PLTW COMPUTER SCIENCE

Activity 1.4.1

Procedural Abstraction

Introduction

A lot of practical, reusable, published code is object-oriented code. The API of an object-oriented library defines the attributes and methods for each class. Attributes are data, and methods are procedures. Procedures, since they are instructions coded in language, are just a special kind of data!

The method's instructions are stored once, when the class is defined. The instructions can be used over and over for the entire class of objects. "Calling a method on an object" tells the computer to execute the class' instructions (the method) for that kind of object (class), using the attribute data that is specific to that particular object (instance).

What are some procedures you perform for various instances of a category? For example you have a procedure for crossing a street, and it can be executed at any given street of a particular kind. What is a procedure that you follow that can be applied as you follow your daily routines? How are those routines applied to slightly different situations?

One of the world's three hundred Univac 1108s running Algol at Carnegie-Mellon University in 1976

Images courtesy of J. Chris Hausler

Materials

- Ping pong ball (distributed in Step 9 to Step 14 by your teacher)
- Practice golf ball (distributed in Step 19 by your teacher)
- Red, green, and blue colored pencils
- Centimeter ruler

Resources

1.4.1 sourceFiles.zip

Reference Card for Pyplot and PIL

Procedure

1. Greet your partner to practice professional skills. Establish team norms specific to the materials in this activity.
2. Computing relies on layers of abstraction. In two previous activities, you focused on abstraction.
    - Data abstraction lets us *ignore the details* of how numbers, letters, sound, and images are represented. We can *generalize* a data type.
    - Programs are data, too! Procedural abstraction lets us *ignore the details* of how instructions are executed. We can *generalize* an instruction.

    Recall one or more steps or ideas from past activities and share with your partner.

Part I: The abstraction of objects, at a low layer of abstraction

Refer to your downloadable resources for this material. Interactive content may not be available in the PDF edition of this course.

3. In this activity we climb up and down the ladder of abstraction with object-oriented programming. Before working from the top of the ladder, let's take a moment to dive down near the bottom of the ladder of abstraction to the layer where data are stored. In the early days, that was on magnetic or hole-punched tape.

   Alan Kay, one of the giants of computer science, coined the term "object-oriented" to describe ideas he learned from Trygve Reenskaug, a Norwegian graduate student at the University of Utah. Writing years later, Kay recalls analyzing Reenskaug's program, which allowed multiple people to work simultaneously on a huge drawing.

   - I actually walked into Dave Evans' office looking for a job and a desk. On Dave's desk was a foot-high stack of brown covered documents, one of which he handed to me: "Take this and read it."

     Alan Kay, *The Early History of Smalltalk*
     © 1993 ACM

   It was 1966. Kay recalls how every new graduate student got one of those files. He describes looking inside Reenskaug's documentation, which explained where Trygve had left off:

   - The title was "Sketchpad: A man-machine graphical communication system," by Ivan Sutherland in 1963. What it could do was quite remarkable, and completely foreign to any use of a computer I had ever encountered.
   - ...Head whirling, I found my desk. On it was a pile of tapes and listings, and a note: "This is the Algol for the 1108. It doesn't work. Please make it work."
   - ...The documentation was incomprehensible. Supposedly, this was the Case-Western Reserve 1107 Algol–but it had been doctored to make a language called Simula. The documentation read like Norwegian transliterated into English, which in fact it was. There were uses of words like *activity* and *process* that didn't seem to coincide with normal English usage. Finally, another graduate student and I unrolled the program listing 80 feet down the hall and crawled over it yelling discoveries to each other.

     --Alan Kay, © 1993 ACM

   Alan Kay and his colleague learned from Trygve Reenskaug the idea of storing data to be

used by procedures alongside data for executing procedures. How would these data have been represented on paper tape?

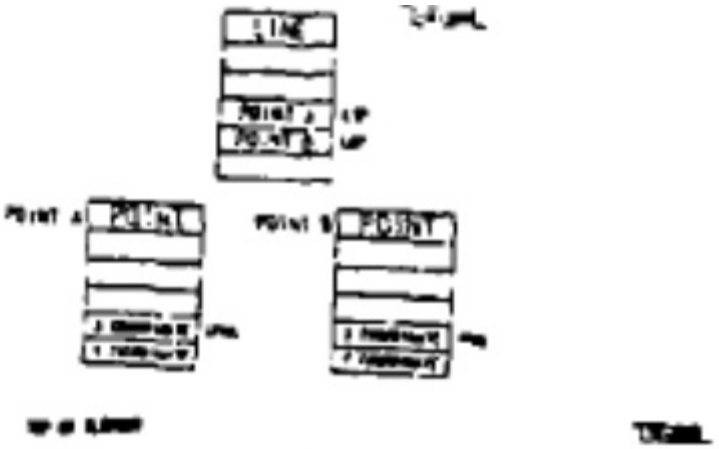
Part II: The abstraction of objects, at a high layer of abstraction

4. The brown-covered envelope Kay refers to contained high-level documentation. High-level documentation for a program omits most of the details. Why is high-level documentation important?

