Team Notebook

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Contents

1 Data Structures

1.1 Doubly Linked List

```python
class Node:
    def __init__(self, data):
        self.data = data
        self.next = None
        self.prev = None
    def get_data(self):
        return self.data
class Sentinel_DLL:
    def __init__(self):
        self.sentinel = Node(None)
        self.sentinel.next = self.sentinel
        self.sentinel.prev = self.sentinel
    def first_node(self):
        if self.sentinel.next == self.sentinel:
            return None
        else:
            return self.sentinel.next
    def insert_after(self, x, data):
        y = Node(data)
        y.prev = x
        y.next = x.next
        x.next = y
        y.next.prev = y
    def append(self, data):
        last_node = self.sentinel.prev
        self.insert_after(last_node, data)
    def prepend(self, data):
        self.insert_after(self.sentinel, data)
    def delete(self, x):
        x.prev.next = x.next
        x.next.prev = x.prev
    def find(self, data):
        self.sentinel.data = data
        x = self.first_node()
        while x.data != data:
            x = x.next
        self.sentinel.data = None
        if x == self.sentinel:
            return None
        else:
            return x
    def __str__(self):
        s = "["
        x = self.sentinel.next
        while x != self.sentinel:
            if type(x.data) == str:
                s += "'"
            s += str(x.data)
            if type(x.data) == str:
                s += "'"
            if x.next != self.sentinel:
                s += ", "
            x = x.next

        s += "]"
        return s
#test
llist = Sentinel_DLL()
llist.append(5)
llist.append(6)
llist.append(2)
llist.prepend(19)
print(llist)
#insert_after = insert a new node with data after node x
#append = insert new node at end of list
#prepend = insert a new node at the start of the list
#delete = delete node x
#find = finds x (note: O(n) )
```

1.2 Least Common Ancestor

```cpp
#include<bits/stdc++.h>
using namespace std;
typedef long long int ll;

int n, l;
vector<vector<int>> adj;

int timer;
vector<int> tin, tout;
vector<vector<int>> up;

void dfs(int v, int p)
{
    tin[v] = ++timer;
    up[v][0] = p;
    for (int i = 1; i <= l; ++i)
        up[v][i] = up[up[v][i-1]][i-1];

    for (int u : adj[v]) {
        if (u != p)
            dfs(u, v);
    }

    tout[v] = ++timer;
}

bool is_ancestor(int u, int v)
{
    return tin[u] <= tin[v] && tout[u] >= tout[v];
}

int lca(int u, int v)
{
    if (is_ancestor(u, v))
        return u;
    if (is_ancestor(v, u))
        return v;
    for (int i = l; i >= 0; --i) {
        if (!is_ancestor(up[u][i], v))
            u = up[u][i];
    }
    return up[u][0];
}

void preprocess(int root) {
    tin.resize(n);
    tout.resize(n);
    timer = 0;
    l = ceil(log2(n));
    up.assign(n, vector<int>(l + 1));
    dfs(root, root);
}

int main(){
    ios_base::sync_with_stdio(false);
    cin.tie(NULL); cout.tie(NULL);

    int q;
    cin >> n >> q;
    adj.resize(n);
    // tree
    for (int i = 1; i < n; i++) {
        int x; cin >> x;
        x--;
        adj[x].push_back(i);
    }
    preprocess(0);
    while (q--) {
        int a, b; cin >> a >> b;
        a--; b--;
        cout << lca(a, b) + 1 << endl;
    }

    return 0;
```

```
}
```

1.3 Order Statistics Tree

```
#include<bits/stdc++.h>
using namespace std;
typedef long long int ll;

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace __gnu_pbds;
typedef tree<pair<ll, int>, null_type, less<pair<ll, int>>,
     rb_tree_tag,
             tree_order_statistics_node_update>
    ordered_set;

int main(){
    ios_base::sync_with_stdio(false);
    cin.tie(NULL); cout.tie(NULL);

    ordered_set s;
    // s.insert(2);
    // s.insert(3);
    // s.insert(5);
    // s.order_of_key(3); // index when 3 is inserted OR how
         many values are to the left of 3
    // s.find_by_order(0); // what is in index i
    // cout << s.order_of_key(3) << endl;
    // cout << s.order_of_key(4) << endl;
    s.insert({-2,2});
    s.insert({-1,1});
    s.insert({-1,3});
    cout << s.order_of_key({-1, 1}) << endl;

    return 0;
}
```

