
ACTINIUM'S ACM TEMPLATE

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1 注意事项

CodeBlocks修改终端:

只要Settings-->Environment-->Terminal to launch console programs

用“gnome-terminal -t \$TITLE -x”替换掉“xterm -T \$TITLE -e”

测试系统速度:

```
1 | #include <iostream>
2 | #include <cstdio>
3 | #include <ctime>
4 | using namespace std;
5 | int main()
6 | {
7 |     int i=0,j=0,k=0;
8 |     time_t start = clock(), end;
9 |     for (int i=0;i<316000000;i++){
10 |    }
11 |     end = clock();
12 |     printf("done, total time:%ld ms\n", (end - start)/1000);
13 |     return 0;
14 | }
```

对拍程序:

```
1 | while true;do
2 | ./gen>in
3 | ./bruteforce<in>ans
4 | ./prog<in>out
5 | if diff out ans;then
6 | echo AC
7 | else
8 | echo WA
9 | read p
10 | fi
11 | sleep 1
12 | done
```

2 数据结构

2.1 倍增法求LCA

```
1 # include <iostream>
2 # include <cstring>
3 # include <cstdio>
4 # include <vector>
5 # define N 55010
6 using namespace std;
7 struct node
8 {
9     int u,w;
10     //node (){}
11     node (int uu=0,int ww=0):u(uu),w(ww){}
12 };
13 vector <node> tree[N];
14 int p[N][50],d[N],dist[N];
15 void dfs (int x,int pre)
16 {
17     int y,len=tree[x].size(),now;
18     for (int i=0;i<len;i++)
19     {
20         y=tree[x][i].u;
21         if (y==pre)
22             continue;
23         now=p[y][0]=x;
24         d[y]=d[x]+1;
25         dist[y]=dist[x]+tree[x][i].w;
26         for (int j=0;now!=-1 && p[now][j]!=-1;j++)
27         {
28             p[y][j+1]=p[now][j];
29             now=p[now][j];
30         }
31         dfs(y,x);
32     }
33 }
34 int LCA(int x,int y)
35 {
36     if (x==y)
37         return x;
38     int tem;
39     if (d[x]<d[y])
40     {
41         tem=x;
42         x=y;
43         y=tem;
44     }
45     int dis=d[x]-d[y],k=0;
46     while (dis)
47     {
48         if (dis&1)
49             x=p[x][k];
50         dis>>=1;
51         k++;
52     }
53     k=0;
54     while (x!=y)
55     {
56         if ( p[x][k]!=p[y][k] || (p[x][k]==p[y][k] && k==0) )
57         {
58             x=p[x][k];
59             y=p[y][k];
```

```

60         k++;
61     }else k--;
62 }
63 return x;
64 }
65 int main (void)
66 {
67     int n,u,v,c,q,m;
68     char s[20];
69     scanf ("%d%d",&n,&m);
70     for (int i=1;i<=n;i++)
71         tree[i].clear();
72     memset(p,-1,sizeof(p));
73     for (int i=0;i<m;i++)
74     {
75         scanf ("%d%d%d%s",&u,&v,&c,s);
76         tree[u].push_back(node(v,c));
77         tree[v].push_back(node(u,c));
78     }
79     dist[1]=0;
80     d[1]=0;
81     dfs(1,-1);
82     scanf ("%d",&q);
83     while (q--)
84     {
85         scanf ("%d%d",&u,&v);
86         printf ("%d\n",dist[u]+dist[v]-2*dist[LCA(u,v)]);
87     }
88     return 0;
89 }

```

2.2 扫描线求面积并

hdu 4419

扫描线+容斥原理

注意lazy标记不用向下传递，因为一条线段被插入之后还会被删除。还有线段树val值的维护

```
1  # include <cstring>
2  # include <cstdio>
3  # include <cstdlib>
4  # include <iostream>
5  # include <algorithm>
6  using namespace std;
7  # define N 20500
8  typedef long long LOL;
9  struct NODE
10 {
11     int x,y1,y2,id,c;
12 }a[N];
13 int val[8][N<<2],len[N<<2],cov[8][N<<2];
14 int x[N],y[N];
15 LOL sum[10],ans[10];
16 void build(int idx,int l,int r)
17 {
18     if (l==r)
19     {
20         len[idx]=y[l+1]-y[l];
21         return ;
22     }
23     int mid=(l+r)>>1;
24     build(idx<<1,l,mid);
25     build(idx<<1|1,mid+1,r);
26     len[idx]=len[idx<<1]+len[idx<<1|1];
27 }
28 inline void up(int now,int idx,int ll)
29 {
30     if (cov[now][idx])
31         val[now][idx]=len[idx];
32     else
33     {
34         if (ll)
35             val[now][idx]=val[now][idx<<1]+val[now][idx<<1|1];
36         else val[now][idx]=0;
37     }
38 }
39 inline int bin(int a[],int l,int r,int x)
40 {
41     int mid;
42     while (l<r)
43     {
44         mid=(l+r+1)>>1;
45         if (a[mid]>x)
46             r=mid-1;
47         else l=mid;
48     }
49     return l;
50 }
51 void update(int now,int idx,int l,int r,int x,int y,int c)
52 {
53     if (x<=l && y>=r)
54     {
55         cov[now][idx]+=c;
56         up(now,idx,r-1);
57         return ;
58     }
```

```

59     int mid=(l+r)>>1;
60     if (y<=mid)
61         update(now,idx<<1,l,mid,x,y,c);
62     else if (x>mid)
63         update(now,idx<<1|1,mid+1,r,x,y,c);
64     else
65     {
66         update(now,idx<<1,l,mid,x,mid,c);
67         update(now,idx<<1|1,mid+1,r,mid+1,y,c);
68     }
69     up(now,idx,r-1);
70 }
71 int cmp(NODE a,NODE b)
72 {
73     return a.x<b.x;
74 }
75 int main (void)
76 {
77     int t,n,ys=0;
78     char op[20];
79     scanf("%d",&t);
80     while (t--)
81     {
82         scanf("%d",&n);
83         int x1,x2,y1,y2,cnt=0;
84         for (int i=1;i<=n;i++)
85         {
86             scanf("%s%d%d%d%d",op,&x1,&y1,&x2,&y2);
87
88             ++cnt;
89             if (op[0]=='R')
90                 a[cnt].c=1;
91             else
92                 if (op[0]=='G')
93                     a[cnt].c=2;
94                 else a[cnt].c=4;
95
96             a[cnt].x=x1;
97             a[cnt].y1=y1,a[cnt].y2=y2;
98             a[cnt].id=1;
99             x[cnt]=x1,y[cnt]=y1;
100
101             ++cnt;
102             a[cnt].c=a[cnt-1].c;
103             a[cnt].x=x2;
104             a[cnt].y1=y1,a[cnt].y2=y2;
105             a[cnt].id=-1;
106             x[cnt]=x2,y[cnt]=y2;
107         }
108
109         sort(x+1,x+1+cnt);
110         sort(y+1,y+1+cnt);
111         sort(a+1,a+1+cnt,cmp);
112
113         int n1=1,n2=1;
114         for (int i=2;i<=cnt;i++)
115             if (x[i]!=x[i-1])
116                 x[++n1]=x[i];
117         for (int i=2;i<=cnt;i++)
118             if (y[i]!=y[i-1])
119                 y[++n2]=y[i];
120
121         memset(val,0,sizeof(val));

