Universidad de Concepción

Apunte ICPC

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Índice general

Notas previas

0.1. Abreviaciones utilizadas

```
1  typedef long long ll;
2  //en ciertos casos es necesario cambiar int por ll
3  typedef vector<int> vi;
4  typedef vector<vector<int> > vvi;
5  typedef pair<int,int> ii;
6  typedef vector<vector<ii> > vvii;   //util para grafos
7  typedef pair<pair<int,int>,int> iii;
8  #define mp(x,y) make_pair(x,y)
9  #define pb(x) push_back(x)
```

Capítulo 1

Estructuras de datos

1.1. Fenwick Tree

Nota: Ambas implementaciones tienen rangos entre 1 a n.

1.1.1. Actualizaciones por rango, consultas puntales

```
1  struct FenwickTree{
2    vi FT;
3    FenwickTree(int N){
4       FT.resize(N+1,0);
5    }
6
7    int query(int i){
8       int ans = 0;
9       for(;i;i-=i&(-i)) ans += FT[i];
10      return ans;
11   }
12
13   int query(int i, int j){
14      return query(j)-query(i-1);
15   }
16
17   void update(int i, int v){
18      for(;i<FT.size();i+=i&(-i)) FT[i] += v;
19   }
20
21   void update(int i, int j, int v){
22      update(i,v); update(j+1,-v);
23   }
24 };
```

1.1.2. Actualizaciones puntuales, consultas por rango

La consulta $query(a, b)$ corresponde a la sumatoria de los elementos entre los índices a y b.

```
1  struct FenwickTree {
2    vi ft;
3    FenwickTree(){}
4    FenwickTree(int n){
5      ft.assign(n + 1, 0);
6    }
7
8    int query(int b) {
9      int sum = 0;
10     for (; b; b -= b&(-b)) sum += ft[b];
11     return sum;
12   }
13
14   int query(int a, int b) { \\RSQ
15     return query(b) - (a == 1 ? 0 : query(a - 1));
16   }
17
18   void update(int k, int v) {                    // note: n = ft.
         size() - 1
19     for (; k < (int)ft.size(); k += k&(-k)) ft[k] += v;
20   }
21 };
```

1.2. Union-Find

Utilizada para trabajar conjuntos disjuntos. Sirve para encontrar componentes conexas en grafos no dirigidos.

```
1  class UnionFind {
2  private:
3    vi p, rank, setSize;
4    int numSets;
5  public:
6    UnionFind(int N) {
7    setSize.assign(N, 1); numSets = N; rank.assign(N, 0);
8    p.assign(N, 0); for (int i = 0; i < N; i++) p[i] = i; }
9    int findSet(int i) { return (p[i] == i) ? i : (p[i] = findSet(p[i
         ])); }
10   bool isSameSet(int i, int j) { return findSet(i) == findSet(j); }
11   void unionSet(int i, int j) {
12   if (!isSameSet(i, j)) { numSets--;
13   int x = findSet(i), y = findSet(j);
14   // rank is used to keep the tree short
15   if (rank[x] > rank[y]) { p[y] = x; setSize[x] += setSize[y]; }
16   else                   { p[x] = y; setSize[y] += setSize[x];
17                               if (rank[x] == rank[y]) rank[y]++; } }
                                    }
18   int numDisjointSets() { return numSets; }
19   int sizeOfSet(int i) { return setSize[findSet(i)]; }
20 };
```

1.3. Segment Tree

1.3.1. Iterativo

```
1  struct prodsgn {
2      int sgn;
3      prodsgn() {sgn = 1;}
4      prodsgn(int x) {
5          sgn = (x > 0) - (x < 0);
6      }
7      prodsgn(const prodsgn &a,
8              const prodsgn &b) {
9          sgn = a.sgn*b.sgn;
10     }
11 };
12
13 // Maximum Sum (SPOJ)
14 struct maxsum {
15     int first, second;
16     maxsum() {first = second = -1;}
17     maxsum(int x) {
18         first = x; second = -1;
19     }
20     maxsum(const maxsum &a,
21            const maxsum &b) {
22         if (a.first > b.first) {
23             first = a.first;
24             second = max(a.second,
25                          b.first);
26         } else {
27             first = b.first;
28             second = max(a.first,
29                          b.second);
30         }
31     }
32     int answer() {
33         return first + second;
34     }
35 };
36
37 // Range Minimum Query
38 struct rminq {
39     int value;
40     rminq() {value = INT_MAX;}
41     rminq(int x) {value = x;}
42     rminq(const rminq &a,
43           const rminq &b) {
44         value = min(a.value,
45                     b.value);
46     }
47 };
48
49
50 template<class node> class ST {
51     vector<node> t;
52     int n;
53
```

```
54 public:
55     ST(vector<node> &arr) {
56         n = arr.size();
57         t.resize(n*2);
58         copy(arr.begin(), arr.end(), t.begin() + n);
59         for (int i = n-1; i > 0; --i)
60             t[i] = node(t[i<<1], t[i<<1|1]);
61     }
62 
63     // 0-indexed
64     void set_point(int p, const node &value) {
65         for (t[p += n] = value; p > 1; p >>= 1)
66             t[p>>1] = node(t[p], t[p^1]);
67     }
68 
69     // inclusive exclusive, 0-indexed
70     node query(int l, int r) {
71         node ansl, ansr;
72         for (l += n, r += n; l < r; l >>= 1, r >>= 1) {
73             if (l&1) ansl = node(ansl, t[l++]);
74             if (r&1) ansr = node(t[--r], ansr);
75         }
76         return node(ansl, ansr);
77     }
78 };
```

1.3.2. Lazy

```
1  struct RSQ {
2      static intt const neutro = 0;
3      static intt op(intt x, intt y) {
4          return x + y;
5      }
6      static intt
7        lazy_op(int i, int j, intt x) {
8          return (j - i + 1)*x;
9      }
10 };
11 
12 struct RMinQ {
13     static intt const neutro = 1e18;
14     static intt op(intt x, intt y) {
15         return min(x, y);
16     }
17     static intt
18       lazy_op(int i, int j, intt x) {
19         return x;
20     }
21 };
22 
23 
24 template<class t> class SegTreeLazy {
25     vector<intt> arr, st, lazy; int n;
26 
27     void build(int u, int i, int j) {
28         if (i == j) {
29             st[u] = arr[i];
```

```
30              return;
31          }
32          int m = (i+j)/2, l = u*2+1, r = u*2+2;
33          build(l, i, m);
34          build(r, m+1, j);
35          st[u] = t::op(st[l], st[r]);
36      }
37
38      void propagate(int u, int i, int j, intt x) {
39          st[u] += t::lazy_op(i, j, x);
40          if (i != j) {
41              lazy[u*2+1] += x;
42              lazy[u*2+2] += x;
43          }
44          lazy[u] = 0;
45      }
46
47      intt query(int a, int b, int u, int i, int j) {
48          if (j < a or b < i)
49              return t::neutro;
50          int m = (i+j)/2, l = u*2+1, r = u*2+2;
51          if (lazy[u])
52              propagate(u, i, j, lazy[u]);
53          if (a <= i and j <= b)
54              return st[u];
55          intt x = query(a, b, l, i, m);
56          intt y = query(a, b, r, m+1, j);
57          return t::op(x, y);
58      }
59
60      void update(int a, int b, intt value,
61      int u, int i, int j) {
62          int m = (i+j)/2, l = u*2+1, r = u*2+2;
63          if (lazy[u])
64              propagate(u, i, j, lazy[u]);
65          if (a <= i and j <= b)
66              propagate(u, i, j, value);
67          else if (j < a or b < i) return; else {
68              update(a, b, value, l, i, m);
69              update(a, b, value, r, m+1, j);
70              st[u] = t::op(st[l], st[r]);
71          }
72      }
73
74  public:
75      SegTreeLazy(vector<intt>& v) {
76          arr = v;
77          n = v.size();
78          st.resize(n*4+5);
79          lazy.assign(n*4+5, 0);
80          build(0, 0, n-1);
81      }
82
83      intt query(int a, int b) {
84          return query(a, b, 0, 0, n-1);
85      }
86
```

```
87      void update(int a, int b, intt value) {
88          update(a, b, value, 0, 0, n-1);
89      }
90  };
```

1.3.3. Pair

```
1   #include <bits/stdc++.h>
2   #define inf 0x7fffffff
3   #define optimizar_io ios_base::sync_with_stdio(0);cin.tie(0);
4
5   using namespace std;
6
7   typedef long long int ll;
8   typedef pair <int,int> par;
9   typedef vector< par > vi;
10  class SegmentTree {
11  public:
12    SegmentTree(const vi&_A){
13      arr = _A; n = (int)arr.size();
14      tree.resize(4*n);
15      lazy.resize(4*n);
16      for(int i = 0; i < 4*n; i++){
17        lazy[i] = 0;
18        tree[i] = make_pair(0,i);
19      }
20      build_tree(1,0,n-1);
21    }
22    par rmq(ll i,ll j) {return query_tree(1,0,n-1,i,j);}
23    void update(ll i,ll j, ll val){update_tree(1,0,n-1,i,j,val);}
24  private:
25    vi arr, tree;
26    vector <long long int >lazy;
27    ll n;
28    void build_tree(ll node, ll a, ll b) {
29      if(a > b) return;
30      if(a == b) {
31        tree[node] = arr[a];
32        return;
33      }
34      build_tree(node*2, a, (a+b)/2);
35      build_tree(node*2+1, 1+(a+b)/2, b);
36      tree[node] =  (tree[node*2].first < tree[node*2 +1].first) ?
            tree[node*2] : tree[node*2+1];
37    }
38
39    void update_tree(ll node, ll a, ll b, ll i, ll j, ll value) {
40      if(lazy[node] != 0) {
41        tree[node].first += lazy[node]; //+=
42        if(a != b) {
43    lazy[node*2] += lazy[node]; //+=
44    lazy[node*2+1] += lazy[node]; //+=
45        }
46        lazy[node] = 0;
47      }
48
49      if(a > b || a > j || b < i) return;
```

```
50      if(a >= i && b <= j) {
51        tree[node].first += value; //+=
52        if(a != b) {
53    lazy[node*2] += value; //+=
54    lazy[node*2+1]+= value; //+=
55        }
56        return;
57      }
58      update_tree(node*2, a, (a+b)/2, i, j, value);
59      update_tree(1+node*2, 1+(a+b)/2, b, i, j, value);
60   tree[node] =  (tree[node*2].first < tree[node*2 +1].first) ? tree[
        node*2] : tree[node*2+1];
61    }
62
63    par query_tree(ll node, ll a, ll b, ll i, ll j) {
64      //Cuidado con -inf que est  como entero en caso de usar long
          long
65      if(a > b || a > j || b < i) return make_pair ((ll)inf,-1); //(-
          inf,max) (inf,min)
66      if(lazy[node] != 0){
67        tree[node].first += lazy[node]; //+=
68        if(a != b) {
69    lazy[node*2] += lazy[node]; //+=
70    lazy[node*2+1] += lazy[node]; //+=
71        }
72        lazy[node] = 0;
73      }
74
75      if(a >= i && b <= j) return tree[node];
76      par q1 = query_tree(node*2, a, (a+b)/2, i, j);
77      par q2 = query_tree(1+node*2, 1+(a+b)/2, b, i, j);
78      par res = (q1.first < q2.first) ? q1 : q2;
79      return res;
80    }
81  };
82
83  int main() {
84    //optimizar_io
85    int a,b,c,d,aux,aux2;
86    scanf("%d␣%d␣%d␣%d",&a,&b,&c,&d);
87    vi conexo,disconexo;
88    conexo.resize(a);
89    disconexo.resize(a);
90    vector <vector <int> > adj;
91    adj.resize(a);
92    for(int i=0;i<b;i++){
93      cin>>aux >> aux2;
94      adj[aux-1].push_back(aux2-1);
95      adj[aux2-1].push_back(aux-1);
96    }
97    for(int i = 0; i < a; i++){
98      conexo[i] = make_pair(adj[i].size(),i);
99      disconexo[i] = make_pair(a-1-adj[i].size(),i);
100   }
101   SegmentTree amigo(conexo);
102   SegmentTree enemigo(disconexo);
103   vector <bool> respuesta;
```

```
104   respuesta.resize(a,true);
105   par temp;
106   while(1){
107     temp = amigo.rmq(0,a-1);
108     if(temp.first >= c || c == 0){
109   temp = enemigo.rmq(0,a-1);
110   if(temp.first >= d || d == 0)break;
111   }
112       respuesta[temp.second] = false;
113       for(int i = 0; i < adj[temp.second].size() ; i++){
114         amigo.update(adj[temp.second][i],adj[temp.second][i],-1);
115         enemigo.update(adj[temp.second][i],adj[temp.second][i],+1);
116       }
117       enemigo.update(0,a-1,-1);
118     amigo.update(temp.second,temp.second,50000000);
119         enemigo.update(temp.second,temp.second,50000000);
120   }
121   ll imprimir = 0;
122   for(int i = 0; i < a; i++)if(respuesta[i])imprimir++;
123   printf("%lld\n",imprimir);
124   return 0;
125 }
```

