10.2. `functools` — Higher-order functions and operations on callable objects

Source code: Lib/functools.py

The `functools` module is for higher-order functions: functions that act on or return other functions. In general, any callable object can be treated as a function for the purposes of this module.

The `functools` module defines the following functions:

`functools.`**`cmp_to_key`**(*func*)

Transform an old-style comparison function to a *key function*. Used with tools that accept key functions (such as `sorted()`, `min()`, `max()`, `heapq.nlargest()`, `heapq.nsmallest()`, `itertools.groupby()`). This function is primarily used as a transition tool for programs being converted from Python 2 which supported the use of comparison functions.

A comparison function is any callable that accept two arguments, compares them, and returns a negative number for less-than, zero for equality, or a positive number for greater-than. A key function is a callable that accepts one argument and returns another value to be used as the sort key.

Example:

```
sorted(iterable, key=cmp_to_key(locale.strcoll))  # locale-aware so
```

For sorting examples and a brief sorting tutorial, see *Sorting HOW TO*.

New in version 3.2.

`@functools.`**`lru_cache`**(*maxsize=128*, *typed=False*)

Decorator to wrap a function with a memoizing callable that saves up to the *maxsize* most recent calls. It can save time when an expensive or I/O bound function is periodically called with the same arguments.

Since a dictionary is used to cache results, the positional and keyword arguments to the function must be hashable.

If *maxsize* is set to None, the LRU feature is disabled and the cache can grow without bound. The LRU feature performs best when *maxsize* is a power-of-two.

If *typed* is set to True, function arguments of different types will be cached separately. For example, `f(3)` and `f(3.0)` will be treated as distinct calls with distinct results.

To help measure the effectiveness of the cache and tune the *maxsize* parameter, the wrapped function is instrumented with a `cache_info()` function that returns a *named tuple* showing *hits*, *misses*, *maxsize* and *currsize*. In a multi-threaded environment, the hits and misses are approximate.

The decorator also provides a `cache_clear()` function for clearing or invalidating the cache.

The original underlying function is accessible through the `__wrapped__` attribute. This is useful for introspection, for bypassing the cache, or for rewrapping the function with a different cache.

An LRU (least recently used) cache works best when the most recent calls are the best predictors of upcoming calls (for example, the most popular articles on a news server tend to change each day). The cache's size limit assures that the cache does not grow without bound on long-running processes such as web servers.

Example of an LRU cache for static web content:

```
@lru_cache(maxsize=32)
def get_pep(num):
    'Retrieve text of a Python Enhancement Proposal'
    resource = 'http://www.python.org/dev/peps/pep-%04d/' % num
    try:
        with urllib.request.urlopen(resource) as s:
            return s.read()
    except urllib.error.HTTPError:
        return 'Not Found'

>>> for n in 8, 290, 308, 320, 8, 218, 320, 279, 289, 320, 9991:
...     pep = get_pep(n)
...     print(n, len(pep))

>>> get_pep.cache_info()
CacheInfo(hits=3, misses=8, maxsize=32, currsize=8)
```

Example of efficiently computing Fibonacci numbers using a cache to implement a dynamic programming technique:

```
@lru_cache(maxsize=None)
```

```
def fib(n):
    if n < 2:
        return n
    return fib(n-1) + fib(n-2)

>>> [fib(n) for n in range(16)]
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610]

>>> fib.cache_info()
CacheInfo(hits=28, misses=16, maxsize=None, currsize=16)
```

New in version 3.2.

Changed in version 3.3: Added the *typed* option.

@functools.**total_ordering**

Given a class defining one or more rich comparison ordering methods, this class decorator supplies the rest. This simplifies the effort involved in specifying all of the possible rich comparison operations:

The class must define one of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`. In addition, the class should supply an `__eq__()` method.

For example:

```
@total_ordering
class Student:
    def _is_valid_operand(self, other):
        return (hasattr(other, "lastname") and
                hasattr(other, "firstname"))
    def __eq__(self, other):
        if not self._is_valid_operand(other):
            return NotImplemented
        return ((self.lastname.lower(), self.firstname.lower()) ==
                (other.lastname.lower(), other.firstname.lower()))
    def __lt__(self, other):
        if not self._is_valid_operand(other):
            return NotImplemented
        return ((self.lastname.lower(), self.firstname.lower()) <
                (other.lastname.lower(), other.firstname.lower()))
```

Note: While this decorator makes it easy to create well behaved totally ordered types, it *does* come at the cost of slower execution and more complex stack traces for the derived comparison methods. If performance benchmarking indicates this is a bottleneck for a given application, implementing all six rich comparison methods instead is likely to provide an easy speed boost.

New in version 3.2.

