Chapter 15

Inheritance

In this chapter we will develop classes to represent playing cards, decks of cards, and poker hands. If you don't play poker, don't worry; I'll tell you what you need to know for the exercises.

But if you are not familiar with common playing cards, now would be a good time to get a deck, or else this chapter might not make much sense.

15.1 Card objects

There are fifty-two cards in a deck, each of which belongs to one of four suits and one of thirteen ranks. The suits are Spades, Hearts, Diamonds, and Clubs (in descending order in bridge). The ranks are Ace, 2, 3, 4, 5, 6, 7, 8, 9, 10, Jack, Queen, and King. Depending on the game that you are playing, an Ace may be higher than King or lower than 2.

If we want to define a new object to represent a playing card, it is obvious what the attributes should be: `rank` and `suit`. It is not as obvious what type the attributes should be. One possibility is to use strings containing words like `"Spade"` for suits and `"Queen"` for ranks. One problem with this implementation is that it would not be easy to compare cards to see which had a higher rank or suit.

An alternative is to use integers to **encode** the ranks and suits. In this context, "encode" means that we are going to define a mapping between numbers and suits, or between numbers and ranks. This kind of encoding is not meant to be a secret (that would be "encryption").

For example, this table shows the suits and the corresponding integer codes:

Spades	$\mapsto$	3
Hearts	$\mapsto$	2
Diamonds	$\mapsto$	1
Clubs	$\mapsto$	0

This code makes it easy to compare cards; because higher suits map to higher numbers, we can compare suits by comparing their codes.

The mapping for ranks is fairly obvious; each of the numerical ranks maps to the corresponding integer, and for face cards:

Jack	$\mapsto$	11
Queen	$\mapsto$	12
King	$\mapsto$	13

I am using the $\mapsto$ symbol to make is clear that these mappings are not part of the Python program. They are part of the program design, but they don't appear explicitly in the code.

The class definition for `Card` looks like this:

```
class Card:
    """represents a standard playing card."""

    def __init__(self, suit=0, rank=2):
        self.suit = suit
        self.rank = rank
```

As usual, the `init` method takes an optional parameter for each attribute. The default card is the 2 of Clubs.

To create a Card, you call `Card` with the suit and rank of the card you want.

```
threeOfClubs = Card(3, 1)
```

In the next section we'll figure out which card that is.

15.2 Class attributes

In order to print Card objects in a way that people can easily read, we need a mapping from the integer codes to the corresponding ranks and suits. A natural way to do that is with lists of strings. We assign these lists to **class attributes**:

```
# inside class Card:

    suit_names = ['Clubs', 'Diamonds', 'Hearts', 'Spades']
    rank_names = [None, 'Ace', '2', '3', '4', '5', '6', '7',
```

```
            '8', '9', '10', 'Jack', 'Queen', 'King']

    def __str__(self):
        return '%s of %s' % (Card.rank_names[self.rank],
                             Card.suit_names[self.suit])
```

Because `suit_names` and `rank_names` are defined outside of any method, they are class attributes; that is, they are associated with the class `Card` rather than with a particular Card instance.

Attributes like `suit` and `rank` are more precisely called **instance attributes** because they are associated with a particular instance.

Both kinds of attribute are accessed using dot notation. For example, in `__str__`, `self` is a Card object, and `self.rank` is its rank. Similarly, `Card` is a class object, and `Card.rank_names` is a list of strings associated with the class.

Every card has its own `suit` and `rank`, but there is only one copy of `suit_names` and `rank_names`.

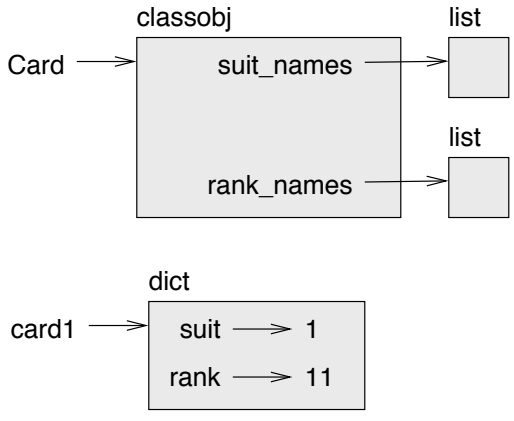
Finally, the expression `Card.rank_names[self.rank]` means "use the attribute `rank` from the object `self` as an index into the list `rank_names` from the class `Card`, and select the appropriate string."

