DP_Theory.cpp

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                      DYNAMIC PROGRAMMING THEORY: MASTER GUIDE
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Dynamic Programming (DP) is a powerful problem-solving technique used to break complex
problems into smaller overlapping subproblems, solving each only once and storing results
for future use. This guide will teach you how to solve any DP problem on your own.

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                                1. WHAT IS DP?
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Dynamic Programming is an optimization technique based on:

- **Overlapping Subproblems**: The same subproblems appear multiple times in recursion.
- **Optimal Substructure**: The optimal solution to a problem can be built from optimal
solutions to its subproblems.

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                             2. WHEN TO USE DP?
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Check if the problem has:

1. **Optimal Substructure**: The solution to a problem depends on solutions to subproblems.
2. **Overlapping Subproblems**: The problem can be broken into smaller subproblems that
repeat.

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                           3. STEPS TO SOLVE DP PROBLEMS
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1. **Define the DP State:**
   - What parameters determine the subproblem?
   - Example: dp[i] = min cost to reach step i.

2. **Formulate Recurrence Relation:**
   - Express `dp[i]` in terms of smaller subproblems.
   - Example: `dp[i] = min(dp[i-1], dp[i-2]) + cost[i]` (Climbing Stairs).

3. **Determine Base Cases:**
   - The simplest subproblem solutions.
   - Example: `dp[0] = 0`, `dp[1] = cost[1]`.

4. **Choose the Approach:**
   - **Top-Down (Memoization)**: Recursive function + memoization table.
   - **Bottom-Up (Tabulation)**: Iteratively compute subproblems.

5. **Optimize if Needed:**
   - Reduce space complexity (e.g., use two variables instead of an array).

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                        4. COMMON DP PATTERNS
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1. **1D DP:**
   - Problems: Fibonacci, Climbing Stairs, Maximum Subarray Sum.
   - Structure: `dp[i] = f(dp[i-1], dp[i-2], ...)`

2. **2D DP:**
   - Problems: Longest Common Subsequence, Unique Paths, Edit Distance.
   - Structure: `dp[i][j]` represents a subproblem depending on two parameters.

3. **Interval DP:**
   - Problems: Matrix Chain Multiplication, Palindrome Partitioning.
   - Structure: Solve subproblems within a range `[i, j]`.

4. **Bitmask DP:**
   - Problems: Traveling Salesman, Hamiltonian Paths.
   - Structure: Use bitmasks to track subsets of elements.

5. **Tree DP:**
   - Problems: Tree Diameter, Independent Set in Trees.
   - Structure: Process tree nodes with DFS and store results at each node.

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                      5. STRATEGY TO SOLVE DP QUESTIONS
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1. **Understand the problem statement.**
2. **Identify if DP applies (overlapping subproblems, optimal substructure).**
3. **Define the DP state carefully.**
4. **Write the recurrence relation.**
5. **Determine base cases.**
6. **Choose an approach (Memoization vs. Tabulation).**
7. **Implement & Optimize.**

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                        6. COMMON DP MISTAKES
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- **Incorrect DP state:** Missing parameters that affect the answer.
- **Wrong base cases:** If base cases are incorrect, the whole DP table will be wrong.
- **Overlapping subproblems not cached:** Leads to exponential time complexity.
- **Unnecessary state space:** Optimizing memory can improve performance.

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                        7. RESOURCES TO MASTER DP
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- **Books:**
  - *Introduction to Algorithms (CLRS)* - Chapter on DP.
  - *Algorithm Design* by Kleinberg & Tardos.

- **Online Platforms:**
  - Codeforces, AtCoder, LeetCode, TopCoder (for practice problems).
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  - HackerRank, GeeksforGeeks (for explanations & tutorials).

- **Contests & Challenges:**
  - Participate in DP-based coding contests to sharpen your skills.

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                        FINAL THOUGHTS: BECOMING A DP MASTER
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- DP requires practice! Solve **diverse** problems across different categories.
- Start with **classic DP problems** like Knapsack, LIS, and Fibonacci.
- **Think in terms of subproblems**: Break the problem into states and build up.
- Optimize solutions by reducing memory **when necessary**.
- If stuck, **work out small cases by hand** to find patterns.

By following these principles, **you will master DP and be able to solve any DP problem
independently!**

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