

Designing Types

From first day of class!

- **Type:** set of values and the operations on them
 - **int** (**set:** integers; **ops:** +, -, *, /, ...)
 - **Time** (**set:** times of day; **ops:** time span, before/after, ...)
 - **Worker** (**set:** all possible workers; **ops:** hire, pay, promote, ...)
 - **Rectangle** (**set:** all axis-aligned rectangles in 2D; **ops:** contains, intersect, ...)
- To define a class, think of a *real type* you want to make
 - Python gives you the tools, but does not do it for you
 - Physically, any object can take on any value
 - Discipline is required to get what you want

Making a Class into a Type

1. Think about what values you want in the set
 - What attributes? What values can they have?
2. Think about what operations you want
 - Often influences the previous question

- To make (1) precise: write a *class invariant*
 - Statement we promise to keep true **after every method call**
- To make (2) precise: write *method specifications*
 - Statement of what method does/what it expects (preconditions)
- Write your code to make these statements true!

Planning out a Class

```

class Time(object):
    """Instances represent times of day.
    Instance Attributes:
    hour: hour of day [int in 0..23]
    min: minute of hour [int in 0..59]"""
    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"""
    def isPM(self):
        """Returns: this time is noon or later."""
  
```

Class Invariant

States what attributes are present and what values they can have.
A statement that will always be true of any Time instance.

Method Specification

States what the method does.
Gives preconditions stating what is assumed true of the arguments.

Planning out a Class

```

class Rectangle(object):
    """Instances represent rectangular
    regions of the plane.
    Instance Attributes:
    t: y coordinate of top edge [float]
    l: x coordinate of left edge [float]
    b: y coordinate of bottom edge [float]
    r: x coordinate of right edge [float]
    For all Rectangles, l <= r and b <= t."""
    def __init__(self, t, l, b, r):
        """The rectangle [l, r] x [t, b]
        Pre: args are floats; l <= r; b <= t"""
    def area(self):
        """Return: area of the rectangle."""
    def intersection(self, other):
        """Return: new Rectangle describing
        intersection of self with other."""
  
```

Class Invariant

States what attributes are present and what values they can have.
A statement that will always be true of any Rectangle instance.

Method Specification

States what the method does.
Gives preconditions stating what is assumed true of the arguments.

Implementing a Class

- All that remains is to fill in the methods. (All?!)
- When implementing methods:
 1. Assume preconditions are true
 2. Assume class invariant is true to start
 3. Ensure method specification is fulfilled
 4. Ensure class invariant is true when done
- Later, when using the class:
 - When calling methods, ensure preconditions are true
 - If attributes are altered, ensure class invariant is true

Implementing an Initializer

```

def __init__(self, hour, min):
    """The time hour:min.
    Pre: hour in 0..23; min in 0..59"""
    self.hour = hour
    self.min = min
  
```

Instance variables:
hour: hour of day [int in 0..23]
min: minute of hour [int in 0..59]

← This is true to start

← You put code here

← This should be true at the end

Implementing a Method

Instance variables:
 hour: hour of day [int in 0..23]
 min: minute of hour [int in 0..59]

This is true to start

```
def increment(self, hours, mins):
    """Move this time <hours> hours
    and <mins> minutes into the future.
    Pre: hours [int] >= 0; mins in 0..59"""
```

What we are supposed to accomplish

This is also true to start

```
self.min = self.min + min
self.hour = (self.hour + hour +
             self.min // 60)
self.min = self.min % 60
self.hour = self.hour % 24
```

You put code here

Instance variables:
 hour: hour of day [int in 0..23]
 min: minute of hour [int in 0..59]

This should be true at the end

Role of Invariants and Preconditions

- They both serve two purposes
 - Help you think through your plans in a disciplined way
 - Communicate to the user* how they are allowed to use the class
- Provide the *interface* of the class
 - interface btw two programmers
 - interface btw parts of an app
- Important concept for making large software systems
 - Will return to this idea in a week

* ...who might well be you!

interface /ɪntərˈfeɪs/ noun

- a point where two systems, subjects, organizations, etc., meet and interact: the interface between accountancy and the law.
 - chiefly *Physics* a surface forming a common boundary between two portions of matter or space, e.g., between two immiscible liquids: the surface tension of a liquid at its air/liquid interface.
- Computing a device or program enabling a user to communicate with a computer.
 - a device or program for connecting two items of hardware or software so that they can be operated jointly or communicate with each other.

—The Oxford American Dictionary

Enforce Method Preconditions with assert

```
class Time(object):
    """Instances represent times of day."""
    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
        assert type(hour) == int
        assert 0 <= hour and hour < 24
        assert type(min) == int
        assert 0 <= min and min < 60
    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"""
        assert type(hour) == int
        assert type(min) == int
        assert hour >= 0 and
        assert 0 <= min and min < 60
```

Instance Attributes:
 hour: hour of day [int in 0..23]
 min: minute of hour [int in 0..59]

Initializer creates/initializes all of the instance attributes.

Asserts in initializer guarantee the initial values satisfy the invariant.

Asserts in other methods enforce the method preconditions.

What About Attributes?

- User can access instance attributes via assignment
- Example:


```
>>> t = Time(2,45)
>>> t.min = 70
```

Invariant violation!
- Nothing we can do
 - Wrote methods assuming invariant always true
 - Our enforcement code is all in method definitions

```
class Time(object):
    """Instances represent times of day.
    Instance Attributes:
    hour: hour of day [int in 0..23]
    min: minute of hour [int in 0..59]"""
    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
        assert type(hour) == int
        assert 0 <= hour and hour < 24
        assert type(min) == int
        assert 0 <= min and min < 60
```

Only protects inside initializer

Data Encapsulation

- Idea:** Force the user to only use methods
- Do not allow direct access of attributes

Setter Method	Getter Method
<ul style="list-style-type: none"> Used to change an attribute Replaces all assignment statements to the attribute Bad: <pre>>>> t.min = 55</pre> Good: <pre>>>> t.setMin(55)</pre> 	<ul style="list-style-type: none"> Used to access an attribute Replaces all usage of attribute in an expression Bad: <pre>>>> h = 60*t.min</pre> Good: <pre>>>> h = 60*t.getMin()</pre>

Data Encapsulation

```
class Time(object):
    """Instances represent times of day.
    Instance Attributes:
    hour: hour of day [int in 0..23]
    min: minute of hour [int in 0..59]"""
    def getMin(self):
        """Returns: min attribute"""
        return self._min
    def setMin(self, mins):
        """Alters min attribute to be mins
        Pre: mins is in 0..59"""
        assert type(mins) == int
        assert 0 <= mins and mins < 60
        self._min = mins
```

Do this for all of your attributes

Getter

Setter

Naming Convention
 The underscore means "should not access the attribute directly."

Precondition is same as attribute invariant.