

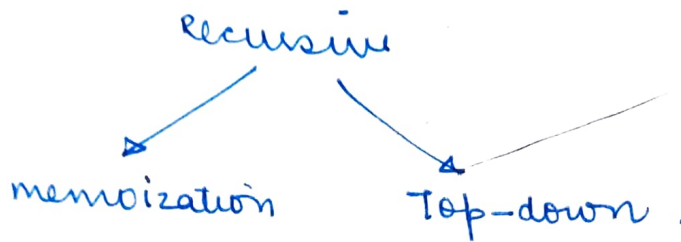
Dynamic Programming

DP → enhanced Recursion

Identification

(to check if a problem is of DP or not)

- choice of including the current element
- optimization is asked

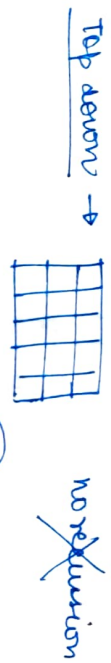
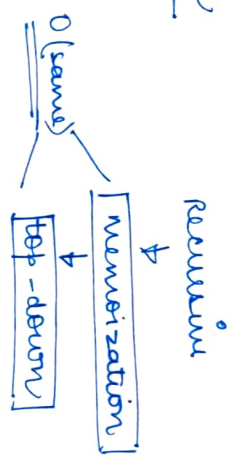
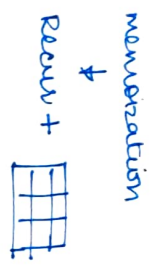


- 1) ~~0-1 knapsack (6)~~
- 2) ~~unbounded knapsack (5)~~
- 3) Fibonacci (7)
- 4) ~~LCS (15)~~
- 5) LIS (10)
- 6) Kadane's Algorithm (6)
- 7) Matrix chain multiplication (7) (★)
- 8) DP on trees (4)
- 9) DP on grids (14)
- 10) others (5)

0-1 knapsack

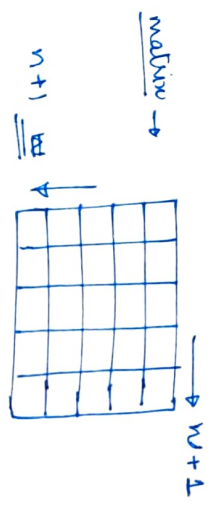
- subset sum
- equal sum
- count of subset sum
- minimum subset sum
- Target sum
- # of subset with given difference

Top-down approach



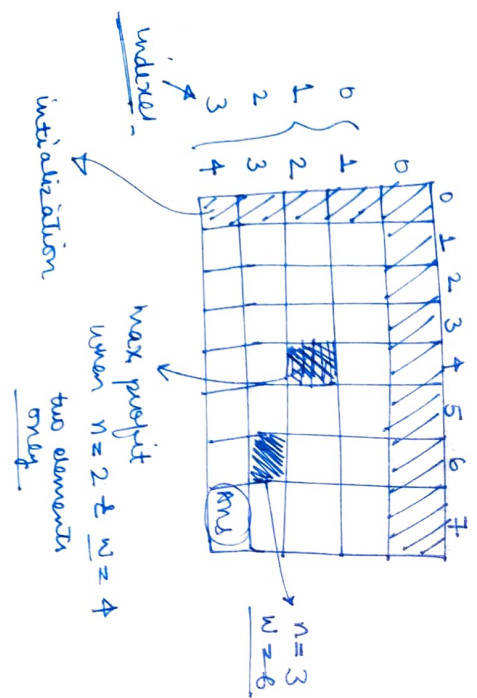
ans $\Rightarrow$ 0/p

as not recursion call are there.



Step 1 $\rightarrow$ Initialize
Step 2 $\rightarrow$ Recursion calls $\rightarrow$ iterative version

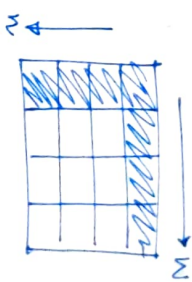
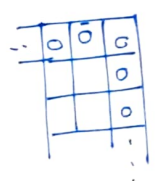
$w = 7$
 $N = 8 \times 4$



Recursion $\rightarrow$ Iterative

Base condition $\rightarrow$ initialization (Top-down)

return 0 $\rightarrow$ $n == 0$ || $w == 0$



Recursion

if ($n == 0$ || $w == 0$)
return 0;

Top-down

for (int $i \rightarrow n+1$)
for (int $j \rightarrow 0 \rightarrow w+1$)
if ($i == 0$ || $j == 0$)
dp[i][j] = 0;

if ($val[n+1] \leq w$) {

return max ($val[n+1] +$
 $kp(wt, val, w - wt[n+1],$
 $n+1)$);

if ($wt[n+1] \leq w$) {

$t[n][w] = \max (val[n+1] +$
 $t[w - wt[n+1]] [n+1],$
 $t[n+1][w])$

else
 $t[n][w] = t[n][w];$

if ($wt[n+1] \leq w$) {

$t[n][w] = \max (val[n+1] + t[n+1][w - wt[n+1]],$
 $t[n+1][w])$

else

$t[n][w] = t[n+1][w]$

now $\rightarrow$ (n, w) $\rightarrow$ (i, j)

and run a loop

```

for (int i = 1; i < n+1; i++) {
    for (int j = 1; j < n+1; j++) {
        if (int [i-1] <= j) {
            t[i][j] = max
                (
                    val [i-1] +
                    t[i-1][j - int [i-1]]
                )
            t[i-1][j]
        }
    }
}

```

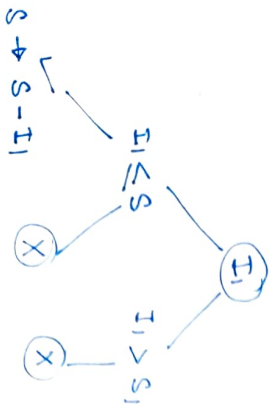
```

else {
    t[i][j] = t[i-1][j];
}
}
Return t[n][n];

```

1) Subarray Sum Problem

I/P → 2 3 7 8 10 → T/F ⇒ given an array
 sum → 11
 check if
 subarray sum is



bool dfs (int i, arr, sum) {
 if (i == arr.size())
 return false;
 if (sum == 0) return T;
 if (arr[i] < sum) {
 return dfs (i+1, sum - arr[i], arr);
 }
 || dfs (i+1, sum, arr);
}

dp [n+1] [sum+1]

