

# University of Tartu ICPC Team Notebook (2017-2018)

October 28, 2017

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## 1 gcc ordered set

```
1 #include <ext/pb_ds/assoc_container.hpp>
2 #include <ext/pb_ds/tree_policy.hpp>
3 using namespace __gnu_pbds;
4 template <typename T>
5 using ordered_set = tree<T, null_type, less<T>, rb_tree_tag, tree_order_statistics_node_update>;
6 int main(){
7     ordered_set<int> cur;
8     cur.insert(1);
9     cur.insert(3);
10    cout << cur.order_of_key(2) << endl; // the number of elements in the set less than 2
11    cout << *cur.find_by_order(0) << endl; // the 0-th smallest number in the set(0-based)
12    cout << *cur.find_by_order(1) << endl; // the 1-th smallest number in the set(0-based)
13 }
```

## 2 Triangle centers

```
1 const double min_delta = 1e-13;
2 const double coord_max = 1e6;
3 typedef complex<double> point;
4 point A, B, C; // vertixes of the triangle
5 bool collinear(){
6     double min_diff = min(abs(A - B), min(abs(A - C), abs(B - C)));
7     if(min_diff < coord_max * min_delta)
8         return true;
9     point sp = (B - A) / (C - A);
10    double ang = M_PI/2-abs(abs(arg(sp))-M_PI/2); //positive angle with the real line
11    return ang < min_delta;
12 }
13 point circum_center(){
14     if(collinear())
15         return point(NAN,NAN);
16     //squared lengths of sides
17     double a2, b2, c2;
18     a2 = norm(B - C);
19     b2 = norm(A - C);
20     c2 = norm(A - B);
21     //barycentric coordinates of the circumcenter
22     double c_A, c_B, c_C;
23     c_A = a2 * (b2 + c2 - a2); //sin(2 * alpha) may be used as well
```

```

24     c_B = b2 * (a2 + c2 - b2);
25     c_C = c2 * (a2 + b2 - c2);
26     double sum = c_A + c_B + c_C;
27     c_A /= sum;
28     c_B /= sum;
29     c_C /= sum;
30     // cartesian coordinates of the circumcenter
31     return c_A * A + c_B * B + c_C * C;
32 }
33 point centroid(){ //center of mass
34     return (A + B + C) / 3.0;
35 }
36 point ortho_center(){ //euler line
37     point O = circum_center();
38     return O + 3.0 * (centroid() - O);
39 };
40 point nine_point_circle_center(){ //euler line
41     point O = circum_center();
42     return O + 1.5 * (centroid() - O);
43 };
44 point in_center(){
45     if(collinear())
46         return point(NAN,NAN);
47     double a, b, c; //side lengths
48     a = abs(B - C);
49     b = abs(A - C);
50     c = abs(A - B);
51     //trilinear coordinates are (1,1,1)
52     //barycentric coordinates
53     double c_A = a, c_B = b, c_C = c;
54     double sum = c_A + c_B + c_C;
55     c_A /= sum;
56     c_B /= sum;
57     c_C /= sum;
58     // cartesian coordinates of the incenter
59     return c_A * A + c_B * B + c_C * C;
60 }

```

### 3 Dinic

```

1 struct MaxFlow{
2     typedef long long ll;
3     const ll INF = 1e18;
4     struct Edge{
5         int u,v;
6         ll c,rc;
7         shared_ptr<ll> flow;
8         pair<int,int> id() const {
9             return make_pair(min(u,v),max(u,v));
10        }
11        Edge(int _u, int _v, ll _c, ll _rc = 0):u(_u),v(_v),c(_c),rc(_rc){
12        }
13        void join(const Edge &t){
14            if(u == t.u){
15                c += t.c;
16                rc += t.rc;
17            }
18            else{
19                c += t.rc;
20                rc += t.c;
21            }
22        }
23    };
24    struct FlowTracker{
25        shared_ptr<ll> flow;
26        ll cap, rcap;
27        bool dir;
28        FlowTracker(ll _cap, ll _rcap, shared_ptr<ll> _flow, int
29                    _dir):cap(_cap),rcap(_rcap),flow(_flow),dir(_dir){ }
30        ll rem() const {
31            if(dir == 0){
32                return cap-*flow;
33            }
34        }
35    };