```



```

122     memset(cov,0,sizeof(cov));
123     memset(sum,0,sizeof(sum));
124     build(1,1,n2-1);
125
126
127     int cur=1;
128     for (int i=1;i<=n1;i++)
129     {
130         for (int p=1;p<8;p++)
131             sum[p]+=(LOL)val[p][1]*(LOL)(x[i]-x[i-1]);
132         while (cur<=cnt && a[cur].x==x[i])
133         {
134             y1=bin(y,1,n2,a[cur].y1);
135             y2=bin(y,1,n2,a[cur].y2)-1;
136             for (int p=1;p<8;p++)
137             {
138                 if (!(a[cur].c&p)) continue;
139                 update(p,1,1,n2-1,y1,y2,a[cur].id);
140             }
141             ++cur;
142         }
143     }
144     LOL tmp3=sum[1]+sum[2]-sum[3];
145     LOL tmp5=sum[1]+sum[4]-sum[5];
146     LOL tmp6=sum[2]+sum[4]-sum[6];
147     LOL tmp7=sum[7]-sum[1]-sum[2]-sum[4]+tmp3+tmp5+tmp6;
148     ans[1]=sum[1]-tmp3-tmp5+tmp7;
149     ans[2]=sum[2]-tmp3-tmp6+tmp7;
150     ans[3]=sum[4]-tmp5-tmp6+tmp7;
151     ans[4]=tmp3-tmp7;
152     ans[5]=tmp5-tmp7;
153     ans[6]=tmp6-tmp7;
154     ans[7]=tmp7;
155     cout<<"Case "<<+ys<<": "<<endl;
156     for (int i=1;i<8;i++)
157         cout<<ans[i]<<endl;
158 }
159 return 0;
160 }

```

2.3 矩形周长并

HDU 1828.cpp

矩形周长并，统计y轴上线段条数

注意cmp函数，先入再出

```
1  # include <iostream>
2  # include <cstdio>
3  # include <cstdlib>
4  # include <cstring>
5  # include <algorithm>
6  using namespace std;
7  # define N 10050
8  struct SEG
9  {
10     int x,y1,y2,flag;
11 }seg[N];
12 struct NODE
13 {
14     int lc,rc,len,sum,num,cover;
15 }tree[N<<2];
16 int x[N],y[N];
17 int cmp(SEG a,SEG b)
18 {
19     if (a.x!=b.x)
20         return a.x<b.x;
21     return a.flag>b.flag;
22 }
23 int bin_search(int a[],int l,int r,int x)
24 {
25     int mid;
26     while (l<r)
27     {
28         mid=(l+r)>>1;
29         if (x>a[mid])
30             l=mid+1;
31         else r=mid;
32     }
33     return l;
34 }
35 void build(int idx,int l,int r)
36 {
37     tree[idx].lc=tree[idx].rc=tree[idx].sum=tree[idx].cover=tree[idx].num=0;
38     if (l==r)
39         tree[idx].len=y[l+1]-y[l];
40     else
41     {
42         int mid=(l+r)>>1;
43         build(idx<<1,l,mid);
44         build(idx<<1|1,mid+1,r);
45         tree[idx].len=tree[idx<<1].len+tree[idx<<1|1].len;
46     }
47 }
48 inline void solve(int idx,int len)
49 {
50     if (tree[idx].cover)
51     {
52         tree[idx].sum=tree[idx].len;
53         tree[idx].num=2;
54         tree[idx].lc=tree[idx].rc=1;
55     }
56     else
57     {
58         if (len>1)
```

```

59     {
60         tree[idx].sum=tree[idx<<1].sum+tree[idx<<1|1].sum;
61         tree[idx].num=tree[idx<<1].num+tree[idx<<1|1].num;
62         if (tree[idx<<1].rc && tree[idx<<1|1].lc)
63             tree[idx].num-=2;
64         tree[idx].lc=tree[idx<<1].lc;
65         tree[idx].rc=tree[idx<<1|1].rc;
66     }
67     else
68     {
69         tree[idx].num=tree[idx].sum=0;
70         tree[idx].lc=tree[idx].rc=0;
71     }
72 }
73 }
74 void update(int idx,int l,int r,int x,int y,int c)
75 {
76     if (x<=l && y>=r)
77     {
78         tree[idx].cover+=c;
79         solve(idx,r-l+1);
80         return ;
81     }
82     int mid=(l+r)>>1;
83     if (y<=mid)
84         update(idx<<1,l,mid,x,y,c);
85     else
86         if (x>mid)
87             update(idx<<1|1,mid+1,r,x,y,c);
88         else
89         {
90             update(idx<<1,l,mid,x,mid,c);
91             update(idx<<1|1,mid+1,r,mid+1,y,c);
92         }
93     solve(idx,r-l+1);
94 }
95 int main (void)
96 {
97     int n;
98     while (cin>>n)
99     {
100         int cnt=0,x1,x2,y1,y2;
101         for (int i=1;i<=n;i++)
102         {
103             scanf ("%d%d%d%d",&x1,&y1,&x2,&y2);
104             seg[++cnt].x=x1,seg[cnt].y1=y1,seg[cnt].y2=y2,seg[cnt].flag=1;
105             x[cnt]=x1,y[cnt]=y1;
106             seg[++cnt].x=x2,seg[cnt].y1=y1,seg[cnt].y2=y2,seg[cnt].flag=-1;
107             x[cnt]=x2,y[cnt]=y2;
108         }
109         sort(x+1,x+1+cnt);
110         sort(y+1,y+1+cnt);
111         sort(seg+1,seg+1+cnt,cmp);
112         int nx=1,ny=1;
113         for (int i=2;i<=cnt;i++)
114         {
115             if (x[i]!=x[i-1])
116                 x[++nx]=x[i];
117             if (y[i]!=y[i-1])
118                 y[++ny]=y[i];
119         }
120         build(1,1,ny-1);
121         int ans=0,last=0,j=1,k;

```

```

122     for (int i=1;i<=nx;i++)
123     {
124         if (i>1)
125             ans+=(x[i]-x[i-1])*tree[1].num;// 加矩形长边
126         for (k=j;k<=cnt && seg[k].x==x[i];k++)
127         {
128             update(1,1,ny-1,bin_search(y,1,ny,seg[k].y1),bin_search(y,1,
129                 ny,seg[k].y2)-1,seg[k].flag);
130             ans+=abs(tree[1].sum-last);// 加矩形宽边，每次加的是增量
131             last=tree[1].sum;
132         }
133         j=k;
134     }
135     cout<<ans<<endl;
136 }
137 return 0;
138 }

```

2.4 树状数组

2.4.1 树状数组区间加减，区间查询

树状数组区间加一个值，然后询问区间的和。假设原数组为a，再维护一个数组b， b_i 记录前i个元素每个全部加了 b_i 的值。当我们查询前x项的值时，那么 $sum = \sum_{i=1}^x a_i + x * \sum_{i=x+1}^n b_i + \sum_{i=1}^x b_i * i$ ，均化为了求和的操作，那么可以用树状数组去维护 b_i 与 $b_i * i$ 的值。

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  using namespace std;
5  int lowbit(int x)
6  {
7      return x&(-x);
8  }
9  typedef long long LOL;
10 const int N = 100010;
11 LOL a[N],d[N],c[N],sum[N];
12 int n;
13 void Add(int x,int v)
14 {
15     if(x==0) return ;
16     LOL t=v*x;
17     while(x<=n)
18     {
19         d[x]+=v;
20         c[x]+=t;
21         x+=lowbit(x);
22     }
23 }
24 LOL getsumd(int x)
25 {
26     LOL u=x;
27     LOL sum=0;
28     while(x>0){
29         sum+=d[x];
30         x-=lowbit(x);
31     }
32     return sum;
33 }
34 LOL getsumc(int x)
35 {
36     LOL u=x;
37     LOL sum=0;
38     while(x>0){
39         sum+=c[x];
40         x-=lowbit(x);
41     }
42     return sum;
43 }
44 LOL getsum(int x)
45 {
46     LOL s1=getsumd(n)-getsumd(x);
47     LOL s2=getsumc(x);
48     return sum[x]+(LOL)x*s1+s2;
49 }
50 char com[2];
51 int main(void)
52 {
53     int m,w;
54     scanf("%d%d",&n,&m);
55     for(int i=1;i<=n;i++)
```

```

56     {
57         scanf ("%lld",&a[i]);
58         sum[i]=sum[i-1]+a[i];
59     }
60     int x,y;
61     for(int i=1;i<=m;i++)
62     {
63         scanf ("%s%d%d",com,&x,&y);
64         if (com[0]=='Q')
65         {
66             printf ("%lld\n",getsum(y)-getsum(x-1));
67         }
68         else
69         {
70             scanf ("%d",&w);
71             Add(y,w);Add(x-1,-w);
72         }
73     }
74     return 0;
75 }

```

2.4.2 树状数组求最值

HDU1754

复杂度为 $O(n * \log n * \log n)$