}

use
 dfs (i+1, sum, arr);

best dp [n+1] [sum+1]

memset (dp, t, sizeof (dp));
 bool dfs (int i, arr, sum) {
 if (i == arr.size()) return false;
 if (dp [i] [sum] != -1) return dp [i] [sum];

Initialization of matrix

	sum			
↓	T	F	F	- - -
↑	T			
n	T			
1	T			

sum = 0 y → T
 n = 0
 sum = 5 y F
 n = 0
 sum = 0 y T
 n = n

for (int i = 0 → n)

for (int j = 0 → sum) {

if (i == 0) dp [i] [j] = false
 if (j == 0) dp [i] [j] = true

for (int i = 1 → n)

for (int j = 1 → sum) {

if (arr [i] <= j) {

t [i] [j] = t [i-1] [j - arr [i]] ||
 t [i-1] [j];

else

t [i] [j] = t [i-1] [j];

Return t [n] [sum];

Equal sum partition

$$5 \ 1 \ 1 \ 5 \ 1 \ 3 \rightarrow [1]_{\text{new}}$$
$$\frac{T}{F} \rightarrow \frac{D}{P}$$

divide array in
two subsets

such that both
have equal sum.

$$\text{sum} \rightarrow \text{sum}(\text{array}) = \underline{\underline{22}}$$

at any element



bool subsetsum(int arr[], int sum, int n) {

$$s_1 + s_2 \rightarrow \text{sum}$$
$$as \quad G = S_2$$

25 = sum

hence sun must be
even

we just have to find a subarray with sum of $\text{arr}[2]$

return substrum (area, i, surf2);

count of subset of given sum :-

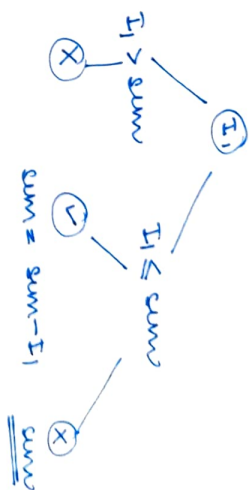
$$I/p \rightarrow$$

arr[] $\rightarrow$ 2 3 5 6 8 10
sum $\rightarrow$ 10

10 → ∞

$$\text{dp}[n+1][\text{sum}+1]$$

3
11
0
↓
7

$$T \rightarrow \text{sum} = 0$$

$$\text{int dfg}(\text{int } i, \text{act}, \text{cum}) \Sigma$$

if (i == arr.size()) return 0;

~~if same - 0 - future - 1~~
$$y[dp[i][sum] - 1] = -1 \text{ return } dp[i][sum]$$

if (sum == 0) return 1;

~~if~~ if (arr[i] ≤ arr[j])

$$\text{dp}[i][\text{sum}] = \text{dfs}(i+1, \text{arr}, \text{sum} - \text{arr}[i]) +$$

dfs (i+1, arr, sum);

```
else dfs(i+1, arr, sum);  
return dp[i][sum];
```

11

5

[illegible]

$$if (arr[i] \leq sum) \{$$
$$\text{else } \text{ap}(i+1)(f);$$

$$\begin{bmatrix} 5 & 1 & 1 & 9 & 7 \end{bmatrix} \rightarrow \text{array} [7] \rightarrow$$

59,13

$$b \leftarrow (t - 91) \bmod 256$$

11,6,55

111

0/0

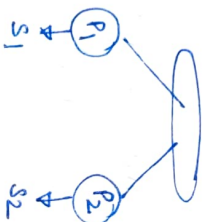
000 (12-11) = 1

int als line vektor an, int s_1) $\{$

 ~~$s_2 = \text{sum} - s_1$~~

if (i == arr.size()) return INT_MAX;

return

$$\text{max} \quad \text{def}(i+1, \text{arr}, s_1 + \text{arr}[i]),$$
$$(\text{dfs}(i+1, \text{acc}, k+1, \text{acc}i)),$$


$abs(s_1 - s_2) + \min$
 previous question
 $abs(s_1 - s_2) = 0$

$$S_2 - S_1 \rightarrow \phi(\min)$$
$$\begin{aligned} & \text{Range} - S_1 - S_1 \rightarrow \min \\ & \text{Range} - 2S_1 \rightarrow \min \end{aligned}$$

As we have to return abs

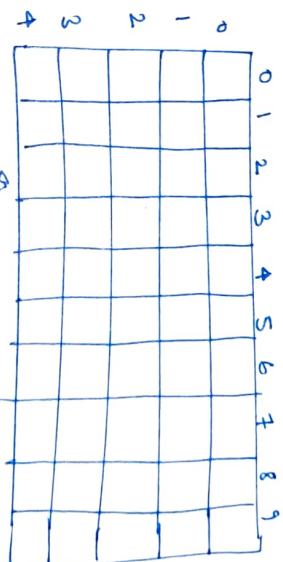
2008/2

range

52-51

always smaller

we have to calculate maximum value

$$s_1 < \text{range}/2$$


For range/2
the maximum val
of S for which
the cell is T is
the value of S1.

we can
square this
by subtract
sum
problem

~~Comp~~ Count the # of subjects with given difference.

$$w_4 = \begin{bmatrix} 1 & 1 & 2 & 3 \end{bmatrix}$$

↓

$$0/p = 3$$
$$\{1, 2\} \quad \{1, 3\}$$

$$\{1, 3\} \quad \{1, 2\}$$

$$\{1, 1, 2\} \quad \{3\}$$

$$s_1 - s_2 = d$$
$$Q_{25} = \frac{d+ar}{d+ar}$$

$$\text{sum}(S1) = \frac{a + \text{sum}(arr)}{2}$$

problem reduced to count of subset

$$S = \frac{a + \text{sum}(arr)}{2}$$

Target sum

arr: [1, 1, 2, 3]

sum: 1
0/1 → 3.

