<https://leetcode.com/problems/furthest-building-you-can-reach/description/>

You are given an integer array heights representing the heights of buildings, some bricks, and some ladders.

You start your journey from building 0 and move to the next building by possibly using bricks or ladders.

While moving from building i to building i+1 (0-indexed),

1. If the current building's height is greater than or equal to the next building's height, you do not need a ladder or bricks.
2. If the current building's height is less than the next building's height, you can either use one ladder or (h[i+1] - h[i]) bricks.

Return the furthest building index (0-indexed) you can reach if you use the given ladders and bricks optimally.

**Example 1:**



**Input:** heights = [4,2,7,6,9,14,12], bricks = 5, ladders = 1

**Output:** 4

**Explanation:** Starting at building 0, you can follow these steps:

- Go to building 1 without using ladders nor bricks since 4 >= 2.

- Go to building 2 using 5 bricks. You must use either bricks or ladders because 2 < 7.

- Go to building 3 without using ladders nor bricks since 7 >= 6.

- Go to building 4 using your only ladder. You must use either bricks or ladders because 6 < 9.

It is impossible to go beyond building 4 because you do not have any more bricks or ladders.

**Example 2:**

**Input:** heights = [4,12,2,7,3,18,20,3,19], bricks = 10, ladders = 2

**Output:** 7

**Example 3:**

**Input:** heights = [14,3,19,3], bricks = 17, ladders = 0

**Output:** 3

**Constraints:**

1. 1 <= heights.length <= 10^5
2. 1 <= heights[i] <= 10^6
3. 0 <= bricks <= 10^9
4. 0 <= ladders <= heights.length

**Attempt 1: 2025-02-04**

**Solution 1: Greedy + Heap (180 min)**

class Solution {

    public int furthestBuilding(int[] heights, int bricks, int ladders) {

        // Min-heap to store the largest jumps where ladders are used

        PriorityQueue<Integer> minHeap = new PriorityQueue<>();

        for (int i = 0; i < heights.length - 1; i++) {

            int diff = heights[i + 1] - heights[i];

            // If the next building is taller, we need to use bricks or a ladder

            if (diff > 0) {

                // Use a ladder for the current jump

                minHeap.offer(diff);

                // If we have more jumps than ladders, replace the smallest ladder jump with bricks

                if (minHeap.size() > ladders) {

                    bricks -= minHeap.poll();

                }

                // If we run out of bricks, we can't proceed further

                if (bricks < 0) {

                    return i;

                }

            }

        }

        // If we can reach the last building, return the last index

        return heights.length - 1;

    }

}

Time Complexity: O(nlogn)

Space Complexity: O(n)

**Refer to**

<https://leetcode.com/problems/furthest-building-you-can-reach/solutions/918515/java-c-python-priority-queue/>

**Explanation**

Heap heap store k height difference that we need to use ladders.

Each move, if the height difference d > 0, we push d into the priority queue pq.

If the size of queue exceed ladders, it means we have to use bricks for one move.

Then we pop out the smallest difference, and reduce bricks.

If bricks < 0, we can't make this move, then we return current index i.

If we can reach the last building, we return A.length - 1.

**Complexity**

Time O(NlogK)

Space O(K)

**Java**

public int furthestBuilding(int[] A, int bricks, int ladders) {

PriorityQueue<Integer> pq = new PriorityQueue<>();

for (int i = 0; i < A.length - 1; i++) {

int d = A[i + 1] - A[i];

if (d > 0)

pq.add(d);

if (pq.size() > ladders)

bricks -= pq.poll();

if (bricks < 0)

return i;

}

return A.length - 1;

}

**Refer to Deepseek**

To solve the LeetCode problem 1642, "Furthest Building You Can Reach," we need to determine the furthest building we can reach given a limited number of bricks and ladders. The idea is to use ladders for the largest jumps and bricks for the smaller ones.

Here's a step-by-step Java solution using a min-heap (priority queue) to keep track of the largest jumps where ladders are used:

import java.util.PriorityQueue;

public class Solution {

public int furthestBuilding(int[] heights, int bricks, int ladders) {

// Min-heap to store the largest jumps where ladders are used

PriorityQueue<Integer> minHeap = new PriorityQueue<>();

for (int i = 0; i < heights.length - 1; i++) {

int diff = heights[i + 1] - heights[i];

// If the next building is taller, we need to use bricks or a ladder

if (diff > 0) {

// Use a ladder for the current jump

minHeap.offer(diff);

// If we have more jumps than ladders, replace the smallest ladder jump with bricks

if (minHeap.size() > ladders) {

bricks -= minHeap.poll();

}

// If we run out of bricks, we can't proceed further

if (bricks < 0) {

return i;

}

}

}

// If we can reach the last building, return the last index

return heights.length - 1;