```

1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  using namespace std;
5  const int N = 200010;
6  int a[N],c[N];
7  int lowbit(int x)
8  {
9      return x&(-x);
10 }
11 void init(int n)
12 {
13     for(int i=1;i<=n;i++){
14         c[i]=a[i];
15         for(int j=1;j<lowbit(i);j<=1){
16             c[i]=max(c[i],c[i-j]);
17         }
18     }
19 }
20 int query(int l,int r)
21 {
22     int ans=a[r];
23     while(l<=r){
24         ans=max(ans,a[r]);
25         if(r-lowbit(r)+1>=1){
26             ans=max(ans,c[r]);
27             r-=lowbit(r);
28         }else{
29             r--;
30         }
31     }
32     return ans;
33 }
34 void modify(int idx,int v,int n)
35 {
36     a[idx]=v;
37     for(int i=idx;i<=n;i+=lowbit(i)){

```

```

38         c[i]=v;
39         for(int j=1;j<lowbit(i);j<=1){
40             c[i]=max(c[i],c[i-j]);
41         }
42     }
43 }
44 int main(void)
45 {
46     int n,m,x,y;
47     while(scanf("%d%d",&n,&m)!=EOF)
48     {
49         for(int i=1;i<=n;i++){
50             scanf("%d",&a[i]);
51         }
52         init(n);
53         char op[2];
54         for(int i=1;i<=m;i++){
55             scanf("%s%d%d",op,&x,&y);
56             if(op[0]=='Q'){
57                 printf("%d\n",query(x,y));
58             }else{
59                 modify(x,y,n);
60             }
61         }
62     }
63     return 0;
64 }

```

2.4.3 树状数组求第K大

```

1 int find(int k)
2 {
3     int cnt=0,res=0;
4     for(int i=18;i>=0;i--){
5         res+=1<<i;
6         if(res>=maxn||cnt+c[res]>=k){
7             res--(1<<i);
8         }else{
9             cnt+=c[res];
10        }
11    }
12    return res+1;
13 }

```

2.5 可修改堆

```
1  #include<iostream>
2  #include<cstdio>
3  #include<cstring>
4  using namespace std;
5  const int N = 1000010;
6  struct HEAP
7  {
8      int x,node;
9  }heap[N];
10 int set[N];
11 int size=0;
12 int a[N];
13 void Swap(int x,int y)
14 {
15     swap(heap[x],heap[y]);
16     set[heap[x].node]=x;
17     set[heap[y].node]=y;
18 }
19 void up(int &pos)
20 {
21     while(pos>=2&&heap[pos].x<heap[pos>>1].x)
22     {
23         Swap(pos,pos>>1);
24         pos=pos>>1;
25     }
26 }
27 void down(int &pos)
28 {
29     int j=pos<<1;
30     while(j<=size)
31     {
32         if(j<size&&heap[j+1].x<heap[j].x)
33         {
34             j++;
35         }
36         if(heap[pos].x<=heap[j].x) break;
37         Swap(pos,j);
38         pos=j;j=pos<<1;
39     }
40 }
41 void insert(int size,int node,int val)
42 {
43     heap[size].x=val;
44     heap[size].node=node;
45     set[node]=size;
46     up(size);
47 }
48 int delmin(int size)
49 {
50     int tmp=heap[1].node;
51     Swap(1,size);
52     size--;
53     int pos=1;
54     down(pos);
55     return tmp;
56 }
57 void modify(int pos,int val)
58 {
59     heap[pos].x=val;
60     up(pos);
61     down(pos);
```



```
62 | }
63 | void del(int pos)
64 | {
65 |     Swap(pos,size);
66 |     size--;
67 |     up(pos);
68 |     down(pos);
69 | }
70 | int main(void)
71 | {
72 |     return 0;
73 | }
```

2.6 莫队算法

基本可以处理各种序列问题，复杂度 $O(n * \sqrt{n})$

```
1  #include<iostream>
2  #include<cstdio>
3  #include<cstring>
4  #include<algorithm>
5  #include<cmath>
6  using namespace std;
7  const int N =100010;
8  struct T
9  {
10     int x,y;
11     int id;
12 }tt[N];
13 int sz;
14 bool cmp(T a,T b)
15 {
16     if(a.x/sz==b.x/sz){
17         return a.y<b.y;
18     }
19     return a.x/sz<b.x/sz;
20 }
21 int a[N];
22 int ans[N];
23 int cnt[N];
24 int num[N];
25 int maxx;
26 void add(int x)
27 {
28     cnt[a[x]]++;
29     num[cnt[a[x]]-1]--;
30     num[cnt[a[x]]]++;
31     if(maxx<cnt[a[x]]){
32         maxx=cnt[a[x]];
33     }
34 }
35 void del(int x)
36 {
37     cnt[a[x]]--;
38     num[cnt[a[x]]+1]--;
39     num[cnt[a[x]]]++;
40     if(maxx==cnt[a[x]]+1){
41         if(num[cnt[a[x]]+1]==0){
42             maxx=cnt[a[x]];
43         }
44     }
45 }
46 int main(void)
47 {
48     int n,m;
49     scanf("%d%d",&n,&m);
50     sz=(int)sqrt((double)n);
51     for(int i=1;i<=n;i++){
52         scanf("%d",&a[i]);
53     }
54     for(int i=1;i<=m;i++){
55         scanf("%d%d",&tt[i].x,&tt[i].y);
56         tt[i].x++;tt[i].y++;
57         tt[i].id=i;
58     }
59     sort(tt+1,tt+1+m,cmp);
60     int cl=1,cr=1;
```

```

61 |     num[0]=n;
62 |     maxx=0;
63 |     add(1);
64 |     for(int i=1;i<=m;++i){
65 |         while(cr < tt[i].y) add(++ cr);
66 |         while(cl < tt[i].x) del(cl ++);
67 |         while(cl > tt[i].x) add(-- cl);
68 |         while(cr > tt[i].y) del(cr --);
69 |         ans[tt[i].id] = maxx;
70 |     }
71 |     for(int i=1;i<=m;++i) printf("%d\n", ans[i]);
72 |     return 0;
73 | }

```

2.7 划分树

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #include<algorithm>
5  using namespace std;
6  const int N = 100010;
7  struct Seg
8  {
9      int left,right;
10     int mid(){
11         return (left+right)>>1;
12     }
13 }tt[N<<2];
14 struct Q
15 {
16     int op,x,y,k,now;
17 }q[N<<1];
18 int val[25][N],toleft[25][N],sorted[N];
19 void build(int left,int right,int d,int idx)
20 {
21     tt[idx].left=left;
22     tt[idx].right=right;
23     if(left==right) return ;
24     int mid=tt[idx].mid();
25     int lsame=mid-left+1;
26     for(int i=left;i<=right;i++)
27     {
28         if(val[d][i]<sorted[mid])
29         {
30             lsame--;
31         }
32     }
33     int lpos=left,rpos=mid+1,same=0;
34     for(int i=left;i<=right;i++)
35     {
36         if(i==left)
37         {
38             toleft[d][i]=0;
39         }
40         else
41         {
42             toleft[d][i]=toleft[d][i-1];
43         }
44         if(val[d][i]<sorted[mid]){
45             toleft[d][i]++;
46             val[d+1][lpos++]=val[d][i];
47         }
48         else if(val[d][i]>sorted[mid])
49         {
50             val[d+1][rpos++]=val[d][i];
51         }
52         else
53         {
54             if(same<lsame)
55             {
56                 same++;
57                 toleft[d][i]++;
58                 val[d+1][lpos++]=val[d][i];
59             }
60             else
61             {
```

```

62         val[d+1][rpos++]=val[d][i];
63     }
64 }
65 }
66 build(left,mid,d+1,idx<<1);
67 build(mid+1,right,d+1,idx<<1|1);
68 }
69 int query(int left,int right,int k,int d,int idx)//left到right的第k小的数
70 {
71     if(left==right)
72     {
73         return val[d][left];
74     }
75     int s;
76     int ss;
77     if(left==tt[idx].left)
78     {
79         s=toleft[d][right];
80         ss=0;
81     }
82     else
83     {
84         s=toleft[d][right]-toleft[d][left-1];
85         ss=toleft[d][left-1];
86     }
87     if(s>=k)
88     {
89         int newl=tt[idx].left+ss;
90         int newr=tt[idx].left+ss+s-1;
91         return query(newl,newr,k,d+1,idx<<1);
92     }
93     else
94     {
95         int mid=tt[idx].mid();
96         int tmp=left-tt[idx].left-ss;
97         int newl=mid+1+tmp;
98         int newr=mid+1+tmp+right-left-s;
99         return query(newl,newr,k-s,d+1,idx<<1|1);
100     }
101 }
102 int find(int d,int id,int x,int idx)//前id个数小于等于x的有多少个
103 {
104     if(id<tt[idx].left) return 0;
105     if(tt[idx].left==tt[idx].right) return sorted[id]<=x;
106     int s=toleft[d][id];
107     int mid=tt[idx].mid();
108     if(sorted[mid]<=x)
109     {
110         return find(d+1,mid+id-tt[idx].left+1-s,x,idx<<1|1)+s;
111     }
112     else
113     {
114         return find(d+1,tt[idx].left+s-1,x,idx<<1);
115     }
116 }
117 char com[20];
118 int main(void)
119 {
120     int n,ys=0;
121     while(scanf("%d",&n)!=EOF)
122     {
123         int len=0;
124         for(int i=1;i<=n;i++)

