COMP 364: Computer Tools for Life Sciences

Algorithm design: Linear and Binary Search

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Key course information

Quiz #4 will be available on Monday!

- available on MyCourses (multiple choice questions)
- Quiz #4 closes at 11:59:59 pm on Monday, October 16th
- questions cover topics from the last two weeks

Midterm

- October 24, 2017 at 7:05-9:05 PM. Location: ENGMC 204
- multiple choice, short answer, and long answer questions
- covers course material until Wednesday, October 18th
- one 8x11 double-sided cheat sheet is allowed
- TAs will hold review sessions (TBA)

What are algorithms?

"The machine learning algorithm wants to know if we'd like a dozen wireless mice to feed the Python book we just bought."

Who is putting all the Algorithm books in the horror section?"

Algorithms

Algorithm (noun): word used by programmers when they do not want to explain what they did

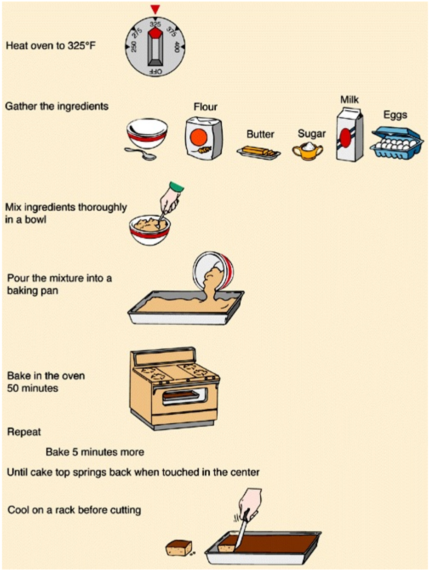
What are they really?

An **algorithm** is a predetermined series of instructions for carrying out a task in a finite number of steps

- or a recipe

Input $\rightarrow$ algorithm $\rightarrow$ output

Example algorithm: baking a cake



Heat oven to 325°F
325
375
400
275
250
OFF
Gather the ingredients
Flour
Butter
Sugar
Milk
Eggs
Mix ingredients thoroughly in a bowl
Pour the mixture into a baking pan
Bake in the oven 50 minutes
Repeat
Bake 5 minutes more
Until cake top springs back when touched in the center
Cool on a rack before cutting

What is the input?

algorithm?

output?

Pseudocode

Pseudocode is an artificial and informal language that helps programmers develop algorithms

- a text-based detail design tool

The rules of Pseudocode

1. you do not talk about Pseudocode
2. you do not talk about Pseudocode
3. ...

Whops, wrong rule set

General rules of Pseudocode

All statements showing **dependency** are to be indented

- includes while, do, for, if, else

Given proper input descriptions, pseudocode

- should be in sufficient detail to directly support the programming effort
- is meant to elaborate on the algorithmic detail and not just cite an abstraction
- should be in prose (not full sentences)

Example Python statements

```python
students = ["Kris", "David", "JC", "Emmanuel"]
grades = [75, 90, 45, 100]
for student, grade in zip(students, grades):
    if grade >= 60:
        print(student, "has passed")
    else:
        print(student, "has failed")
#output:
#Kris has passed
#David has passed
#JC has failed
#Emmanuel has passed
```

Example psuedocode

Algorithm 1 Student assessment

```
1: for each student do
2:     if student's grade $\geq$ 60 then
3:         print 'student has passed'
4:     else
5:         print 'student has failed'
6:     end if
7: end for
```

Search algorithms

Search algorithms locate an item in a data structure

- **Sorting** algorithms will be covered next lecture

Input: a list of (un)sorted items and value of item to be searched

Algorithms: linear and binary search algorithms will be covered

- images if search algorithms taken from: `http://www.tutorialspoint.com/data_structures_algorithms/`

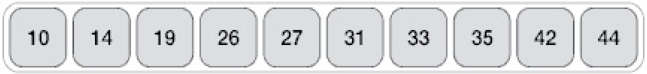
Output: if value is found in the list, return index of item

