Team notebook

10 de agosto de 2015

Índice

1. Articulation Point in Graph

```
vector<int> graph[410];
set<int> ans;
set<int>::iterator it;

int dfs(int u){
    int less = vis[u] = times++;
    int filhos = 0;
    for(int i = 0; i< graph[u].size(); i++){
       if(vis[graph[u][i]]==0){
          filhos++;
          int m = dfs(graph[u][i]);
          less = min(less,m);
          if(vis[u] <= m && (u != 0 || filhos >= 2)){
              ans.insert(u);
          }
       }else{
          less = min(less, vis[graph[u][i]]);
       }
    }
    return less;
}
times = 1;
ans.clear();
dfs(0);
```

2. Bellman Ford

```
vector <pair<int, int> > edges;
int graph[MAXN][MAXN];
int dist[MAXN];

int N;
bool bellman_ford(int s) {
        int M = edges.size();
        memset (dist, INF, sizeof(int)*n);
        dist[s] = 0;
        for (int k = 0; k < N-1; ++k) {
                for (int j = 0; j < M; ++j) {
                        int u = edges[j].first;
                        int v = edges[j].second;
                        if (dist[u] < INF && dist[v] > dist[u] +
                            graph[u][v])
                               dist[v] = dist[u] + graph[u][v];
                }
        }
        //Negative Cycle
        for (int j = 0; j < m; ++j) {
                int u = edges[j].first, v = edges[j].second;
                if (dist[u] < INF && dist[v] > dist[u] + graph[u][v]) {
                        return false;
                }
        }
        return true;
}
```

3. Binomial Coefficient with DP

```
//Binomial Coefficient
//C(N, K) = N!/(K!(N - K)!)
//Dynamic Programming
int bin[N][K];

bin[0][0] = 1;

for (int n = 1; n < MAXN; n++) {
    bin[n][0] = 1;
    bin[n][n] = 1;
```

```
    for (int k = 1; k < n; k++) {
                bin[n][k] = bin[n - 1][k] + bin[n - 1][k - 1];
                if (bin[n][k] >= MOD) {
                        bin[n][k] -= MOD;
                }
    }
}
```

4. Binomial Coefficient

```
Int nCr(Int n, Int k) {
        Int res = 1;

        if (k > (n >> 1LL)) {
                k = n-k;
        }
        for (Int i = 1; i <= k; i++, n--) {
                res = (res * n) / i;
        }

        return res;
}
```

5. Bipartite Check Algorithm

```
bool dfs(int node, int c) {
    if(color[node] != 0) {
        if(color[node] == c) {
            return true;
        } else {
            return false;
        }
    }
    color[node] = c;
    for(int i = 1; i <= n; i++)
                if(gr[node][i] == 1) {
                        if(!dfs(i, -c)) {
                                return false;
                        }
                }
        }
    }
    return true;
}
```

6. Closest Pair

```
///----Closes pair with divide and conquer----///
struct point{
    double x, y;
    point(double a, double b): x(a), y(b){}
    point(){};
};

bool compareX(point a, point b){
    return a.x < b.x;
}

bool compareY(point a, point b){
    return a.y < b.y;
}

double bruteForce(vector<point> &p){
    double ans = 40000.*40001.;
    for(int i = 0; i < p.size(); i++){
        for(int j = i + 1; j < p.size(); j++){
            double dst = hypot(p[j].x - p[i].x, p[j].y - p[i].y);
            if(dst < ans){
                ans = dst;
            }
        }
    }
    return ans;
}

double strip(vector<point> &p, double d){
    sort(p.begin(), p.end(), compareY);
    double ans = d;
    for(int i = 0; i < p.size(); i++){
        for(int j = i + 1; j < p.size() && (p[j].y - p[i].y) < d; j++){
            double dst = hypot(p[j].x - p[i].x, p[j].y - p[i].y);
```

```
            if(dst < ans){
                ans = dst;
            }
        }
    }
    return ans;
}

double X, Y;
int n;
double closest(vector<point> v){
    int n = v.size();
    if(n <= 3){
            return bruteForce(v);
    }
    vector<point> left;
    vector<point> right;
    int mid = n >> 1;
    for(int i = 0; i < mid; i++){
        left.push_back(v[i]);
    }
    for(int i = mid; i < n; i++){
        right.push_back(v[i]);
    }

    double lh = closest(left);
    double rh = closest(right);
    double d = min(lh,rh);
    vector<point> stripArray;
    for(int i = 0; i < n; i++){
        if(fabs(v[i].x - v[mid].x) < d){
            stripArray.push_back(v[i]);
        }
    }
    return min(d, strip(stripArray,d));
}

sort(pos.begin(), pos.begin()+n, compareX);
double ans = closest(pos);
```

7. Coin Change

```
//Coin Change
int dp[1001];
int coins[] = {1, 5, 10, 25, 50};

dp[0] = 0;

for(int i = 1; i <= N; i++) {
        int min = 1000001;
    for(int j = 0; j < M; j++) {
            if(coins[j] <= i) {
                    int m = dp[i - coins[j]] + 1;
            if(m < min) min = m;
        }
    }
    dp[i] = min;
}
```

8. Convex Hull

```
//Convex Hull
struct point {
    int x, y;
    point(int x, int y): x(x), y(y){}
    point(){}
    bool operator <(const point &p) const {
        return x < p.x || (x == p.x && y < p.y);
    }
    bool operator==(const point &p) const {
        return x == p.x && y == p.y;
    }
};
ll cross(const point &O, const point &A, const point &B) {
    return (A.x - O.x) * (B.y - O.y) - (A.y - O.y) * (B.x - O.x);
}

vector<point> convex_hull(vector<point> &P) {
    int n = P.size(), k = 0;
    vector<point> H(2*n);

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

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

```
        while (k >= 2 && cross(H[k-2], H[k-1], P[i]) <= /*change to < to
            remove equal points */ 0) k--;
        H[k++] = P[i];
    }
    for (int i = n-2, t = k+1; i >= 0; i--) {
        while (k >= t && cross(H[k-2], H[k-1], P[i]) <= /*change to < to
            remove equal points */ 0) k--;
        H[k++] = P[i];
    }
    H.resize(k);
    return H;
}
```

9. Convex Polygon Area