Changed in version 3.4: Returning NotImplemented from the underlying comparison function for unrecognised types is now supported.

functools.**partial**(*func*, **args*, ***keywords*)

Return a new `partial` object which when called will behave like *func* called with the positional arguments *args* and keyword arguments *keywords*. If more arguments are supplied to the call, they are appended to *args*. If additional keyword arguments are supplied, they extend and override *keywords*. Roughly equivalent to:

```
def partial(func, *args, **keywords):
    def newfunc(*fargs, **fkeywords):
        newkeywords = keywords.copy()
        newkeywords.update(fkeywords)
        return func(*(args + fargs), **newkeywords)
    newfunc.func = func
    newfunc.args = args
    newfunc.keywords = keywords
    return newfunc
```

The `partial()` is used for partial function application which "freezes" some portion of a function's arguments and/or keywords resulting in a new object with a simplified signature. For example, `partial()` can be used to create a callable that behaves like the `int()` function where the *base* argument defaults to two:

```
>>> from functools import partial
>>> basetwo = partial(int, base=2)
>>> basetwo.__doc__ = 'Convert base 2 string to an int.'
>>> basetwo('10010')
18
```

class functools.**partialmethod**(*func*, **args*, ***keywords*)

Return a new `partialmethod` descriptor which behaves like `partial` except that it is designed to be used as a method definition rather than being directly callable.

func must be a *descriptor* or a callable (objects which are both, like normal functions, are handled as descriptors).

When *func* is a descriptor (such as a normal Python function, `classmethod()`, `staticmethod()`, `abstractmethod()` or another instance of `partialmethod`), calls to `__get__` are delegated to the underlying descriptor, and an appropriate `partial` object returned as the result.

When *func* is a non-descriptor callable, an appropriate bound method is created dynamically. This behaves like a normal Python function when used as a method: the *self* argument will be inserted as the first positional argument, even before the *args* and *keywords* supplied to the `partialmethod` constructor.

Example:

```
>>> class Cell(object):
...     def __init__(self):
...         self._alive = False
...     @property
...     def alive(self):
...         return self._alive
...     def set_state(self, state):
...         self._alive = bool(state)
...     set_alive = partialmethod(set_state, True)
...     set_dead = partialmethod(set_state, False)
...
>>> c = Cell()
>>> c.alive
False
>>> c.set_alive()
>>> c.alive
True
```

New in version 3.4.

functools.**reduce**(*function*, *iterable*[, *initializer*])

Apply *function* of two arguments cumulatively to the items of *sequence*, from left to right, so as to reduce the sequence to a single value. For example, `reduce(lambda x, y: x+y, [1, 2, 3, 4, 5])` calculates `((((1+2)+3)+4)+5)`. The left argument, *x*, is the accumulated value and the right argument, *y*, is the update value from the *sequence*. If the optional *initializer* is present, it is placed before the items of the sequence in the calculation, and serves as a default when the sequence is empty. If *initializer* is not given and *sequence* contains only one item, the first item is returned.

Roughly equivalent to:

```
def reduce(function, iterable, initializer=None):
    it = iter(iterable)
    if initializer is None:
        value = next(it)
```

```
    else:
        value = initializer
    for element in it:
        value = function(value, element)
    return value
```

@functools.**singledispatch**(*default*)

Transforms a function into a *single-dispatch generic function*.

To define a generic function, decorate it with the `@singledispatch` decorator. Note that the dispatch happens on the type of the first argument, create your function accordingly:

```
>>> from functools import singledispatch
>>> @singledispatch
... def fun(arg, verbose=False):
...     if verbose:
...         print("Let me just say,", end=" ")
...     print(arg)
```

To add overloaded implementations to the function, use the `register()` attribute of the generic function. It is a decorator, taking a type parameter and decorating a function implementing the operation for that type:

```
>>> @fun.register(int)
... def _(arg, verbose=False):
...     if verbose:
...         print("Strength in numbers, eh?", end=" ")
...     print(arg)
...
>>> @fun.register(list)
... def _(arg, verbose=False):
...     if verbose:
...         print("Enumerate this:")
...     for i, elem in enumerate(arg):
...         print(i, elem)
```

To enable registering lambdas and pre-existing functions, the `register()` attribute can be used in a functional form:

```
>>> def nothing(arg, verbose=False):
...     print("Nothing.")
...
>>> fun.register(type(None), nothing)
```

The `register()` attribute returns the undecorated function which enables decorator stacking, pickling, as well as creating unit tests for each variant independently:

```
>>> @fun.register(float)
... @fun.register(Decimal)
... def fun_num(arg, verbose=False):
...     if verbose:
...         print("Half of your number:", end=" ")
...     print(arg / 2)
...
>>> fun_num is fun
False
```

When called, the generic function dispatches on the type of the first argument:

```
>>> fun("Hello, world.")
Hello, world.
>>> fun("test.", verbose=True)
Let me just say, test.
>>> fun(42, verbose=True)
Strength in numbers, eh? 42
>>> fun(['spam', 'spam', 'eggs', 'spam'], verbose=True)
Enumerate this:
0 spam
1 spam
2 eggs
3 spam
>>> fun(None)
Nothing.
>>> fun(1.23)
0.615
```

Where there is no registered implementation for a specific type, its method resolution order is used to find a more generic implementation. The original function decorated with `@singledispatch` is registered for the base `object` type, which means it is used if no better implementation is found.