Ex: $+1-1+2+1-1-2+3$

$$= 1$$

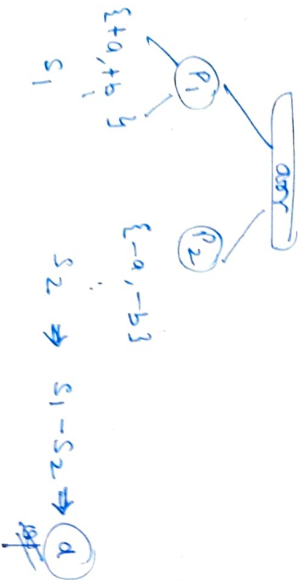
$$+1-1-2+3$$

$$= 1$$

assign value +/- in front of every element & then check the result

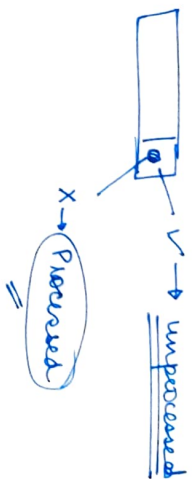
1st approach → $\text{dfs}(i+1, \text{nums}, \text{sum} + \text{arr}[i]);$
 $\text{dfs}(i+1, \text{nums}, \text{sum} - \text{arr}[i]);$

2nd approach → same as previous one



Unbounded Knapsack

multiple occurrences of same item is allowed.



repeatedly

if item is taken or not it is taken as considered (processed)

$$\text{return } \max(\text{val}[i] + \text{dfs}(i-1, \text{cap} - \text{wt}[i]), \text{dfs}(i-1, \text{cap}))$$

unbounded.

$$\text{max}(\text{val}[i] + \text{dfs}(i, \text{cap} - \text{wt}[i]), \text{dfs}(i+1, \text{cap}))$$

$$\text{t}[i][f] =$$

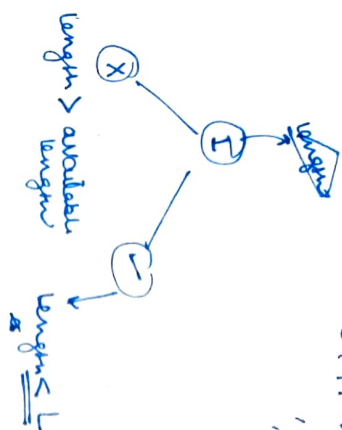
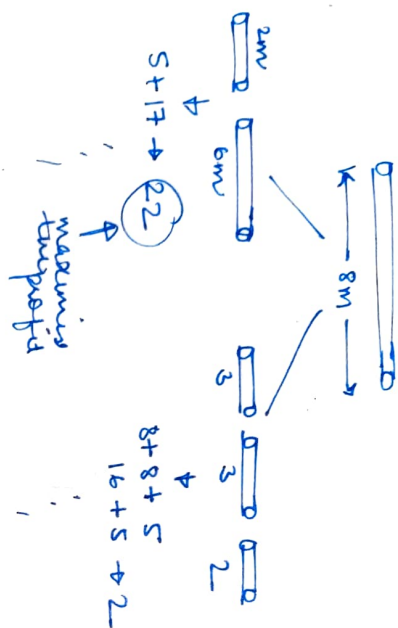
$$\max(\text{t}[i][f - \text{wt}[i]] + \text{val}[i-1], \text{t}[i-1][f])$$

variations

- Knock cutting
- coin change-1
- coin change-2
- Maximum items cut.

Rod Cutting Problem

length[] $\rightarrow$ 1 2 3 4 5 6 7 8
 price[] $\rightarrow$ 1 5 8 9 10 17 17 20
 L $\rightarrow$ 8



we can include any piece two or more times

length $\rightarrow$ 1 2 3 4 5 6 7 8
 price $\rightarrow$ 1 5 8 9 10 17 17 20

dp[i, L] $\rightarrow$ max price of length i

if (len[i] < L) {
 int ans = dp[i, L];
 if (i > len.size()) return 0;
 if (len[i] < L) {
 ans = max(ans, dp[i, L - len[i]] + price[i]);
 return ans;
 }
 return dp[i, L];
}

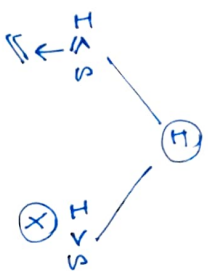
else
 return dp[i, L];

Coin Change - I # of ways

coin[] $\rightarrow$ 1 2 3
 sum $\rightarrow$ 5

1+2+2
 2+1+1+1
 3+2
 1+1+1+1+1
 3+1+1
 sum = 5

5 numbers of ways to produce 5 as output



unbounded because we can have multiple instances of single coin

int dp(int i, int arr, s) {
 if (arr[i] > s) return 0;
 return dp(i, arr, s - arr[i]) + dp(i+1, arr, s);
}

int dp(int i, int arr, s) {
 if (i > arr.size()) return 0; if (s == 0) return 1;
 if (arr[i] < s) {
 return dp(i, arr, s - arr[i]) + dp(i+1, arr, s);
 }
 return dp(i+1, arr, s);
}

else
 return dp(i+1, arr, s);

using dp $\rightarrow$ sum

size $\downarrow$

1	0	0	0	...
1	1			

$if (wt[i-1] \leq j)$

$t[i][j] = t[i][j - arr[i-1]] + t[i-1][j]$

else

$t[i][j] = t[i-1][j];$

Coin Change - II

coin[] $\rightarrow$ [1, 2, 3, ...]

sum $\rightarrow$ 5

$(2+3)$
 $1+2+2$
 $1+1+1+2$
 $1+1+3$
 $1+1+1+1+1$

$\min = 2$

O/P $\rightarrow$ min # $\rightarrow$ 2

size $\downarrow$

0	0	0	0	...
0	0	0	0	...

$\rightarrow$ sum

Longest Common Subsequence

I/P $\rightarrow$

$x: a b c d e f g$
 $y: a b c d e f g$

Ans $\rightarrow$ abdc

O/P $\rightarrow$ 4

subsequence

we can skip element

substring

we have to choose continuous

int dfs (string x, string y, i, j) {

~~if (i == x.length() || j == y.length())~~

$if (i \geq x.length() || j \geq y.length())$

return 0;

$if (x[i] == y[j])$ {

return 1 + dfs (x, y, i+1, j+1);

} else {

return max (dfs (x, y, i+1, j),

dfs (x, y, i, j+1));

}

memoized

$\rightarrow$ build an array/vector of longest inp+1

vector <vector <int>> memo (n+1, vector <int> (m+1, -1));

$n \rightarrow x.length()$

$m \rightarrow y.length()$

Top down DP:

X	:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100		

$$y(x[i-1]) = y[i-1]$$
$$tE_{ij}E_{ij} = 1 + tE_{i-1}E_{i-1};$$

3
the 2

$$+E_i E_j = \max \{ +E_{i-1} E_j, +E_i E_{j-1} \};$$

longest common substring

X → abcde
Y → abfde

must be contagious

② → 5/8

int abs { ~~string~~ x, string y, int i, int j }

$$if (i \geq x.length() || i \geq y.length()) return 0;$$
 ~~$y(x) = y(x)$~~

```
int temp = 1 + abs(i+1, j+1);
```

$$jhs = \max(\text{likes}, \text{temp})$$

3 ~~extra~~
get abs (i+1, j+1)

```
int ops (string X, string Y, int i, int j, int end)
```

if $li \geq x.length()$ then $y.length()$ returns cnt ;

$$y(x_{ij}) = y(i, j) \{$$

base count = ~~base~~ (dfs(i+1, j+1, cnt+1))

5. else

count = max

$$(\text{count}, \text{dfs}(i+1, t, a), \text{dfs}(i, t+1, 0))$$

return count;

Print longest common subsequence.

