

UNIVERSITY of WISCONSIN-MADISON  
Computer Sciences Department

CS 202: Introduction to Computation Professor Andrea Arpaci-Dusseau

## How can computation... find what you are looking for?



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I DON'T REMEMBER THE TITLE, BUT IT WAS ON A LITTLE PIECE OF WHITE PAPER.



The Max element is 976 at index 72

| Index | Value |
|-------|-------|
| 84    | 621   |
| 87    | 752   |
| 88    | 307   |
| 89    | 180   |
| 90    | 434   |
| 91    | 25    |
| 92    | 903   |
| 93    | 630   |
| 94    | 62    |
| 95    | 390   |
| 96    | 501   |
| 97    | 299   |
| 98    | 714   |
| 99    | 610   |
| 100   | 626   |

lengths: 100

## How to Make List with 100 Random Numbers?

Script: Create Valuable Numbers

- Puts result in List: Valuable Numbers
  - Contains 100 elements
  - Each element: Integer between 1 and 1000

```

when I receive Create Valuable Numbers
delete Valuable Numbers
repeat
insert pick random 1 to 1000 at last of Valuable Numbers
            
```

## How to plot contents of List?

## How to plot contents of List?

Same approach as drawing function for y

Just grab next value of y from list instead

```

when clicked
hide
pen up
clear
set Max X to 240
set Min X to 240
set counter to 1
broadcast Draw Function and wait

when I receive Draw Function
set pen color to blue
set Y to Min X
set counter to 1
set X to item counter of Random Numbers
go to x X y Y
pen down
repeat until X = Max X
set Y to item counter of Random Numbers
play note Y for 0.01 beats
go to x X y Y
change X by 1
change counter by 1

delete all of Random Numbers
repeat 400
add pick random 100 to 1000 to Random Numbers
            
```

## Check-Up

How many items can you put in a list?  
 How do you find the number of items in a list?  
 What is the difference:  
 What is the difference:  
 For the given list, what would this code do?

| Valuable Numbers |     |
|------------------|-----|
| 1                | 689 |
| 2                | 42  |
| 3                | 575 |
| 4                | 823 |
| 5                | 33  |
| 6                | 563 |
| 7                | 320 |
| 8                | 591 |
| 9                | 93  |
| 10               | 639 |
| 11               | 132 |
| 12               | 73  |
| 13               | 859 |
| 14               | 149 |
| 15               | 197 |

length: 100

## "Search" has many meanings

- Look up "name" in phonebook (get number)
- Find "credit-worthy" consumers in database
- Find web pages relevant to "computer music"
- Identify suspicious cell phone conversations originating in Country X
- Find the meaning of life
- Today: Very straight-forward
  - Find specified KEY in a LIST
  - Find maximum element in a LIST

## Search Demo

| Valuable Numbers |     |
|------------------|-----|
| 86               | 661 |
| 87               | 752 |
| 88               | 307 |
| 89               | 180 |
| 90               | 434 |
| 91               | 28  |
| 92               | 903 |
| 93               | 630 |
| 94               | 62  |
| 95               | 390 |
| 96               | 501 |
| 97               | 399 |
| 98               | 714 |
| 99               | 610 |
| 100              | 626 |

length: 100

## How can you find value in list?

**What does it mean to "find" value? (e.g. 93?)**  
 Know "index" (or location) of value in list (index = 9)

**What algorithm would you use?**

- Look at each item of list
  - Is this value looking for? Yes?
    - Done! No?
    - Look at next element
- Repeat for all elements of list
- If reach end and don't find?
  - Item not in list

**Robust to length of List**

- Should work for list of any length
- Not just 100 elements

## How to implement search?

- Look at each item of list
  - Is this value looking for?
    - Yes, done!
    - No, look at next element
- Repeat for all in list
- If reach end and don't find?
  - Item not in list
- Robust to any length

### Variables?

List of Valuable Numbers (input)  
 Key: Value searching for (input)  
 Key Index: Answer (output)  
 Index : Loop through List; tracks current location

```

when I receive Find Key
set index to 1
set Key Index to 0
repeat
    if item index of Valuable Numbers = Key
        set Key Index to index
        stop script
    change index by 1
    
```

## How to display matching Name?

Have corresponding Names list

Use Key Index to "index" into Name list

Take care to use broadcast and wait

- (and not just broadcast)
- Find Key script must finish to guarantee it has set value of "Key Index" variable

How do we know if Key not found?

