Relationship to the Python Object System

Object attributes are stored as dictionaries

Some special names, \_\_<name>\_, require special handling

An object has an "attribute" called \_\_dict\_\_ that is a dictionary of its user-defined instance attributes

Demo

In Python, classes have classes too

The equivalent of init\_instance can be customized (metaclass)
Generic Functions

An abstraction might have more than one representation
Generic Functions

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- Python has many sequence types: tuples, ranges, lists, etc.
Generic Functions

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An abstract data type might have multiple implementations
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• Generic functions using message passing
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• String representations of objects
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• Generic functions using message passing
• String representations of objects
• Multiple representations of abstract data types
• Property methods
String Representations
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String Representations

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For instance, by producing a string representation of itself
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- The "str" is legible to **humans**.
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- The "str" is legible to **humans**
- The "repr" is legible to the **Python interpreter**
String Representations

An object value should **behave** like the kind of data it is meant to represent.

For instance, by **producing a string** representation of itself.

Strings are important: they represent *language* and *programs*.

In Python, all objects produce two string representations:
- The "str" is legible to **humans**.
- The "repr" is legible to the **Python interpreter**.

When the "str" and "repr" **strings are the same**, we're doing **something right** in our programming language!
The "repr" String for an Object
The "repr" String for an Object

The repr function returns a Python expression (as a string) that evaluates to an equal object
The "repr" String for an Object

The `repr` function returns a Python expression (as a string) that evaluates to an equal object.

```
repr(object) -> string
```

Return the canonical string representation of the object. For most object types, `eval(repr(object)) == object`. 
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The result of calling `repr` on the value of an expression is what Python prints in an interactive session.
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\text{repr}(\text{object}) \rightarrow \text{string}
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The result of calling repr on the value of an expression is what Python prints in an interactive session

\[
>>> 12e12
12000000000000.0
\]
The "repr" String for an Object

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>>> 12e12
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>>> print(repr(12e12))
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The "repr" String for an Object

The repr function returns a Python expression (as a string) that evaluates to an equal object

\[ \text{repr(object)} \rightarrow \text{string} \]

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Some objects don't have a simple Python-readable string
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>>> 12e12
12000000000000.0
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12000000000000.0
```

Some objects don't have a simple Python-readable string

```
>>> repr(min)
'<built-in function min>'
```
The "str" String for an Object

Human interpretable strings are useful as well
The "str" String for an Object

Human interpretable strings are useful as well

```python
>>> import datetime
```
The "str" String for an Object

Human interpretable strings are useful as well

```python
>>> import datetime
>>> today = datetime.date(2011, 10, 7)
```
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>>> import datetime

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```python
>>> import datetime
>>> today = datetime.date(2011, 10, 7)
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>>> str(today)
'2011-10-07'
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Demo
Message Passing Enables Polymorphic Functions
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*Polymorphic function:* A function that can be applied to many (poly) different forms (morph) of data
Message Passing Enables Polymorphic Functions

*Polymorphic* function: A function that can be applied to many *(poly)* different forms *(morph)* of data

str and repr are both polymorphic; they apply to anything
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repr invokes a zero-argument method `__repr__` on its argument
Polymorphic function: A function that can be applied to many (poly) different forms (morph) of data.

str and repr are both polymorphic; they apply to anything.

repr invokes a zero-argument method __repr__ on its argument.

```python
>>> today.__repr__()
'datetime.date(2011, 10, 7)'
```
Message Passing Enables Polymorphic Functions

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demo invokes a zero-argument method `__repr__` on its argument

```python
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```

str invokes a zero-argument method `__str__` on its argument
Message Passing Enables Polymorphic Functions

*Polymorphic* function: A function that can be applied to many (poly) different forms (morph) of data

str and repr are both polymorphic; they apply to anything

repr invokes a zero-argument method `__repr__` on its argument

```python
>>> today.__repr__()
'datetime.date(2011, 10, 7)'
```