~~X X~~

~~(P) (P)~~

~~(P) (P)~~

~~(P) (P)~~

~~P P~~

~~P T~~

~~T~~

Handwritten symbols:

Top row: χ , $\times$

Middle row: $\odot$, $\odot$

Bottom row: $\ominus$, $\ominus$

O/P → ans

A handwritten diagram of a 6x6 grid. The columns are labeled at the top with letters: a, b, c, d, e, f. The rows are labeled on the right with numbers: 0, 1, 2, 3, 4, 5. The grid contains the following letters (row by row):

a	b	c	d	e	f
a	b	c	d	e	f
a	b	c	d	e	f
a	b	c	d	e	f
a	b	c	d	e	f
a	b	c	d	e	f

A path is marked with circled numbers 1 through 6 and arrows, starting from (0,0) and ending at (5,5). The path is: (0,0) → (1,1) → (2,2) → (3,3) → (4,4) → (5,5).

we'll do the
reverse.

start with $i = n$ & $j = m$
if $x(i-1) = x(j-1)$ {

Engineering

100

if equal $i, j \rightarrow i--, j--$
 else $i, j \rightarrow \max \left(\begin{matrix} i-1, j \\ i, j-1 \end{matrix} \right)$

int $i = m; j = n;$
 while ($i > 0$ or $j > 0$) {

if ($a[i-1] == b[j-1]$) {

s.push_back(a[i-1]);

$i--; j--;$

}
 else {

if ($a[i-1] > b[j-1]$)

$i--;$

else $j--;$

}

}

reverse(s.begin(), s.end());

}

Shortest common supersequence

a: "geek"
 b: "eke"

merge $\rightarrow$ geek eke $\rightarrow$ geeeke

geeeke

a: "AGGTAB"
 b: "GXTXAYB"

AGGTGXTABTXYB

not necessarily
 continuous.

both sequences
 are present
 in this string

Algorithm for A, B

length $\rightarrow$ 9

Shortest
 Supersequence

AGGXTXAYB

G T A B

we have used this
 only once as it is
 present in both.

to calculate
 the length
 we can just

$m + n - \text{LCS}$

In other
 terms, it is
 called as
LCS

Shortest length $\rightarrow m + n - \text{LCS}$

Minimum # of insertion and deletion

a → heap
b → pea

heap → pea

pea

Insert P
Remove to
Reverse P.
this: 1
del: 2

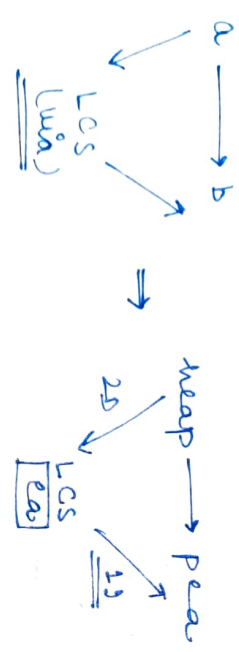
a → b

perform insert and delete on string a to reverse it to convert it to 'b'

① If we note the special point

② ea remains intact as this is the

LCS

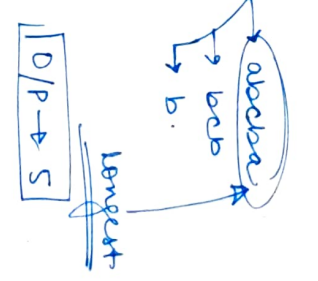


of deletions = a.length() - LCS.length
of insertion = b.length() - LCS.length

Longest Palindromic Subsequence

I/P → s: abcba

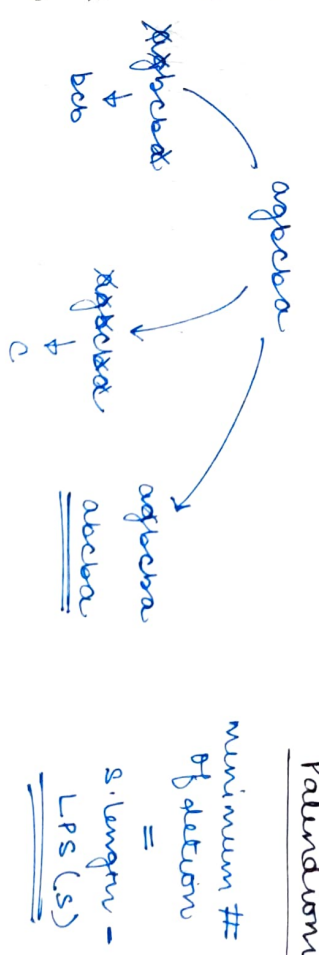
we can have discontinuous/continuous sequence → that is a palindromic sequence



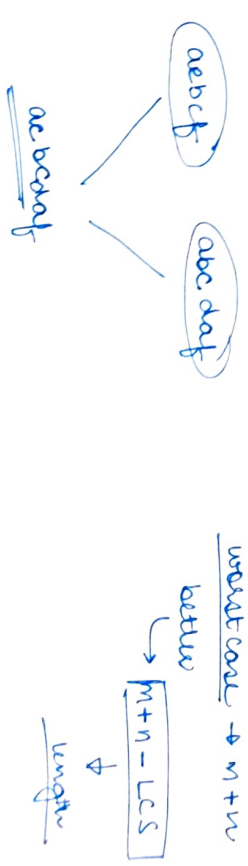
② we can find the longest common subsequence of s and reverse (s)

$$LPS(a) \equiv LCS(a, reverse(a))$$

Minimum # of deletions in a string to make it Palindrome



Print LCS → shortest common supersequence



Longest Repeating Subsequence

str = "A A B E B C D D"

We have to find a subsequence in this string which is repeating

① A B E ② C ③ D — (A) (B) E — C (D)
 [A B D] — repeating ABD

0/p → ABD → length = 3

We will find LCS among str and dup(str)

A A B E B C D D
 A B E B C D D

while including in result

if $a[i-1] == b[i-1]$ & at $i == j$

→ we will not include it

$a[i-1] == b[i-1]$ & $i \neq j \Rightarrow$ include

if $(a[i-1] == b[i-1] \text{ \& \& } i \neq j) \{$

$t[i][j] = t[i-1][j-1] + 1;$

$\}$
 res.

