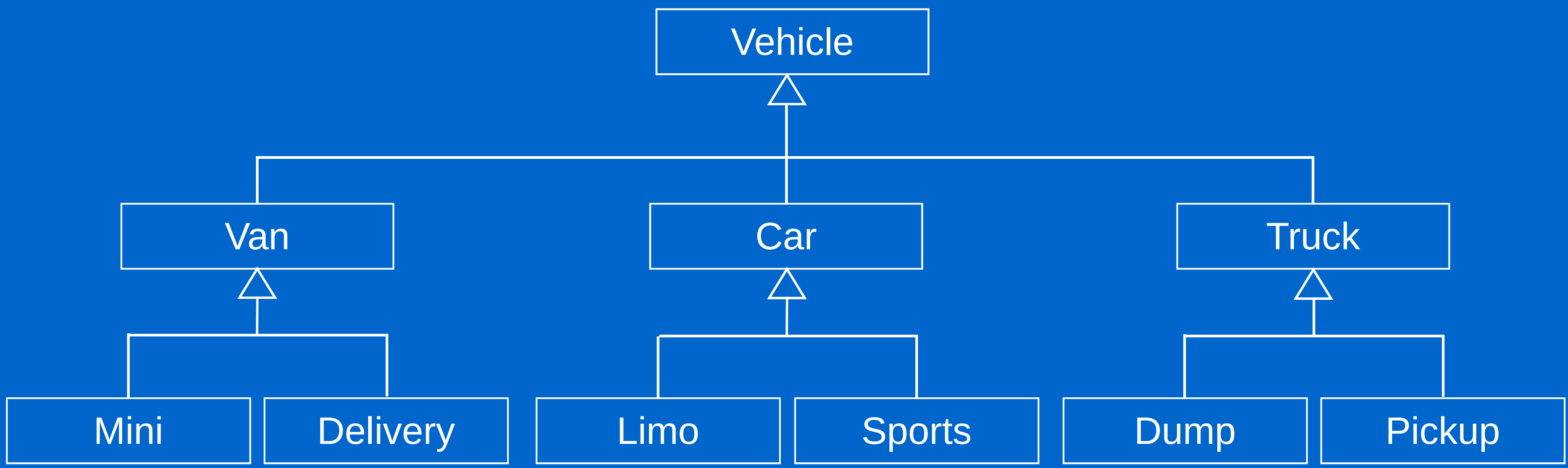

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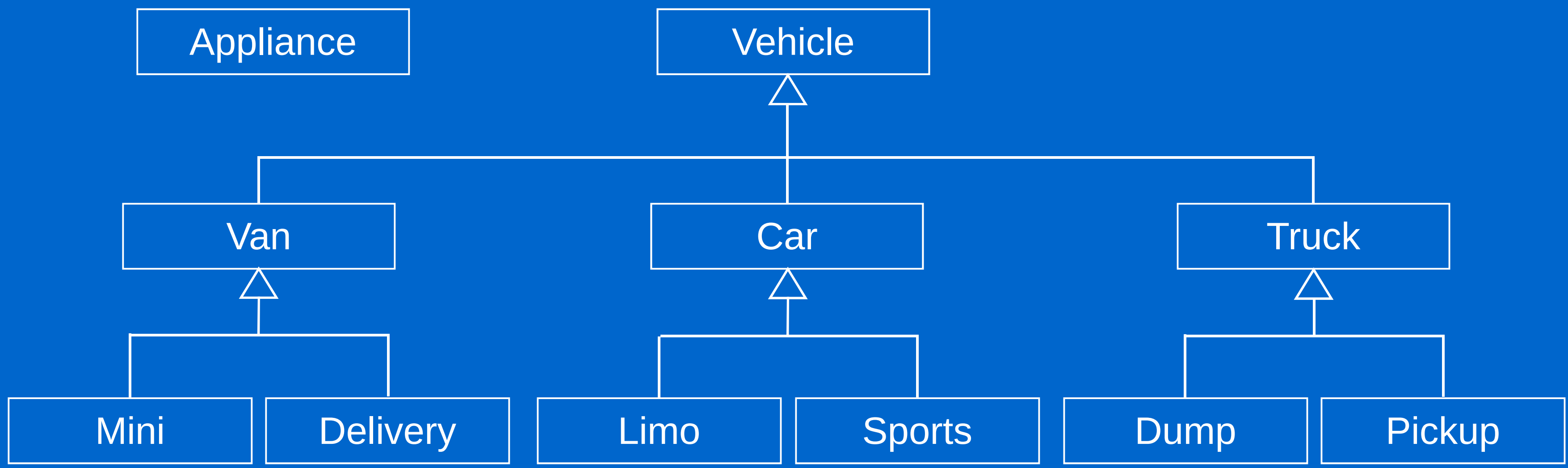

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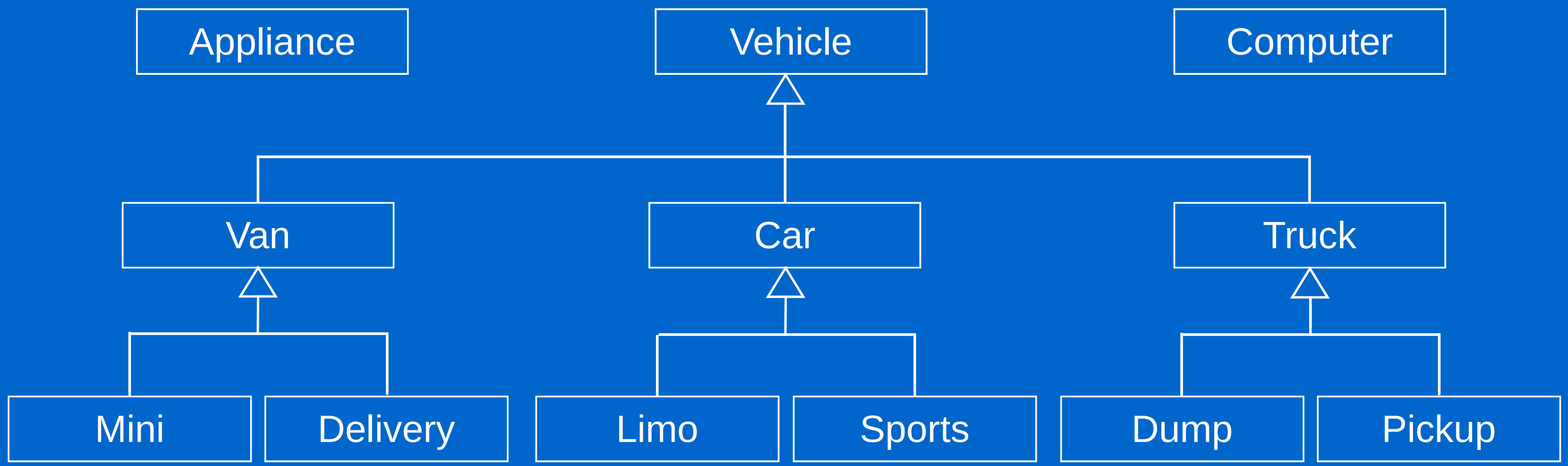

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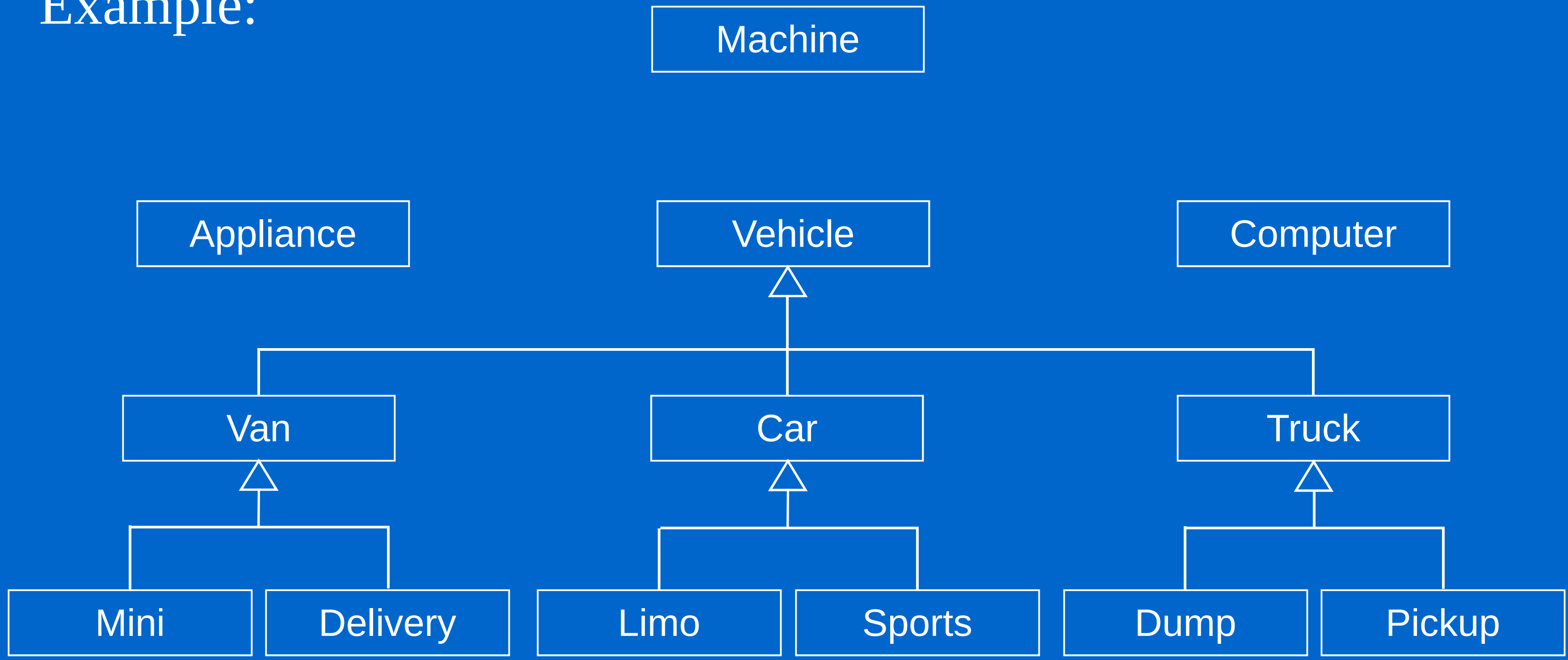

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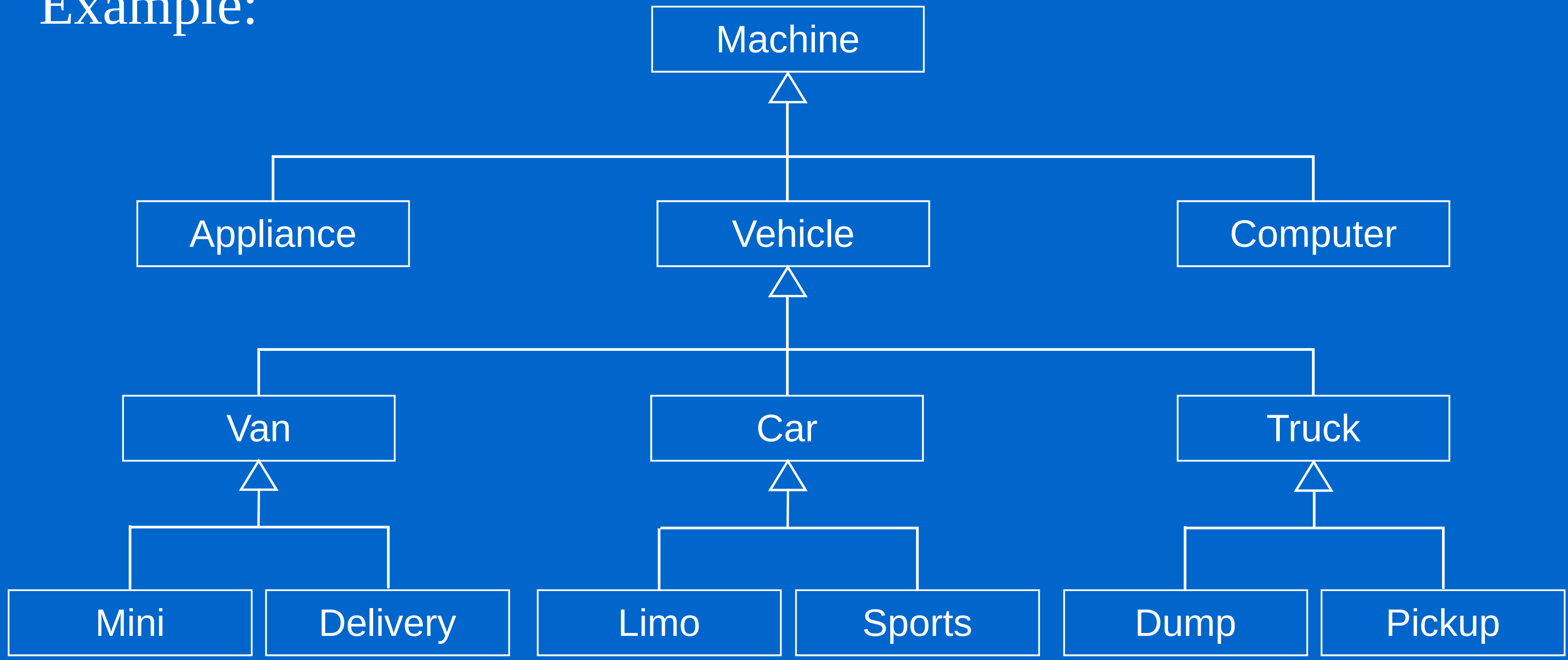

Real-World Examples Of Inheritance

- Microsoft Foundation Class Version 6.0

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  - A tree-style class hierarchy

Real-World Examples Of Inheritance

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- …

Microsoft Foundation Class Library Version 6.0

CObject

- **Application Architecture**
  - **CCmdTarget**
    - CWinThread
      - CWinApp
        - COleControlModule
          - user application
    - CDocTemplate
      - CSingleDocTemplate
      - CMultiDocTemplate
    - COleObjectFactory
      - COleTemplateServer
    - COleDataSource
    - COleDropSource
    - COleDropTarget
    - COleMessageFilter
    - CConnectionPoint
    - CDocument
      - COleDocument
        - COleLinkingDoc
          - COleServerDoc
            - CRichEditDoc
      - user documents
    - CDocItem
      - COleClientItem
        - COleDocObjectItem
        - CRichEditCntrItem
        - user client items
      - COleServerItem
        - CDocObjectServerItem
        - user server items
    - CDocObjectServer
    - **Window Support**
    - **CWnd**
      - **Frame Windows**
      - CFrameWnd
        - CMDIChildWnd
          - user MDI windows
        - CMDIFrameWnd
          - user MDI workspaces
        - CMiniFrameWnd
        - user SDI windows
        - COleIPFrameWnd
      - CSplitterWnd
      - **Dialog Boxes**
      - CDialog
        - CCommonDialog
          - CColorDialog
          - CFileDialog
          - CFindReplaceDialog
          - CFontDialog
          - COleDialog
            - COleBusyDialog
            - COleChangeIconDialog
      - **Views**
      - CView
        - CCtrlView
          - CEditView
          - CListView
          - CRichEditView
          - CTreeView
        - CScrollView
          - user scroll views
          - CFormView
      - **Controls**
      - CAnimateCtrl
      - CButton
        - CBitmapButton
      - CComboBox
        - CComboBoxEx
      - CDateTimeCtrl
      - CEdit
      - CHeaderCtrl
      - CHotKeyCtrl
- user objects
- **Exceptions**
- CException
  - CArchiveException
  - CDaoException
  - CDBException
  - CFileException
  - CInternetException
  - CMemoryException
  - CNotSupportedException
  - COleException
  - COleDispatchException
  - CResourceException
  - CUserException
- **File Services**
- CFile
  - CMemFile
    - CSharedFile
  - COleStreamFile
    - CMonikerFile
      - CAsyncMonikerFile
        - CDataPathProperty
          - CCachedDataPathProperty
  - CSocketFile
  - CStdioFile
    - CInternetFile
      - CGopherFile
      - CHttpFile
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- **Gra**
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- **Gra Dra**
- **Me**
- **Cor**
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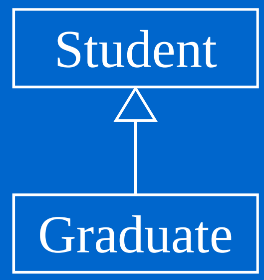
Inheritance Design

Exploring Solutions to Inheritance

- The University database program

Exploring Solutions to Inheritance

✧ The University database program



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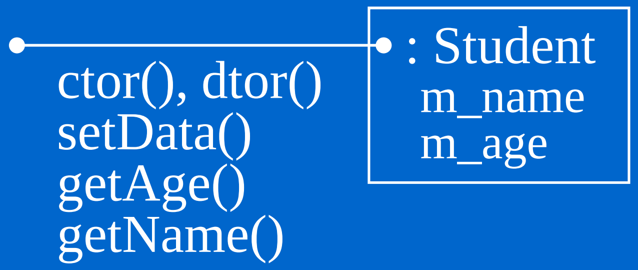

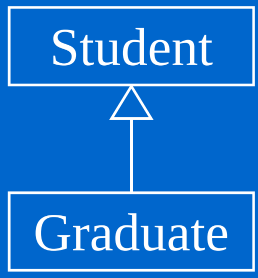

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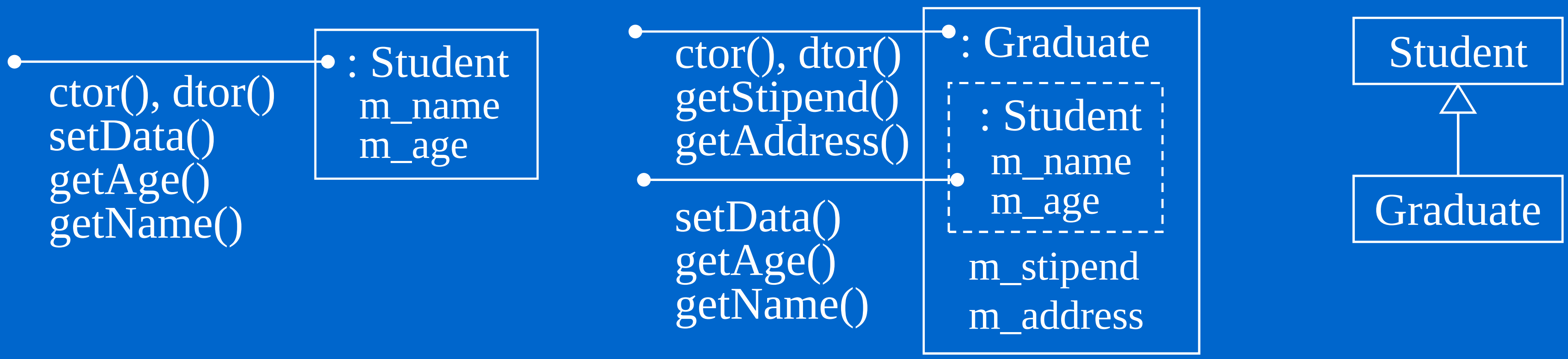

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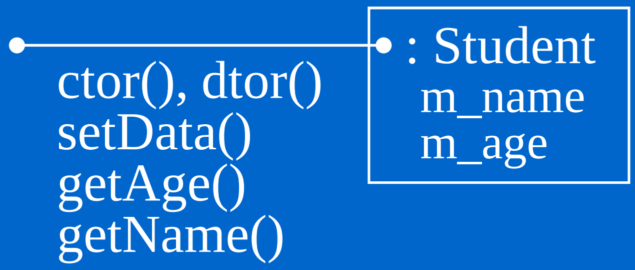

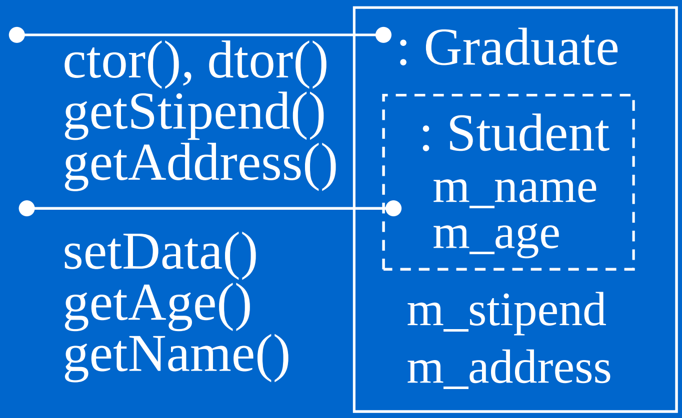

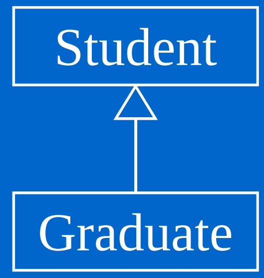

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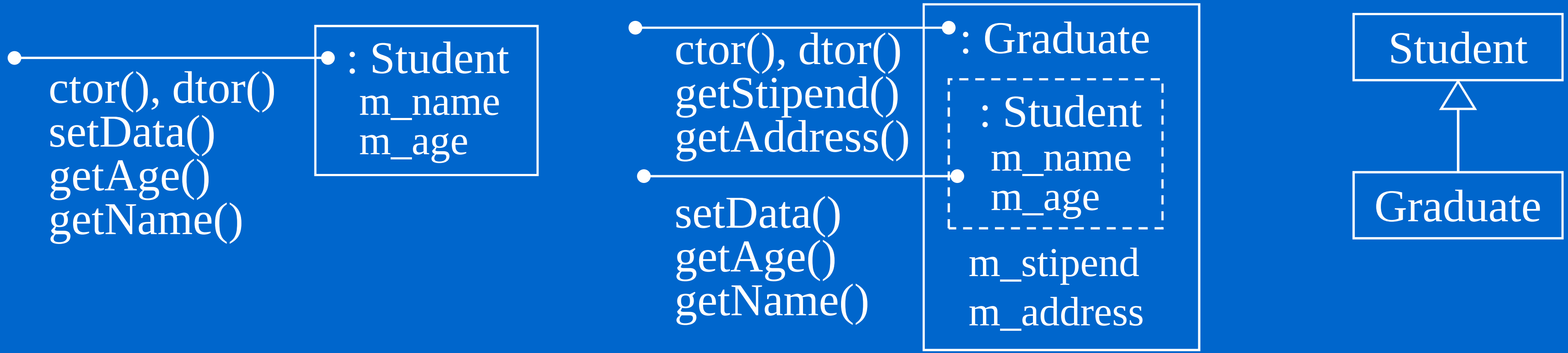

