Energy Informatics

System Design — Data Modeling

UNI FREIBURG

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30 Jan 2018

Data Modeling I

Simple Classes

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Definition

A **class** describes compound data that consists of subsidiary data (called **attributes**) collected in an **instance** of the class.
Additionally, it can describe **operations** on that data (later).

- Instances are often called **objects**.
- Operations are often called **methods**.

Example for simple class: Tea

Class description for Tea

A tea shop describes a particular brand of **tea** in stock by its **name**; a **description** of its color, flavor, etc; the **weight** in stock (in g); and its **price** in cent per kg.

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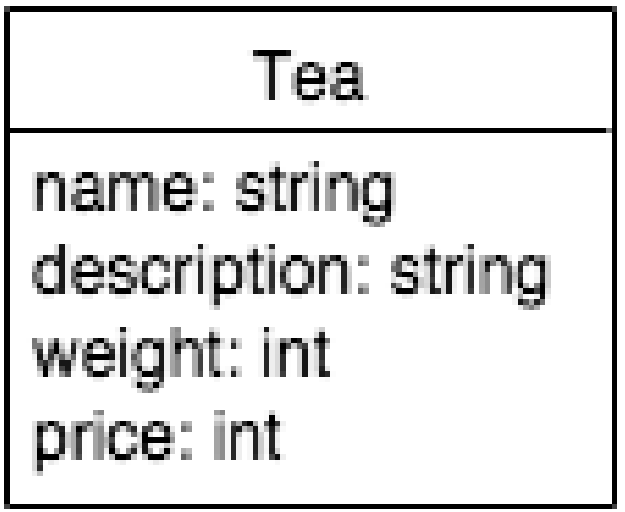
Class diagram for Tea



Simple Classes in Python

A class diagram can be mapped line-by-line to Python code.

Class declaration

```
>>> class Tea:
...     def __init__(self,name,desc,wgt,price):
...         self.name = name
...         self.description = desc
...         self.weight = wgt
...         self.price = price
...
```

- `__init__` is a function that is called when a new `Tea` instance is created. The `self` parameter is the new instance, the paramters `name`, `desc`, `wgt`, and `price` are used to initialize the respective attributes as shown.

Using simple classes

Creating and examining tea

```
>>> earl_grey = Tea("Earl␣Grey",
                    "Flavored␣black␣tea",
                    10000, 4335)
>>> earl_grey
<__main__.Tea instance at 0x1051dd950>
>>> earl_grey.name     # get name attribute
'Earl␣Grey'
>>> earl_grey.price    # get price attribute
4335
```

- `Tea()` creates a new Tea instance and calls its `__init__` method
- Access attributes using *instance.attribute*

Simple class with operation

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Extended class description for Tea

A tea shop describes a particular brand of **tea** in stock by its **name**; a **description** of its color, flavor, etc; the **weight** in stock (in g); and its **price** in cent per kg. The shop wants to determine the stock value. It also wants to be able to print an inventory line.

Simple class with operation

Extended class description for Tea

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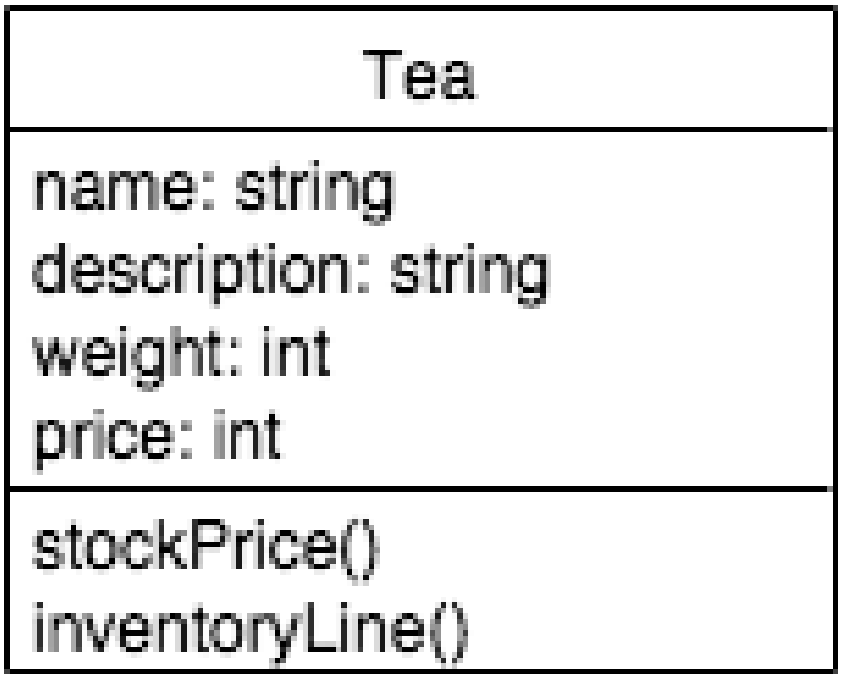
Two operations