```

```

33         else{
34             return rcap+*flow;
35         }
36     }
37     void add_flow(ll f){
38         if(dir == 0)
39             *flow += f;
40         else
41             *flow -= f;
42         assert(*flow <= cap);
43         assert(-*flow <= rcap);
44     }
45     operator ll() const { return rem(); }
46     void operator-=(ll x){ add_flow(x); }
47     void operator+=(ll x){ add_flow(-x); }
48 };
49 int source,sink;
50 vector<vector<int>> adj;
51 vector<vector<FlowTracker>> cap;
52 vector<Edge> edges;
53 MaxFlow(int _source, int _sink):source(_source),sink(_sink){
54     assert(source != sink);
55 }
56 int add_edge(Edge e){
57     edges.push_back(e);
58     return edges.size()-1;
59 }
60 int add_edge(int u, int v, ll c, ll rc = 0){
61     return add_edge(Edge(u,v,c,rc));
62 }
63 void group_edges(){
64     map<pair<int,int>,vector<Edge>> edge_groups;
65     for(auto edge: edges)
66         if(edge.u != edge.v)
67             edge_groups[edge.id()].push_back(edge);
68     vector<Edge> grouped_edges;
69     for(auto group: edge_groups){
70         Edge main_edge = group.second[0];
71         for(int i = 1; i < group.second.size(); ++i)
72             main_edge.join(group.second[i]);
73         grouped_edges.push_back(main_edge);
74     }
75     edges = grouped_edges;
76 }
77 vector<int> now,lvl;
78 void prep(){
79     int max_id = max(source,sink);
80     for(auto edge : edges)
81         max_id = max(max_id,max(edge.u,edge.v));
82     adj.resize(max_id+1);
83     cap.resize(max_id+1);
84     now.resize(max_id+1);
85     lvl.resize(max_id+1);
86     for(auto &edge : edges){
87         auto flow = make_shared<ll>(0);
88         adj[edge.u].push_back(edge.v);
89         cap[edge.u].push_back(FlowTracker(edge.c,edge.rc,flow,0));
90         adj[edge.v].push_back(edge.u);
91         cap[edge.v].push_back(FlowTracker(edge.c,edge.rc,flow,1));
92         assert(cap[edge.u].back() == edge.c);
93         edge.flow = flow;
94     }
95 }
96 bool dinic_bfs(){
97     fill(now.begin(),now.end(),0);
98     fill(lvl.begin(),lvl.end(),0);
99     lvl[source] = 1;
100    vector<int> bfs(1,source);
101    for(int i = 0; i < bfs.size(); ++i){
102        int u = bfs[i];
103        for(int j = 0; j < adj[u].size(); ++j){
104            int v = adj[u][j];
105

```

```

106         if(cap[u][j] > 0 && lvl[v] == 0){
107             lvl[v] = lvl[u]+1;
108             bfs.push_back(v);
109         }
110     }
111     return lvl[sink] > 0;
112 }
113 ll dinic_dfs(int u, ll flow){
114     if(u == sink)
115         return flow;
116     while(now[u] < adj[u].size()){
117         int v = adj[u][now[u]];
118         if(lvl[v] == lvl[u] + 1 && cap[u][now[u]] != 0){
119             ll res = dinic_dfs(v,min(flow,(ll)cap[u][now[u]]));
120             if(res > 0){
121                 cap[u][now[u]] -= res;
122                 return res;
123             }
124         }
125     }
126     ++now[u];
127 }
128 return 0;
129 }
130 ll calc(){
131     prep();
132     ll ans = 0;
133     while(dinic_bfs()){
134         ll cur = 0;
135         do{
136             cur = dinic_dfs(source,INF);
137             ans += cur;
138         }while(cur > 0);
139     }
140     return ans;
141 }
142 };
143 int main(){
144     int n,m;
145     cin >> n >> m;
146     auto mf = MaxFlow(1,n);
147     int edge_index;
148     for(int i = 0; i < m; ++i){
149         int a,b,c;
150         cin >> a >> b >> c;
151         edge_index = mf.add_edge(a,b,c); //store edge index if care about flow value
152         mf.add_edge(b,a,c);
153     }
154     mf.group_edges(); // call if we have multiple directed edges or self loops
155     cout << mf.calc() << '\n';
156 //cout << *mf.edges[edge_index].flow << '\n'; // can call only if group_edges() was not called
157 }
```