```
//Area de um Poligono Convexo
double area() {
        int N = 4;

        //Points
        int[] x = { 2, -4, 5, 2 };
        int[] y = { 5, 3, 1, 5 };

        double ma = x[N - 1] * y[0], mb = x[0] * y[N - 1];

        for (int i = 0; i < N - 1; i++) {
                ma += (x[i] * y[i + 1]);
                mb += (x[i + 1] * y[i]);
        }

        double ans = Math.abs((ma - mb) * 0.5);
}
```

10. Cycle Retrieval Algorithm

```
//It only works in graphs without compound cycles
bool inq[MAXN], vis[MAXN];

void dfs(int node, int parent, int len) {
        vis[node] = true;
        cle[node] = len;

        stk[stk_pointer++] = node;
        inq[node] = true;

        for (int i = 0; i < (int) graph[node].size(); i++) {
                int next = graph[node][i].first;
                int cost = graph[node][i].second;

                if (next == parent) continue;

                if (!vis[next]) {
                        dfs(next, node, len + cost);
                } else {
                        if (inq[next]) {
                                int curr;
                                int real_len = len + cost - cle[next];

                                while (stk_pointer > 0) {
                                        curr = stk[--stk_pointer];
                                        inq[curr] = false;
                                        cycle_len[curr] = real_len;
                                        if (curr == next) break;
                                }
                        }
                }
        }

        if (inq[node]) {
                while (stk_pointer > 0) {
                        inq[stk[stk_pointer-1]] = false;
                        if (stk[stk_pointer-1] == node) {
                                stk_pointer--;
                                break;
                        }
                        stk_pointer--;
                }
        }
}

stk_pointer = 0;
dfs(1, -1, 0);
```

11. Dijkstra Algorithm

```
struct MyLess {
    bool operator()(int x, int y) {
        return dist[x] > dist[y];
    }
};

int dijsktra(int source, int destiny) {
        for(int i = 0; i <= 110; i++) {
                dist[i] = INT_MAX;
        }
        priority_queue<int, vector<int>, MyLess> q;
        dist[source] = 0;
        q.push(source);

        while(!q.empty()) {
                int tmp = q.top(); q.pop();
                for(int i = 0; i < graph[tmp].size(); i++) {
            int aux_dist = dist[tmp] + graph[tmp][i].second;
            int actual_dist = dist[graph[tmp][i].first];
            if(aux_dist < actual_dist) {
                dist[graph[tmp][i].first] = aux_dist;
                q.push(graph[tmp][i].first);
            }
        }
    }
        return dist[destiny];
}
// Reconstruo  do Caminho
vector<int> path;
int start = destiny;

while(start != -1) {
        path.push_back(start);
        start = prev[start];
}
```

12. Dinic Algorithm

```
//Max Flow dinic O(V^2*E)
const int MAXN = 101010;

const int INF = 101011;

struct edge {
    int to,rev;
    Int cap;
    edge(int to, Int cap, int rev): to(to), cap(cap), rev(rev) {}
};

vector<edge> G[MAXN];
Int level[MAXN];
int iter[MAXN];

void init(int N) {
    for (int i = 0; i < N; i++) {
        G[i].clear();
    }
}

void add_edge(int from,int to,Int cap) {
    G[from].push_back(edge(to, cap, G[to].size()));
    G[to].push_back(edge(from, 0, G[from].size()-1));
}

void bfs(int s) {
    memset(level, -1, sizeof(level));
    queue<int> que;
    level[s] = 0;
    que.push(s);

    while(!que.empty()) {
        int v = que.front();
        que.pop();
        for (int i = 0; i < G[v].size(); i++) {
            edge& e = G[v][i];
            if(e.cap > 0 && level[e.to] < 0) {
                level[e.to] = level[v] + 1;
                que.push(e.to);
            }
        }
    }
}

Int dfs(int v, int t, Int f) {
    if(v == t) return f;
    for(int& i = iter[v]; i < (int) G[v].size(); i++) {
```

```
        edge &e = G[v][i];
        if(e.cap > 0 && level[v] < level[e.to]) {
            Int d = dfs(e.to, t, min(f, e.cap));
            if (d > 0) {
                e.cap -= d;
                G[e.to][e.rev].cap += d;
                return d;
            }
        }
    }
    return 0;
}

int max_flow(int s, int t) {
    Int flow = 0;
    for( ; ; ) {
        bfs(s);
        if (level[t] < 0) {
            return flow;
        }
        memset(iter, 0, sizeof(iter));
        int f;
        while ((f=dfs(s,t,INF*INF)) > 0) {
            flow += f;
        }
    }
}
```

13. Fast Integer Input

```
inline void rd(int &x) {
    register int c = getchar_unlocked();
    x = 0;
    int neg = 0;

    for (; ((c<48 || c>57) && c != '-'); c = getchar_unlocked());

    if (c=='-') {
        neg = 1;
        c = getchar_unlocked();
    }

    for ( ; c>47 && c<58 ; c = getchar_unlocked()) {
        x = (x<<1) + (x<<3) + c - 48;
    }

    if (neg) {
        x = -x;
    }
}
```

14. Floyd Warshall

```
//Floyd-Warshall - O(n^3)
for(int k = 0; k < n; k++) {
        for(int i = 0; i < n; i++) {
                for(int j = 0; j < n; j++) {
                        dist[i][j] = min(dist[i][j], dist[i][k] +
                            dist[k][j]);
                }
        }
}
```

15. Fraction Library

```
struct fraction {
    int num, denom;
    fraction(int num, int denom): num(num), denom(denom){
    }
    fraction() { num = 0; denom = 0; }
    void reduce(fraction& f) {
        int l = gcd(f.num, f.denom);
        f.num = f.num/l;
        f.denom = f.denom/l;
    }
    fraction operator+(const fraction& f) {
        fraction ans;
        int l = lcm(denom, f.denom);
        ans.num = ((l / denom) * num) + ((l / f.denom) * f.num);
        ans.denom = l;
        reduce(ans);
```

