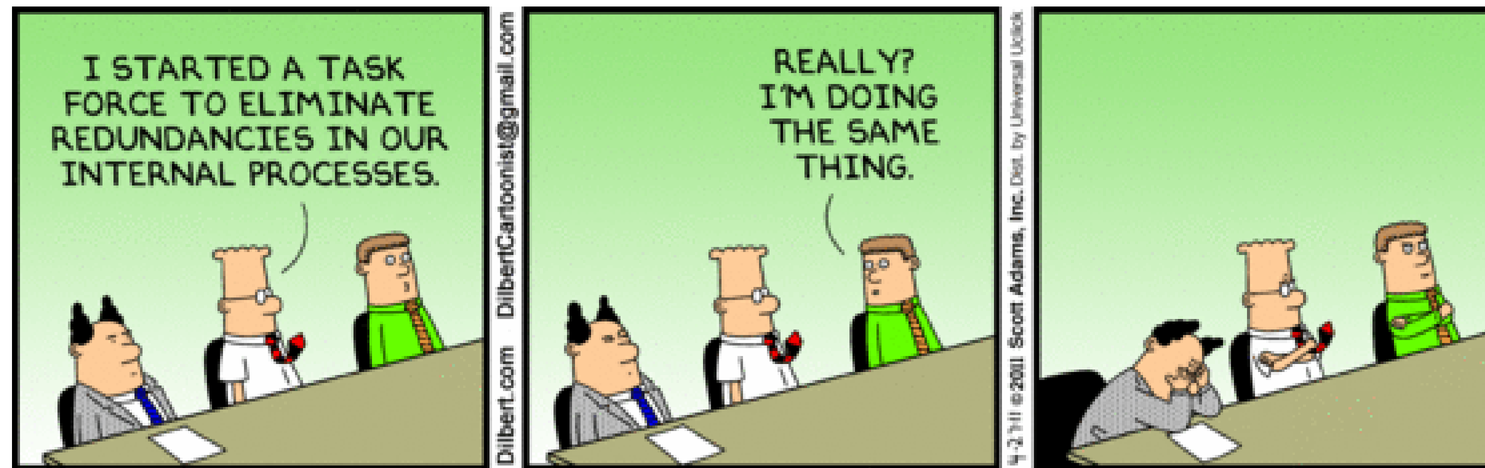
CSc 110, Spring 2017

Lecture 35: Inheritance

Adapted from slides by Marty Stepp and Stuart Reges

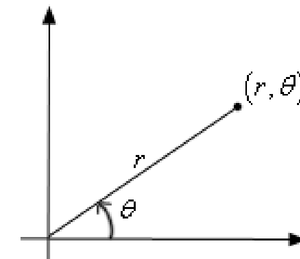


Benefits of encapsulation

- Provides abstraction between an object and users of the object.

- Protects an object from unwanted access by code outside the class.
  - A bank app forbids a client to change an `Account`'s balance.

- Allows you to change the class implementation.
  - `Point` could be rewritten to use polar coordinates (radius *r*, angle ϑ), but with the same methods.



- Allows you to constrain objects' state (**invariants**).
  - Example: Only allow `Point`s with non-negative coordinates.

BankAccount – Version 2

```
class BankAccount:
    def __init__(self, account_number, name, amount):
        self.__balance = amount
        self.__account_number = account_number
        self.__name = name
        self.__tcount = 1

    def withdraw(self, amount):
        self.__tcount += 1
        if(self.__balance - amount < 0):
            print("transaction rejected: not enough money")
        else:
            self.__balance -= amount

    def deposit(self, amount):
        self.__tcount += 1
        self.__balance += amount

    def transaction_count(self):
        return self.__tcount
```

Bank account – Version 3

- Modify the `BankAccount` class to keep track of the transactions in a list of tuples.
- Each tuple consists of the string `"d"` ,`"w"`, or `"r"` and the associated amount.
- Modify the `transaction_count` method to use the list.
- Encapsulation allows us to do this without changing any code that *uses* `transaction_count`.

BankAccount – Version 3

```
class BankAccount:
    def  __init__(self, account_number, name, amount):
        self.__balance = amount
        self.__account_number = account_number
        self.__name = name
        self.__tlist =  [("d", amount)]

    def withdraw(self, amount):
        if(self.__balance - amount < 0):
            print("transaction rejected: not enough money")
            self.__tlist.append(("r",amount))
        else:
            self.__balance -= amount
            self.__tlist.append(("w",amount))

    def deposit(self, amount):
        self.__tlist.append(("d",amount))
        self.__balance += amount

    def transaction_count(self):
        return len(self.__tlist)
```

Exploring instance variables – Deep Dive

- Consider the following code:

```
class Foo:
    def __init__(self,x):
        self.__x = x

    def get_x(self):
        return self.__x
```

- Now use the class `Foo`:

```
>>> f = Foo(10)
>>> f.get_x()
10
>>> f.__x = 20
>>>
```

- Why didn't the assignment to the private instance variable `f.__x` generate an error?