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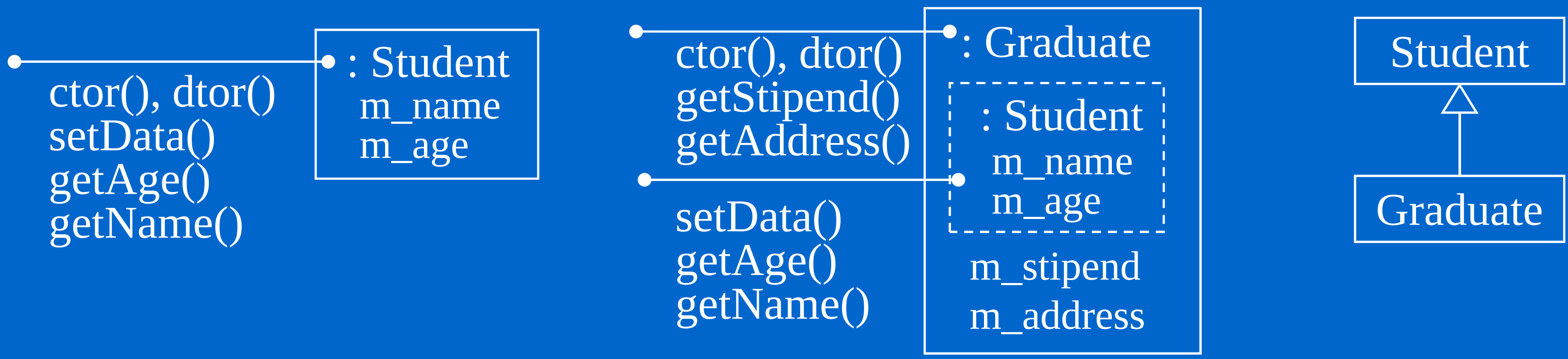

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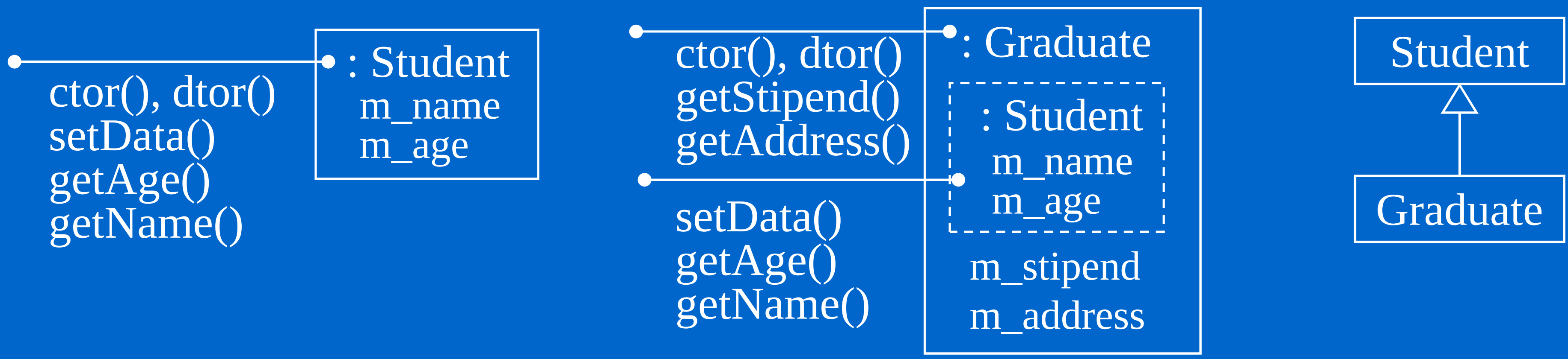

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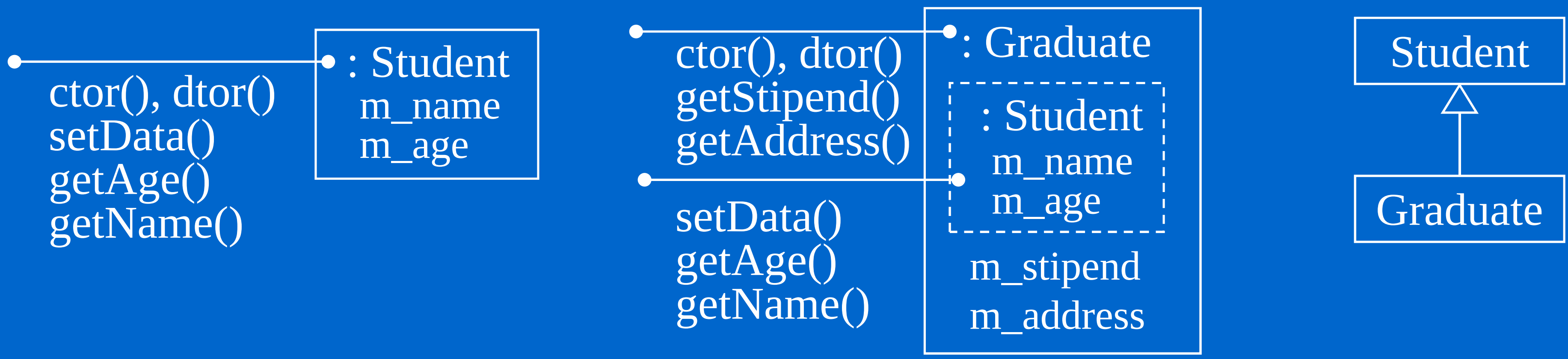

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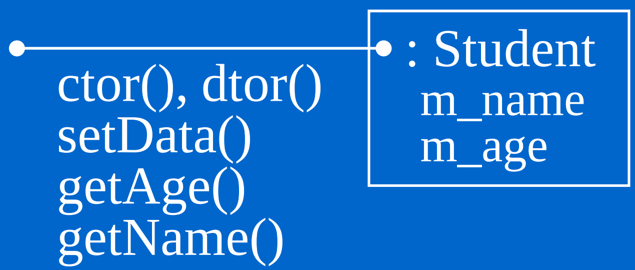

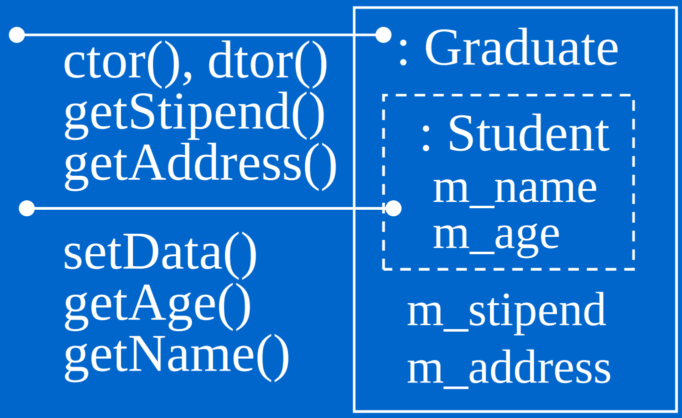

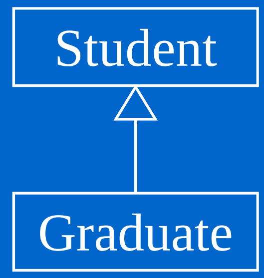

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- Let us first try inheriting Faculty from Graduate since the two groups have so much data in common

Exploring Solutions (cont'd)

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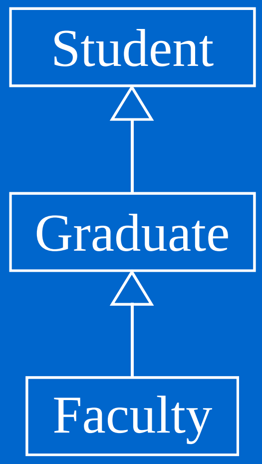

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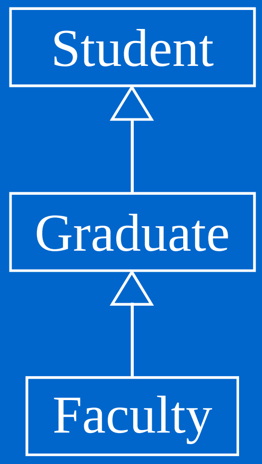

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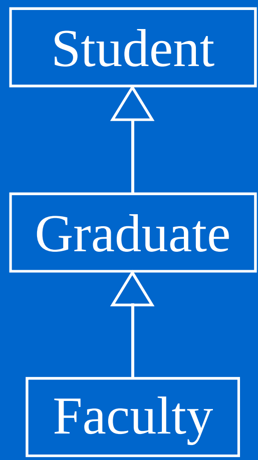

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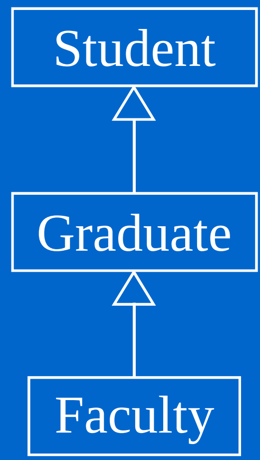

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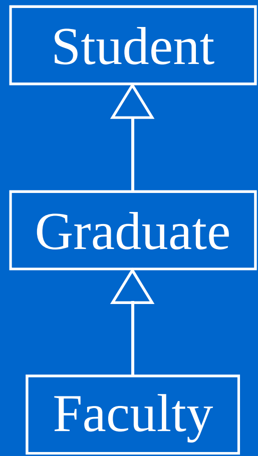

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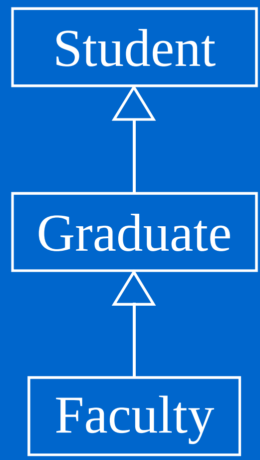

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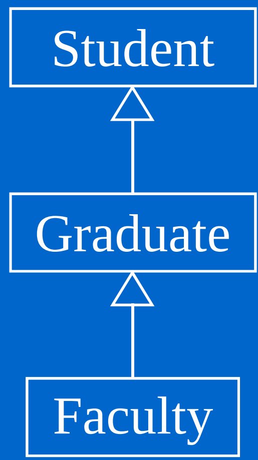

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This is NOT a good solution!

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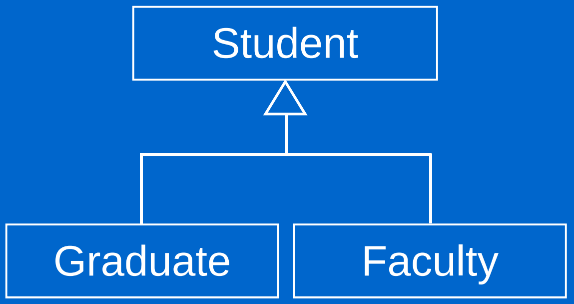

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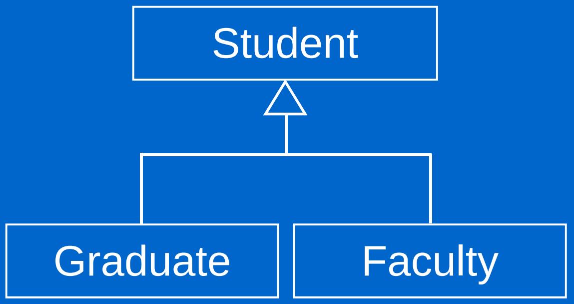

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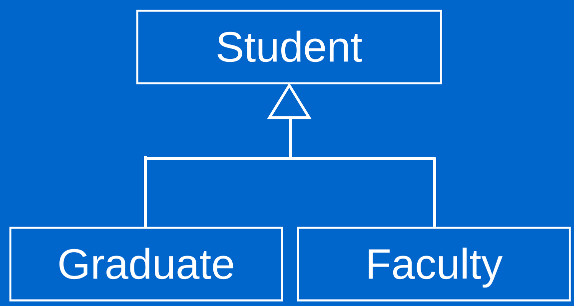

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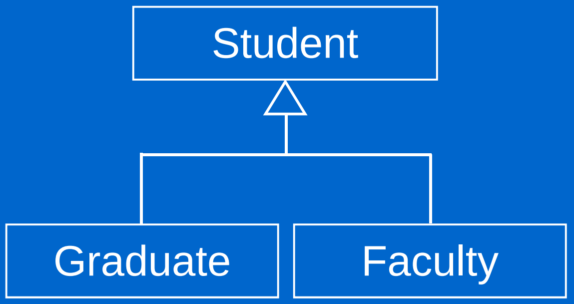

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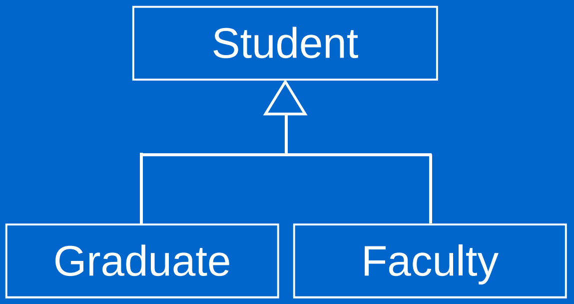

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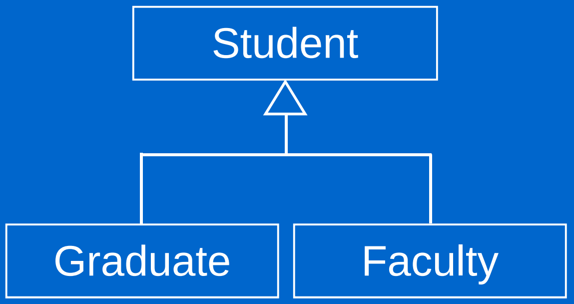

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"Inheritance SHOULD **NOT** be designed based on solely implementation considerations – eg. code reuse."

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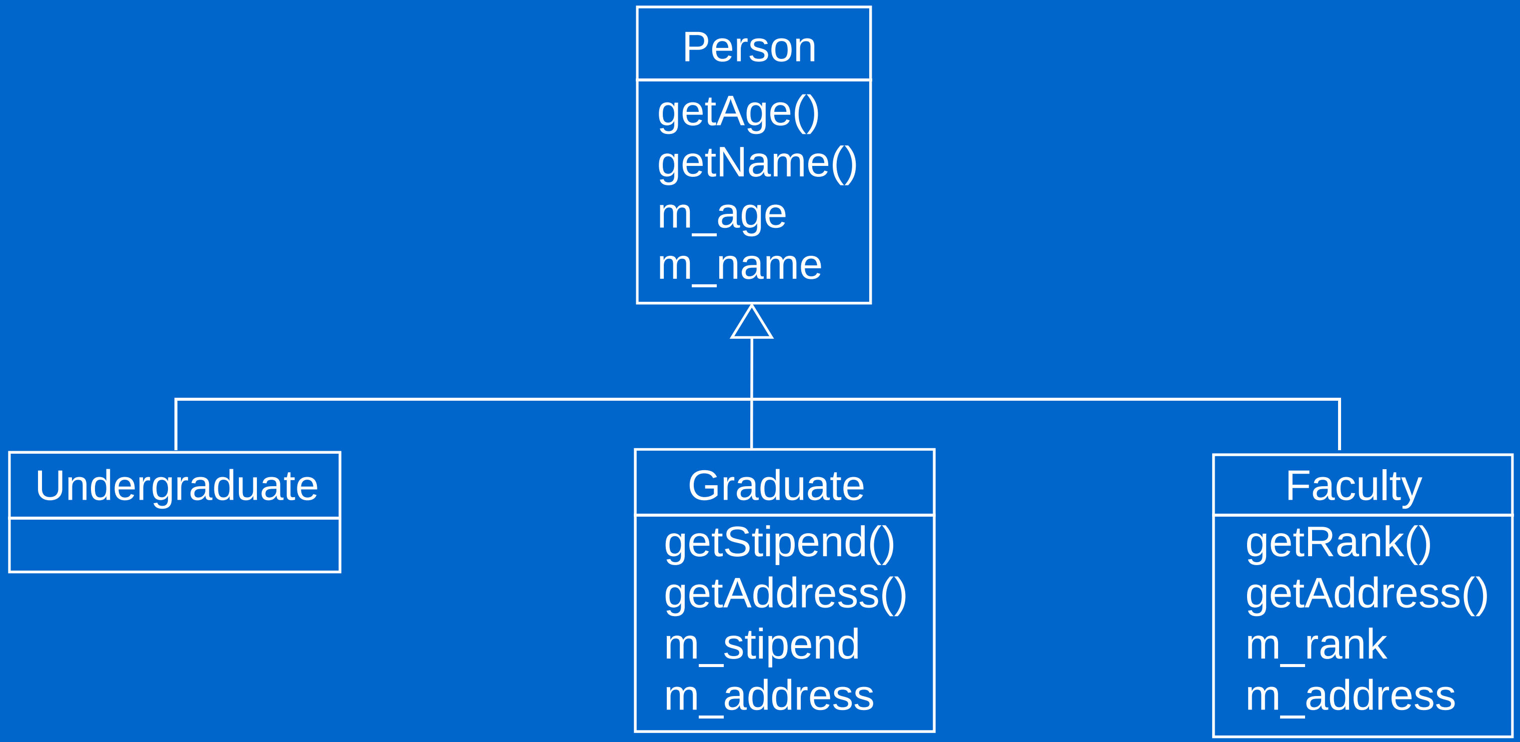

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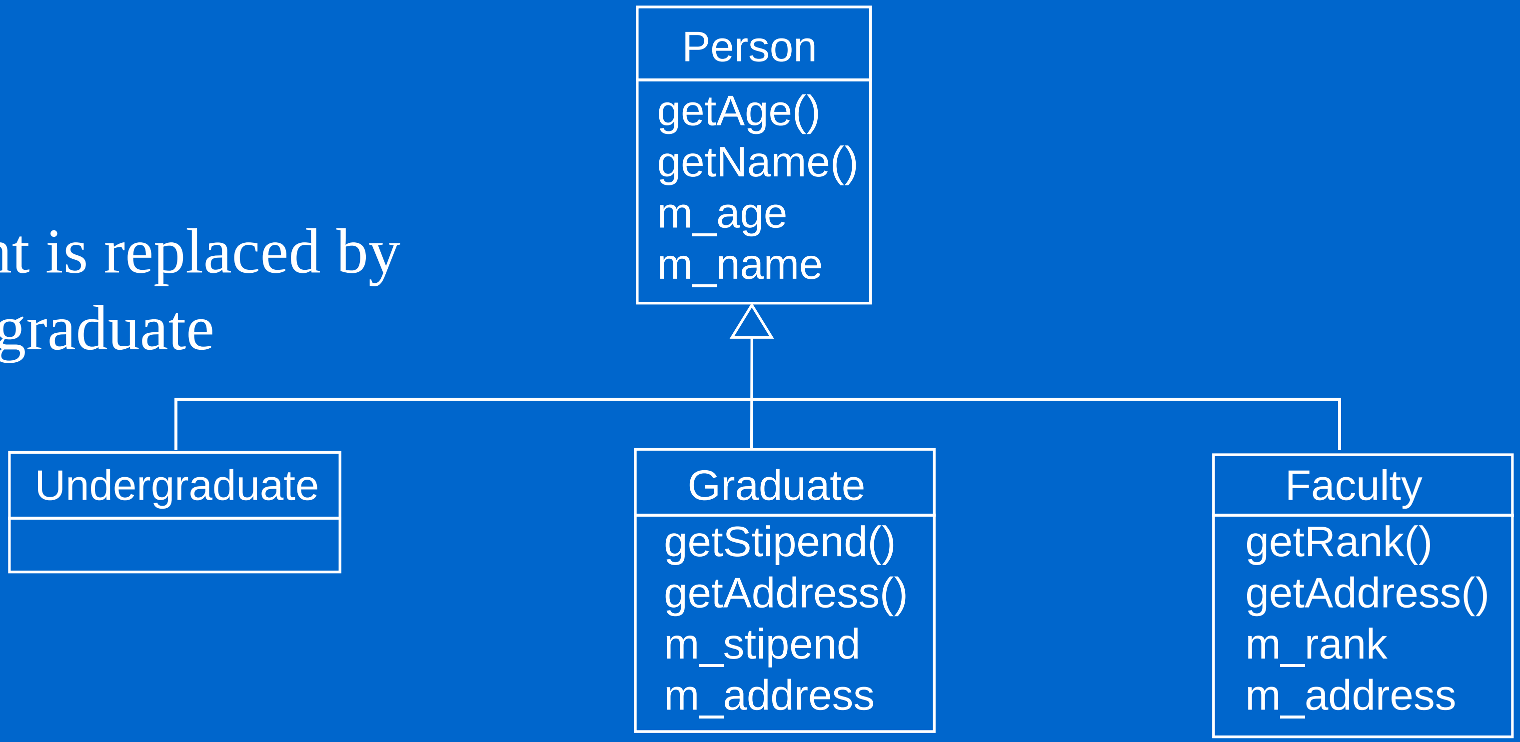

