ButterRoti ICPC Team Notebook (2017-18)

Contents

1 Sublime

1.1 Build

```
{
"cmd": ["g++ -std=c++14 -g -Wall '${file}' &&
   timeout 15s '${file_path}/./a.out'<'${file_path
   }/input.txt'>'${file_path}/output.txt'"],
"shell":true
}
```

1.2 Snippet

```
#include <bits/stdc++.h>

using namespace std;

template<typename T> using V = vector<T>;
template<typename T, typename V> using P = pair<T,
    V>;
template<typename T> using min_heap =
   priority_queue<T, V<T>, greater<T>>;

using LL = long long;
using ll = LL;
using LD = long double;
using ld = long double;

#define fi first
#define ff first
#define se second
#define ss second
#define pp push_back
#define pb pp
#define endl '\n'
#define SYNC std::ios::sync_with_stdio(false);
   cin.tie(NULL);
#define ALL(v) v.begin(), v.end()
#define FOR0(i,n) for(int i=0, _##i=(n); i<_##i;
   ++i)
#define FOR(i,l,r) for(int i=(l), _##i=(r); i<_##i
   ; ++i)
#define FORD(i,l,r) for(int i=(r), _##i=(l); --i>=
   _##i; )
#define rep(i,a) FOR0(i, a)
#define repn(i,a) FOR(i, 1, a + 1)
#define REP(i, n) rep(i, n)
#define REPN(i, n) repn(i, n)
#define SZ(a) ((int)((a).size()))
#define mp make_pair
#define dzx cerr << "here";
#define her cerr << "HERE "
#define pii pair<int,int>
#define ii pii
#define en(v) *(--v.end())

const int MOD = (int)1e9 + 7, inf = 0x3f3f3f3f;
const ll INF = 0x3f3f3f3f3f3f3f3f;

int32_t main() {SYNC;

    return 0;
}
```

2 Combinatorial optimization

2.1 Lowest Common Ancestor

```
// 0-based vertex indexing. memset to -1
int log(int t){
  int res = 1;
  for(; 1 << res <= t; res++);
  return res;
}
```

```
int lca(int u , int v){
  if(h[u] < h[v])swap(u , v);
  int L = log(h[u]);
  for(int i = L - 1; i >= 0; i--){
    if(par[u][i] + 1 && h[u] - (1 << i) >= h[v])
      u = par[u][i];
  }
  if(v == u) return u;
  for(int i = L - 1; i >= 0; i--){
    if(par[u][i] + 1 && par[u][i] != par[v][i]){
      u = par[u][i]; v = par[v][i];
    }
  }
  return par[u][0];
}
```

2.2 Auxiliary Tree

```
//std::vector<int> a contains vertices to form the
    aux t
sort(ALL(a), [](const int & a, const int & b) ->
   bool{
  return st[a] < st[b];
});
set<int> s(a);
for(int i = 0, k = (int)a.size(); i + 1 < k; i++){
  int v = lca(a[i], a[i + 1]);
  if(s.find(v) == s.end())
    a.push_back(v);
  s.insert(v);
}

sort(ALL(a), [](const int & a, const int & b) ->
   bool{
  return st[a] < st[b];
});

stack<int> S;
S.push(a[0]);

auto anc = [](int & a, int & b) -> bool{
  return st[b] >= st[a] && en[b] <= en[a];
};

for(int i = 1; i < (int)a.size(); i++){
  while(!anc(S.top(), a[i])) S.pop();
  G[S.top()].pp(a[i]);
  G[a[i]].pp(S.top());
  S.push(a[i]);
}
//G is the Aux tree
```

2.3 Articulation Point and Bridges

```
#include <bits/stdc++.h>

using namespace std;
const int N = 50;
int dis[N], low[N], par[N], AP[N],vis[N],tits;
void update(int u , int i, int child) {
  //For Cut Vertices
  if(par[u] != -1 && low[i] >= dis[u]) AP[u] =
     true;
  if(par[u] == -1 && child > 1) AP[u] = true;

  //For Finding Cut Bridge
  if(low[i] > dis[u]){
    //articulation bridge found.
  }
}
void dfs(int u){
  vis[u] = true;
  low[u] = dis[u] = (++tits); int child = 0;
  for(int i : g[u]) {
    if(!vis[i]){
      child++;
      par[i] = u;
      dfs(i);
      low[u] = min(low[u] , low[i]);
      update(u, i, child);
    }
    else if(i != par[u]) {
      low[u] = min(low[u] , dis[i]);
    }
  }
}
```