Linear search

A very simple search algorithm

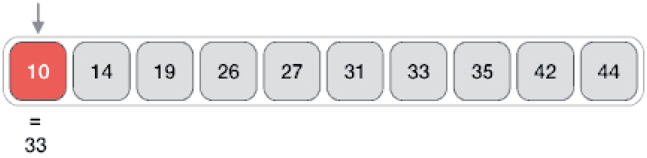
- a sequential search is made over all items one by one
- every item is checked
- if a match is found, then that particular item is returned
- otherwise the search continues until the end of the sequence

Example: search for the item with value 33

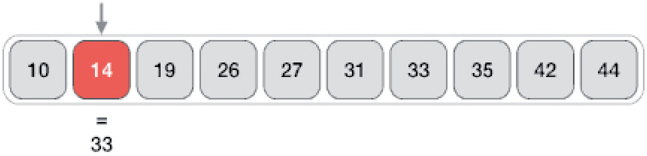


Linear search #2

Starting with the first item in the sequence:

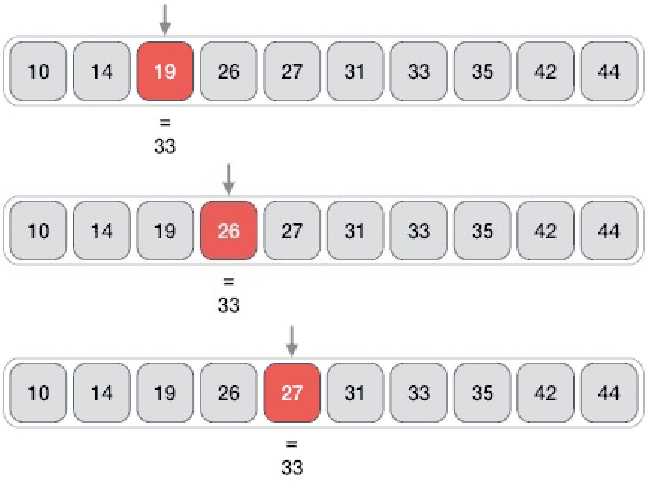


Then the next:



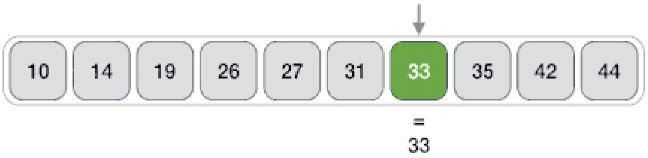
Linear search #3

And so on and so on...



Linear search #4

Until an item with a matching value is found:



If no item has a matching value, the search continues until the end of the sequence

Linear search: pseudocode

Algorithm 2 Linear search

```
1: procedure LINEAR_SEARCH(sequence, value)
2:     for each item in sequence do
3:         if item == value then
4:             return item's location
5:         end if
6:     end for
7: end procedure
```

Linear search: algorithm

Linear search (*sequence*, *value*)

```
Step 1 - set index to 0
Step 2 - if $index > N_{sequence}$ then go to Step 7
Step 3 - if $sequence[index] == value$ then go to Step 6
Step 4 - increase index by 1
Step 5 - go to Step 2
Step 6 - return value is found at index
Step 7 - return value not found
```

Linear search: Python implementation

```python
def linear_search(sequence, value):
    index = 0
    found = False
    N = len(sequence)
    while index < N and not found:
        if sequence[index] == value:
            found = True
        index += 1

    if found:
        return str(value)+" is found at "+str(index)
    else:
        return str(value)+" not found"
```

Binary search

A fast search algorithm (compared to linear)

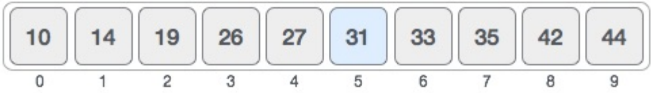
- works on the principle of ‘divide and conquer’
- the sequence of items must be sorted

Looks for a particular item

- by comparing the middle most item first
- if a match occurs, then the index of item is returned
- if the middle item is greater than the item, then the item is searched in the sub-list to the left
- otherwise, the item is searched for in the sub-list to the right
- this continues until the size of the sub-list reduces to zero