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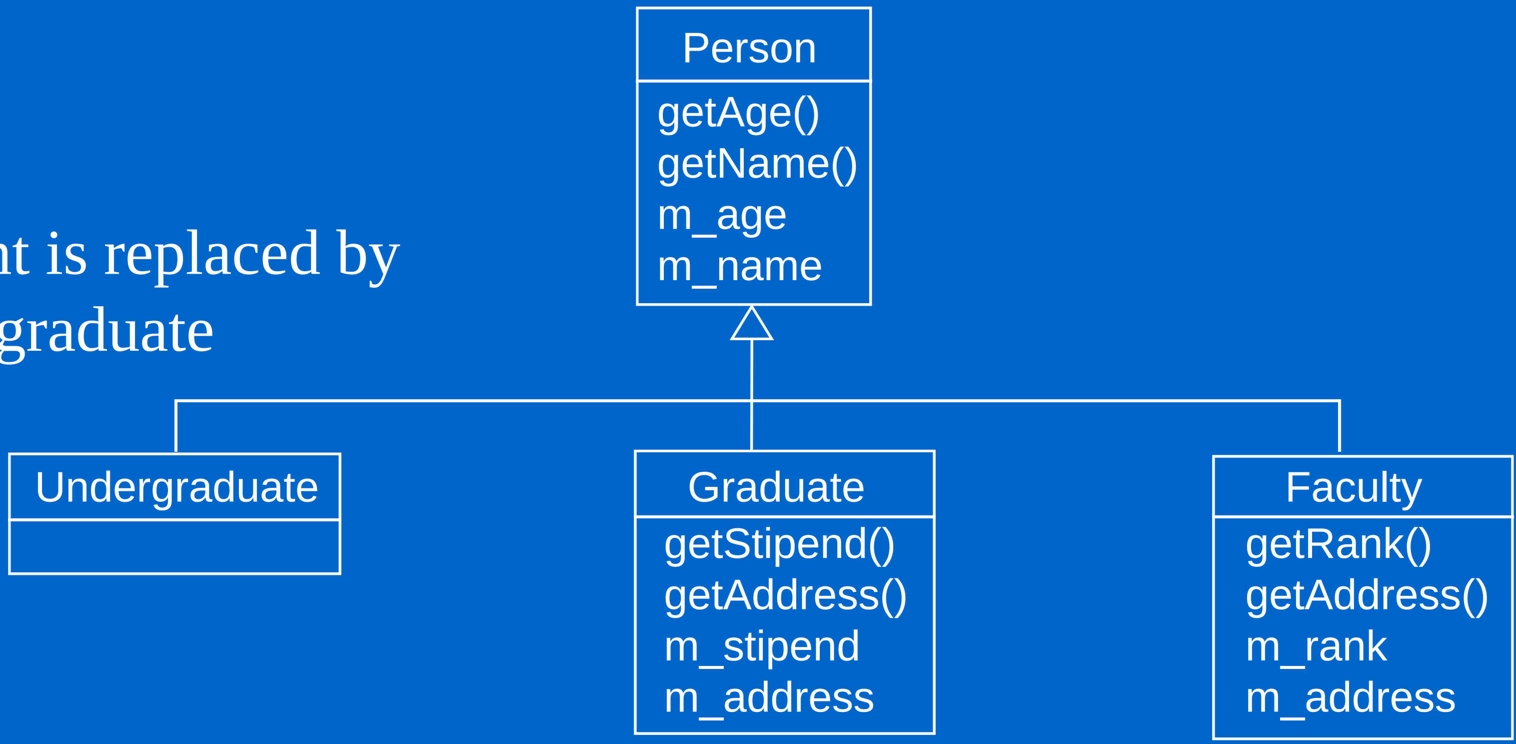

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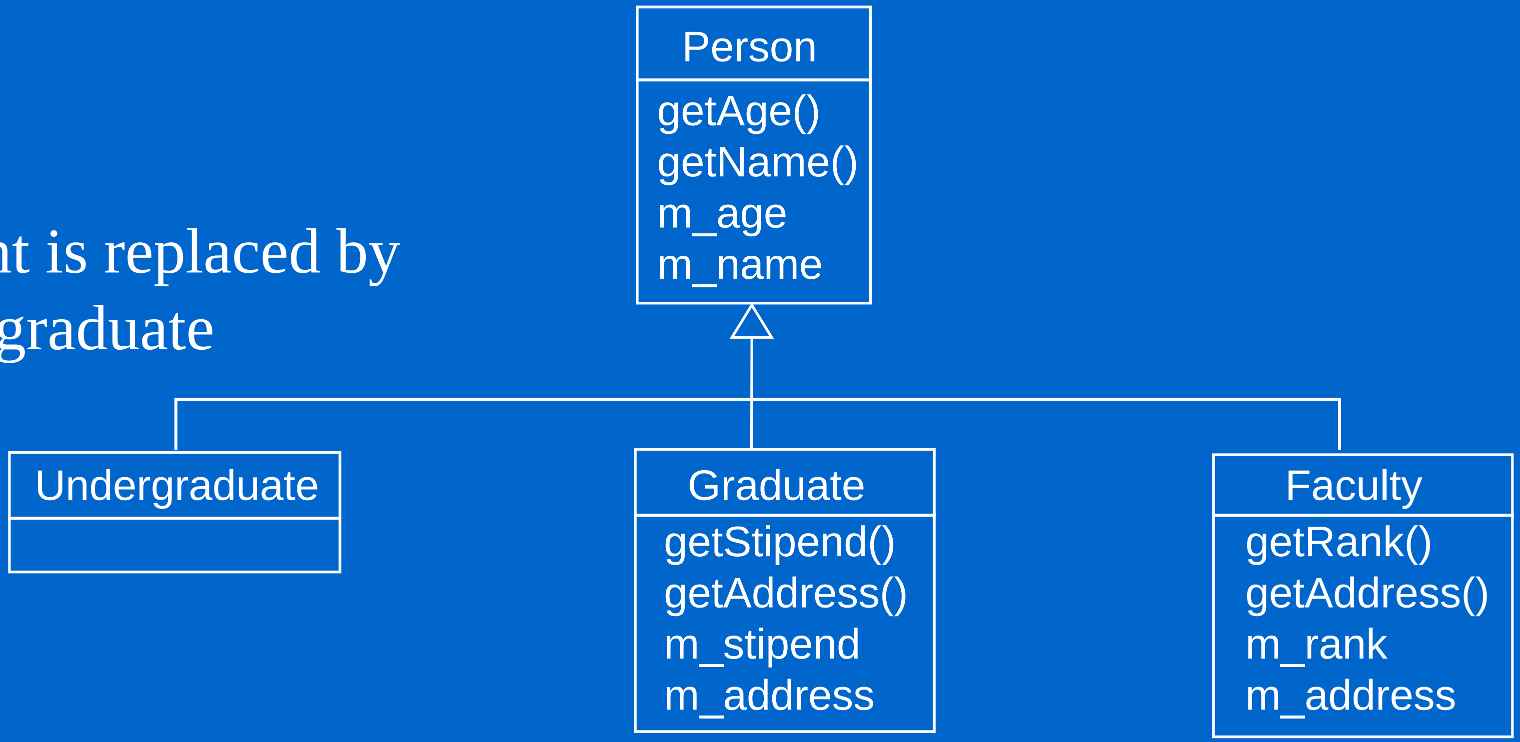

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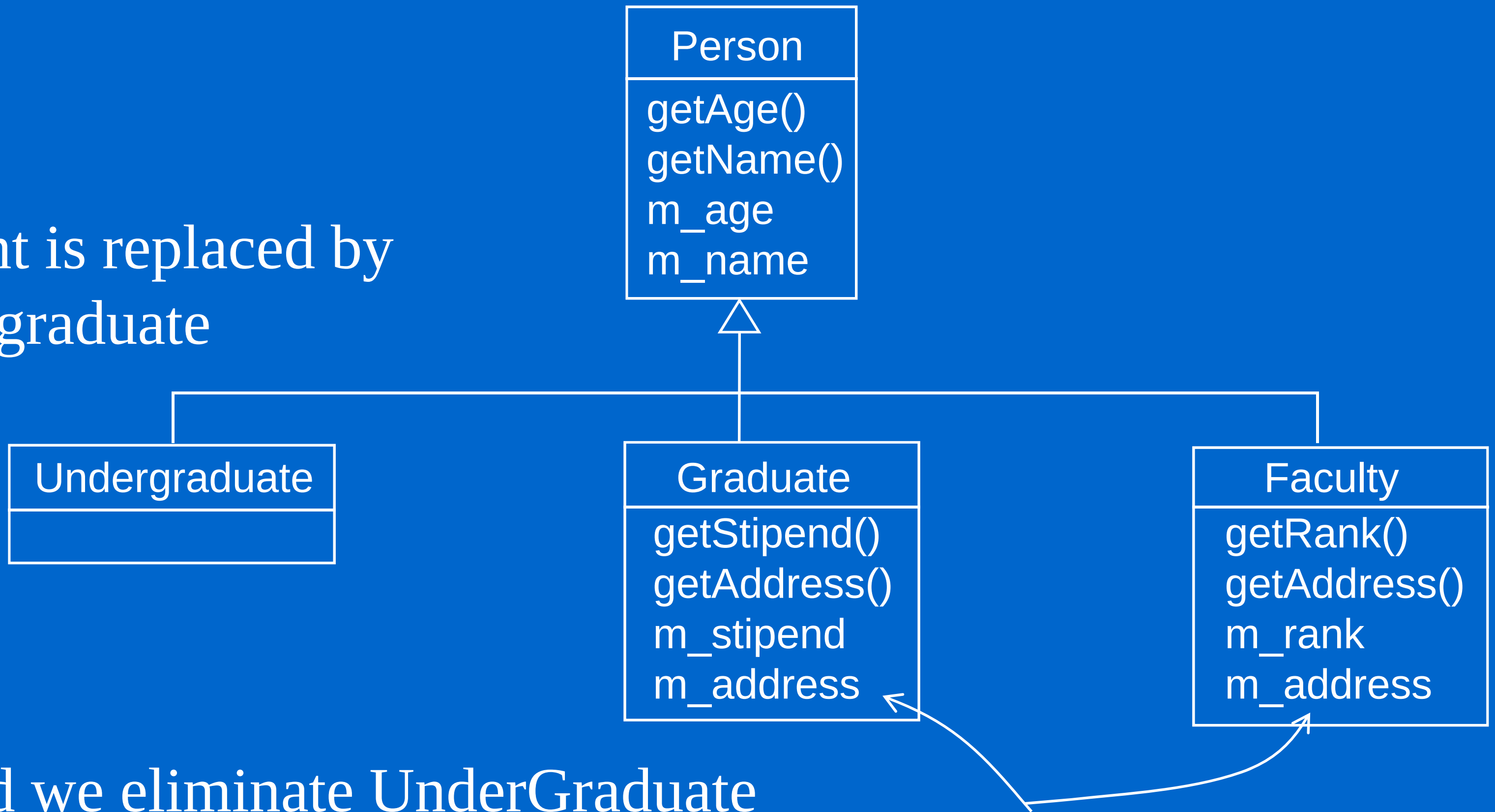

Is there any redundancy?

- Should we eliminate UnderGraduate and use only Person in its place?
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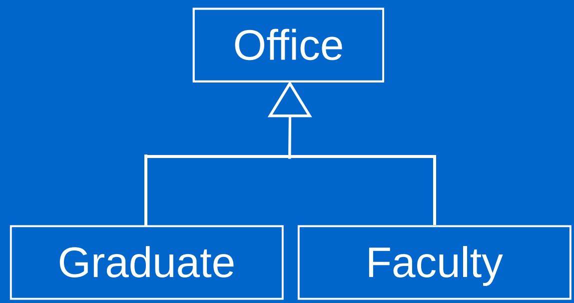

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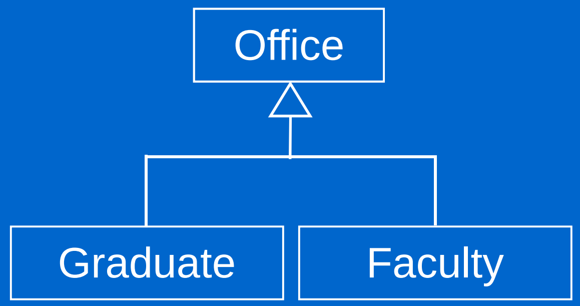

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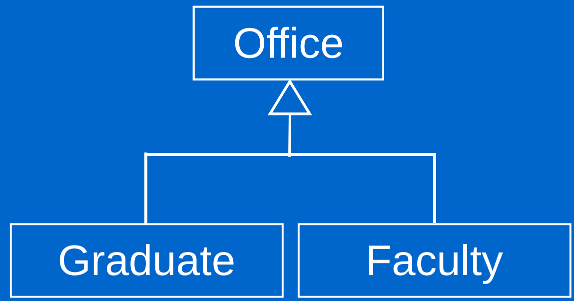

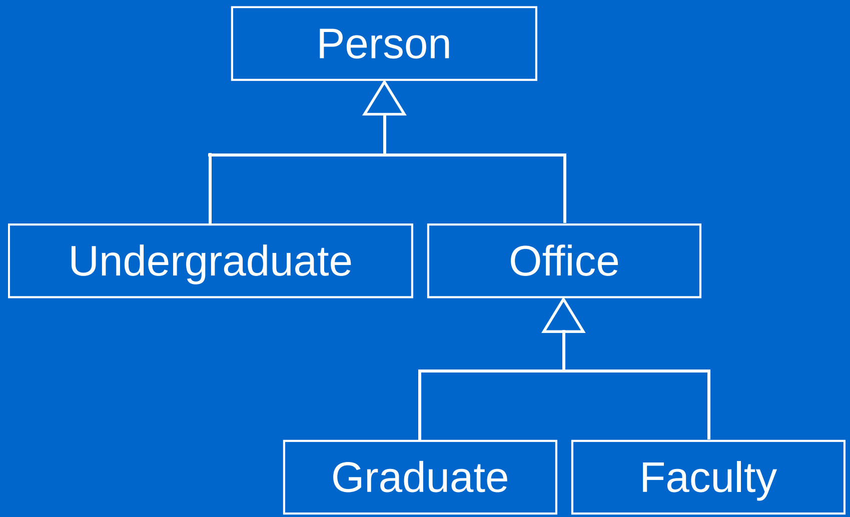

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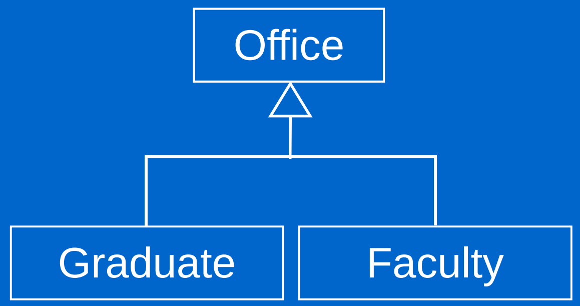

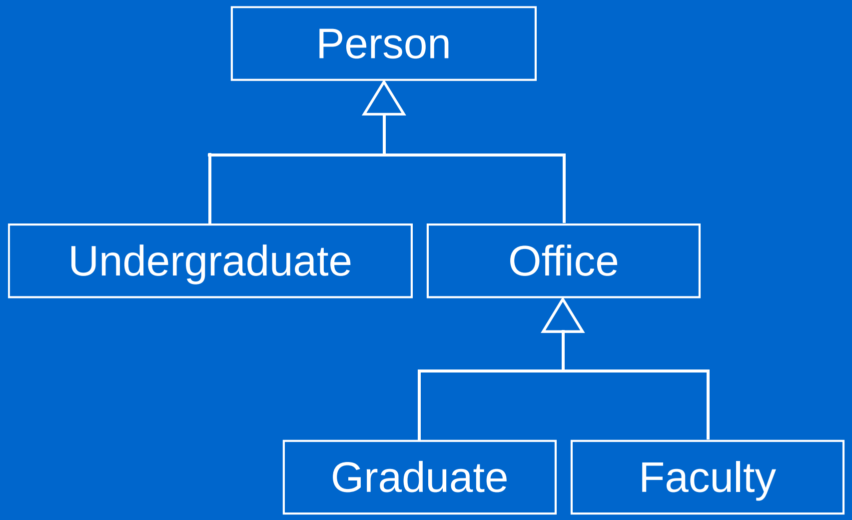

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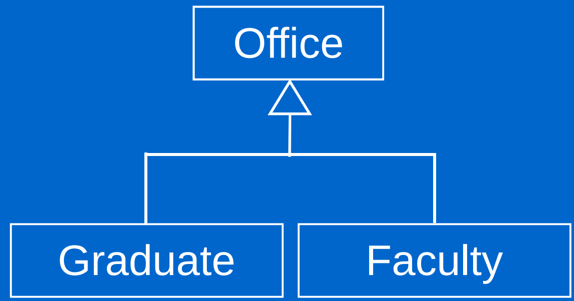

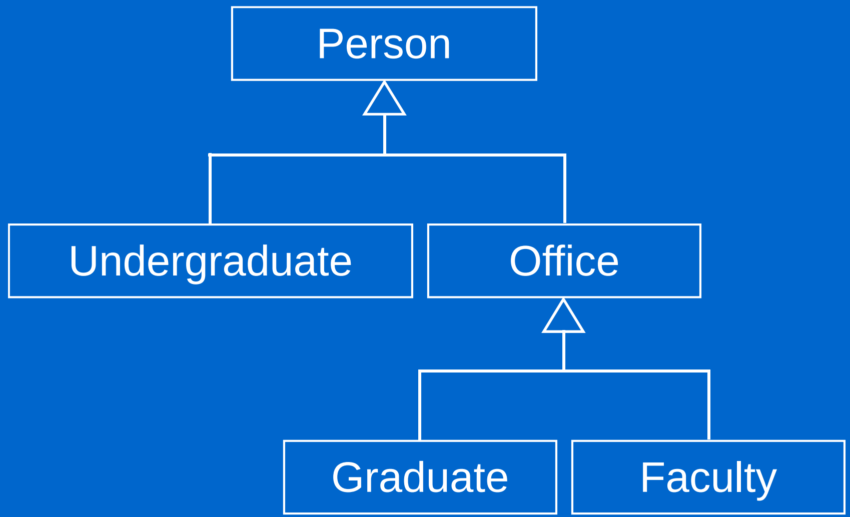

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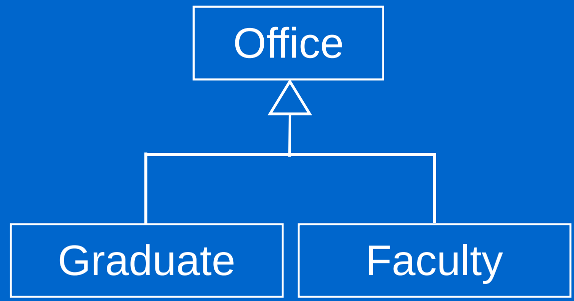

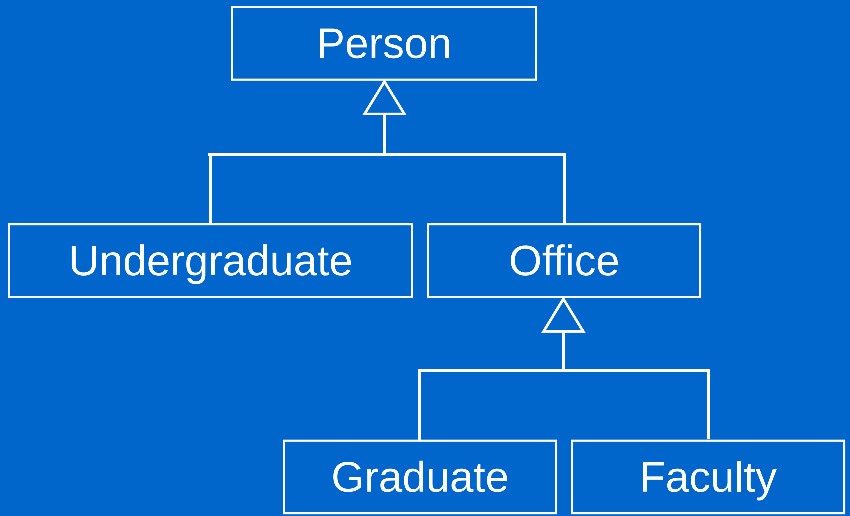

Bad design!! Problematic!!?

What's wrong?