$t[i][j] = \max(t[i][i-1], t[i-1][j])$

	a	b	c	a	a	b
a	0	1	1	1	1	1
b	0	1	1	2	2	2
c	0	1	2	3	3	3
b	0	1	2	3	3	4

abcbda
 abcb
 LCS → abcb

while $(i > 0 \text{ \& \& } j > 0) \{$

~~if $(a[i-1] == b[i-1])$ {~~

if $(a[i-1] == b[i-1]) \{$

$i--; j--;$

res.push_back(a[i-1]);

$\}$
 else {

~~if $(a[i-1] > b[i-1])$ {~~

if $(t[i-1][j] > t[i][j-1]) \{$

res.push_back(a[i-1]);

$i--;$
 $\}$
 else {

res.push_back(b[i-1]);

$j--;$
 $\}$
 $\}$

while $(i > 0) \{$
 s.push_back(a[i-1])
 $\}$
 while $(j > 0) \{$

s.push_back(b[i-1])

$\}$

reverse(res)

Sequence Pattern Matching

I/P $\rightarrow$ a: "AXY"

b: "ADXCXY"

if A is a subsequence of B

we can run two loops and check if it is equal or we can just try LCS

LCS("AXY", "ADXCXY") == "AXY"

True
else false

Minimum Number of insertions to make it

palindrome

S: a e / e b e b a

~~a e / e b e b a~~

S $\rightarrow$ a e b c b d a

a @ e b c b @ d a

even value

add

length - (LCS length)

characters

we'll find the LCS and the remaining elements (which are not included in LCS) are those which do not have a pair

Matrix Chain Multiplications

- 1) MCM
- 2) Printing MCM
- 3) Evaluate Exp to True / Boolean Parenthesis
- 4) Max/min value
- 5) Palindrome partitioning
- 6) Scramble string
- 7) Egg dropping

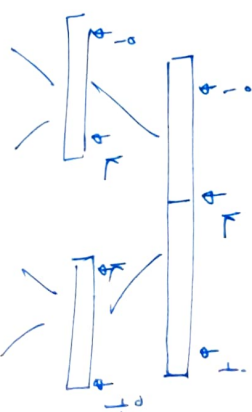
Identification + formal

breaking the string at any point

fun(i, j)

fun(i, k)

fun(k, j)



int solve (int arr[], int i, int j) {

if (i > j) return 0;

for (int k = i; k < j; k++) {

temp = solve(arr, i, k)

$\oplus \leftarrow$ (any operation)
solve(arr, k+1, j)

ans = fun(temp, ans);

}

Matrix chain multiplication

cost of multiplying two matrices



$a \times b \times c$



$a_1 a_2 a_3 a_4$
 $((a_1 a_2) (a_3 a_4))$
 $((a_1 (a_2 a_3)) a_4)$

$A \rightarrow 5 * 30$
 $B \rightarrow 30 * 7$
 $C \rightarrow 7 * 10$
 $ABC \rightarrow$

5	30	7	10
---	----	---	----

$AB \rightarrow (5 \times 30 \times 7)$
 $= 5 \times 1050$
 5×7

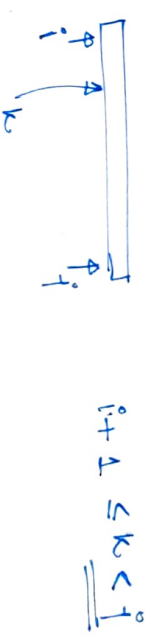
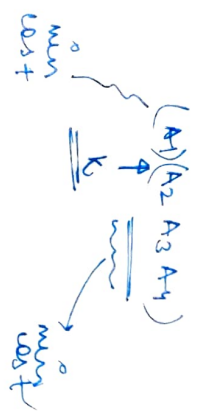
Return minimum cost after multiplications

$arr[] \rightarrow$

0	1	2	3	4
40	20	30	70	30

 no of matrices = $a.size() - 1$

$a_1 \rightarrow 40 \times 20$
 $a_2 \rightarrow 20 \times 30$
 $a_3 \rightarrow 30 \times 10$
 $a_4 \rightarrow 10 \times 30$
 $A_i \rightarrow arr[i-1] * arr[i]$



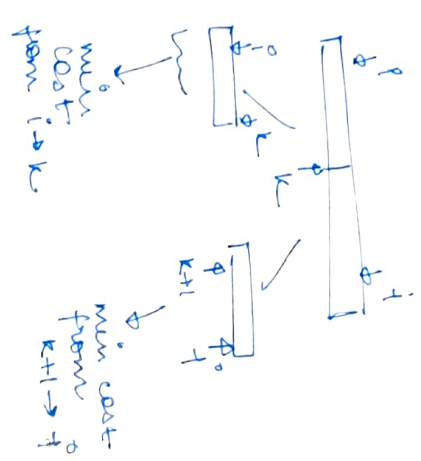
$arr[i] \rightarrow$

40	20	30	10	30
----	----	----	----	----

 $A_i \rightarrow arr[i-1] \times arr[i]$

int solve (int i, int j, int arr[]) {
 if ($i \geq j$) return 0;
 // move k $i \rightarrow j$
 for (int k = i; k < j; k++) {
 solve (arr, i, k);
 solve (arr, k+1, j);
 }

we have ensured that a group contains atleast 1 matrix...