- `stockPrice()`: no parameters, return total value of the tea brand in stock
- `inventoryLine()`: no parameters, return a string for printing the tea as an inventory item

Revised class diagram



Revised class declaration

```
class Tea:
    # __init__ omitted (same as before)
    def stockPrice(self):
        return self.weight * self.price / 1000
    def inventoryLine(self):
        return (self.name + '. ' +
                self.description + '. ' +
                str(self.weight) + 'g. ' +
                str(self.price) + ' c/kg.')
```

Remarks

- The implementation of `stockPrice` and `inventoryLine` belongs to the class declaration.
- Their first parameter is `self` and they can access all attributes.
- `str()` converts a number to a string

Meter Readings

Reading

A reading of a metering device consists of a **reading date** and a **reading value**.

Meter Readings

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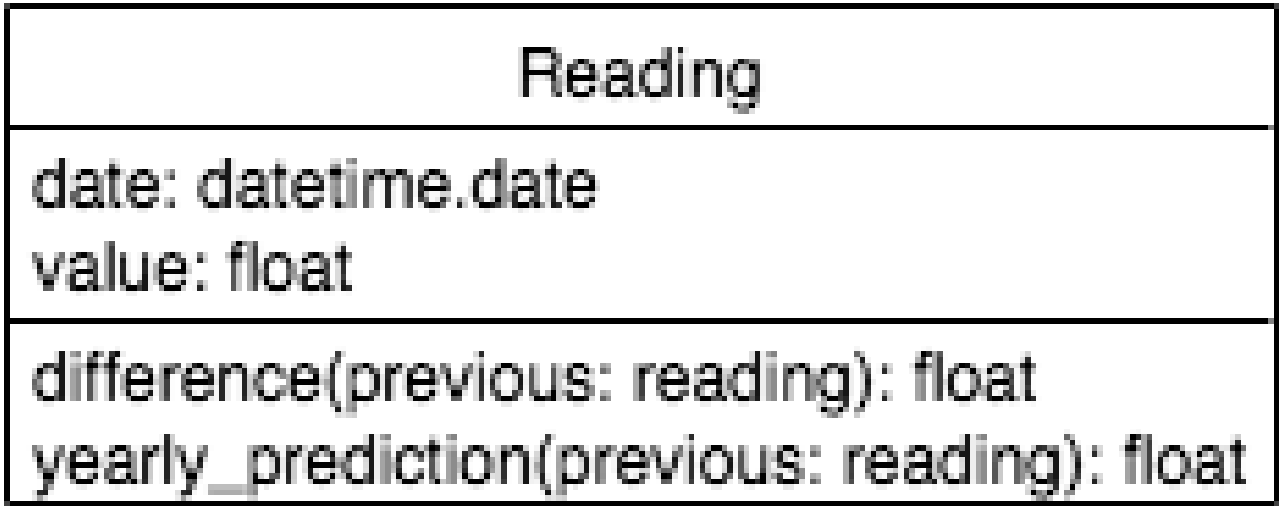
Class diagram



Meter Readings implemented

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Explanation

- `datetime` is a **module** that contains utilities for manipulating dates
- made available using
  `import datetime`

Meter Readings implemented

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Implementation

```
import datetime

class Reading:
    def __init__(self, date, value):
        self.date = date     # datetime.date
        self.value = value   # float
    def difference(self, previous):
        return self.value - previous.value
    def yearly_prediction(self, previous):
        value_diff = self.value - previous.value
        date_diff = self.date - previous.date
        factor = 365.25 / date_diff.days
        return value_diff * factor
```

Compound Classes

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Household

A household has an allocated amount of space (in square meters) and a number of occupants. Furthermore, a household has meter readings for several dates in the past.

