OOP & Exceptions

Principles of Programming Languages

Colorado School of Mines

https://lambda.mines.edu

Object Oriented Programming

What is OOP?

- Object oriented programming is a type of programming with objects that maintain internal state and pass messages between each other.
- First appeared in the mid-1960s in Simula: a programming language designed for discrete event simulations
- It should not come as a surprise that OOP was first used for simulations, the real world can easily be modeled using objects that pass messages between eachother and maintain state
- Smalltalk (1971) also featured OOP and really caused OOP to kick off. Go to CPW's office sometime and chat with him about Smalltalk: he really likes this language!

OOP: Common Patterns

Classes: *Classes provide a definition for the data format and the procedures available for member objects.*

Objects: *Objects are instances of a certain class, that follow the rules defined in the class.*

Each of these have a variety of kinds of fields:

Instance Variables: *Variables which are associated with each individual object, these preform the state-maintenance we need for OOP.*

Class Variables: *Variables which are associated with the class itself, all of the objects of that class share this variable and do not have their own copy.*

Likewise class/instance methods refer to the methods available from the class versus the instance.

OOP: Not just tossing functions in a class

Object-oriented programming is more than just classes and objects; it's a whole programming paradigm based around objects (data structures) that contain data fields and methods. It is essential to understand this; using classes to organize a bunch of unrelated methods together is not object orientation.

—Junade Ali, Mastering PHP Design Patterns

Encapsulation

Encapsulation prevents external code from being concerned with the inner workings of an object by allowing the objects methods to define how state is manipulated.

- Some languages distinguish between private and public variables to specify which variables should be able to be modified by other objects, and which ones should not be.
- Python does this by convention: private methods and variables should be prefixed with an underscore.

Inheritance

Often times, one object may share variables and methods with another class.

Example

An `Employee` might inherit from a `Person` as:

- Both have variables to store first and last names
- They share a method to generate a full name

But the `Employee` also has variables that make HR people happy...

Polymorphism

Polymorphism allows methods to take objects of different types.

- Instances of subclasses can be called on functions that take their parent's type, for example, if `load_elevator` can be called on a `Person`, `Employee` inherits from `Person`, then `load_elevator` should be able to be called on an `Employee` instance as well.
- Statically typed languages often provide **generics**, which allows a method to be called on multiple types, even if there is not inheritance between them. An example is templates in C++.
- Dynamically typed languages provide a method to check if an object is an instance of another to allow the same function to take multiple types. In Python, this is `isinstance`.

Polymorphism Techniques: isinstance

In Python, we can use `isinstance` to make our functions take objects of different types:

```
# n can be an int or a float
def frobnicate(n):
    if isinstance(n, float):
        return ...
    elif isinstance(n, int):
        return ...
    raise TypeError("I only take ints and floats")
```

Polymorphism Techniques: Duck Typing

If it walks like a duck and quacks like a duck, then it must be a duck!

Duck typing is a specific kind of polymorphism where we accept any object which has certain variables or methods, even if the objects do not have a common parent.

In Python, we can do this with `hasattr`:

```
def f(x):
    if hasattr(x, "walk") and hasattr(x, "quack"):
        x.walk()
        x.quack()
    else:
        raise TypeError("I only take ducks!")
```

OOP in Python: An Intro

To define a class in Python, use the `class` syntax:

```
class Person:
    def __init__(self, fname, lname):
        self.fname = fname
        self.lname = lname
```

- The `__init__` method is the name of the **magic method** that Python calls to construct an instance of the class.
- To construct an instance, call `Person(fname, lname)`.
- All instance methods (such as `__init__`) take a reference to the instance as their first argument. By convention, this is usually named `self`.

Magic Methods

Magic methods are special method names recognized by Python's internals when it needs to preform a certain action. They start and end with a double underscore.