1.4 Segment Tree - Range Compression

```
struct CompressedST {
  int n;
  vector<ll> st, lazy;

  // compressed information
  vector<pair<ll,ll>> lr;
  map<ll, int> compress;

CompressedST(vector<ll> &c) {
  int sz = c.size();
  for (int i = 0; i < sz-1; i++) {
    compress[c[i]] = lr.size();
    lr.push_back({c[i], c[i]});
    if (c[i]+1 <= c[i+1]-1)
      lr.push_back({c[i]+1, c[i+1]-1});
  }
  compress[c[sz-1]] = lr.size();
  lr.push_back({c[sz-1], c[sz-1]});
  n = lr.size();

  st.assign(4*n, 0);
  lazy.assign(4*n, 0);
}

void pull(int p) {
  st[p] = st[p<<1] + st[p<<1|1];
}

void push(int p, int i, int j) {
  if (lazy[p]) {
    st[p] += (lr[j].second-lr[i].first+1)*lazy[p];
    if (i != j) {
      lazy[p<<1] += lazy[p];
      lazy[p<<1|1] += lazy[p];
    }
    lazy[p] = 0;
  }
}

void update(int l, int r, ll v, int p, int i, int j) {
  push(p, i, j);
  if (l <= i && j <= r) {
    lazy[p] += v;
    push(p, i, j);
  }
  else if (j < l || r < i);
  else {
    int k = (i+j)/2;
    update(l, r, v, p<<1, i, k);
    update(l, r, v, p<<1|1, k+1, j);
    pull(p);
  }
}

ll query(int l, int r, int p, int i, int j) {
  push(p, i, j);
  if (l <= i && j <= r) return st[p];
  else if (j < l || r < i) return 0;
    else {
      int k = (i+j)/2;
      return query(l, r, p<<1, i, k)
        + query(l, r, p<<1|1, k+1, j);
    }
  }

  ll query(ll l, ll r) {
    return query(compress[l], compress[r], 1, 0, n-1);
  }
  void update(ll l, ll r, ll v) {
    update(compress[l], compress[r], v, 1, 0, n-1);
  }
};
```

1.5 Segment Tree - Range Update

```
struct segtree {
    int n, *vals, *deltas;
    segtree(vector<int> &ar) {
        n = ar.size();
        vals = new int[4*n];
        deltas = new int[4*n];
        build(ar, 1, 0, n-1);
    }

    void build(vector<int> &ar, int p, int i, int j) {
        deltas[p] = 0;
        if (i == j) {
            vals[p] = ar[i];
        }
        else {
            int k = (i + j) / 2;
            build(ar, p<<1, i, k);
            build(ar, p<<1|1, k+1, j);
            pull(p);
        }
    }

    void pull(int p) {
        vals[p] = vals[p<<1] + vals[p<<1|1];
    }

    void push(int p, int i, int j) {
        if (deltas[p]) {
            vals[p] += (j - i + 1) * deltas[p];
            if (i != j) {
                deltas[p<<1] += deltas[p];
                deltas[p<<1|1] += deltas[p];
```

```
            }
            deltas[p] = 0;
        }
    }

    // i, j starts at 0, n-1
    void update(int _i, int _j, int v, int p, int i, int j) {
        push(p, i, j);
        // query overlaps or equates i, j
        if (_i <= i && j <= _j) {
            deltas[p] += v;
            push(p, i, j);
        }
        // no overlap
        else if (_j < i || j < _i) {}
        else {
            int k = (i + j) / 2;
            update(_i, _j, v, p<<1, i, k);
            update(_i, _j, v, p<<1|1, k+1, j);
            pull(p);
        }
    }

    int query(int _i, int _j, int p, int i, int j) {
        push(p, i, j);
        if (_i <= i && j <= _j)
            return vals[p];
        else if (_j < i || j < _i)
            return 0;
        else {
            int k = (i + j) / 2;
            return query(_i, _j, p<<1, i, k) +
                    query(_i, _j, p<<1|1, k+1, j);
        }
    }

    void update(int _i, int _j, int v) {
        update(_i, _j, v, 1, 0, n-1);
    }

    int query(int _i, int _j) {
        return query(_i, _j, 1, 0, n-1);
    }
};
```