1.4. Sparse Table

```
1  struct SparseTable{
2      //se puede cambiar gcd por funcion f que cumpla
3      // f(a,b,c)=f(a,f(b,c))=f(f(a,b),c)
4      int table[10000][17],n;
5      int ZERO;   // f(ZERO,x)=f(x,ZERO)=x
6      vector<int> A;
7      SparseTable(vector<int> &_A){
8          A=_A;
9          ZERO=0;
10         n=A.size();
11         for(int i=0;i<n;i++){
12             table[i][0]=A[i];
13         }
14         for(int j=1;j<=17;j++){
15             for(int i=0;i<=n-(1<<j);i++){
16                 table[i][j]=__gcd(table[i][j-1],table[i+(1<<(j-1))
                       ][j-1]);
17             }
18         }
19     }
20     int query(int L,int R){
21         int answer=ZERO;
22         for(int j=17;j>=0;j--){
23             if(L+(1<<j)-1<=R){
24                 answer=__gcd(answer,table[L][j]);
25                 L+=1<<j;
26             }
27         }
28         return answer;
29     }
30 };
```

1.5. Wavelet Tree

```
typedef vector<int>::iterator iter;

class WaveTree {
    vector<vector<int>> r0; int n, s;
    vector<int> arrCopy;

    void build(iter b, iter e, int l, int r, int u) {
        if (l == r)
            return;
        int m = (l+r)/2;
        r0[u].reserve(e-b+1); r0[u].push_back(0);
        for (iter it = b; it != e; ++it)
            r0[u].push_back(r0[u].back() + (*it<=m));
        iter p = stable_partition(b, e, [=](int i){
                                    return i<=m;});
        build(b, p, l, m, u*2);
        build(p, e, m+1, r, u*2+1);
    }

    int q, w;
    int range(int a, int b, int l, int r, int u) {
        if (r < q or w < l)
            return 0;
        if (q <= l and r <= w)
            return b-a;
        int m = (l+r)/2, za = r0[u][a], zb = r0[u][b];
        return range(za, zb, l, m, u*2) +
            range(a-za, b-zb, m+1, r, u*2+1);
    }

public:
    //arr[i] in [0,sigma)
    WaveTree(vector<int> arr, int sigma) {
        n = arr.size(); s = sigma;
        r0.resize(s*2); arrCopy = arr;
        build(arr.begin(), arr.end(), 0, s-1, 1);
    }

    //k in [1,n], [a,b) is 0-indexed, -1 if error
    int quantile(int k, int a, int b) {
        //extra conditions disabled
        if (/*a < 0 or b > n or*/ k < 1 or k > b-a)
            return -1;
        int l = 0, r = s-1, u = 1, m, za, zb;
        while (l != r) {
            m = (l+r)/2;
            za = r0[u][a]; zb = r0[u][b]; u*=2;
            if (k <= zb-za)
                a = za, b = zb, r = m;
            else
                k -= zb-za, a -= za, b -= zb,
                l = m+1, ++u;
        }
        return r;
    }
```

```
56
57      //counts numbers in [x,y] in positions [a,b)
58      int range(int x, int y, int a, int b) {
59          if (y < x or b <= a)
60              return 0;
61          q = x; w = y;
62          return range(a, b, 0, s-1, 1);
63      }
64
65      //count occurrences of x in positions [0,k)
66      int rank(int x, int k) {
67          int l = 0, r = s-1, u = 1, m, z;
68          while (l != r) {
69              m = (l+r)/2;
70              z = r0[u][k]; u*=2;
71              if (x <= m)
72                  k = z, r = m;
73              else
74                  k -= z, l = m+1, ++u;
75          }
76          return k;
77      }
78
79      //x in [0,sigma)
80      void push_back(int x) {
81          int l = 0, r = s-1, u = 1, m, p; ++n;
82          while (l != r) {
83              m = (l+r)/2;
84              p = (x<=m);
85              r0[u].push_back(r0[u].back() + p);
86              u*=2; if (p) r = m; else l = m+1, ++u;
87          }
88      }
89
90      //doesn't check if empty
91      void pop_back() {
92          int l = 0, r = s-1, u = 1, m, p, k; --n;
93          while (l != r) {
94              m = (l+r)/2; k = r0[u].size();
95              p = r0[u][k-1] - r0[u][k-2];
96              r0[u].pop_back();
97              u*=2; if (p) r = m; else l = m+1, ++u;
98          }
99      }
100
101     //swap arr[i] with arr[i+1], i in [0,n-1)
102     void swap_adj(int i) {
103         int &x = arrCopy[i], &y = arrCopy[i+1];
104         int l = 0, r = s-1, u = 1;
105         while (l != r) {
106             int m = (l+r)/2, p = (x<=m), q = (y<=m);
107             if (p != q) {
108                 r0[u][i+1] ^= r0[u][i] ^ r0[u][i+2];
109                 break;
110             }
111             u*=2; if (p) r = m; else l = m+1, ++u;
112         }
```

```
113             swap(x, y);
114         }
115     };
```

Capítulo 2

Grafos

2.1. DFS

```
1  void graphCheck(int u) {               // DFS for checking graph
       edge properties
2    dfs_num[u] = DFS_GRAY;   // color this as DFS_GRAY (temp) instead
         of DFS_BLACK
3    for (int j = 0; j < (int)AdjList[u].size(); j++) {
4      ii v = AdjList[u][j];             // weighted graph
5      if (dfs_num[v.first] == DFS_WHITE) {     // Tree Edge, DFS_GRAY
           to DFS_WHITE
6        dfs_parent[v.first] = u;                  // parent of this
             children is me
7        graphCheck(v.first);
8      }
9      else if (dfs_num[v.first] == DFS_GRAY) {             //
           DFS_GRAY to DFS_GRAY
10       if (v.first == dfs_parent[u])          // to differentiate
             these two cases
11         printf("␣Bidirectional␣(%d,␣%d)␣-␣(%d,␣%d)\n", u, v.first,
               v.first, u);
12       else  // the most frequent application: check if the given
             graph is cyclic
13         printf("␣Back␣Edge␣(%d,␣%d)␣(Cycle)\n", u, v.first);
14     }
15     else if (dfs_num[v.first] == DFS_BLACK)             // DFS_GRAY
           to DFS_BLACK
16       printf("␣Forward/Cross␣Edge␣(%d,␣%d)\n", u, v.first);
17   }
18   dfs_num[u] = DFS_BLACK;     // after recursion, color this as
       DFS_BLACK (DONE)
19   topoSort.push_back(u);
20 }
```

2.2. Brexit

```
1  int main(){
2    int c,p,x,l;
```

```
3     cin>>c>>p>>x>>l;
4     int u,v;
5     vector<vector<int> > g(c,vector<int>());
6     for(int i=0;i<p;i++){
7       cin>>u>>v;
8       g[u-1].push_back(v-1);
9       g[v-1].push_back(u-1);
10    }
11    vector<int> d(c,0);
12    vector<int> ori(c,0);
13    for(int i=0;i<c;i++){
14      d[i]=ori[i]=g[i].size();
15    }
16    x--;
17    l--;
18    vector<bool> vivo(c,true);
19    vivo[l]=false;
20    queue<int> q;
21    q.push(l);
22    while(!q.empty()){
23      int nodo=q.front();
24      q.pop();
25      vivo[nodo]=false;
26      for(int i=0;i<g[nodo].size();i++){
27        int next=g[nodo][i];
28        if(vivo[next]){
29          d[next]--;
30          if(d[next]==ori[next]/2){
31            q.push(next);
32          }
33        }
34      }
35    }
36    if(vivo[x]){
37      puts("stay");
38    }else{
39      puts("leave");
40    }
41    return 0;
42  }
```

2.3. Kruskal

```
1  vector< pair<int, ii> > EdgeList;   // (weight, two vertices) of
       the edge
2  for (int i = 0; i < E; i++) {
3    scanf("%d␣%d␣%d", &u, &v, &w);            // read the triple: (u,
         v, w)
4    EdgeList.push_back(make_pair(w, ii(u, v)));                // (w,
         u, v)
5    AdjList[u].push_back(ii(v, w));
6    AdjList[v].push_back(ii(u, w));
7  }
8  sort(EdgeList.begin(), EdgeList.end()); // sort by edge weight O(E
       log E)
9                      // note: pair object has built-in comparison
                           function
```

```
10
11 int mst_cost = 0;
12 UnionFind UF(V);                        // all V are disjoint sets
       initially
13 for (int i = 0; i < E; i++) {                         // for each edge
       , O(E)
14   pair<int, ii> front = EdgeList[i];
15   if (!UF.isSameSet(front.second.first, front.second.second)) {  //
         check
16     mst_cost += front.first;                // add the weight of e
         to MST
17     UF.unionSet(front.second.first, front.second.second);    //
         link them
18 } }                          // note: the runtime cost of UFDS is very
      light
19
20 // note: the number of disjoint sets must eventually be 1 for a
       valid MST
21 printf("MST␣cost␣=␣%d␣(Kruskal's)\n", mst_cost);
```