2.4 Biconnected Components

```
#include <bits/stdc++.h>
```

```cpp
using namespace std;
const int N = (int)2e5 + 10;

vector<vector<int>> tree, g;
bool isBridge[N << 2], vis[N];
int Time, arr[N], U[N], V[N], cmpno, comp[N];
vector<int> temp; //temp stores component values

int adj(int u, int e){
  return (u == U[e] ? V[e] : U[e]);
}

int find_bridge(int u , int edge){
  vis[u] = true;
  arr[u] = Time++;
  int x = arr[u];

  for(auto & i : g[u]){
    int v = adj(u, i);
    if(!vis[v]){
      x = min(x,find_bridge(v, i));
    }
    else if(i != edge){
      x = min(x,arr[v]);
    }
  }

  if(x == arr[u] && edge != -1){
    isBridge[edge] = true;
  }
  return x;
}

void dfs1(int u){
  int current = cmpno;
  queue<int> q;
  q.push(u);
  vis[u] = 1;
  temp.push_back(current);

  while(!q.empty()){
    int v = q.front();
    q.pop();
    comp[v] = current;

    for(auto & i : g[v]) {
      int w = adj(v, i);
      if(vis[w])continue;
      if(isBridge[i]){
        cmpno++;
        tree[current].push_back(cmpno);
        tree[cmpno].push_back(current);
        dfs1(w);
      }
      else{
        q.push(w);
        vis[w] = 1;
      }
    }
  }
}

int main(){
  int n, m;
  cin >> n >> m;
  g.resize(n + 2); tree.resize(n + 2);

  for(int i = 0; i < m; i ++){
    cin >> U[i] >> V[i];
    g[U[i]].push_back(i);
    g[V[i]].push_back(i);
  }

  cmpno = Time = 0;
  memset(vis, false, sizeof vis);

  for(int i = 0; i < n; i ++){
    if(!vis[i]){
      find_bridge(i , -1);
    }
  }

  memset(vis, false, sizeof vis);
  cmpno = 0;

  for(int i = 0; i < n; i ++){
    if(!vis[i]){
      temp.clear();
      cmpno++;
      dfs1(i);
    }
  }
}
```

2.5 2-SAT

```
class sat_2{
public:
  int n, m, tag;
  V<V<int>> g, grev;
  V<bool> val;
  V<int> st;
  V<int> comp;

  sat_2(){}
  sat_2(int n) : n(n), m(2 * n), tag(0), g(m + 1),
      grev(m + 1), val(n + 1) { }

  void add_edge(int u, int v) { //u or v
    auto make_edge = [&](int a, int b) {
      if(a < 0) a = n - a;
      if(b < 0) b = n - b;
      g[a].pp(b);
      grev[b].pp(a);
    };

    make_edge(-u, v);
    make_edge(-v, u);
  }

  void truth_table(int u, int v, V<int> t) {
    for(int i = 0; i < 2; i ++) for(int j = 0; j <
        2; j ++) {
      if(!t[i * 2 + j])
        add_edge((2 * (i ^ 1) - 1) * u, (2 * (j ^
            1) - 1) * v);
    }
  }

  void dfs(int u, V<V<int>> & G, bool first) {
    comp[u] = tag;
    for(int & i : G[u]) if(comp[i] == -1)
      dfs(i, G, first);
    if(first) st.push_back(u);
  }

  bool satisfiable() {
    tag = 0; comp.assign(m + 1, -1);
    for(int i = 1; i <= m; i ++) {
      if(comp[i] == -1)
        dfs(i, g, true);
    }reverse(ALL(st));

    tag = 0; comp.assign(m + 1, -1);
    for(int & i : st) {
      if(comp[i] != -1) continue;
      tag++;
      dfs(i, grev, false);
    }

    for(int i = 1; i <= n; i ++) {
      if(comp[i] == comp[i + n]) return false;
      val[i] = comp[i] > comp[i + n];
    }

    return true;
  }
};
```

