122COM: Searching

David Croft

Coventry University

david.croft@coventry.ac.uk

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Overview

Introduction

Searching is used everywhere in computing.

- Obvious applications.
  - Text files.
  - Databases.
  - File systems.
- Hidden applications.
  - Computer games.
  - FOV search for objects in view.

Path finding

A

- Path finding algorithms in games
  - `https://www.youtube.com/watch?v=19h1g22hby8`
- Brute force approaches that find the best/shortest/fastest solution are too slow (travelling salesman).
- Heuristic aproaches are used instead.
  - Find ”good enough” solutions.
  - Not always the best solution.
  - Dijkstra’s algorithm.
  - A* algorithm.

Linear search

C

Simplest search.

- Also called sequential search.
- Iterate over elements.
- Until found or until end of sequence.
- Potentially slow.
- $O(n)$
  - Will discuss $O()$ notation in a later week.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	B	Z	Q	K	L	G	H	U	A	P	L	F	N	R
↑ Z														

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Binary search

I

Muuuuuuch faster than linear search.

- Divide & conquer.
- Only works on sorted sequences.
- Algorithm is:
  1. Find middle value of sequence.
  2. If search value == middle value then success.
  3. If search value is $<$ middle value then forget about the top half of the sequence.
  4. If search value is $>$ middle value then forget about the bottom half of the sequence.
  5. Repeat from step 1 until `len(sequence)==0`.

Binary search II

I

Find E.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O

Binary search II

I

Find E.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
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A	B	C	D	E	F	G	H	I	J	K	L	M	N	O

↑

A	B	C	D	E	F	G

H I J K L M N O

Binary search II

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Find E.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O

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Binary search II

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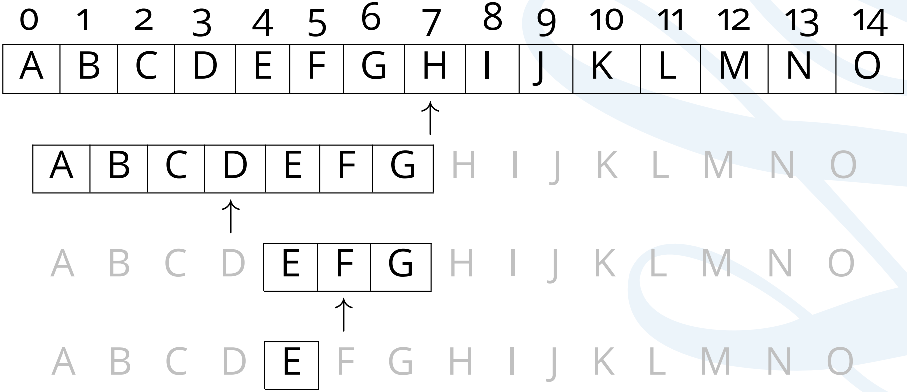
Find E.

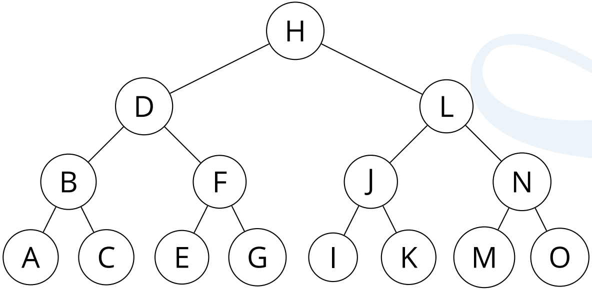


Complexity

A

How many comparisons do we need to do for binary search?

- How many times can we divide our list by 2?

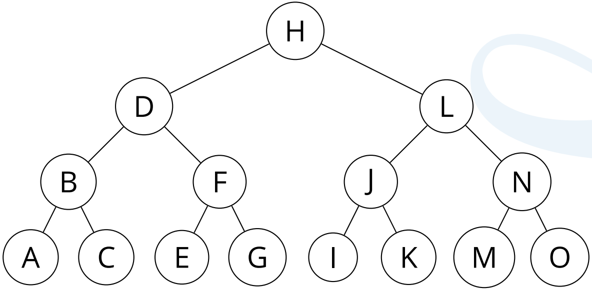


Complexity

A

How many comparisons do we need to do for binary search?