- **If the Office has a clean() method, The Faculty automatically has a clean() method. What does it mean?**
- **What if a faculty has two offices?**

Code for Office Solution

```
class Office: public Person {
public:
   Office(char *name, int age, char address);
   ~Office()
   const char *getAddress() const;
private:
   char *m_address;
};
```

Code for Office Solution

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class Office: public Person {
public:
   Office(char *name, int age, char address);
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   --------------------------------------------------------------
class Graduate: public Office {
public:
   Graduate(char *name, int age, int stipend, char *address);
   int getStipend() const;
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   int m_stipend;
};
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class Faculty: public Office {
public:
   Faculty(char *name, int age, char *address, char *rank);
   ~Faculty();
   const char *getRank() const;
private:
   char *m_rank;
};
```

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```
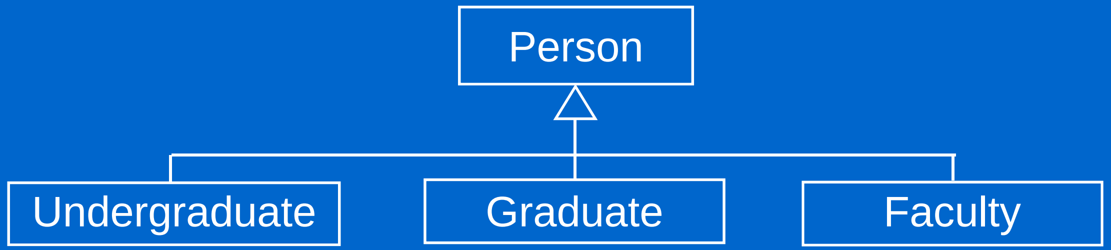

Poor design!!
Problematic!!?

Final Solution

- Back to our original inheritance design (good design)



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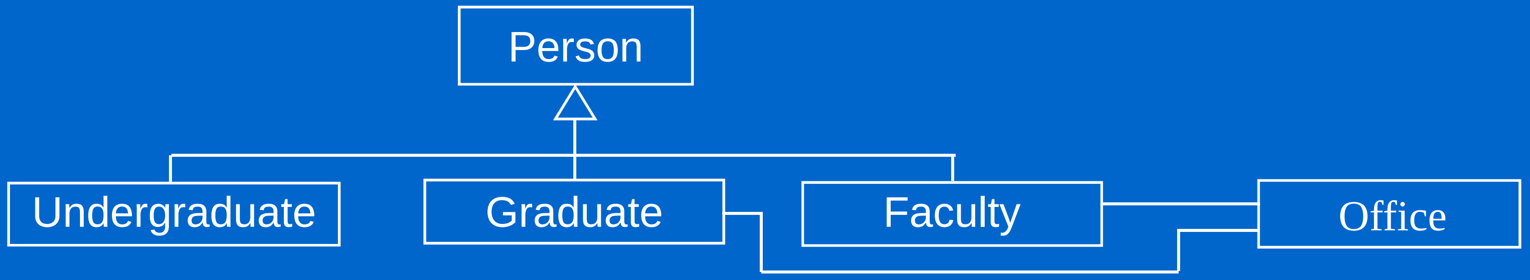

- Instead of having Graduate and Faculty inherit from Office, we store an Office object within each classes

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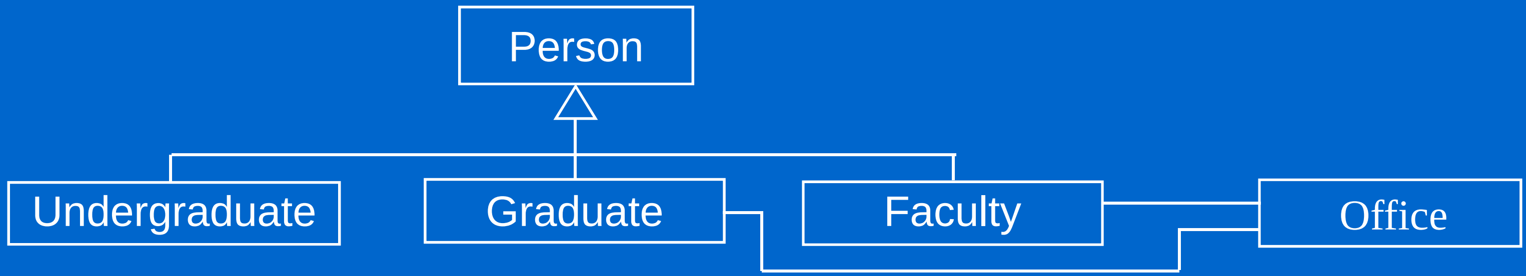

- Instead of having Graduate and Faculty inherit from Office, we store an Office object within each classes
- The office class exists separately, without involving any inheritance
- Codes:

```
class Office {
public:
   Office(char *address);
   ~Office();
   const char *getAddress() const;
private:
   char *m_address;
};
```

Final Solution (cont'd)

```
class Graduate: public Person {
public:
   Graduate(char *name, int age, int stipend, char *address);
   int getStipend() const;
   const char* getAddress() const;
private:
   int m_stipend;
   Office m_office;
};
```

Final Solution (cont'd)

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```
const char* Graduate::
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  return m_office.getAddress();
}
```

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class Faculty: public Person
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```

- Note: the data part m_office in Graduate and Faculty is replicated. However, the code to handle address is reduced to a single copy, i.e. Office::getAddress(). If we want to maintain a single object for the same office, we can use pointer or reference to implement m_office.

Further Abstraction

- When the relationships between Graduate or Faculty objects and other objects are common, we can model their relationships within a parent class.

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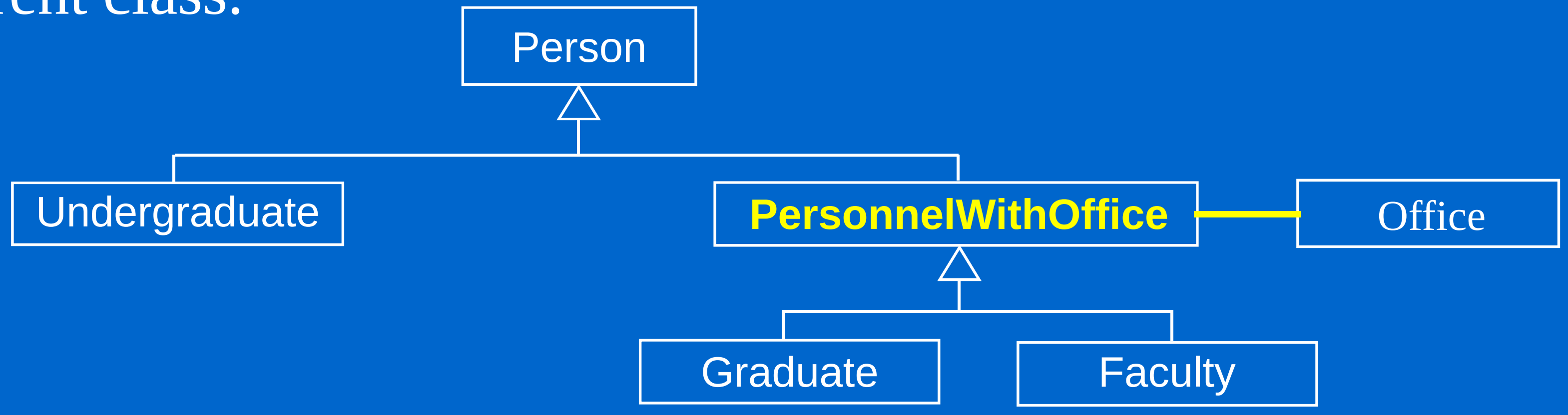

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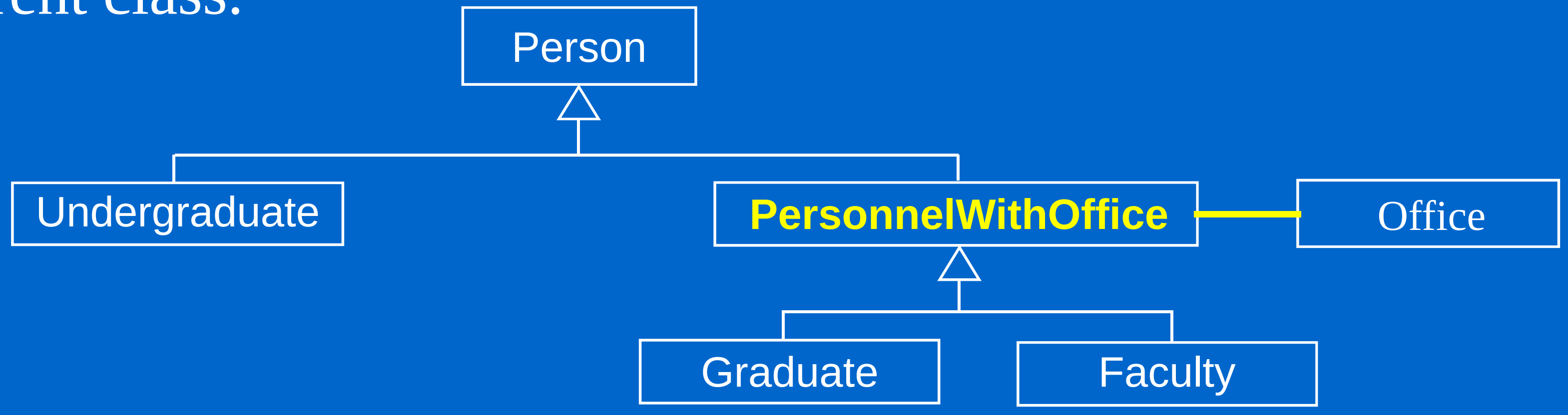