- Key index is 0!

```

when clicked
broadcast Create Valuable Numbers and wait
ask What number should I search for? and wait
set Key to answer
broadcast Find Key and wait
if not Key Index = 0
    say join join The key Key join is located at index Key Index for 2 secs
    say join The matching name is item Key Index of Names
else
    say join join The key Key was not found!

when I receive Find Key
set index to 1
set Key Index to 0
repeat length of Valuable Numbers
    if item index of Valuable Numbers = Key
        set Key Index to index
        stop script
    change index by 1
    
```

## How can you find Max value in list?

How is this different than finding specified key?

- Don't know max value before start

How do you know found maximum?

- Greater than (or equal to) all others in list

Approach to finding maximum?

- Remember the largest seen so far
- If current key > current max, remember current key as new max

| Valuable Numbers |     |
|------------------|-----|
| 1                | 689 |
| 2                | 42  |
| 3                | 575 |
| 4                | 823 |
| 5                | 33  |
| 6                | 563 |
| 7                | 320 |
| 8                | 591 |
| 9                | 93  |
| 10               | 639 |
| 11               | 132 |
| 12               | 73  |
| 13               | 859 |
| 14               | 149 |
| 15               | 197 |

+ length: 100



## Similar Code Structure

### Find Key

```

when I receive Find Key
  set index to 1
  set Key Index to 0
  repeat length of Valuable Numbers
    if (item index of Valuable Numbers) = Key
      set Key Index to index
      stop script
  change index by 1
  
```

### Find Max

```

when I receive Find Max
  set Max to 0
  set index to 1
  set Max Index to 0
  repeat length of Valuable Numbers
    if (item index of Valuable Numbers) > Max
      set Max to (item index of Valuable Numbers)
      set Max Index to index
  change index by 1
  
```

**Similarities?**

Loop through List using "index" which starts at 1, increments by 1, thru length  
 Key Index or Max Index set to index where element is located

**Differences?**

Find Max: Uses Max to record current max (initialize to 0...)  
 Find Max: Must look through every element of list (don't stop early)

## Demo "Find Max"

## Linear Search

Summary: Examine all of the elements of list looking for a match; examine elements in order

Inefficient algorithm; why?

Efficiency (performance) really matters when millions or billions of elements!

## How efficient is an algorithm?

Option 1: Could run and measure how it takes

- Disadvantage: Depends on hardware
- Disadvantage: Don't know efficiency on different lists

Option 2: Can analyze code

- Count number of operations performed
- Advantage: Understand how behavior depends upon size of input
- Use  $N$  for number of elements in input (List)

## How many operations to find max?

Count number of Scratch blocks

Which blocks to count?  
Exclude reading variables

```

when I receive Find Max
  set Max to 0
  set index to 1
  set Max Index to 0
  repeat length of Valuable Numbers
    if item index of Valuable Numbers > Max
      set Max to item index of Valuable Numbers
      set Max Index to index
    change index by 1
  
```

How many blocks?

How many before loop?

- 3 blocks to start up

How many in loop?

- Assume worst-case (take if = true)
- Approx 6...

How many times is loop executed????

- N

Total: 3+7\*N blocks

- O(N) blocks
- # times loop executed, not # blocks in loop

Linear Search



## Check-Up



```

when I receive Find Max
  set Max to 0
  set index to 1
  set Max Index to 0
  repeat length of Valuable Numbers
    if item index of Valuable Numbers > Max
      set Max to item index of Valuable Numbers
      set Max Index to index
    change index by 1
  
```

What assumption does script make?

- Values in list > 0

How to implement "Find Min"?

- What to set Min to?
- Item 1 of Valuable Numbers

## Challenge Check-Up

What does this script do?

```

when I receive Create Valuable Numbers
  delete all of Valuable Numbers
  delete all of Names
  repeat 100
    add pick random 1 to 1000 to Valuable Numbers
    set One Name to 1
    repeat 5
      set One Name to join letter pick random 1 to 26 of abcdefghijklmnopqrstuvwxyz length: 100
    add One Name to Names
  
```

| Names |       |
|-------|-------|
| 1     | qpjap |
| 2     | ultnu |
| 3     | rmeto |
| 4     | zpkdz |
| 5     | vpfsk |
| 6     | rrdwr |
| 7     | wvmzw |
| 8     | kwrtz |
| 9     | yubki |
| 10    | lbeod |
| 11    | swvll |
| 12    | qfrrs |
| 13    | azxer |
| 14    | ekauu |
| 15    | khnzp |

Output:

- List: Valuable Numbers (100 elements)
- List: Names
  - 100 elements, each element is a 5 letter random string

## Announcements

Today's Topic: How to search (find value in List)

- Basic approach: Loop thru list using index variable, inc index by 1 til end
- How many ops to find element in List: O(N) with Linear Search

Announcements

- Exam 1 returned (Ave 90)
- Homework 5: Due Friday at 5pm
  - Compose Random Music (Save values to replay song in list!)
  - Visualization