str invokes a zero-argument method `__str__` on its argument

```python
>>> today.__str__()
'2011-10-07'
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Implementing repr and str
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The behavior of repr is slightly more complicated than invoking __repr__ on its argument:
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- An instance attribute called __repr__ is ignored (demo)
Implementing repr and str

The behavior of `repr` is slightly more complicated than invoking `__repr__` on its argument:

- An instance attribute called `__repr__` is ignored (demo)
- **Question:** How would we implement this behavior?
Implementing `repr` and `str`

The behavior of `repr` is slightly more complicated than invoking `__repr__` on its argument:

- An instance attribute called `__repr__` is ignored (demo)
- **Question:** How would we implement this behavior?

The behavior of `str`: 
Implementing repr and str

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The behavior of str:

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Implementing repr and str

The behavior of repr is slightly more complicated than invoking __repr__ on its argument:

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The behavior of str:

• An instance attribute called __str__ is ignored
• If no __str__ attribute is found, uses repr string (demo)
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The behavior of str:

• An instance attribute called __str__ is ignored
• If no __str__ attribute is found, uses repr string (demo)

**Question**: How would we implement this behavior?

• str is a class, not a function
Interfaces
Interfaces

Message passing allows different data types to respond to the same message
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Message passing allows **different data types** to respond to the **same message**.

A shared message that elicits similar behavior from different object classes is a powerful method of abstraction.
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A shared message that elicits similar behavior from different object classes is a powerful method of abstraction

An *interface* is a **set of shared messages**, along with a specification of **what they mean**
Interfaces

Message passing allows **different data types** to respond to the **same message**

A shared message that elicits similar behavior from different object classes is a powerful method of abstraction.

An *interface* is a **set of shared messages**, along with a specification of **what they mean**.

Classes that implement `__repr__` and `__str__` methods that return Python- and human-readable strings thereby **implement an interface** for producing Python string representations.
Multiple Representations of Abstract Data
Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers
Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers
Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers

\[(1, 1)\]
Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers

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Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers

\[(1, 1)\]

\[(\sqrt{2}, \frac{\pi}{4})\]
Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers

Most operations don't care about the representation
Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers

Most operations don't care about the representation

Some mathematical operations are easier on one than the other
Arithmetic Abstraction Barriers

Rectangular representation  Polar representation
Arithmetic Abstraction Barriers

- real
- imag
- magnitude
- angle

Rectangular representation

Polar representation
Complex numbers as two-dimensional vectors

real  imag  magnitude  angle

Rectangular representation  Polar representation
Complex numbers as two-dimensional vectors

Rectangular representation

Polar representation
Arithmetic Abstraction Barriers

Complex numbers in the problem domain

add_complex  mul_complex

Complex numbers as two-dimensional vectors

real  imag  magnitude  angle

Rectangular representation

Polar representation
An Interface for Complex Numbers
An Interface for Complex Numbers

All complex numbers should produce real and imag components
An Interface for Complex Numbers

All complex numbers should produce real and imag components.

All complex numbers should produce a magnitude and angle.
An Interface for Complex Numbers

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Demo
An Interface for Complex Numbers

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Demo

Using this interface, we can implement complex arithmetic
An Interface for Complex Numbers

All complex numbers should produce real and imag components

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Demo

Using this interface, we can implement complex arithmetic

```python
>>> def add_complex(z1, z2):
    return ComplexRI(z1.real + z2.real,
                     z1.imag + z2.imag)
```
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    return ComplexMA(z1.magnitude * z2.magnitude,
                     z1.angle + z2.angle)
```
Property Methods

Often, we want the value of instance attributes to be linked
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```python
>>> f = Fraction(3, 5)
```
Property Methods

Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
>>> f.float_value
```
Property Methods

Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
>>> f.float_value
0.6
```
Property Methods

Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
>>> f.float_value
0.6
>>> f.numer = 4
```
Property Methods

Often, we want the value of instance attributes to be linked

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>>> f = Fraction(3, 5)
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>>> f.numer = 4
>>> f.float_value
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Property Methods

Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
>>> f.float_value
0.6
>>> f.numer = 4
>>> f.float_value
0.8
```
Property Methods

Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
>>> f.float_value
0.6
>>> f.numer = 4
>>> f.float_value
0.8
>>> f.denom -= 3
```
Property Methods

Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
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>>> f = Fraction(3, 5)
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>>> f.numer = 4
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>>> f.float_value
2.0
```
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Often, we want the value of instance attributes to be linked

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>>> f = Fraction(3, 5)
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The `@property` decorator on a method designates that it will be called whenever it is looked up on an instance.
Often, we want the value of instance attributes to be linked.

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```

The `@property` decorator on a method designates that it will be called whenever it is *looked up* on an instance.

It allows zero-argument methods to be called without the standard call expression syntax.
Often, we want the value of instance attributes to be linked

```python
>>> f = Fraction(3, 5)
>>> f.float_value
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>>> f.numer = 4
>>> f.float_value
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Demo
The Rectangular Representation
The Rectangular Representation

class ComplexRI(object):

The Rectangular Representation

class ComplexRI(object):

    def __init__(self, real, imag):
        self.real = real
        self.imag = imag
The Rectangular Representation

class ComplexRI(object):

    def __init__(self, real, imag):
        self.real = real
        self.imag = imag

@property
def magnitude(self):
    return (self.real ** 2 + self.imag ** 2) ** 0.5
The Rectangular Representation

