3.1.3 Searching algorithms 2

Lesson plan and printable activities

Teacher notes

Lesson 2 PowerPoint contains information on how to follow the binary search (slides 11–19). Depending on the pace of learning during the earlier slides, it may be necessary to complete this section in a second lesson.

Materials needed

1. 3.1.3 Lesson 2 PowerPoint.
2. Binary search analysis Quiz.

Lesson aims

1. To get students to think about the mechanism of the binary search algorithm and to realise that there are differences in the efficiency of different searching algorithms.

Lesson objectives

1. Understand and explain how the binary search algorithm works.
2. Compare and contrast linear and binary search algorithms.

Starter activity (5 minutes)

1. Slide 2: Start with a short revision discussion that makes students think once more about the potential size of datasets that must be searched.

Main activities (40 minutes without extension task)

1. Slide 5: Definition of binary search.
2. Slide 6: Explain that the binary search algorithm is more complex to follow than a conventional linear search.
3. **Slide 7:** YouTube video. Watch from 3:12 minutes to 6:31 minutes.

4. **Slide 8:** Show students an example of a binary search algorithm. This is the same algorithm used in the extension task.

5. **Slide 9:** Comparing linear and binary searches.

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**Plenary activity (20 minutes)**

1. **Slide 10:** BBC Bitesize activity.

   Students recap the information from this lesson and the previous one with this activity from BBC Bitesize: [bbc.co.uk/education-guides/zgr2mp3/revision/2](http://bbc.co.uk/education-guides/zgr2mp3/revision/2)

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**Extension task (Slides 11–19)**

- Explain that you will be showing how a search term can be located within a 21-member array of data.
- Explain that a pre-requisite for using the binary search is that the dataset must be sorted, eg by ascending numerical order or by alphabetical order.
- Go through the example step-by-step, it is suggested that students are given a copy of the dry-running trace table provided and that they should come up with the variable values themselves. This can be tricky for many students but it’s essential practice for other areas of the specification eg programming.
- Make it clear that the scope of the search ‘area’ diminishes with each iteration of the algorithm’s loop.
3.1 Fundamentals of algorithms

Think about this…
A software company is asked to create a program for searching through a database of mobile-phone records for everyone owning a phone in the UK so that any individual’s number can be retrieved.

How many records might need to be searched through?

Objectives

Understand and explain how the binary search algorithm works

Compare and contrast linear and binary search algorithms

Introduction to binary searching

We looked previously at performing a linear search and saw that it can be inefficient.

A more efficient algorithm is the binary search.

Definition of a binary search

A method for searching data that splits datasets into two components repeatedly until the search term is located.

What is a dataset?
A collection of data, e.g., a table in a database.

Why do we use the word binary?
Binary implies two states — here we talk about splitting a dataset into two.

Before we can start…
A binary search can only work with an ordered list.

An ordered list is one where the fields are sorted in a preferred order, e.g., by numerical or alphabetical order.

Besides the list being sorted, we will also need to know its size to enable us to identify the middle of the list.
3.1 Fundamentals of algorithms

Watch this video

youtube.com/watch?v=JQhcTuD3E8&nohtml5=False

Comparing linear and binary searches

A linear search has an algorithm that is easier to understand, whereas the binary search algorithm is more complex.

The binary search will be much quicker than a linear search – particularly where the volume of data being searched is large.

Binary search algorithm

Store SearchTerm
StartPointer <- 1
EndPoint <- DataSize
Do
MidPointer <- (StartPointer + EndPointer) / 2 (round answer down)
If Record[MidPointer] < SearchTerm Then
StartPointer <- MidPointer + 1
End If
If Record[MidPointer] > SearchTerm Then
EndPointer <- MidPointer – 1
End If
Until Record[MidPointer] = SearchTerm OR StartPointer = EndPointer

To round things off...

Recap with BBC Bitesize:

bbc.co.uk/education/guides/zgr2mp3/revision/2

The ordered list...

The ordered list we are going to search is shown below:

| 0 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 15 | 17 | 18 | 19 | 29 | 26 | 29 | 43 | 45 | 47 | 49 | 67 | 78 | 99 |

Position of item in list
Value of item [4]

Binary search algorithm

Store SearchTerm
StartPointer <- 1
EndPointer <- DataSize
Do
MidPointer <- (StartPointer + EndPointer) / 2 (round answer down)
If Record[MidPointer] < SearchTerm Then
StartPointer <- MidPointer + 1
End If
If Record[MidPointer] > SearchTerm Then
EndPointer <- MidPointer – 1
End If
Until Record[MidPointer] = SearchTerm OR StartPointer = EndPointer
3.1 Fundamentals of algorithms

Data area covered during each loop

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</tbody>
</table>

Trace table

<table>
<thead>
<tr>
<th>Index</th>
<th>Position</th>
<th>Description</th>
<th>StartPointer</th>
<th>EndPointer</th>
<th>Trace Table</th>
<th>Reference</th>
<th>Data Area Covered during Each Loop</th>
</tr>
</thead>
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<tr>
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Following the binary search algorithm 1

Loop #1: [On entering loop, StartPointer = 1, EndPointer = 21, Search term = 43]
Condition now met has requirement = Change StartPointer
Start point < 12

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</table>

Following the binary search algorithm 2

Loop #2
Midpoint = Cell [15] = 45
Condition now met has requirement = Change EndPointer
End point < 15

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</table>

Following the binary search algorithm 3

Loop #3
Midpoint = Cell [13] = 26
Condition has now met requirement = Change StartPointer
Start point < 14

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</table>

Following the binary search algorithm 4

Loop #4
Midpoint = Cell [14] = 29
Condition has now met requirement = Change StartPointer
Start point < 15

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Following the binary search algorithm 5

Loop #5
Midpoint = Cell [19] = 43
Condition met = Search term matched
Exit program

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</tbody>
</table>
Quiz – Binary search analysis

Question 1
Here is an array of sorted numerical data that is to be searched until the term ‘78’ is located. How many times does the loop get entered before the search term is found? Show your working as well as the final answer.
Note: Not all the loops provided in the table may be needed.

