Fundamentos de Programação

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Summary

- Searching
  - Sequential search
  - Binary search
- Sorting
- Functions as arguments
- Lambda expressions

Searching

- Searching for an element X in a list L (or some other sequence) is a common operation in many problems.
  - Sometimes we just need to check if the element is there.(*)

    In Python, we can do this with: `X in L`
  - Other times we need to know where it is.

    In Python, we can do this with: `L.index(X)`
- These operations are simple, but they can be **expensive**: it takes time (and energy) to search a very large list!

(*) Note that if all we need is checking membership, then using a set or a dictionary is much faster than a list!

Sequential search

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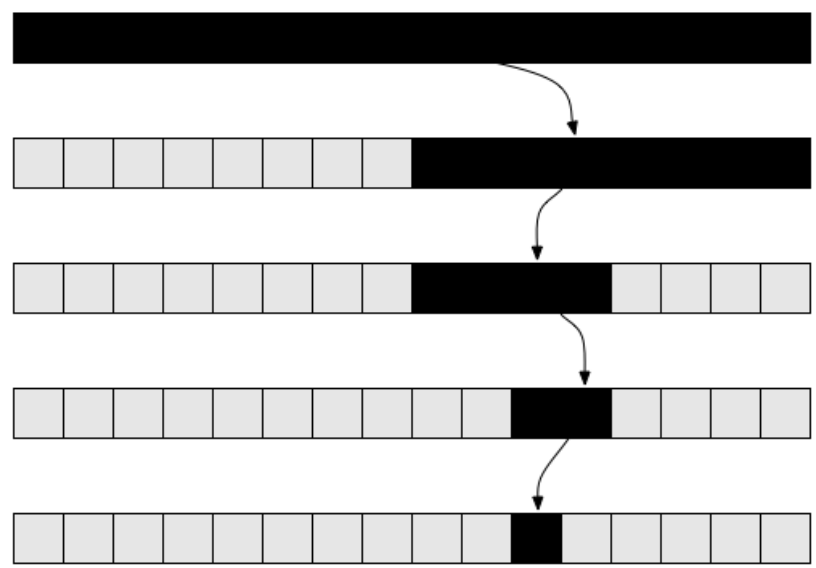
- A **sequential search** scans a list from start to end (or the from the end to the start).

```python
def seqSearch(lst, x):
    """Return k such that x == lst[k], or None if no such k."""
    for i in range(len(lst)):
        if x == lst[i]:
            return i
    return None
```

- This is what the list `index` method and the `in` operator do.
- Finding an element in a list of length N requires up to N comparisons.

Binary search

- If the list is sorted, `L[0]<=L[1]<=… <=L[-1]`, there's a much better way to search!
  1. Compare X to the middle element of L.
  2. If X is smaller, search only in the first half of L.
  3. If X is larger, search only in the second half.
- This is the **binary search** algorithm.
- This is much better:
  - N=15 => just 4 comparisons.
  - N=31 => 5 comparisons
  - N ~ 1 thousand => 10 comparisons.
  - N ~ 1 million => 20 comparisons!
- If N < 2**k => k comparisons.



Binary search (2)

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- Binary search for exact match (stops when equal).

```
def binSearchExact(lst, x):
    """Find k such that x == lst[k]. (Or None if no such k.)"""
    first = 0               # first index that could be solution
    last = len(lst)         # first index that cannot be solution
    while first < last:
        mid = (first+last)//2
        if x < lst[mid]:
            last = mid
        elif x > lst[mid]:
            first = mid+1
        else:
            return mid
    return None
```

- This works exactly like `seqSearch`, but much faster!
- But we can make it faster yet, with a minor modification.

Binary search (3)

- Binary search. (Equivalent to `bisect.bisect_left`.)

```
def binSearch(lst, x):
    """Find k such that: lst[k-1] < x <= lst[k] (not quite!)."""
    first = 0             # first index that can be result
    last = len(lst)       # last index that can be result
    while first < last:
        mid = (first+last)//2
        if x <= lst[mid]:       # (just 1 comparison inside loop!)
            last = mid
        else:
            first = mid+1
    return first
```

- If x is not found, still returns index k of where x should be!
- If k<len(lst) and x == lst[k], then we know x was found.
- This is slightly faster, in general.

Sorting

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- A sorted list is much faster to search.
- Sorting is putting the elements of a list in order.
- In Python, use the `sorted` function or the list `sort` method.

```
L.sort()          # Modifies L in-place
L2 = sorted(L)    # Creates L2. L is not modified!
```

- `sorted` returns a list, but takes any kind of collection.

```
sorted('banana')  #-> ['a', 'a', 'a', 'b', 'n', 'n']
L = [9, 7, 2, 8, 5, 3]
print(sorted(L))   #-> [2, 3, 5, 7, 8, 9]
L = ["maria", "carla", "anabela", "antonio", "nuno"]
print(sorted(L))
  #-> ['anabela', 'antonio', 'carla', 'maria', 'nuno']
```

Sorting criteria

- These functions can sort by different criteria.

```
L = ["Mario", "Carla", "anabela", "Maria", "nuno"]
print(sorted(L))  # lexicographic sort
  #-> ['Carla', 'Maria', 'Mario', 'anabela', 'nuno']
print(sorted(L, key=len))  # sort by length
  #-> ['nuno', 'Mario', 'Carla', 'Maria', 'anabela']
print(sorted(L, key=str.lower))
  #-> ['anabela', 'Carla', 'Maria', 'Mario', 'nuno']
```

- The optional `key` argument receives a function to sort the elements by.
- The key function is applied to each element and results are compared.
- There is also a `reversed` optional argument.

Sorting complex data

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- Lists of tuples can be sorted, too.

```
dates = [(1910, 10, 5, 'Republic'),
         (1974, 4, 25, 'Liberty'),
         (1640, 12, 1, 'Independence')]
print(sorted(dates))  # "lexicographic" order
```

- Tuples are compared like strings: left-to-right.
- For a different order, use the `key` argument.

```
sorted(dates, key=lambda t: t[3])  #by name
sorted(dates, key=lambda t:(t[1],t[2])) #by month,day
```

- We're using lambda expressions here!

Lambda expressions

- **Lambda expressions** are define anonymous functions.

```
sq = lambda x: x**2
sq(5)   #-> 25
add = lambda x,y: x+y
```

```
# Same as:
def sq(x):
    return x**2
```

- Result must be an expression. No statements allowed!
- Should only be used for simple functions.
- They're useful to pass as arguments (such as key=...).
- Exercise: use a lambda expression to sort names by length, then alphabetically.

```
sorted(L, key=lambda s: (len(s),s))
  #-> ['nuno', 'Carla', 'Maria', 'Mario', 'anabela']
```

Insertion sort

- The insertion sort algorithm:
  1. Assume the first K elements are sorted. L[K] is not.
  2. Save L[K] in T.
  3. Move every L[J]>T to L[J+1], starting from J=K-1 down.
  4. Put T into the vacant slot.
  5. Now, increment K and repeat.