Binary search #2

Example: let's search for the value 31 in the following sorted sequence



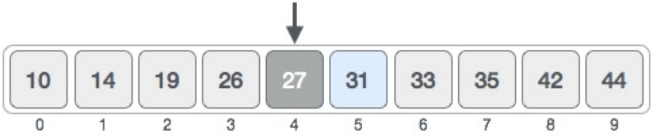
First, we need to determine the middle item:

```python
sequence = [10, 14, 19, 26, 27, 31, 33, 35, 42, 44]
low = 0
high = len(sequence) - 1
mid = low + (high-low)/2     # integer division
print (mid) # prints: 4
```

Binary search #3

Since *index* = 4 is the midpoint of the sequence

- we compare the value stored (27)
- against the value being searched (31)

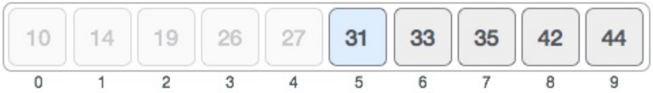


The value at index 4 is 27, which is not a match

- the value being search is greater than 27
- since we have a sorted array
- we know that the target value can only be in the upper portion of the list

Binary search #4

low is changed to *mid* + 1



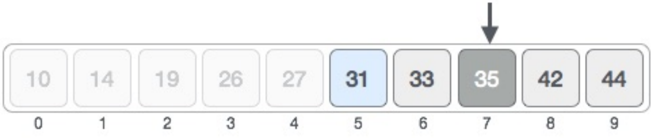
Now, we find the new *mid* First, we need to determine the middle item:

```
low = mid + 1    # 5
mid = low + (high-low)/2     # integer division
print (mid) # prints: 7
```

Binary search #4

mid is 7 now

- compare the value stored at index 7 with our value being searched (31)



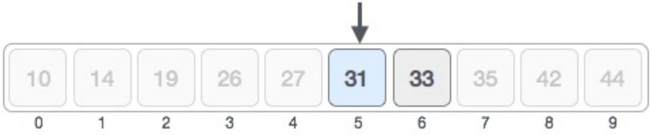
The value stored at location 7 is not a match

- 35 is greater than 31
- since it's a sorted list, the value must be in the lower half
- set *high* to *mid* - 1

Binary search #5

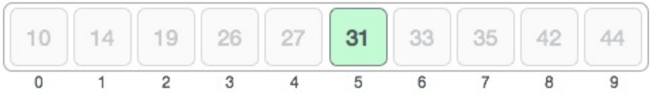
Calculate the mid again

- *mid* is now equal to 5



We compare the value stored at index 5 with our value being searched (31)

- It is a match!



Binary search #6

Remember,

- binary search halves the searchable items
- improves upon linear search, but...
- requires a sorted collection

Useful links

bisect - Python module that implements binary search

- `https://docs.python.org/2/library/bisect.html`

Visualization of binary search

- `http://interactivepython.org/runestone/static/pythonds/SortSearch/TheBinarySearch.html`

Binary search: pseudocode

Algorithm 3 Binary search

```
procedure BINARY_SEARCH($sequence$, $value$)
    $low, high = 0, N_{sequence}$-1
    while $low \leq high$ do
        $mid = (low + high) / 2$
        if $sequence[mid] > value$ then
            $high = mid$ - 1
        else if $sequence[mid] < value$ then
            $low = mid + 1$
        else
            return $mid$
        end if
    end while
    return ‘Not found’
end procedure
```

Binary search: algorithm

Binary search (*sequence*, *value*)

```
Step 1 - set low to 0
Step 2 - set high to $N_{sequence}$ - 1
Step 3 - if $low > high$, return 'Not found'
Step 4 - set mid to average of low and high
Step 5 - if $sequence[mid] == value$, return mid
Step 6 - if $sequence[mid] < value$,
         set low to $mid + 1$ and go to Step 3
Step 7 - if $sequence[mid] > value$,
         set high to mid - 1 and go to Step 3
```

Binary search: Python implementation

```python
def binary_search(sequence, value):
    low = 0
    high = len(sequence) - 1
    #....complete as homework
```