- How many times can we divide our list by 2?
- Ideally depth of tree is $\log_2(n)$
  - $n = 15$.
  - $\log_2(15) = 3.9 \Rightarrow 3$



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- How many times can we divide our list by 2?
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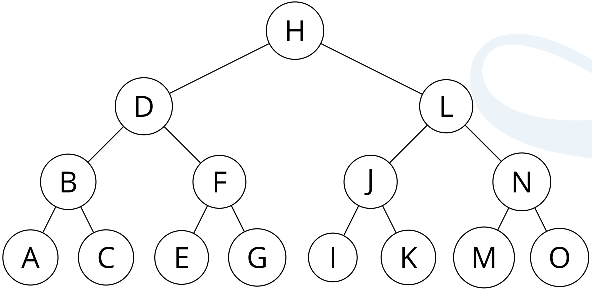
- Binary search has a complexity of $O(\log n)$.
  - Will cover $O()$ complexity in later week.



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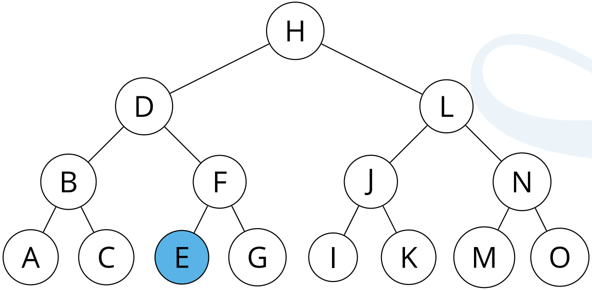

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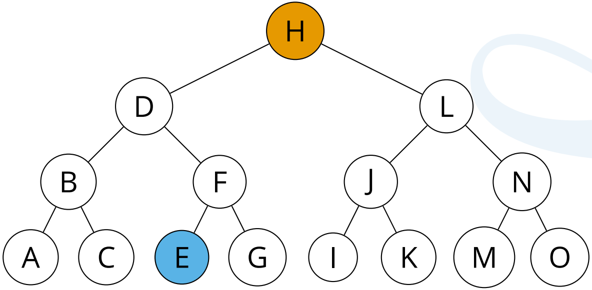

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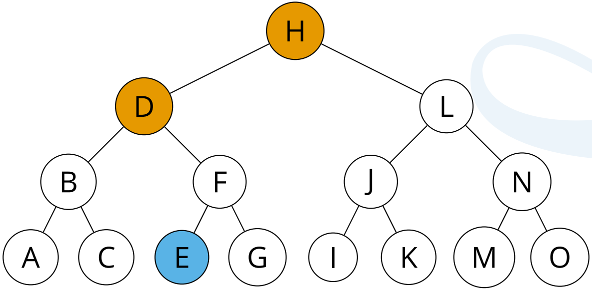

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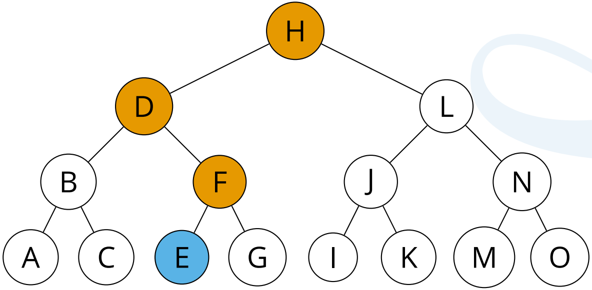

It's HOW much faster?!?!!

I

Clearly much faster than linear search.

- To search a trillion elements linearly could mean a trillion comparisons.
- 40 with binary search.

But...

- Have to sort the list first.
- Sorting lists can be expensive.
- Can't always sort sequences.
- Ordering is important.
- Cant always search for sequences.
  - Text documents.
  - Genetic codes.

String searching

C

I.e. Text searching.

- Finding one sequence in another sequence.
- Naive search.
  - Like linear search.
  - Is very slow.

text =	t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
search =	e	x	a	m	p	l	e											

t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
	e	x	a	m	p	l	e										

t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
		e	x	a	m	p	l	e									

t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
			e	x	a	m	p	l	e								

etc, etc, etc.