2.4. Single source shortest path

2.5. Edmond Blonsson

```
1  /*
2  GETS:
3  V->number of vertices
4  E->number of edges
5  pair of vertices as edges (vertices are 1..V)
6
7  GIVES:
8  output of edmonds() is the maximum matching
9  match[i] is matched pair of i (-1 if there isn't a matched pair)
10  */
11
12 // RECORDAR SETEAR LA VARIABLE GLOBAL  V Y EL VECTOR DE VISITADOS
       ED O SINO NO FUNCIONA!!
13 #include <bits/stdc++.h>
14 using namespace std;
15 const int M=500;
16 struct struct_edge{int v;struct_edge* n;};
17 typedef struct_edge* edge;
18 struct_edge pool[M*M*2];
19 edge top=pool,adj[M];
20 int V,E,match[M],qh,qt,q[M],father[M],base[M];
21 bool inq[M],inb[M],ed[M][M];
22 void add_edge(int u,int v){
23   top->v=v,top->n=adj[u],adj[u]=top++;
24   top->v=u,top->n=adj[v],adj[v]=top++;
25 }
26 int LCA(int root,int u,int v){
27   static bool inp[M];
28   memset(inp,0,sizeof(inp));
29   while(1)
30     {
31       inp[u=base[u]]=true;
```

```
32        if (u==root) break;
33        u=father[match[u]];
34      }
35    while(1)
36      {
37        if (inp[v=base[v]]) return v;
38        else v=father[match[v]];
39      }
40  }
41  void mark_blossom(int lca,int u){
42    while (base[u]!=lca)
43      {
44        int v=match[u];
45        inb[base[u]]=inb[base[v]]=true;
46        u=father[v];
47        if (base[u]!=lca) father[u]=v;
48      }
49  }
50  void blossom_contraction(int s,int u,int v){
51    int lca=LCA(s,u,v);
52    memset(inb,0,sizeof(inb));
53    mark_blossom(lca,u);
54    mark_blossom(lca,v);
55    if (base[u]!=lca)
56      father[u]=v;
57    if (base[v]!=lca)
58      father[v]=u;
59    for (int u=0;u<V;u++)
60      if (inb[base[u]])
61        {
62    base[u]=lca;
63    if (!inq[u])
64      inq[q[++qt]=u]=true;
65        }
66  }
67  int find_augmenting_path(int s){
68    memset(inq,0,sizeof(inq));
69    memset(father,-1,sizeof(father));
70    for (int i=0;i<V;i++) base[i]=i;
71    inq[q[qh=qt=0]=s]=true;
72    while (qh<=qt)
73      {
74        int u=q[qh++];
75        for (edge e=adj[u];e;e=e->n)
76          {
77      int v=e->v;
78      if (base[u]!=base[v]&&match[u]!=v)
79        if ((v==s)||(match[v]!=-1 && father[match[v]]!=-1))
80          blossom_contraction(s,u,v);
81        else if (father[v]==-1)
82          {
83      father[v]=u;
84      if (match[v]==-1)
85        return v;
86      else if (!inq[match[v]])
87        inq[q[++qt]=match[v]]=true;
88          }
```

```
89          }
90        }
91      return -1;
92    }
93    int augment_path(int s,int t){
94      int u=t,v,w;
95      while (u!=-1)
96        {
97          v=father[u];
98          w=match[v];
99          match[v]=u;
100         match[u]=v;
101         u=w;
102       }
103     return t!=-1;
104   }
105   int edmonds(){
106     int matchc=0;
107     memset(match,-1,sizeof(match));
108     for (int u=0;u<V;u++)
109       if (match[u]==-1)
110         matchc+=augment_path(u,find_augmenting_path(u));
111     return matchc;
112   }
113   int main(){
114     int n,m;
115     scanf("%d␣%d",&n,&m);
116     string s;
117     vector < vector <string> > jueces(n);
118     vector < pair <int,int> >parejas;
119     int distintos = 0;
120     map <string,int> M;
121     int contador = 0;
122     for(int i = 0; i < n; i++){
123       for(int j = 0; j < m; j++){
124         cin >> s;
125         if(M.count(s) == 0){
126           distintos++;
127       //    cout << s <<endl;
128           M[s] = contador;
129           contador++;
130         }
131         jueces[i].push_back(s);
132       }
133     }
134     //printf("distintos = %d\n",distintos);
135     vector <vector <bool> > adj(distintos,vector <bool>(distintos,
          true));
136     for(int i = 0; i < n; i++){
137       for(int j =0 ; j < m; j++){
138         for(int k = j+1; k < m; k++){
139           adj[M[jueces[i][j]]][M[jueces[i][k]]] = false;
140           adj[M[jueces[i][k]]][M[jueces[i][j]]] = false;
141         }
142       }
143     }
144     V = distintos;
```

```
145   for(int i = 0; i < adj.size();i++){
146     for(int j = i+1; j < adj[i].size();j++){
147       if(adj[i][j] && !ed[i][j]){
148         add_edge(i,j);
149       ed[i][j]=ed[j][i]=true;
150       }
151     }
152   }
153   int final =edmonds();
154   if(final >= abs(m-distintos))puts("S");
155   else puts("N");
156   return 0;
157 }
```

2.6. Flood Fill

```
1  #include <bits/stdc++.h>
2
3  using namespace std;
4
5  int n,m;
6  int mapa[2020][2020];
7  int total;
8  int w;
9  int sumar=507;
10 int xx[]={0,0,1,-1};
11 int yy[]={1,-1,0,0};
12 #define fix(x) (x)=2*((x)+sumar)
13 typedef pair<int,int> ii;
14 inline bool check(int x,int y){
15   return x>=0 && x<2020 && y>=0 && y<2020;
16 }
17
18 void fill(int x,int y){
19   total--;
20   queue<ii> q;
21   q.push(ii(x,y));
22   mapa[x][y]=-1;
23   while(!q.empty()){
24     x=q.front().first;
25     y=q.front().second;
26
27     q.pop();
28     for(int i=0;i<4;i++){
29       //printf("ini:%d %d\n",x+xx[i],y+yy[i]);
30       if(check(x+xx[i],y+yy[i]) && mapa[x+xx[i]][y+yy[i]]<w){
31         //printf("a:%d %d\n",x+xx[i],y+yy[i]);
32         //printf("%d\n",mapa[x+2*xx[i]][y+2*yy[i]]);
33         if(check(x+2*xx[i],y+2*yy[i])&&mapa[x+2*xx[i]][y+2*yy[i
               ]]!=-1){
34           //printf("b:%d %d\n",x+2*xx[i],y+2*yy[i]);
35           mapa[x+2*xx[i]][y+2*yy[i]]=-1;
36           //puts("a");
37           total++;
38           q.push(ii(x+2*xx[i],y+2*yy[i]));
39           //printf("%d %d\n",q.front().first,q.front().second);
40         }
```

```
41
42        }
43
44      }
45    }
46    //puts("fin");
47  }
48
49  int main(){
50    int x1,y1,x2,y2,h,minX,maxX,minY,maxY;
51    while(scanf("%d",&n)){
52      total=0;
53
54      if(n==0){
55        break;
56      }
57      for(int i=0;i<2020;i++){
58        for(int j=0;j<2020;j++){
59          mapa[i][j]=0;
60        }
61      }
62      minX=minY=10000;
63      while(n--){
64        scanf("%d␣%d␣%d␣%d␣%d",&x1,&y1,&x2,&y2,&h);
65        fix(x1);
66        fix(y1);
67        fix(x2);
68        fix(y2);
69        if(x1==x2){
70          for(int i=min(y1,y2);i<=max(y1,y2);i++){
71            mapa[x1][i]=h;
72          }
73        }else{
74          for(int i=min(x1,x2);i<=max(x1,x2);i++){
75            mapa[i][ y1]=h;
76          }
77        }
78
79      }
80
81      scanf("%d",&w);
82      fill(1,1);
83
84      printf("%d\n",1010*1010-total-2);
85
86    }
87    return 0;
88  }
```

2.7. Dijkstra

Utilizamos la representacion vvii con pares (vecino,peso)

```
1   asd
```

Capítulo 3

Matemática

3.1. Formulas útiles

3.1.1. Sumatorias

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$$

$$\sum_{i=1}^{n} i^2 = \frac{n(n+1)(2n+1)}{6}$$

$$\sum_{i=1}^{n} i^3 = \frac{n^2(n+1)^2}{4}$$

3.2. Teorema chino del resto

Para el sistema de congruencias:

$$x \equiv a_1 \pmod{n_1}$$

$$x \equiv a_2 \pmod{n_2}$$

$$\vdots$$

$$x \equiv a_k \pmod{n_k}$$

Si $\forall i, j, i \neq j : n_i$ y n_j son coprimos, entonces el sistema tiene solución única módulo $M = n_1 n_2 ... n_k$

3.3. Pascal

```
for(int i=1;i<150;i++){
    for(int j=1;j<i+3;j++){
      pascal[i][j]=pascal[i-1][j-1]+pascal[i-1][j];
    }
  }
  cin>>n;
  for(ll i=0;i<n+1;i++){
      printf("%lld ",pascal[n-1][i]);
  }
```

3.4. Criba

```
vector<bool> isprime;
vector<int> primes;
void sieve(int n) {
  isprime.assign(n + 1,true);

  isprime[1] = false; isprime[2] = true;
  for (int i = 2; i <= n; i++) {
    if (isprime[i]) {
      for (int j = i*i;  j < n; j+=i) {
          isprime[j] = false;
      }
    }
  }
  for (int i = 2; i < n; i++) {
    if (isprime[i]) {
      primes.push_back(i);
    }
  }
  return;
}
```

3.5. Algoritmo de Gausss

```
#include <cmath>
#include <cstdio>
using namespace std;

#define MAX_N 3                                 // adjust this value
    as needed
struct AugmentedMatrix { double mat[MAX_N][MAX_N + 1]; };
struct ColumnVector { double vec[MAX_N]; };

ColumnVector GaussianElimination(int N, AugmentedMatrix Aug) {
  // input: N, Augmented Matrix Aug, output: Column vector X, the
      answer
  int i, j, k, l; double t;

  for (i = 0; i < N - 1; i++) {             // the forward
      elimination phase
    l = i;
```

```
15      for (j = i + 1; j < N; j++)        // which row has largest
            column value
16        if (fabs(Aug.mat[j][i]) > fabs(Aug.mat[l][i]))
17          l = j;                                          // remember
                this row l
18      // swap this pivot row, reason: minimize floating point error
19      for (k = i; k <= N; k++)             // t is a temporary double
            variable
20        t = Aug.mat[i][k], Aug.mat[i][k] = Aug.mat[l][k], Aug.mat[l][
              k] = t;
21      for (j = i + 1; j < N; j++)      // the actual forward
            elimination phase
22        for (k = N; k >= i; k--)
23          Aug.mat[j][k] -= Aug.mat[i][k] * Aug.mat[j][i] / Aug.mat[i
                ][i];
24    }
25
26    ColumnVector Ans;                              // the back
          substitution phase
27    for (j = N - 1; j >= 0; j--) {                           // start
          from back
28      for (t = 0.0, k = j + 1; k < N; k++) t += Aug.mat[j][k] * Ans.
            vec[k];
29      Ans.vec[j] = (Aug.mat[j][N] - t) / Aug.mat[j][j]; // the answer
             is here
30    }
31    return Ans;
32  }
33
34  int main() {
35    AugmentedMatrix Aug;
36    Aug.mat[0][0] = 1; Aug.mat[0][1] = 1; Aug.mat[0][2] = 2; Aug.mat
          [0][3] = 9;
37    Aug.mat[1][0] = 2; Aug.mat[1][1] = 4; Aug.mat[1][2] = -3; Aug.mat
          [1][3] = 1;
38    Aug.mat[2][0] = 3; Aug.mat[2][1] = 6; Aug.mat[2][2] = -5; Aug.mat
          [2][3] = 0;
39
40    ColumnVector X = GaussianElimination(3, Aug);
41    printf("X␣=␣%.1lf,␣Y␣=␣%.1lf,␣Z␣=␣%.1lf\n", X.vec[0], X.vec[1], X
          .vec[2]);
42
43    return 0;
44  }
```