$(AB)(CD)$
 min cost of multiplying AB
 min cost of multiplying CD
 And then multiply both resultant matrix

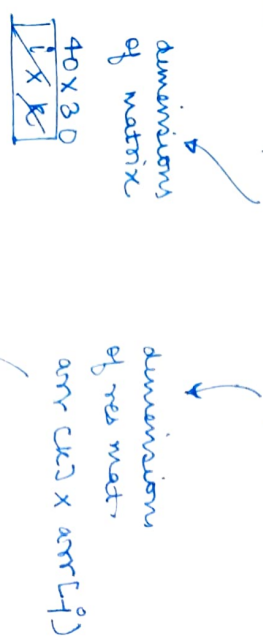
40	20	30	10	45	60
----	----	----	----	----	----

min cost of multiplication of $i \rightarrow k$ (40×20) (20×30)

min cost of multiplication of $k \rightarrow j$ (30×10) (10×45) (45×60)

tempans 1 = solve (i, k)
tempans 2 = solve (k+1, j)

sum $\rightarrow$ tempans 1 + tempans 2 +



arr[i-1] x arr[k] x arr[j]

$\rightarrow$ arr[i-1] x arr[k] x arr[j]

temp-res = temp 1 + temp 2 + arr[i-1] x arr[k] x arr[j]

int solve (int arr[], int i, int j) {

if (i >= j) return 0; int ans = INT_MAX;

for (int k = i; k <= j-1; k++) {

int tempans = solve (arr, i, k) +

solve (arr, k+1, j) + arr[i-1] * arr[k] * arr[j];

if (temp < min) min = temp;

return min;

memoization

matrix $\rightarrow$ int memo [i+1] [j+1]

size of array

int memo [n+1] [n+1];

if (dp [i] [j] == -1) return dp [i] [j]

dp [i] [j] = temp-res

return dp [i] [j];

Palindrome Partitioning

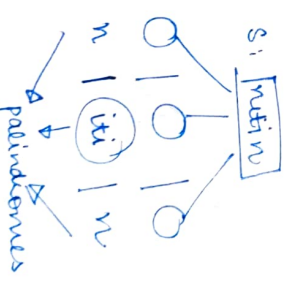
worst case

partition after every character as every letter is a palindrome

multiply

no of partitions $\rightarrow 2$

min



Optimization → After memorization

There is a probability that the recursive problems i.e. solve (i, k) for solve (k+1, j) might get solved previously.

int temp = 1 + solve (s, i, k) + solve (s, k+1, j);

if (memoize(s, i, k) != -1) left = so -

if (dp[i][k] != -1) left = dp[i][k];
if (dp[k+1][j] != -1) right = dp[k+1][j];

storing values if already present

Evaluate Expressions to True | Boolean Parenthesis

string → T | F & F

symbols can be of T, F, |, &, ^

Ex:-

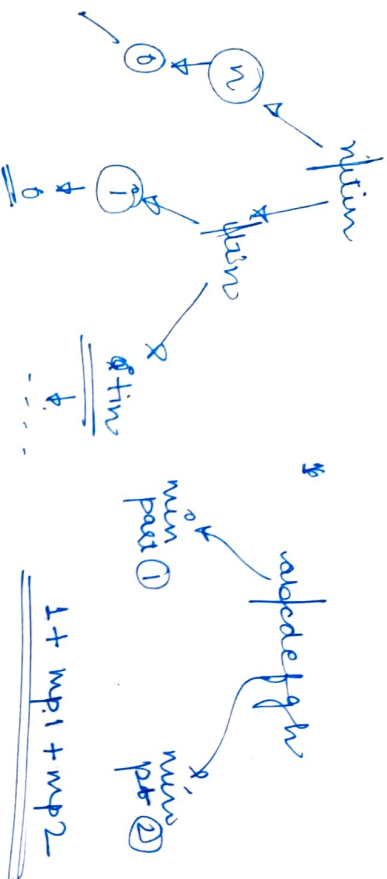
put the brackets in a way so that the evaluated string becomes true

(T ^ F) & T

T ^ (F & T)

T & T

T



whenever we find a palindrome string we need 0 positions

int solve (int over [], int i, int j) {

if (i > j) return 0; int res = INT_MAX;
if (isPalindrome (over, i, j)) return 0;
for (int k = i; k <= j; k++) {

int temp1 = solve (i, k);
int temp2 = solve (k+1, j);

int temp_res = 1 + temp1 + temp2;
res = min (res, temp_res);

return res;

}

$T \mid F \& T \wedge F$
 $\downarrow$
 $(T \mid F) \& (T \wedge F)$
 $T \& T$
 T
 T

$T \mid (F \& T \wedge F)$
 $T \mid (F \& T)$
 $T \mid T$
 T

* we'll put the position of k in such a way that $k-1$ we $\&$ $k+1$ we have bracket

$T \mid (F \& T \wedge F)$
 $\uparrow$
 k

T or F and T xor F
 $\uparrow$
 k
 $\text{exp}' \text{ xor } \text{exp}'$
 $(i, k-1) \quad (k+1, j)$

we'll always put a bracket on operator to jump on operators always $k = k+2$

1) Find $i \neq j$
 $i = 1, j = n-2$
 $n \rightarrow s.length()$

2) Find base condition

$\text{if } (i > j) \text{ return False}$
 $\text{if } (i == j) \{$
 $\text{if } (s[i] == s[j]) \text{ return True}$
 else
 $\text{return } s[i] == 'F';$

if we wanted
 True only else F
 return T else F

we have to find both
 1) when the expression is evaluated true
 2) when the expression is evaluated false

$\text{exp1} \wedge \text{exp2}$
 $T \wedge F \rightarrow T$
 $F \wedge T \rightarrow T$

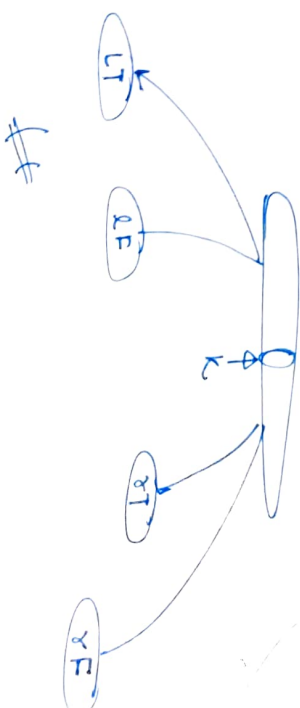
$\text{exp1} \quad \text{exp2}$
 $(T \rightarrow 2) \quad (T \rightarrow 3)$
 $(F \rightarrow 4) \quad (F \rightarrow 5)$
 $2 \times 5 + 4 \times 3$
 $10 + 12 = 22$

so for doing function call, we'll pass parameter
 solve (i, j, T)
 solve (i, j, F)

for $(int k = i+1; k \leq j-1; k = k+2) \{$

$\text{int } LT = \text{solve}(i, k-1, T);$
 $\text{int } RT = \text{solve}(k+1, j, T);$
 $\text{int } LF = \text{solve}(i, k-1, F);$
 $\text{int } RF = \text{solve}(k+1, j, F);$

