

A **subsequence** of a sequence (for example, an array, linked list, or string), obtained by removing zero or more elements and keeping the rest in the same sequence order. A subsequence is called a **substring** if its elements are contiguous in the original sequence. For example:

- **SUBSEQUENCE**, **UBSEQU**, and the empty string ϵ are all substrings (and therefore subsequences) of the string **SUBSEQUENCE**;
- **SBSQNC**, **SQUEE**, and **EEE** are all subsequences of **SUBSEQUENCE** but not substrings;
- **QUEUE**, **EQUUS**, and **DIMAGGIO** are not subsequences (and therefore not substrings) of **SUBSEQUENCE**.

Describe recursive backtracking algorithms for the following problems. *Don't worry about running times.*

- 1** Given an array $A[1..n]$ of integers, compute the length of a **longest increasing subsequence**. A sequence $B[1..\ell]$ is *increasing* if $B[i] > B[i-1]$ for every index $i \geq 2$.

For example, given the array

$\langle 3, \underline{1}, \underline{4}, 1, \underline{5}, 9, 2, \underline{6}, 5, 3, 5, \underline{8}, \underline{9}, 7, 9, 3, 2, 3, 8, 4, 6, 2, 7 \rangle$

your algorithm should return the integer 6, because $\langle 1, 4, 5, 6, 8, 9 \rangle$ is a longest increasing subsequence (one of many).

- 2** Given an array $A[1..n]$ of integers, compute the length of a **longest decreasing subsequence**. A sequence $B[1..\ell]$ is *decreasing* if $B[i] < B[i-1]$ for every index $i \geq 2$.

For example, given the array

$\langle 3, 1, 4, 1, 5, \underline{9}, 2, \underline{6}, 5, 3, \underline{5}, 8, 9, 7, 9, 3, 2, 3, 8, \underline{4}, 6, \underline{2}, 7 \rangle$

your algorithm should return the integer 5, because $\langle 9, 6, 5, 4, 2 \rangle$ is a longest decreasing subsequence (one of many).

- 3** Given an array $A[1..n]$ of integers, compute the length of a **longest alternating subsequence**. A sequence $B[1..\ell]$ is *alternating* if $B[i] < B[i-1]$ for every even index $i \geq 2$, and $B[i] > B[i-1]$ for every odd index $i \geq 3$.

For example, given the array

$\langle \underline{3}, \underline{1}, \underline{4}, \underline{1}, \underline{5}, 9, \underline{2}, \underline{6}, \underline{5}, 3, 5, \underline{8}, 9, \underline{7}, \underline{9}, \underline{3}, 2, 3, \underline{8}, \underline{4}, \underline{6}, \underline{2}, \underline{7} \rangle$

your algorithm should return the integer 17, because $\langle 3, 1, 4, 1, 5, 2, 6, 5, 8, 7, 9, 3, 8, 4, 6, 2, 7 \rangle$ is a longest alternating subsequence (one of many).

To think about later:

- 4** Given an array $A[1..n]$ of integers, compute the length of a longest **convex** subsequence of A . A sequence $B[1..\ell]$ is *convex* if $B[i] - B[i-1] > B[i-1] - B[i-2]$ for every index $i \geq 3$.

For example, given the array

$\langle \underline{3}, \underline{1}, 4, \underline{1}, 5, 9, \underline{2}, 6, 5, 3, \underline{5}, 8, \underline{9}, 7, 9, 3, 2, 3, 8, 4, 6, 2, 7 \rangle$

your algorithm should return the integer 6, because $\langle 3, 1, 1, 2, 5, 9 \rangle$ is a longest convex subsequence (one of many).

- 5 Given an array $A[1..n]$, compute the length of a longest *palindrome* subsequence of A . Recall that a sequence $B[1..l]$ is a *palindrome* if $B[i] = B[l - i + 1]$ for every index i .

For example, given the array

$\langle 3, 1, \underline{4}, 1, 5, \underline{9}, 2, 6, \underline{5}, \underline{3}, \underline{5}, 8, 9, 7, \underline{9}, 3, 2, 3, 8, \underline{4}, 6, 2, 7 \rangle$

your algorithm should return the integer 7, because $\langle 4, 9, 5, 3, 5, 9, 4 \rangle$ is a longest palindrome subsequence (one of many).

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