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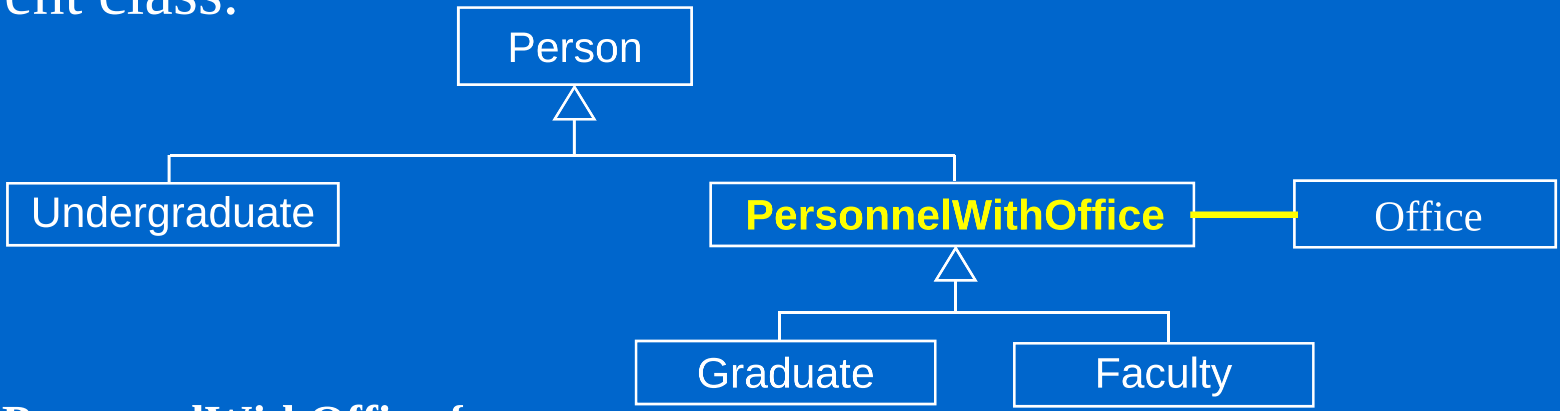


```
class PersonnelWithOffice {
public:
    const char *getAddress() const;
private:
    Office m_office;
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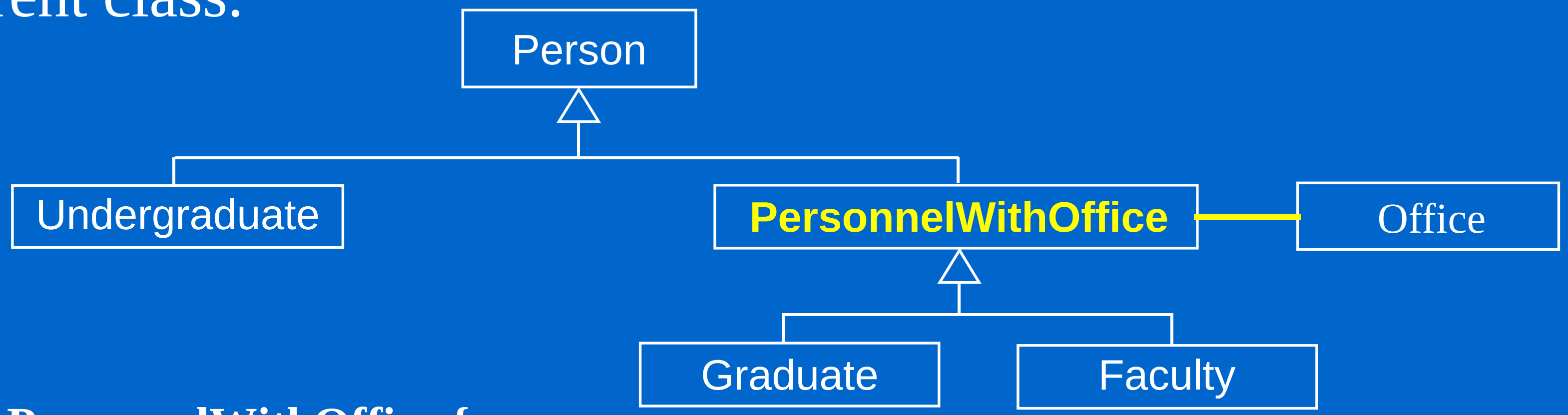


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Note: in the above class diagram, each Graduate object or Faculty object has an association with an Office object

- If there could be several offices for a certain personnel, the private member could be a container, ex. vector<Office> m_offices;

Design Rules for Inheritance

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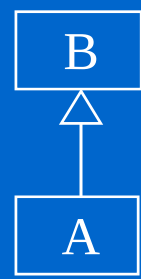

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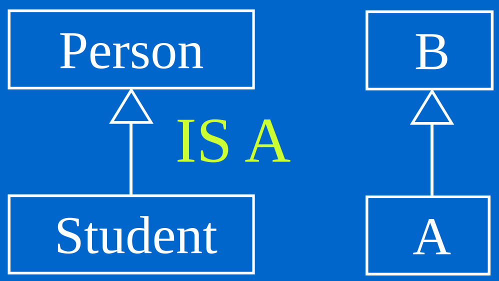

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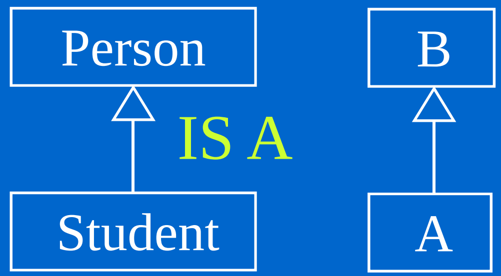

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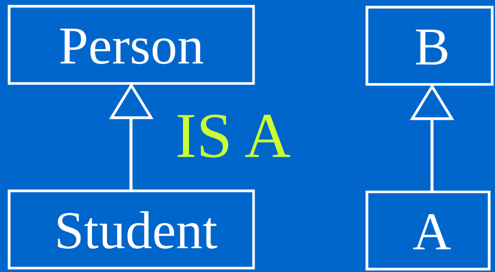

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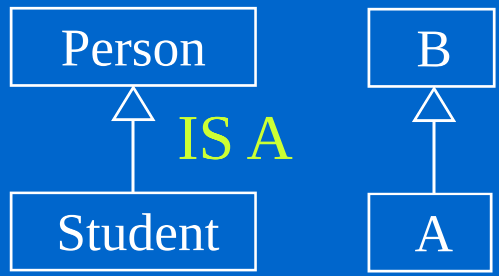

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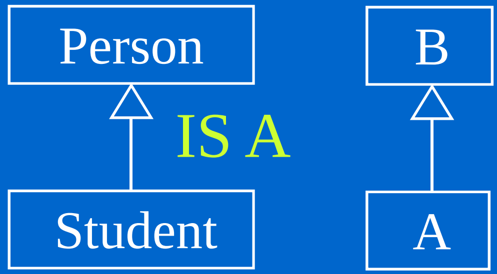

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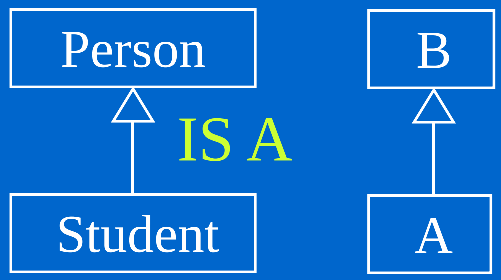

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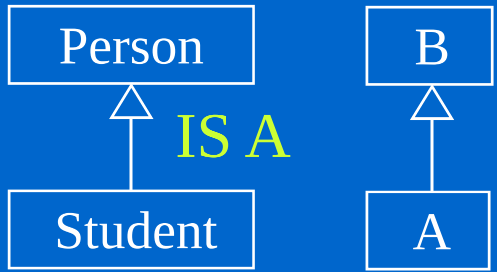

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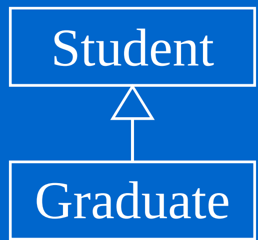
Proper inheritance



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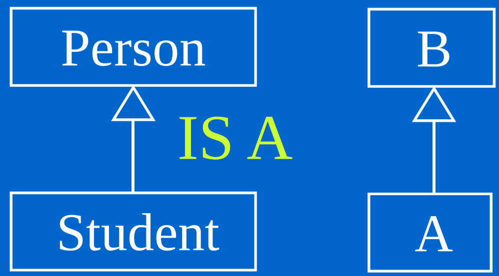

