LeetCode Training Day 11 DP II

Today we will continue to discuss Dynamic Programming, unlike yesterday we simply **look back** to build the result from previous result. We will do it differently. For example, we can build from beginning, push the intermediate result to future and get aggregated there, then we can process them in the future. We call this methodology as **Carry Forward.**

**55. Jump Game**

Medium

You are given an integer array nums. You are initially positioned at the array's **first index**, and each element in the array represents your maximum jump length at that position.

Return true*if you can reach the last index, or*false*otherwise*.

**Example 1:**

**Input:** nums = [2,3,1,1,4]

**Output:** true

**Explanation:** Jump 1 step from index 0 to 1, then 3 steps to the last index.

**Example 2:**

**Input:** nums = [3,2,1,0,4]

**Output:** false

**Explanation:** You will always arrive at index 3 no matter what. Its maximum jump length is 0, which makes it impossible to reach the last index.

**Constraints:**

* 1 <= nums.length <= 104
* 0 <= nums[i] <= 105

### Analysis:

On every position you can know the right most position you can jump to. We process every position from left to right.

/// <summary>

/// Leet Code 55. Jump Game

///

/// Medium

///

/// You are given an integer array nums. You are initially positioned at

/// the array's first index, and each element in the array represents

/// your maximum jump length at that position.

///

/// Return true if you can reach the last index, or false otherwise.

///

/// Example 1:

/// Input: nums = [2,3,1,1,4]

/// Output: true

/// Explanation: Jump 1 step from index 0 to 1, then 3 steps to the last

/// index.

///

/// Example 2:

/// Input: nums = [3,2,1,0,4]

/// Output: false

/// Explanation: You will always arrive at index 3 no matter what. Its

/// maximum jump length is 0, which makes it impossible to reach the last

/// index.

///

/// Constraints:

/// 1. 1 <= nums.length <= 10^4

/// 2. 0 <= nums[i] <= 10^5

/// </summary>

bool LeetCodeDP::canJump(vector<int>& nums)

{

int right\_most = 0;

int index = 0;

while (index < right\_most + 1 && right\_most < (int)nums.size() - 1)

{

right\_most = max(right\_most, index + nums[index]);

index++;

}

if (right\_most >= (int)nums.size() - 1)

{

return true;

}

else

{

return false;

}

}

## 45. Jump Game II

Medium

Given an array of non-negative integers nums, you are initially positioned at the first index of the array.

Each element in the array represents your maximum jump length at that position.

Your goal is to reach the last index in the minimum number of jumps.

You can assume that you can always reach the last index.

**Example 1:**

**Input:** nums = [2,3,1,1,4]

**Output:** 2

**Explanation:** The minimum number of jumps to reach the last index is 2. Jump 1 step from index 0 to 1, then 3 steps to the last index.

**Example 2:**

**Input:** nums = [2,3,0,1,4]

**Output:** 2

**Constraints:**

* 1 <= nums.length <= 104
* 0 <= nums[i] <= 1000

### Analysis:

For every step we iterate to right most position from last step.

/// <summary>

/// Leet Code 45. Jump Game II

///

/// Medium

///

/// Given an array of non-negative integers nums, you are initially

/// positioned at the first index of the array.

///

/// Each element in the array represents your maximum jump length at that

/// position.

///

/// Your goal is to reach the last index in the minimum number of jumps.

///

/// You can assume that you can always reach the last index.

///

/// Example 1:

/// Input: nums = [2,3,1,1,4]

/// Output: 2

/// Explanation: The minimum number of jumps to reach the last index is 2.

/// Jump 1 step from index 0 to 1, then 3 steps to the last index.

///

/// Example 2:

/// Input: nums = [2,3,0,1,4]

/// Output: 2

///

/// Constraints:

/// 1. 1 <= nums.length <= 10^4

/// 2. 0 <= nums[i] <= 1000

/// </summary>

int LeetCodeDP::jump(vector<int>& nums)

{

int end = 0;

int index = 0;

int result = 0;

while (end < (int)nums.size() - 1)

{

int right = end;

result++;

while (index <= right)

{

end = max(end, index + nums[index]);

index++;

}

}

return result;

}

## 91. Decode Ways

Medium

A message containing letters from A-Z can be **encoded** into numbers using the following mapping:

'A' -> "1"

'B' -> "2"

...