```

```

125     {
126         scanf ("%s", com);
127         if (strcmp (com, "Insert") == 0)
128         {
129             scanf ("%d", &q[i].x);
130             q[i].op=1;
131             ++len;
132             val[0][len]=q[i].x;
133             sorted[len]=val[0][len];
134         }
135         else if (strcmp (com, "Query_1") == 0)
136         {
137             scanf ("%d%d%d", &q[i].x, &q[i].y, &q[i].k);
138             q[i].op=2;
139         }
140         else if (strcmp (com, "Query_2") == 0)
141         {
142             scanf ("%d", &q[i].k);
143             q[i].op=3;
144             q[i].x=1; q[i].y=len;
145         }
146         else
147         {
148             scanf ("%d", &q[i].k);
149             q[i].op=4;
150             q[i].x=1; q[i].y=len;
151         }
152     }
153     sort(sorted+1, sorted+1+len);
154     build(1, len, 0, 1);
155     printf ("Case %d:\n", ++ys);
156     long long sum1=0, sum2=0, sum3=0;
157     for(int i=1; i<=n; i++)
158     {
159         if (q[i].op==2)
160         {
161             sum1+=(long long)query(q[i].x, q[i].y, q[i].k, 0, 1);
162         }
163         else if (q[i].op==4)
164         {
165             sum3+=(long long)query(q[i].x, q[i].y, q[i].k, 0, 1);
166         }
167         else if (q[i].op==3)
168         {
169             sum2+=(long long)find(0, q[i].y, q[i].k, 1);
170         }
171     }
172     printf ("%lld\n%lld\n%lld\n", sum1, sum2, sum3);
173 }
174 return 0;
175 }

```

2.8 二维RMQ

```
1 #include<iostream>
2 #include<cstring>
3 #include<cstdio>
4 using namespace std;
5 const int M = 301;
6 int val[M][M];
7 int Max[9][9][M][M];
8 int idx[M];
9 void initRMQ(int n,int m){
10     for(int i=1;i<=n;i++){
11         for(int j=1;j<=m;j++){
12             Max[0][0][i][j]=val[i][j];
13         }
14     }
15     for(int i=0;i<=idx[n];i++){
16         int limit1=n+1-(1<<i);
17         for(int j=0;j<=idx[m];j++){
18             if(!i&&!j) continue;
19             int limit2=m+1-(1<<j);
20             for(int ii=1;ii<=limit1;ii++){
21                 for(int jj=1;jj<=limit2;jj++){
22                     if(i) Max[i][j][ii][jj]=min(Max[i-1][j][ii+(1<<i>>1)][jj],Max[i-1][j][ii][jj]);
23                     else Max[i][j][ii][jj]=min(Max[i][j-1][ii][jj],Max[i][j-1][ii][jj+(1<<j>>1)]);
24                 }
25             }
26         }
27     }
28 }
29 int query(int a,int b,int c,int d)
30 {
31     int n=idx[c-a+1],m=idx[d-b+1];
32     c--=(1<<n)-1;
33     d--=(1<<m)-1;
34     return min(min(Max[n][m][a][b],Max[n][m][a][d]),min(Max[n][m][c][b],Max[n][m][c][d]));
35 }
36 int main(void)
37 {
38     idx[0]=-1;
39     for(int i=1;i<=300;i++){
40         idx[i]=(i&(i-1))?idx[i-1]:idx[i-1]+1;
41     }
42     int T,n;
43     scanf("%d",&T);
44     while(T--){
45         scanf("%d",&n);
46         for(int i=1;i<=n;i++){
47             for(int j=1;j<=n;j++){
48                 scanf("%d",&val[i][j]);
49             }
50         }
51         initRMQ(n,n);
52         int a,b,c,d,m;
53         scanf("%d",&m);
54         while(m--){
55             scanf("%d%d%d%d",&a,&b,&c,&d);
56             printf("%d\n",query(a,b,c,d));
57         }
58     }
```

```
59 |     return 0;  
60 | }
```


2.9 主席树

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #include<algorithm>
5  using namespace std;
6  const int N = 200001,M=200001,NN=3000000;
7  struct Seg
8  {
9      int l,r,lson,rson,s;
10 }a[NN];
11 int root[N];
12 int b[N],v[N],now[N];
13 int m;
14 int bin(int x)
15 {
16     int left=1,right=m;
17     while(left<=right)
18     {
19         int mid=(left+right)>>1;
20         if(v[mid]==x)
21         {
22             return mid;
23         }
24         if(v[mid]<x) left=mid+1;
25         else right=mid-1;
26     }
27     return 0;
28 }
29 int tot=0;
30 int build(int l,int r)
31 {
32     int k=++tot;
33     a[k].l=l;a[k].r=r;a[k].s=0;
34     if(l==r)
35     {
36         return k;
37     }
38     int mid=(l+r)>>1;
39     a[k].lson=build(l,mid);
40     a[k].rson=build(mid+1,r);
41     return k;
42 }
43 int change(int p,int x,int w)
44 {
45     int k=++tot;
46     a[k].l=a[p].l;a[k].r=a[p].r;
47     a[k].lson=a[p].lson;a[k].rson=a[p].rson;
48     a[k].s=a[p].s+w;
49     if(a[k].l==a[k].r) return k;
50     int mid=(a[k].l+a[k].r)>>1;
51     if(mid<x)
52     {
53         a[k].rson=change(a[p].rson,x,w);
54     }
55     else
56     {
57         a[k].lson=change(a[p].lson,x,w);
58     }
59     return k;
60 }
61 int query(int p,int q,int k)
```

```

62 {
63     if(a[p].l==a[p].r) return a[p].l;
64     int now=a[a[q].lson].s-a[a[p].lson].s;
65     if(now>=k)
66     {
67         return query(a[p].lson,a[q].lson,k);
68     }
69     else
70     {
71         return query(a[p].rson,a[q].rson,k-now);
72     }
73 }
74 int main(void)
75 {
76     int n,q,x,y,k;
77     scanf("%d%d",&n,&q);
78     for(int i=1;i<=n;i++)
79     {
80         scanf("%d",&b[i]);
81         v[i]=b[i];
82     }
83     sort(v+1,v+1+n);
84     m=1;
85     for(int i=2;i<=n;i++)
86     {
87         if(v[i]!=v[i-1])
88         {
89             v[++m]=v[i];
90         }
91     }
92     for(int i=1;i<=n;i++)
93     {
94         now[i]=bin(b[i]);
95     }
96     root[0]=build(1,m);
97     for(int i=1;i<=n;i++)
98     {
99         root[i]=change(root[i-1],now[i],1);
100     }
101     for(int i=1;i<=q;i++)
102     {
103         scanf("%d%d%d",&x,&y,&k);
104         printf("%d\n",v[query(root[x-1],root[y],k)]);
105     }
106     return 0;
107 }

```

2.10 树链剖分