```
        return ans;
    }
    fraction operator-(const fraction& f) {
        fraction ans;
        ans.num = num - f.num;
        ans.denom = denom - f.denom;
        reduce(ans);
        return ans;
    }
    fraction operator*(const fraction& f) {
        fraction ans;
        ans.num = num * f.num;
        ans.denom = denom * f.denom;
        reduce(ans);
        return ans;
    }
    fraction operator/(const fraction& f) {
        fraction ans;
        ans.num = num * f.denom;
        ans.denom = denom * f.num;
        reduce(ans);
        return ans;
    }
    bool operator!=(const fraction& f) {
        return num != f.num || denom != f.denom;
    }
    bool operator==(const fraction& f) {
        return num == f.num && denom == f.denom;
    }
    friend ostream &operator<<(ostream &out, fraction f) {
        out << f.num << "/" << f.denom << "\n";
        return out;
    }
    friend istream &operator>>(istream &in, fraction f) {
        in >> f.num >> f.denom;
        return in;
    }
};
```

16. Heap Sort

```
int n, a[MAXN];

void downheap(int v) {
    int w = 2*v+1;
    while (w < n) {
        if(w + 1 < n) {
            if (a[w+1]>a[w]) w++;
        }
        if(a[v] >= a[w]) return;
        swap(a[v], a[w]);
        v = w;
        w = 2*v+1;
    }
}

void buildheap() {
    for (int v = n/2-1; v >= 0; v--) {
        downheap(v);
    }
}

void heapsort() {
    buildheap();
    while (n > 1) {
        n--;
        swap(a[0], a[n]);
        downheap(0);
    }
}
```

17. Heavy Light Decomposition

```
vector<vector<pair<int,int> > > g(MAXN);
int cnt[MAXN], prev[MAXN], chainNode[MAXN], chainHead[MAXN],
    posInChain[MAXN], base[MAXN], level[MAXN], chainIdx, idxSegTree;
int H[MAXN], L[MAXN << 1], E[MAXN << 1], idx;

struct LCA{
        int tree[MAXN * 8];
        LCA(int root, int n){
                build(1, 0, 2*n-1);
        }
```

```
//NlogN build the segtree and minimize the height of the I'th
    visited node
void build(int node, int l, int r){
	if(l > r) return;
	if(l == r){
		tree[node] = l;
	}else{
		int mid = (l+r) >> 1;
		build(node*2, l, mid);
		build(node*2+1, mid+1, r);
		int A = tree[node*2];
		int B = tree[node*2+1];
		if(L[A] <= L[B]){
			tree[node] = A;
		}else{
			tree[node] = B;
		}
	}
}

//Get the vertex with the minimum height, then it will be the LCA
    of A and B.
int rmq(int node, int l, int r, int ra, int rb){
	if(l > rb || r < ra){
		return -1;
	}else if(l >= ra && r <= rb){
		return tree[node];
	}else{
		int mid = (l+r) >> 1;
		int q1 = rmq(node*2, l, mid, ra, rb);
		int q2 = rmq(node*2+1, mid+1, r, ra, rb);
		if(q1 == -1){
			return q2;
		}else if(q2 == -1){
			return q1;
		}else{
			if(L[q1] <= L[q2]){
				return q1;
			}else{
				return q2;
			}
		}
	}
}
	int getLCA(int u, int v, int n){
		int goFrom = H[u];
		int goTo = H[v];
		if(goFrom > goTo){
			swap(goFrom, goTo);
		}
		return E[rmq(1, 0, 2*n-1, goFrom, goTo)]; //is the LCA of
		    A and B;
	}
};

struct SegTree{

	int tree[MAXN*4];

	SegTree(){
		memset(tree,0,sizeof(tree));
	}


	void build(int node, int l, int r){
		if(l > r) return;
		if(l == r){
			tree[node] = l;
		}else{
			int mid = (l+r) >> 1;
			build(node*2, l, mid);
			build(node*2+1, mid+1, r);
			int A = tree[node*2];
			int B = tree[node*2+1];
			tree[node] = base[A] > base[B] ? A : B;
		}
	}

	int rmq(int node, int l, int r, int ra, int rb){
		if(l > rb || r < ra){
			return -1;
		}else if(l >= ra && r <= rb){
			return tree[node];
		}else{
			int mid = (l+r) >> 1;
			int q1 = rmq(node*2, l, mid, ra, rb);
			int q2 = rmq(node*2+1, mid+1, r, ra, rb);
			if(q1 == -1){
				return q2;
```

```
                }else if(q2 == -1){
                        return q1;
                }else{
                        return base[q1] > base[q2] ? q1 : q2;
                }
        }
    }

    void update(int node, int l, int r, int pos, int value) {
        if (l > r) return;
        if (l == r) {
            base[pos] = value;
        } else {
            int m = (l + r) >> 1;
            if (pos <= m) {
                update(2 * node, l, m, pos, value);
            } else {
                update(2 * node + 1, m + 1, r, pos, value);
            }
            tree[node] = base[tree[2 * node]] > base[tree[2 *
                node + 1]] ? tree[2 * node] : tree[2 * node +
                1];
        }
    }
};

//Decompose the tree into chains
void HLD(int node, int cost, int parent){
    if(chainHead[chainIdx] == -1){
        chainHead[chainIdx] = node;
    }
    chainNode[node] = chainIdx;
    posInChain[node] = idxSegTree;
    base[idxSegTree++] = cost;
    int nodeHeavy = -1, nextCost;
    //seeking the special child (the one with most childs on the
        subtrees)
    for(int i = 0; i < g[node].size(); i++){
        int next = g[node][i].first;
        if(next != parent && (nodeHeavy == -1 || cnt[next] >
            cnt[nodeHeavy])){
            nodeHeavy = next;
            nextCost = g[node][i].second;
        }
    }
    if(nodeHeavy > -1){
        //expanding the current chain
        HLD(nodeHeavy, nextCost, node);
    }

    for(int i = 0; i < g[node].size(); i++){
        int next = g[node][i].first;
        if(next != nodeHeavy && next != parent){
            chainIdx++;
            HLD(next, g[node][i].second, node);
        }
    }