The first element of `rank_names` is `None` because there is no card with rank zero. By including `None` as a place-keeper, we get a mapping with the nice property that the index 2 maps to the string `'2'`, and so on.

With the methods we have so far, we can create and print cards:

```
>>> card1 = Card(1, 11)
>>> print card1
Jack of Diamonds
```

Here is a diagram that shows the `Card` class object and one Card instance:



Card is a class object, so it has type classobj. card1 has type Card. (To save space, I didn't draw the contents of suit_names and rank_names).

15.3 Comparing cards

For built-in types, there are conditional operators (<, >, ==, etc.) that compare values and determine when one is greater than, less than, or equal to another. For user-defined types, we can override the behavior of the built-in operators by providing a method named __cmp__.

The cmp method takes two parameters, self and other, and returns a positive number if the first object is greater, a negative number if the second object is greater, and 0 if they are equal to each other.

The correct ordering for cards is not obvious. For example, which is better, the 3 of Clubs or the 2 of Diamonds? One has a higher rank, but the other has a higher suit. In order to compare cards, you have to decide whether rank or suit is more important.

The answer might depend on what game you are playing, but to keep things simple, we'll make the arbitrary choice that suit is more important, so all of the Spades outrank all of the Diamonds, and so on.

With that decided, we can write __cmp__:

```
# inside class Card:

    def __cmp__(self, other):
        # check the suits
        if self.suit > other.suit: return 1
        if self.suit < other.suit: return -1

        # suits are the same... check ranks
        if self.rank > other.rank: return 1
        if self.rank < other.rank: return -1

        # ranks are the same... it's a tie
        return 0
```

You can write this more concisely using tuple comparison:

```
# inside class Card:

    def __cmp__(self, other):
        t1 = self.suit, self.rank
        t2 = other.suit, other.rank
        return cmp(t1, t2)
```

The built-in function cmp has the same interface as the method __cmp__: it takes two values and returns a positive number if the first is larger, a negative number of the second is larger, and 0 if they are equal.

Exercise 15.1. *Write a __cmp__ method for Time objects. Hint: you can use tuple comparison, but you also might consider using integer subtraction.*

15.4 Decks

Now that we have Card objects, the next step is to define a class to represent decks. Since a deck is made up of cards, a natural choice is for each Deck object to contain a list of cards as an attribute.

The following is a class definition for Deck. The init method creates the attribute cards and generates the standard set of fifty-two cards:

```
class Deck:

    def __init__(self):
        self.cards = []
        for suit in range(4):
            for rank in range(1, 14):
                card = Card(suit, rank)
                self.cards.append(card)
```

The easiest way to populate the deck is with a nested loop. The outer loop enumerates the suits from 0 to 3. The inner loop enumerates the ranks from 1 to 13. Each iteration of the inner loop creates a new Card with the current suit and rank, and appends it to self.cards.

15.5 Printing the deck

Here is a str method for Deck:

```
#inside class Deck:

    def __str__(self):
        res = []
        for card in self.cards:
            res.append(str(card))
        return '\n'.join(res)
```

This method demonstrates an efficient way to accumulate a large string, by building a list of strings and then using join. The built-in function str invokes the __str__ method on each card and returns the string representation.

Since we invoke `join` on a newline character, the cards are separated by newlines. Here's what the result looks like:

```
>>> deck = Deck()
>>> print deck
Ace of Clubs
2 of Clubs
3 of Clubs
...
10 of Spades
Jack of Spades
Queen of Spades
King of Spades
```

Even though the result appears on 52 lines, it is one long string that contains newlines.

15.6 Add, remove, shuffle and sort

To deal cards, we would like a method that removes a card from the deck and returns it. The list method `pop` provides a convenient way to do that:

```
#inside class Deck:

    def pop_card(self):
        return self.cards.pop()
```

Since `pop` removes the *last* card in the list, we are in effect dealing from the bottom of the deck.