```
1 // #pragma comment(linker, "/STACK:1024000000,1024000000")
2 #include<iostream>
3 #include<cstring>
4 #include<cstdio>
5 #include<vector>
6 using namespace std;
7 const int N = 500010;
8 int sz[N], dep[N], fa[N], son[N], val[N], top[N];
9 int g[N], d[N];
10 vector<int> edge[N];
11 int loc=0;
12 void dfs(int x, int dp, int pa)
13 {
14     fa[x]=pa;
15     sz[x]=1;
16     dep[x]=dp;
17     son[x]=0;
18     for(int i=0; i<edge[x].size(); i++)
19     {
20         int u=edge[x][i];
21         if(u!=pa)
22         {
23             dfs(u, dp+1, x);
24             sz[x]+=sz[u];
25             if(sz[son[x]]<sz[u])
26             {
27                 son[x]=u;
28             }
29         }
30     }
31 }
32 void find_link(int x, int tp)
33 {
34     val[x]=++loc;
35     d[loc]=g[x];
36     top[x]=tp;
37     if(son[x]!=0)
38     {
39         find_link(son[x], tp);
40     }
41     for(int i=0; i<edge[x].size(); i++)
42     {
43         int u=edge[x][i];
44         if(u!=son[x]&&fa[u]==x)
45         {
46             find_link(u, u);
47         }
48     }
49 }
50 int add[N<<2], sum[N<<2];
51 void up(int idx)
52 {
53     sum[idx]=sum[idx<<1]+sum[idx<<1|1];
54 }
55 void down(int idx, int l)
56 {
57     if(add[idx]!=0)
58     {
59         add[idx<<1]+=add[idx];
60         add[idx<<1|1]+=add[idx];
61         sum[idx<<1]+=add[idx]*(1-(l>>1));
```

```

62         sum[idx<<1|1]+=add[idx]*(l>>1);
63         add[idx]=0;
64     }
65 }
66 void build(int left,int right,int idx)
67 {
68     add[idx]=0;
69     if(left==right)
70     {
71         sum[idx]=d[left];
72         return ;
73     }
74     int mid=(left+right)>>1;
75     build(left,mid,idx<<1);
76     build(mid+1,right,idx<<1|1);
77     up(idx);
78 }
79 void update(int left,int right,int L,int R,int v,int idx)
80 {
81     if(left>=L&&right<=R)
82     {
83         add[idx]+=v;
84         sum[idx]+=v*(right-left+1);
85         return ;
86     }
87     down(idx,right-left+1);
88     int mid=(left+right)>>1;
89     if(mid<L)
90     {
91         update(mid+1,right,L,R,v,idx<<1|1);
92     }
93     else if(mid>=R)
94     {
95         update(left,mid,L,R,v,idx<<1);
96     }
97     else
98     {
99         update(left,mid,L,mid,v,idx<<1);
100         update(mid+1,right,mid+1,R,v,idx<<1|1);
101     }
102     up(idx);
103 }
104 int query(int left,int right,int id,int idx)
105 {
106     if(left==right)
107     {
108         return sum[idx];
109     }
110     down(idx,right-left+1);
111     int mid=(left+right)>>1;
112     if(mid<id)
113     {
114         return query(mid+1,right,id,idx<<1|1);
115     }
116     else
117     {
118         return query(left,mid,id,idx<<1);
119     }
120 }
121 void modify(int va,int vb,int v)
122 {
123     int f1=top[va],f2=top[vb];
124     while(f1!=f2)

```

```

125     {
126         if (dep[f1] < dep[f2])
127         {
128             swap(f1, f2);
129             swap(va, vb);
130         }
131         update(1, loc, val[f1], val[va], v, 1);
132         va = fa[f1]; f1 = top[va];
133     }
134     if (dep[va] < dep[vb]) swap(va, vb);
135     update(1, loc, val[vb], val[va], v, 1);
136 }
137 int main(void)
138 {
139     int n, m, q, x, y, w;
140     char op[2];
141     while (scanf("%d%d%d", &n, &m, &q) != EOF)
142     {
143         for (int i = 1; i <= n; i++)
144         {
145             scanf("%d", &g[i]);
146             edge[i].clear();
147         }
148         for (int i = 1; i <= m; i++)
149         {
150             scanf("%d%d", &x, &y);
151             edge[x].push_back(y);
152             edge[y].push_back(x);
153         }
154         loc = 0;
155         dfs(1, 0, -1);
156         find_link(1, 1);
157         build(1, n, 1);
158         for (int i = 1; i <= q; i++)
159         {
160             scanf("%s", op);
161             if (op[0] == 'I')
162             {
163                 scanf("%d%d%d", &x, &y, &w);
164                 modify(x, y, w);
165             }
166             else if (op[0] == 'Q')
167             {
168                 scanf("%d", &x);
169                 int ans = query(1, n, val[x], 1);
170                 printf("%d\n", ans);
171             }
172             else
173             {
174                 scanf("%d%d%d", &x, &y, &w);
175                 modify(x, y, -w);
176             }
177         }
178     }
179 }
180 return 0;
181 }

```

2.11 KD树

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #include<algorithm>
5  #include<queue>
6  #include<vector>
7  using namespace std;
8  const int N = 100010;
9  const int oo = 20010;
10 int Div[N];
11 struct P
12 {
13     int a[5];
14     int num;
15     int dis;
16 }tt[N],p[N],tmp,tx;
17 int m,now,k;
18 int minn[10],maxx[10];
19 struct Pcmp
20 {
21     bool operator()(P a,P b)
22     {
23         return a.dis<b.dis;
24     }
25 };
26 priority_queue<P,vector<P>,Pcmp> que;
27 bool cmp(P a,P b)
28 {
29     return a.a[now]<b.a[now];
30 }
31 int dist(P a,P b)
32 {
33     int sum=0;
34     for(int i=0;i<k;i++)
35     {
36         sum+=(a.a[i]-b.a[i])*(a.a[i]-b.a[i]);
37     }
38     return sum;
39 }
40 void build(int l,int r,P p[])
41 {
42     if(l>r) return ;
43     int mid=(l+r)>>1;
44     for(int i=0;i<k;i++)
45     {
46         minn[i]=oo;
47         maxx[i]=-oo;
48     }
49     for(int i=l;i<=r;i++)
50     {
51         for(int j=0;j<k;j++)
52         {
53             minn[j]=min(minn[j],p[i].a[j]);
54             maxx[j]=max(maxx[j],p[i].a[j]);
55         }
56     }
57     now=0;
58     for(int i=1;i<k;i++)
59     {
60         if(maxx[i]-minn[i]>maxx[now]-minn[now])
61         {
```

```

62         now=i;
63     }
64 }
65 Div[mid]=now;
66 nth_element(p+l,p+mid,p+r+1,cmp);
67 build(l,mid-1,p);
68 build(mid+1,r,p);
69 }
70 void find(int l,int r,P a,P p[])
71 {
72     if(l>r) return ;
73     int mid=(l+r)>>1;
74     int dis=dist(a,p[mid]);
75     if(queue.size()<m)
76     {
77         tx=p[mid];tx.dis=dis;
78         queue.push(tx);
79     }
80     else if(queue.top().dis>dis)
81     {
82         tx=p[mid];tx.dis=dis;
83         queue.pop();
84         queue.push(tx);
85     }
86     int d=a.a[Div[mid]]-p[mid].a[Div[mid]];
87     int l1=l,l2=mid+1,r1=mid-1,r2=r;
88     if(d>0) swap(l1,l2),swap(r1,r2);
89     find(l1,r1,a,p);
90     if(queue.size()<m||d*d<queue.top().dis) find(l2,r2,a,p);
91 }
92 int main(void)
93 {
94     int n,q;
95     //freopen("1009.in","r",stdin);
96     //freopen("1.out","w",stdout);
97     while(scanf("%d%d",&n,&k)!=EOF)
98     {
99         for(int i=1;i<=n;i++)
100         {
101             for(int j=0;j<k;j++)
102             {
103                 scanf("%d",&tt[i].a[j]);
104                 p[i].a[j]=tt[i].a[j];
105             }
106         }
107         build(1,n,p);
108         scanf("%d",&q);
109         while(q--)
110         {
111             for(int i=0;i<k;i++)
112             {
113                 scanf("%d",&tmp.a[i]);
114             }
115             scanf("%d",&m);
116             while(!queue.empty()) queue.pop();
117             vector<P> v;
118             find(1,n,tmp,p);
119             while(!queue.empty()) v.push_back(queue.top()),queue.pop();
120             printf("the closest %d points are:\n",m);
121             for(int i=v.size()-1;i>=0;i--)
122             {
123                 for(int j=0;j<k;j++)
124                 {