- `__init__` gets called on newly constructed instances of the object.
- `__del__` gets called when an instance is destructed.
- `__eq__` gets called to test if two instances are equal.
- `__call__` gets called when an instance is called as a function.
- `__getitem__` gets called when an instance gets square brackets (such as to get an item from a list)
- `__repr__` called by the built-in `repr()` function for the "official" string representation of an object.
- `__str__` called by the built-in `str()` function for the "informal", more human-readable, string representation of an object.

Example of Using Magic Methods

```
class Employee(Person):
    ...
    def __str__(self):
        name = f'{self.fname} {self.lname}'
        return f'<Employee name="{name}" salary=${self.salary}
```

Then, to use this:

```
>>> s = Employee('Linus Torvalds', 250000)
>>> print(str(s))
<Employee name="Linus Torvalds" salary=$250000>
```

Inheritance in Python

The type written in parentheses after the name defines the **base class**. This class will inherit from the base class.

```
class Employee(Person):
    def __init__(self, ssn, account, *args, **kwargs):
        self.ssn = ssn
        self.account = account
        super().__init__(*args, **kwargs)
```

- `Employee` inherits from `Person`
- `super()` refers to the object in it's base class. In this case, we call the init of our base class with the remaining arguments.

Multiple Inheritance

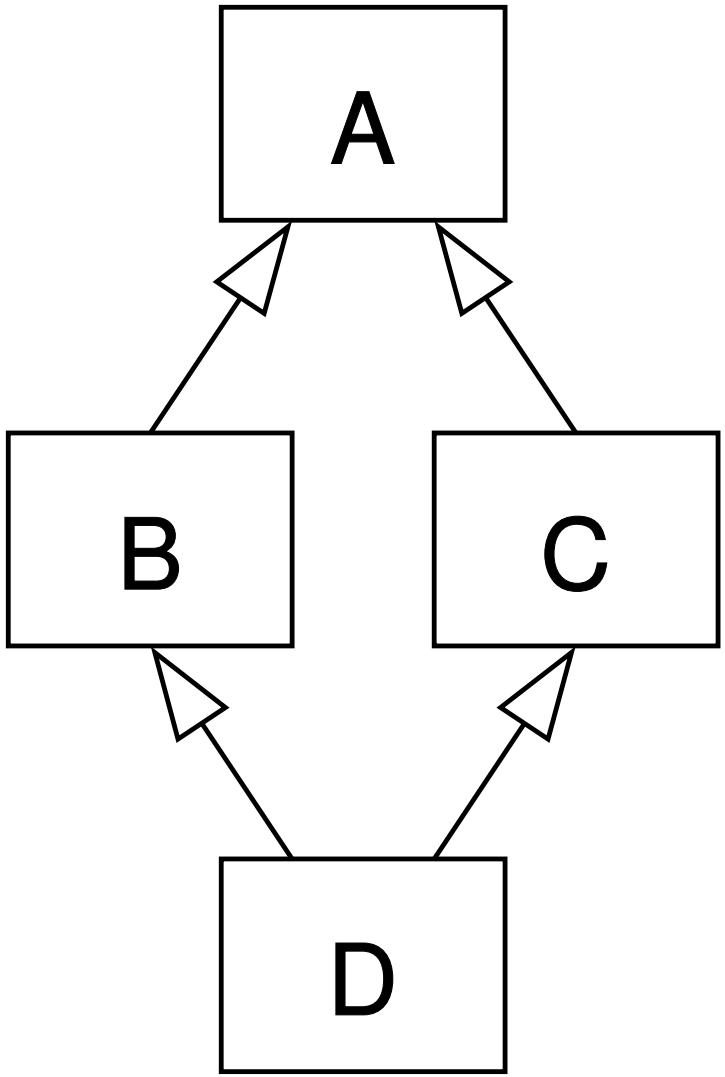
Unlike Java, Python classes can inherit from multiple base classes, allowing common variables and methods from two classes. For example (maybe in a GUI toolkit):

```
class Button(Rectangle, Clickable, Labeled):
    ...
```

The Diamond Problem

Suppose we have a base class `A`. We also have subclasses `B` and `C` that inherit from `A`. `D` inherits from both `B` and `C`.
If `B` and `C` both override the same method from `A`, which method does `D` get?

