Competitive programming Notebook 🎈

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1 General

1.1 Split

```
vector<string> split(string s, char key=' ') {
    vector<string> ans;
    string aux = "";

    for (int i = 0; i < (int)s.size(); i++) {
        if (s[i] == key) {
            if (aux.size() > 0) {
                ans.push_back(aux);
                aux = "";
            }
        } else {
            aux += s[i];
        }
    }

    if ((int)aux.size() > 0) {
        ans.push_back(aux);
    }

    return ans;
}
```

1.2 Random

```
random_device dev;
mt19937 rng(dev());

uniform_int_distribution<mt19937::result_type> dist(1, 6); // distribution in range [1, 6]

int val = dist(rng);
```

1.3 Base Converter

```
const string digits = "0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ";

ll tobase10(string number, int base) {
    map<char, int> val;
    for (int i = 0; i < digits.size(); i++) {
        val[digits[i]] = i;
    }

    ll ans = 0, pot = 1;

    for (int i = number.size() - 1; i >= 0; i--) {
        ans += val[number[i]] * pot;
        pot *= base;
    }

    return ans;
}

string frombase10(ll number, int base) {
    if (number == 0) return "0";

    string ans = "";

    while (number > 0) {
        ans += digits[number % base];
        number /= base;
    }

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

    return ans;
}

// verifica se um nÃžmero estÃą na base especificada
bool verify_base(string num, int base) {
    map<char, int> val;
    for (int i = 0; i < digits.size(); i++) {
        val[digits[i]] = i;
    }

    for (auto digit : num) {
        if (val[digit] >= base) {
            return false;
        }
    }

    return true;
}
```

1.4 Template

```
// MEIA NOITE EU TE CONTO
#include <bits/stdc++.h>

using namespace std;

#define _ ios_base::sync_with_stdio(0);cin.tie(0);

typedef long long ll;

const int INF = 0x3f3f3f3f;
const ll LINF = 0x3f3f3f3f3f3f3f3fll;

int main() { _
    return 0;
}
```

2 Math

2.1 2sat

```
// 2SAT
//
// verifica se existe e encontra soluÃğÃčo
// para fÃşrmulas booleanas da forma
// (a or b) and (!a or c) and (...)
//
// indexado em 0
// n(a) = 2*x e n(~a) = 2*x+1
// a = 2 ; n(a) = 4 ; n(~a) = 5 ; n(a)^1 = 5 ; n(~a)^1 = 4
//
// https://cses.fi/problemset/task/1684/
// https://codeforces.com/gym/104120/problem/E
// (add_eq, add_true, add_false e at_most_one nÃčo foram testadas)
//
// O(n + m)

struct sat {
    int n, tot;
    vector<vector<int>> adj, adjt; // grafo original, grafo transposto
    vector<int> vis, comp, ans;
    stack<int> topo; // ordem topolÃşgica

    sat() {}
    sat(int n_) : n(n_), tot(n), adj(2*n), adjt(2*n) {}

    void dfs(int x) {
        vis[x] = true;

        for (auto e : adj[x]) {
            if (!vis[e]) dfs(e);
        }

        topo.push(x);
    }

    void dfst(int x, int& id) {
        vis[x] = true;
        comp[x] = id;

        for (auto e : adjt[x]) {
            if (!vis[e]) dfst(e, id);
        }
    }

    void add_impl(int a, int b) { // a -> b = (!a or
    b)
        a = (a >= 0 ? 2*a : -2*a-1);
        b = (b >= 0 ? 2*b : -2*b-1);

        adj[a].push_back(b);
        adj[b^1].push_back(a^1);

        adjt[b].push_back(a);
        adjt[a^1].push_back(b^1);
    }

    void add_or(int a, int b) { // a or b
        add_impl(~a, b);
    }

    void add_nor(int a, int b) { // a nor b = !(a or
    b)
        add_or(~a, b), add_or(a, ~b), add_or(~a, ~b);
    }

    void add_and(int a, int b) { // a and b
        add_or(a, b), add_or(~a, b), add_or(a, ~b);
    }

    void add_nand(int a, int b) { // a nand b = !(a
    and b)
        add_or(~a, ~b);
    }

    void add_xor(int a, int b) { // a xor b = (a != b
    )
        add_or(a, b), add_or(~a, ~b);
    }

    void add_xnor(int a, int b) { // a xnor b = !(a
    xor b) = (a = b)
        add_xor(~a, b);
    }

    void add_true(int a) { // a = T
        add_or(a, ~a);
    }

    void add_false(int a) { // a = F
        add_and(a, ~a);
    }

    // magia - brunomaletta
    void add_true_old(int a) { // a = T (n sei se
    funciona)
        add_impl(~a, a);
    }

    void at_most_one(vector<int> v) { // no max um
    verdadeiro
        adj.resize(2*(tot+v.size()));
        for (int i = 0; i < v.size(); i++) {
            add_impl(tot+i, ~v[i]);
            if (i) {
                add_impl(tot+i, tot+i-1);
                add_impl(v[i], tot+i-1);
            }
        }
        tot += v.size();
    }

    pair<bool, vector<int>> solve() {
        ans.assign(n, -1);
        comp.assign(2*tot, -1);
        vis.assign(2*tot, 0);
        int id = 1;

        for (int i = 0; i < 2*tot; i++) if (!vis[i])
    dfs(i);

        vis.assign(2*tot, 0);
        while (topo.size()) {
            auto x = topo.top();
            topo.pop();

            if (!vis[x]) {
                dfst(x, id);
                id++;
            }
        }

        for (int i = 0; i < tot; i++) {
            if (comp[2*i] == comp[2*i+1]) return {
    false, {}};
            ans[i] = (comp[2*i] > comp[2*i+1]);
        }

        return {true, ans};
    }
};
```