Capítulo 4

Geometria

4.1. Intersection

```
1  #include <bits/stdc++.h>
2  using namespace std;
3  template< class T > bool inside(T a, T b, T c) { return a<=b && b<=
       c; }
4  typedef vector<int> vi;
5
6  class UnionFind{
7  private:
8    vi p, rank;
9  public:
10   UnionFind(int N){
11     rank.assign(N,0);
12     p.assign(N,0);
13     for(int i=0;i<N;i++){
14       p[i]=i;
15     }
16   }
17   int findSet(int i){
18     return (p[i]==i) ? i : (p[i] = findSet(p[i]));
19   }
20   bool isSameSet(int i, int j){
21     return findSet(i) == findSet(j);
22   }
23   void unionSet(int i,int j){
24     if(!isSameSet(i,j)){
25       int x = findSet(i), y = findSet(j);
26       if(rank[x]>rank[i]) p[y]=x;
27       else{
28     p[x]=y;
29     if(rank[x]==rank[y]) rank[y]++;
30       }
31     }
32   }
33   void imprimir(){
34     for(int i=0;i<p.size();i++) printf("%d␣",p[i]);
35     puts("");
```

```
36    }
37  };
38
39  const int MAX = 1024;
40
41  struct Point { int x, y; };
42  struct Segment { Point a, b; };
43
44  Segment seg[MAX];
45  inline int direction(Point &pi, Point &pj, Point &pk) {
46    return (pk.x-pi.x)*(pj.y-pi.y)-(pj.x-pi.x)*(pk.y-pi.y);
47  }
48
49  inline bool onsegment(Point &pi, Point &pj, Point &pk) {
50    return (inside(min(pi.x,pj.x),pk.x,max(pi.x,pj.x)) && inside(min(
          pi.y,pj.y),pk.y,max(pi.y,pj.y)));
51  }
52
53  inline bool intersect(Point &p1, Point &p2, Point &p3, Point &p4) {
54    int d1, d2, d3, d4;
55    d1 = direction(p3, p4, p1);
56    d2 = direction(p3, p4, p2);
57    d3 = direction(p1, p2, p3);
58    d4 = direction(p1, p2, p4);
59    if(((d1>0 && d2<0)||(d1<0 && d2>0)) && ((d3>0 && d4<0)||(d3<0 &&
          d4>0))) return true;
60    if(!d1 && onsegment(p3, p4, p1)) return true;
61    if(!d2 && onsegment(p3, p4, p2)) return true;
62    if(!d3 && onsegment(p1, p2, p3)) return true;
63    if(!d4 && onsegment(p1, p2, p4)) return true;
64    return false;
65  }
66
67
68  int main(){
69      int t;
70    cin>>t;
71    int n,m;
72    while(t--){
73      Point p[n];
74      Point q[n];
75      cin>>n>>m;
76      for(int i=0;i<n;i++){
77        int a,b,c,d;
78        cin>>a>>b>>c>>d;
79        seg[i].a.x = a;
80        seg[i].a.y = b;
81        seg[i].b.x = c;
82        seg[i].b.y = d;
83      }
84      UnionFind uf(n);
85      for(int i=0;i<n;i++){
86        for(int j=i+1;j<n;j++){
87      if( intersect(seg[i].a, seg[i].b, seg[j].a, seg[j].b)){
88        uf.unionSet(i,j);
89      }
90        }
```

```
91      }
92      // uf.imprimir();
93      for(int i=0;i<m;i++){
94        int a,b;
95        cin>>a>>b;
96        if(uf.isSameSet(a-1,b-1)) puts("YES");
97        else puts("NO");
98      }
99    }
100   return 0;
101 }
```

4.2. Rectangle union

```
1  #include <cstdio>
2  #include <algorithm>
3  using namespace std;
4  struct event {
5    int ind; // Index of rectangle in rects
6    bool type; // Type of event: 0 = Lower-left ; 1 = Upper-right
7    event() {};
8    event(int ind, int type) : ind(ind), type(type) {};
9    };
10   struct point {
11   int x, y;
12 };
13 int n, e; // n = number of rectangles; e = number of edges
14 point rects [1000][2]; // Each rectangle consists of 2 points: [0]
       = lower-left ; [1] = upper-right
15 event events_v [2000]; // Events of horizontal sweep line
16 event events_h [2000]; // Events of vertical sweep line
17 bool compare_x(event a, event b) { return rects[a.ind][a.type].x<
       rects[b.ind][b.type].x; }
18 bool compare_y(event a, event b) { return rects[a.ind][a.type].y<
       rects[b.ind][b.type].y; }
19 bool in_set [10000]; // Boolean array in place of balanced binary
       tree (set)
20 long long area; // The output: Area of the union
21 int main() { /// x -> v; y -> h
22   scanf("%d", &n);
23   for (int i=0;i<n;++i) {
24     scanf("%d␣%d␣%d␣%d", &rects[i][0].x, &rects[i][0].y, // Lower-
           left coordinate
25     &rects[i][1].x, &rects[i][1].y); // Upper-right coordinate
26     events_v[e] = event(i, 0);
27     events_h[e++] = event(i, 0);
28     events_v[e] = event(i, 1);
29     events_h[e++] = event(i, 1);
30   }
31   sort(events_v, events_v+e, compare_x);
32   sort(events_h, events_h+e, compare_y); // Pre-sort set of
         horizontal edges
33   in_set[events_v[0].ind] = 1;
34   for (int i=1;i<e;++i) { // Vertical sweep line
35     event c = events_v[i];
36     int cnt = 0; // Counter to indicate how many rectangles are
           currently overlapping
```

```
37      // Delta_x: Distance between current sweep line and previous
            sweep line
38      int delta_x = rects[c.ind][c.type].x - rects[events_v[i-1].ind
            ][events_v[i-1].type].x;
39      int begin_y;
40      if (delta_x==0) continue;
41      for (int j=0;j<e;++j) if (in_set[events_h[j].ind]==1) { //
            Horizontal sweep line
42        if (events_h[j].type==0) {
43          if (cnt==0) begin_y = rects[events_h[j].ind][0].y; // Block
                starts
44          ++cnt;
45        } else {
46          --cnt;
47          if (cnt==0) { // Block ends
48            int delta_y = (rects[events_h[j].ind][1].y-begin_y);
49            area+=delta_x * delta_y;
50          }
51        }
52      }
53      in_set[c.ind] = (c.type==0);
54    }
55    printf("%lld\n", area);
56    return 0;
57  }
```

4.3. Closest pair

```
1   #define px second
2   #define py first
3   typedef pair<ll,ll> pairll;
4   int n;
5   pairll pnts[100000];
6   set<pairll> box;
7   double best;
8   int compx(pairll a,pairll b){
9     return a.px<b.px;
10  }
11  int main(){
12    scanf("%d",&n);
13    for(int i=0;i<n;i++){
14      scanf("%lld␣%lld",&pnts[i].px,&pnts[i].py);
15    }
16    sort(pnts,pnts+n,compx);
17    best=100000000000;
18    box.insert(pnts[0]);
19    int left=0;
20    for(int i=1;i<n;i++){
21      while(left<i && pnts[i].px-pnts[left].px > best) box.erase(pnts
            [left++]);
22      for(typeof(box.begin()) it=box.lower_bound(make_pair(pnts[i].py
            -best, pnts[i].px-best));
23      it!=box.end() && pnts[i].py+best>=it->py; it++){
24            best = min(best, sqrt(pow(pnts[i].py - it->py, 2.0)+pow(
                  pnts[i].px - it->px, 2.0)));
25      }
26      box.insert(pnts[i]);
```

```
27      printf("%.2f\n",best);
28    }
29  }
```

4.4. Radial sweep example

```
1   #include <bits/stdc++.h>
2   using namespace std;
3
4   const double eps = 1e-10, PI = acos(-1.0);
5
6   inline int sgn(double x) {
7       if (fabs(x) <= eps) return 0;
8       else if (x > eps) return 1;
9       else return -1;
10  }
11
12  struct Point {
13      double x, y, ang;
14      Point() : x(0), y(0) {}
15      Point(double a, double b) : x(a), y(b) {
16          ang = atan2(y, x);
17      }
18      Point operator + (const Point &rhs) const {
19          return Point(x + rhs.x, y + rhs.y);
20      }
21      Point operator - (const Point &rhs) const {
22          return Point(x - rhs.x, y - rhs.y);
23      }
24      Point operator * (double k) const {
25          return Point(x * k, y * k);
26      }
27      Point operator / (double k) const {
28          return Point(x / k, y / k);
29      }
30      double dot(const Point &rhs) const {
31          return x * rhs.x + y * rhs.y;
32      }
33      double det(const Point &rhs) const {
34          return x * rhs.y - y * rhs.x;
35      }
36      double abs() const {
37          return hypot(x, y);
38      }
39      void read() {
40          scanf("%lf%lf", &x, &y);
41      }
42  } O;
43
44  double nowAng;
45
46  Point inter(Point A, Point B, Point C, Point D) {
47      return A + (B - A) * ((D - C).det(C - A) / (D - C).det(B - A));
48  }
49
50  struct Line {
51      Point A, B;
```

```
52      Line() {}
53      Line(Point a, Point b) : A(a), B(b) {}
54      double dis() const {
55          if (sgn((O - A).det(O - B)) == 0) return min((O - A).abs(),
                (O - B).abs());
56          return (O - inter(A, B, O, Point(cos(nowAng), sin(nowAng)))
                ).abs();
57      }
58      bool operator < (const Line &rhs) const {
59          return sgn(dis() - rhs.dis()) < 0;
60      }
61  };
62
63  struct Event {
64      double ang;
65      int id, type;
66      Event() : ang(0), id(0), type(0) {}
67      Event(double a, int b, int c) : ang(a), id(b), type(c) {}
68      bool operator < (const Event &rhs) const {
69          if (sgn(ang - rhs.ang) != 0) return sgn(ang - rhs.ang) < 0;
70          return type < rhs.type;
71      }
72  };
73
74  const int MAXN = 30000 + 10;
75
76  Point P[MAXN];
77  Line L[MAXN];
78  int S, N, M;
79
80  vector<Event> E;
81  set<Line> Seg;
82  set<Line>::iterator its[MAXN];
83
84  double fix(double x) {
85      if (x < 0) x += PI * 2;
86      if (x >= PI * 2) x -= PI * 2;
87      return x;
88  }
89
90  int gao(int id) {
91      int ret = 0;
92      E.clear();
93      for (int i = 0; i < N; ++ i) {
94          if (i == id) continue;
95          Point tmp = P[i] - P[id];
96          E.push_back(Event(tmp.ang, i, 1));
97      }
98      for (int i = 0; i < M; ++ i) {
99          Point A = L[i].A - P[id];
100         Point B = L[i].B - P[id];
101         double delta = fix(B.ang - A.ang);
102         if (sgn(delta - PI) > 0) swap(A, B);
103         if (sgn(A.ang - B.ang) > 0) {
104             E.push_back(Event(A.ang, i, 0));
105             E.push_back(Event(PI, i, 2));
106             E.push_back(Event(-PI, i, 0));
```

```
107             E.push_back(Event(B.ang, i, 2));
108         }
109         else {
110             E.push_back(Event(A.ang, i, 0));
111             E.push_back(Event(B.ang, i, 2));
112         }
113     }
114     sort(E.begin(), E.end());
115     Seg.clear();
116     for (int i = 0; i < (int)E.size(); ++ i) {
117         int nowID = E[i].id;
118         nowAng = E[i].ang;
119         if (E[i].type == 0) {
120             its[nowID] = Seg.insert(Line(L[nowID].A - P[id], L[
                    nowID].B - P[id])).first;
121         }
122         else if (E[i].type == 1) {
123             ret += (Seg.empty() || sgn(Seg.begin()->dis() - (P[id]
                    - P[nowID]).abs()) > 0);
124         }
125         else if (E[i].type == 2) {
126             Seg.erase(its[nowID]);
127         }
128     }
129     return ret;
130 }
131
132 int main() {
133     O = Point(0, 0);
134     while (scanf("%d%d%d", &S, &N, &M) == 3) {
135         for (int i = 0; i < N; ++ i) P[i].read();
136         for (int i = 0; i < M; ++ i) {
137             L[i].A.read();
138             L[i].B.read();
139         }
140         for (int i = 0; i < S; ++ i) {
141             printf("%d\n", gao(i));
142         }
143     }
144     return 0;
145 }
```