'Z' -> "26"

To **decode** an encoded message, all the digits must be grouped then mapped back into letters using the reverse of the mapping above (there may be multiple ways). For example, "11106" can be mapped into:

* "AAJF" with the grouping (1 1 10 6)
* "KJF" with the grouping (11 10 6)

Note that the grouping (1 11 06) is invalid because "06" cannot be mapped into 'F' since "6" is different from "06".

Given a string s containing only digits, return *the****number****of ways to****decode****it*.

The answer is guaranteed to fit in a **32-bit** integer.

**Example 1:**

**Input:** s = "12"

**Output:** 2

**Explanation:** "12" could be decoded as "AB" (1 2) or "L" (12).

**Example 2:**

**Input:** s = "226"

**Output:** 3

**Explanation:** "226" could be decoded as "BZ" (2 26), "VF" (22 6), or "BBF" (2 2 6).

**Example 3:**

**Input:** s = "0"

**Output:** 0

**Explanation:** There is no character that is mapped to a number starting with 0.

The only valid mappings with 0 are 'J' -> "10" and 'T' -> "20", neither of which start with 0.

Hence, there are no valid ways to decode this since all digits need to be mapped.

**Example 4:**

**Input:** s = "06"

**Output:** 0

**Explanation:** "06" cannot be mapped to "F" because of the leading zero ("6" is different from "06").

**Constraints:**

* 1 <= s.length <= 100
* s contains only digits and may contain leading zero(s).

### Analysis:

For any non-zero digit, we can map to 1 character, thus we carry it to position + 1, for any two digits less than 26, we can also map to 1 character, this we carry it as another result to position +2. At the end point we collect total numbers.

/// <summary>

/// Leet code 91. Decode Ways

///

/// A message containing letters from A-Z is being encoded to numbers using

/// the following mapping:

///

/// 'A' -> 1

/// 'B' -> 2

/// ...

/// 'Z' -> 26

/// Given a non-empty string containing only digits, determine the total

/// number of ways to decode it.

///

/// Example 1:

///

/// Input: "12"

/// Output: 2

/// Explanation: It could be decoded as "AB" (1 2) or "L" (12).

///

/// Example 2:

///

/// Input: "226"

/// Output: 3

/// Explanation: It could be decoded as "BZ" (2 26), "VF" (22 6), or "BBF"

/// (2 2 6).

/// </summary>

int LeetCodeDP::numDecodings(string s)

{

if (s.empty()) return 0;

vector<int> dp(s.size()+1);

dp[0] = 1;

for (size\_t i = 0; i < s.size(); i++)

{

if (s[i] != '0') dp[i+1] += dp[i];

if (i < s.size() - 1)

{

if ((s[i] == '1') || (s[i] == '2' && s[i + 1] >= '0' && s[i + 1] <= '6'))

{

dp[i + 2] += dp[i];

}

}

}

return dp[s.size()];

}

## 361. Bomb Enemy

Medium

Given an m x n matrix grid where each cell is either a wall 'W', an enemy 'E' or empty '0', return *the maximum enemies you can kill using one bomb*. You can only place the bomb in an empty cell.

The bomb kills all the enemies in the same row and column from the planted point until it hits the wall since it is too strong to be destroyed.

**Example 1:**

A picture containing text, building, window, clipart

Description automatically generated

**Input:** grid = [["0","E","0","0"],["E","0","W","E"],["0","E","0","0"]]

**Output:** 3

**Example 2:**

A picture containing graphical user interface

Description automatically generated

**Input:** grid = [["W","W","W"],["0","0","0"],["E","E","E"]]

**Output:** 1

**Constraints:**

* m == grid.length
* n == grid[i].length
* 1 <= m, n <= 500
* grid[i][j] is either 'W', 'E', or '0'.

### Analysis:

We scan the grid from left to right, top to bottom, right to left and bottom to top. On every position, we know how many enemies on left, right, up and down. We choose the maximum number in the matrix.

/// <summary>

/// Leet code #361. Bomb Enemy

///

/// Given a 2D grid, each cell is either a wall 'W', an enemy 'E' or empty '0'

/// (the number zero), return the maximum enemies you can kill using one bomb.