}

void dfsCnt(int node, int parent, int depth = 0){
    if(H[node] == -1) H[node] = idx;//mark first time the i'th node is
        visited
    L[idx] = depth;//when you visit a node you should mark the the
        depth you have found it.
    E[idx++] = node;//the i'th recursion, global variable
    level[node] = depth;
    cnt[node] = 1;
    for(int i = 0; i < g[node].size(); i++){
        int next = g[node][i].first;
        if(next != parent){
            prev[next] = node;
            dfsCnt(next, node, depth + 1);
            cnt[node] += cnt[next];
            L[idx] = depth;
            E[idx++] = node;
        }
    }
}

int walkChain(int U, int V, SegTree &q, int n){
    if(U == V) return 0;
    int ans = 0;
    while(chainNode[U] != chainNode[V]){
        int Left = posInChain[chainHead[chainNode[U]]];
        int Right = posInChain[U];
        int val = base[q.rmq(1, 0, n-1, Left, Right)];
        if(val > ans) ans = val;
        U = prev[chainHead[chainNode[U]]];
    }
```

```
        if(U == V) return ans;
        int val = base[q.rmq(1, 0, n-1, posInChain[V]+1, posInChain[U])];
        if(val > ans) ans = val;
        return ans;
}

int getMax(int U, int V, LCA &ref, SegTree &q, int n){
        int lca = ref.getLCA(U, V, n),a=0,b=0;
        if(lca != U)
                a = walkChain(U, lca, q, n);
        if(lca != V)
                b = walkChain(V, lca, q, n);
        return max(a,b);
}

void update(int a, int b, int c, SegTree &q, int n){
        if(level[a] < level[b]){//update b
                q.update(1,0,n-1,posInChain[b], c);
        }else{//update a
                q.update(1,0,n-1,posInChain[a], c);
        }
}
void add(int a, int b, int c){
        g[a].push_back(make_pair(b,c));
        g[b].push_back(make_pair(a,c));
}

int n, t, from[MAXN], to[MAXN], cost[MAXN], A, B;
char TYPE[20];

int main(void){
        scanf("%d", &t);
        while(t--){
                scanf("%d", &n);
                chainIdx = idxSegTree = idx = 0;
                for(int i = 0; i <= n; i++){
                        cnt[i] = prev[i] = chainNode[i] = base[i] =
                            level[i] = 0;
                        chainHead[i] = posInChain[i] = H[i] = -1;
                        g[i].clear();
                }
                memset(L,0,sizeof(L));
                memset(E,0,sizeof(E));
                for(int i = 0; i < n - 1; i++){
                        scanf("%d%d%d", &from[i], &to[i], &cost[i]);
                        from[i]--;
                        to[i]--;
                        add(from[i], to[i], cost[i]);
                }
                dfsCnt(0,-1);
                LCA lca(0,n);
                HLD(0,-1, -1);
                SegTree query;
                query.build(1,0,n-1);
                while(1){
                        scanf("%s", TYPE);
                        if(TYPE[0] == 'D') break;
                        scanf("%d%d", &A, &B);
                        A--;
                        if(TYPE[0] == 'Q'){
                                B--;
                                printf("%d\n", getMax(A, B, lca, query, n));
                        }else if(TYPE[0] == 'C'){
                                update(from[A], to[A], B, query, n);
                        }
                }
        }
    return 0;
}
```

18. Kadane 2D

```
//Kadane 2D
for (int i = 1; i <= N; i++) {
        for (int j = 1; j <= N; j++) {
                cin >> M[i][j];
        }
        for (int j = 1; j <= N; j++) {
                dp[i][j] = dp[i][j - 1] + M[i][j];
        }
 }

int ans = -INT_MAX / 3;
for (int i = 1; i <= N; i++) {
        for (int j = i; j <= N; j++) {
                int sum = 0;
                for (int k = 1; k <= N; k++) {
```

```
                    sum += dp[k][j] - dp[k][i - 1];
                    chmax(ans, sum);
                    if (sum < 0) sum = 0;
                }
        }
}
```

19. Knuth Morris Pratt

```
vector<int> KMP(string S, string K) {
    vector<int> T(K.size() + 1, -1);
    vector<int> matches;

    if(K.size() == 0) {
        matches.push_back(0);
        return matches;
    }
    for(int i = 1; i <= K.size(); i++) {
        int pos = T[i - 1];
        while(pos != -1 && K[pos] != K[i - 1]) pos = T[pos];
        T[i] = pos + 1;
    }

    int sp = 0;
    int kp = 0;
    while(sp < S.size()) {
        while(kp != -1 && (kp == K.size() || K[kp] != S[sp])) kp = T[kp];
        kp++;
        sp++;
        if(kp == K.size()) matches.push_back(sp - K.size());
    }

    return matches;
}
```

20. Kosaraju Algorithm

```
//ga -> Regular Adjacency List
//gb -> Transposed Adjacency List

void dfs1(int x) {
    used[x] = 1;
    for(int b = 0; b < g[x].size(); b++) {
        if(!used[g[x][b]]) dfs1(g[x][b]);
    }
        order.push_back(x);
}

void dfs2(int x) {
    used[x] = 1;
        comoponent.insert(x);
    for(int b = 0; b < gr[x].size(); b++) {
        if(!used[gr[x][b]]) dfs2(gr[x][b]);
    }
}

//Topological Sort
for (int i = 1; i <= n; i++) if(!used[i]) dfs1(i);

//Get components
for(int i = 0; i < order.size(); i++) {
    int v = order[i];
        if(!used[v]) {
                dfs2(v);
        ans++;
        component.clear();
        }
}
```

21. Kruskal Algorithm

```
//Kruskal Algorithm
struct edge {
    int from, to, cost;
    edge() {}
    edge(int from, int to, int cost): from(from), to(to), cost(cost) {};

    bool operator<(const edge& e) const {
                return cost < e.cost;
    }
};
```

```
//Sendo 'M' o numero de arestas, 'u' uma implementao do conjunto disjunto
    'UnionFind' e 'ans' o menor custo
vector<edge> edges; //Populado com as arestas
int ans = 0;
UnionFind u(N);
for(i = 0; i < m; i++) {
	if(!u.find(edges[i].from, edges[i].to)) {
		u.unite(edges[i].from, edges[i].to);
		ans += edges[i].cost;
	}
}
```

22. LCA with Segment Tree