3 Geometry

3.1 Convex Hull

```
// Convex Hull - Graham scan
//
// Convex Hull is the subset of points that forms the
    smallest convex polygon
// which encloses all points in the set.
//
// https://cses.fi/problemset/task/2195/
// https://open.kattis.com/problems/convexhull (
   counterclockwise)
//
// O(n log(n))

typedef long long ftype;

struct Point {
    ftype x, y;

    Point() {};
    Point(ftype x, ftype y) : x(x), y(y) {};

    bool operator<(Point o) {
        if (x == o.x) return y < o.y;
        return x < o.x;
    }

    bool operator==(Point o) {
        return x == o.x && y == o.y;
    }
```

```cpp
};

ftype cross(Point a, Point b, Point c) {
    // v: a -> c
    // w: a -> b

    // v: c.x - a.x, c.y - a.y
    // w: b.x - a.x, b.y - a.y

    return (c.x - a.x) * (b.y - a.y) - (c.y - a.y) *
    (b.x - a.x);
}

ftype dir(Point a, Point b, Point c) {
    // 0 -> colineares
    // -1 -> esquerda
    // 1 -> direita

    ftype cp = cross(a, b, c);

    if (cp == 0) return 0;
    else if (cp < 0) return -1;
    else return 1;
}

vector<Point> convex_hull(vector<Point> points) {
    sort(points.begin(), points.end());
    points.erase( unique(points.begin(), points.end()
    ), points.end()); // somente pontos distintos
    int n = points.size();

    if (n == 1) return { points[0] };

    vector<Point> upper_hull = {points[0], points
    [1]};
    for (int i = 2; i < n; i++) {
        upper_hull.push_back(points[i]);

        int sz = upper_hull.size();

        while (sz >= 3 && dir(upper_hull[sz-3],
    upper_hull[sz-2], upper_hull[sz-1]) == -1) {
            upper_hull.pop_back();
            upper_hull.pop_back();
            upper_hull.push_back(points[i]);
            sz--;
        }
    }

    vector<Point> lower_hull = {points[n-1], points[n
    -2]};
    for (int i = n-3; i >= 0; i--) {
        lower_hull.push_back(points[i]);

        int sz = lower_hull.size();

        while (sz >= 3 && dir(lower_hull[sz-3],
    lower_hull[sz-2], lower_hull[sz-1]) == -1) {
            lower_hull.pop_back();
            lower_hull.pop_back();
            lower_hull.push_back(points[i]);
            sz--;
        }
    }

    // reverse(lower_hull.begin(), lower_hull.end());
     // counterclockwise

    for (int i = (int)lower_hull.size() - 2; i > 0; i
    --) {
        upper_hull.push_back(lower_hull[i]);
    }

    return upper_hull;
}
```