5. High level documentation for object-oriented code shows class diagrams and indicates how the diagrams are related to each other. A class diagram shows three things:

class name
list of attribute names
list of method names

Reenskaug's documentation included class diagrams very similar to today's standard. This image of Reenskaug's work reproduced from *The Early History of Smalltalk* is close to our modern standard!



In the 1990s the majority of programmers began to work in the object-oriented programming paradigm. The diagrams became standardized in **Unified Modeling Language (UML)**. UML was adopted as the standard for communicating and documenting software design in 1997 by the standards consortium OMG (Object Management Group). OMG had been created eight years earlier by eleven companies, including IBM, Apple, HP, Sun, American Airlines, and Data General.

What problems are created if people don't collaborate to create standards?

6. The *Python*® programming language uses a dot notation to refer to the attributes of an object and to call the class' methods on an object. For example we used the `AxesSubplot` class and called `set_title()` on `ax`, which was an `AxesSubplot`:

```
ax.set_title('My picture')
```

Here is the `AxesSubplot` class described with a UML diagram:

`AxesSubplot`	class name
`title`	attribute names
`set_title()`	method names

What is another method from `AxesSubplot` that would be listed in this UML class diagram?

7. Consider the following class:

`PingPongBall`	class name
`radius` `color`	attribute names
`draw_circle()`	method names

Many programming languages support programming in the object-oriented **programming paradigm**. In all of the languages that support object-oriented programming, if you instantiate an object in the class described by this UML, the computer stores the object's attribute data. You can then call the class' methods on the object.

In the *Python* programming language, you might use the `PingPongBall` class as shown here. **Note: Computers aren't used in this activity. It is an "unplugged" activity.**

```
In []: import realityArtist as fiat
In []: mike = fiat.PingPongBall()
In []: print mike.color
In []: mike.draw_circle()
```

We will explore these four commands to understand what they do. The `import` statement executes the class definitions in `realityArtist` and gives it the nickname `fiat`.

```
In []: import realityArtist as fiat
```

Where is the class definition? It is code in the `realityArtist` module, and it might look like this. This is how a new class is created. You won't have to create classes in this course, but we're glancing at the magic behind the curtain.

```
# module realityArtist.py
```

```
class PingPongBall(object):
    def __init__(self, myRadius=20, myColor='#BB7700'):
        """ Creates a new PingPongBall

        radius expressed in millimeters
        color is expressed in a 6-digit hexadecimal
        color defaults to xBB red and x77 green (orangish)
        """
        # Implement with a human so that:
        self.radius = myRadius
        self.color = myColor

    def draw_circle(self, diameter=10, color='#FF0000', fill=False):
        """ Draws a circle on a random location on the ball

        uses colored pencil
        diameter is expressed in millimeters
        color is expressed in a 6-digit hexadecimal string
        default color red
        """
        # Implement with human
```

Once this code is executed with the `import` statement, the computer knows how to create objects of the class. The constructor function in *Python*, which instantiates the class, is always the special function `__init__()`. Instead of being called with `__init__()`, it is called by using the class name. To reinforce concepts with a tactile activity, we have made up (tongue-in-cheek) a blend of "People" and *Python*. **Lines 10 and 22 comment that a human will implement part of the code!**

How many arguments does the `__init__` function definition have?

The `self` argument is always first in class function definitions. It refers to the object being instantiated or the object on which the method is called.

8. Now we'll instantiate a `PingPongBall`.

```
In []: mike = fiat.PingPongBall()
```

Why is `fiat` there?

Your teacher should manifest a ping pong ball using the specified arguments, here defaulting to 20 mm radius and orangish color. Hand it to Mike. If there's no Mike in your class, use someone else and pretend his/her name is Mike.

