Introduction to Programming in Python

Algorithms and Data Structures: Searching and Sorting

Outline

Searching

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The search problem involves searching for a key in a collection of n keys

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Linear search

</> linearsearch.py

```
from instream import InStream
import stdio
import sys

def indexOf(a, key):
    for i in range(len(a)):
        if a[i] == key:
            return i
    return -1

def _main():
    inStream = InStream(sys.argv[1])
    whiteList = inStream.readAllInts()
    while not stdio.isEmpty():
        key = stdio.readInt()
        if indexOf(whiteList, key) == -1:
            stdio.writeln(key)

if __name__ == '__main__':
    _main()
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```

Running time: $T(n) = n$ (linear)

Searching

Searching

```
>_ ~/workspace/ipp/programs

$ /usr/bin/time --format='%e seconds' python3 linearsearch.py ../data/tinyW.txt < ../data/tinyT.txt
50
99
13
0.05 seconds
$ /usr/bin/time --format='%e seconds' python3 linearsearch.py ../data/largeW.txt < ../data/largeT.txt
Takes way too long
```

Searching

Searching

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	11	12	16	18	23	29	33	48	54	57	68	77	84	98

item = 23

Searching

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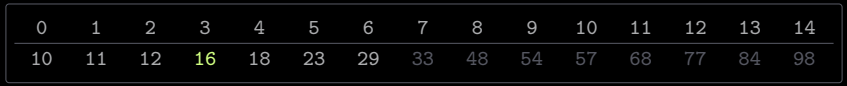
Searching



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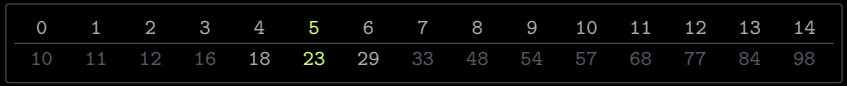

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Searching

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item = 50

Searching

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	11	12	16	18	23	29	33	48	54	57	68	77	84	98

item = 50

Searching

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10	11	12	16	18	23	29	33	48	54	57	68	77	84	98

item = 50

Searching

Searching

</> binarysearch.py

```
from instream import InStream
import stdio
import sys

def indexOf(a, key):
    lo = 0
    hi = len(a) - 1
    while lo <= hi:
        mid = (lo + hi) // 2
        if key < a[mid]:
            hi = mid - 1
        elif key > a[mid]:
            lo = mid + 1
        else:
            return mid
    return -1

def _main():
    inStream = InStream(sys.argv[1])
    whiteList = inStream.readAllInts()
    whiteList.sort()
    while not stdio.isEmpty():
        key = stdio.readInt()
        if indexOf(whiteList, key) == -1:
            stdio.writeln(key)

if __name__ == '__main__':
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```

Searching

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50
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0.05 seconds
$ /usr/bin/time --format='%e seconds' python3 binarysearch.py ../data/largeW.txt < ../data/largeT.txt
...
29798919
9505145
32449528
38862597
69830567
75.47 seconds
```

Searching

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...
29798919
9505145
32449528
38862597
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75.47 seconds
```

Running time: $T(n) = \log n$ (logarithmic)

Sorting

Sorting

The sort problem involves rearranging a sequence of objects so as to put them in some logical order

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Insertion sort is similar to sorting a bridge hand — consider the cards one at a time, inserting each into its proper place among those already considered

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Insertion sort is similar to sorting a bridge hand — consider the cards one at a time, inserting each into its proper place among those already considered

Running tiime: $T(n) = n^2$ (quadratic)

Sorting

Sorting

</> insertion.py

```
import stdio
import sys

def sort(a, key=None):
    n = len(a)
    for i in range(1, n):
        for j in range(i, 0, -1):
            v, w = a[j], a[j - 1]
            if key:
                v, w = key(v), key(w)
            if v >= w:
                break
            _exchange(a, j, j - 1)

def _exchange(a, i, j):
    temp = a[i]
    a[i] = a[j]
    a[j] = temp

def _main():
    a = stdio.readAllStrings()
    if sys.argv[1] == '-':
        sort(a, key=lambda x: x.lower())
    elif sys.argv[1] == '+':
        sort(a)
    else:
        raise Exception('Illegal command-line argument')
    for s in a:
        stdio.write(s + ' ')
    stdio.writeln()

if __name__ == '__main__':
    _main()
```

Sorting

Sorting

```
>_ ~/workspace/ipp/programs

$ python3 insertion.py -
I n s e r t i o n S o r t
<ctrl-d>
e I i n n o o r r s S t t
$ python3 insertion.py +
I n s e r t i o n S o r t
<ctrl-d>
I S e i n n o o r r s t t
```

Sorting

Sorting

Merge sort is based on a simple operation known as merging: combining two ordered lists to make one larger ordered list

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To sort a list, we divide it into two halves, sort the two halves recursively, and then merge the results

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Merge sort is based on a simple operation known as merging: combining two ordered lists to make one larger ordered list

To sort a list, we divide it into two halves, sort the two halves recursively, and then merge the results

input	M	E	R	G	E	S	O	R	T	E	X	A	M	P	L	E
sort left half	E	E	G	M	O	R	R	S	T	E	X	A	M	P	L	E
sort right half	E	E	G	M	O	R	R	S	A	E	E	L	M	P	T	X
merge results	A	E	E	E	E	G	L	M	M	O	P	R	R	S	T	X

Running time: $T(n) = n \log n$ (linearithmic)

Sorting

Sorting

</> merge.py

```
import stdarray
import stdio
import sys

def sort(a, key=None):
    aux = stdarray.create1D(len(a), None)
    _sort(a, aux, 0, len(a) - 1, key)

def _sort(a, aux, lo, hi, key=None):
    if hi <= lo:
        return
    mid = lo + (hi - lo) // 2
    _sort(a, aux, lo, mid, key)
    _sort(a, aux, mid + 1, hi, key)
    _merge(a, aux, lo, mid, hi, key)

def _merge(a, aux, lo, mid, hi, key=None):
    for k in range(lo, hi + 1):
        aux[k] = a[k]
    i, j = lo, mid + 1
    for k in range(lo, hi + 1):
        if i > mid:
            a[k] = aux[j]
            j += 1
        elif j > hi:
            a[k] = aux[i]
            i += 1
        else:
            v, w = aux[i], aux[j]
            if key:
                v, w = key(v), key(w)
            if w < v:
                a[k] = aux[j]
                j += 1
            else:
```

Sorting

</> merge.py

```
                a[k] = aux[i]
                i += 1

def _main():
    a = stdio.readAllStrings()
    if sys.argv[1] == '-':
        sort(a, key=lambda x: x.lower())
    elif sys.argv[1] == '+':
        sort(a)
    else:
        raise Exception('Illegal command-line argument')
    for s in a:
        stdio.write(s + ' ')
    stdio.writeln()

if __name__ == '__main__':
    _main()
```

Sorting

Sorting

```
>_ ~/workspace/ipp/programs
```

```
$ python3 merge.py -
M e r g e S o r t
M e e g r S o r t
$ python3 merge.py +
M e r g e S o r t
M S e e g o r r t
```