Algorithm
Store SearchTerm
StartPointer <- 1
EndPointer <- DataSetSize
Do
   MidPointer <- (StartPointer + EndPointer) / 2 (Rounded down if needed)
   If Record[MidPointer] < SearchTerm Then
      StartPointer <- MidPointer + 1
   End If
   If Record[MidPointer] > SearchTerm Then
      EndPointer <- MidPointer – 1
   End If
Until Record[MidPointer] = SearchTerm OR StartPointer = EndPointer

Array contents

<p>| | | | | | | | | | | | | | |</p>
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<td>123</td>
<td>145</td>
<td>178</td>
<td>179</td>
<td>200</td>
<td>201</td>
</tr>
</tbody>
</table>

Trace table

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| StartPointer | EndPointer | MidPointer | Record[MidPointer] < SearchTerm | Record[MidPointer] > SearchTerm | Record[MidPointer] = SearchTerm OR StartPointer = EndPointer |
| Initial |   |   |   |   |   |
| Loop #1 |   |   |   |   |   |
| Loop #2 |   |   |   |   |   |
| Loop #3 |   |   |   |   |   |
| Loop #4 |   |   |   |   |   |
3.1 Fundamentals of algorithms

Quiz – Binary search analysis – answers

Question 1

Correctly identifies 15 elements and labels.
Correct values on each line for Loops only StartPointer and EndPointer and MidPointer.
States that the loop was entered twice.

Algorithm
Store SearchTerm
StartPointer <- 1
EndPointer <- DataSetSize
Do
MidPointer <- (StartPointer + EndPointer) / 2 (Rounded down if needed)
If Record[MidPointer] < SearchTerm Then
StartPointer <- MidPointer + 1
End If
If Record[MidPointer] > SearchTerm Then
EndPointer <- MidPointer – 1
End If
Until Record[MidPointer] = SearchTerm OR StartPointer = EndPointer

Array contents

<table>
<thead>
<tr>
<th></th>
<th>1</th>
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Trace table – [DataSetSize = 15, SearchTerm = 78]

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<tr>
<th>StartPointer</th>
<th>EndPointer</th>
<th>MidPointer</th>
<th>Record[MidPointer] &lt; SearchTerm</th>
<th>Record[MidPointer] &gt; SearchTerm</th>
<th>Record[MidPointer] = SearchTerm OR StartPointer = EndPointer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
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<tr>
<td>Loop #1</td>
<td>7</td>
<td>8</td>
<td></td>
<td>109 &gt; 78</td>
<td></td>
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<td>Loop #2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Record[MidPointer] = SearchTerm</td>
</tr>
</tbody>
</table>
3.1 Fundamentals of algorithms

Extension task

Binary search algorithm

Store SearchTerm
StartPointer  <-  1
EndPoint  <-  DataSetSize
Do
    MidPointer  <-  (StartPointer + EndPointer ) / 2 (Rounded down if needed)
    If Record[MidPointer] < SearchTerm Then
        StartPointer  <-  MidPointer + 1
    End If
    If Record[MidPointer] > SearchTerm Then
        EndPointer  <-  MidPointer – 1
    End If
Until Record[MidPointer] = SearchTerm OR StartPointer = EndPointer

Data area covered during each loop

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<td>18</td>
<td>19</td>
<td>26</td>
<td>29</td>
<td>43</td>
<td>45</td>
<td>47</td>
<td>49</td>
<td>67</td>
<td>78</td>
</tr>
</tbody>
</table>
### Trace table

<table>
<thead>
<tr>
<th>DataSetSize</th>
<th>SearchTerm</th>
<th>StartPointer</th>
<th>EndPointer</th>
<th>MidPointer</th>
<th>Record[MidPointer] &lt; SearchTerm</th>
<th>Record[MidPointer] &gt; SearchTerm</th>
<th>Record[MidPointer] = SearchTerm</th>
<th>[END]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed</strong></td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td>43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Initial</strong></td>
<td></td>
<td>1</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loop #1</strong></td>
<td></td>
<td>12</td>
<td>22</td>
<td>11</td>
<td>18 &lt; 43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loop #2</strong></td>
<td></td>
<td>15</td>
<td></td>
<td>16</td>
<td></td>
<td>45 &gt; 43</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loop #3</strong></td>
<td></td>
<td>14</td>
<td></td>
<td>13</td>
<td>26 &lt; 43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loop #4</strong></td>
<td></td>
<td>15</td>
<td></td>
<td>14</td>
<td>29 &lt; 43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loop #5</strong></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>(15 + 15 = 30)/2 = 15*</td>
<td></td>
<td>Met!</td>
<td></td>
</tr>
</tbody>
</table>

* = Rounded down