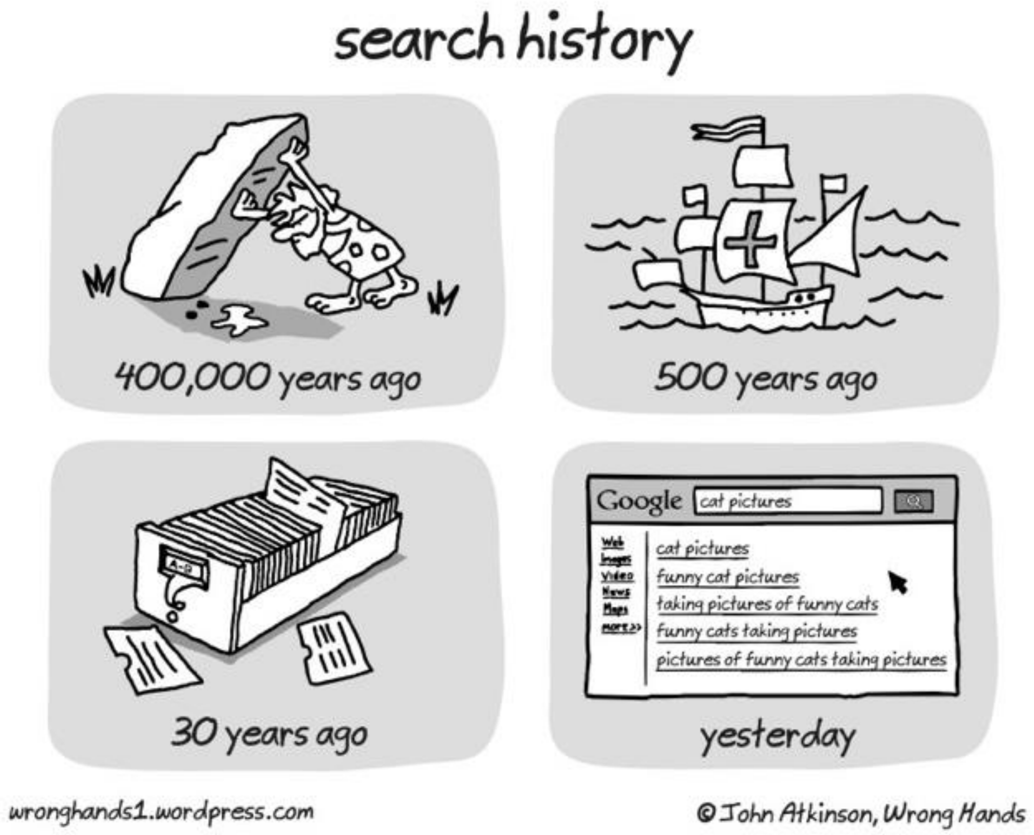
# CSc 110, Autumn 2017

Lecture 36: searching

Adapted from slides by Marty Stepp and Stuart Reges



# Sequential search

- **sequential search**: Locates a target value in a list by examining each element from start to finish. Used in `index`.
  - How many elements will it need to examine?
  - Example: Searching the list below for the value **42**:

| index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| value | -4 | 2 | 7 | 10 | 15 | 20 | 22 | 25 | 30 | 36 | 42 | 50 | 56 | 68 | 85 | 92 | 103 |

i

# Sequential search

- How many elements will be checked?

```
def index(value):
    for i in range(0, size):
        if my_list[i] == value:
            return i
    return -1    # not found
```

| index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| value | -4 | 2 | 7 | 10 | 15 | 20 | 22 | 25 | 30 | 36 | 42 | 50 | 56 | 68 | 85 | 92 | 103 |

- On average how many elements will be checked?

# Binary search

- **binary search**: Locates a target value in a *sorted* list by successively eliminating half of the list from consideration.
  - How many elements will it need to examine?
  - Example: Searching the list below for the value **42**:

| index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| value | -4 | 2 | 7 | 10 | 15 | 20 | 22 | 25 | 30 | 36 | 42 | 50 | 56 | 68 | 85 | 92 | 103 |

min mid max

# Binary search runtime

- For an list of size N, it eliminates ½ until 1 element remains.

  N, N/2, N/4, N/8, ..., 4, 2, 1

  - How many divisions does it take?

- Think of it from the other direction:
  - How many times do I have to multiply by 2 to reach N?

    1, 2, 4, 8, ..., N/4, N/2, N
  - Call this number of multiplications "x".

    $2^x = N$

    $\mathbf{x = \log_2 N}$

- Binary search looks at a **logarithmic** number of elements

# binary_search

Write the following two functions:

```
# searches an entire sorted list for a given value
# returns the index the value should be inserted at to maintain sorted
  order
# Precondition: list is sorted
binary_search(list, value)

# searches given portion of a sorted list for a given value
# examines min_index (inclusive) through max_index (exclusive)
# returns the index of the value or -(index it should be inserted at + 1)
# Precondition: list is sorted
binary_search(list, value, min_index, max_index)
```

# Using binary_search

```
# index 0  1  2  3   4   5   6   7   8   9  10  11  12  13  14  15
a  =  {-4, 2, 7, 9, 15, 19, 25, 28, 30, 36, 42, 50, 56, 68, 85, 92}

index1 = binary_search(a, 42)
index2 = binary_search(a, 21)
index3 = binary_search(a, 17, 0, 16)
index2 = binary_search(a, 42, 0, 10)
```

- `binary_search` returns the index of the number

or

- (index where the value should be inserted + 1)

# Binary search code

```
# Returns the index of an occurrence of target in a,
# or a negative number if the target is not found.
# Precondition: elements of a are in sorted order
def binary_search(a, target, start, stop):
    min = start
    max = stop - 1

    while min <= max:
        mid = (min + max) // 2
        if a[mid] < target:
            min = mid + 1
        elif a[mid] > target:
            max = mid - 1
        else:
            return mid    # target found

    return -(min + 1)     # target not found
```