```
//LCA using segment tree
int H[MAXN], L[MAXN << 1], E[MAXN << 1], vis[MAXN], tree[MAXN * 8],
    path[MAXN << 1];
vector<vector<pair<int, int> > > g(MAXN);

void dfs(int x, int depth){
	vis[x] = 1;//visited
	if(H[x] == -1) H[x] = idx;//mark first time the i'th node is
	    visited
	L[idx] = depth;//when you visit a node you should mark the the
	    depth you have found it.
	E[idx++] = x;//the i'th recursion, global variable
	for(int i = 0; i < g[x].size(); i++){
		int next = g[x][i].first;
		if(!vis[next]){
			path[next] = x;
			dfs(next, depth+1);
			L[idx] = depth;
			E[idx++] = x;
		}
	}
}

//NlogN build the segtree and minimize the height of the I'th visited node
void build(int node, int l, int r){
	if(l > r) return;
	if(l == r){
		tree[node] = l;
	}else{
		int mid = (l+r) >> 1;
		build(node*2, l, mid);
		build(node*2+1, mid+1, r);
		int A = tree[node*2];
		int B = tree[node*2+1];
		if(L[A] <= L[B]){
			tree[node] = A;
		}else{
			tree[node] = B;
		}
	}
}

//Get the vertex with the minimum height, then it will be the LCA of A
    and B.
int rmq(int node, int l, int r, int ra, int rb){
	if(l > rb || r < ra){
		return -1;
	}else if(l >= ra && r <= rb){
		return tree[node];
	}else{
		int mid = (l+r) >> 1;
		int q1 = rmq(node*2, l, mid, ra, rb);
		int q2 = rmq(node*2+1, mid+1, r, ra, rb);
		if(q1 == -1){
			return q2;
		}else if(q2 == -1){
			return q1;
		}else{
			if(L[q1] <= L[q2]){
				return q1;
			}else{
				return q2;
			}
		}
	}
}

idx = 0;
for(int i = 0; i <= n; i++){
	g[i].clear();
	H[i] = -1;
	L[i] = E[i] = vis[i] = 0;
	path[i] = -1;
```

```
 }
dfs(0,0);
build(1, 0, 2*n-1);
for(int i = 0; i < k; i++){
        scanf("%d%d", &u, &v);
        u--;
        v--;
        int goFrom = H[u];
        int goTo = H[v];
        if(goFrom > goTo){
                swap(goFrom, goTo);
        }
        int lcaAB = E[rmq(1, 0, 2*n-1, goFrom, goTo)]; //is the LCA of A
            and B;
 }
```

23. LCA with Sparse Table

```
//LCA O(<Nlog(N)>, <log(N)>)
int N, Q, A, B;
vector<pair<int, int> > adj[MAXN];
int parent[MAXN], L[MAXN], vis[MAXN];
vector<int> level[MAXN];
int P[MAXN][20];
Int dist[MAXN];

void dfs(int pos, int par){
    if(parent[pos] == -1){
        parent[pos] = par;

        for(int i = adj[pos].size() - 1,to;i >= 0;--i){
            to = adj[pos][i].first;
            if(to != par) {
                dist[to] = dist[pos] + adj[pos][i].second;
                dfs(to,pos);
            }
        }
    }
}

int get_level(int u){
    if(L[u]!=-1) return L[u];
    else if(parent[u]==-1) return 0;
    return 1+get_level(parent[u]);
}

void init() {
        for(int i = 0;i<N;++i) {
                L[i] = get_level(i);
        }

        for(int i = 0;i < N;++i) {
                level[L[i]].push_back(i);
        }

        memset(P,-1,sizeof(P));

        for(int i = 0; i < N; ++i) {
                P[i][0] = parent[i];
        }

        for(int j = 1; (1<<j) < N; ++j) {
                for(int i = 0; i < N; ++i) {
                        if(P[i][j-1]!=-1) {
                                P[i][j] = P[P[i][j-1]][j-1];
                        }
                }
        }
}

int LCA(int p, int q) {
    if(L[p] < L[q]) {
                swap(p,q);
        }

    int log = 1;
    while((1<<log)<=L[p]) ++log;
    --log;

    for(int i = log;i>=0;--i)
        if(L[p]-(1<<i)>=L[q])
            p = P[p][i];

    if (p==q) return p;

    for(int i = log;i>=0;--i){
        if(P[p][i]!=-1 && P[p][i]!=P[q][i]){
```

```
            p = P[p][i];
            q = P[q][i];
        }
    }

    return parent[p];
}

for (i = 0; i <= N; i++) {
        vis[i] = 0;
        L[i] = parent[i] = -1;
        dist[i] = 0LL;
        adj[i].clear();
 }
for (i = 1; i < N; i++) {
        scanf("%d%d", &t, &l);
        adj[i].push_back(make_pair(t, l));
        adj[t].push_back(make_pair(i, l));
 }

dfs(0, -2);
parent[0] = -1;
init();
```

24. Line Point Distance

```
//Distance between point - line
double dot(pair<int, int> &A, pair<int, int> &B, pair<int, int> &C) {
    return (double) (B.first - A.first) * (C.first - B.first) + (B.second
        - A.second) * (C.second - B.second);
}

double cross(pair<int, int> &A, pair<int, int> &B, pair<int, int> &C) {
    return (double) (B.first-A.first) * (C.second-A.second) -
        (B.second-A.second) * (C.first-A.first);
}

double _distance(pair<int, int> A, pair<int, int> B) {
    int d1 = A.first - B.first;
    int d2 = A.second - B.second;
    return sqrt(d1*d1+d2*d2);
}

double linePointDist(pair<int, int> A, pair<int, int> B, pair<int, int>
    C, bool isSegment) {
    double dist = cross(A,B,C) / _distance(A,B);
    if(isSegment) {
        int dot1 = dot(A,B,C);
        if(dot1 > 0)return _distance(B,C);
        int dot2 = dot(B,A,C);
        if(dot2 > 0)return _distance(A,C);
    }
    return abs(dist);
}
```

25. Longest Increasing Subsequence $O(n^2)$