/// The bomb kills all the enemies in the same row and column from the planted

/// point until it hits the wall since the wall is too strong to be destroyed.

/// Note that you can only put the bomb at an empty cell.

///

/// Example:

///

/// For the given grid

/// 0 E 0 0

/// E 0 W E

/// 0 E 0 0

///

/// return 3. (Placing a bomb at (1,1) kills 3 enemies)

/// </summary>

int LeetCodeDP::maxKilledEnemies(vector<vector<char>>& grid)

{

if (grid.size() == 0 || grid[0].size() == 0) return 0;

int max\_enemies = 0;

pair<int, int> max\_pos;

vector<vector<pair<int, int>>> sum(grid.size(), vector<pair<int, int>>(grid[0].size()));

for (size\_t i = 0; i < grid.size(); i++)

{

for (size\_t j = 0; j < grid[i].size(); j++)

{

pair<int, int> count;

if (grid[i][j] == 'W')

{

count = make\_pair(0, 0);

}

else if (grid[i][j] == '0')

{

if (i == 0) count.first = 0;

else count.first = sum[i - 1][j].first;

if (j == 0) count.second = 0;

else count.second = sum[i][j - 1].second;

}

else if (grid[i][j] == 'E')

{

if (i == 0) count.first = 1;

else count.first = sum[i - 1][j].first + 1;

if (j == 0) count.second = 1;

else count.second = sum[i][j - 1].second + 1;

}

sum[i][j] = count;

}

}

for (int i = grid.size() - 1; i >= 0; i--)

{

for (int j = grid[i].size() - 1; j >= 0; j--)

{

if (grid[i][j] == 'W') continue;

if (i < (int)grid.size() - 1)

{

sum[i][j].first = max(sum[i + 1][j].first, sum[i][j].first);

}

if (j < (int)grid[i].size() - 1)

{

sum[i][j].second = max(sum[i][j + 1].second, sum[i][j].second);

}

if (grid[i][j] == '0')

{

int enemies = sum[i][j].first + sum[i][j].second;

if (enemies > max\_enemies)

{

max\_enemies = enemies;

max\_pos = make\_pair(i, j);

}

}

}

}

return max\_enemies;

}

## 264. Ugly Number II

Medium

An **ugly number** is a positive integer whose prime factors are limited to 2, 3, and 5.

Given an integer n, return *the* nth ***ugly number***.

**Example 1:**

**Input:** n = 10

**Output:** 12

**Explanation:** [1, 2, 3, 4, 5, 6, 8, 9, 10, 12] is the sequence of the first 10 ugly numbers.

**Example 2:**

**Input:** n = 1

**Output:** 1

**Explanation:** 1 has no prime factors, therefore all of its prime factors are limited to 2, 3, and 5.

**Constraints:**

* 1 <= n <= 1690

### Analysis:

We store smallest ugly number for each factor, select the minimum number from all factor candidate and move this index one step forward.

/// <summary>

/// Leet code #264. Ugly Number II

///

/// Write a program to find the n-th ugly number.

///

/// Ugly numbers are positive numbers whose prime factors only

/// include 2, 3, 5.

///

/// Example:

///

/// Input: n = 10

/// Output: 12

/// Explanation: 1, 2, 3, 4, 5, 6, 8, 9, 10, 12 is the sequence of

/// the first 10 ugly numbers.

/// Note:

///

/// 1. 1 is typically treated as an ugly number.

/// 2. n does not exceed 1690.

/// </summary>

int LeetCodeDP::nthUglyNumber(int n)

{

vector<int> result;

vector<int> dp(3);

vector<int> factor = { 2, 3, 5 };

result.push\_back(1);

while (result.size() < (size\_t)n)

{

int index = 0;

int min\_num = INT\_MAX;

for (size\_t i = 0; i < dp.size(); i++)

{

if (min\_num > result[dp[i]] \* factor[i])

{

index = i;

min\_num = result[dp[i]] \* factor[i];

}

}

if (min\_num > result.back()) result.push\_back(min\_num);

dp[index]++;

}

return result.back();

}

## 313. Super Ugly Number

Medium

A **super ugly number** is a positive integer whose prime factors are in the array primes.

Given an integer n and an array of integers primes, return *the* nth ***super ugly number***.