4.5. Line sweep example

```
1  struct point{
2    int x,y,valor;
3  };
4
5  bool comp1(const point &lhs,const point &rhs){
6    return lhs.y<rhs.y;
7  }
8
9  bool comp2(const point &lhs,const point &rhs){
10   return (lhs.x==rhs.x?lhs.y<rhs.y:lhs.x<rhs.x);
11 }
12
13 point poly[200010];
```

```
14
15  int main(){
16    int p,v;
17    while(scanf("%d␣%d",&p,&v)!=EOF){
18      for(int i=0;i<p;i++){
19        scanf("%d␣%d",&poly[i].x,&poly[i].y);
20        poly[i].valor=i+1;
21      }
22      for(int i=p;i<p+v;i++){
23        scanf("%d␣%d",&poly[i].x,&poly[i].y);
24        poly[i].valor=-1;
25      }
26
27      sort(poly,poly+p+v,comp1);         //orden por y;
28
29      int original=poly[0].y;          //compresion de puntos por y
30      int comprimido=1;
31      poly[0].y=comprimido;
32      for(int i=1;i<p+v;i++){
33        if(poly[i].y==original){
34          poly[i].y=comprimido;
35        }else{
36          original=poly[i].y;
37          comprimido++;
38          poly[i].y=comprimido;
39        }
40      }
41      FenwickTree FT(800010);
42      sort(poly,poly+p+v,comp2);         //orden por x
43      int perdido=0;
44      for(int i=0;i<p+v;i++){
45        if(poly[i].valor==-1){
46          FT.update(poly[i].y,poly[i+1].y-1,1); //los vertices
                siempre van de a pares
47          i++;
48        }else{
49          if(FT.query(poly[i].y)%2==0){
50            perdido+=poly[i].valor;
51          }
52        }
53      }
54      printf("%lld\n",perdido);
55    }
56    return 0;
57  }
```

4.6. Distancia punto-recta

```
1  double distPointLine(const point &a,const point &b, const point &
       pnt){
2    double u=((pnt.x-a.x)*(b.x-a.x)+(pnt.y-a.y)*(b.y-a.y))/distsqr(a,
         b);
3    point intersection;
4    intersection.x=a.x+u*(b.x-a.x);
5    intersection.y=a.y+u*(b.y-a.y);
6    return dist(pnt,intersection);
7  }
```

4.7. Distancia punto-segmento

```
1  inline double dist(const point &a,const point &b){
2    return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
3  }
4
5  inline double distsqr(const point &a,const point &b){
6    return (a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y);
7  }
8
9  double distPointSegment(const point &a,const point &b, const point
       &pnt){
10   double u=((pnt.x-a.x)*(b.x-a.x)+(pnt.y-a.y)*(b.y-a.y))/distsqr(a,
         b);
11   point intersection;
12   intersection.x=a.x+u*(b.x-a.x);
13   intersection.y=a.y+u*(b.y-a.y);
14   if(u<0.0 || u>1.0){
15     return min(dist(a,pnt),dist(b.pnt));
16   }
17   return dist(pnt,intersection);
18 }
```

4.8. Check if convex

```
1  double turn(const point &a, const point &b,const point &c){
2    double z=(b.x-a.x)*(c.y-a.y)-(b.y-a.y)*(c.x-a.x);
3    if(fabs(z)<1e-9) return 0.0;
4    return z;
5  }
6
7  bool isConvexPolygon(const vector<point> &p){
8    int mask=0;
9    int n=p.size();
10   for(int i=0;i<n;i++){
11     int j=(i+1)%n;
12     int k=(i+2)%n;
13     double z=turn(p[i],p[j],p[k]);
14     if(z<0.0){
15       mask|=1;
16     }else if(z>0.0){
17       mask|=2;
18     }
19     if mask==3 return false;
20   }
21   return mask!=0;
22 }
```

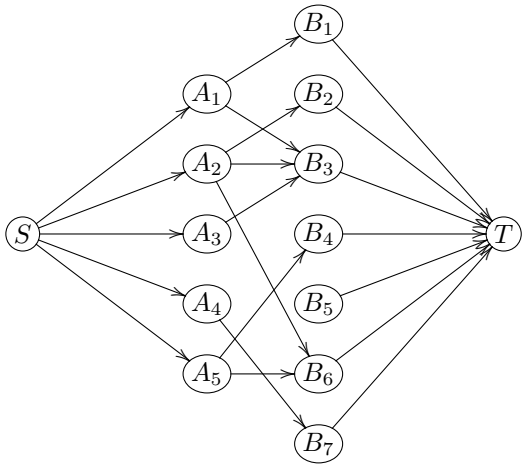
Capítulo 5

Flujo

5.1. Problemas de asignación

5.1.1. Bipartite matching

Tenemos dos conjuntos A y B, donde cada elemento de A es compatible con ciertos elementos de B. Además, tenemos la condición de que podemos asociar cada elemento de A con a lo más un solo elemento de B. Bipartite matching nos permite saber la cantidad máxima de asociaciones posibles.



Modelamiento utilizado. Todas las aristas llevan 1 de flujo.

5.2. Dinic

```
#include <bits/stdc++.h>
using namespace std;

typedef long long intt;
typedef pair<int, int> par;
typedef vector<vector<int> > graph;
typedef vector<vector<par> > wgraph;
#define pb push_back
#define ppb pop_back
vector <int> origen,destino,capacidad,costos,dia,orden,inicial;
class Dinic {
  struct edge {
    int to, rev;
    intt f, cap;
  };
  vector<vector<edge>> g;
  vector<intt> dist;
  vector<int> q, work;
  int n, sink;
  bool bfs(int start, int finish) {
    dist.assign(n, -1);
    dist[start] = 0;
    int head = 0, tail = 0;
    q[tail++] = start;
    while (head < tail) {
      int u = q[head++];
      for (const edge &e : g[u]) {
        int v = e.to;
        if (dist[v] == -1 and e.f < e.cap) {
          dist[v] = dist[u] + 1;
          q[tail++] = v;
        }
      }
    }
    return dist[finish] != -1;
  }
  intt dfs(int u, intt f) {
    if (u == sink) return f;
    for (int &i = work[u]; i < (int)g[u].size(); ++i) {
      edge &e = g[u][i];
      int v = e.to;
      if (e.cap <= e.f or dist[v] != dist[u] + 1)
        continue;
      intt df = dfs(v, min(f, e.cap - e.f));
      if (df > 0) {
        e.f += df;
        g[v][e.rev].f -= df;
        return df;
      }
    }
    return 0;
  }
public:
  Dinic(int n) {
    this->n = n;
```

```
56      g.resize(n);
57      dist.resize(n);
58      q.resize(n);
59    }
60    Dinic(){
61
62    }
63    // aristas bidireccionales si cap de edge b = cap, si es 0 no son
          bidireccionales!!
64    void add_edge(int u, int v, intt cap) {
65      edge a = {v, (int)g[v].size(), 0, cap};
66      edge b = {u, (int)g[u].size(), 0, 0};
67      g[u].pb(a);
68      g[v].pb(b);
69    }
70    intt max_flow(int source, int dest) {
71      sink = dest;
72      intt ans = 0;
73      while (bfs(source, dest)) {
74        work.assign(n, 0);
75        while (intt delta = dfs(source, 1000)) ans += delta;
76      }
77      return ans;
78    }
79  };
80
81  //contruyo el dinic
82
83  Dinic construir(int maximo,int tam,int g,int d){
84    Dinic D(tam+1);
85    for(int i = 0;i < inicial.size();i++){
86      D.add_edge(0,(i)*(d+1) +1,inicial[i]);
87    }
88    for(int i = 0; i < inicial.size();i++){
89      for(int j = 0; j < d; j++){
90        D.add_edge(i*(d+1) + 1 + j,i*(d+1)+2+j,g);
91      }
92    }
93    for(int i = 0;i <origen.size();i++)if(costos[i] <= maximo){
94      D.add_edge(origen[i],destino[i],capacidad[i]);
95     }
96    return D;
97  }
98
99  // buscqueda binaria cuando quiero minimizar un valor X asociado al
        flujo
100
101 int BS(int lo,int hi, int tam,int tope,int d){
102   int mi;
103   while(lo<hi){
104     mi = (lo+hi)/2;
105   Dinic D = construir(orden[mi],tam,tope,d);
106     int flujo = D.max_flow(0,tam);
107     if(flujo==tope) hi = mi;
108     else lo = mi+1;
109     }
110   return lo;
```

```
111 }
112 int main(){
113   int t,aux;
114   scanf("%d",&t);
115   int caso = 1;
116   while(t--){
117     int n,d,m,u,v,c,p,e;
118     scanf("%d␣%d␣%d",&n,&d,&m);
119     origen.clear();destino.clear();capacidad.clear();
120     costos.clear(),orden.clear(),inicial.clear();
121     set <int> ordenNR;
122     for(int i = 0; i < m; i++){
123       scanf("%d␣%d␣%d␣%d␣%d",&u,&v,&c,&p,&e);
124       origen.push_back( (u-1)*(d+1) + e +1);
125       destino.push_back( (v-1)*(d+1) + e+2);
126       capacidad.push_back(c);
127       costos.push_back(p);
128       ordenNR.insert(p);
129     }
130     int total = 0;
131     for(int i = 0; i < n; i++){
132       scanf("%d",&aux);
133       inicial.pb(aux);
134       total += aux;
135     }
136     for(auto it = ordenNR.begin();it != ordenNR.end();it++){
137       orden.push_back(*it);
138     }
139     int tama = n*(d+1);
140     sort(orden.begin(),orden.end());
141     int sol = BS(0,orden.size()-1,tama,total,d);
142     printf("Case␣#%d:",caso);
143     Dinic D = construir(orden[sol],tama,total,d);
144     int flujo = D.max_flow(0,tama);
145     if(flujo>=total)printf("␣%d\n",orden[sol]);
146     else puts("␣Impossible");
147     caso++;
148   }
149   return 0;
150 }
```

Capítulo 6

Programación dinámica

6.1. 0/1 Knapsack

```
1  int f[1000]={0};
2  int n=0, m=0;
3  int main(void)
4  {
5  cin >> n >> m;
6  for (int i=1;i<=n;i++)
7  {
8  int price=0, value=0;
9  cin >> price >> value;
10 for (int j=m;j>=price;j--)
11 if (f[j-price]+value>f[j])
12 f[j]=f[j-price]+value;
13 }
14 cout << f[m] << endl;
15 return 0;
16 }
```

6.2. Longest Common Subsequence

```
1  int dp[2000][2000];
2
3  int lcs(const string &s, const string &t){
4    int m=s.size(),n=t.size();
5    if(m==0 || n==0) return 0;
6    for(int i=0;i<=m;i++){
7      dp[i][0]=0;
8    }
9    for(int i=0;i<=n;i++){
10     dp[0][i]=0;
11   }
12   for(int i=0;i<m;i++){
13     for(int j=0;j<n;j++){
14       if(s[i]==t[j]){
15         dp[i+1][j+1]=dp[i][j]+1;
```

```
16        }else{
17          dp[i+1][j+1]=max(dp[i+1][j],dp[i][j+1]);
18        }
19      }
20    }
21    return dp[m][n];
22  }
```

6.3. Bitonic Sequence

```
1   /*
2   DP para obtener la secuencia bitonic mas larga
3   BitonicSubsequence = secuencia que en primera instacia crece, y
        luego decrece.
4   Complejidas O(n^2)
5   Espaciio lineal
6   */
7
8   #include <bits/stdc++.h>
9
10  using namespace std;
11
12  int bitonicSequence(vector <int> &bitonic){
13    int lis[bitonic.size()],lds[bitonic.size()];
14    for(int i = 0; i < bitonic.size();i++){
15      lis[i] = 1;
16      lds[i] = 1;
17    }
18    for(int i = 1; i < bitonic.size();i++){
19      for(int j = 0; j < i; j++){
20        if(bitonic[i] > bitonic[j])lis[i] = max(lis[i],lis[j]+1);
21      }
22    }
23    for(int i = bitonic.size()-2; i >= 0 ;i--){
24      for(int j = bitonic.size()-1; j > i; j--){
25        if(bitonic[i] > bitonic[j])lds[i] = max(lds[i],lds[j]+1);
26      }
27    }
28    int max = 0;
29    for(int i = 0; i < bitonic.size();i++){
30      if(max < lis[i] + lds[i]-1)max = lis[i] + lds[i]-1;
31    }
32    return max;
33  }
34
35  int main(){
36    vector <int> bitonic;
37    int n,aux;
38    scanf("%d␣%d",&n);
39    for(int i = 0; i < n; i++){
40    scanf("%d",&aux);
41    bitonic.push_back(aux);
42    }
43    printf("%d\n",bitonicSequence(bitonic));
44    return 0;
45  }
46
```

```
47 /*
48 16
49 0 8 4 12 2 10 6 14 1 9 5 13 3 11 7 5
50 */
```