```
int lis(int array[], int n) {
    int best[n], prev[n];

    for(int i = 0; i < n; i++) {
        best[i] = 1;
        prev[i] = i;
    }

    for(int i = 1; i < n; i++) {
        for(int j = 0; j < i; j++) {
            if(array[i] > array[j] && best[i] < best[j] + 1) {
                best[i] = best[j] + 1; prev[i] = j;
            }
        }
    }
    int ans = 0; for(int i = 0; i < n; i++) ans = max(ans, best[i]);
    return ans;
}
```

26. Manacher Algorithm

```
//Manacher Algorithm (Longest Palindromic Substring)
string preProcess(string s) {
  int n = s.length();
```

```
  if (n == 0) return "^$";
  string ret = "^";
  for (int i = 0; i < n; i++)
    ret += "#" + s.substr(i, 1);

  ret += "#$";
  return ret;
}

vector<int> manacher(string s) {
  string T = preProcess(s);
  int n = T.length();
  vector<int> P(n);

  int C = 0, R = 0;
  for (int i = 1; i < n-1; i++) {
        int i_mirror = 2*C-i;

        P[i] = (R > i) ? min(R-i, P[i_mirror]) : 0;

        while (T[i + 1 + P[i]] == T[i - 1 - P[i]]) {
              P[i]++;
        }

        if (i + P[i] > R) {
              C = i;
              R = i + P[i];
        }
  }

  int maxLen = 0;
  int centerIndex = 0;
  for (int i = 1; i < n-1; i++) {
        if (P[i] > maxLen) {
              maxLen = P[i];
              centerIndex = i;
        }
  }
  //to return actual longets substring
  //  return s.substr((centerIndex - 1 - maxLen)/2, maxLen);
  // P[i] is the length of the largest palindrome centered at i
  return P;
}
```

27. Mathematical Expression Solver

```
//Solver for mathematical expressions
void doOp(stack<double> &num, stack<char> &op){
       double A = num.top(); num.pop();
       double B = num.top(); num.pop();
       char oper = op.top(); op.pop();
       double ans;
       if(oper == '+'){
              ans = A+B;
       }else if(oper == '-'){
              ans = B-A;
       }else if(oper == '*'){
              ans = A*B;
       }else{
              if(A != 0){
                     ans = B/A;
              }else{
                     //division by 0
                     ans = -1;
              }
       }
       num.push(ans);
}

double parse(string s){
    stack<char> op;
    stack<double> num;
    map<char,int> pr;

    //setting the priorities, greater values with higher pr
    pr['+'] = 0;
    pr['-'] = 0;
    pr['*'] = 1;
    pr['/'] = 1;

    for (int i = 0; i < s.size(); i++){
        if (s[i] == ')'){
            while(!op.empty() && op.top() != '('){
                doOp(num,op);
            }
            op.pop();
        } else if(s[i] == '('){
                     op.push('(');
```

```
        } else if(!(s[i] >= '0' && s[i] <= '9')){
            while(!op.empty() && pr[s[i]] <= pr[op.top()] && op.top() !=
                '('){
                doOp(num,op);
            }
            op.push(s[i]);
        } else {
            double ans = 0;
            while(i < s.size() && s[i] >= '0' && s[i] <= '9'){
                ans = ans * 10 + (s[i] - '0');
                i++;
            }
            i--;
            num.push(ans);
        }
    }
    while (op.size()) {
        doOp(num,op);
    }
    return num.top();
}
```

28. Matrix Multiplication

```
vector<vector<int> > multiply(vector<vector<int> > a, vector<vector<int>
    > b) {
        vector<vector<int> > res(c, vector<int>(c));
        for(int i = 0; i < c; i++) {
                for(int j = 0; j < c; j++) {
                        int sum = 0;
                        for (int k = 0; k < c; k++) {
                                sum |= a[i][k] & b[k][j];
                        }
                        res[i][j] = sum;
                }
        }
        return res;
}

vector<vector<int> > binPow(vector<vector<int> > a, int n) {
        if (n == 1) {
                return a;
        } else if ((n & 1) != 0) {
                return multiply(a, binPow(a, n - 1));
        } else {
                vector<vector<int> > b = binPow(a, n / 2);
                return multiply(b, b);
        }
}
```

29. Maximum Bipartite Matching

```
//Maximum Bipartite Matching (Prefereed implementation)
vector<int> graph[MAXN];

bool bpm(int u, bool seen[], int matchR[]) {
    for (int i = 0; i < (int) graph[u].size(); i++) {
                int v = graph[u][i];

        if (!seen[v]) {
            seen[v] = true;

            if (matchR[v] < 0 || bpm(matchR[v], seen, matchR)) {
                matchR[v] = u;
                return true;
            }
        }
    }
    return false;
}

int maxBPM() {
    int matchR[MAXN];

    memset(matchR, -1, sizeof(matchR));

    int result = 0;
    for (int u = 1; u <= C; u++) {
        bool seen[MAXN];
        memset(seen, 0, sizeof(seen));

        if (bpm(u, seen, matchR)) {
            result++;
                }
```

```
    }
    return result;
}
```

30. Median Online Algorithm

```
//Get median of a sequence in O(log(n))
int median_retrieve(void) {
	if (minHeap.empty() && maxHeap.empty()) return 0;

	if (minHeap.size() == maxHeap.size()) {
		return min(minHeap.top(), maxHeap.top());
	} else {
		if (minHeap.size() > maxHeap.size()) {
			return minHeap.top();
		} else {
			return maxHeap.top();
		}
	}
}

void median_insert(int x) {
	if (x > median_retrieve()) {
		minHeap.push(x);
	} else {
		maxHeap.push(x);
	}

	while (abs((int) (minHeap.size() - maxHeap.size())) > 1) {
		if (minHeap.size() > maxHeap.size()) {
			int tmp = minHeap.top();
			minHeap.pop();
			maxHeap.push(tmp);
		} else {
			int tmp = maxHeap.top();
			maxHeap.pop();
			minHeap.push(tmp);
		}
	}
}
```

31. Merge Sort