Compound Classes

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Class diagram

Association: Household — Reading

- The connection between `Household` and `Reading` in the class diagram is an **association**.
- It comes with a direction that indicates the direction in which it can be traversed with an arrowhead.
- We choose to represent the association with a list of readings stored in the Household instance.
- Requires a "housekeeping" method to add new readings.

Implementing Household

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```
class Household:
    def __init__(self, space, occupants):
        self.space      = space
        self.occupants = occupants
        self.readings   = []
    def add_reading(self, reading):
        self.readings   = [reading] + self.readings
```

Further Household Methods

Requirements

For a household, we want to be able to determine the number of readings taken. If there are multiple readings, we want to give a statistical yearly prediction.

Implementation

```
class Household:          # __init__ ... as before
    def nr_readings(self):
        return len(self.readings)
    def yearly_average(self):
        if len(self.readings) < 2:
            return None  # more than one reading
        first_reading = self.readings[-1]
        last_reading  = self.readings[0]
        return last_reading.yearly_prediction(
                                first_reading)
```

Data Modeling II

Data Modeling II

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- Union
- Abstraction
- Inheritance

Union of classes

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Task

A drawing program wants to manage different geometric shapes in a coordinate system. Initially, there are three kinds of figures:

- squares with reference point upper left and given side length
- circles with reference point in the middle and a given radius
- points that just consist of the reference point

Union of classes

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A drawing program wants to manage different geometric shapes in a coordinate system. Initially, there are three kinds of figures:

- squares with reference point upper left and given side length
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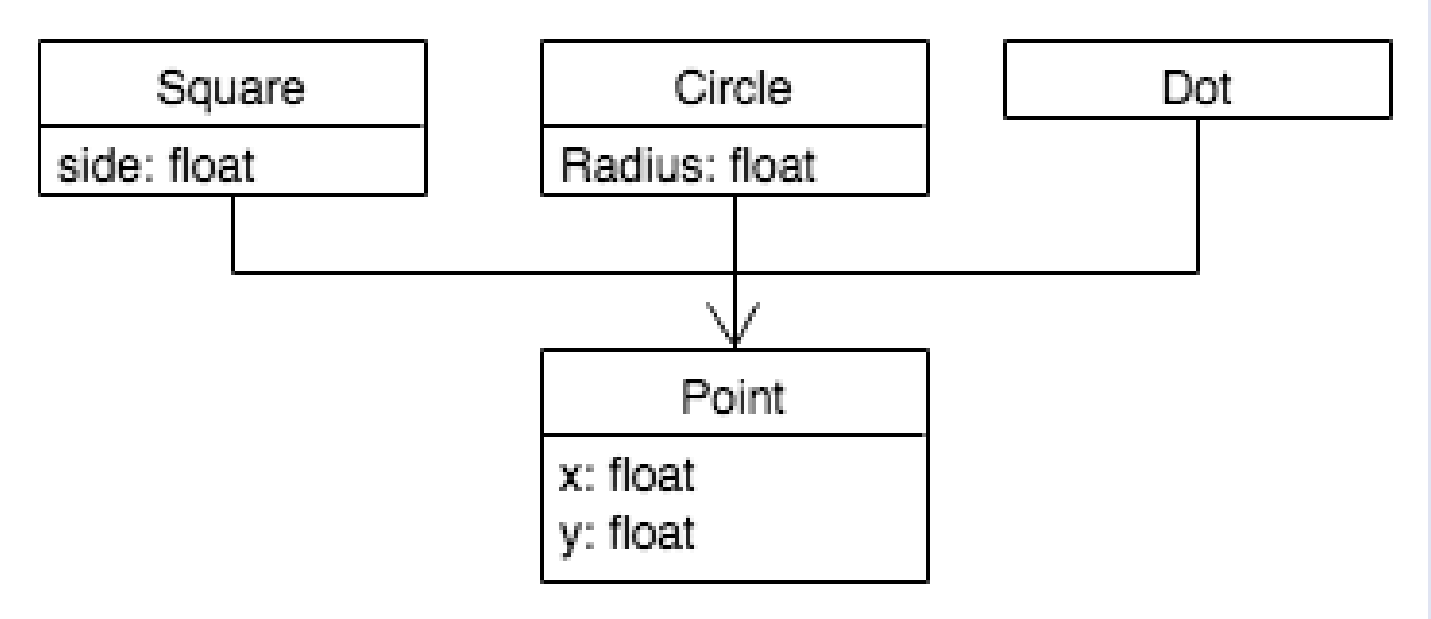
- points that just consist of the reference point

Approach

- Each kind of figure can be represented by a compound class. The reference point is a separate Point object.
- In many languages the instances of these classes could not be used together. The mix of classes presents no problem in Python.

Union of classes

Class diagram



Python implementation