## 4 Min cost max flow $O(\text{flow} \cdot n^2)$

```

1 const int nmax=1055;
2 const ll inf=1e14;
3 int t, n, v;
4 ll rem_flow[nmax][nmax];
5 ll cost[nmax][nmax];
6 ll min_dist[nmax];
7 int prev_node[nmax];
8 ll node_flow[nmax];
9 bool visited[nmax];
10 ll tot_cost, tot_flow;
11 void mincmaxf(){
12     tot_cost=0;
13     tot_flow=0;
14     ll sink_pot=0;
15     while(true){
16         for(int i=0; i<=v; ++i){
17             min_dist[i]=inf;
18             visited[i]=false;
```

```

19 }
20 min_dist[0]=0;
21 node_flow[0]=inf;
22 int min_node;
23 while(true){
24     int min_node=v;
25     for(int i=0; i<v; ++i){
26         if((!visited[i]) && min_dist[i]<min_dist[min_node]){
27             min_node=i;
28         }
29     }
30     if(min_node==v){
31         break;
32     }
33     visited[min_node]=true;
34     for(int i=0; i<v; ++i){
35         if((!visited[i]) && min_dist[min_node]+cost[min_node][i] < min_dist[i]){
36             min_dist[i]=min_dist[min_node]+cost[min_node][i];
37             prev_node[i]=min_node;
38             node_flow[i]=min(node_flow[min_node], rem_flow[min_node][i]);
39         }
40     }
41 }
42 if(min_dist[v-1]==inf){
43     break;
44 }
45 for(int i=0; i<v; ++i){
46     for(int j=0; j<v; ++j){
47         if(cost[i][j]!=inf){
48             cost[i][j]+=min_dist[i];
49             cost[i][j]-=min_dist[j];
50         }
51     }
52 }
53 sink_pot+=min_dist[v-1];
54 tot_flow+=node_flow[v-1];
55 tot_cost+=sink_pot*node_flow[v-1];
56 int cur=v-1;
57 while(cur!=0){
58     rem_flow[prev_node[cur]][cur]-=node_flow[v-1];
59     rem_flow[cur][prev_node[cur]]+=node_flow[v-1];
60     cost[cur][prev_node[cur]]=0;
61     if(rem_flow[prev_node[cur]][cur]==0){
62         cost[prev_node[cur]][cur]=inf;
63     }
64     cur=prev_node[cur];
65 }
66 }
67 }

```

## 5 Aho Corasick O(|alpha| $\sum$ len)

```

1 const int alpha_size=26;
2 struct node{
3     node *nxt[alpha_size]; //May use other structures to move in trie
4     node *suffix;
5     node(){
6         memset(nxt, 0, alpha_size*sizeof(node *));
7     }
8     int cnt=0;
9 };
10 node *aho_corasick(vector<vector<char> > &dict){
11     node *root= new node;
12     root->suffix = 0;
13     vector<pair<vector<char> *, node *> > cur_state;
14     for(vector<char> &s : dict)
15         cur_state.emplace_back(&s, root);
16     for(int i=0; !cur_state.empty(); ++i){
17         vector<pair<vector<char> *, node *> > nxt_state;
18         for(auto &cur : cur_state){
19             node *nxt=cur.second->nxt[(*cur.first)[i]];
20             if(nxt){
21                 cur.second=nxt;

