# CSc 110, Autumn 2016

## Lecture 33: Inheritance

Adapted from slides by Marty Stepp and Stuart Reges

# The software crisis

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

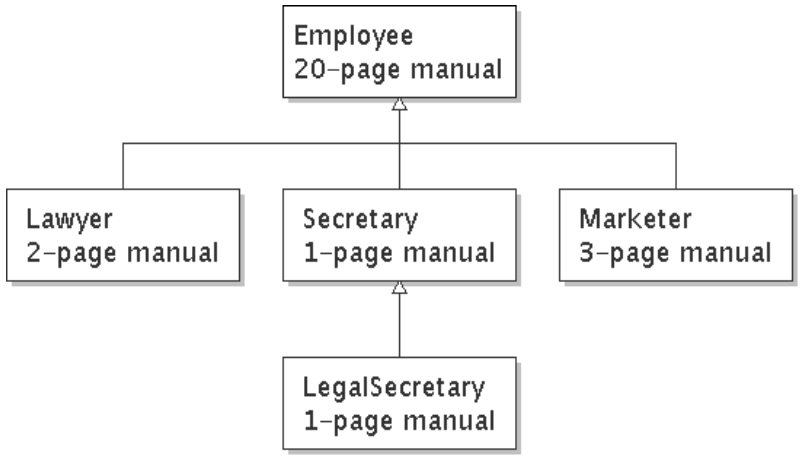
- Large-scale projects face many issues:
  - programmers working together
  - getting code finished on time
  - avoiding redundant code
  - finding and fixing bugs
  - maintaining, reusing existing code


- **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.?

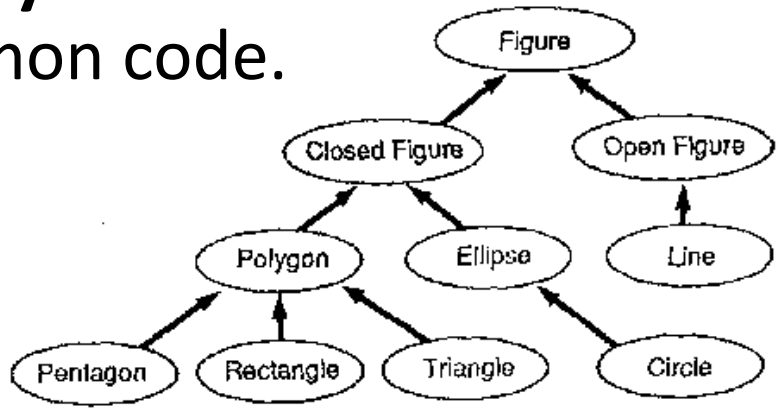
- Some advantages of the separate manuals:
  - maintenance: Only one update if a common rule changes.
  - locality: Quick discovery of all rules specific to lawyers.

- 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.)

# Redundant `Secretary` class

```
# A redundant 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/behavior.
  - a way to group related classes
  - a way to share code between two or more classes

- One class can *extend* another, absorbing its data/behavior.
  - **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 field and method from superclass

# Inheritance syntax

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

- Example:

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

- By extending `Employee`, each `Secretary` object now:
  - receives a `get_hours`, `get_salary`, `get_vacation_days`, and `get_vacation_form` method automatically
  - can be treated as an `Employee` by client code (seen later)

# Improved `Secretary` code

```
# 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 each type.
  - `Secretary` inherits `get_hours`, `get_salary`, `get_vacation_days`, and `getVacationForm` methods from `Employee`.
  - `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():
        print("Act now while supplies last!")

    def get_salary():
        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 fields

- 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 fields 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)
```