heapq – Heap Sort Algorithm

Purpose: The heapq implements a min-heap sort algorithm suitable for use with Python’s lists.

A *heap* is a tree-like data structure in which the child nodes have a sort-order relationship with the parents. *Binary heaps* can be represented using a list or array organized so that the children of element N are at positions 2 * *N* + 1 and 2 * *N* + 2 (for zero-based indexes). This layout makes it possible to rearrange heaps in place, so it is not necessary to reallocate as much memory when adding or removing items.

A max-heap ensures that the parent is larger than or equal to both of its children. A min-heap requires that the parent be less than or equal to its children. Python’s heapq module implements a min-heap.

Example Data

The examples in this section use the data in heapq_heapdata.py.

```
# heapq_heapdata.py

# This data was generated with the random module.

data = [19, 9, 4, 10, 11]
```

The heap output is printed using heapq_showtree.py.

```
# heapq_showtree.py

import math
from io import StringIO


def show_tree(tree, total_width=36, fill=' '):
    """Pretty-print a tree."""
    output = StringIO()
    last_row = -1
    for i, n in enumerate(tree):
        if i:
            row = int(math.floor(math.log(i + 1, 2)))
        else:
            row = 0
        if row != last_row:
            output.write('\n')
        columns = 2 ** row
        col_width = int(math.floor(total_width / columns))
        output.write(str(n).center(col_width, fill))
        last_row = row
    print(output.getvalue())
    print('-' * total_width)
    print()
```

Creating a Heap

There are two basic ways to create a heap: heappush() and heapify().

```
# heapq_heappush.py

import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

heap = []
print('random :', data)
print()
print()

for n in data:
    print('add {:>3}:'.format(n))
    heapq.heappush(heap, n)
    show_tree(heap)
```

When heappush() is used, the heap sort order of the elements is maintained as new items are added from a data source.

```
$ python3 heapq_heappush.py

random : [19, 9, 4, 10, 11]

add  19:

                 19
------------------------------------

add   9:

                 9
        19
------------------------------------

add   4:

                 4
        19                9
------------------------------------

add  10:

                 4
        10                9
    19
------------------------------------

add  11:

                 4
        10                9
    19       11
------------------------------------
```

If the data is already in memory, it is more efficient to use heapify() to rearrange the items of the list in place.

```
# heapq_heapify.py

import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

print('random    :', data)
heapq.heapify(data)
print('heapified :')
show_tree(data)
```

The result of building a list in heap order one item at a time is the same as building an unordered list and then calling heapify().

```
$ python3 heapq_heapify.py

random    : [19, 9, 4, 10, 11]
heapified :

                 4
        9                 19
    10       11
------------------------------------
```

Accessing the Contents of a Heap

Once the heap is organized correctly, use heappop() to remove the element with the lowest value.

```
# heapq_heappop.py

import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

print('random    :', data)
heapq.heapify(data)
print('heapified :')
show_tree(data)
print()

for i in range(2):
    smallest = heapq.heappop(data)
    print('pop    {:>3}:'.format(smallest))
    show_tree(data)
```

In this example, adapted from the stdlib documentation, heapify() and heappop() are used to sort a list of numbers.

```
$ python3 heapq_heappop.py

random    : [19, 9, 4, 10, 11]
heapified :

                 4
        9                 19
    10       11
------------------------------------


pop      4:

                 9
        10                19
    11
------------------------------------

pop      9:

                 10
        11                19
------------------------------------
```

To remove existing elements and replace them with new values in a single operation, use heapreplace().

```
# heapq_heapreplace.py

import heapq
from heapq_showtree import show_tree
from heapq_heapdata import data

heapq.heapify(data)
print('start:')
show_tree(data)

for n in [0, 13]:
    smallest = heapq.heapreplace(data, n)
    print('replace {:>2} with {:>2}:'.format(smallest, n))
    show_tree(data)
```

Replacing elements in place makes it possible to maintain a fixed-size heap, such as a queue of jobs ordered by priority.

```
$ python3 heapq_heapreplace.py

start:
```

```
start:

                 4
        9                 19
    10       11
------------------------------------

replace  4 with  0:

                 0
        9                 19
    10       11
------------------------------------

replace  0 with 13:

                 9
        10                19
    13       11
------------------------------------
```

Data Extremes from a Heap

heapq also includes two functions to examine an iterable and find a range of the largest or smallest values it contains.

```
# heapq_extremes.py

import heapq
from heapq_heapdata import data

print('all       :', data)
print('3 largest :', heapq.nlargest(3, data))
print('from sort :', list(reversed(sorted(data)[-3:])))
print('3 smallest:', heapq.nsmallest(3, data))
print('from sort :', sorted(data)[:3])
```

Using `nlargest()` and `nsmallest()` is efficient only for relatively small values of *n* > 1, but can still come in handy in a few cases.

```
$ python3 heapq_extremes.py

all       : [19, 9, 4, 10, 11]
3 largest : [19, 11, 10]
from sort : [19, 11, 10]
3 smallest: [4, 9, 10]
from sort : [4, 9, 10]
```

Efficiently Merging Sorted Sequences

Combining several sorted sequences into one new sequence is easy for small data sets.

```
list(sorted(itertools.chain(*data)))
```

For larger data sets, this technique can use a considerable amount of memory. Instead of sorting the entire combined sequence, `merge()` uses a heap to generate a new sequence one item at a time, determining the next item using a fixed amount of memory.

```
# heapq_merge.py

import heapq
import random


random.seed(2016)

data = []
for i in range(4):
    new_data = list(random.sample(range(1, 101), 5))
    new_data.sort()
    data.append(new_data)

for i, d in enumerate(data):
    print('{}: {}'.format(i, d))

print('\nMerged:')
for i in heapq.merge(*data):
    print(i, end=' ')
print()
```

Because the implementation of `merge()` uses a heap, it consumes memory based on the number of sequences being merged, rather than the number of items in those sequences.

```
$ python3 heapq_merge.py

0: [33, 58, 71, 88, 95]
1: [10, 11, 17, 38, 91]
2: [13, 18, 39, 61, 63]
3: [20, 27, 31, 42, 45]

Merged:
10 11 13 17 18 20 27 31 33 38 39 42 45 58 61 63 71 88 91 95
```

See also

- Standard library documentation for heapq
- Wikipedia: Heap (data structure) – A general description of heap data structures.
- Priority Queue – A priority queue implementation from Queue in the standard library.

array — Sequence of Fixed-type Data

bisect — Maintain Lists in Sorted Order

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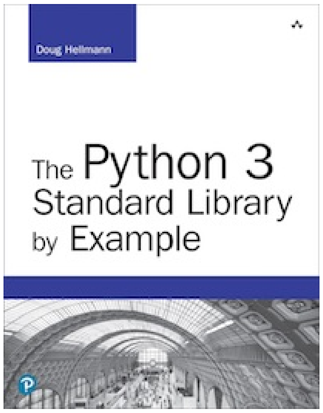

The output from all the example programs from PyMOTW-3 has been generated with Python 3.7.1, unless otherwise noted. Some of the features described here may not be available in earlier versions of Python.

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