2.6 Dinic's Max Flow

```
// from stanford notebook
struct edge {
  int u, v;
  ll c, f;
  edge() { }
  edge(int _u, int _v, ll _c, ll _f = 0): u(_u), v
      (_v), c(_c), f(_f) { }
};
int n;
vector<edge> edges;
vector<vector<int> > g;
vector<int> d, pt;

void addEdge(int u, int v, ll c, ll f = 0) {
  g[u].emplace_back(edges.size());
  edges.emplace_back(edge(u,v,c,f));
  g[v].emplace_back(edges.size());
  edges.emplace_back(edge(v,u,0,0));
}
bool bfs(int s, int t) {
  queue<int> q({s});
  d.assign(n+1, n+2);
  d[s] = 0;
  while(!q.empty()) {
    int u = q.front(); q.pop();
```

```
      if (u == t) break;
      for(int k : g[u]) {
        edge &e = edges[k];
        if(e.f < e.c && d[e.v] > d[e.u] + 1){
          d[e.v] = d[e.u] + 1;
          q.push(e.v);
        }
      }
    }
    return d[t] < n+2;
  }

  ll dfs(int u, int t, ll flow = -1) {
    if(u == t || !flow) return flow;
    for(int &i = pt[u]; i < (int)(g[u].size()); i++)
        {
      edge &e = edges[g[u][i]], &oe=edges[g[u][i
         ]^1];
      if(d[e.v] == d[e.u] + 1) {
        ll amt = e.c - e.f;
        if (flow != -1 && amt > flow) amt = flow;
        if(ll pushed = dfs(e.v,t,amt)) {
          e.f += pushed;
          oe.f -= pushed;
          return pushed;
        }
      }
    }
    return 0;
  }

  ll flow(int s, int t) {
    ll ans = 0;
    while(bfs(s,t)) {
      pt.assign(n+1, 0);
      while(ll val = dfs(s,t)) ans += val;
    }
    return ans;
  }
```

2.7 Min Cost Max Flow

```
  int tt=0;
  class CostFlowGraph{
  public:
    struct Edge{
      int v,f,c;
      Edge(){}
      Edge(int v,int f,int c):v(v),f(f),c(c){}
    };
    V<V<int> > g;
    V<Edge> e;
    V<int> pot;
    int n, flow, cost;
    CostFlowGraph(int sz){
      n=sz;
      g.resize(n);
      pot.assign(n,0);
      flow=0;
      cost=0;
    }
    void clear(){
      flow=0;cost=0;
      for(int i=0;i<(int)e.size();i++){
        e[i].f+=e[i^1].f;
        e[i^1].f=0;
      }
    }
    void addEdge(int u,int v,int cap,int c){
      g[u].pb((int)e.size());
      e.pb(Edge(v,cap,c));
      g[v].pb((int)e.size());
      e.pb(Edge(u,0,-c));
    }
    void assignPots(int s){
      priority_queue<pii,V<pii>,greater<pii>> q;
      V<int> npot(n,inf);
      q.push({s,0});
      while(!q.empty()){
        auto cur=q.top();q.pop();
        if(npot[cur.fi]<=cur.se)
          continue;
        npot[cur.fi]=cur.se;
        for(auto i:g[cur.fi]) if(e[i].f>0){
          int cst=pot[cur.fi]-pot[e[i].v]+e[i].c;
          q.push({e[i].v,cst+cur.se});
        }
      }
      for(int i=0;i<n;i++)  if(npot[i]!=inf){
        pot[i]+=npot[i];
      }
    }
```

```
  void dfs(int t,V<bool> &v,V<int> &stk){
    auto cur=stk.back();
    v[e[cur].v]=1;
    if(e[stk.back()].v==t)
      return ;
    for(auto i:g[e[cur].v]) if(!v[e[i].v] && e[i].
       f>0 && (pot[e[cur].v]-pot[e[i].v]+e[i].c)
       ==0){
      stk.pb(i);
      dfs(t,v,stk);
      if(e[stk.back()].v==t)
        return ;
    }
    stk.pop_back();
  }
  int augment(int s,int t){
    V<bool> v(n,false);
    vector<int> stk;
    if(g[s].size()==0)
      return 0;
    stk.pb(g[s][0]^1);
    dfs(t,v,stk);
    if(stk.empty())
      return 0;
    int mx=inf;
    for(int i=1;i<(int)stk.size();i++)
      mx=min(mx,e[stk[i]].f);
    for(int i=1;i<(int)stk.size();i++){
      e[stk[i]].f-=mx;
      e[(stk[i])^1].f+=mx;
    }
    return mx;
  }
  void mcf(int s,int t){
    int cur=0;
    do{
      flow+=cur;
      cost+=(pot[t]-pot[s]);
      assignPots(s);
      cur=augment(s,t);
    }while(cur);
  }
};
```