1.6 Union Find

```
class DisjointSet
{
    // put this in main()
    //vector<int> univ;
    //for (int i = 1; i <= n; i++) univ.push_back(i);
    //DisjointSet ds;
    //ds.makeSet(univ);

    unordered_map<int, int> parent;
    unordered_map<int, int> rank;
    unordered_map<int, int> members;

public:
    void makeSet(vector<int> const &universe)
    {
        for (int i: universe)
        {
            parent[i] = i;
            rank[i] = 0;
            members[i] = 1;
        }
    }

    int Find(int k)
    {
        if (parent[k] != k)
        {
            parent[k] = Find(parent[k]);
        }

        return parent[k];
    }

    void Union(int a, int b)
    {
        int x = Find(a);
        int y = Find(b);

        if (x == y) {
            return;
        }

        if (rank[x] > rank[y]) {
            parent[y] = x;
            members[x] += members[y];
        }
        else if (rank[x] < rank[y]) {
            parent[x] = y;
            members[y] += members[x];
        }
        else {
            parent[x] = y;
            rank[y]++;
            members[y] += members[x];
        }
    }

    int GetMembers(int a)
    {
        // get the number of members of the disjoint set
            where a is included
        int x = Find(a);
        return members[x];
    }
};
```

2 Graph Algorithms

2.1 Bellman-Ford

```
bool bellman(int s){
    dist[s] = 0;
    for (int i = 0; i < n-1; i++){
        for (int u = 1; u <= n; u++){
            for (auto& [v, w] : adj[u]){
                dist[v] = max(dist[v], dist[u] + w);
            }
        }
    }
    ll ans = dist[n];
    for (int u = 1; u <= n; u++){
        for (auto& [v, w] : adj[u]){
            dist[v] = max(dist[v], dist[u] + w);
            // if dist[v] changes, there's a cycle
        }
    }
    return ans == dist[n];
}
```

2.2 Binary Lifting

```
#include<bits/stdc++.h>
using namespace std;
typedef long long int ll;

void binary_lift(vector<vector<int>>& lift, int n, int l){
    // generates binary lift DS.
```

```
    // lift[u][steps] - resulting node after jumping 2^steps
        from node u
    // lift[u][0] for any u should be pre-computed already
    // n - no. of nodes. 1-indexed
    // l - 2^(l-1) is the max no. of steps

    for (int j = 1; j < l; j++){
        for (int u = 1; u <= n; u++){
            lift[u][j] = lift[lift[u][j-1]][j-1];
        }
    }
}

int jump(int u, int steps, vector<vector<int>>& lift){
    // jumps 'steps' steps from u. returns resulting node.
    int bit = 0;
    while (steps){
        if (steps & 1){
            u = lift[u][bit];
        }
        bit++;
        steps >>= 1;
    }
    return u;
}

int main(){
    ios_base::sync_with_stdio(false);
    cin.tie(NULL); cout.tie(NULL);

    int n, l;
    int q;
    cin >> n >> q;
    l = 30; // log2(1e9) exclusive
    vector<vector<int>> lift(n+1, vector<int>(l));

    for (int u = 1; u <= n; u++){
        cin >> lift[u][0];
    }

    binary_lift(lift, n, l);

    while (q--){
        int u, steps;
        cin >> u >> steps;
        cout << jump(u, steps, lift) << "\n";
    }
    return 0;
}
```