The nth **super ugly number** is **guaranteed** to fit in a **32-bit** signed integer.

**Example 1:**

**Input:** n = 12, primes = [2,7,13,19]

**Output:** 32

**Explanation:** [1,2,4,7,8,13,14,16,19,26,28,32] is the sequence of the first 12 super ugly numbers given primes = [2,7,13,19].

**Example 2:**

**Input:** n = 1, primes = [2,3,5]

**Output:** 1

**Explanation:** 1 has no prime factors, therefore all of its prime factors are in the array primes = [2,3,5].

**Constraints:**

* 1 <= n <= 106
* 1 <= primes.length <= 100
* 2 <= primes[i] <= 1000
* primes[i] is **guaranteed** to be a prime number.
* All the values of primes are **unique** and sorted in **ascending order**.

### Analysis:

Same as above, We store smallest ugly number for each factor, select the minimum number from all factor candidate and move this index one step forward.

/// <summary>

/// Leet code #313. Super Ugly Number

///

/// Write a program to find the nth super ugly number.

///

/// Super ugly numbers are positive numbers whose all prime factors

/// are in the given prime list primes of size k.

///

/// Example:

///

/// Input: n = 12, primes = [2,7,13,19]

/// Output: 32

/// Explanation: [1,2,4,7,8,13,14,16,19,26,28,32] is the sequence of the

/// first 12 super ugly numbers given primes = [2,7,13,19] of size 4.

/// Note:

///

/// 1. 1 is a super ugly number for any given primes.

/// 2. The given numbers in primes are in ascending order.

/// 3. 0 < k ≤ 100, 0 < n ≤ 106, 0 < primes[i] < 1000.

/// 4. The nth super ugly number is guaranteed to fit in a 32-bit signed

/// integer.

/// </summary>

int LeetCodeDP::nthSuperUglyNumber(int n, vector<int>& primes)

{

vector<int> result;

vector<int> dp(primes.size());

result.push\_back(1);

while (result.size() < (size\_t)n)

{

int index = 0;

int min\_num = INT\_MAX;

for (size\_t i = 0; i < dp.size(); i++)

{

int product = result[dp[i]] \* primes[i];

if (min\_num > product)

{

index = i;

min\_num = product;

}

}

if (min\_num > result.back()) result.push\_back(min\_num);

dp[index]++;

}

return result.back();

}

# Advanced Problems

## 639. Decode Ways II

Hard

A message containing letters from A-Z can be **encoded** into numbers using the following mapping:

'A' -> "1"

'B' -> "2"

...

'Z' -> "26"

To **decode** an encoded message, all the digits must be grouped then mapped back into letters using the reverse of the mapping above (there may be multiple ways). For example, "11106" can be mapped into:

* "AAJF" with the grouping (1 1 10 6)
* "KJF" with the grouping (11 10 6)

Note that the grouping (1 11 06) is invalid because "06" cannot be mapped into 'F' since "6" is different from "06".

**In addition** to the mapping above, an encoded message may contain the '\*' character, which can represent any digit from '1' to '9' ('0' is excluded). For example, the encoded message "1\*" may represent any of the encoded messages "11", "12", "13", "14", "15", "16", "17", "18", or "19". Decoding "1\*" is equivalent to decoding **any** of the encoded messages it can represent.

Given a string s consisting of digits and '\*' characters, return *the****number****of ways to****decode****it*.

Since the answer may be very large, return it **modulo** 109 + 7.

**Example 1:**

**Input:** s = "\*"

**Output:** 9

**Explanation:** The encoded message can represent any of the encoded messages "1", "2", "3", "4", "5", "6", "7", "8", or "9".

Each of these can be decoded to the strings "A", "B", "C", "D", "E", "F", "G", "H", and "I" respectively.

Hence, there are a total of 9 ways to decode "\*".

**Example 2:**

**Input:** s = "1\*"

**Output:** 18

**Explanation:** The encoded message can represent any of the encoded messages "11", "12", "13", "14", "15", "16", "17", "18", or "19".

Each of these encoded messages have 2 ways to be decoded (e.g. "11" can be decoded to "AA" or "K").

Hence, there are a total of 9 \* 2 = 18 ways to decode "1\*".