```
class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y

class Square:
    def __init__(self, ref, side):
        self.ref = ref
        self.side = side
```

- and so on

Functionality for shapes

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Task

For each shape, we want to be able to compute the area and we want to move it around.

Functionality for shapes

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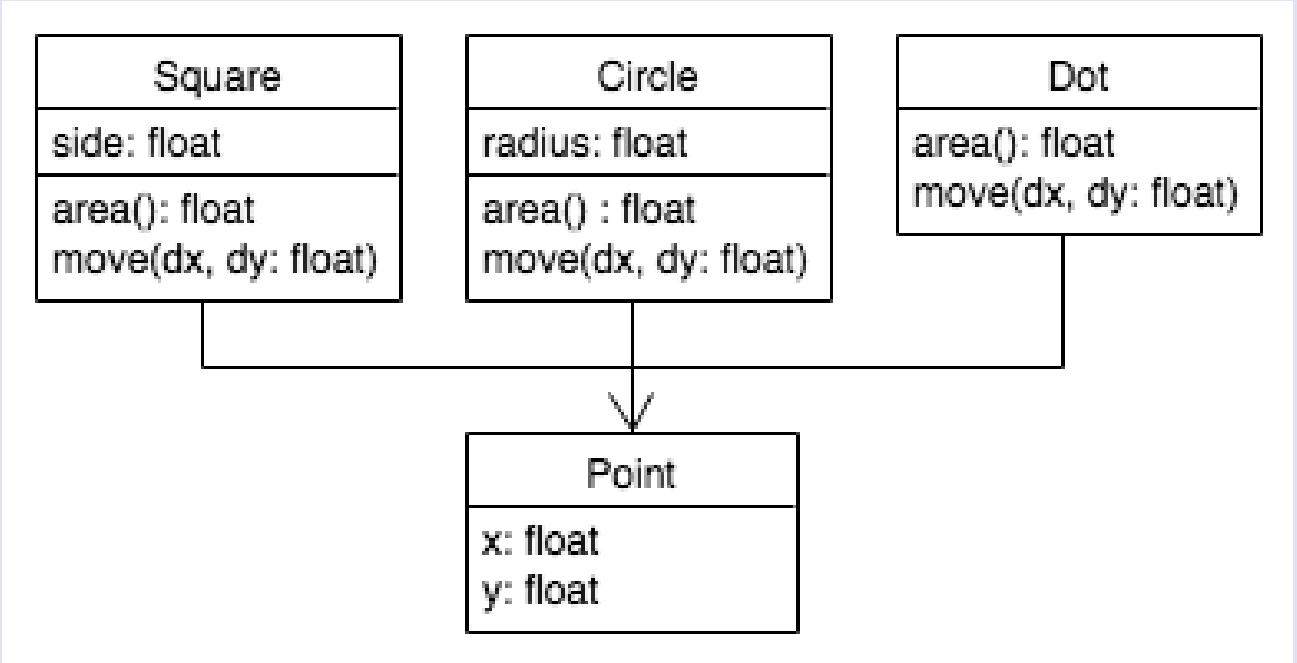
Class diagram with operations



Python implementation

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Square

```
def area(self):
    return self.side * self.side
def move(self, dx, dy):
    self.ref.move (dx, dy)
```

Python implementation

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Square

```
def area(self):
    return self.side * self.side
def move(self, dx, dy):
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```

Circle

```
def area(self):
    return 2 * math.pi * self.radius
def move(self, dx, dy):
    self.ref.move (dx, dy)
```

Python implementation

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def area(self):
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```

Dot ...

Python implementation II

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- All implementations assume a `move` method in `Point`.

Point

```
def move (self, dx, dy):
    self.x += dx
    self.y += dy
```

Python implementation II

- All implementations assume a `move` method in `Point`.

Point

```
def move (self, dx, dy):
    self.x += dx
    self.y += dy
```

Observation

- the move methods in `Square`, `Circle`, and `Dot` are all identical
- it would be nice to be able to advertise that all shape classes have methods `move` and `area`.