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@property
def angle(self):
    return atan2(self.imag, self.real)
The Rectangular Representation

class ComplexRI(object):

    def __init__(self, real, imag):
        self.real = real
        self.imag = imag

    @property
    def magnitude(self):
        return (self.real ** 2 + self.imag ** 2) ** 0.5

    @property
    def angle(self):
        return math.atan2(self.imag, self.real)

Property decorator: "Call this function on attribute look-up"

math.atan2(y,x): Angle between x-axis and the point (x,y)
The Rectangular Representation

class ComplexRI(object):

    def __init__(self, real, imag):
        self.real = real
        self.imag = imag

    @property
    def magnitude(self):
        return (self.real ** 2 + self.imag ** 2) ** 0.5

    @property
    def angle(self):
        return math.atan2(self.imag, self.real)

    def __repr__(self):
        return 'ComplexRI({0}, {1})'.format(self.real, self.imag)
The Polar Representation
The Polar Representation

class ComplexMA(object):

class ComplexMA(object):
    def __init__(self, magnitude, angle):
        self.magnitude = magnitude
        self.angle = angle

The Polar Representation
The Polar Representation

class ComplexMA(object):

    def __init__(self, magnitude, angle):
        self.magnitude = magnitude
        self.angle = angle

@property
def real(self):
    return self.magnitude * cos(self.angle)
class ComplexMA(object):
    def __init__(self, magnitude, angle):
        self.magnitude = magnitude
        self.angle = angle

    @property
def real(self):
        return self.magnitude * cos(self.angle)

    @property
def imag(self):
        return self.magnitude * sin(self.angle)
class ComplexMA(object):

    def __init__(self, magnitude, angle):
        self.magnitude = magnitude
        self.angle = angle

    @property
    def real(self):
        return self.magnitude * cos(self.angle)

    @property
    def imag(self):
        return self.magnitude * sin(self.angle)

    def __repr__(self):
        return 'ComplexMA({0}, {1})'.format(self.magnitude, self.angle)
Using Complex Numbers

Either type of complex number can be passed as either argument to add_complex or mul_complex
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Either type of complex number can be passed as either argument to add_complex or mul_complex

```python
>>> def add_complex(z1, z2):
    return ComplexRI(z1.real + z2.real,
                     z1.imag + z2.imag)

>>> def mul_complex(z1, z2):
    return ComplexMA(z1.magnitude * z2.magnitude,
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Using Complex Numbers

Either type of complex number can be passed as either argument to `add_complex` or `mul_complex`:

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    return ComplexMA(z1.magnitude * z2.magnitude, z1.angle + z2.angle)

>>> from math import pi
```
Using Complex Numbers

Either type of complex number can be passed as either argument to `add_complex` or `mul_complex`.

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>>> def add_complex(z1, z2):
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>>> def mul_complex(z1, z2):
    return ComplexMA(z1.magnitude * z2.magnitude,
                      z1.angle + z2.angle)

>>> from math import pi
>>> add_complex(ComplexRI(1, 2), ComplexMA(2, pi/2))
ComplexRI(1.0000000000000002, 4.0)
```
Using Complex Numbers

Either type of complex number can be passed as either argument to `add_complex` or `mul_complex`

```python
>>> def add_complex(z1, z2):
    return ComplexRI(z1.real + z2.real,
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```python
>>> from math import pi
```

```python
>>> add_complex(ComplexRI(1, 2), ComplexMA(2, pi/2))
ComplexRI(1.0000000000000002, 4.0)
```

```python
>>> mul_complex(ComplexRI(0, 1), ComplexRI(0, 1))
ComplexMA(1.0, 3.141592653589793)
```
Special Methods

Adding instances of user-defined classes use __add__ method
Special Methods

Adding instances of user-defined classes use `__add__` method

Demo
Special Methods

Adding instances of user-defined classes use `__add__` method

Demo

```python
>>> ComplexRI(1, 2) + ComplexMA(2, 0)
ComplexRI(3.0, 2.0)
```
Special Methods

Adding instances of user-defined classes use `__add__` method

Demo

```python
>>> ComplexRI(1, 2) + ComplexMA(2, 0)
ComplexRI(3.0, 2.0)
```

```python
>>> ComplexRI(0, 1) * ComplexRI(0, 1)
ComplexMA(1.0, 3.141592653589793)
```
Adding instances of user-defined classes use `__add__` method

Demo

```python
>>> ComplexRI(1, 2) + ComplexMA(2, 0)
ComplexRI(3.0, 2.0)
>>> ComplexRI(0, 1) * ComplexRI(0, 1)
ComplexMA(1.0, 3.141592653589793)
```


http://docs.python.org/py3k/reference/datamodel.html#special-method-names