6.4. Box Stacking

```
1  package com.interview.dynamic;
2
3  import java.util.Arrays;
4
5  /**
6   * Date 05/09/2015
7   * @author tusroy
8   *
9   * Given different dimensions and unlimited supply of boxes for
        each dimension, stack boxes
10  * on top of each other such that it has maximum height but with
        caveat that length and width
11  * of box on top should be strictly less than length and width of
        box under it. You can
12  * rotate boxes as you like.
13  *
14  * 1) Create all rotations of boxes such that length is always
        greater or equal to width
15  * 2) Sort boxes by base area in non increasing order (length *
        width). This is because box
16  * with more area will never ever go on top of box with less area.
17  * 3) Take T[] and result[] array of same size as total boxes after
         all rotations are done
18  * 4) Apply longest increasing subsequence type of algorithm to get
         max height.
19  *
20  * If n number of dimensions are given total boxes after rotation
        will be 3n.
21  * So space complexity is O(n)
22  * Time complexity - O(nlogn) to sort boxes. O(n^2) to apply DP on
        it So really O(n^2)
23  *
24  * References
25  * http://www.geeksforgeeks.org/dynamic-programming-set-21-box-
        stacking-problem/
26  * http://people.cs.clemson.edu/~bcdean/dp_practice/
27  */
28 public class BoxStacking {
29
30     public int maxHeight(Dimension[] input) {
31         //get all rotations of box dimension.
32         //e.g if dimension is 1,2,3 rotations will be 2,1,3  3,2,1
               3,1,2  . Here length is always greater
33         //or equal to width and we can do that without loss of
               generality.
34         Dimension[] allRotationInput = new Dimension[input.length *
               3];
35         createAllRotation(input, allRotationInput);
36
```

```
37          //sort these boxes in non increasing order by their base
                area.(length X width)
38          Arrays.sort(allRotationInput);
39
40          //apply longest increasing subsequence kind of algorithm on
                 these sorted boxes.
41          int T[] = new int[allRotationInput.length];
42          int result[] = new int[allRotationInput.length];
43
44          for (int i = 0; i < T.length; i++) {
45              T[i] = allRotationInput[i].height;
46              result[i] = i;
47          }
48
49          for (int i = 1; i < T.length; i++) {
50              for (int j = 0; j < i; j++) {
51                  if (allRotationInput[i].length < allRotationInput[j
                        ].length
52                          && allRotationInput[i].width <
                                allRotationInput[j].width) {
53                      if( T[j] + allRotationInput[i].height > T[i]){
54                          T[i] = T[j] + allRotationInput[i].height;
55                          result[i] = j;
56                      }
57                  }
58              }
59          }
60
61          //find max in T[] and that will be our max height.
62          //Result can also be found using result[] array.
63          int max = Integer.MIN_VALUE;
64          for(int i=0; i < T.length; i++){
65              if(T[i] > max){
66                  max = T[i];
67              }
68          }
69
70          return max;
71      }
72
73      //create all rotations of boxes, always keeping length greater
            or equal to width
74      private void createAllRotation(Dimension[] input,
75              Dimension[] allRotationInput) {
76          int index = 0;
77          for (int i = 0; i < input.length; i++) {
78              allRotationInput[index++] = Dimension.createDimension(
79                      input[i].height, input[i].length, input[i].
                            width);
80              allRotationInput[index++] = Dimension.createDimension(
81                      input[i].length, input[i].height, input[i].
                            width);
82              allRotationInput[index++] = Dimension.createDimension(
83                      input[i].width, input[i].length, input[i].
                            height);
84
85          }
```

```
86      }
87
88      public static void main(String args[]) {
89          BoxStacking bs = new BoxStacking();
90          Dimension input[] = { new Dimension(3, 2, 5), new Dimension
                (1, 2, 4) };
91          int maxHeight = bs.maxHeight(input);
92          System.out.println("Max␣height␣is␣" + maxHeight);
93          assert 11 == maxHeight;
94      }
95  }
96
97  /**
98   * Utility class to hold dimensions
99   * @author tusroy
100  *
101  */
102 class Dimension implements Comparable<Dimension> {
103     int height;
104     int length;
105     int width;
106
107     Dimension(int height, int length, int width) {
108         this.height = height;
109         this.length = length;
110         this.width = width;
111     }
112
113     Dimension() {
114     }
115
116     static Dimension createDimension(int height, int side1, int
            side2) {
117         Dimension d = new Dimension();
118         d.height = height;
119         if (side1 >= side2) {
120             d.length = side1;
121             d.width = side2;
122         } else {
123             d.length = side2;
124             d.width = side1;
125         }
126         return d;
127     }
128
129     /**
130      * Sorts by base area(length X width)
131      */
132     @Override
133     public int compareTo(Dimension d) {
134         if (this.length * this.width >= d.length * d.width) {
135             return -1;
136         } else {
137             return 1;
138         }
139     }
140
```

```
141     @Override
142     public String toString() {
143         return "Dimension␣[height=" + height + ",␣length=" + length
144                 + ",␣width=" + width + "]";
145     }
146 }
```

6.5. Break multiple words with no space into space

```
1  package com.interview.dynamic;
2
3  import java.util.*;
4
5  /**
6   * Date 08/01/2014
7   * @author tusroy
8   *
9   * Given a string and a dictionary, split this string into multiple
        words such that
10  * each word belongs in dictionary.
11  *
12  * e.g peanutbutter -> pea nut butter
13  * e.g Iliketoplay -> I like to play
14  *
15  * Solution
16  * DP solution to this problem
17  * if( input[i...j] belongs in dictionary) T[i][j] = i
18  * else{
19  *      T[i][j] = k if T[i][k-1] != -1 && T[k][j] != -1
20  *
21  * Test cases
22  * 1) Empty string
23  * 2) String where entire string is in dictionary
24  * 3) String which cannot be split into words which are in
        dictionary
25  * 3) String which can be split into words which are in dictionary
26  *
27  */
28 public class BreakMultipleWordsWithNoSpaceIntoSpace {
29
30
31     /**
32      * Recursive and slow version of breaking word problem.
33      * If no words can be formed it returns null
34      */
35     public String breakWord(char[] str,int low,Set<String>
            dictionary){
36         StringBuffer buff = new StringBuffer();
37         for(int i= low; i < str.length; i++){
38             buff.append(str[i]);
39             if(dictionary.contains(buff.toString())){
40                 String result = breakWord(str, i+1, dictionary);
41                 if(result != null){
42                     return buff.toString() + "␣" + result;
43                 }
```

```
44              }
45          }
46          if(dictionary.contains(buff.toString())){
47              return buff.toString();
48          }
49          return null;
50      }
51
52      /**
53       * Dynamic programming version for breaking word problem.
54       * It returns null string if string cannot be broken into
             multipe words
55       * such that each word is in dictionary.
56       * Gives preference to longer words over splits
57       * e.g peanutbutter with dict{pea nut butter peanut} it would
             result in
58       * peanut butter instead of pea nut butter.
59       */
60      public String breakWordDP(String word, Set<String> dict){
61          int T[][] = new int[word.length()][word.length()];
62
63          for(int i=0; i < T.length; i++){
64              for(int j=0; j < T[i].length ; j++){
65                  T[i][j] = -1; //-1 indicates string between i to j
                        cannot be split
66              }
67          }
68
69          //fill up the matrix in bottom up manner
70          for(int l = 1; l <= word.length(); l++){
71              for(int i=0; i < word.length() -l + 1 ; i++){
72                  int j = i + l-1;
73                  String str = word.substring(i,j+1);
74                  //if string between i to j is in dictionary T[i][j]
                         is true
75                  if(dict.contains(str)){
76                      T[i][j] = i;
77                      continue;
78                  }
79                  //find a k between i+1 to j such that T[i][k-1] &&
                        T[k][j] are both true
80                  for(int k=i+1; k <= j; k++){
81                      if(T[i][k-1] != -1 && T[k][j] != -1){
82                          T[i][j] = k;
83                          break;
84                      }
85                  }
86              }
87          }
88          if(T[0][word.length()-1] == -1){
89              return null;
90          }
91
92          //create space separate word from string is possible
93          StringBuffer buffer = new StringBuffer();
94          int i = 0; int j = word.length() -1;
95          while(i < j){
```

```
96              int k = T[i][j];
97              if(i == k){
98                  buffer.append(word.substring(i, j+1));
99                  break;
100             }
101             buffer.append(word.substring(i,k) + "␣");
102             i = k;
103         }
104
105         return buffer.toString();
106     }
107
108     /**
109      * Prints all the words possible instead of just one
             combination.
110      * Reference
111      * https://leetcode.com/problems/word-break-ii/
112      */
113     public List<String> wordBreakTopDown(String s, Set<String>
            wordDict) {
114         Map<Integer, List<String>> dp = new HashMap<>();
115         int max = 0;
116         for (String s1 : wordDict) {
117             max = Math.max(max, s1.length());
118         }
119         return wordBreakUtil(s, wordDict, dp, 0, max);
120     }
121
122     private List<String> wordBreakUtil(String s, Set<String> dict,
            Map<Integer, List<String>> dp, int start, int max) {
123         if (start == s.length()) {
124             return Collections.singletonList("");
125         }
126
127         if (dp.containsKey(start)) {
128             return dp.get(start);
129         }
130
131         List<String> words = new ArrayList<>();
132         for (int i = start; i < start + max && i < s.length(); i++)
                {
133             String newWord = s.substring(start, i + 1);
134             if (!dict.contains(newWord)) {
135                 continue;
136             }
137             List<String> result = wordBreakUtil(s, dict, dp, i + 1,
                     max);
138             for (String word : result) {
139                 String extraSpace = word.length() == 0 ? "" : "␣";
140                 words.add(newWord + extraSpace + word);
141             }
142         }
143         dp.put(start, words);
144         return words;
145     }
146
147     /**
```

```
148         * Check if any one solution exists.
149         * https://leetcode.com/problems/word-break/
150         */
151        public boolean wordBreakTopDownOneSolution(String s, Set<String
               > wordDict) {
152            Map<Integer, Boolean> dp = new HashMap<>();
153            int max = 0;
154            for (String s1 : wordDict) {
155                max = Math.max(max, s1.length());
156            }
157            return wordBreakTopDownOneSolutionUtil(s, wordDict, 0, max,
                    dp);
158
159        }
160
161        private boolean wordBreakTopDownOneSolutionUtil(String s, Set<
               String> dict, int start, int max, Map<Integer, Boolean> dp)
                {
162            if (start == s.length()) {
163                return true;
164            }
165
166            if (dp.containsKey(start)) {
167                return dp.get(start);
168            }
169
170            for (int i = start; i < start + max && i < s.length(); i++)
                    {
171                String newWord = s.substring(start, i + 1);
172                if (!dict.contains(newWord)) {
173                    continue;
174                }
175                if (wordBreakTopDownOneSolutionUtil(s, dict, i + 1, max
                       , dp)) {
176                    dp.put(start, true);
177                    return true;
178                }
179            }
180            dp.put(start, false);
181            return false;
182        }
183
184        public boolean wordBreakBottomUp(String s, List<String>
               wordList) {
185            boolean[] T = new boolean[s.length() + 1];
186            Set<String> set = new HashSet<>();
187            for (String word : wordList) {
188                set.add(word);
189            }
190            T[0] = true;
191            for (int i = 1; i <= s.length(); i++) {
192                for (int j = 0; j < i; j++) {
193                    if(T[j] && set.contains(s.substring(j, i))) {
194                        T[i] = true;
195                        break;
196                    }
197                }
```

```
198         }
199         return T[s.length()];
200     }
201
202     public static void main(String args[]){
203         Set<String> dictionary = new HashSet<String>();
204         dictionary.add("I");
205         dictionary.add("like");
206         dictionary.add("had");
207         dictionary.add("play");
208         dictionary.add("to");
209         String str = "Ihadliketoplay";
210         BreakMultipleWordsWithNoSpaceIntoSpace bmw = new
                BreakMultipleWordsWithNoSpaceIntoSpace();
211         String result1 = bmw.breakWordDP(str, dictionary);
212
213         System.out.print(result1);
214     }
215 }
```