- **Name mangling**: any instance variable `__v` (two leading underscores) is textually replaced with a with `_classname__v`, where `classname` is the name of the class.

```
>>> f = Foo(10)
>>> f.get_x()
10
>>> f
<__main__.Foo object at 0x031B2E30>
>>> f.__dict__
{'_Foo__x': 10}
>>> f.__x = 20
>>> f.__dict__
{'__x': 20, '_Foo__x': 10}
>>> f.get_x()
10
>>>
```

Writing software

- **software engineering**: The practice of developing, designing, documenting, testing large computer programs.

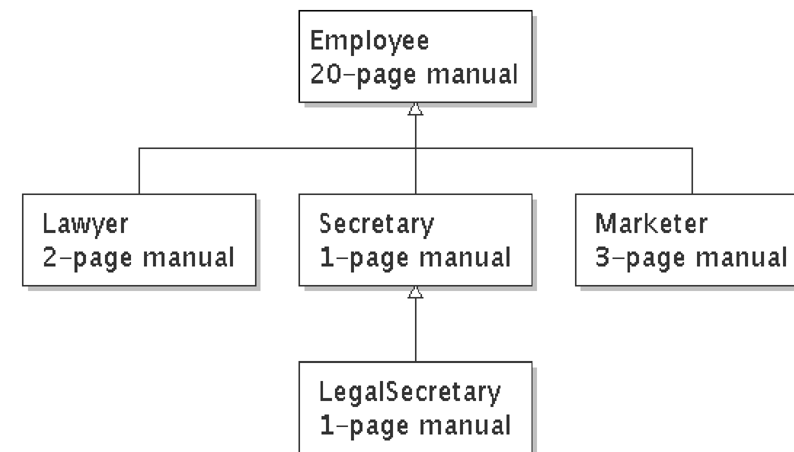
- Large-scale projects face many issues:
  - programmers working together
  - getting code finished on time
  - avoiding repetitive code
  - finding and fixing bugs
  - maintaining, reusing existing code

- **code reuse**: The practice of writing program code once and using it in many contexts.

Law firm employee analogy

- common rules: hours, vacation, benefits, regulations ...
  - all employees attend a common orientation to learn general company rules
  - each employee receives a 20-page manual of common rules

- each subdivision also has specific rules:
  - employee receives a smaller (1-3 page) manual of these rules
  - smaller manual adds some new rules and also changes some rules from the large manual



Separating behavior

- Why not just have a 22 page Lawyer manual, a 21-page Secretary manual, a 23-page Marketer manual, etc.?

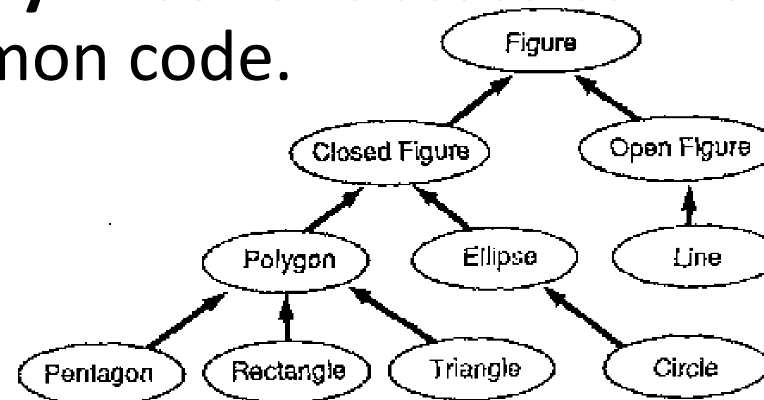
- Some advantages of the separate manuals:
  - maintenance: Only one update if a common rule changes.
  - locality: Quick discovery of all rules specific to lawyers.

- Some key ideas from this example:
  - General rules are useful (the 20-page manual).
  - Specific rules that may override general ones are also useful.

Is-a relationships, hierarchies

- **is-a relationship**: A hierarchical connection where one category can be treated as a specialized version of another.
  - every marketer *is an* employee
  - every legal secretary *is a* secretary

- **inheritance hierarchy**: A set of classes connected by is-a relationships that can share common code.