```

```

125 |                                     printf("%d%c",v[i].a[j],j==k-1?'\\n':' ');
126 |                                     }
127 |                                 }
128 |                             }
129 |     }
130 |     return 0;
131 | }

```


2.12 treap

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #include<cstdlib>
5  using namespace std;
6  const int N = 1000010;
7  struct Node
8  {
9      int val,fix,left,right;
10     int size,weight;
11 }tn[N];
12 int loc,root;
13 void init()
14 {
15     loc=0,root=0,srand(1992);
16 }
17 int newnode(int v)
18 {
19     ++loc;
20     tn[loc].left=0;tn[loc].right=0;
21     tn[loc].size=tn[loc].weight=1;
22     tn[loc].val=v;
23     tn[loc].fix=rand();
24     return loc;
25 }
26 void up(int x)
27 {
28     tn[x].size=tn[tn[x].left].size+tn[tn[x].right].size+tn[x].weight;
29 }
30 void lr(int &x)
31 {
32     int y=tn[x].right;
33     tn[x].right=tn[y].left;
34     tn[y].left=x;
35     up(x);
36     up(y);
37     x=y;
38 }
39 void rr(int &x)
40 {
41     int y=tn[x].left;
42     tn[x].left=tn[y].right;
43     tn[y].right=x;
44     up(x);
45     up(y);
46     x=y;
47 }
48 void insert(int &x,int v)
49 {
50     if(x==0){
51         x=newnode(v);
52         return ;
53     }
54     tn[x].size++;
55     if(tn[x].val==v){
56         tn[x].weight++;
57     }else if(tn[x].val<v){
58         insert(tn[x].right,v);
59         if(tn[tn[x].right].fix<tn[x].fix){
60             lr(x);
61         }
```

```

62     }else{
63         insert(tn[x].left,v);
64         if(tn[tn[x].left].fix<tn[x].fix){
65             rr(x);
66         }
67     }
68 }
69 bool contain(int x,int v)
70 {
71     if(!x){
72         return false;
73     }
74     if(tn[x].val==v){
75         return true;
76     }else if(tn[x].val<v){
77         return contain(tn[x].right,v);
78     }else{
79         return contain(tn[x].left,v);
80     }
81 }
82 void erase(int &x)
83 {
84     if(tn[x].left+tn[x].right==0){
85         x=0;
86     }else if(tn[x].left*tn[x].right==0){
87         x=tn[x].left+tn[x].right;
88     }else if(tn[tn[x].left].fix<tn[tn[x].right].fix){
89         rr(x);
90         erase(tn[x].right);
91     }else{
92         lr(x);
93         erase(tn[x].left);
94     }
95 }
96 void remove(int &x,int v)
97 {
98     if(!contain(x,v)){
99         return ;
100     }
101     tn[x].size--;
102     if(tn[x].val>v){
103         remove(tn[x].left,v);
104     }else if(tn[x].val<v){
105         remove(tn[x].right,v);
106     }else{
107         tn[x].weight--;
108         if(tn[x].weight==0){
109             erase(x);
110         }
111     }
112 }
113 int find_kth(int x,int v)
114 {
115     if(tn[x].size<v){
116         return -1;
117     }
118     if(tn[tn[x].left].size>=v){
119         return find_kth(tn[x].left,v);
120     }else if(tn[x].weight+tn[tn[x].left].size>=v){
121         return v;
122     }else{
123         return find_kth(tn[x].right,v-tn[x].weight-tn[tn[x].left].size);
124     }

```

```

125 | }
126 | void Debug(int x)
127 | {
128 |     if(tn[x].left!=0){
129 |         Debug(tn[x].left);
130 |     }
131 |     printf("%d的为dvalue%, 为dfix%, 左儿子为d%d右儿子
      |     为,%d\n",x,tn[x].val,tn[x].fix,tn[x].left,tn[x].right);
132 |     if(tn[x].right!=0){
133 |         Debug(tn[x].right);
134 |     }
135 | }
136 | int main(void)
137 | {
138 |     return 0;
139 | }

```

2.13 DancingLinks

2.13.1 精确覆盖

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #define N 1010
5  #define M N*N
6  int R[M],L[M],U[M],D[M];
7  int C[M],S[N],O[N],row[M];
8  int size;
9  int ak;
10 void remove(int c)
11 { //删除一列, 并删除同列覆盖的每行
12     int i,j;
13     L[R[c]]=L[c];
14     R[L[c]]=R[c];
15     for(i=D[c];i!=c;i=D[i]){
16         for(j=R[i];j!=i;j=R[j]){
17             U[D[j]]=U[j];
18             D[U[j]]=D[j];
19             S[C[j]]--;
20         }
21     }
22 }
23
24 void resume(int&c)
25 { //恢复一列及此列覆盖的行
26     int i,j;
27     for(i=U[c];i!=c;i=U[i]){
28         for(j=L[i];j!=i;j=L[j]){
29             U[D[j]]=D[U[j]]=j;
30             S[C[j]]++;
31         }
32     } R[L[c]]=L[R[c]]=c;
33 }
34 int Dfs(int k)
35 {
36     int min,c,i,j;
37     if(R[0]==0){ //得到结果
38         ak=k;return 1;
39     }
40
41     for(min=1000000,c=0,i=R[0];i!=0;i=R[i]){
42         if(S[i]<min) min=S[i],c=i; //选取列元素数最少的
43     }
44     remove(c);
45     for(i=D[c];i!=c;i=D[i]){
46
47         for(j=R[i];j!=i;j=R[j])
48             remove(C[j]); //删除
49
50         O[k]=row[i]; //记录结果
51         if(Dfs(k+1))
52             return 1;
53
54         for(j=L[i];j!=i;j=L[j])
55             resume(C[j]); //恢复
56     }
57     resume(c);
58     return 0;
59 }
```

```

60 int main(void)
61 {
62     int n,m,num,x;
63     while (scanf ("%d%d",&n,&m) != EOF)
64     {
65         memset(S, 0, sizeof(S));
66         for(int i=1;i<=m;i++)
67         {
68             R[i-1]=L[i+1]=U[i]=D[i]=i;
69         }
70         R[m]=0; L[0]=m;
71         size=m+1;
72         for(int i=1;i<=n;i++)
73         {
74             int rowh=-1;
75             scanf ("%d",&num);
76             for(int j=1;j<=num;j++)
77             {
78                 scanf ("%d",&x);
79                 C[size]=x;
80                 D[U[x]]=size;
81                 U[size]=U[x];
82                 D[size]=x;
83                 U[x]=size;
84                 S[x]++;
85                 row[size]=i;
86                 if(rowh==-1)
87                 {
88                     L[size]=R[size]=size;
89                     rowh=size;
90                 }
91                 else
92                 {
93                     R[size]=rowh;
94                     L[size]=L[rowh];
95                     R[L[rowh]]=size;
96                     L[rowh]=size;
97                 }
98                 size++;
99             }
100         }
101         int ans=Dfs(0);
102         if(ans==0)
103         {
104             printf("NO\n");
105         }
106         else
107         {
108             printf("%d",ak);
109             for(int i=0;i<ak;i++)
110             {
111                 printf(" %d",O[i]);
112             }
113             printf("\n");
114         }
115     }
116     return 0;
117 }