// answer logic



if (s[k] == '1') {

if (isTrue == true) {

ans = ans + (LT * NT);

else

ans += (LF * RT + LF * RF + LF * RF);

}

else if (s[k] == '1') {

if (isTrue) {

ans +=

(LT * RT + LT * RF + LF * RT);

}

else

ans += LF * RF;

}

else if (s[k] == '1') {

if (isTrue) {

ans += (LF * RT + LT * RF);

}

else

ans += (LF * RT + LT * RT);

}

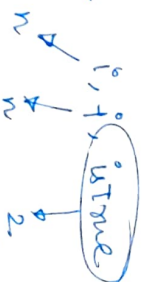
return ans;

memoization

1D | 2D | 3D

→ Dimension depends on number of variables changing in function call

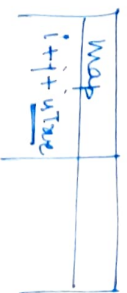
Here ~~max~~ variables (changing) →



dimension → [n+1][n+1][2]

Better way

we can use map



key = to-string(i) + to-string(j) + to-string(isTrue)
= "5+9+F"
→ key of the map

Scrambled string

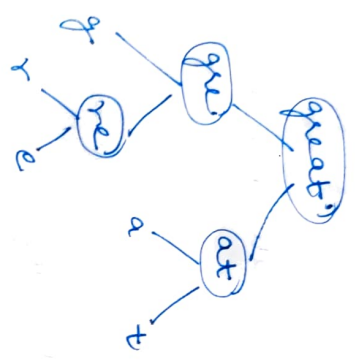
I/P → a: "great"
b: "rgaet"

O/P → True

We represent the string as a binary tree by partitioning it into two non-empty string recursively.

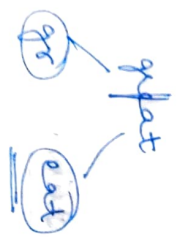
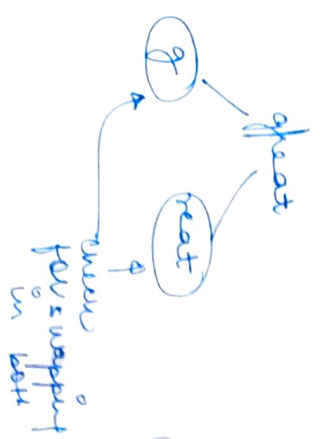
Scrambled string → to generate a scrambled string we can choose any two non-leaf nodes and swap them

- 1) Binary tree only
- 2) NO empty string



Non-leaf node, can be swapped by children

great > scrambled again strings. T

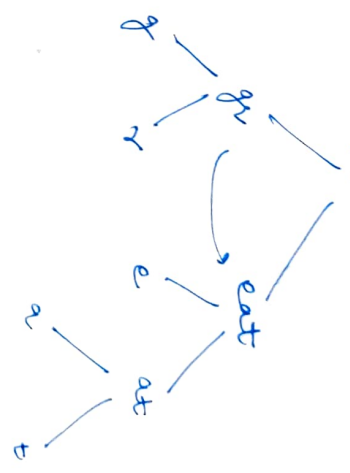


$$k = i + 1 \rightarrow n - 1$$

great

swapping $\rightarrow$ zero or more

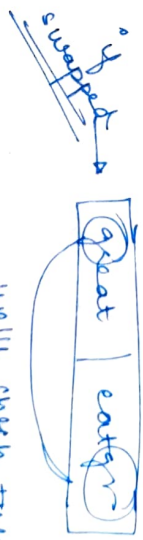
$$i=2 \quad \text{great} \Rightarrow \underline{\text{eatgr}}$$



great $\rightarrow$ great swap X
 great $\rightarrow$ eatgr swap V

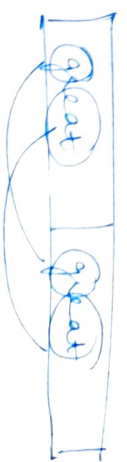
> Notion Trees in both cases.

we can have 2 case eat any i
 - either swap
 - not swap

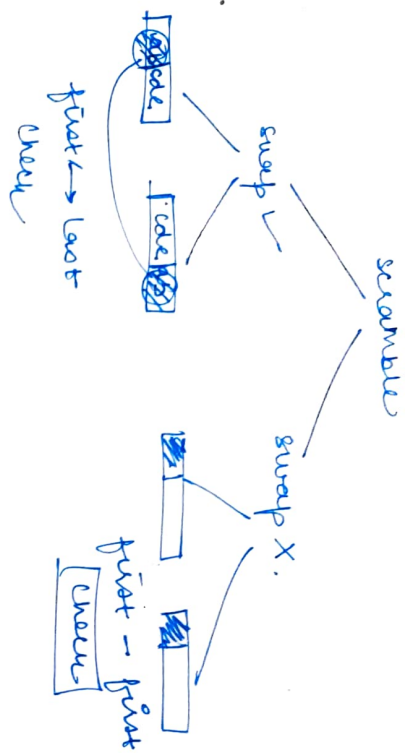


we'll check the first k letters of string with last k if it's scrambled.

not swapped $\rightarrow$



even in order only



if (solve (a.substr (0, k), b.substr (n-k, k)))

return True

else solve (a.substr (k, n-k), b.substr (0, n-k))

return True

if (solve (a.substr (0, k), b.substr (0, k)))

else solve (a.substr (k, n-k), b.substr (k, n-k))

return True

return True

if (solve (a.substr (0, k), b.substr (n-k, k)))

else

solve (a.substr (k, n-k), b.substr (0, n-k))

return True

bool solve (string a, string b)

if (a.compare (b) == 0) return True;

if (a.length () < 1) return false;

return false;

int n = a.length ();

bool flag = false;

for (int i = 1; i < n; i++)

if (cond 1 || cond 2)

flag = true

break;

}

}

return flag;

}

minimization → use wrap 2 key can be

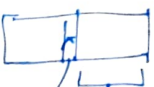
$a + b + 1 + b$

$a + 1 + 1 + b$

$a + 1 + 1 + b$

Egg Dropping Problem

$e = 3$
 $f = 5$



egg break

measured/critical floor

minimum number of attempts to find critical floor

• we drop egg from every floor and check if it breaks.

we have to use 'e' numbers of eggs ideally so that in minimum eggs we can find the critical floor.