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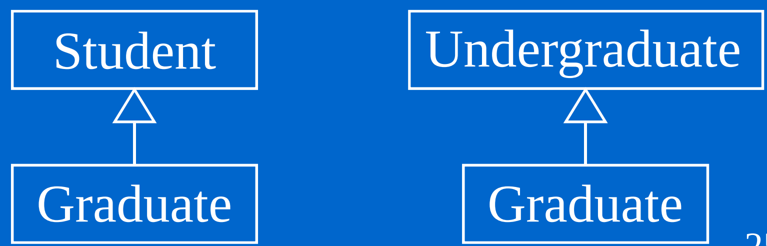
Proper inheritance **Improper inheritance**



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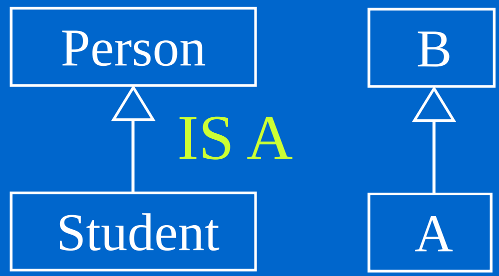

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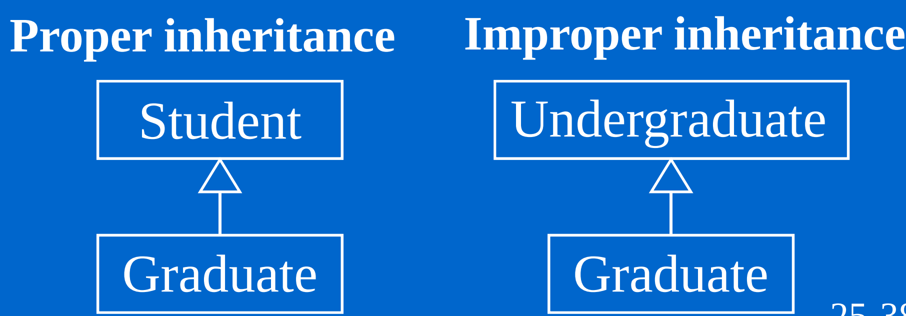
- Inheritance should be "natural"
  - The second case is a bad inheritance even if Undergraduate is internally identical to Student.

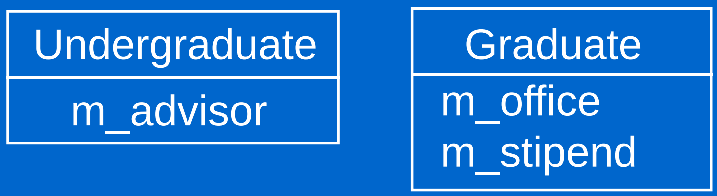


Design Rules (cont'd)

Design Rules (cont'd)

Undergraduate
m_advisor

Design Rules (cont'd)



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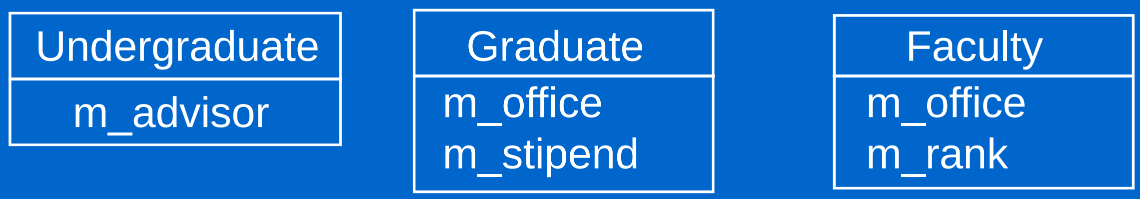

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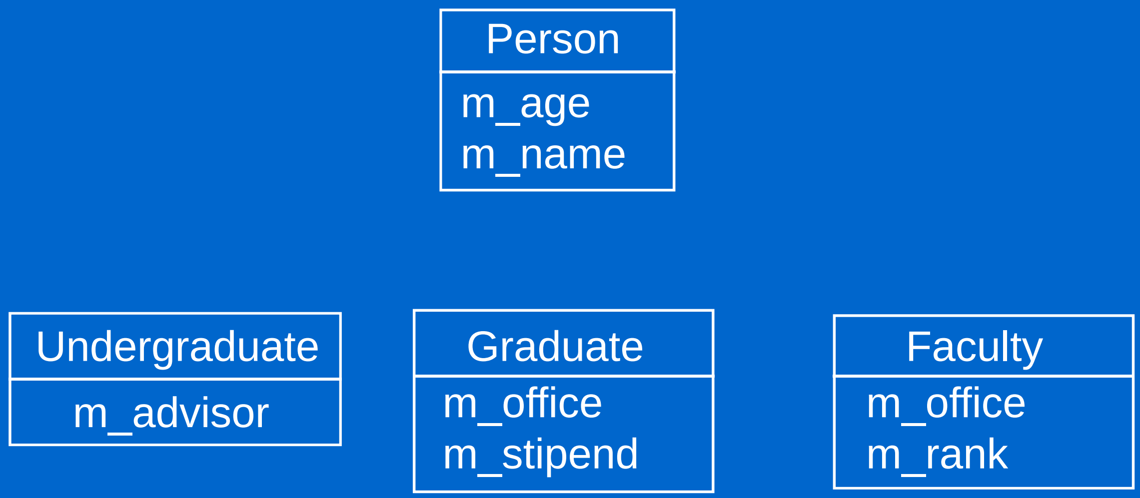

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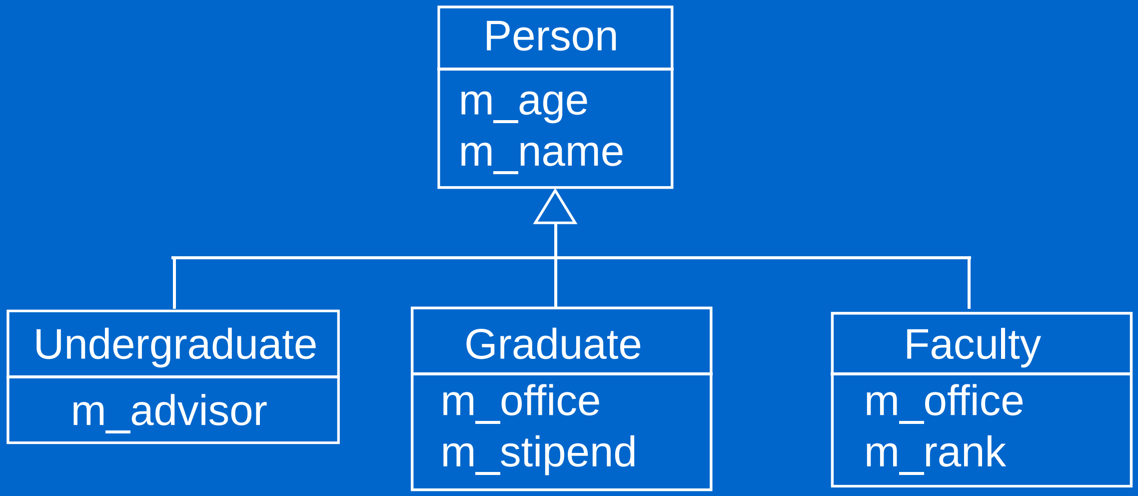
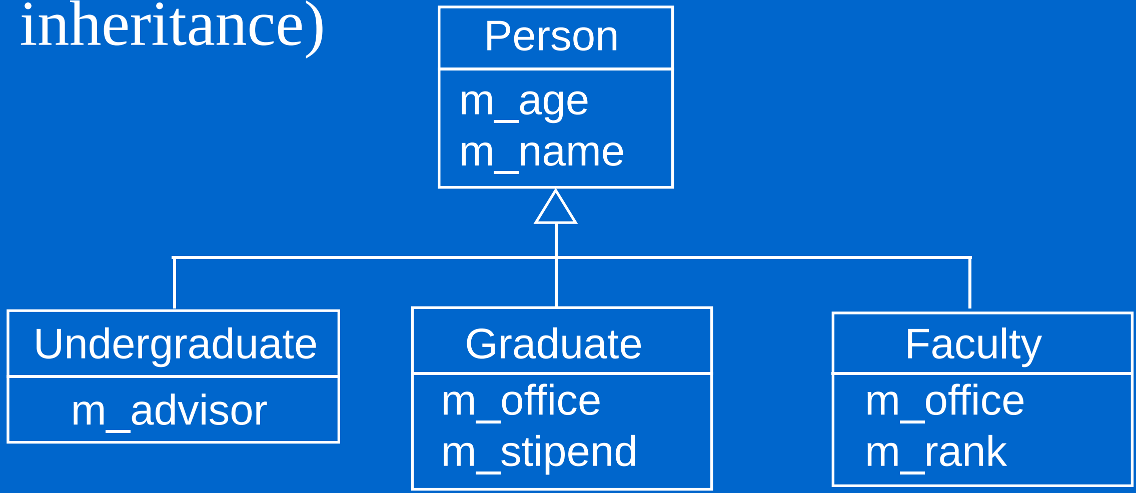


Design Rules (cont'd)

- **Common code and data** between classes can be shared by creating a base class (one of the two primary benefits we can get from inheritance)



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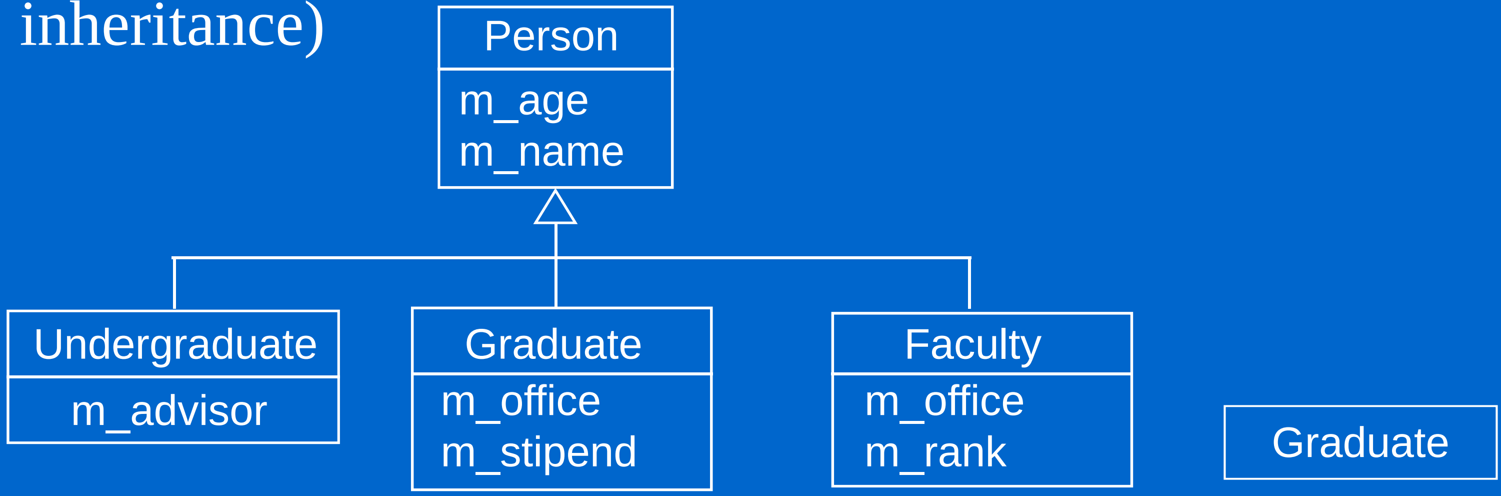

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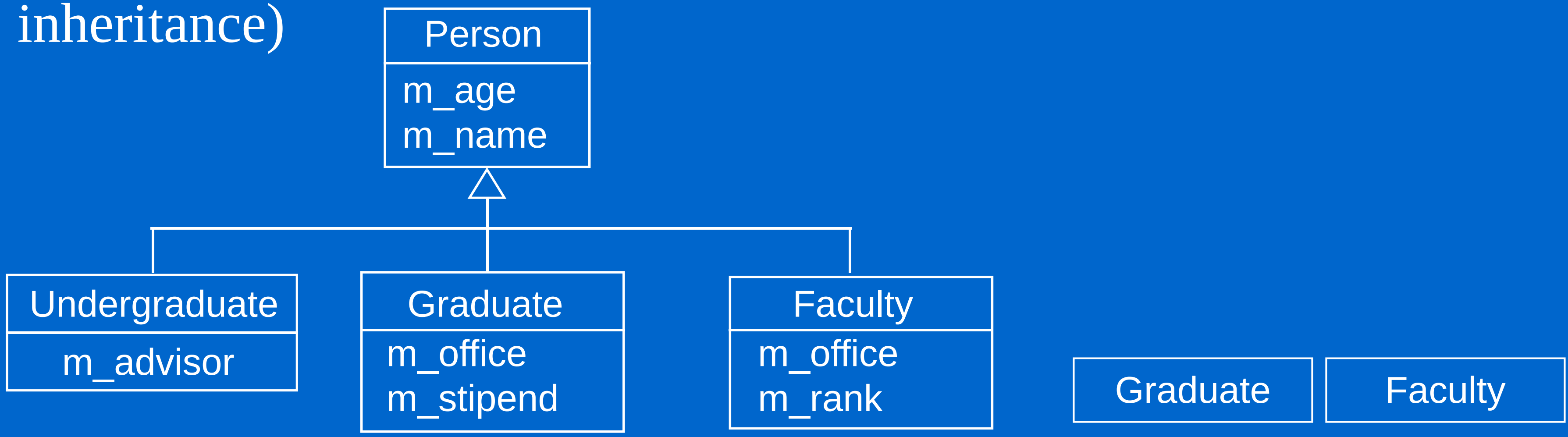

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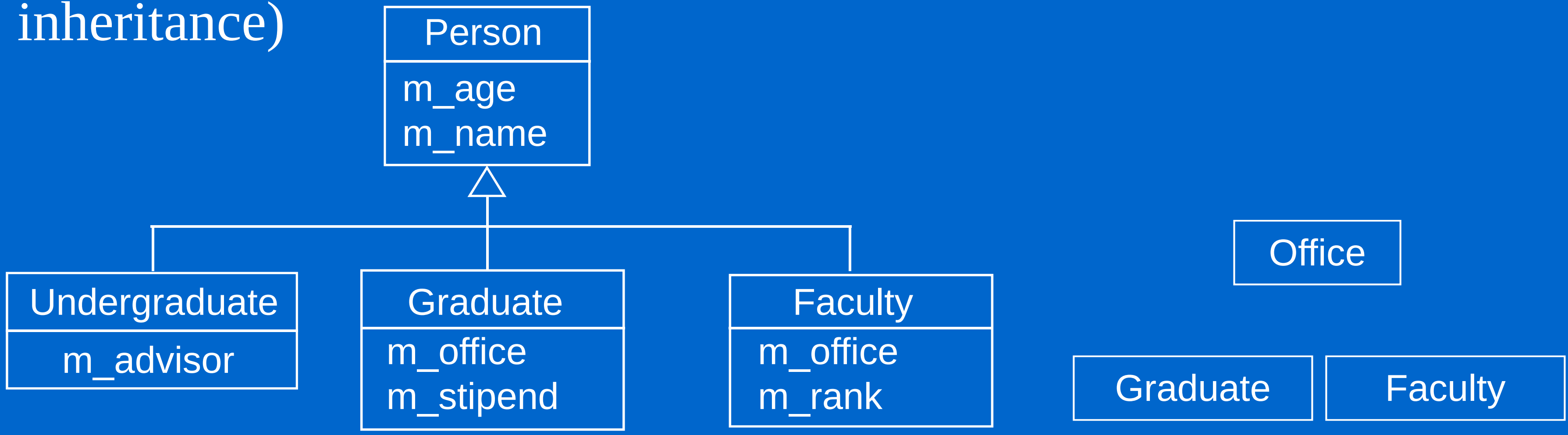

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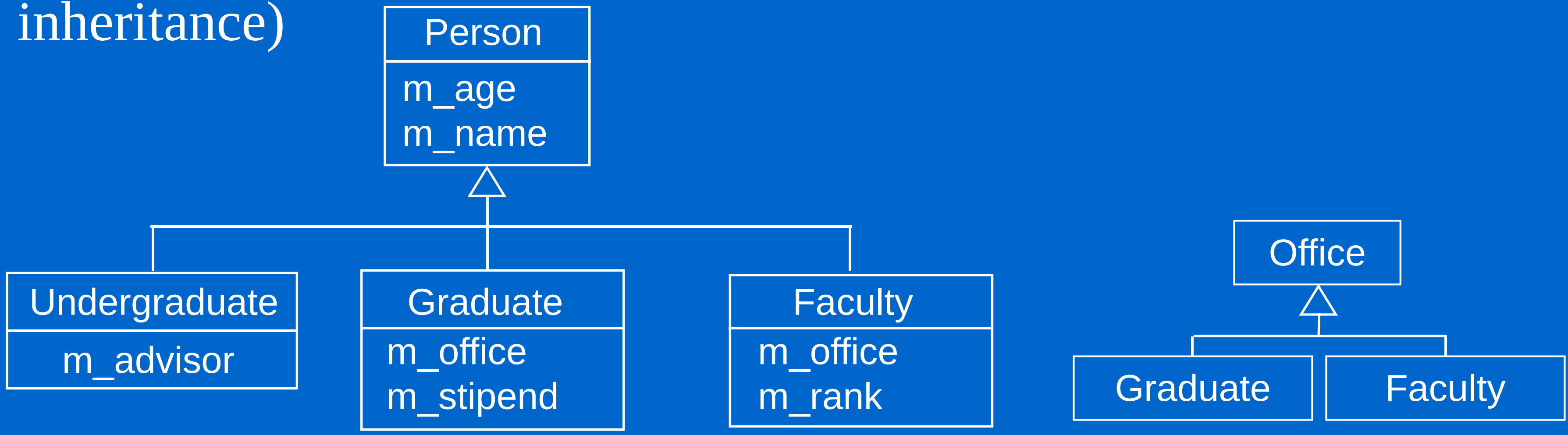

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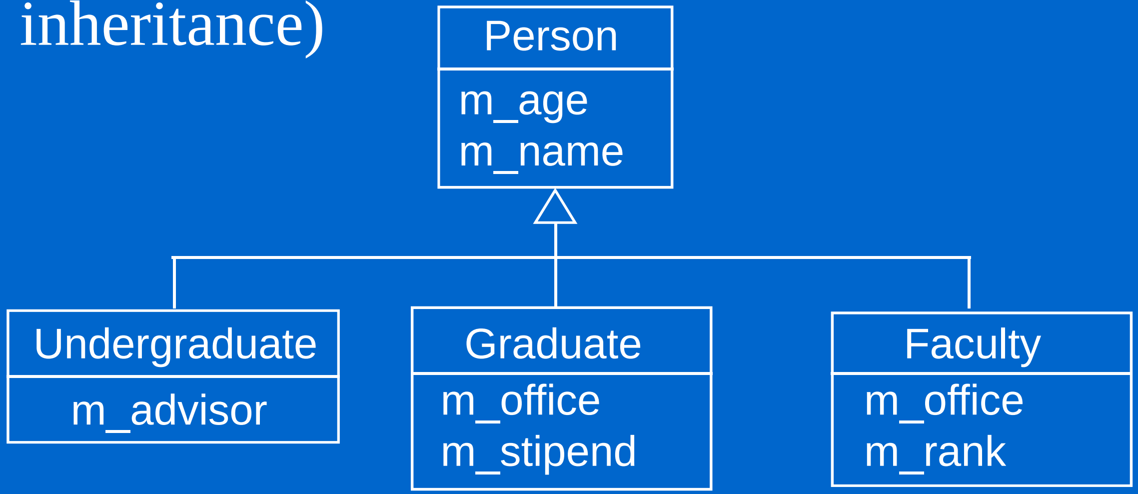