```
//Merge-Sort O(N log N)
vector<int> merge(vector<int>& b, vector<int>& c) {
	vector<int> a;

	while(!b.empty() && !c.empty()) {
		if(*b.begin() < *c.begin()) {
			a.push_back(*b.begin());
			b.erase(b.begin());
		} else if(*b.begin() > *c.begin()) {
			a.push_back(*c.begin());
			c.erase(c.begin());
		} else {
			a.pb(*b.begin());
			a.pb(*c.begin());
			b.erase(b.begin());
			c.erase(c.begin());
		}
	}
	while(!b.empty()) { a.pb(*b.begin()); b.erase(b.begin()); }
	while(!c.empty()) { a.pb(*c.begin()); c.erase(c.begin()); }
	return a;
}

vector<int> mergeSort(vector<int>& a) {
	if(sz(a) <= 1) {
		return a;
	}
	vector<int> b;
	vector<int> c;

	for(int i = 0; i < sz(a) / 2; i++) {
		b.pb(a[i]);
	}
	for(int i = sz(a) / 2; i < sz(a); i++) {
		c.pb(a[i]);
	}
	vector<int> sb = mergeSort(b);
	vector<int> sc = mergeSort(c);
	return merge(sb, sc);
}
```

32. Min Cost Max Flow

```
typedef int Flow;
typedef int Cost;
const Flow INF = 0x3f3f3f3f;
struct Edge {
    int src, dst;
    Cost cst;
    Flow cap;
    int rev;
};
bool operator<(const Edge a, const Edge b) {
    return a.cst > b.cst;
}

typedef vector<Edge> Edges;
typedef vector<Edges> Graph;

void add_edge(Graph&G, int u, int v, Flow c, Cost l) {
    G[u].push_back((Edge){ u, v, l, c, int(G[v].size()) });
    G[v].push_back((Edge){ v, u, -l, 0, int(G[u].size()-1) });
}

pair<Flow, Cost> flow(Graph&G, int s, int t, int K) {
    int n = G.size();
    Flow flow = 0;
    Cost cost = 0;
    for ( ; ; ) {
        priority_queue<Edge> Q;
        vector<int> prev(n, -1), prev_num(n, -1);
        vector<Cost> length(n, INF);
        Q.push((Edge){-1,s,0,0,0});
        prev[s]=s;
        for (;!Q.empty();) {
            Edge e=Q.top();
                      Q.pop();
            int v = e.dst;
            for (int i=0; i<(int)G[v].size(); i++) {
                if (G[v][i].cap>0 &&
                    length[G[v][i].dst]>e.cst+G[v][i].cst) {
                    prev[G[v][i].dst]=v;
                    Q.push((Edge){v, G[v][i].dst, e.cst+G[v][i].cst,0,0});
                    prev_num[G[v][i].dst]=i;
                    length[G[v][i].dst]=e.cst+G[v][i].cst;
                }
            }
        }
        if (prev[t]<0) return make_pair(flow, cost);

        Flow mi=INF;
        Cost cst=0;
        for (int v=t; v!=s; v=prev[v]) {
            mi=min(mi, G[prev[v]][prev_num[v]].cap);
            cst+=G[prev[v]][prev_num[v]].cst;
        }

               K -= cst*mi;
        cost+=cst*mi;

        for (int v=t; v!=s; v=prev[v]) {
            Edge &e=G[prev[v]][prev_num[v]];
            e.cap-=mi;
            G[e.dst][e.rev].cap+=mi;
        }
        flow += mi;
    }

}
```

33. Next Permutation in Java

```
boolean next_permutation(int[] p) {
       for (int a = p.length - 2; a >= 0; --a)
              if (p[a] < p[a + 1])
                     for (int b = p.length - 1; --b)
                            if (p[b] > p[a]) {
                                   int t = p[a];
                                   p[a] = p[b];
                                   p[b] = t;
                                   for (++a, b = p.length - 1; a < b;
                                       ++a, --b) {
                                          t = p[a];
                                          p[a] = p[b];
                                          p[b] = t;
                                   }
                                   return true;
```

```
                        }
        return false;
}
```

34. Prim Algorithm

```
int g[MAXN][MAXN], used[MAXN], min_e[MAXN], sel_e[MAXN];
min_e[0] = 0;
for (int i = 0; i < n; ++i) {
        int v = -1;
        for(int j = 0; j < n; ++j) {
                if (!used[j] && (v == -1 || min_e[j] < min_e[v])) {
                        v = j;
                }
        }
        used[v] = true;
        if (sel_e[v] != -1) {
                ans += min_e[v];
        }
        for (int to = 0; to < n; ++to) {
                if (g[v][to] < min_e[to]) {
                        min_e[to] = g[v][to];
                        sel_e[to] = v;
                }
        }
}
```

35. Quicksort

```
//Worst Case O(n^2) but usually O(n log(n))
void quicksort(int lo, int hi) {
    int i=lo, j=hi, h;

    int x=a[(lo+hi)/2];

    do {
        while (a[i]<x) i++;
        while (a[j]>x) j--;
        if (i<=j) {
            swap(a[i], a[j]);
            i++;
            j--;
        }
    } while (i<=j);

    if (lo<j) quicksort(lo, j);
    if (i<hi) quicksort(i, hi);
}
```

36. Stoer Wagner Algorithm

```
//Global Min-Cut Stoer-Wager O(N^3)
int graph[MAXN][MAXN] //Matrix de Adjacencia do grafo.

int minCut(int n) {
    bool a[n];
    int v[n];
    int w[n];
    for(int i = 0; i < n; i++) v[i] = i;
    int best = INF;
    while(n > 1) {
        int maxj = 1;
        a[v[0]] = true;
        for(int i = 1; i < n; ++i) {
            a[v[i]] = false;
            w[i] = graph[v[0]][v[i]];
            if(w[i] > w[maxj]) {
                maxj = i;
            }
        }
        int prev= 0 ,buf = n;
        while(--buf) {
            a[v[maxj]]=true;
            if(buf == 1) {
                best = min(best, w[maxj]);
                for(int k = 0; k < n; k++) {
                    graph[v[k]][v[prev]]= (graph[v[prev]][v[k]] +=
                        graph[v[maxj]][v[k]]);
                }
                v[maxj] = v[--n];
            }
```

```
            prev = maxj;
            maxj = -1;
            for(int j = 1; j < n; ++j) {
                if(!a[v[j]]) {
                    w[j] += graph[v[prev]][v[j]];
                    if(maxj < 0 || w[j] > w[maxj]) {
                        maxj=j;
                    }
                }
            }
        }
    }
    return best;
}
```

37. String Edit Distance