Employee regulations

- Consider the following employee regulations:
  - Employees work 40 hours / week.
  - Employees make $40,000 per year, except legal secretaries who make $5,000 extra per year ($45,000 total), and marketers who make $10,000 extra per year ($50,000 total).
  - Employees have 2 weeks of paid vacation leave per year, except lawyers who get an extra week (a total of 3).
  - Employees should use a yellow form to apply for leave, except for lawyers who use a pink form.

- Each type of employee has some unique behavior:
  - Lawyers know how to sue.
  - Marketers know how to advertise.
  - Secretaries know how to take dictation.
  - Legal secretaries know how to prepare legal documents.

An `Employee` class

```
# A class to represent employees in general (20-page manual).
class Employee:
    def get_hours(self):
        return 40                   # works 40 hours / week

    def get_salary(self):
        return 40000.0              # $40,000.00 / year

    def get_vacation_days(self):
        return 10                   # 2 weeks' paid vacation

    def get_vacation_form(self):
        return "yellow"             # use the yellow form
```

- Exercise: Implement class `Secretary`, based on the previous employee regulations. (Secretaries can take dictation.)

Repetitive Secretary class

```
# A repetitive class to represent secretaries.
class Secretary:
    def get_hours(self):
        return 40                 # works 40 hours / week

    def get_salary(self):
        return 40000.0            # $40,000.00 / year

    defget_vacation_days(self):
        return 10                 # 2 weeks' paid vacation

    def get_vacation_form(self):
        return "yellow"           # use the yellow form

    def take_dictation(self, text):
        print("Taking dictation of text: " + text)
```

Desire for code-sharing

- `take_dictation` is the only unique behavior in `Secretary`.

- We'd like to be able to say:

```
# A class to represent secretaries.
class Secretary:
    copy all the contents from the Employee class

    def take_dictation(self, text):
        print("Taking dictation of text: " + text)
```

Inheritance

- **inheritance**: A way to form new classes based on existing classes, taking on their attributes and methods.
    - a way to group related classes
    - a way to share code between two or more classes

- One class can *extend* another, absorbing its attributes and methods.
    - **superclass**: The parent class that is being extended.
    - **subclass**: The child class that extends the superclass and inherits its behavior.
        - Subclass gets a copy of every attribute and method from the superclass

Inheritance syntax

```
class name(superclass):
```

- Example:

```
class Secretary(Employee):
    ...
```

- By extending `Employee`, each `Secretary` object automatically gets the methods:

```
get_hours
get_salary
get_vacation_days
get_vacation_form
```

A `Secretary` object is used just like an `Employee` object by client code

Secretary defined using inheritance

```
# A class to represent secretaries.
class Secretary (Employee):

    def take_dictation(self, text):
        print("Taking dictation of text: " + text)
```

- Now we only write the parts unique to a Secretary type
  - Secretary inherits all methods in Employee:
    get_hours,
    get_salary
    get_vacation_days
    get_vacation_form
  - Secretary adds the take_dictation method.

Implementing `Lawyer`

- Consider the following lawyer regulations:
  - Lawyers who get an extra week of paid vacation (a total of 3).
  - Lawyers use a pink form when applying for vacation leave.
  - Lawyers have some unique behavior: they know how to sue.

- Problem: We want lawyers to inherit *most* behavior from employee, but we want to replace parts with new behavior.

Overriding methods

- **override**: To write a new version of a method in a subclass that replaces the superclass's version.
  - No special syntax required to override a superclass method.
    Just write a new version of it in the subclass.

```
class Lawyer(Employee):
    # overrides get_vacation_form method in Employee
class
    def get_vacation_form():
        return "pink"
    ...
```

- Exercise: Complete the `Lawyer` class.
  - (3 weeks vacation, pink vacation form, can sue)

Lawyer class

```
# A class to represent lawyers.
class Lawyer(Employee):
    # overrides get_vacation_form from Employee class
    def get_vacation_form(self):
        return "pink"

    # overrides get_vacation_days from Employee class
    def get_vacation_days(self):
        return 15               # 3 weeks vacation

    def sue(self):
        print("I'll see you in court!")
```

- Exercise: Complete the `Marketer` class. Marketers make $10,000 extra ($50,000 total) and know how to advertise.

Marketer class

```
# A class to represent marketers.
class Marketer(Employee):
    def advertise(self):
        print("Act now while supplies last!")

    def get_salary(self):
        return 50000.0      # $50,000.00 / year
```

Levels of inheritance

- Multiple levels of inheritance in a hierarchy are allowed.
  - Example: A legal secretary is the same as a regular secretary but makes more money ($45,000) and can file legal briefs.

```
class LegalSecretary(Secretary):
    ...
```

  - Exercise: Complete the `LegalSecretary` class.