To check which implementation will the generic function choose for a given type, use the `dispatch()` attribute:

```
>>> fun.dispatch(float)
<function fun_num at 0x1035a2840>
>>> fun.dispatch(dict)    # note: default implementation
<function fun at 0x103fe0000>
```

To access all registered implementations, use the read-only `registry` attribute:

```
>>> fun.registry.keys()
dict_keys([<class 'NoneType'>, <class 'int'>, <class 'object'>,
          <class 'decimal.Decimal'>, <class 'list'>,
          <class 'float'>])
>>> fun.registry[float]
<function fun_num at 0x1035a2840>
>>> fun.registry[object]
<function fun at 0x103fe0000>
```

New in version 3.4.

functools.**update_wrapper**(*wrapper*, *wrapped*, *assigned=WRAPPER_ASSIGNMENTS*, *updated=WRAPPER_UPDATES*)

Update a *wrapper* function to look like the *wrapped* function. The optional arguments are tuples to specify which attributes of the original function are assigned directly to the matching attributes on the wrapper function and which attributes of the wrapper function are updated with the corresponding attributes from the original function. The default values for these arguments are the module level constants *WRAPPER_ASSIGNMENTS* (which assigns to the wrapper function's *__name__*, *__module__*, *__annotations__* and *__doc__*, the documentation string) and *WRAPPER_UPDATES* (which updates the wrapper function's *__dict__*, i.e. the instance dictionary).

To allow access to the original function for introspection and other purposes (e.g. bypassing a caching decorator such as `lru_cache()`), this function automatically adds a `__wrapped__` attribute to the wrapper that refers to the function being wrapped.

The main intended use for this function is in *decorator* functions which wrap the decorated function and return the wrapper. If the wrapper function is not updated, the metadata of the returned function will reflect the wrapper definition rather than the original function definition, which is typically less than helpful.

`update_wrapper()` may be used with callables other than functions. Any attributes named in *assigned* or *updated* that are missing from the object being wrapped are ignored (i.e. this function will not attempt to set them on the wrapper function). `AttributeError` is still raised if the wrapper function itself is missing any attributes named in *updated*.

New in version 3.2: Automatic addition of the `__wrapped__` attribute.

New in version 3.2: Copying of the `__annotations__` attribute by default.

Changed in version 3.2: Missing attributes no longer trigger an `AttributeError`.

Changed in version 3.4: The `__wrapped__` attribute now always refers to the wrapped function, even if that function defined a `__wrapped__` attribute. (see issue 17482)

`@functools.`**`wraps`**(*wrapped*, *assigned=WRAPPER_ASSIGNMENTS*, *updated=WRAPPER_UPDATES*)

This is a convenience function for invoking `update_wrapper()` as a function decorator when defining a wrapper function. It is equivalent to `partial(update_wrapper, wrapped=wrapped, assigned=assigned, updated=updated)`. For example:

```
>>> from functools import wraps
>>> def my_decorator(f):
...     @wraps(f)
...     def wrapper(*args, **kwds):
...         print('Calling decorated function')
...         return f(*args, **kwds)
...     return wrapper
...
>>> @my_decorator
... def example():
...     """Docstring"""
...     print('Called example function')
...
>>> example()
Calling decorated function
Called example function
>>> example.__name__
'example'
>>> example.__doc__
'Docstring'
```

Without the use of this decorator factory, the name of the example function would have been `'wrapper'`, and the docstring of the original `example()` would have been lost.

10.2.1. `partial` Objects

`partial` objects are callable objects created by `partial()`. They have three read-only attributes:

`partial.`**`func`**

A callable object or function. Calls to the `partial` object will be forwarded to `func` with new arguments and keywords.

`partial.`**`args`**

The leftmost positional arguments that will be prepended to the positional arguments provided to a `partial` object call.

`partial.`**`keywords`**

The keyword arguments that will be supplied when the `partial` object is called.

`partial` objects are like `function` objects in that they are callable, weak referencable, and can have attributes. There are some important differences. For instance, the `__name__` and `__doc__` attributes are not created automatically. Also, `partial` objects defined in classes behave like static methods and do not transform into bound methods during instance attribute look-up.