6.6. Burst Balloon

```
1  package com.interview.dynamic;
2
3  /**
4   * Date 03/02/2016
5   * @author Tushar Roy
6   *
7   * Given n balloons, indexed from 0 to n-1. Each balloon is painted
        with a number on it represented
8   * by array nums. You are asked to burst all the balloons. If the
        you burst balloon i you will
9   * get nums[left] * nums[i] * nums[right] coins. Here left and
        right are adjacent indices of i. After the burst,
10  * the left and right then becomes adjacent.
11  * Find the maximum coins you can collect by bursting the balloons
        wisely.
12  *
13  * Time complexity O(n^3)
14  * Space complexity O(n^2)
15  *
16  * Reference
17  * https://leetcode.com/problems/burst-balloons/
18  */
19 public class BurstBalloons {
20
21     /**
22      * Dynamic programming solution.
23      */
24     public int maxCoinsBottomUpDp(int[] nums) {
25
26         int T[][] = new int[nums.length][nums.length];
27
28         for (int len = 1; len <= nums.length; len++) {
29             for (int i = 0; i <= nums.length - len; i++) {
30                 int j = i + len - 1;
31                 for (int k = i; k <= j; k++) {
```

```
32                      //leftValue/rightValue is initially 1. If there
                            is element on
33                      // left/right of k then left/right value will
                            take that value.
34                      int leftValue = 1;
35                      int rightValue = 1;
36                      if (i != 0) {
37                          leftValue = nums[i-1];
38                      }
39                      if (j != nums.length -1) {
40                          rightValue = nums[j+1];
41                      }
42
43                      //before is initially 0. If k is i then before
                            will
44                      //stay 0 otherwise it gets value T[i][k-1]
45                      //after is similarly 0 initially. if k is j
                            then after will
46                      //stay 0 other will get value T[k+1][j]
47                      int before = 0;
48                      int after = 0;
49                      if (i != k) {
50                          before = T[i][k-1];
51                      }
52                      if (j != k) {
53                          after = T[k+1][j];
54                      }
55                      T[i][j] = Math.max(leftValue * nums[k] *
                            rightValue + before + after,
56                              T[i][j]);
57                  }
58              }
59          }
60          return T[0][nums.length - 1];
61      }
62
63      /**
64       * Recursive solution.
65       */
66      public int maxCoinsRec(int nums[]) {
67          int[] nums1 = new int[nums.length + 2];
68          nums1[0] = 1;
69          nums1[nums1.length - 1] = 1;
70          for (int i = 0; i < nums.length; i++) {
71              nums1[i+1] = nums[i];
72          }
73          return maxCoinsRecUtil(nums1);
74      }
75
76      private int maxCoinsRecUtil(int[] nums) {
77          if (nums.length == 2) {
78              return 0;
79          }
80
81          int max = 0;
82          for (int i = 1; i < nums.length - 1; i++) {
```

```
83              int val = nums[i - 1]*nums[i]*nums[i+1] +
                    maxCoinsRecUtil(formNewArray(nums, i));
84              if (val > max) {
85                  max = val;
86              }
87           }
88          return max;
89
90      }
91
92      private int[] formNewArray(int[] input, int doNotIncludeIndex)
            {
93          int[] newArray = new int[input.length - 1];
94          int index = 0;
95          for (int i = 0; i < input.length; i++) {
96              if (i == doNotIncludeIndex) {
97                  continue;
98              }
99              newArray[index++] = input[i];
100         }
101         return newArray;
102     }
103
104
105     public static void main(String args[]) {
106         BurstBalloons bb = new BurstBalloons();
107         int input[] = {2, 4, 3, 5};
108         System.out.print(bb.maxCoinsBottomUpDp(input));
109     }
110 }
```

6.7. Catalan

```
1  #include <bits/stdc++.h>
2  using namespace std;
3   /*
4  1) Count the number of expressions containing n pairs of
       parentheses which are correctly matched. For n = 3,
5  possible expressions are ((())), ()(()), ()()(), (())(), (()()).
6  2) Count the number of possible Binary Search Trees with n keys (
       See this)
7  3) Count the number of full binary trees (A rooted binary tree is
       full if every vertex has either two children or no children)
       with n+1 leaves.
8   */
9  // A recursive function to find nth catalan number
10 unsigned long int catalan(unsigned int n)
11 {
12     // Base case
13     if (n <= 1) return 1;
14
15     // catalan(n) is sum of catalan(i)*catalan(n-i-1)
16     unsigned long int res = 0;
17     for (int i=0; i<n; i++)
18         res += catalan(i)*catalan(n-i-1);
19
20     return res;
```

```
21 }
22
23 // Driver program to test above function
24 int main()
25 {
26     for (int i=0; i<10; i++)
27         cout << catalan(i) << " ";
28     return 0;
29 }
```

6.8. Coin changing

```
1  /*
2  DP sobre la cantidad de formas de pagar X dado un set de monedas(
       cantidad infinita)
3  Complejidad X*|Monedas|
4  */
5
6  #include <bits/stdc++.h>
7
8  using namespace std;
9
10 int solution(int total, vector<int>&monedas){
11   vector <int> temp(total+1,0);
12   temp[0] = 1;
13   for(int i = 0; i < monedas.size();i++){
14     for(int j = 1; j <= total; j++)
15       if(j >= monedas[i])temp[j]+= temp[j-monedas[i]];
16   }
17   return temp[total];
18 }
19
20 int main(){
21   int total = 15;
22     vector <int> monedas;
23     monedas.push_back(3);
24     monedas.push_back(4);
25   monedas.push_back(6);
26   monedas.push_back(7);
27   monedas.push_back(9);
28     printf("%d\n",solution(total,monedas));
29   return 0;
30 }
```

6.9. Cutting sticks

```
1  //dada una vara, con cortes dados, el cortar cuesta el tama o de
       la vara, se busca minimizar el costo total de realizar los
       cortes
2
3  #include <bits/stdc++.h>
4
5  int n, l, C[52], DP[52][52];
6  int min(int a, int b){ return (a < b)? a:b; }
7
```

```
8  int BottomUp(int ini, int fin)
9  {
10     int i, j, k, L;
11
12     /*Caso Base*/
13     for(i = 0; i < fin; i++)
14         DP[i][i+1] = 0;
15
16     for(L = 2; L <= fin; L++){
17         for(i = 0; i <= (fin - L); i++){
18             j = i + L;
19             DP[i][j] = INT_MAX;
20             for(k = i+1; k < j; k++){
21                 DP[i][j] = min(DP[i][j], DP[i][k] + DP[k][j] + (C[j
                       ] - C[i]));
22             }
23         }
24     }
25
26     return DP[0][fin];
27 }
28
29 int main()
30 {
31     int i, sol;
32
33     while(1)
34     {
35         scanf("%d", &l);
36         if(l == 0) break;
37         scanf("%d", &n);
38         C[0] = 0;
39         for(i = 1; i <= n; i++)
40             scanf("%d", &C[i]);
41         C[n+1] = l;
42         sol = BottomUp(0, n+1);
43         printf("The␣minimum␣cutting␣is␣%d.\n", sol);
44     }
45     return 0;
46 }
```

6.10. Distinct subsequence

```
1  package com.interview.dynamic;
2
3  /**
4   * Date 03/20/2016
5   * @author Tushar Roy
6   *
7   * Given a string S and a string T, count the number of distinct
        subsequences of T in S.
8   *
9   * Time complexity O(n^2)
10  * Space complexity O(n^2)
11  *
12  * https://leetcode.com/problems/distinct-subsequences/
13  */
```

```
14 public class DistinctSubsequence {
15     public int numDistinct(String s, String t) {
16         if (s.length() == 0 || t.length() == 0) {
17             return 0;
18         }
19         int[][] T = new int[t.length() + 1][s.length() + 1];
20         for (int i = 0; i < T[0].length; i++) {
21             T[0][i] = 1;
22         }
23         for (int i = 1; i < T.length; i++) {
24             for (int j = 1; j < T[0].length; j++) {
25                 if (s.charAt(j - 1) == t.charAt(i - 1)) {
26                     T[i][j] = T[i-1][j-1] + T[i][j-1];
27                 } else {
28                     T[i][j] = T[i][j-1];
29                 }
30             }
31         }
32         return T[t.length()][s.length()];
33     }
34
35     public static void main(String args[]) {
36         DistinctSubsequence ds = new DistinctSubsequence();
37         System.out.println(ds.numDistinct("abdacgblc", "abc"));
38     }
39 }
```

6.11. Divide and conquer

```
1  / tags: DP + divide and conquer optimization
2  #include <bits/stdc++.h>
3  using namespace std;
4  #define rep(i,a,b) for(int i=a; i<=b; i++)
5  typedef long long int ll;
6  #define MAXN 6000
7
8  int N;
9  ll B,C;
10 ll H[MAXN];
11 ll accH[MAXN];
12 ll accKH[MAXN];
13 ll dp[MAXN+1][MAXN];
14
15 ll deltaAccH(int i, int j) { return i > 0 ? accH[j] - accH[i-1] :
       accH[j]; }
16 ll deltaAccKH(int i, int j) { return i > 0 ? accKH[j] - accKH[i-1]
       : accKH[j]; }
17
18 // Compute total distance cost between i and j assuming that
19 // there is a station in both i and j
20 // (if i < 0, only in j)
21 // (if j >= N, only in i)
22 ll cost(int i, int j) {
23     // station only in j
24     if (i < 0) return j * accH[j] - accKH[j];
25
26     // station only in i
```

```
27      if (j >= N) return deltaAccKH(i, N-1) - i * deltaAccH(i, N-1);
28
29      // normal case: both stations
30      int ml = (i+j)/2;
31      int mr = ml+1;
32      ll left_cost = deltaAccKH(i, ml) - i * deltaAccH(i, ml);
33      ll right_cost = j * deltaAccH(mr, j) - deltaAccKH(mr, j);
34      return left_cost + right_cost;
35  }
36
37  // Solve DP[k][i] where i1 <= i <= i2 using divide and conquer
        optimization
38  // DP[k][i] = min { DP[k-1][j-1] + cost(j, i+1) for p1 <= j <= p2}
39  void fill(int k, int i1, int i2, int j1, int j2) {
40      if (i1 > i2) return;
41      int im = (i1+i2)/2;
42      int jmin = max(j1, k-1);
43      int jmax = min(j2, im);
44      ll min_val = LLONG_MAX;
45      int best_j = -1;
46      rep(j,jmin,jmax) {
47          ll val = cost(j,im+1) + (j > 0 ? dp[k-1][j-1] : 0);
48          if (val < min_val) min_val = val, best_j = j;
49      }
50      dp[k][im] = min_val;
51      fill(k,i1,im-1,j1,best_j);
52      fill(k,im+1,i2,best_j,j2);
53  }
54
55  int main() {
56      while (scanf("%d%lld%lld", &N, &B, &C) == 3) {
57          rep(i,0,N-1) scanf("%lld", &H[i]);
58
59          // -- precompute acc sums --
60          accH[0] = H[0];
61          accKH[0] = 0;
62          rep(k, 1, N-1) {
63              accH[k] = accH[k-1] + H[k];
64              accKH[k] = accKH[k-1] + H[k] * k;
65          }
66
67          // -- DP --
68          // k = 0
69          rep(i,0,N-2) dp[0][i] = cost(-1, i+1);
70          // k >= 1
71          rep(k,1,N) fill(k,k-1,N-1,0,N-1);
72
73          // -- print output --
74          rep(k,1,N) {
75              if (k > 1) printf("␣");
76              ll total_cost = dp[k][N-1] * C + k * B;
77              printf("%lld", total_cost);
78          }
79          puts("");
80      }
81
82      return 0;
```

```
83 }
```