2.8 Global Min Cut

```
// Adj mat. Stoer-Wagner min cut algorithm.
// Running time:O(|V|^3)
typedef vector<int> VI;
typedef vector<VI> VVI;

const int INF = 1000000000;

pair<int, VI> GetMinCut(VVI &weights) {
  int N = weights.size();
  VI used(N), cut, best_cut;
  int best_weight = -1;

  for (int phase = N-1; phase >= 0; phase--) {
    VI w = weights[0];
    VI added = used;
    int prev, last = 0;
    for (int i = 0; i < phase; i++) {
      prev = last;
      last = -1;
      for (int j = 1; j < N; j++)
  if (!added[j] && (last == -1 || w[j] > w[last]))
      last = j;
      if (i == phase-1) {
  for (int j = 0; j < N; j++) weights[prev][j] +=
     weights[last][j];
  for (int j = 0; j < N; j++) weights[j][prev] =
     weights[prev][j];
  used[last] = true;
  cut.push_back(last);
  if (best_weight == -1 || w[last] < best_weight)
     {
    best_cut = cut;
    best_weight = w[last];
  }
      } else {
  for (int j = 0; j < N; j++)
    w[j] += weights[last][j];
  added[last] = true;
      }
    }
  }
  return make_pair(best_weight, best_cut);
}

int main() {
  int N;
```

```
    cin >> N;
    for(int i = 0; i < N; i++) {
      int n, m;
      cin >> n >> m;
      VVI weights(n, VI(n));
      for (int j = 0; j < m; j++) {
        int a, b, c;
        cin >> a >> b >> c;
        weights[a-1][b-1] = weights[b-1][a-1] = c;
      }
      pair<int, VI> res = GetMinCut(weights);
      cout << "Case #" << i+1 << ": " << res.first
         << endl;
    }
  }
```

2.9 Bipartite Matching

```
  // maximum cardinality bipartite matching using
     augmenting paths.
  // assumes that first n elements of graph
     adjacency list belong to the left vertex set.
  int n;
  vector<vector<int>> graph;
  vector<int> match, vis;

  int augment(int l) {
    if(vis[l]) return 0;
    vis[l] = 1;
    for(auto r: graph[l]) {
      if(match[r]==-1 || augment(match[r])) {
        match[r]=l; return 1;
      }
    }
    return 0;
  }

  int matching() {
    int ans = 0;
    for(int l = 0; l < n; l++) {
      vis.assign(n, 0);
      ans += augment(l);
    }
    return ans;
  }
```

2.10 Hopcraft-Karp

```
  #define MAX 100001
  #define NIL 0
  #define INF (1<<28)

  vector< int > G[MAX];
  int n, m, match[MAX], dist[MAX];
  // n: number of nodes on left side, nodes are
     numbered 1 to n
  // m: number of nodes on right side, nodes are
     numbered n+1 to n+m
  // G = NIL[0]  ł  G1[G[1---n]]  ł  G2[G[n+1---n+m
     ]]

  bool bfs() {
      int i, u, v, len;
      queue< int > Q;
      for(i=1; i<=n; i++) {
          if(match[i]==NIL) {
              dist[i] = 0;
              Q.push(i);
          }
          else dist[i] = INF;
      }
      dist[NIL] = INF;
      while(!Q.empty()) {
          u = Q.front(); Q.pop();
          if(u!=NIL) {
              len = G[u].size();
              for(i=0; i<len; i++) {
                  v = G[u][i];
                  if(dist[match[v]]==INF) {
                      dist[match[v]] = dist[u] + 1;
                      Q.push(match[v]);
                  }
              }
          }
      }
      return (dist[NIL]!=INF);
  }

  bool dfs(int u) {
      int i, v, len;
      if(u!=NIL) {
```

```
        len = G[u].size();
        for(i=0; i<len; i++) {
            v = G[u][i];
            if(dist[match[v]]==dist[u]+1) {
                if(dfs(match[v])) {
                    match[v] = u;
                    match[u] = v;
                    return true;
                }
            }
        }
        dist[u] = INF;
        return false;
    }
    return true;
}

int hopcroft_karp() {
    int matching = 0, i;
    // match[] is assumed NIL for all vertex in G
    while(bfs())
        for(i=1; i<=n; i++)
            if(match[i]==NIL && dfs(i))
                matching++;
    return matching;
}
```