2.3 Edmonds-Karp

```
#include<bits/stdc++.h>
using namespace std;
using ll = long long int;

struct edge {
    size_t i; // index at edges
    int v;
    ll c, f; // directed to v, capacity, flow
    ll residue() { return c - f; }
};

struct flow_network {
    int n, s, t;
    vector<edge> edges; // even indeces are forward flows,
        e_i+1 are reverse flows.
    vector<vector<int>> adj; // stores index pointing in
        edges
    vector<int> parent;
    set<pair<int, int>> edge_cuts;
    set<int> A; // set of nodes that belongs to one side of
        the cut

    flow_network(int n, int s, int t) : n(n), s(s), t(t) {
        adj.resize(n);
        parent.resize(n);
    }

    void add_edge(int u, int v, ll cap) {
        edges.push_back({edges.size(), v, cap, 0});
        adj[u].push_back((int)edges.size()-1);
        edges.push_back({edges.size(), u, 0, 0}); // reverse
        adj[v].push_back((int)edges.size()-1);
    }

    bool aug_path() {
        for (int i=0; i<n; i++) parent[i] = -1;
        parent[s] = s;
        queue<int> q;
        q.push(s);
        while (!q.empty()) {
            int u = q.front(); q.pop();
            if (u == t) break;
            for (auto ind : adj[u]){
                edge& e = edges[ind];
                if (e.residue() > 0 && parent[e.v] == -1) {
                    parent[e.v] = e.i;
                    q.push(e.v);
                }
            }
        }
        return parent[t] != -1;
    };

    ll augment() {
        ll bottleneck = numeric_limits<ll>::max();
        for (int v = t; v != s; v = edges[parent[v] ^ 1].v) {
            bottleneck = min(bottleneck, edges[parent[v]].
                residue());
        }
        for (int v = t; v != s; v = edges[parent[v] ^ 1].v) {
            edges[parent[v]].f += bottleneck;
            edges[parent[v] ^ 1].f -= bottleneck;
        }
        return bottleneck;
    }

    ll calc_max_flow() {
        ll flow = 0;
        while (aug_path()){
            flow += augment();
        }
        return flow;
    }

    void calc_edge_cuts() {
        queue<int> q;
        q.push(s);
        vector<int> vis(n, 0);

        while (!q.empty()) {
            int u = q.front(); q.pop();
            A.insert(u);
            for (auto ind : adj[u]) {
                edge& e = edges[ind];
                if (ind % 2 == 0 && !vis[e.v] && e.residue() >
                    0) {
                    vis[e.v] = 1;
                    q.push(e.v);
                }
            }
        }
        for (int u = 0; u < n; u++) {
            for (auto ind : adj[u]) {
                edge& e = edges[ind];
                int a = u, b = e.v;
                if (a > b) swap(a, b);
```

```
                if ((A.find(a) != A.end() && A.find(b) == A.
                    end()) ||
                   (A.find(a) == A.end() && A.find(b) != A.
                       end())){
                   edge_cuts.insert({a, b});
                }
            }
        }

    }
};

int main(){
    int n, m;
    cin >> n >> m;
    int s = 0, t = n-1;
    flow_network fn(n, s, t);
    for (int i = 0; i < m; i++) {
        int u, v;
        ll cap;
        cin >> u >> v >> cap;
        u--; v--;
        fn.add_edge(u, v, cap);
    }

    cout << fn.calc_max_flow() << endl;
}
```

2.4 Kruskal

```
void kruskal(vector<pair<ll, pair<ll, ll>>> &res){
    // res == minimum spanning tree vector
    // needs DisjointSet class
    DisJointSet ds;
    vector<int> univ;
    for (int i = 1; i <= n; i++)
        univ.push_back(i);
    ds.makeSet(univ);
    // edges == vector of edges, vector< weight , uv >
    // edges should be sorted.
    for (auto edge : edges){
        int u = edge.second.first;
        int v = edge.second.second;
        if (ds.hasCycle(u, v))
            continue;
        ds.Union(u, v);
        res.push_back(edge);
    }
}
```

2.5 Prim

```
void prim(int start, vector<pair<ll, pair<ll, ll>>> &res){
    // res == minimum spanning tree vector
    priority_queue<pair<ll, pair<ll, ll>>> pq;
    vector<bool> vis(n+1, false);
    vis[start] = true;

    for (auto &[v, w] : graph[start]){
        pq.push({w, {start, v}});
    }

    while (!pq.empty()){
        auto edge = pq.top();
        pq.pop();
        ll u = edge.second.second;
        if (vis[u]) continue;
        vis[u] = true;
        res.push_back(edge);
        for (auto &[v, w] : graph[u])
          if (!vis[v]) pq.push({w, {u, v}});
    }
}
```