9. Record what you think the next line would print.

```
In[ c]: print mike.color
```

10. Before we instantiate more instances of `PingPongBall`, let's see `mike` draw a circle.

```
In[]: mike.draw_circle()
```

According to the docstring above, this code draws a random circle on the ball. According to the default parameters, what size and color will be drawn? The student Mike should draw that circle.

11. What lines of code would instantiate a ball called `emily` and then draw the black, red, and gray circles as shown in the picture below? Record your IPython session code. After the classroom discusses it, "execute" the code so that Emily gets a ping pong ball and draws on it.

12. Now we'll make an aggregator to remember all instances of `PingPongBall` in the classroom.

```
In []: items = [mike, emily]
```

As a classroom of students, instantiate more instances of `PingPongBall`.

```
In []: for i in range(6):
...  :     items.append(PingPongBall())
```

What is `items[1]` ?

What is `items[3].color`?

13. As a classroom, implement this code.

```
In []: items[3].draw_circle(myColor='#00FF00', diameter=6)
```

Describe what it did.

14. As a classroom, implement this code.

```
In []:  for pingpong in items:
...  :  pingpong.draw_circle(diameter=6, fill=True)
```

Describe what it did.

15. As a classroom, implement this code.

```
In []: for pingpong in items:
...  :     pingpong.append(PingPongBall())
```

Describe what it did.

16. Now we will define a new class, shown in UML and *Python* below.

`GolfBall`	class name
`radius`	attribute names

`color`	
`draw_circle()`	method names

The *Python* below continues the realityArtist module shown above.

```
# module realityArtist.py

class GolfBall(object):
    def __init__(self, myRadius=38, myColor='#FFFFFF'):
        """ Creates a new practice-style GolfBall

        myRadius expressed in millimeters
        myColor is expressed in a 6-digit hexadecimal
        """
        # Implement with a human so that:
        self.radius = myRadius
        self.color = myColor

    def draw_circle(self, diameter=5, color='#00FF00', fill=True):
        """ Draws a circle on a random location on the ball

        uses colored pencil
        diameter is expressed in millimeters
        color is expressed in a 6-digit hexadecimal string
        """
        # Implement with human
```

What are some differences between the `GolfBall` and `PingPongBall` classes?

17. As a classroom, implement this code.

```
In []: for i in range(8):
...  :     items.append(GolfBall())
```

Describe what it did.

18. As a classroom, implement this code.

```
In []: for ball in items:
...  :     ball.draw_circle(
```

Describe what it did.

Part III: The abstraction of objects, at another high layer of abstraction

19. As a classroom, design an abstraction for a class of objects. Your teacher will guide you in this step. Record the abstraction in UML here.

20. Abstraction is defined by the following two characteristics.

    - Discarding some details
    - Generalizi

    class name

    attribute names

    method names

Describe some of the details that were lost and describe what generality was gained with the abstraction from the previous step.

21. As a team of two, design an abstraction for a class of objects. Record the abstraction in UML here.

22. Software developers often use UML diagrams to describe their ideas during the early stages of software development.

    class name

    attribute names

    method names

Suppose you and your partner are working on a word processor.

- Describe what you would want the user to be able to do with the word processing software.
- Circle all nouns in your description.
- For each noun that you think would make sense as a class, make up a class name and title a UML class diagram with it.
- In your UML class diagram, record attributes and methods that would make sense with objects in these classes.

Conclusion

1. Think of an example from your daily life where you use abstraction. Describe some of the details you discard and some of the generality you gain by using the abstraction.
2. What is the difference between procedural abstraction and data abstraction?

3. The GUI was first developed in 1961 by Ivan Sutherland for his Ph.D. at M.I.T. You might watch a 1964 video produced by MIT, especially the demo of Sutherland's work starting at 3:20, at **http://www.youtube.com/watch?v=USyoT_Ha_bA**.

   Bill Gates at Microsoft got inspiration for Windows from Apple's Steve Jobs. Steve Jobs at Apple got inspiration for Macintosh from Xerox's Alan Kay. Alan Kay at Xerox got inspiration for Star from Trygve Reenskaug.

   Trygve Reenskaug created the program Autokon with a graphical user interface in 1963 to design ships.

   Trygve Reenskaug got inspiration for Autokon from M.I.T.'s Ivan Sutherland.

   All along the way, GUI programming, object-oriented programming, and abstraction have been intertwined. Why do you think GUIs, objects, and abstraction have been connected like this in the history of computer science?