}

}

**Explanation:**

1. Priority Queue (Min-Heap):
   1. We use a min-heap to keep track of the largest jumps where ladders are used. This allows us to efficiently replace the smallest ladder jump with bricks if we run out of ladders.
2. Iterate Through Buildings:
   1. We iterate through the buildings, calculating the height difference (diff) between the current building and the next one.
   2. If diff > 0, it means we need to climb, so we use either bricks or a ladder.
3. Using Ladders:
   1. We always use a ladder for the current jump by adding diff to the min-heap.
   2. If the number of jumps in the heap exceeds the number of ladders, we replace the smallest ladder jump with bricks by subtracting it from the bricks count.
4. Check Bricks:
   1. If at any point the bricks count goes negative, it means we can't proceed further, so we return the current index.
5. Return the Last Building:
   1. If we can reach the last building without running out of bricks, we return the index of the last building.

**Example Usage:**

public class Main {

public static void main(String[] args) {

Solution solution = new Solution();

int[] heights = {4, 2, 7, 6, 9, 14, 12};

int bricks = 5;

int ladders = 1;

System.out.println(solution.furthestBuilding(heights, bricks, ladders)); // Output: 4

}

}

This solution efficiently determines the furthest building you can reach using a combination of bricks and ladders, with a time complexity of O(N log L), where N is the number of buildings and L is the number of ladders.

**Is that possible to resolve with pure DFS solution ?**

Yes, it is possible to solve the "Furthest Building You Can Reach" problem using a pure DFS (Depth-First Search) approach. However, it is important to note that a DFS solution will likely be **inefficient** for large inputs due to its exponential time complexity. This is because DFS explores all possible combinations of using bricks and ladders, which can lead to a huge number of recursive calls.

Here’s how you can implement a pure DFS solution in Java:

**DFS Wrong Solution Code:**

public class Solution {

public int furthestBuilding(int[] heights, int bricks, int ladders) {

return dfs(heights, 0, bricks, ladders);

}

private int dfs(int[] heights, int index, int bricks, int ladders) {

// If we reach the last building, return the index

if (index == heights.length - 1) {

return index;

}

int diff = heights[index + 1] - heights[index];

// If the next building is not taller, move to the next building

if (diff <= 0) {

return dfs(heights, index + 1, bricks, ladders);

}

// Try using bricks first

int useBricks = -1;

if (bricks >= diff) {

useBricks = dfs(heights, index + 1, bricks - diff, ladders);

}

// Try using a ladder

int useLadder = -1;

if (ladders > 0) {

useLadder = dfs(heights, index + 1, bricks, ladders - 1);

}

// Return the maximum index reached by either using bricks or a ladder

return Math.max(useBricks, useLadder);

}

}

**Explanation of the DFS Approach:**

1. Base Case:
   1. If we reach the last building (index == heights.length - 1), return the current index.
2. Height Difference:
   1. Calculate the height difference (diff) between the current building and the next building.
3. No Climbing Needed:
   1. If diff <= 0, no bricks or ladders are needed. Move to the next building.
4. Use Bricks:
   1. If there are enough bricks to cover the height difference, recursively call dfs with the updated brick count (bricks - diff).
5. Use Ladder:
   1. If there are ladders available, recursively call dfs with one less ladder (ladders - 1).
6. Return the Maximum Index:
   1. Return the maximum index reached by either using bricks or a ladder.

**Example Usage:**

public class Main {

public static void main(String[] args) {

Solution solution = new Solution();

int[] heights = {4, 2, 7, 6, 9, 14, 12};

int bricks = 5;

int ladders = 1;

System.out.println(solution.furthestBuilding(heights, bricks, ladders)); // Output: 4

}

}

**Why DFS is Inefficient:**

1. Exponential Time Complexity:
   1. For each building, we have two choices (use bricks or use a ladder), leading to a time complexity of \*\*O(2^N)\*\*, where N is the number of buildings.
2. Redundant Calculations:
   1. The same subproblems (e.g., using a certain number of bricks and ladders at a specific index) are computed multiple times, leading to inefficiency.
3. Stack Overflow Risk:
   1. For large inputs, the recursion depth can become too large, causing a stack overflow.

**In pure DFS solution above, it has wrong output with below input, can you fix it ?:**

heights = [4,2,7,6,9,14,12]

bricks = 5

ladders = 1

The wrong output = -1, expected = 4

You're correct that the **pure DFS solution** I provided earlier has a bug. Specifically, the issue arises because the useBricks and useLadder variables are initialized to -1, and if neither option is valid (e.g., no bricks or ladders left), the function returns -1 instead of the current index. This is incorrect because we should return the current index if we cannot proceed further.

Let me fix the **pure DFS solution** to handle this case correctly.