4 DP

4.1 Lcs

```cpp
// LCS (Longest Common Subsequence)
//
// maior subsequencia comum entre duas strings
//
// tamanho da matriz da dp eh |a| x |b|
// lcs(a, b) = string da melhor resposta
// dp[a.size()][b.size()] = tamanho da melhor
    resposta
//
// https://atcoder.jp/contests/dp/tasks/dp_f
//
// O(n^2)

string lcs(string a, string b) {
    int n = a.size();
    int m = b.size();

    int dp[n+1][m+1];
    pair<int, int> p[n+1][m+1];

    memset(dp, 0, sizeof(dp));
    memset(p, -1, sizeof(p));

    for (int i = 1; i <= n; i++) {
        for (int j = 1; j <= m; j++) {
            if (a[i-1] == b[j-1]) {
                dp[i][j] = dp[i-1][j-1] + 1;
                p[i][j] = {i-1, j-1};
            } else {
                if (dp[i-1][j] > dp[i][j-1]) {
                    dp[i][j] = dp[i-1][j];
                    p[i][j] = {i-1, j};
                } else {
                    dp[i][j] = dp[i][j-1];
                    p[i][j] = {i, j-1};
                }
            }
        }
    }

    // recuperar resposta

    string ans = "";
    pair<int, int> curr = {n, m};

    while (curr.first != 0 && curr.second != 0) {
        auto [i, j] = curr;

        if (a[i-1] == b[j-1]) {
            ans += a[i-1];
        }

        curr = p[i][j];
    }

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

    return ans;
}
```

4.2 Knapsack

4.3 Edit Distance

```cpp
// Edit Distance / Levenshtein Distance
//
// numero minimo de operacoes
// para transformar
// uma string em outra
//
// tamanho da matriz da dp eh |a| x |b|
// edit_distance(a.size(), b.size(), a, b)
//
// https://cses.fi/problemset/task/1639
//
// O(n^2)

int tb[MAX][MAX];

int edit_distance(int i, int j, string &a, string &b)
 {
    if (i == 0) return j;
    if (j == 0) return i;

    int &ans = tb[i][j];

    if (ans != -1) return ans;

    ans = min({
        edit_distance(i-1, j, a, b) + 1,
        edit_distance(i, j-1, a, b) + 1,
        edit_distance(i-1, j-1, a, b) + (a[i-1] != b[
    j-1])
    });

    return ans;
}
```

5 Graph

5.1 Dinic

```cpp
// Dinic / Dinitz
//
// max-flow / min-cut
//
// https://cses.fi/problemset/task/1694/
//
// O(E * V^2)

using ll = long long;
const ll FLOW_INF = 1e18 + 7;

struct Edge {
    int from, to;
    ll cap, flow;
    Edge* residual; // a inversa da minha aresta

    Edge() {};

    Edge(int from, int to, ll cap) : from(from), to(
    to), cap(cap), flow(0) {};

    ll remaining_cap() {
        return cap - flow;
    }

    void augment(ll bottle_neck) {
        flow += bottle_neck;
        residual->flow -= bottle_neck;
    }

    bool is_residual() {
        return cap == 0;
    }
};

struct Dinic {
    int n;
    vector<vector<Edge*>> adj;
    vector<int> level, next;

    Dinic(int n): n(n) {
        adj.assign(n+1, vector<Edge*>());
        level.assign(n+1, -1);
        next.assign(n+1, 0);
    }

    void add_edge(int from, int to, ll cap) {
        auto e1 = new Edge(from, to, cap);
        auto e2 = new Edge(to, from, 0);

        e1->residual = e2;
        e2->residual = e1;

        adj[from].push_back(e1);
        adj[to].push_back(e2);
    }

    bool bfs(int s, int t) {
        fill(level.begin(), level.end(), -1);
        queue<int> q;

        q.push(s);
        level[s] = 1;

        while (q.size()) {
            int curr = q.front();
            q.pop();

            for (auto edge : adj[curr]) {
                if (edge->remaining_cap() > 0 &&
level[edge->to] == -1) {
                    level[edge->to] = level[curr] +
1;
                    q.push(edge->to);
                }
            }
        }

        return level[t] != -1;
    }

    ll dfs(int x, int t, ll flow) {
        if (x == t) return flow;

        for (int& cid = next[x]; cid < (int)adj[x].
size(); cid++) {
            auto& edge = adj[x][cid];
            ll cap = edge->remaining_cap();

            if (cap > 0 && level[edge->to] == level[x
] + 1) {
                ll sent = dfs(edge->to, t, min(flow,
cap)); // bottle neck
                if (sent > 0) {
                    edge->augment(sent);
                    return sent;
                }
            }
        }

        return 0;
    }

    ll solve(int s, int t) {
        ll max_flow = 0;

        while (bfs(s, t)) {
            fill(next.begin(), next.end(), 0);

            while (ll sent = dfs(s, t, FLOW_INF)) {
                max_flow += sent;
            }
        }

        return max_flow;
    }

    // path recover
    vector<bool> vis;
    vector<int> curr;

    bool dfs2(int x, int& t) {
        vis[x] = true;
        bool arrived = false;

        if (x == t) {
            curr.push_back(x);
            return true;
        }

        for (auto e : adj[x]) {
            if (e->flow > 0 && !vis[e->to]) { // !e->
    is_residual() &&
                bool aux = dfs2(e->to, t);

                if (aux) {
                    arrived = true;
                    e->flow--;
                }
            }
        }

        if (arrived) curr.push_back(x);

        return arrived;
    }

    vector<vector<int>> get_paths(int s, int t) {
        vector<vector<int>> ans;

        while (true) {
            curr.clear();
            vis.assign(n+1, false);

            if (!dfs2(s, t)) break;

            reverse(curr.begin(), curr.end());
            ans.push_back(curr);
        }

        return ans;
    }
};
```