```

```

22     }else{
23         nxt = new node;
24         cur.second->nxt[(*cur.first)[i]] = nxt;
25         node *suf = cur.second->suffix;
26         cur.second = nxt;
27         nxt->suffix = root; //set correct suffix link
28         while(suf){
29             if(suf->nxt[(*cur.first)[i]]){
30                 nxt->suffix = suf->nxt[(*cur.first)[i]];
31                 break;
32             }
33             suf=suf->suffix;
34         }
35     }
36     if(cur.first->size() > i+1)
37         nxt_state.push_back(cur);
38 }
39 cur_state=nxt_state;
40 }
41 return root;
42 }
43 node *walk(node *cur, char c){
44     while(true){
45         if(cur->nxt[c])
46             return cur->nxt[c];
47         if(!cur->suffix){
48             return cur;
49         }
50         cur = cur->suffix;
51     }
52 }
53 void cnt_matches(node *root, vector<char> &match_in){
54     node *cur = root;
55     for(char c : match_in){
56         cur = walk(cur, c);
57         ++cur->cnt;
58     }
59 }
60 void add_cnt(node *root){
61     vector<node *> to_visit = {root};
62     for(int i=0; i<to_visit.size(); ++i){
63         node *cur = to_visit[i];
64         for(int j=0; j<alpha_size; ++j){
65             if(cur->nxt[j]){
66                 to_visit.push_back(cur->nxt[j]);
67             }
68         }
69     }
70     for(int i=to_visit.size()-1; i>0; --i){
71         to_visit[i]->suffix->cnt += to_visit[i]->cnt;
72     }
73 }
```

## 6 Suffix automaton $O((n + q) \log(|\text{alpha}|))$

```

1 class AutoNode {
2     private:
3     map<char, AutoNode * > nxt_char; // Map is faster than hashtable and unsorted arrays
4     public:
5     int len;
6     AutoNode *suf;
7     bool has_nxt(char c) const {
8         return nxt_char.count(c);
9     }
10    AutoNode *nxt(char c) {
11        if (!has_nxt(c))
12            return NULL;
13        return nxt_char[c];
14    }
15    void set_nxt(char c, AutoNode *node) {
16        nxt_char[c] = node;
17    }
18    AutoNode *split(int new_len, char c) {
```

```

19 AutoNode *new_n = new AutoNode;
20 new_n->nxt_char = nxt_char;
21 new_n->len = new_len;
22 new_n->suf = suf;
23 suf = new_n;
24 return new_n;
25 }
26 // Extra functions for matching and counting
27 AutoNode *lower_depth(int depth) {
28     if (suf->len >= depth)
29         return suf->lower_depth(depth);
30     return this;
31 }
32 AutoNode *walk(char c, int depth, int &match_len) {
33     match_len = min(match_len, len);
34     if (has_nxt(c)) {
35         ++match_len;
36         return nxt(c)->lower_depth(depth);
37     }
38     if (suf)
39         return suf->walk(c, depth, match_len);
40     return this;
41 }
42 int paths_to_end = 0;
43 void set_as_end() {
44     paths_to_end = 1;
45     if (suf) suf->set_as_end();
46 }
47 bool vis = false;
48 void calc_paths_to_end() {
49     if (!vis) {
50         vis = true;
51         for (auto cur : nxt_char) {
52             cur.second->calc_paths_to_end();
53             paths_to_end += cur.second->paths_to_end;
54         }
55     }
56 }
57 };
58 struct SufAutomaton {
59     AutoNode *last;
60     AutoNode *root;
61     void extend(char new_c) {
62         AutoNode *new_end = new AutoNode; // The equivalence class containing the whole new string
63         new_end->len = last->len + 1;
64         AutoNode *suf_w_nxt = last; // The whole old string class
65         while (suf_w_nxt && !suf_w_nxt->has_nxt(new_c)) { // is turned into the longest suffix which
66             // can be turned into a substring of old state
67             // by appending new_c
68             suf_w_nxt->set_nxt(new_c, new_end);
69             suf_w_nxt = suf_w_nxt->suf;
70         }
71         if (!suf_w_nxt) { // The new character isn't part of the old string
72             new_end->suf = root;
73         } else {
74             AutoNode *max_sbstr = suf_w_nxt->nxt(new_c); // Equivalence class containing longest
75                                         // substring which is a suffix of the new state.
76             if (suf_w_nxt->len + 1 == max_sbstr->len) { // Check whether splitting is needed
77                 new_end->suf = max_sbstr;
78             } else {
79                 AutoNode *eq_sbstr = max_sbstr->split(suf_w_nxt->len + 1, new_c);
80                 new_end->suf = eq_sbstr;
81                 // Make suffixes of suf_w_nxt point to eq_sbstr instead of max_sbstr
82                 AutoNode *w_edge_to_eq_sbstr = suf_w_nxt;
83                 while (w_edge_to_eq_sbstr != 0 && w_edge_to_eq_sbstr->nxt(new_c) == max_sbstr) {
84                     w_edge_to_eq_sbstr->set_nxt(new_c, eq_sbstr);
85                     w_edge_to_eq_sbstr = w_edge_to_eq_sbstr->suf;
86                 }
87             }
88         }
89         last = new_end;
90     }
91     SufAutomaton(string to_suffix) {