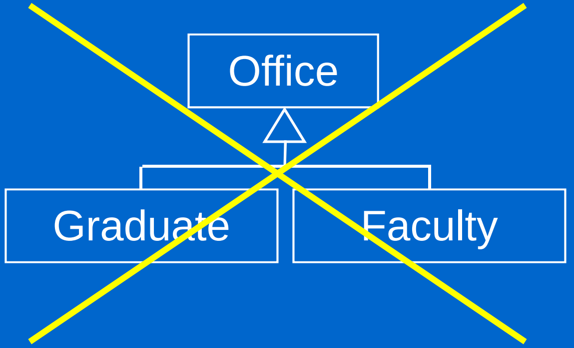

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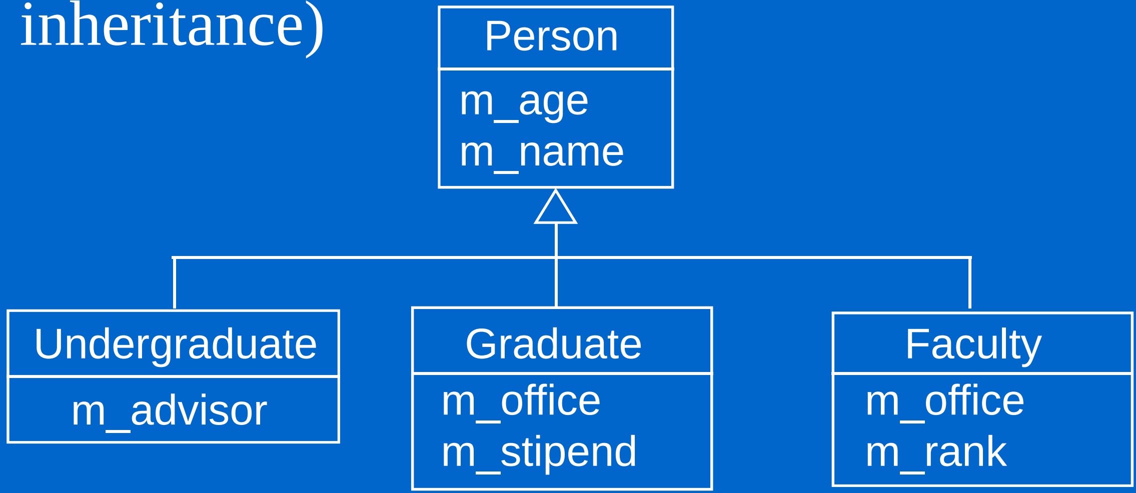

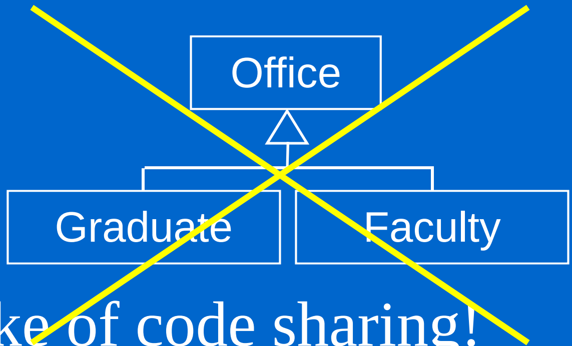

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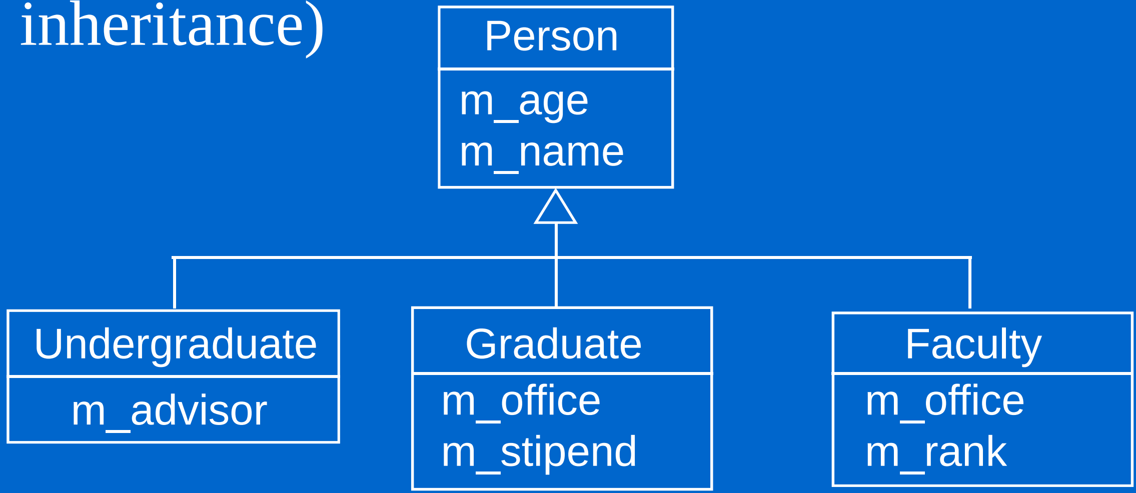

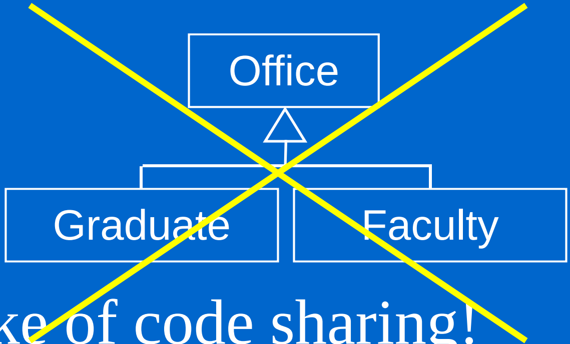

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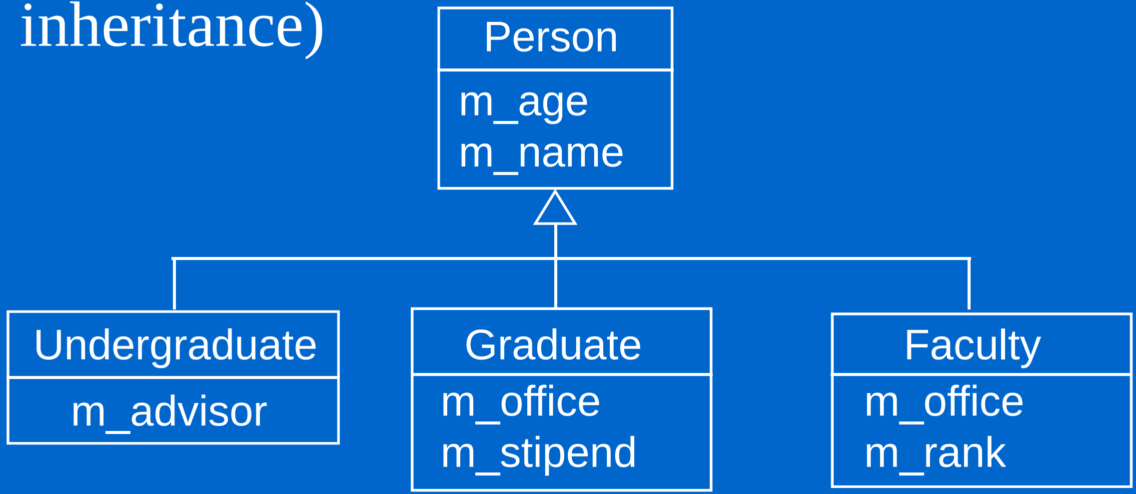

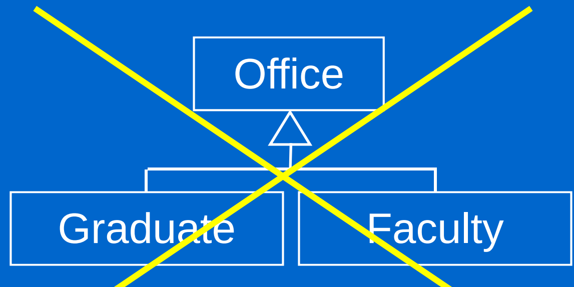

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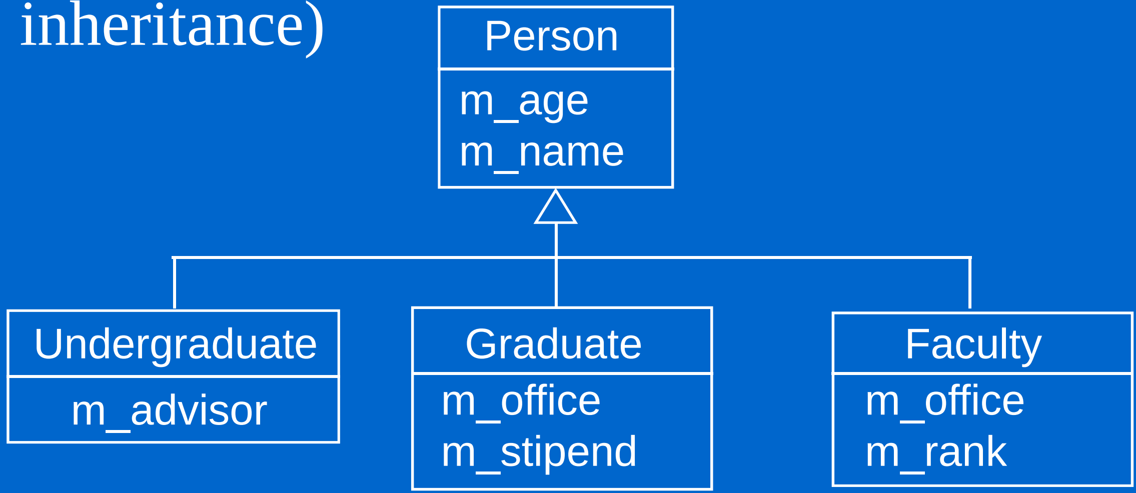

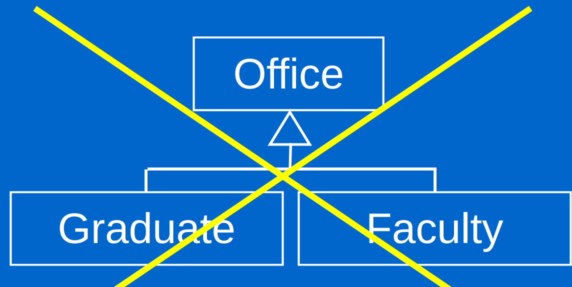

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This is referred to as the HAS-A relationship.

It operates in the form of delegation.

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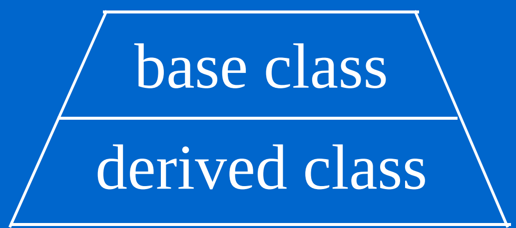

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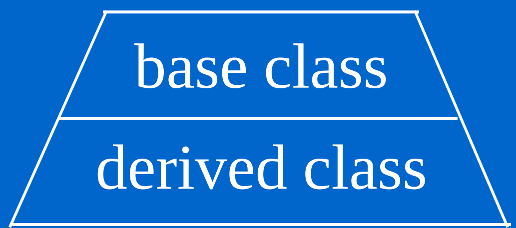
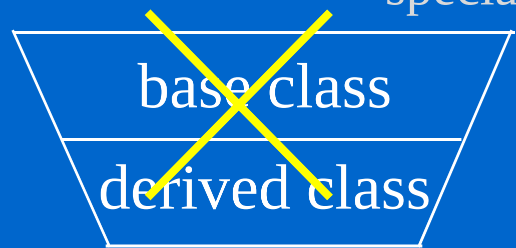
specialization





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Summary

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Undergraduate
m_advisor m_tuition

Summary

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Graduate
m_stipend

Summary

Student

m_home
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Undergraduate

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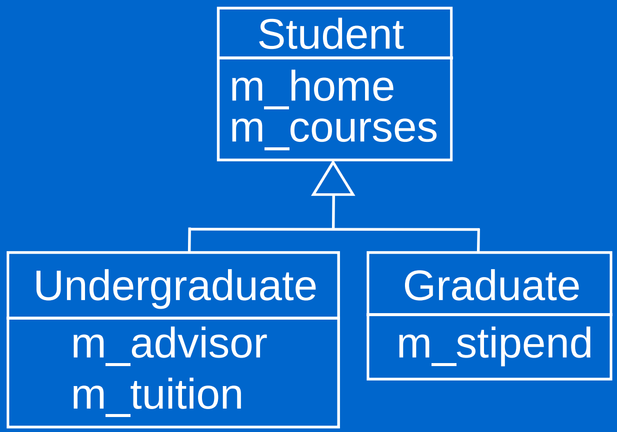
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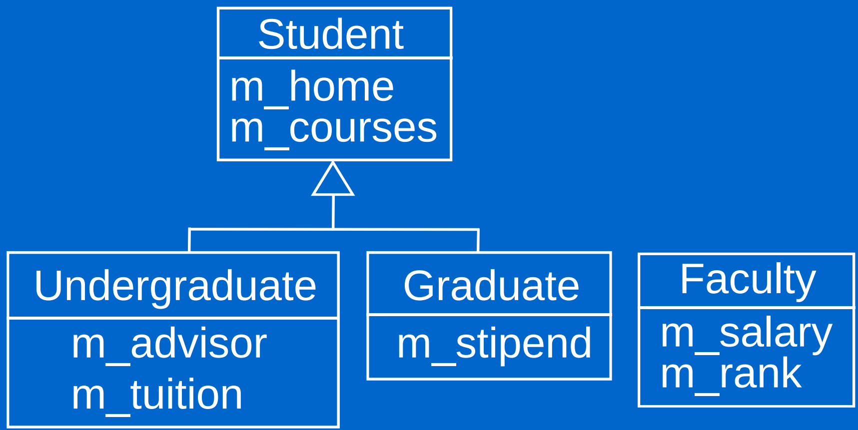
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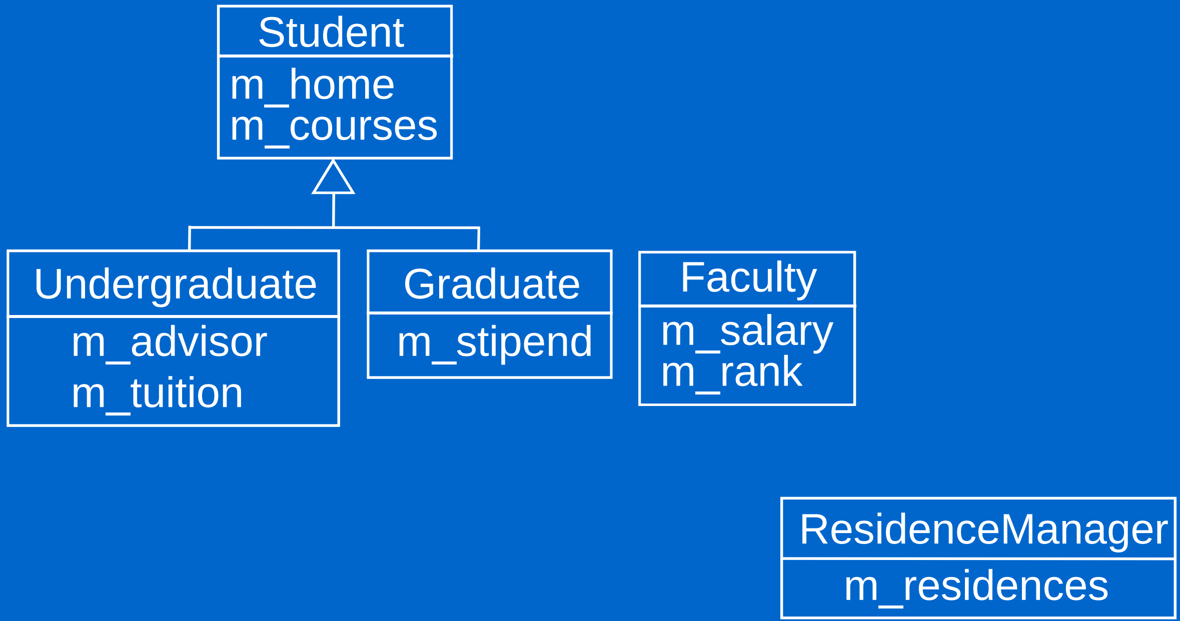