To add a card, we can use the list method `append`:

```
#inside class Deck:

    def add_card(self, card):
        self.cards.append(card)
```

A method like this that uses another function without doing much real work is sometimes called a **veneer**. The metaphor comes from woodworking, where it is common to glue a thin layer of good quality wood to the surface of a cheaper piece of wood.

In this case we are defining a "thin" method that expresses a list operation in terms that are appropriate for decks.

As another example, we can write a Deck method named `shuffle` using the function `shuffle` from the `random` module:

```
# inside class Deck:

    def shuffle(self):
        random.shuffle(self.cards)
```

Don't forget to import `random`.

Exercise 15.2. *Write a Deck method named* `sort` *that uses the list method* `sort` *to sort the cards in a* `Deck`. `sort` *uses the* `__cmp__` *method we defined to determine sort order.*

15.7 Inheritance

The language feature most often associated with object-oriented programming is **inheritance**. Inheritance is the ability to define a new class that is a modified version of an existing class.

It is called "inheritance" because the new class inherits the methods of the existing class. Extending this metaphor, the existing class is called the **parent** class and the new class is called the **child**.

As an example, let's say we want a class to represent a "hand," that is, the set of cards held by one player. A hand is similar to a deck: both are made up of a set of cards, and both require operations like adding and removing cards.

A hand is also different from a deck; there are operations we want for hands that don't make sense for a deck. For example, in poker we might compare two hands to see which one wins. In bridge, we might compute a score for a hand in order to make a bid.

This relationship between classes—similar, but different—lends itself to inheritance.

The definition of a child class is like other class definitions, but the name of the parent class appears in parentheses:

```
class Hand(Deck):
    """represents a hand of playing cards"""
```

This definition indicates that `Hand` inherits from `Deck`; that means we can use methods like `pop_card` and `add_card` for Hands as well as Decks.

`Hand` also inherits the `init` method from `Deck`, but it doesn't really do what we want: instead of populating the hand with 52 new cards, the `init` method for Hands should initialize `cards` with an empty list.

If we provide an `init` method in the `Hand` class, it overrides the one in the `Deck` class:

```
# inside class Hand:

    def __init__(self, label=''):
```

```
        self.cards = []
        self.label = label
```

So when you create a Hand, Python invokes this `init` method:

```
>>> hand = Hand('new hand')
>>> print hand.cards
[]
>>> print hand.label
new hand
```

But the other methods are inherited from `Deck`, so we can use `pop_card` and `add_card` to deal a card:

```
>>> deck = Deck()
>>> card = deck.pop_card()
>>> hand.add_card(card)
>>> print hand
King of Spades
```

The next natural step is to encapsulate this code in a method called `move_cards`:

```
#inside class Deck:

    def move_cards(self, hand, num):
        for i in range(num):
            hand.add_card(self.pop_card())
```

`move_cards` takes two arguments, a Hand object and the number of cards to deal. It modifies both `self` and `hand`, and returns `None`.

In some games, cards are moved from one hand to another, or from a hand back to the deck. You can use `move_cards` for any of these operations: `self` can be either a Deck or a Hand, and `hand`, despite the name, can also be a `Deck`.

Exercise 15.3. *Write a Deck method called* `deal_hands` *that takes two parameters, the number of hands and the number of cards per hand, and that creates new Hand objects, deals the appropriate number of cards per hand, and returns a list of Hand objects.*

Inheritance is a useful feature. Some programs that would be repetitive without inheritance can be written more elegantly with it. Inheritance can facilitate code reuse, since you can customize the behavior of parent classes without having to modify them. In some cases, the inheritance structure reflects the natural structure of the problem, which makes the program easier to understand.

On the other hand, inheritance can make programs difficult to read. When a method is invoked, it is sometimes not clear where to find its definition. The relevant code may be scattered among several modules. Also, many of the things that can be done using inheritance can be done as well or better without it.