**Correct DFS Solution:**

public class Solution {

public int furthestBuilding(int[] heights, int bricks, int ladders) {

return dfs(heights, 0, bricks, ladders);

}

private int dfs(int[] heights, int index, int bricks, int ladders) {

// If we reach the last building, return the index

if (index == heights.length - 1) {

return index;

}

int diff = heights[index + 1] - heights[index];

// If the next building is not taller, move to the next building

if (diff <= 0) {

return dfs(heights, index + 1, bricks, ladders);

}

// Try using bricks first

int useBricks = index; // Default to current index if bricks cannot be used

if (bricks >= diff) {

useBricks = dfs(heights, index + 1, bricks - diff, ladders);

}

// Try using a ladder

int useLadder = index; // Default to current index if ladder cannot be used

if (ladders > 0) {

useLadder = dfs(heights, index + 1, bricks, ladders - 1);

}

// Return the maximum index reached by either using bricks or a ladder

return Math.max(useBricks, useLadder);

}

}

**Explanation of the Fix:**

1. Default to Current Index:
   1. **If we cannot use bricks or a ladder (e.g., no bricks or ladders left), we default to the current index (index) instead of returning -1. This ensures that we return the furthest building we can reach, even if we cannot proceed further.**
2. Recursive Calls:
   1. If bricks or ladders are available, we make recursive calls to explore further.
   2. If neither is available, we stop and return the current index.
3. Result Selection:
   1. We use Math.max(useBricks, useLadder) to select the furthest building we can reach by either using bricks or a ladder.

**Example Usage:**

public class Main {

public static void main(String[] args) {

Solution solution = new Solution();

int[] heights = {4, 2, 7, 6, 9, 14, 12};

int bricks = 5;

int ladders = 1;

System.out.println(solution.furthestBuilding(heights, bricks, ladders)); // Output: 4

}

}

**Walkthrough of the Fixed Solution:**

**Input:**

1. heights = [4, 2, 7, 6, 9, 14, 12]
2. bricks = 5
3. ladders = 1

**Execution:**

1. Start at building 0 (height = 4).
2. Move to building 1 (height = 2). No bricks or ladders needed.
3. Move to building 2 (height = 7). Need to climb 5 units.
   1. Use bricks: Subtract 5 from bricks (bricks = 0), move to building 3.
   2. Use ladder: Subtract 1 from ladders (ladders = 0), move to building 3.
4. Move to building 3 (height = 6). No bricks or ladders needed.
5. Move to building 4 (height = 9). Need to climb 3 units.
   1. Use bricks: Not enough bricks (bricks = 0).
   2. Use ladder: No ladders left (ladders = 0).
   3. Cannot proceed further. Return current index 4.

**Output:**

1. The furthest building we can reach is 4.

**Key Takeaways:**

1. The fixed DFS solution now correctly handles cases where we cannot proceed further due to insufficient bricks or ladders.
2. The solution returns the furthest building index we can reach, even if we cannot proceed beyond a certain point.
3. While this solution works for small inputs, it is still **inefficient** for large inputs due to its exponential time complexity. For larger inputs, **the greedy approach with a min-heap** is the recommended solution.

**Optimizing DFS with Memoization:**

To make the DFS solution more efficient, you can use **memoization** to cache the results of subproblems. This reduces redundant calculations and improves performance.

Here’s how you can add memoization:

import java.util.HashMap;

import java.util.Map;

public class Solution {

public int furthestBuilding(int[] heights, int bricks, int ladders) {

// Memoization map to store results of subproblems

Map<String, Integer> memo = new HashMap<>();

return dfs(heights, 0, bricks, ladders, memo);

}

private int dfs(int[] heights, int index, int bricks, int ladders, Map<String, Integer> memo) {

// If we reach the last building, return the index

if (index == heights.length - 1) {

return index;

}

// Create a unique key for the current state

String key = index + "-" + bricks + "-" + ladders;

// If the result is already computed, return it

if (memo.containsKey(key)) {

return memo.get(key);

}

int diff = heights[index + 1] - heights[index];

// If the next building is not taller, move to the next building

if (diff <= 0) {

int result = dfs(heights, index + 1, bricks, ladders, memo);

memo.put(key, result);

return result;

}

// Try using bricks first

int useBricks = index; // Default to current index if bricks cannot be used

if (bricks >= diff) {

useBricks = dfs(heights, index + 1, bricks - diff, ladders, memo);

}

// Try using a ladder

int useLadder = index; // Default to current index if ladder cannot be used

if (ladders > 0) {

useLadder = dfs(heights, index + 1, bricks, ladders - 1, memo);

}

// Store the result in the memoization map

int result = Math.max(useBricks, useLadder);

memo.put(key, result);

return result;

}

}

**Key Takeaways:**

1. A **pure DFS solution** is possible but inefficient for large inputs due to its exponential time complexity.
2. Adding **memoization** can significantly improve performance by avoiding redundant calculations.
3. For large inputs, the **greedy approach with a min-heap** (as shown in the first solution) is the most efficient and recommended method.