Abstraction

Abstraction in programming

- identify programming patterns
  repeated program fragments with similar semantics
- generalization
  replace specific parts by variables
- extraction
  give a name to the thus generalized program fragment
  invoke in the original places

Abstraction

Abstraction in programming

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  replace specific parts by variables
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  give a name to the thus generalized program fragment
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What does that mean?

- generally avoid duplication
- look for similarities
- try to solve each problem only once

Similarity among classes

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Goal

- identify similar field and method declarations

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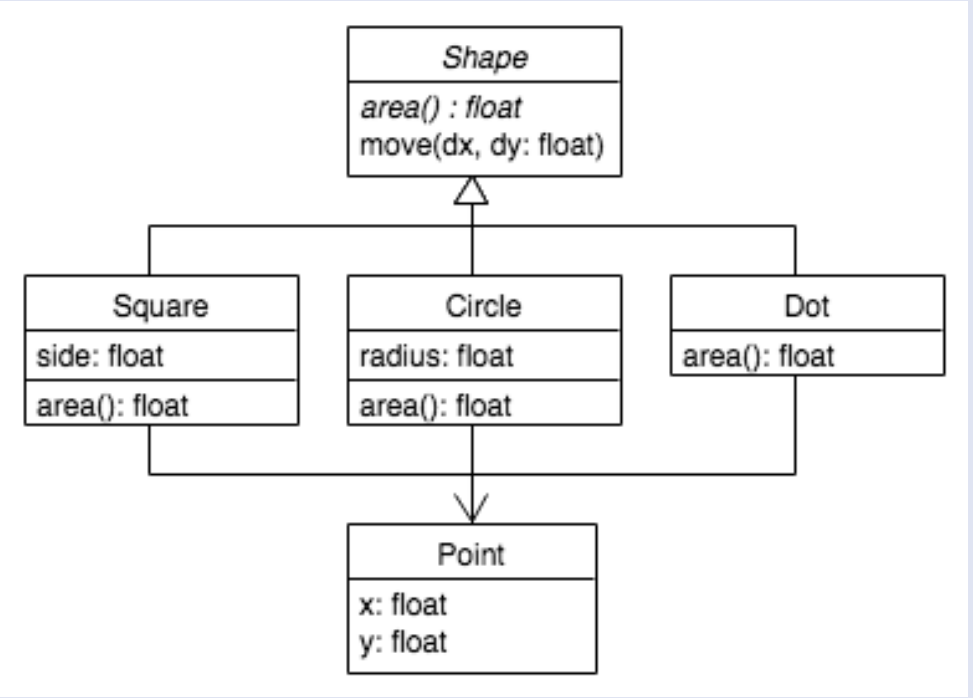
Goal

- identify similar field and method declarations
- example: `Square.move`, `Circle.move`, `Dot.move`
- approach: introduce common **super class** `Shape`
- indicated by arrow with open triangle head