**Example 3:**

**Input:** s = "2\*"

**Output:** 15

**Explanation:** The encoded message can represent any of the encoded messages "21", "22", "23", "24", "25", "26", "27", "28", or "29".

"21", "22", "23", "24", "25", and "26" have 2 ways of being decoded, but "27", "28", and "29" only have 1 way.

Hence, there are a total of (6 \* 2) + (3 \* 1) = 12 + 3 = 15 ways to decode "2\*".

**Constraints:**

* 1 <= s.length <= 105
* s[i] is a digit or '\*'.

### Analysis:

For character ‘\*’, we iterate from 1-9 and carry result forward.

/// <summary>

/// Leet code #639. Decode Ways II

///

/// A message containing letters from A-Z is being encoded to numbers using

/// the following mapping way:

/// 'A' -> 1

/// 'B' -> 2

/// ...

/// 'Z' -> 26

/// Beyond that, now the encoded string can also contain the character '\*',

/// which can be treated as one of the numbers from 1 to 9.

/// Given the encoded message containing digits and the character '\*', return

/// the total number of ways to decode it.

/// Also, since the answer may be very large, you should return the output

/// mod 10^9 + 7.

///

/// Example 1:

/// Input: "\*"

/// Output: 9

/// Explanation: The encoded message can be decoded to the string: "A", "B",

/// "C", "D", "E", "F", "G", "H", "I".

///

/// Example 2:

/// Input: "1\*"

/// Output: 9 + 9 = 18

///

/// Note:

/// The length of the input string will fit in range [1, 10^5].

/// The input string will only contain the character '\*' and digits '0' - '9'.

/// </summary>

int LeetCode::numDecodingsII(string s)

{

if (s.empty()) return 0;

int M = 1000000007;

vector<int> dp(s.size());

for (size\_t i = 0; i < s.size(); i++)

{

if ((s[i] >= '1') && (s[i] <= '9'))

{

if (i == 0) dp[i] += 1;

else dp[i] = (dp[i] + dp[i - 1]) % M;

}

else if (s[i] == '\*')

{

if (i == 0) dp[i] += 9;

else dp[i] = (int)(((long long)dp[i] + 9 \* (long long)dp[i - 1]) % M);

}

if (i > 0)

{

if ((s[i - 1] == '1' && s[i] >= '0' && s[i] <= '9') ||

(s[i - 1] == '2' && s[i] >= '0' && s[i] <= '6'))

{

if (i == 1) dp[i] += 1;

else dp[i] = (dp[i] + dp[i - 2]) % M;

}

else if (s[i - 1] == '1' && s[i] == '\*')

{

if (i == 1) dp[i] += 9;

else dp[i] = (int)(((long long)dp[i] + 9 \* (long long)dp[i - 2]) % M);

}

else if (s[i - 1] == '2' && s[i] == '\*')

{

if (i == 1) dp[i] += 6;

else dp[i] = (int)(((long long)dp[i] + 6 \* (long long)dp[i - 2]) % M);

}

else if (s[i - 1] == '\*' && s[i] == '\*')

{

if (i == 1) dp[i] += 15;

else dp[i] = (int)(((long long)dp[i] + 15 \* (long long)dp[i - 2]) % M);

}

else if (s[i - 1] == '\*' && s[i] >= '0' && s[i] <= '6')

{

if (i == 1) dp[i] += 2;

else dp[i] = (int)(((long long)dp[i] + 2 \* (long long)dp[i - 2]) % M);

}

else if (s[i - 1] == '\*' && s[i] >= '7' && s[i] <= '9')

{

if (i == 1) dp[i] += 1;

else dp[i] = (int)(((long long)dp[i] + 1 \* (long long)dp[i - 2]) % M);

}

}

}

return dp[s.size() - 1];

}

**1751. Maximum Number of Events That Can Be Attended II**

Hard

You are given an array of events where events[i] = [startDayi, endDayi, valuei]. The ith event starts at startDayiand ends at endDayi, and if you attend this event, you will receive a value of valuei. You are also given an integer k which represents the maximum number of events you can attend.

You can only attend one event at a time. If you choose to attend an event, you must attend the **entire** event. Note that the end day is **inclusive**: that is, you cannot attend two events where one of them starts and the other ends on the same day.