2.6 Shortest Path Faster Algo

```
void spfa(int s){
    for (int u = 0; u <= n; u++){
        dist[u] = 1e18;
    }
    dist[s] = 0;
    queue<int> q;
    q.push(s);
    vis[s] = 1;
    while (!q.empty()){
        int u = q.front(); q.pop();
        vis[u] = 0;
        for (int i = 0; i < adj[u].size(); i++){
            int v = adj[u][i].first;
            int w = adj[u][i].second;
            if (dist[v] > dist[u] + w){
                dist[v] = dist[u] + w;
                if (!vis[v]){
                    q.push(v);
                    vis[v] = 1;
                }
            }
        }
    }
}
```

2.7 Tarjan

```
#include<bits/stdc++.h>
using namespace std;
typedef long long int ll;

const int MAXN = 1e5+10;
int n;
vector<vector<int>> adj;

int id = 0, sccCount = 0;
int ids[MAXN], low[MAXN], onStack[MAXN];
stack<int> st;

void dfs(int at){
    st.push(at);
    onStack[at] = 1;
    ids[at] = low[at] = id++;

    for (auto to : adj[at]){
        if (ids[to] == -1)
            dfs(to);
        if (onStack[to])
            low[at] = min(low[at], low[to]);
    }

    if (ids[at] == low[at]){
        while (!st.empty()){
            int node = st.top();
            st.pop();
            onStack[node] = 0;
            low[node] = ids[at];
            if (node == at)
                break;
        }
        sccCount++;
    }
}

void fixIndex(){
    map<int, int> old_new;
    int newi = 0;
    for (int i = 0; i < n; i++){
```

```
        if (old_new.find(low[i]) == old_new.end()){
            old_new[low[i]] = newi++;
        }
    }
    for (int i = 0; i < n; i++){
        low[i] = old_new[low[i]];
    }
}

void tarjan(){
    memset(ids, -1, sizeof(ids));
    for (int i = 0; i < n; i++){
        if (ids[i] == -1)
            dfs(i);
    }
    fixIndex();
}

int main(){
    ios_base::sync_with_stdio(false);
    cin.tie(NULL); cout.tie(NULL);



    return 0;
}
```

3 Math

3.1 Sieve

```
MXN = 100000;
bool prime[MXN + 1];

void sieve()
{
    memset(prime, true, sizeof(prime));

    for (int p = 2; p * p <= MXN; p++) {
        if (prime[p] == true) {
            for (int i = p * p; i <= MXN; i += p)
                prime[i] = false;
        }
    }
}
```

4 z Miscellaneous

4.1 CPP Fast IO

```
#include<bits/stdc++.h>
using namespace std;
typedef long long int ll;

int main(){
    ios_base::sync_with_stdio(false);
    cin.tie(NULL); cout.tie(NULL);

    return 0;
}
```

4.2 Comparator

```
struct{
    bool operator()(int a, int b) const { return abs(a) < abs
        (b); }
}
abscomp;
```

4.3 Stress Test

```
import random, subprocess

def generate():
    '''Insert generator here'''

solution = input("Solution file: ")
brutef = input("Bruteforce file: ")

passed = 0
while passed <= 1000:
    test_case = generate()
    with open('input.txt', mode='w') as f:
        print(test_case, file=f)
    p1 = subprocess.run(
        f'python3 {brutef} < input.txt',
        check=True, shell=True, capture_output=True, text=
            True
    )
    p2 = subprocess.run(
        f'./{solution} < input.txt',
        check=True, shell=True, capture_output=True, text=
            True
    )
    if p1.stdout != p2.stdout:
        print('Failed!')
        print('Expected:', p1.stdout)
        print('Output:', p2.stdout)
        print("Test Case:\n" + test_case)
        break

    passed += 1
    print(f'{passed} cases passed')
```