6.12. Edit Distance

```
1  package com.interview.dynamic;
2
3  import java.util.List;
4
5  /**
6   * Date 07/07/2014
7   * @author Tushar Roy
8   *
9   * Given two strings how many minimum edits(update, delete or add)
        is needed to convert one string to another
10  *
11  * Time complexity is O(m*n)
12  * Space complexity is O(m*n)
13  *
14  * References:
15  * http://www.geeksforgeeks.org/dynamic-programming-set-5-edit-
        distance/
16  * https://en.wikipedia.org/wiki/Edit_distance
17  */
18 public class EditDistance {
19
20     /**
21      * Uses recursion to find minimum edits
22      */
23     public int recEditDistance(char[]  str1, char str2[], int len1,
           int len2){
24
25         if(len1 == str1.length){
26             return str2.length - len2;
27         }
28         if(len2 == str2.length){
29             return str1.length - len1;
30         }
31         return min(recEditDistance(str1, str2, len1 + 1, len2 + 1)
               + str1[len1] == str2[len2] ? 0 : 1, recEditDistance(
               str1, str2, len1, len2 + 1) + 1, recEditDistance(str1,
               str2, len1 + 1, len2) + 1);
32     }
33
34     /**
35      * Uses bottom up DP to find the edit distance
36      */
37     public int dynamicEditDistance(char[] str1, char[] str2){
38         int temp[][] = new int[str1.length+1][str2.length+1];
39
40         for(int i=0; i < temp[0].length; i++){
41             temp[0][i] = i;
42         }
43
44         for(int i=0; i < temp.length; i++){
45             temp[i][0] = i;
46         }
47
```

```
48          for(int i=1;i <=str1.length; i++){
49              for(int j=1; j <= str2.length; j++){
50                  if(str1[i-1] == str2[j-1]){
51                      temp[i][j] = temp[i-1][j-1];
52                  }else{
53                      temp[i][j] = 1 + min(temp[i-1][j-1], temp[i-1][
                            j], temp[i][j-1]);
54                  }
55              }
56          }
57          printActualEdits(temp, str1, str2);
58          return temp[str1.length][str2.length];
59
60      }
61
62      /**
63       * Prints the actual edits which needs to be done.
64       */
65      public void printActualEdits(int T[][], char[] str1, char[]
            str2) {
66          int i = T.length - 1;
67          int j = T[0].length - 1;
68          while(true) {
69              if (i == 0 || j == 0) {
70                  break;
71              }
72              if (str1[i-1] == str2[j-1]) {
73                  i = i-1;
74                  j = j-1;
75              } else if (T[i][j] == T[i-1][j-1] + 1){
76                  System.out.println("Edit␣" + str2[j-1] + "␣in␣
                        string2␣to␣" + str1[i-1] + "␣in␣string1");
77                  i = i-1;
78                  j = j-1;
79              } else if (T[i][j] == T[i-1][j] + 1) {
80                  System.out.println("Delete␣in␣string1␣" + str1[i
                        -1]);
81                  i = i-1;
82              } else if (T[i][j] == T[i][j-1] + 1){
83                  System.out.println("Delete␣in␣string2␣" + str2[j
                        -1]);
84                  j = j -1;
85              } else {
86                  throw new IllegalArgumentException("Some␣wrong␣with
                        ␣given␣data");
87              }
88
89          }
90      }
91
92      private int min(int a,int b, int c){
93          int l = Math.min(a, b);
94          return Math.min(l, c);
95      }
96
97      public static void main(String args[]){
98          String str1 = "azced";
```

```
99          String str2 = "abcdef";
100         EditDistance editDistance = new EditDistance();
101         int result = editDistance.dynamicEditDistance(str1.
                toCharArray(), str2.toCharArray());
102         System.out.print(result);
103     }
104
105 }
```

6.13. Sum 2D Rectangle

```
1  package com.interview.dynamic;
2
3  /**
4   * Date 03/11/2016
5   * @author Tushar Roy
6   *
7   * Given a 2D array find the sum in given range defining a
        rectangle.
8   *
9   * Time complexity construction O(n*m)
10  * Time complexity of query O(1)
11  * Space complexity is O(n*m)
12  *
13  * Reference
14  * https://leetcode.com/problems/range-sum-query-2d-immutable/
15  */
16 public class Immutable2DSumRangeQuery {
17     private int[][] T;
18
19     public Immutable2DSumRangeQuery(int[][] matrix) {
20         int row = 0;
21         int col = 0;
22         if (matrix.length != 0) {
23             row = matrix.length;
24             col = matrix[0].length;
25         }
26         T = new int[row + 1][col + 1];
27         for (int i = 1; i < T.length; i++) {
28             for (int j = 1; j < T[0].length; j++) {
29                 T[i][j] = T[i - 1][j] + T[i][j - 1] + matrix[i -
                        1][j - 1] - T[i - 1][j - 1];
30             }
31         }
32    }
33
34     public int sumQuery(int row1, int col1, int row2, int col2) {
35         row1++;
36         col1++;
37         row2++;
38         col2++;
39         return T[row2][col2] - T[row1 - 1][col2] - T[row2][col1 -
                1] + T[row1 - 1][col1 - 1];
40     }
41
42     public static void main(String args[]) {
43         int[][] input = {{3, 0, 1, 4, 2},
```

```
44                          {5, 6, 3, 2, 1},
45                          {1, 2, 0, 1, 5},
46                          {4, 1, 0, 1, 7},
47                          {1, 0, 3, 0, 5}};
48
49          int[][] input1 = {{2,0,-3,4}, {6, 3, 2, -1}, {5, 4, 7, 3},
                {2, -6, 8, 1}};
50          Immutable2DSumRangeQuery isr = new Immutable2DSumRangeQuery
                (input1);
51          System.out.println(isr.sumQuery(1, 1, 2, 2));
52      }
53  }
```

6.14. Sum Dice

```
1
2   package com.interview.dynamic;
3
4   /**
5    * @author Tushar Roy
6    * http://www.geeksforgeeks.org/dice-throw-problem/
7    * This solution assumes that 1,2,1 is different from 2,1,1 which
         is different from 1,1 2
8    * so total 3 ways are possible
9    * program to find number of ways to get sum 'x' with 'n'
10   */
11  public class DiceThrowWays {
12
13      public int numberOfWays(int n, int f, int k){
14
15          int T[][] = new int[n+1][k+1];
16          T[0][0] = 1;
17      /*  for(int i=0; i < T.length; i++){
18              T[0][i] = 1;
19          }*/
20
21          for(int i=1; i <= n; i++){
22              for(int j =1; j <= i*f && j <= k ; j++){
23                  if(j == i){
24                      T[i][j] = 1;
25                      continue;
26                  }
27                  if(j < i){
28                      continue;
29                  }
30                  for(int l =1; l <=f ;l++){
31                      if(j >= l){
32                          T[i][j] += T[i-1][j-l];
33                      }
34                  }
35              }
36          }
37          return T[n][k];
38      }
39
40      public static void main(String args[]){
41          DiceThrowWays dtw = new DiceThrowWays();
```

```
42          System.out.println(dtw.numberOfWays(3, 3, 6));
43      }
44  }
```

Capítulo 7

Misc

7.1. Fechas

```
1  string dayOfWeek[]={"Mon","Tue","Wed","Thu","Fri","Sat","Sun"};
2
3  int dateToInt(int m,int d,int y){
4    return 1461*(y+4800+(m-14)/12)/4+
5    367*(m-2-(m-14)/12*12)/12-
6    3*((y+4900+(m-14)/12)/100)/4 + d-32075;
7  }
8
9  void intToDate(int jk,int &m,int &d,int &y){
10   int x,n,i,j;
11   x=jd+68569;
12   n=4*x/146097;
13   x-=(146097*n+3)/4;
14   i=(4000*(x+1))/1461001;
15   x-=1461*i/4-31;
16   j=80*x/2447;
17   d=x-2447*j/80;
18   x=j/11;
19   m=j+2-12*x;
20   y=100*(n-49)+i+x;
21 }
22
23 string intToDay(int jd){
24   return dayOfWeek(jd%7);
25 }
```

7.2. Inversion Count

```
1  vector<int> a;
2  vector<int> b;
3  vector<int> c;
4
5  long long inversiones;
6
7  void merge(int l,int m,int r){
```

```
8    int s=m-l+1;
9    int aux=s;
10   int t=r-m;
11   for(int i=0;i<s;i++) b[i]=a[l+i];
12   for(int i=0;i<t;i++) c[i]=a[m+1+i];
13   int i=0,j=0,k=l;
14   while(i<s && j<t){
15     if(b[i]>c[j]){
16       inversiones+=aux;
17       a[k++]=c[j++];
18     }else{
19       aux--;
20       a[k++]=b[i++];
21     }
22   }
23   while(i<s) a[k++]=b[i++];
24   while(j<t) a[k++]=c[j++];
25 }
26 void merge_sort(int l,int r){
27   if(r>l){
28     int m=(l+r)/2;
29     merge_sort(l,m); merge_sort(m+1,r); merge(l,m,r);
30   }
31 }
32
33 int main(){
34   int t;
35   cin>>t;
36   while(t--){
37     int n;
38     inversiones=0;
39     cin>>n;
40     a.assign(n,0);b.assign(n,0);c.assign(n,0);
41     for(int i=0;i<n;i++){
42       int aux;
43       cin>>aux;
44       a[i]=aux;
45     }
46     merge_sort(0,n-1);
47     cout<<inversiones<<endl;
48   }
49   return 0;
50 }
```

7.3. Longest palindrome subsequence

```
1  #include <bits/stdc++.h>
2
3  using namespace std;
4
5  vector<vector<int> > dp(6200,vector<int>(6200,-1));
6  string str;
7
8  int solve(int l,int r){
9    if(dp[l][r]!=-1)
10     return dp[l][r];
11   if(l==r)
```

```
12      return dp[l][r]=1;
13    if(l+1==r)
14      return dp[l][r]=(str[l]==str[r])?2:1;
15    if(str[l]==str[r]){
16      return dp[l][r]=2+solve(l+1,r-1);
17    }else{
18      return dp[l][r]=max(solve(l,r-1),solve(l+1,r));
19    }
20  }
21
22  int main(){
23    int t;
24    cin>>t;
25    while(t--){
26      cin>>str;
27      dp.assign(6200,vector<int>(6200,-1));
28      cout<<solve(0,str.size())<<endl;
29    }
30    return 0;
31  }
```

Capítulo 8

Contenido adicional

8.1. Fast input

```
1
2  #define GETCHAR getchar_unlocked
3  #define PUTCHAR putchar_unlocked
4
5  inline void readInt(int &n){
6    n = 0;
7    bool flag=1;
8    char c;
9    int sign=1;
10   while (1){
11     c = GETCHAR();
12     if(c=='-') sign=-1;
13     else if(c>='0'&&c<='9') {n = n * 10 + c - '0';flag=0;}
14     else if(flag!=1) break;
15   }
16   n *= sign;
17 }
```

8.2. Usar en caso de emergencia

GOD BLESS OUR SAVIOUR

Índice alfabético