2.11 Hungarian

```
//  Min cost BPM via shortest augmenting paths
//  O(n^3).Solves 1000x1000 in ~1s
//  cost[i][j] = cost for pairing left node i with
    right node j
//  Lmate[i] = index of right node that left node
   i pairs with
//  Rmate[j] = index of left node that right node
   j pairs with
//  The values in cost[i][j] may be +/-.  To
   perform
//  maximization, negate cost[][].
typedef vector<double> VD;
typedef vector<VD> VVD;
typedef vector<int> VI;

double MinCostMatching(const VVD &cost, VI &Lmate,
    VI &Rmate) {
int n = int(cost.size());

// construct dual feasible solution
VD u(n);
VD v(n);
for (int i = 0; i < n; i++) {
  u[i] = cost[i][0];
  for (int j = 1; j < n; j++) u[i] = min(u[i],
     cost[i][j]);
}
for (int j = 0; j < n; j++) {
  v[j] = cost[0][j] - u[0];
  for (int i = 1; i < n; i++) v[j] = min(v[j],
     cost[i][j] - u[i]);
}

// construct primal solution satisfying
   complementary slackness
Lmate = VI(n, -1);
Rmate = VI(n, -1);
int mated = 0;
for (int i = 0; i < n; i++) {
  for (int j = 0; j < n; j++) {
    if (Rmate[j] != -1) continue;
    if (fabs(cost[i][j] - u[i] - v[j]) < 1e-10)
       {
  Lmate[i] = j;
  Rmate[j] = i;
  mated++;
  break;
    }
  }
}

VD dist(n);
VI dad(n);
VI seen(n);

// repeat until primal solution is feasible
while (mated < n) {

  // find an unmatched left node
  int s = 0;
  while (Lmate[s] != -1) s++;

  // initialize Dijkstra
  fill(dad.begin(), dad.end(), -1);
```

```
  fill(seen.begin(), seen.end(), 0);
  for (int k = 0; k < n; k++)
    dist[k] = cost[s][k] - u[s] - v[k];

  int j = 0;
  while (true) {

    // find closest
    j = -1;
    for (int k = 0; k < n; k++) {
  if (seen[k]) continue;
  if (j == -1 || dist[k] < dist[j]) j = k;
    }
    seen[j] = 1;

    // termination condition
    if (Rmate[j] == -1) break;

    // relax neighbors
    const int i = Rmate[j];
    for (int k = 0; k < n; k++) {
  if (seen[k]) continue;
  const double new_dist = dist[j] + cost[i][k] -
      u[i] - v[k];
  if (dist[k] > new_dist) {
    dist[k] = new_dist;
    dad[k] = j;
  }
    }
  }

    // update dual variables
    for (int k = 0; k < n; k++) {
      if (k == j || !seen[k]) continue;
      const int i = Rmate[k];
      v[k] += dist[k] - dist[j];
      u[i] -= dist[k] - dist[j];
    }
    u[s] += dist[j];

    // augment along path
    while (dad[j] >= 0) {
      const int d = dad[j];
      Rmate[j] = Rmate[d];
      Lmate[Rmate[j]] = j;
      j = d;
    }
    Rmate[j] = s;
    Lmate[s] = j;

    mated++;
  }

  double value = 0;
  for (int i = 0; i < n; i++)
    value += cost[i][Lmate[i]];

  return value;
}
```