```
int dist(string& s1, string& s2) {
    int N1 = s1.size(), N2 = s2.size();

    for (int i = 0; i <= N1; i++) dp[i][0] = i;
    for (int i = 0; i <= N2; i++) dp[0][i] = i;

    for (int i = 1; i <= N1; i++) {
                for (int j = 1; j <= N2; j++) {
                        if(s1[i-1] == s2[j-1]) {
                                dp[i][j] = dp[i-1][j-1];
                        } else {
                                dp[i][j] = 1 + min(min(dp[i-1][j],
                                    dp[i][j-1]), dp[i-1][j-1]);
                        }
                }
        }
        return dp[N1][N2];
}
```

38. Suffix Array

```
//Suffix Array O(n log n) and LCP in O(n)

//Better Implementation

const int MAXN = 100005;

// Begins Suffix Arrays implementation
// O(n log n) - Manber and Myers algorithm

//Usage:
// Fill str with the characters of the string.
// Call SuffixSort(n), where n is the length of the string stored in str.
// That's it!

//Output:
// pos = The suffix array. Contains the n suffixes of str sorted in
    lexicographical order.
//      Each suffix is represented as a single integer (the position of
    str where it starts).
// rnk = The inverse of the suffix array. rnk[i] = the index of the
    suffix str[i..n)
//       in the pos array. (In other words, pos[i] = k <==> rnk[k] = i)
//       With this array, you can compare two suffixes in O(1): Suffix
    str[i..n) is smaller
//       than str[j..n) if and only if rnk[i] < rnk[j]

int str[MAXN]; //input
int rnk[MAXN], pos[MAXN]; //output
int cnt[MAXN], nxt[MAXN]; //internal
bool bh[MAXN], b2h[MAXN];

bool smaller_first_char(int a, int b){
    return str[a] < str[b];
}

void SuffixSort(int n){
 //sort suffixes according to their first character
    for (int i=0; i<n; ++i){
        pos[i] = i;
    }
    sort(pos, pos + n, smaller_first_char);
 //{pos contains the list of suffixes sorted by their first character}

    for (int i=0; i<n; ++i){
        bh[i] = i == 0 || str[pos[i]] != str[pos[i-1]];
        b2h[i] = false;
    }
```

```
 for (int h = 1; h < n; h <<= 1){
//{bh[i] == false if the first h characters of pos[i-1] == the first h
    characters of pos[i]}
    int buckets = 0;
    for (int i=0, j; i < n; i = j){
        j = i + 1;
        while (j < n && !bh[j]) j++;
        nxt[i] = j;
        buckets++;
    }
    if (buckets == n) break; // We are done! Lucky bastards!
//{suffixes are separted in buckets containing strings starting with
    the same h characters}

    for (int i = 0; i < n; i = nxt[i]){
        cnt[i] = 0;
        for (int j = i; j < nxt[i]; ++j){
            rnk[pos[j]] = i;
        }
    }

    cnt[rnk[n - h]]++;
    b2h[rnk[n - h]] = true;
    for (int i = 0; i < n; i = nxt[i]){
        for (int j = i; j < nxt[i]; ++j){
            int s = pos[j] - h;
            if (s >= 0){
                int head = rnk[s];
                rnk[s] = head + cnt[head]++;
                b2h[rnk[s]] = true;
            }
        }
        for (int j = i; j < nxt[i]; ++j){
            int s = pos[j] - h;
            if (s >= 0 && b2h[rnk[s]]){
                for (int k = rnk[s]+1; !bh[k] && b2h[k]; k++) b2h[k] =
                    false;
            }
        }
    }
    for (int i=0; i<n; ++i){
        pos[rnk[i]] = i;
        bh[i] |= b2h[i];
    }
    }
    for (int i=0; i<n; ++i){
        rnk[pos[i]] = i;
    }
}
// End of suffix array algorithm


// Begin of the O(n) longest common prefix algorithm
int lcp[MAXN];
// lcp[i] = length of the longest common prefix of suffix pos[i] and
    suffix pos[i-1]
// lcp[0] = 0
void getLcp(int n){
    for (int i=0; i<n; ++i) rnk[pos[i]] = i;
    lcp[0] = 0;
    for (int i=0, h=0; i<n; ++i){
        if (rnk[i] > 0){
            int j = pos[rnk[i]-1];
            while (i + h < n && j + h < n && str[i+h] == str[j+h]) h++;
            lcp[rnk[i]] = h;
            if (h > 0) h--;
        }
    }
}
// End of the longest common prefix algorithm

int N = (int) S.size();

for (int i = 0; i < N; i++) {
       str[i] = S[i];
}

SuffixSort(N);
getLcp(N);
```

39. Topological Sort - Iterative

```
priority_queue<int, vector<int>, greater<int> > pq;

for (int i = 0; i < N; i++) {
       if(deg[i] == 0) {
```

```
                pq.push(i);
        }
 }
int on = 0;
while (!pq.empty()) {
        int now = pq.top();
        pq.pop();
        order.push_back(now);
        for (int i = 0; i < (int) graph[now].size(); i++) {
                int next = graph[now][i];
                deg[next] -= 1;

                if(deg[next] == 0) {
                        pq.push(next);
                }
        }
 }
```

40. Topological Sort - Recursive

```
void dfs(int x) {
    vis[x] = 1;
    for(int u = 0; u < n; u++) {
        if(vis[u] == 1 && graph[x][u] == 1) has = true;
        if(vis[u] == 0 && graph[x][u] == 1) {
            dfs(u);
        }
    }
    vis[x] = 2;
    order.push_back(x);
}
```

41. Z Function

```
//Z-Function O(n) => Z[i] = biggest prefix of a substring starting from i
    which is as a prefix of s
vector<int> z_function (string s) {
        int n = (int) s.length();
        vector<int> z (n);
        for (int i=1, l=0, r=0; i<n; ++i) {
                if (i <= r) {
                        z[i] = min (r-i+1, z[i-l]);
                }
                while (i+z[i] < n && s[z[i]] == s[i+z[i]]) {
                        ++z[i];
                }
                if (i+z[i]-1 > r) {
                        l = i;
                        r = i+z[i]-1;
                }
        }
        return z;
}
```