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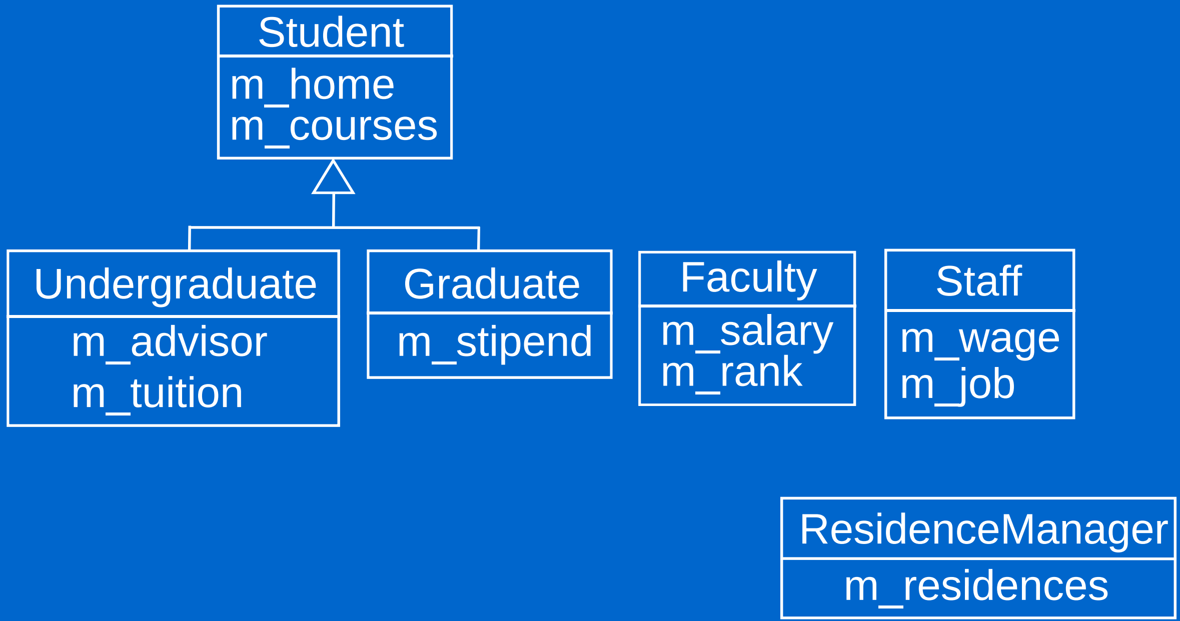
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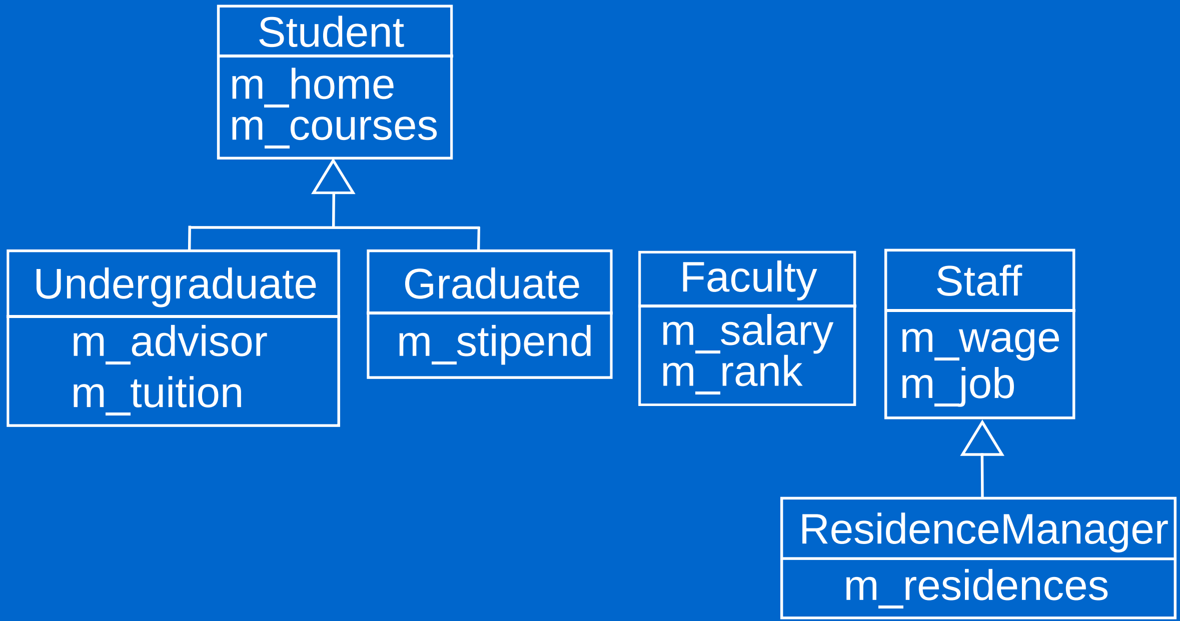
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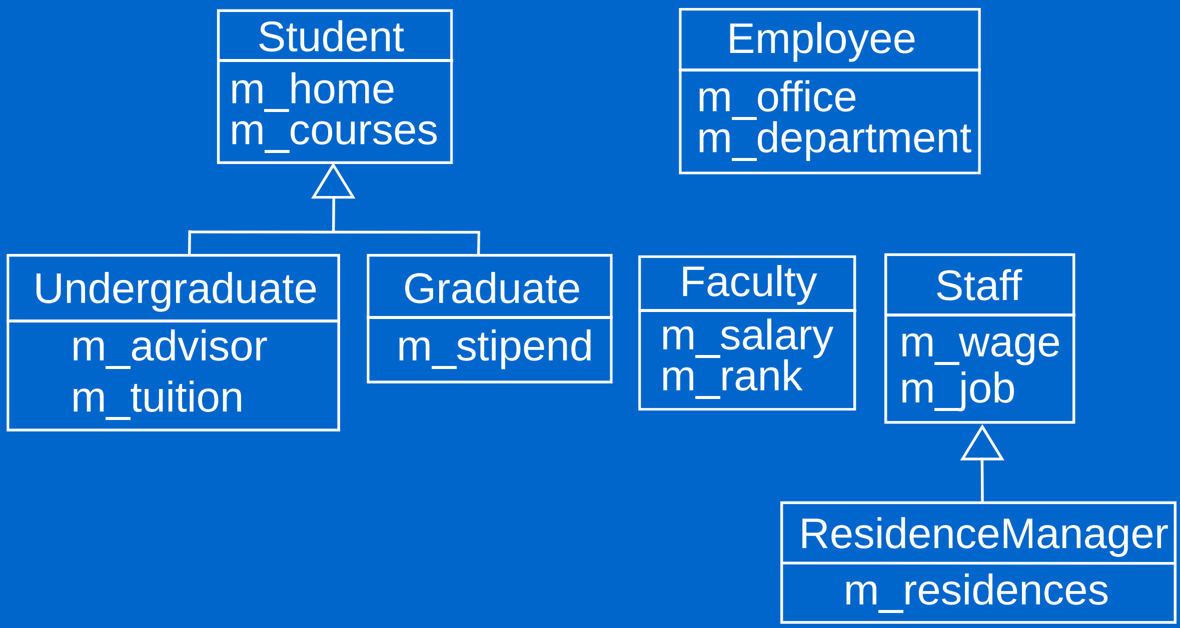
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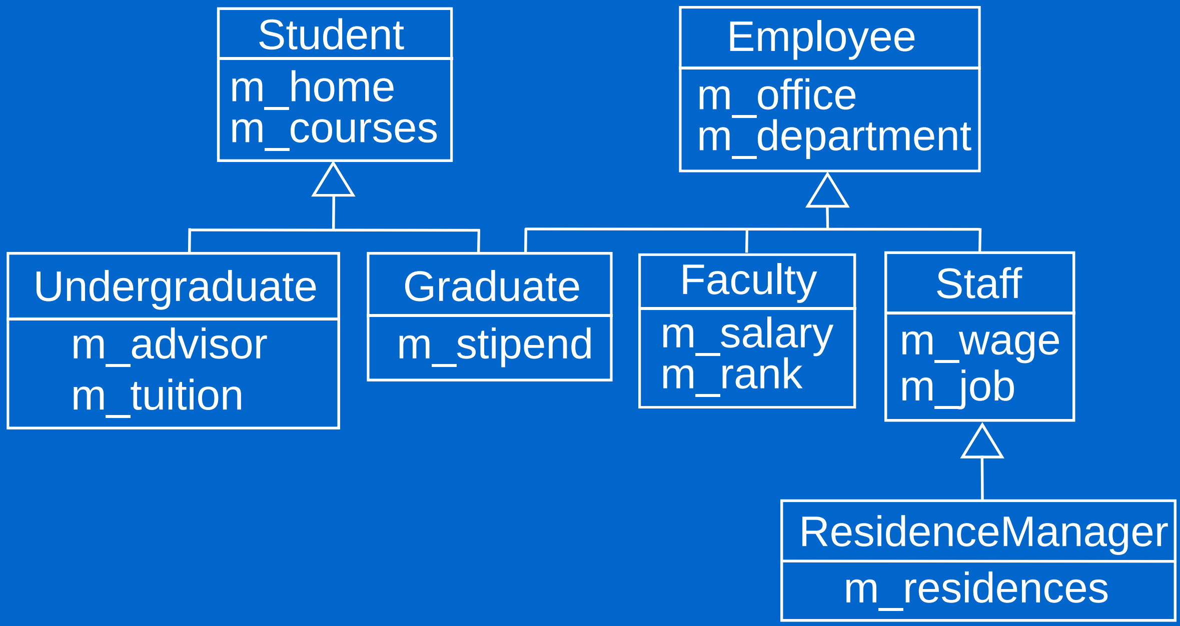
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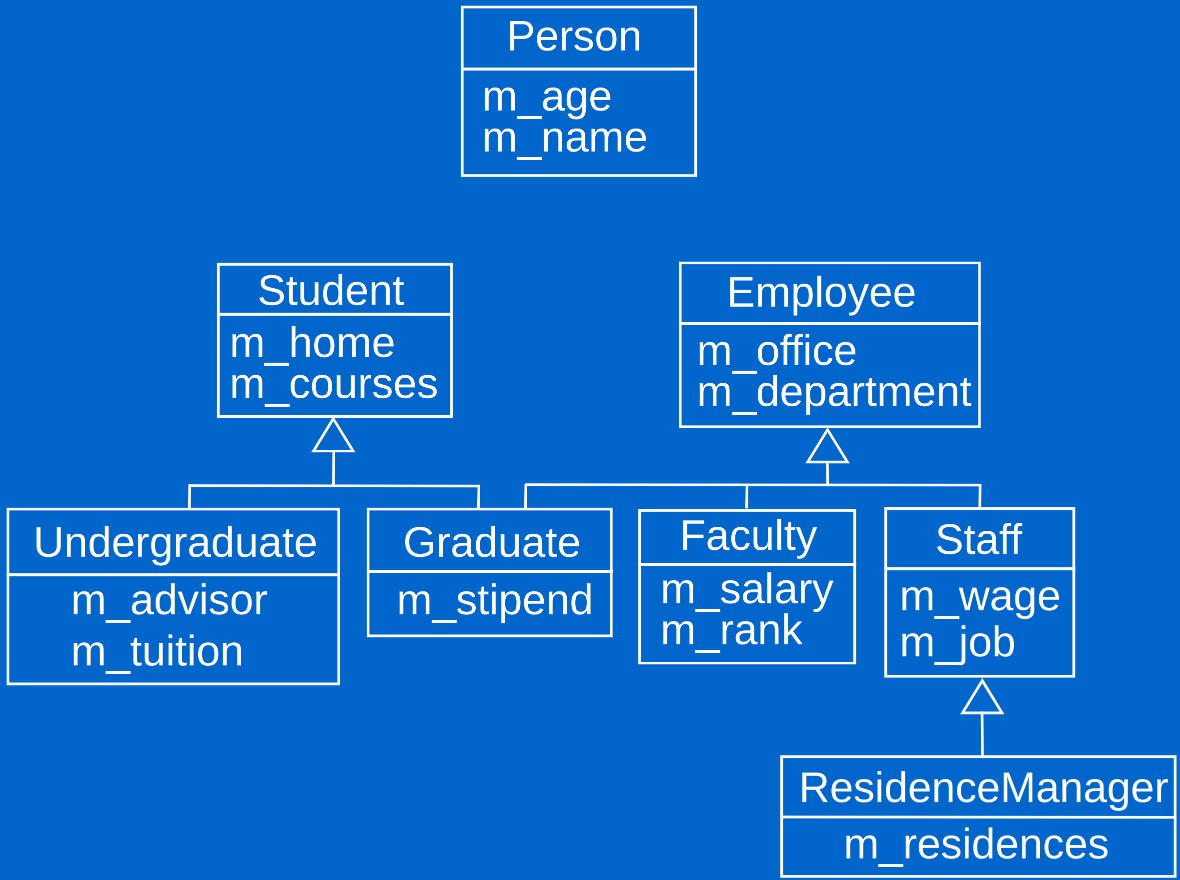

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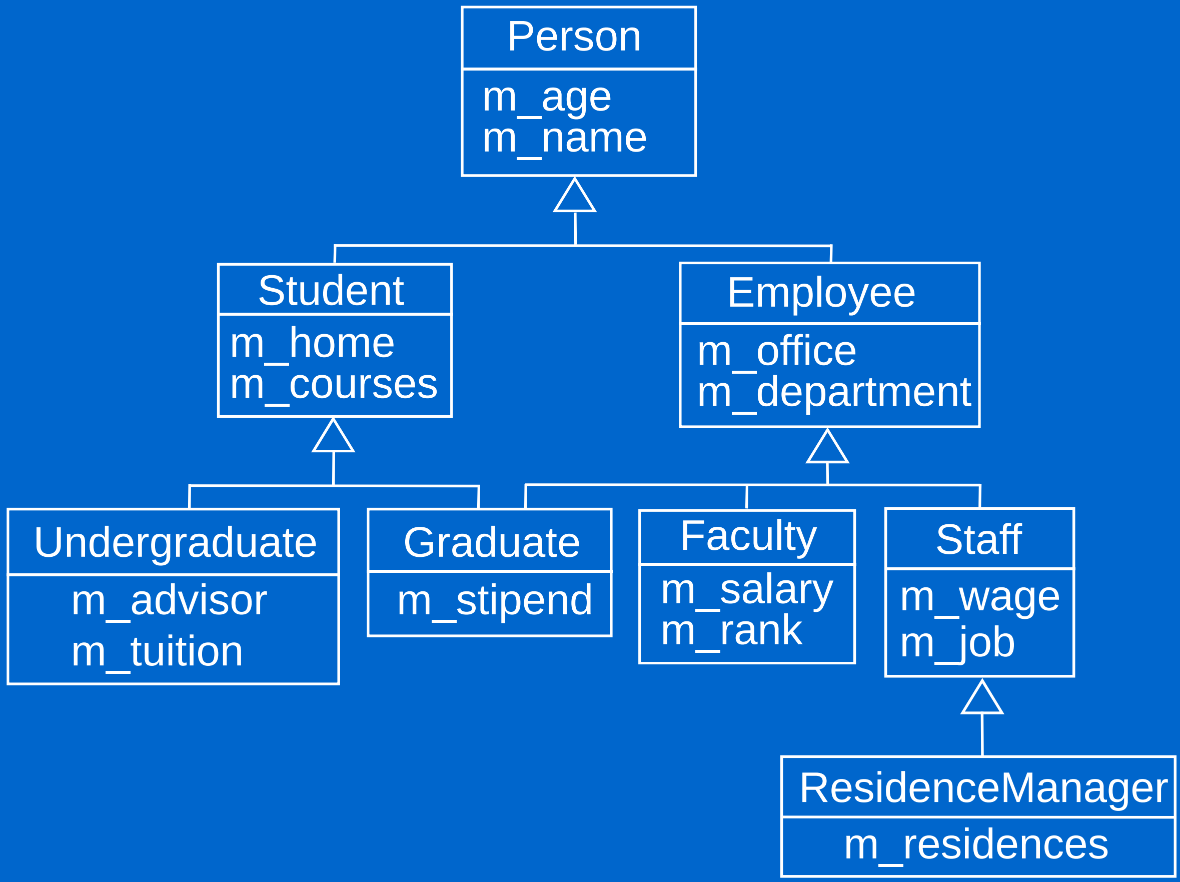
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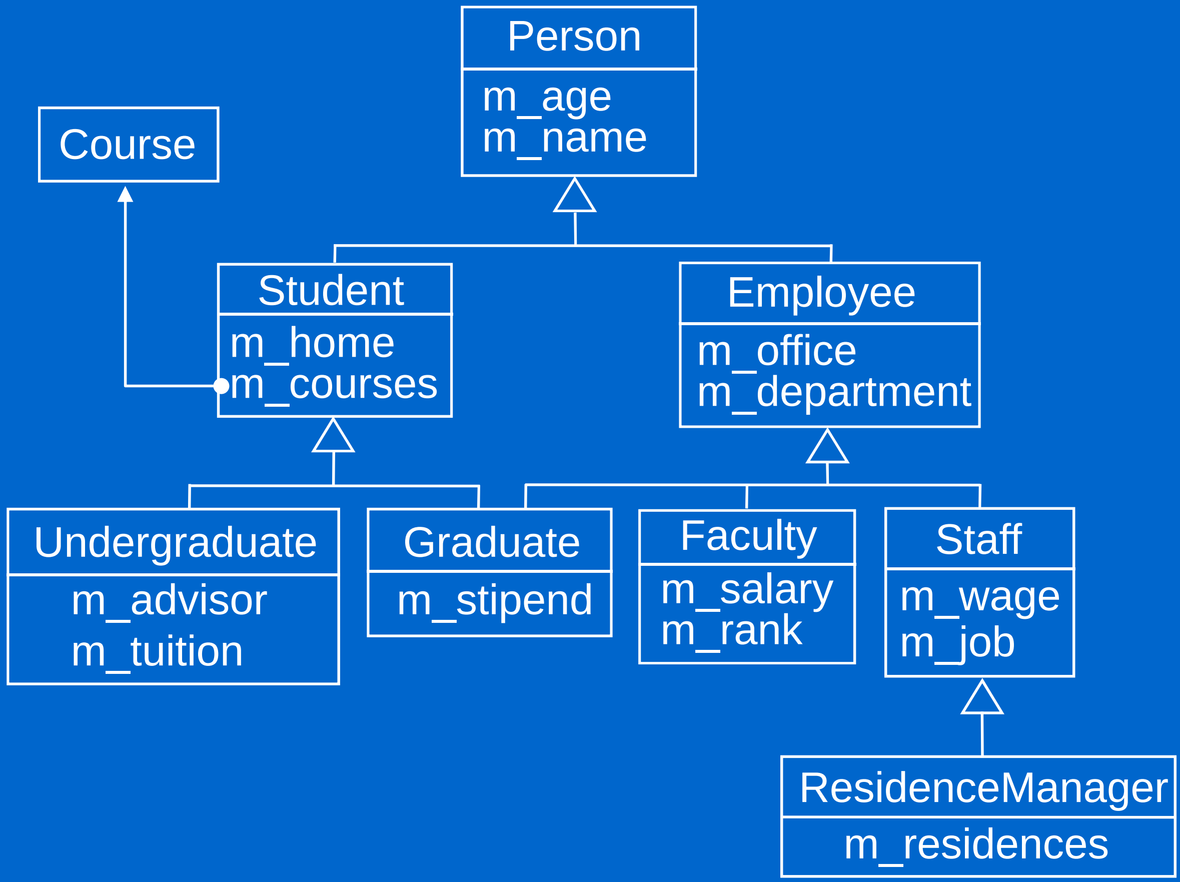
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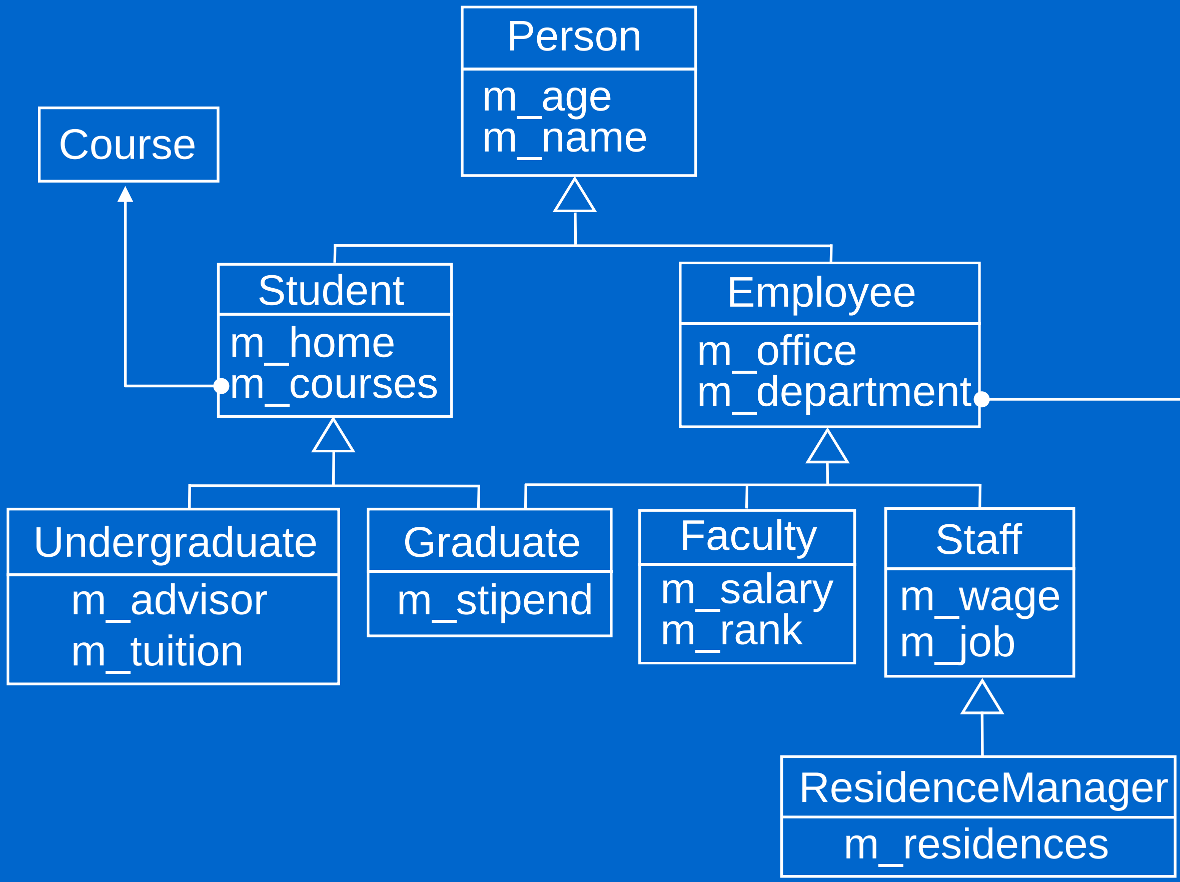
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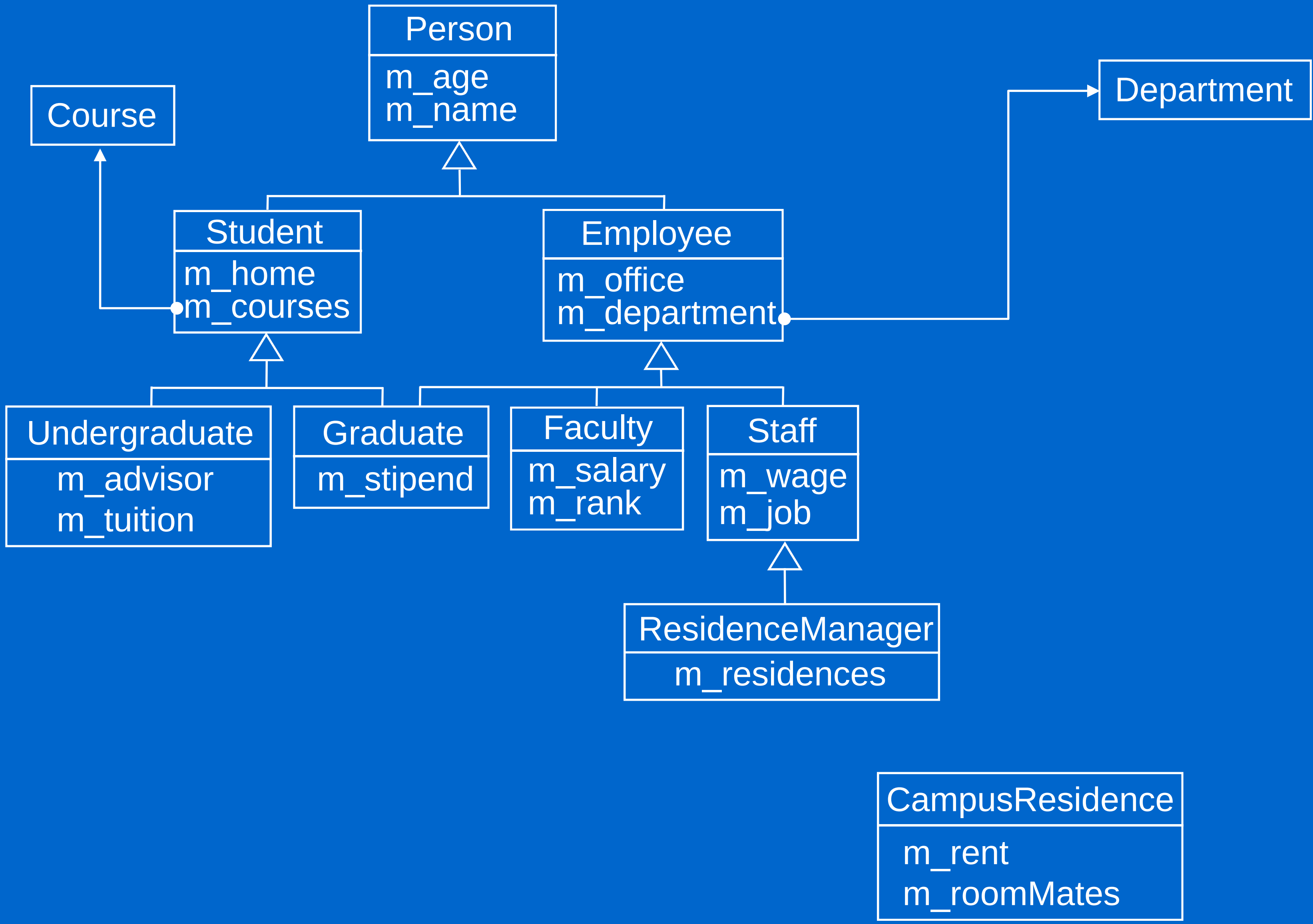

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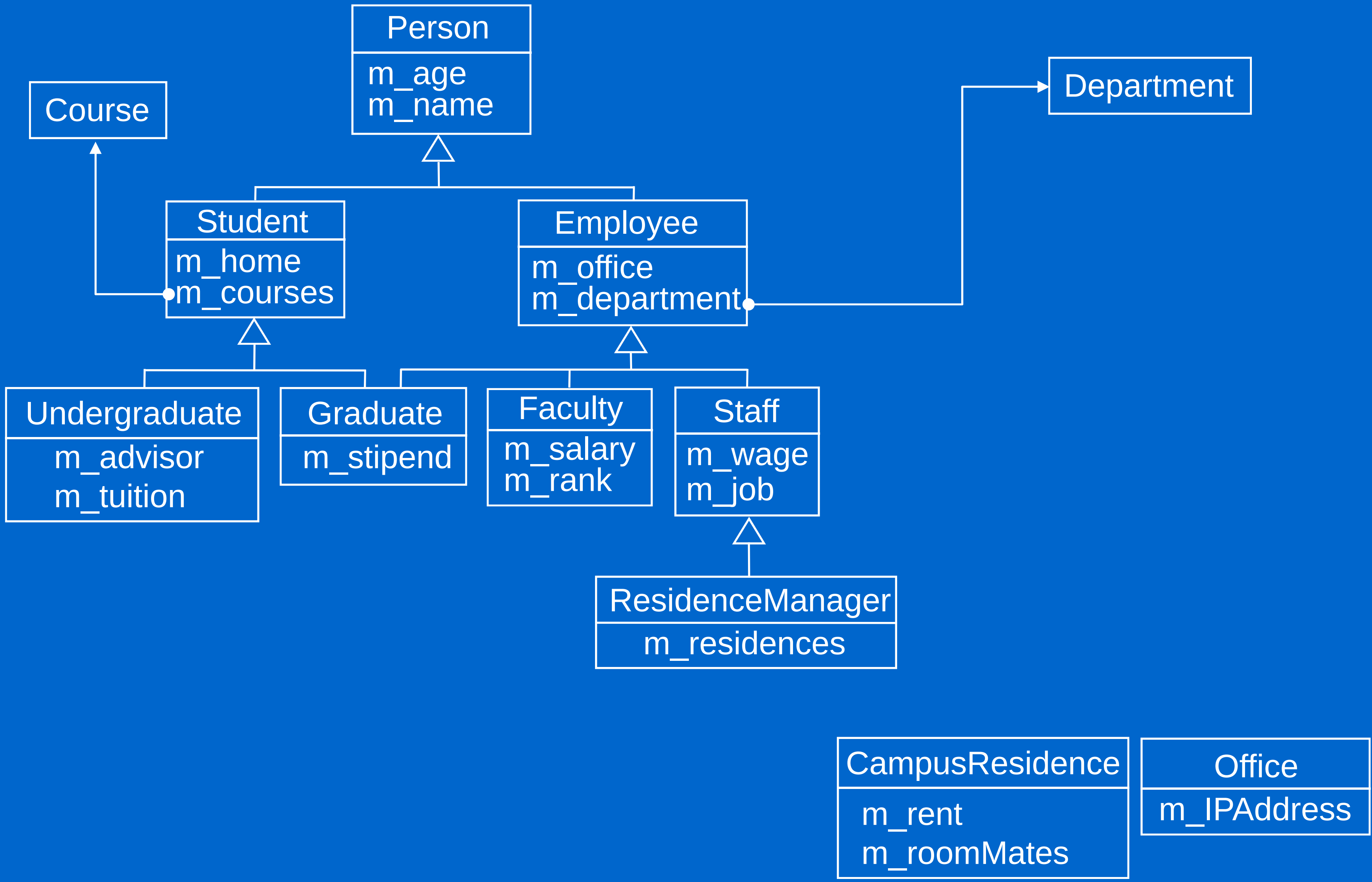
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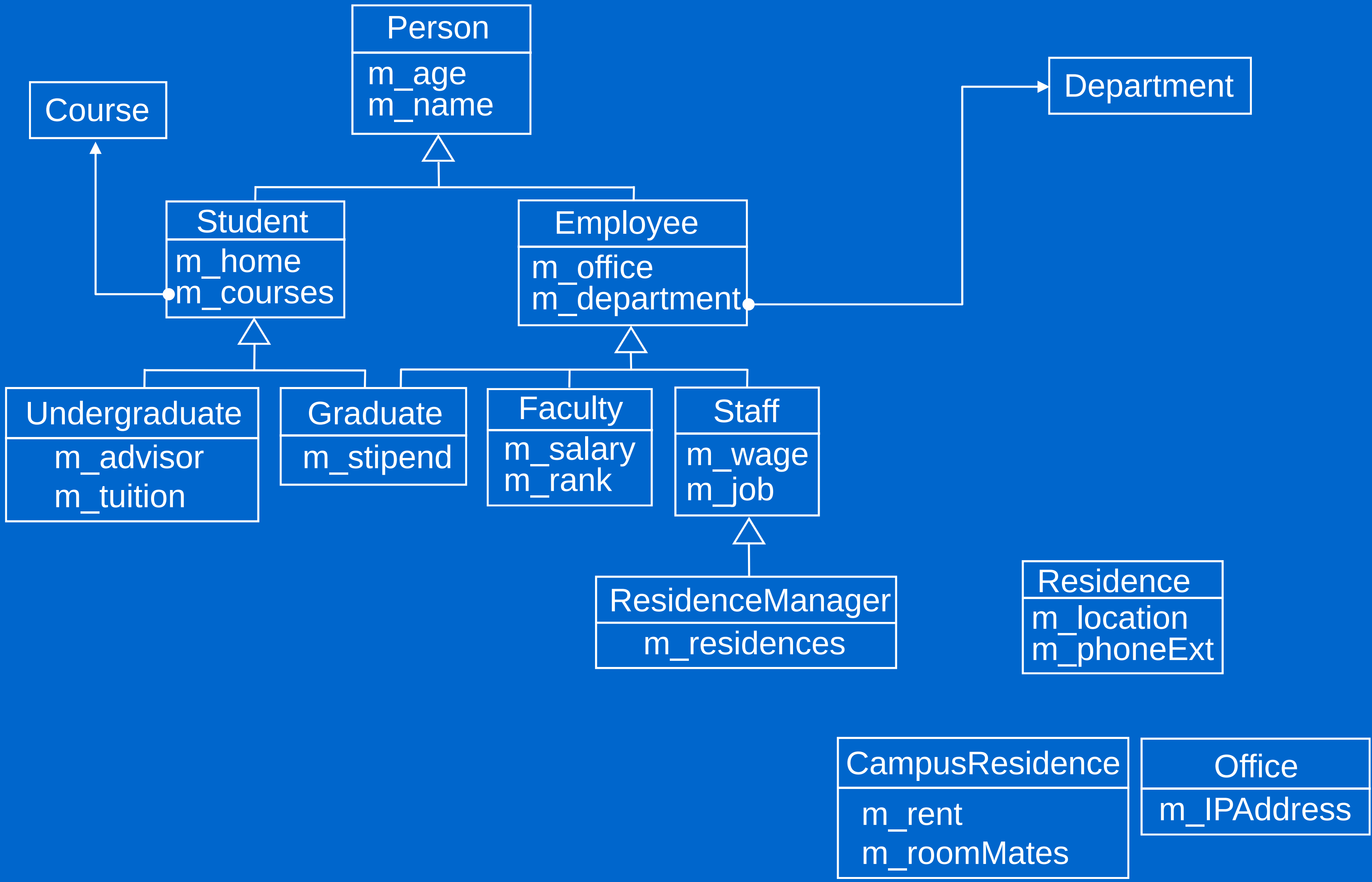
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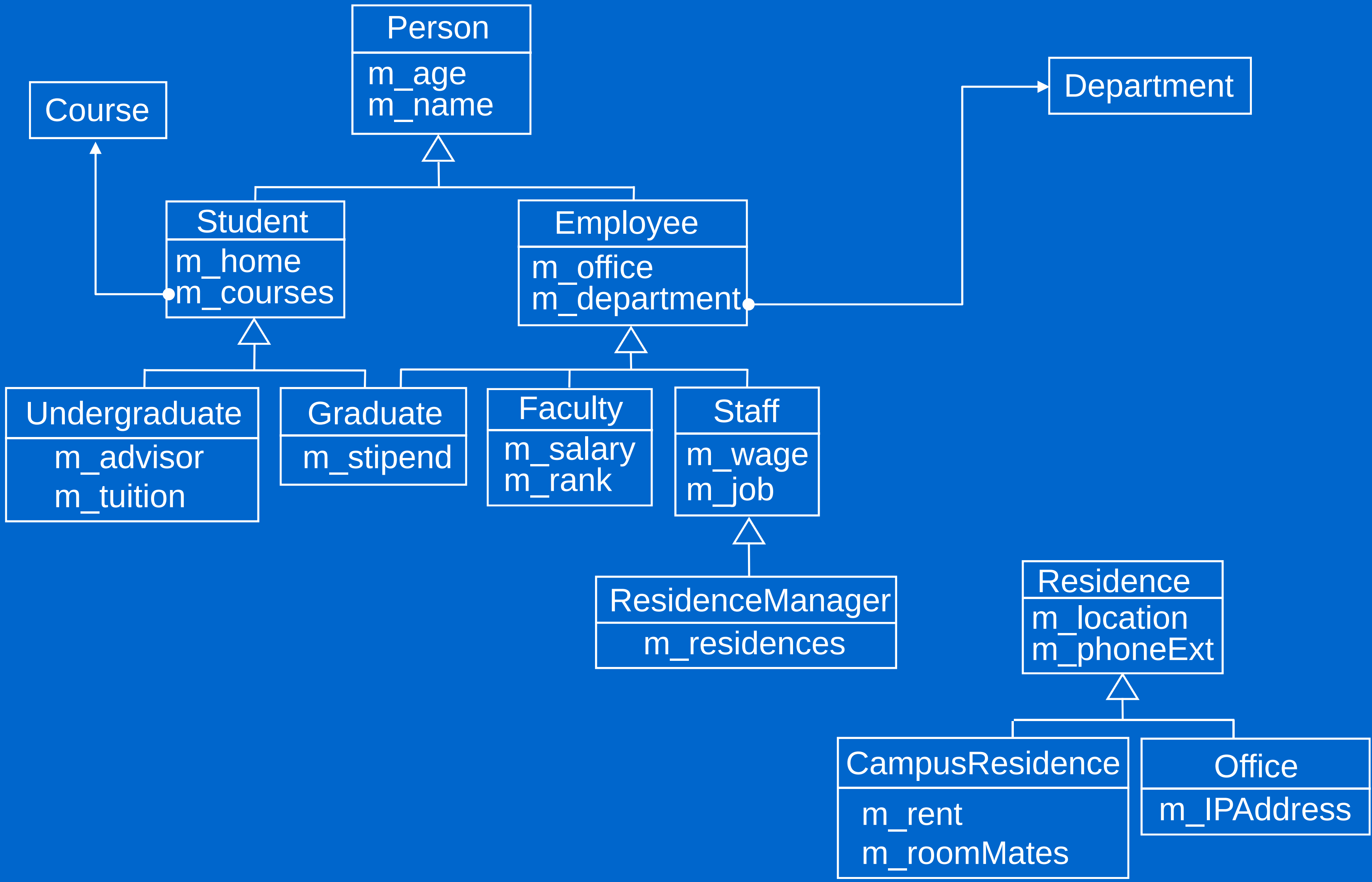
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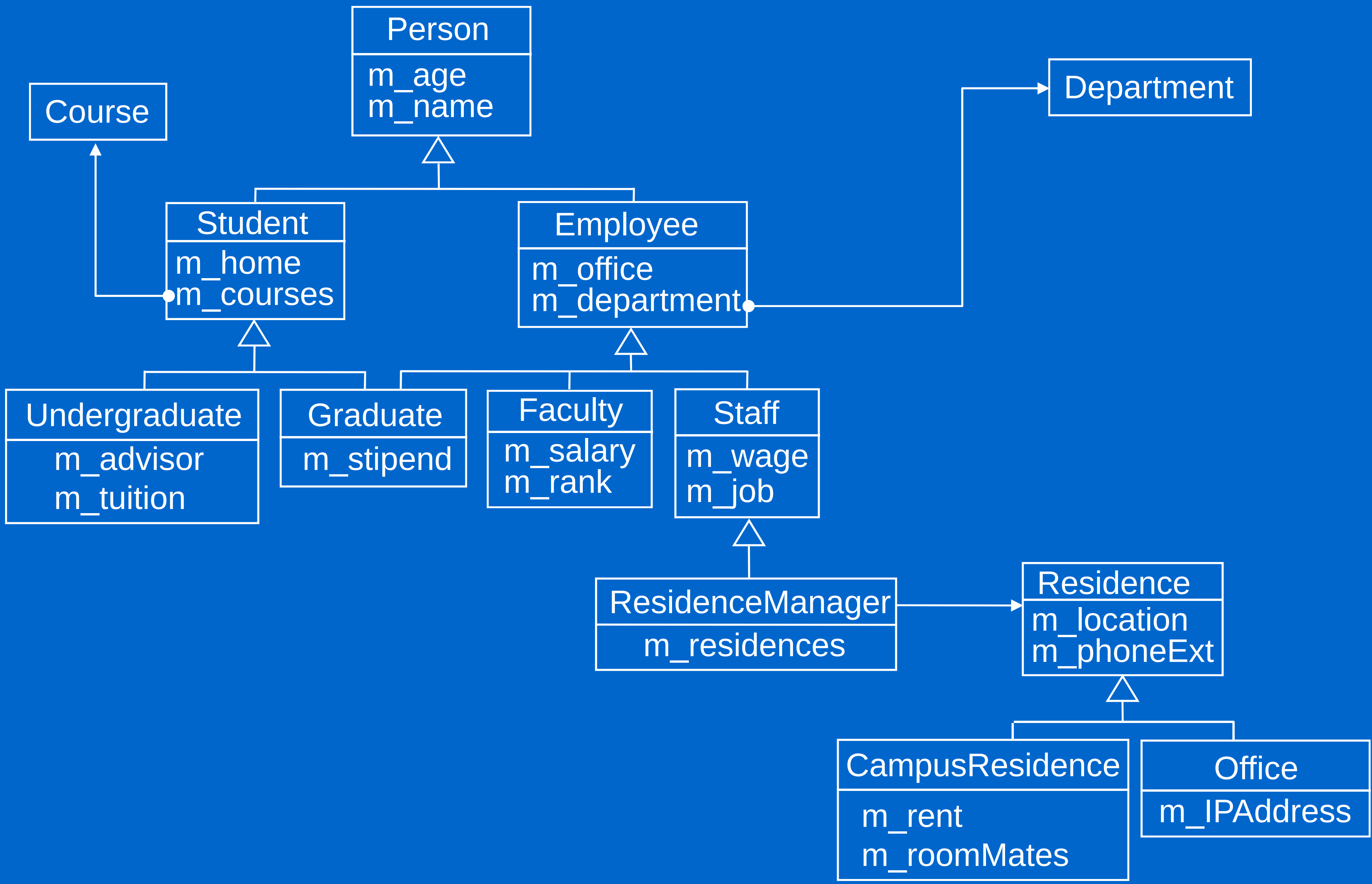
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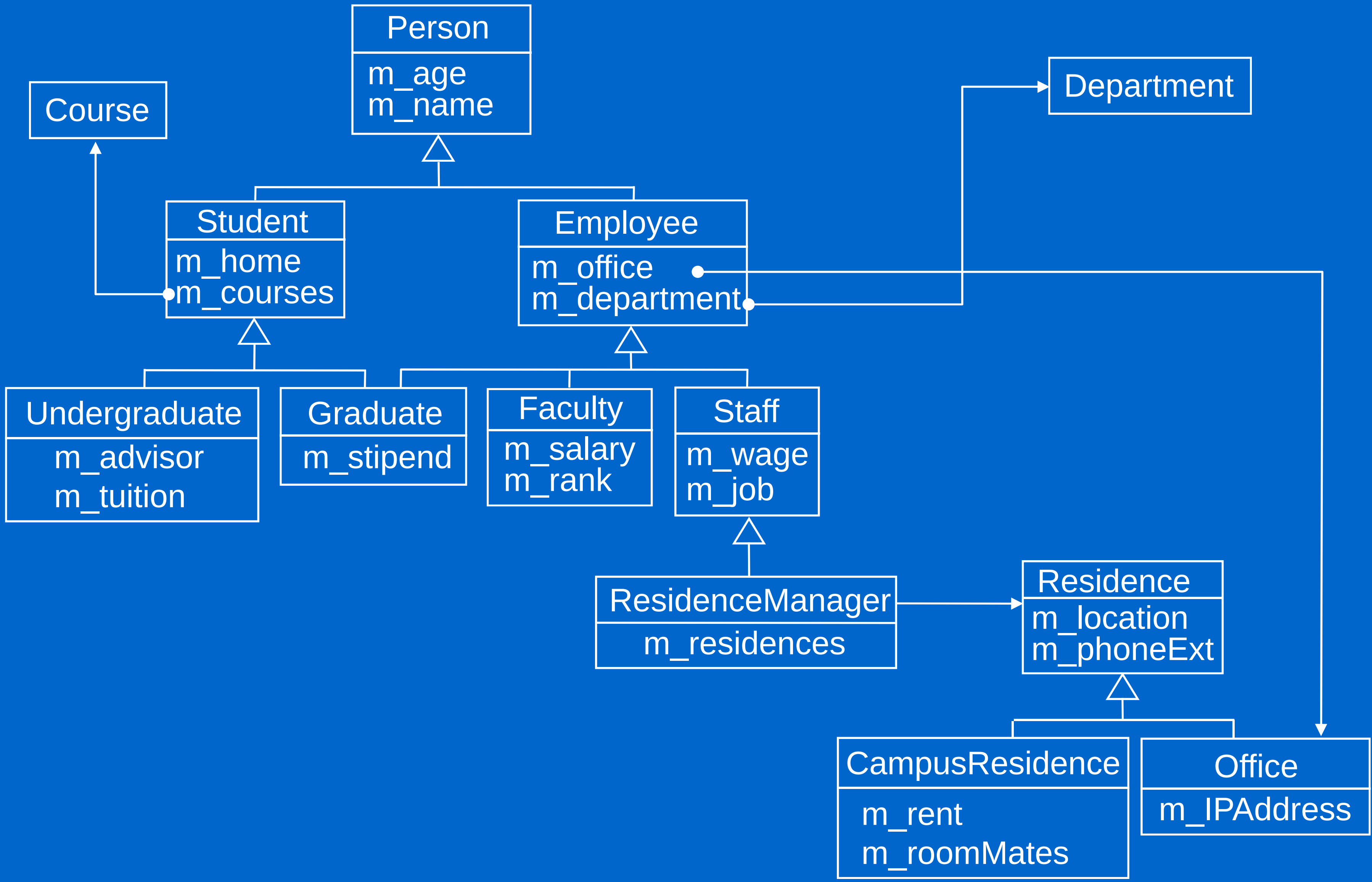
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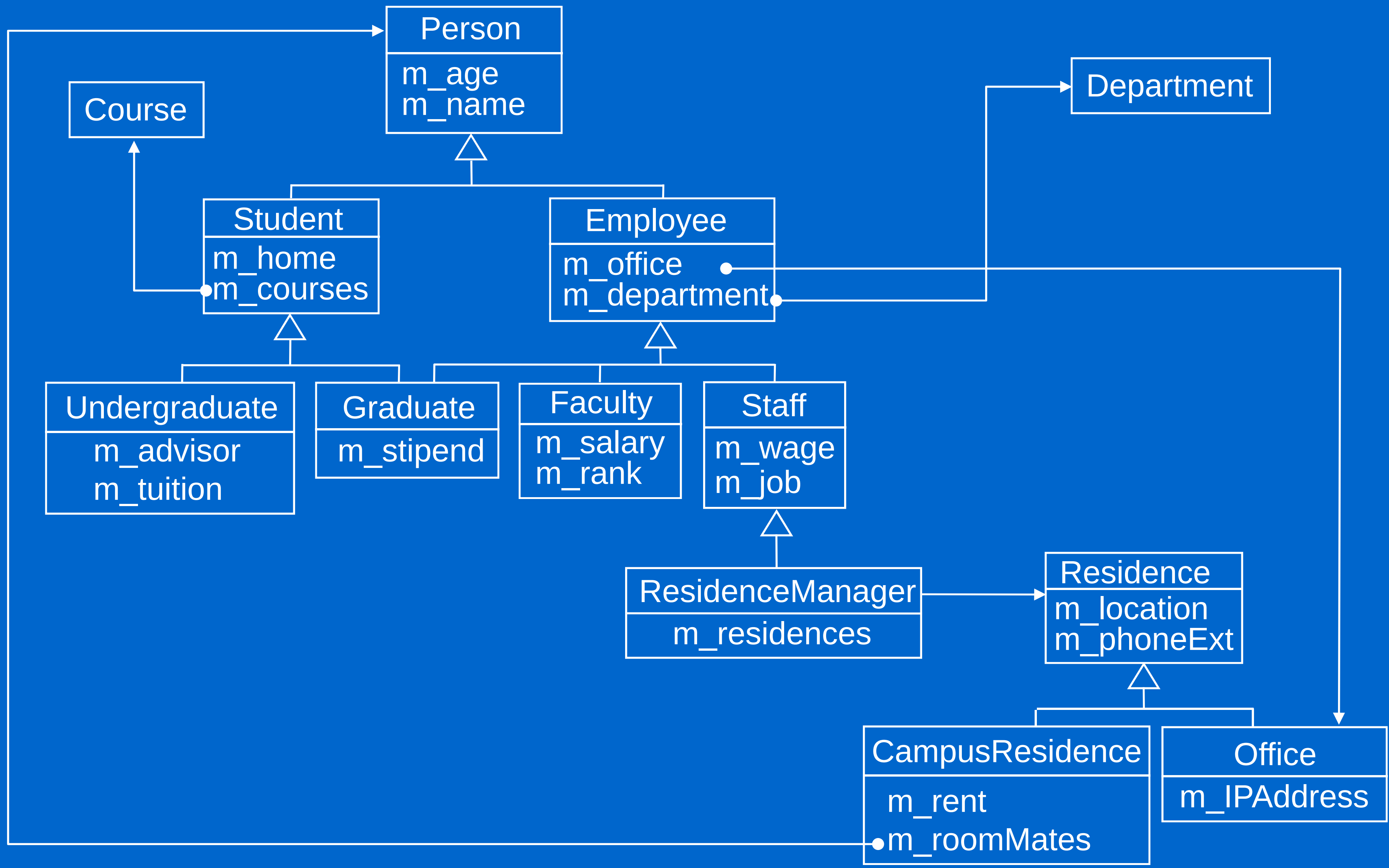

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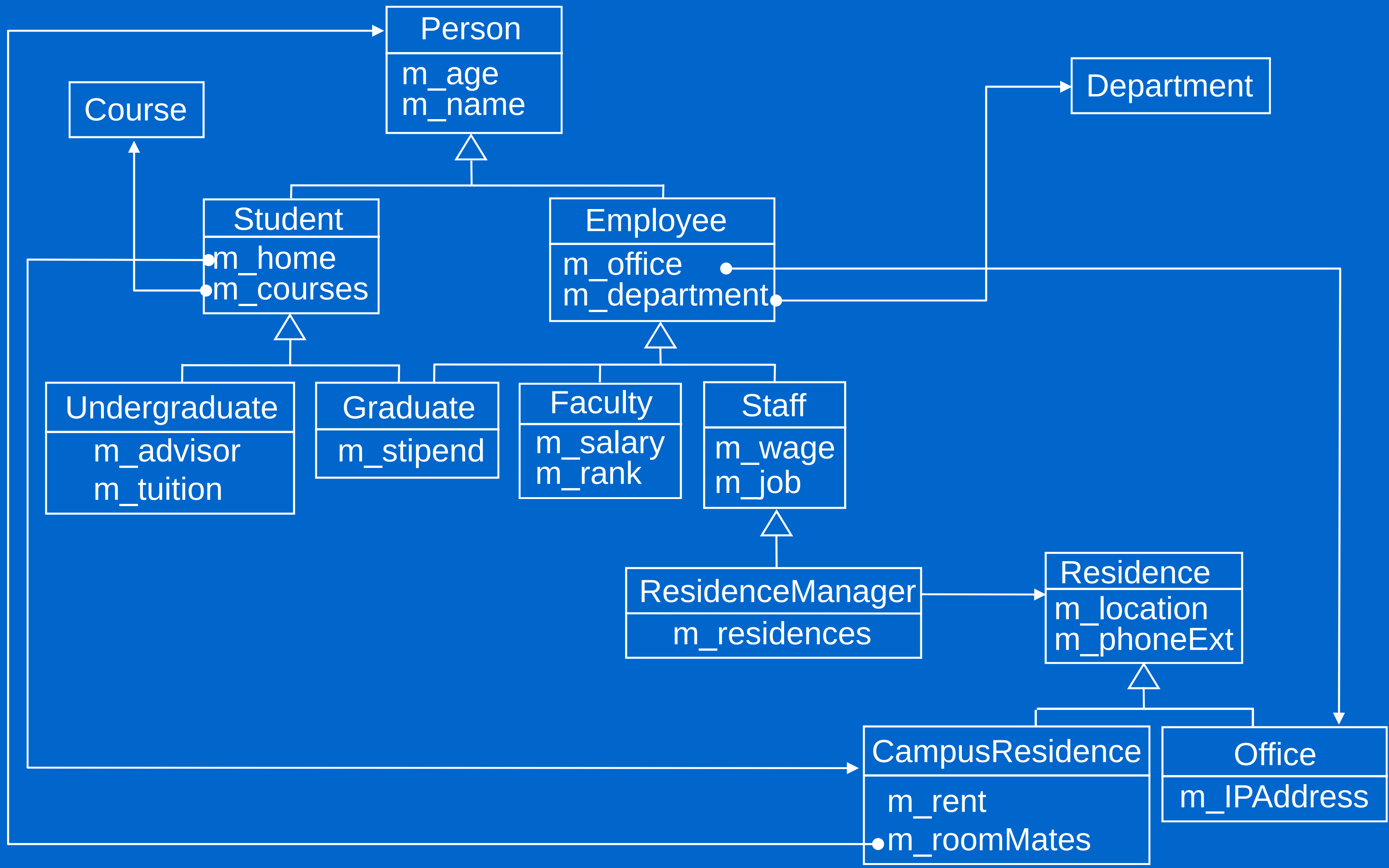
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