```

```

92     root = new AutoNode;
93     root->len = 0;
94     root->suf = NULL;
95     last = root;
96     for (char c : to_suffix) extend(c);
97 }
98 };

```

## 7 Templatized multi dimensional BIT $O(\log(n)^{\dim})$

```

1 // Fully overloaded any dimensional BIT, use any type for coordinates, elements, return_value.
2 // Includes coordinate compression.
3 template < typename elem_t, typename coord_t, coord_t n_inf, typename ret_t >
4 class BIT {
5     vector< coord_t > positions;
6     vector< elem_t > elems;
7     bool initiated = false;
8
9 public:
10    BIT() {
11        positions.push_back(n_inf);
12    }
13    void initiate() {
14        if (initiated) {
15            for (elem_t &c_elem : elems)
16                c_elem.initiate();
17        } else {
18            initiated = true;
19            sort(positions.begin(), positions.end());
20            positions.resize(unique(positions.begin(), positions.end()) - positions.begin());
21            elems.resize(positions.size());
22        }
23    }
24    template < typename... loc_form >
25    void update(coord_t cord, loc_form... args) {
26        if (initiated) {
27            int pos = lower_bound(positions.begin(), positions.end(), cord) - positions.begin();
28            for (; pos < positions.size(); pos += pos & -pos)
29                elems[pos].update(args...);
30        } else {
31            positions.push_back(cord);
32        }
33    }
34    template < typename... loc_form >
35    ret_t query(coord_t cord, loc_form... args) { //sum in open interval (-inf, cord)
36        ret_t res = 0;
37        int pos = (lower_bound(positions.begin(), positions.end(), cord) - positions.begin())-1;
38        for (; pos > 0; pos -= pos & -pos)
39            res += elems[pos].query(args...);
40        return res;
41    }
42 };
43 template < typename internal_type >
44 struct wrapped {
45     internal_type a = 0;
46     void update(internal_type b) {
47         a += b;
48     }
49     internal_type query() {
50         return a;
51     }
52     // Should never be called, needed for compilation
53     void initiate() {
54         cerr << 'i' << endl;
55     }
56     void update() {
57         cerr << 'u' << endl;
58     }
59 };
60 int main() {
61     // return type should be same as type inside wrapped
62     BIT< BIT< wrapped< ll >, int, INT_MIN, ll >, int, INT_MIN, ll > fenwick;
63     int dim = 2;

```

```
64 vector< tuple< int, int, ll > > to_insert;
65 to_insert.emplace_back(1, 1, 1);
66 // set up all positions that are to be used for update
67 for (int i = 0; i < dim; ++i) {
68     for (auto &cur : to_insert)
69         fenwick.update(get< 0 >(cur), get< 1 >(cur)); // May include value which won't be used
70     fenwick.initiate();
71 }
72 // actual use
73 for (auto &cur : to_insert)
74     fenwick.update(get< 0 >(cur), get< 1 >(cur), get< 2 >(cur));
75 cout << fenwick.query(2, 2) << '\n';
76 }
```