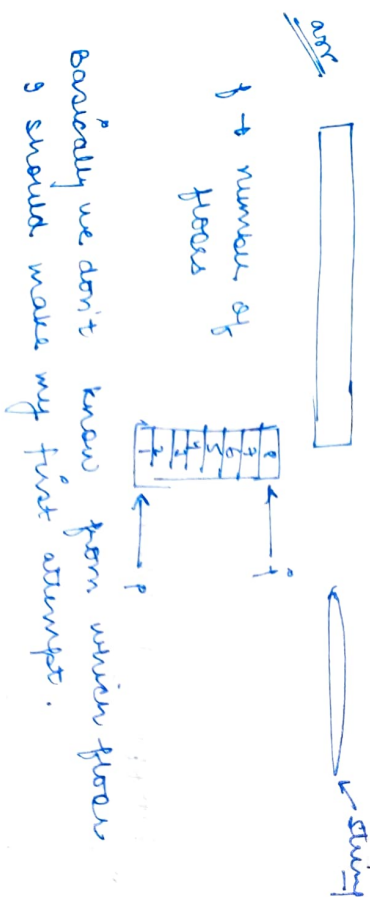
OR

suppose no of >> number of eggs.

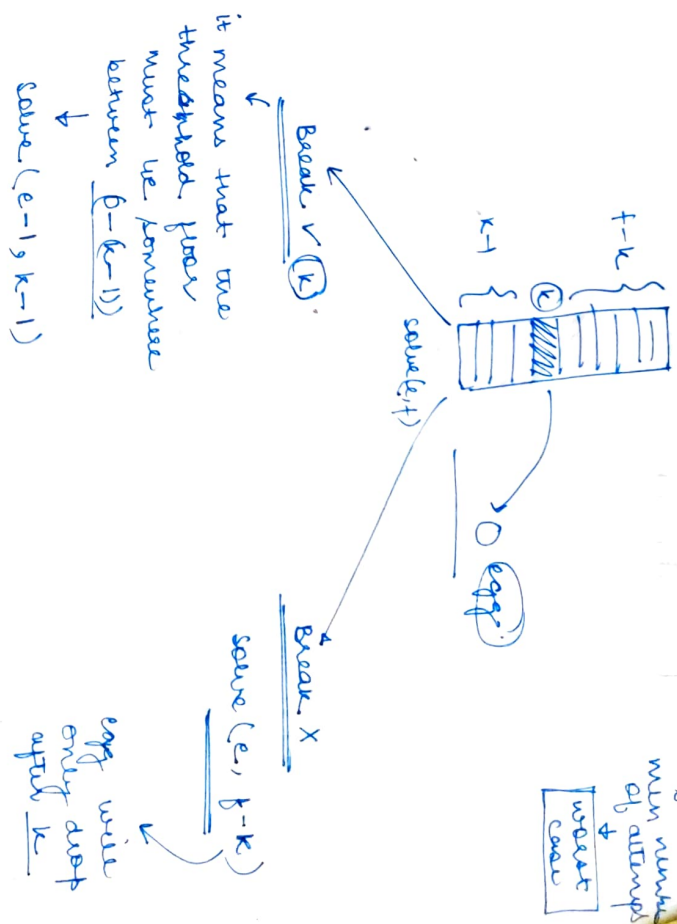
in this case, if we don't use the eggs ideally we won't be able to find the critical floor after using all the eggs also

Also suppose we'll start from bottom we can find the critical floor in 1 egg only but the attempts $\rightarrow$ huge //

• we use egg ideally $\pm$ minimize # of attempts.



basically we don't know from which floor it should make my first attempt.



it means that the threshold floor must be somewhere between $f-(k-1)$ and $f-k$

$\downarrow$
solve(e-1, k-1)

int solve (int e, int f) {

if (f == 0 || f == 1) return f;

if (e == 1) return f;

int min = INT_MAX;

for (int k = 1; k <= f; k++) {

int temp = 1 + max (solve(e-1, k-1),

solve(e, f-k));

min = min (min, temp);

}

return min;

}

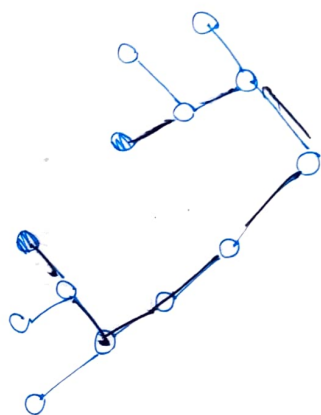
DP ON TREES

Diameter of tree

maximum path between two leaf nodes

Identification

we're traversing a tree and on each node we again need to call recursive functions.



General Syntax

```
int solve (Node *root, int &res) {
    if (root == NULL) return 0;
```

```
    int l = solve (root->left, res);
    int r = solve (root->right, res);
```

```
    int temp = calculate temp ans
```

```
    res = max (res, temp)
```

question dependent

1)

Diameter of Binary Tree

```
int res = INT_MIN;
int solve (Node *root) {
```

```
    if (root == NULL)
        return 0;
```

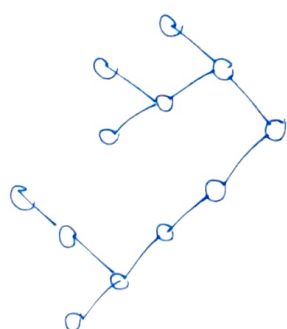
```
    int l = solve (root->left);
```

```
    int r = solve (root->right);
```

```
    int tempAns = 1 + l + r;
```

```
    res = max (res, tempAns);
```

```
    return 1 + max (l, r);
```



Maximum Path sum

maximum path sum from any node to any node

question becomes different when value of node becomes negative

if the value of 'l' or 'r' comes out to be negative then we won't include that

```
max (
    max (l, r) + root->val,
    root->val
)
```

```
int solve (Node *root, int &res) {
```

```
    if (root == NULL) return 0;
```

```
    // getting l & r
```

```
    int temp = max (
        root->val + max (l, r),
        root->val
    );
```

```
    res = max (temp, res);
    return temp;
```

Maximum Path sum from leaf to leaf

```
int solve (Node *root) {  
    if (root == NULL) return 0;  
    int l = solve (root->left);  
    int r = solve (root->right);  
    int temp-ans = max(l, r) + root->val;  
    res = max(res, root->val + l + r);  
    int ans = max(temp-ans, l + r + root->val);  
    res = max(ans, res);  
    return temp;  
}
```