15.8 Class diagrams

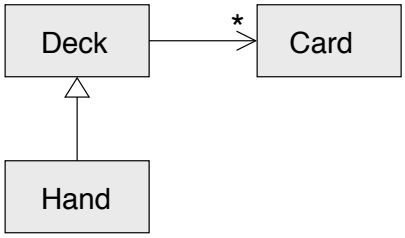
So far we have seen stack diagrams, which show the state of a program, and object diagrams, which show the attributes of an object and their values. These diagrams represent a snapshot in the execution of a program, so they change as the program runs.

They are also highly detailed, and for some applications, too detailed. A class diagrams is a more abstract representation of the structure of a program. Instead of showing individual objects, it shows classes and the relationships between them.

There are several kinds of relationship between classes:

- Objects in one class might contain references to objects in another class. For example, each Rectangle contains a reference to a Point, and each Deck contains references to many Cards. This kind of relationship is called **HAS-A**, as in, "a Rectangle has a Point."
- One class might inherit from another. This relationship is called **IS-A**, as in, "a Hand is a kind of a Deck."
- Once class might depend on another in the sense that changes in one class would require changes in the other.

A **class diagram** is a graphical representation of these relationships between classes. For example, this diagram shows the relationships between `Card`, `Deck` and `Hand`.



The arrow with a hollow triangle head represents an IS-A relationship; in this case it indicates that Hand inherits from Deck.

The standard arrow head represents a HAS-A relationshop; in this case a Deck has references to Card objects.

The star (`*`) near the arrow head is a **multiplicity**; it indicates how many Cards a Deck has. A multiplicity can be a simple number, like `52`, a range, like `5..7` or a star, which indicates that a Deck can have any number of Cards.

15.9 Glossary

encode: To represent one set of values using another set of values by constructing a mapping between them.

class attribute: An attribute associated with a class object. Class attributes are defined inside a class definition but outside any method.

instance attribute: An attribute associated with an instance of a class.

veneer: A method or function that provides a different interface to another function without doing much computation.

inheritance: The ability to define a new class that is a modified version of a previously defined class.

parent class: The class from which a child class inherits.

child class: A new class created by inheriting from an existing class; also called a "subclass."

IS-A relationship: The relationship between a child class and its parent class.

HAS-A relationship: The relationship between two classes where instances of one class contain references to instances of the other.

class diagram: A diagram that shows the classes in a program and the relationships between them.

multiplicity: A notation in a class diagram that shows, for a HAS-A relationship, how many references there are to instances of another class.

15.10 Exercises

The following are the possible hands in poker, in increasing order of value (and decreasing order of probability):

pair: two cards with the same rank

two pair: two pairs of cards with the same rank

three of a kind: three cards with the same rank

straight: five cards with ranks in sequence (aces can be high or low, so `Ace-2-3-4-5` is a straight and so is `10-Jack-Queen-King-Ace`, but `Queen-King-Ace-2-3` is not.)

flush: five cards with the same suit

full house: three cards with one rank, two cards with another

four of a kind: four cards with the same rank

straight flush: five cards in sequence (as defined above) and with the same suit

The goal of these exercises is to estimate the probability of drawing these various hands.

1. Download the following files from `thinkpython.com/code`:

   `Card.py` : A complete version of the `Card`, `Deck` and `Hand` classes in this chapter.

   `PokerHand.py` : An incomplete implementation of a class that represents a poker hand, and some code that tests it.

2. If you run `PokerHand.py`, it deals six 7-card poker hands and checks to see if any of them contains a flush. Read this code carefully before you go on.

3. Add methods to `PokerHand.py` named `has_pair`, `has_twopair`, etc. that return True or False according to whether or not the hand meets the relevant criteria. Your code should work correctly for "hands" that contain any number of cards (although 5 and 7 are the most common sizes).

4. Write a method named `classify` that figures out the highest-value classification for a hand and sets the `label` attribute accordingly. For example, a 7-card hand might contain a flush and a pair; it should be labeled "flush".

5. When you are convinced that your classification methods are working, the next step is to estimate the probablities of the various hands. Write a function in `PokerHand.py` that shuffles a deck of cards, divides it into hands, classifies the hands, and counts the number of times various classifications appear.

6. Print a table of the classifications and their probabilities. Run your program with larger and larger numbers of hands until the output values converge to a reasonable degree of accuracy.