5.2 Ford Fulkerson

```
// Ford-Fulkerson
//
// max-flow / min-cut
//
// MAX nÃşs
//
// https://cses.fi/problemset/task/1694/
//
// O(m * max_flow)

using ll = long long;
const int MAX = 510;

struct Flow {
    int n;
    ll adj[MAX][MAX];
    bool used[MAX];

    Flow(int n) : n(n) {};

    void add_edge(int u, int v, ll c) {
        adj[u][v] += c;
        adj[v][u] = 0; // cuidado com isso
    }

    ll dfs(int x, int t, ll amount) {
        used[x] = true;

        if (x == t) return amount;

        for (int i = 1; i <= n; i++) {
            if (adj[x][i] > 0 && !used[i]) {
                ll sent = dfs(i, t, min(amount, adj[x
][i]));

                if (sent > 0) {
                    adj[x][i] -= sent;
                    adj[i][x] += sent;

                    return sent;
                }
            }
        }

        return 0;
    }

    ll max_flow(int s, int t) { // source and sink
        ll total = 0;
        ll sent = -1;

        while (sent != 0) {
            memset(used, 0, sizeof(used));
            sent = dfs(s, t, INT_MAX);
            total += sent;
        }

        return total;
    }
};
```

5.3 Dfs

```
// DFS
//
// Percorre todos os vertices
// priorizando profundidade
//
// O(n+m)

vector<vector<int>> g;
vector<bool> vis;

void dfs(int s){
    if(vis[s]) return;
    vis[s] = true;
    for(auto v : g[s]){
        dfs(v);
    }
}
```

6 DS

6.1 Dsu

```cpp
/*
DSU - Disjoint Set Union (or Union Find)

find(x) -> find component that x is on
join(a, b) -> union of a set containing 'a' and set
    containing b

find / join with path compreension -> O(inv_Ackermann
    (n)) [O(1)]
find / join without path compreension -> O(logN)

https://judge.yosupo.jp/submission/126864
*/

struct DSU {

    int n = 0, components = 0;
    vector<int> parent;
    vector<int> size;

    DSU(int nn){
        n = nn;
        components = n;
        size.assign(n + 5, 1);
        parent.assign(n + 5, 0);
        iota(parent.begin(), parent.end(), 0);
    }

    int find(int x){
        if(x == parent[x]) {
            return x;
        }
        //path compression
        return parent[x] = find(parent[x]);
    }

    void join(int a, int b){
        a = find(a);
        b = find(b);
        if(a == b) {
            return;
        }
        if(size[a] < size[b]) {
            swap(a, b);
        }
        parent[b] = a;
        size[a] += size[b];
        components -= 1;
    }

    int sameSet(int a, int b) {
        a = find(a);
        b = find(b);
        return a == b;
    }

};
```

6.2 Ordered Set

```cpp
// Ordered Set
//
// set roubado com mais operacoes
//
// para alterar para multiset
// trocar less para less_equal
//
// ordered_set<int> s
//
// order_of_key(k) // number of items strictly
    smaller than k -> int
// find_by_order(k) // k-th element in a set (
    counting from zero) -> iterator
//
// https://cses.fi/problemset/task/2169
//
// O(log N) para insert, erase (com iterator),
    order_of_key, find_by_order

using namespace __gnu_pbds;
template <typename T>
using ordered_set = tree<T,null_type,less<T>,
    rb_tree_tag,tree_order_statistics_node_update>;
```