Boyer-Moore

A

Boyer-Moore string searching algorithm.

- 1977.
- Not going to talk about the whole algorithm here.
  - Gets really complex.

- Right to left comparison.
- Can skip sections of the text.
  - Don't need to test every position.
- How?

Boyer-Moore

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Boyer-Moore string searching algorithm.

- 1977.
- Not going to talk about the whole algorithm here.
  - Gets really complex.
- Right to left comparison.
- Can skip sections of the text.
  - Don't need to test every position.
- How?
- Pre-processes the search string.
  - Bad character rule table.
  - Explained in a minute.

example ⇒

a	e	l	m	p	x	*
4	6	1	3	2	5	7

Boyer-Moore II

A

example $\Rightarrow$

a	e	l	m	p	x	*
4	6	1	3	2	5	7

text =	t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
search =	e	x	a	m	p	l	e											

Boyer-Moore II

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example $\Rightarrow$

a	e	l	m	p	x	*
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↓

text =	t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
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Boyer-Moore II

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example ⇒

a	e	l	m	p	x	*
4	6	1	3	2	5	7

7
↓

text =	t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
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example ⇒

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↓

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t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
							e	x	a	m	p	l	e				

Boyer-Moore II

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example ⇒

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↓

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search =	e	x	a	m	p	l	e											

4
↓

t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
						e	x	a	m	p	l	e					

Boyer-Moore II

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example ⇒

a	e	l	m	p	x	*
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↓

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search =	e	x	a	m	p	l	e											

4

↓

t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
							e	x	a	m	p	l	e				

t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
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															4 ↓			
	t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
								e	x	a	m	p	l	e				

																		6 ↓
	t	h	i	s	␣	i	s	␣	a	n	␣	e	x	a	m	p	l	e
												e	x	a	m	p	l	e

Boyer-Moore III

A

Creating the bad character table.

- For each character.
- Just count number of places between it and end of search string.

example $\Rightarrow$	a	e	l	m	p	x	*

Boyer-Moore III

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Creating the bad character table.

- For each character.
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$$\text{example} \Rightarrow \begin{array}{ccccccc} a & e & l & m & p & x & * \\ \hline 4 & & & & & & \end{array}$$

Boyer-Moore III

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Boyer-Moore III

A

Creating the bad character table.

- For each character.
- Just count number of places between it and end of search string.

example ⇒

a	e	l	m	p	x	*
4	6	1				

Boyer-Moore III

A

Creating the bad character table.

- For each character.
- Just count number of places between it and end of search string.

$$\text{example} \Rightarrow \begin{array}{ccccccc} a & e & l & m & p & x & * \\ \hline 4 & 6 & 1 & 3 & & & \end{array}$$

Boyer-Moore III

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Creating the bad character table.

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$$\text{example} \Rightarrow \begin{array}{ccccccc} a & e & l & m & p & x & * \\ \hline 4 & 6 & 1 & 3 & 2 & & \end{array}$$

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- For each character.
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$$\text{example} \Rightarrow \begin{array}{ccccccc} a & e & l & m & p & x & * \\ \hline 4 & 6 & 1 & 3 & 2 & 5 & \end{array}$$

Boyer-Moore III

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Creating the bad character table.

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example $\Rightarrow$

a	e	l	m	p	x	*
4	6	1	3	2	5	7

Boyer-Moore IV

A

Doesn't need to sort or modify the sequence being searched.

- Small amount of pre-processing on the search value.

Worst case.

- Linear time.

Average case

- Sub-linear.

Not the only string searching algorithm.

- Knuth-Morris-Pratt.
- Finite State Machine (FSM).
- Rabin-Karp.

Quiz

Recap

- Searching
  - Applications everywhere.
- Linear search.
  - Simple.
  - Slow.
- Binary search.
  - Ordered sequence.
  - Very fast.
  - Divide & Conquer.
- String searching.
  - Finding subsequence in sequence.
  - Boyers-Moore.
  - Preprocessing.
  - Skipping sections.

The End