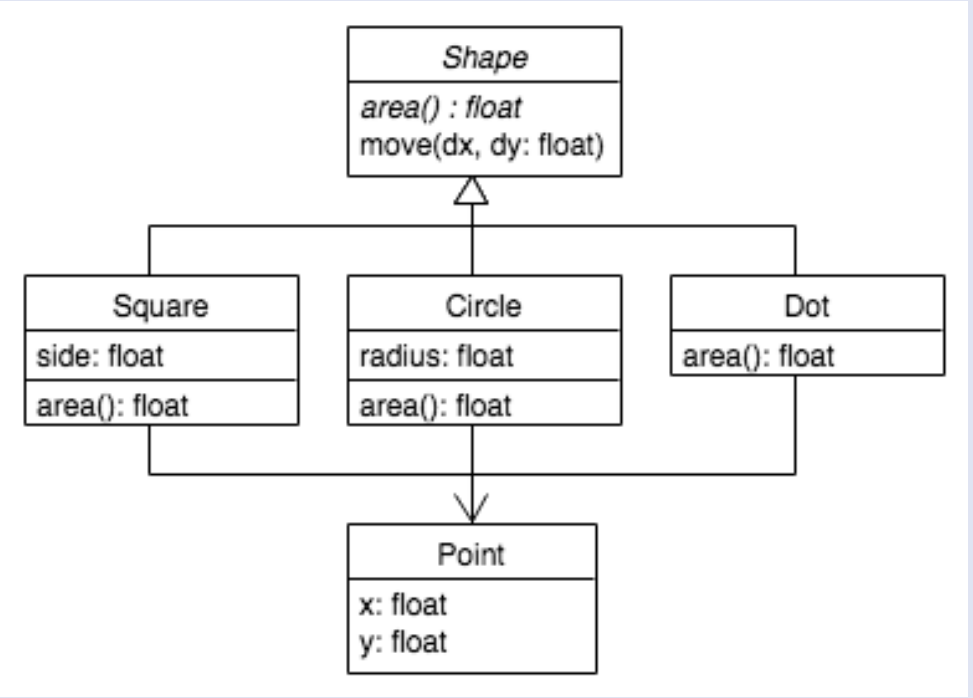
Inheritance

Class diagram: the Shape superclass



Inheritance

Class diagram: the Shape superclass



Italics indicate abstract items

- *Shape* is an **abstract class**: no instances
- *Shape.area()* is an **abstract method**: no implementation

Inheritance in Python

Super class Shape

```
class Shape:
    def __init__(self, ref):
        self.ref = ref
    def move(self, dx, dy):
        self.ref.move(dx, dy)
    def area(self):
        return 0
```

- it's not easily possible to define proper abstract classes in Python (you can create Shape instances)
- it's not possible to define abstract methods in Python; the way to do it would be to drop the definition of `area()`

Subclasses in Python

Square

```
class Square (Shape):
    def __init__ (self, ref, side):
        Shape.__init__(self, ref)
        self.side = side
    def area(self):
        return self.side * self.side
```

Subclasses in Python

Square

```
class Square (Shape):
    def __init__ (self, ref, side):
        Shape.__init__(self, ref)
        self.side = side
    def area(self):
        return self.side * self.side
```

Notes

- call `__init__` method of the super class `Shape`
- no need to define `move()`,
  its definition is **inherited** from `Shape`
- **override** `Shape`'s definition of `area()`

Exploiting inheritance

Weather data

We want to keep track of various recordings of weather data all comprising of a high and a low reading. Two examples are temperature and pressure readings. All should be printable.

Exploiting inheritance

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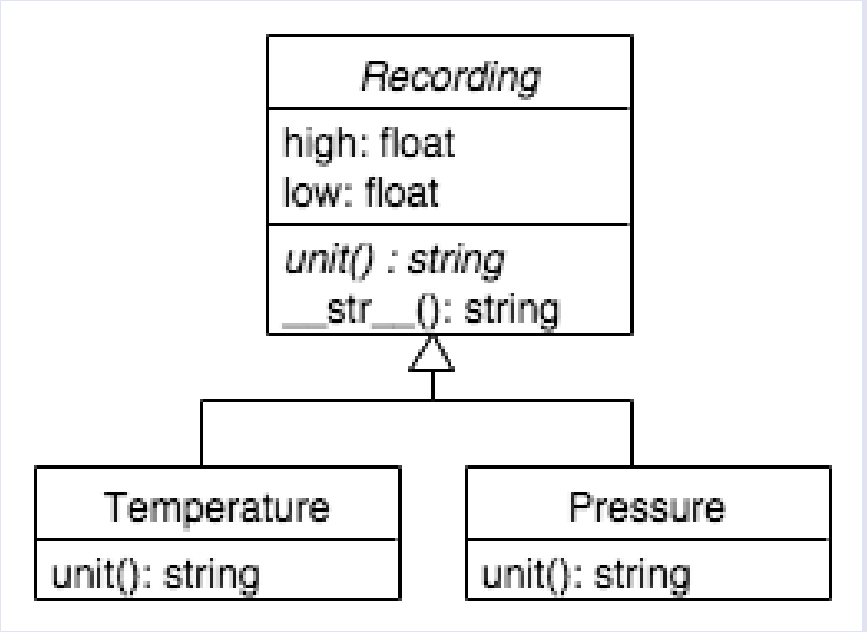
Consider this class diagram



Implementing weather data

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Printable

If a Python object has a method `__str__`, then that method is used to convert the object to a string.

Implementing weather data

Printable

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Printable Recording

```
class Recording:
    def __init__(self, low, high):
        self.low = low
        self.high = high
    def __str__(self):
        return (str (self.low) + ' - ' +
                str (self.high) + ' ' +
                self.unit())
```

Template Method

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Printable Temperature recording

Temperature/Pressure can inherit printing from `Recording`, but it has to define the `unit()` method to make printing work!

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Implementing concrete recordings

```
class Temperature (Recording):
    def unit():
        return "degrees"

class Pressure (Recording):
    def unit():
        return "hPa"
```