**Rather than optimize with memoization, can we solve with bottom-up Dynamic Programming solution ?**

Yes, it is possible to solve the "Furthest Building You Can Reach" problem using **a bottom-up Dynamic Programming (DP)** approach. **However, this problem is not naturally suited for a traditional DP solution because it involves two variables (bricks and ladders) that can change independently, making the state space quite large. As a result, a DP solution would likely be inefficient and impractical for large inputs due to its high time and space complexity.**

That said, I'll provide **a bottom-up DP solution** for educational purposes. Keep in mind that this approach is not optimal for this problem, and the greedy approach with a min-heap (as shown in the first solution) is the recommended method.

**Bottom-Up DP Solution Code:**

public class Solution {

public int furthestBuilding(int[] heights, int bricks, int ladders) {

int n = heights.length;

// DP table: dp[i][j][k] represents the furthest building we can reach

// at index i, with j bricks and k ladders remaining.

// Initialize with -1 to indicate unreachable states.

int[][][] dp = new int[n][bricks + 1][ladders + 1];

for (int i = 0; i < n; i++) {

for (int j = 0; j <= bricks; j++) {

for (int k = 0; k <= ladders; k++) {

dp[i][j][k] = -1;

}

}

}

// Base case: Start at building 0 with all bricks and ladders.

dp[0][bricks][ladders] = 0;

// Iterate through each building

for (int i = 0; i < n - 1; i++) {

for (int j = 0; j <= bricks; j++) {

for (int k = 0; k <= ladders; k++) {

if (dp[i][j][k] == -1) {

continue; // Skip unreachable states

}

int diff = heights[i + 1] - heights[i];

// If the next building is not taller, move to the next building

if (diff <= 0) {

dp[i + 1][j][k] = Math.max(dp[i + 1][j][k], dp[i][j][k] + 1);

} else {

// Try using bricks

if (j >= diff) {

dp[i + 1][j - diff][k] = Math.max(dp[i + 1][j - diff][k], dp[i][j][k] + 1);

}

// Try using a ladder

if (k > 0) {

dp[i + 1][j][k - 1] = Math.max(dp[i + 1][j][k - 1], dp[i][j][k] + 1);

}

}

}

}

}

// Find the maximum index reached

int maxIndex = 0;

for (int i = 0; i < n; i++) {

for (int j = 0; j <= bricks; j++) {

for (int k = 0; k <= ladders; k++) {

if (dp[i][j][k] != -1) {

maxIndex = Math.max(maxIndex, i);

}

}

}

}

return maxIndex;

}

}

**Explanation of the DP Approach:**

1. DP Table Definition:
   1. dp[i][j][k] represents the furthest building we can reach at index i, with j bricks and k ladders remaining.
   2. Initialize the DP table with -1 to indicate unreachable states.
2. Base Case:
   1. Start at building 0 with all bricks (bricks) and ladders (ladders). Set dp[0][bricks][ladders] = 0.
3. State Transitions:
   1. For each building i, iterate through all possible remaining bricks (j) and ladders (k).
   2. If the next building is not taller (diff <= 0), move to the next building without using any resources.
   3. If the next building is taller:
      1. Try using bricks (if enough bricks are available).
      2. Try using a ladder (if ladders are available).
4. Result Extraction:
   1. After filling the DP table, find the maximum index i where dp[i][j][k] != -1.

**Why DP is Inefficient for This Problem:**

1. Large State Space:
   1. The DP table has dimensions n x (bricks + 1) x (ladders + 1), which can be very large for big inputs. For example, if n = 10^5, bricks = 10^6, and ladders = 10^2, the table size becomes impractical.
2. High Time Complexity:
   1. The time complexity is O(n \* bricks \* ladders), which is too slow for large inputs.
3. High Space Complexity:
   1. The space complexity is also O(n \* bricks \* ladders)\*\*, which can easily exceed memory limits.

**Example Usage:**

public class Main {

public static void main(String[] args) {

Solution solution = new Solution();

int[] heights = {4, 2, 7, 6, 9, 14, 12};

int bricks = 5;

int ladders = 1;

System.out.println(solution.furthestBuilding(heights, bricks, ladders)); // Output: 4

}

}

**Key Takeaways:**

1. A bottom-up DP solution is possible but inefficient for this problem due to its large state space and high time/space complexity.
2. The greedy approach with a min-heap is the most efficient and recommended solution for this problem.
3. Use DP only for problems where the state space is manageable and the problem naturally fits a DP structure.

**Refer to**

[L1405.Longest Happy String (Ref.L1642)](note://WEB763090169ff4f39cc98fd2e2a07dd80a)