- Python and Perl's solution: take the method from the first base class listed when the class was declared.
- C++: requires explicit statement of which class the method will dispatch from.
- Java: only allows single



Error Handling

Error Handling: Theory

Our programs may encounter errors, for example, if a file was not found, or we were not able to connect to a remote server. Rather than crashing the entire program, software engineers often desire a way to clean up the error and report an error occurred.

Old School Error Handling

In a C program, you might handle errors like this:

```c
/* Return code -1 = error, and errno will be set */
int f(int x) {
    char *A = malloc(x);
    /* ... */
    int pid = fork();
    if (pid == -1)
        goto fail;
    /* ... */
    return z;
fail:
    /* cleanup from error */
    free(A);
    return -1;
}
```

What's the issue with old school?

1. Return codes for errors are never standard, and the programmer always needs to look up what a function call might return.
2. If a programmer forgets to handle an error from a function they call, it could have undesired results.
3. Functions which handle errors that just want to pass the error up to their caller have to have this error handling code, even though they are not using it directly.

Go's Error Handling

In Go, functions that return errors return two values: the result, and an error object:

```
f, err := os.Open("filename.ext")
```

It is then the programmer's responsibility to handle the error, potentially returning the error to the caller:

```
if err != nil {
    return err
}
```

Is Go Any Better?

1. Return codes for errors are never standard, and the programmer always needs to look up what a function call might return. **Taken care of using error objects!**
2. If a programmer forgets to handle an error from a function they call, it could have undesired results. **Still an issue!**
3. Functions which handle errors that just want to pass the error up to their caller have to have this error handling code, even though they are not using it directly. **Still an issue!**

How About Python?

Python provides an **exception handling** system.

- An exception is a special kind of object, like an error object in Go.
- Exceptions are *raised*, not returned.
- A `try`/`except` block can be used to intercept an exception, and preform cleanup from the error.
- If function only cares about passing the error to their caller, they need not write any error handling code just to pass it to their caller.

Try/Except Example

```
def graph(data):
    for point in data:
        if not isinstance(point, GraphPoint):
            raise TypeError('need GraphPoint data')
        ...

def graph_string(s):
    data = user_convert(s)
    return graph(data)

def graph_from_user():
    while True:
        try:
            graph_string(input('point>'))
        except TypeError as e:
            print(e)
```

Try/Except/Else

An `else` block placed after a `try/except` will be executed only if the exception did not occur:

```
while True:
    try:
        f = open(name)
    except FileNotFoundError as e:
        os.chdir('..')
    else:
        print('File Opened!')
        break
```

Try/Except/Finally

Code listed in the `finally` block of a `try`/`except`/(`else`) will always be executed, regardless of whether an exception occurs.

```
# note that this "GUIDialog" is made up, but this
# presents a real-world type usage
def promptyn(prompt):
    try:
        g = GUIDialog(buttons=YESNO, text=prompt)
        g.show()
        return g.response()
    except ValueError:
        logger.log("Unable to set prompt string")
    finally:
        g.close()
```

Note that the context manager (`with` statement) in Python can often be used as a substitute for a `finally`.

Custom Exceptions

Python has a large set of built-in exceptions, but when one of the built-ins is insufficient, you can subclass `Exception` and make your own.

```
class PlottingError(Exception):
    pass
```

Note that you should usually try and use one of exceptions the language provides rather than define your own.

Is Python Any Better?

1. Return codes for errors are never standard, and the programmer always needs to look up what a function call might return. **Solved!**
2. If a programmer forgets to handle an error from a function they call, it could have undesired results. **Solved!**
3. Functions which handle errors that just want to pass the error up to their caller have to have this error handling code, even though they are not using it directly. **Solved!**