```

2.13.2 重复覆盖

```

1 #include<iostream>
2 #include<cstring>
3 #include<cstdio>

```

```

4  #include<climits>
5  using namespace std;
6  #define N 100
7  #define M N*N
8  int R[M],L[M],U[M],D[M];
9  int C[M],S[N],O[N],row[M];
10 int Col[M];
11 int size=0;
12 void remove(int &c) {
13     for(int i = D[c]; i != c ; i = D[i]) {
14         L[R[i]] = L[i];
15         R[L[i]] = R[i];
16     }
17 }
18 void resume(int &c) {
19     for(int i = U[c]; i != c ; i = U[i]) {
20         L[R[i]] = i;
21         R[L[i]] = i;
22     }
23 }
24 int h() {
25     bool hash[51];
26     memset(hash,false,sizeof(hash));
27     int ret = 0;
28     for(int c = R[0]; c != 0 ; c = R[c]) {
29         if(!hash[c]) {
30             ret ++;
31             hash[c] = true;
32             for(int i = D[c] ; i != c ; i = D[i]) {
33                 for(int j = R[i] ; j != i ; j = R[j]) {
34                     hash[Col[j]] = true;
35                 }
36             }
37         }
38     }
39     return ret;
40 }
41 int ans=INT_MAX;
42 void dfs(int deep) {
43     if(deep + h() >= ans) {
44         return ;
45     }
46     if(R[0] == 0) {
47         ans=min(ans,deep);
48         return ;
49     }
50     int idx , i , j , minnum = 99999;
51     for(i = R[0] ; i != 0 ; i = R[i]) {
52         if(S[i] < minnum) {
53             minnum = S[i];
54             idx = i;
55         }
56     }
57     for(i = D[idx]; i != idx; i = D[i]) {
58         remove(i);
59         for(j = R[i]; j != i ; j = R[j]) {
60             remove(j);
61         }
62         dfs(deep+1);
63         for(j = L[i]; j != i ; j = L[j]) {
64             resume(j);
65         }
66         resume(i);

```

```

67     }
68     return ;
69 }
70 int main(void)
71 {
72     int n,m,num,x;
73     scanf ("%d%d",&n,&m);
74     memset (S,0,sizeof (S));
75     for(int i=1;i<=n;i++){
76         R[i-1]=L[i+1]=U[i]=D[i]=i;
77     }
78     R[n]=0;L[0]=n;
79     size=n+1;
80     for(int i=1;i<=m;i++){
81         int rowh=-1;
82         scanf ("%d",&num);
83         for(int j=1;j<=num;j++){
84             scanf ("%d",&x);
85             D[U[x]]=size;
86             U[size]=U[x];
87             D[size]=x;
88             U[x]=size;
89             S[x]++;
90             row[size]=i;
91             Col[size]=x;
92             if(rowh==-1)
93             {
94                 L[size]=R[size]=size;
95                 rowh=size;
96             }
97             else
98             {
99                 R[size]=rowh;
100                L[size]=L[rowh];
101                R[L[rowh]]=size;
102                L[rowh]=size;
103            }
104            size++;
105        }
106    }
107    dfs(0);
108    printf ("%d\n",ans);
109    return 0;
110 }

```

3 字符串

3.1 最小表示法

返回的是最小表示法得到的起始值的位置（以0开始）

```
1 int minirepresent(char *s)
2 {
3     int len=strlen(s);
4     int k=0,i=0,j=1;
5     while(j<len&& k<len)
6     {
7         if(s[(i+k)%len]==s[(j+k)%len])
8         {
9             k++;
10        }
11        else
12        {
13            if(s[(i+k)%len]<s[(j+k)%len])
14            {
15                j+=k+1;
16            }
17            else
18            {
19                i=max(j,i+k+1);
20                j=i+1;
21            }
22            k=0;
23        }
24    }
25    return i;
26 }
```


3.2 manacher

可以求出以某位为中心的回文串的最长回文串的长度（若是偶数，则中心在'#'上），最后的结果为p[id]-1;

```
1 void manacher(char *s)
2 {
3     int len=strlen(s);
4     p[0]=1;p[1]=1;p[2]=2;
5     int id=2;
6     for(int i=3;i<len;i++)
7     {
8         int u=2*id-i;
9         if(p[u]+i<p[id]+id)
10        {
11            p[i]=p[u];
12        }
13        else
14        {
15            int j=p[id]+id-i;
16            while(i+j<len&& s[i+j]==s[i-j])
17            {
18                j++;
19            }
20            p[i]=j;
21            id=i;
22        }
23    }
24 }
25 void init(char *s,int len)
26 {
27     str[0]='$';
28     str[1]='#';
29     for(int i=0;i<len;i++)
30     {
31         str[i*2+2]=s[i];
32         str[i*2+3]='#';
33     }
34     str[len*2+2]='\0';
35 }
```

3.3 扩展KMP

next[i]表示以i为起点和自己串匹配的最长公共前缀

```
1 void get_next(char *s)
2 {
3     int len=strlen(s),id;
4     next[0]=len;
5     next[1]=0;
6     int k=0;
7     while(k+1<len&&s[k]==s[k+1])
8     {
9         k++;
10        next[1]++;
11    }
12    id=1;
13    for(int i=2;i<len;i++)
14    {
15        int u=i-id;
16        if(next[u]+i>=next[id]+id)
17        {
18            int j=next[id]+id-i;
19            if(j<0) j=0;
20            while(j+i<len&&s[j]==s[j+i]) j++;
21            next[i]=j;
22            id=i;
23        }
24        else
25        {
26            next[i]=next[u];
27        }
28    }
29 }
```

t是模式串, s是原串,extend[i]表示以i为起点与模式串最长公共前缀的长度

```
1 void solve(char *t,char *s)//
2 {
3     get_next(t);
4     int m=strlen(t);
5     int n=strlen(s);
6     int k=0;
7     while(k<min(n,m)&&t[k]==s[k])
8     {
9         k++;
10    }
11    extend[0]=k;
12    int id=0;
13    for(int i=1;i<n;i++)
14    {
15        int u=i-id;
16        if(i+next[u]<extend[id]+id)
17        {
18            extend[i]=next[u];
19        }
20        else
21        {
22            int j=extend[id]+id-i;
23            if(j<0) j=0;
24            while(j+i<n&&t[j]==s[j+i]) j++;
25            extend[i]=j;
26            id=i;
27        }
28    }
29 }
```

3.4 KMP

```
1 void get_next(char *s)
2 {
3     int len=strlen(s);
4     next[0]=-1;
5     for(int i=1;i<len;i++)
6     {
7         int u=next[i-1];
8         while(u>=0&& s[u+1]!=s[i])
9         {
10             u=next[u];
11         }
12         if(s[u+1]==s[i])
13         {
14             u++;
15         }
16         next[i]=u;
17     }
18 }
19 int solve(char *s,char *t)
20 {
21     get_next(t);
22     int sum=0;
23     int u=-1;
24     int n=strlen(s),m=strlen(t);
25     for(int i=0;i<n;i++){
26         while(u>=0&& s[i]!=t[u+1]){
27             u=next[u];
28         }
29         if(s[i]==t[u+1]){
30             u++;
31         }
32         if(u==m-1){
33             sum++;
34             u=next[u];
35         }
36     }
37     return sum;
38 }
```