Return *the****maximum sum****of values that you can receive by attending events.*

**Example 1:**

Chart, bar chart

Description automatically generated

**Input:** events = [[1,2,4],[3,4,3],[2,3,1]], k = 2

**Output:** 7

**Explanation:** Choose the green events, 0 and 1 (0-indexed) for a total value of 4 + 3 = 7.

**Example 2:**

Chart, bar chart

Description automatically generated

**Input:** events = [[1,2,4],[3,4,3],[2,3,10]], k = 2

**Output:** 10

**Explanation:** Choose event 2 for a total value of 10.

Notice that you cannot attend any other event as they overlap, and that you do **not** have to attend k events.

**Example 3:**

**Chart, waterfall chart

Description automatically generated**

**Input:** events = [[1,1,1],[2,2,2],[3,3,3],[4,4,4]], k = 3

**Output:** 9

**Explanation:** Although the events do not overlap, you can only attend 3 events. Pick the highest valued three.

**Constraints:**

* 1 <= k <= events.length
* 1 <= k \* events.length <= 106
* 1 <= startDayi <= endDayi <= 109
* 1 <= valuei <= 106

### Analysis:

We sort the events based on starting time, before processing every event, we harvest the accumulated event values happened before the event and when we process the event, we set event value based on the previous harvest value and current event at end time (if end time has conflict, we need to choose maximum), such end time event value can be harvested later again.

/// <summary>

/// Leet code 1751. Maximum Number of Events That Can Be Attended II

///

/// Hard

///

/// You are given an array of events where events[i] = [startDayi,

/// endDayi, valuei]. The ith event starts at startDayi and ends at

/// endDayi, and if you attend this event, you will receive a value of

/// valuei. You are also given an integer k which represents the

/// maximum number of events you can attend.

///

/// You can only attend one event at a time. If you choose to attend

/// an event, you must attend the entire event. Note that the end day

/// is inclusive: that is, you cannot attend two events where one of

/// them starts and the other ends on the same day.

///

/// Return the maximum sum of values that you can receive by attending

/// events.

///

/// Example 1:

/// Input: events = [[1,2,4],[3,4,3],[2,3,1]], k = 2

/// Output: 7

/// Explanation: Choose the green events, 0 and 1 (0-indexed) for a total

/// value of 4 + 3 = 7.

///

/// Example 2:

///

/// Input: events = [[1,2,4],[3,4,3],[2,3,10]], k = 2

/// Output: 10

/// Explanation: Choose event 2 for a total value of 10.

/// Notice that you cannot attend any other event as they overlap, and

/// that you do not have to attend k events.

///

/// Example 3:

/// Input: events = [[1,1,1],[2,2,2],[3,3,3],[4,4,4]], k = 3

/// Output: 9

/// Explanation: Although the events do not overlap, you can only attend

/// 3 events. Pick the highest valued three.

///

/// Constraints:

/// 1. 1 <= k <= events.length

/// 2. 1 <= k \* events.length <= 10^6

/// 3. 1 <= startDayi <= endDayi <= 10^9

/// 4. 1 <= valuei <= 10^6

/// </summary>

int LeetCodeDP::maxValue(vector<vector<int>>& events, int k)

{

map<int, vector<int>> event\_values;

sort(events.begin(), events.end());

vector<int> prev\_event = { 0 };

int result = 0;

for (size\_t i = 0; i < events.size(); i++)

{

int start = events[i][0];

int end = events[i][1];

int value = events[i][2];

// collect all previous event maximum values

while (!event\_values.empty() && event\_values.begin()->first < start)

{

auto itr = event\_values.begin();

for (size\_t j = 0; j < itr->second.size(); j++)

{

if (j >= prev\_event.size())

{

prev\_event.push\_back(itr->second[j]);

}

else

{

prev\_event[j] = max(prev\_event[j], itr->second[j]);

}

}

event\_values.erase(event\_values.begin());

}

if (event\_values.count(end) == 0)

{

event\_values[end] = { 0 };

}

for (int j = 0; (j < prev\_event.size() && j < k); j++)

{

if (j + 1 >= event\_values[end].size())

{

event\_values[end].push\_back(prev\_event[j] + value);

}

else

{

event\_values[end][j+1] = max(event\_values[end][j + 1], prev\_event[j] + value);

}

result = max(result, event\_values[end][j + 1]);

}

}

return result;

}