LegalSecretary class

```
# A class to represent legal secretaries.
class LegalSecretary(Secretary):
    def file_legal_briefs(self):
        print("I could file all day!")

    def get_salary(self):
        return 45000.0          # $45,000.00 / year
```

Calling overridden methods

- Subclasses can call overridden methods with `super`

  `super(`**ClassName**`, self).`**method**`(`**parameters**`)`

  - Example:

```
class LegalSecretary(Secretary):
    def get_salary(self):
        base_salary = super(LegalSecretary,self).get_salary()
        return base_salary + 5000.0
    ...
```

Inheritance and constructors

- Imagine that we want to give employees more vacation days the longer they've been with the company.
  - For each year worked, we'll award 2 additional vacation days.
  - When an Employee object is constructed, we'll pass in the number of years the person has been with the company.
  - This will require us to modify our `Employee` class and add some new state and behavior.
  - Exercise: Make necessary modifications to the `Employee` class.

Modified `Employee` class

```
class Employee:
    def __init__(self, initial_years):
        self.__years = initial_years

    def get_hours(self):
        return 40

    def get_salary(self):
        return 50000.0

    def get_vacation_days(self):
        return 10 + 2 * self.__years

    def get_vacation_form(self):
        return "yellow"
```

Problem with constructors

- Now that we've added the constructor to the `Employee` class, our subclasses do not compile. The error:

```
TypeError: __init__() missing 1 required positional
  argument: 'initial_years'
```

  - The short explanation: Once we write a constructor (that requires parameters) in the superclass, we must now write constructors for our employee subclasses as well.

Modified `Marketer` class

```
# A class to represent marketers.
class Marketer(Employee):
    def __init__(years):
        super(Marketer, self).__init__(years)

    def advertise():
        selfprint("Act now while supplies last!")

    def get_salary():
        return super(Marketer, self).get_salary() + 10000.0
```

- Exercise: Modify the `Secretary` subclass.
  - Secretaries' years of employment are not tracked.
  - They do not earn extra vacation for years worked.

Modified `Secretary` class

```
# A class to represent secretaries.
class Secretary(Employee):
    def __init__(self):
        super(Secretary, self).__init__(0)

    def take_dictation(self, text):
        print("Taking dictation of text: " + text)
```

- Since `Secretary` doesn't require any parameters to its constructor, `LegalSecretary` compiles without a constructor.
  - Its default constructor calls the `Secretary` constructor.

Inheritance and attributes

- Try to give lawyers $5000 for each year at the company:

```
class Lawyer(Employee):
    ...
    def get_salary(self):
        return super(Lawyer, self).get_salary() + 5000 *
 years
    ...
```

- Does not work; the error is the following:

```
AttributeError: 'Lawyer' object has no attribute
 '_Employee__years'                                   ^
```

- Private attributes cannot be directly accessed from subclasses.
  - One reason: So that subclassing can't break encapsulation.
  - How can we get around this limitation?

Improved Employee code

Add an accessor for any field needed by the subclass.

```
class Employee:
    self.__years

    def __init__(self, initial_years):
        self.__years = initial_years

    def get_years(self):
        return self.__years
    ...

class Lawyer(Employee):
    def __init__(self, years):
        super(Lawyer, self).__init__(years)

    def get_salary(self):
        return super(Lawyer, self).get_salary() + 5000 *
  get_years()
    ...
```

Revisiting `Secretary`

- The `Secretary` class currently has a poor solution.
  - We set all Secretaries to 0 years because they do not get a vacation bonus for their service.
  - If we call `get_years` on a `Secretary` object, we'll always get 0.
  - This isn't a good solution; what if we wanted to give some other reward to *all* employees based on years of service?

- Redesign our `Employee` class to allow for a better solution.

Improved `Employee` code

- Let's separate the standard 10 vacation days from those that are awarded based on seniority.

```
class Employee:
    def __init__(self, initial_years):
        self.__years = initial_years

    def get_vacation_days(self):
        return 10 + self.get_seniority_bonus()

    # vacation days given for each year in the company
    def get_seniority_bonus(self):
        return 2 * self.__years
    ...
```

- How does this help us improve the `Secretary`?

Improved `Secretary` code

- `Secretary` can selectively override `get_seniority_bonus`; when `get_vacation_days` runs, it will use the new version.
  - Choosing a method at runtime is called *dynamic binding*.

```
class Secretary(Employee):
    def __init__(self, years):
        super(Secretary, self).__init__(years)

    # Secretaries don't get a bonus for their years of service.
    def get_seniority_bonus(self):
        return 0

    def take_dictation(self, text):
        print("Taking dictation of text: " + text)
```