3.5 AC自动机

```
1 #include<iostream>
2 #include<cstring>
3 #include<cstdio>
4 #include<algorithm>
5 const int MAX_NODE = 50*10000+10;
6 const int CHILD_NUM = 26;
7 struct Aho_Corasick
8 {
9     int trie[MAX_NODE][CHILD_NUM];
10    int word[MAX_NODE];
11    int fail[MAX_NODE];
12    int vis[MAX_NODE];
13    int Q[MAX_NODE];
14    int sw[128];
15    int sz;
16    void Initialize(){
17        fail[0]=0;
18        for(int i=0;i<CHILD_NUM;i++){
19            sw[i+(int)'a']=i;
20        }
21    }
22    void Reset(){
23        memset(trie[0],0,sizeof(trie[0]));
24        word[0]=0;
25        memset(vis,0,sizeof(vis));
26        memset(word,0,sizeof(word));
27        sz=0;
28    }
29    void Insert(char *s)
30    {
31        int r=0,len=strlen(s);
32        for(int i=0;i<len;i++){
33            int idx=sw[s[i]];
34            if(!trie[r][idx]){
35                trie[r][idx]=++sz;
36                for(int j=0;j<CHILD_NUM;j++){
37                    trie[sz][j]=0;
38                }
39                word[sz]=0;fail[sz]=0;vis[sz]=0;
40            }
41            r=trie[r][idx];
42        }
43        word[r]++;
44    }
45    void Build(){
46        int front=0,rear=0;
47        for(int i=0;i<CHILD_NUM;i++){
48            int u=trie[0][i];
49            if(u){
50                fail[u]=0;
51                Q[rear++]=u;
52            }
53        }
54        while(front<rear){
55            int u=Q[front++];
56            for(int i=0;i<CHILD_NUM;i++){
57                int v=trie[u][i];
58                if(v){
59                    fail[v]=trie[fail[u]][i];
60                    Q[rear++]=v;
61                }else{
```

```

62         trie[u][i]=trie[fail[u]][i];
63     }
64 }
65 }
66 }
67 int Work(char *s)
68 {
69     int n=strlen(s);
70     int sum=0;
71     int r=0;
72     for(int i=0;i<n;i++){
73         int idx=sw[s[i]];
74         r=trie[r][idx];
75         int u=r;
76         while(u!=0&&!vis[u]){
77             sum+=word[u];
78             vis[u]=1;
79             u=fail[u];
80         }
81     }
82     return sum;
83 }
84 }AC;
85 char str[60],s[1000010];
86 int main(void)
87 {
88     int T,n;
89     AC.Initialize();
90     scanf("%d",&T);
91     while(T--){
92         AC.Reset();
93         scanf("%d",&n);
94         for(int i=1;i<=n;i++){
95             scanf("%s",str);
96             AC.Insert(str);
97         }
98         AC.Build();
99         scanf("%s",s);
100         printf("%d\n",AC.Work(s));
101     }
102     return 0;
103 }

```

3.6 后缀数组

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #include<cmath>
5  #define lowbit(x) (x&(-x))
6  using namespace std;
7  const int N = 10000;
8  const int CH = 256;//字母表大小
9  char str[N];
10 int p[N],s[N],c[N],pn[N],cn[N],height[N],cnt[N];
11 int val[N];
12 void init()
13 {
14     int n=strlen(str);
15     for(int i=0;i<n;i++){
16         s[i]=(int)str[i];
17     }
18     s[n]=0;
19 }
20 void Debug(int a[],int n)
21 {
22     printf("/*****\n");
23     for(int i=0;i<n;i++){
24         {
25             printf("%d ",a[i]);
26         }
27     }
28     printf("/*****\n");
29 }
30 void build_sa(int s[],int n,int alphabet)//s[]为字符串转化的数组，n为字符串长度
    加1,alp为字母表大小
31 {
32     memset(cnt,0,sizeof(cnt));
33     for(int i=0;i<n;i++)
34         ++cnt[s[i]];
35     for(int i=1;i<alphabet;i++)
36         cnt[i]+=cnt[i-1];
37     for(int i=n-1;i>=0;i--)
38         p[--cnt[s[i]]]=i;
39     c[p[0]]=0;
40     int classes=1;
41     for(int i=1;i<n;i++)
42     {
43         if(s[p[i]]!=s[p[i-1]]) ++classes;
44         c[p[i]]=classes-1;
45     }
46     //第一次排序结束
47     for(int h=0;(1<=h)<n;h++)
48     {
49         int m=1<=h;
50         for (int i=0; i<n; ++i) {
51             pn[i] = p[i] - (1<=h);
52             if (pn[i] < 0) pn[i] += n;
53         }
54         memset(cnt,0,sizeof(cnt));
55         for(int i=0;i<n;i++)
56             ++cnt[c[pn[i]]];
57         for(int i=1;i<classes;i++)
58             cnt[i]+=cnt[i-1];
59         for(int i=n-1;i>=0;i--)
60             p[--cnt[c[pn[i]]]]=pn[i];
```

```

61         cn[p[0]]=0;
62         classes=1;
63         for(int i=1;i<n;i++)
64         {
65             if(c[p[i]]!=c[p[i-1]]||c[p[i]+m]!=c[p[i-1]+m])
66                 ++classes;
67             cn[p[i]]=classes-1;
68         }
69         memcpy(c,cn,n*sizeof(int));
70         if(classes==n) break;//有所优化
71     }
72 }
73 void get_lcp(int n,int s[])//大小为n,height从1开始到n为真正有用的值,height[i]表
    示sa[i]与sa[i-1]的最长公共前缀
74 {
75     memset(height,0,sizeof(height));
76     for(int i=0;i<n;i++){
77         if(c[i]==0) continue;
78         int st=max(height[c[i-1]]-1,0);
79         int j=i+st,k=p[c[i]-1]+st;
80         while(j<n&&k<n&&s[j]==s[k])
81         {
82             st++;j++;k++;
83         }
84         height[c[i]]=st;
85     }
86 }
87 void rmq_init(int n,int height[])
88 {
89     for(int i=1;i<=n;i++)
90     {
91         val[i]=height[i];
92     }
93     for(int i=1;i<=n;i++)
94     {
95         for(int j=i;j<=n;j+=lowbit(j))
96         {
97             val[j]=min(val[j],height[i]);
98         }
99     }
100 }
101
102 int get_rmq(int l,int r)
103 {
104     if(l>r) swap(l,r);
105     l++;
106     int ans=height[r];
107     while(r>=l)
108     {
109         if(r-lowbit(r)+1>=l)
110         {
111             ans=min(ans,val[r]);
112             r-=lowbit(r);
113         }
114         else
115         {
116             ans=min(ans,height[r]);
117             r--;
118         }
119     }
120     return ans;
121 }
122 int main(void)

```

```

123 | {
124 |     int T;
125 |     scanf("%d",&T);
126 |     while(T--)
127 |     {
128 |         scanf("%s",str);
129 |         init();
130 |         int n=strlen(str);
131 |         build_sa(s,n+1,128);
132 |         get_lcp(n,s);
133 |         long long sum=0;
134 |         for(int i=0;i<=n;i++)
135 |         {
136 |             sum+=n-p[i]-height[i];
137 |         }
138 |         cout<<sum<<endl;
139 |         //~ Debug(p,n+1);
140 |         //~ Debug(c,n+1);
141 |     }
142 |     return 0;
143 | }

```


4 图论

4.1 SPFA判负环

如果没有负环的话跑的超慢，解决办法是初始贪心初始化，每个点由周围的点更新一次

```
1 void spfa(int x)
2 {
3     if(flag) return ;
4     instack[x]=1;
5     for(int cur=first[x]; cur!=-1; cur=edge[cur].next)
6     {
7         int u=edge[cur].v;
8         if (dis[u]>dis[x]+edge[cur].val)
9         {
10             dis[u]=dis[x]+edge[cur].val;
11             if(!instack[u]) spfa(u);
12             else{
13                 flag=1;
14                 return ;
15             }
16         }
17     }
18     instack[x]=0;
19 }
```

4.2 tarjan

4.2.1 求SCC

```
1  #include<stdio.h>
2  #include<string.h>
3  #define N 10005
4  #define M 50005
5  int first[N],next[M],end[M],dfn[N],ins[N],low[N],stack[N],color[N],cnt[N],
    degree[N],top,c,indx;
6
7  void tarjan(int u)
8  {
9      int i,v;
10
11      stack[++top]=u;
12      ins[u]=1;
13      dfn[u]=low[u]=++indx;
14
15      for (i=first[u];i;i=next[i])
16      {
17          v=end[i];
18
19          if (dfn[v]==0)
20          {
21              tarjan(v);
22              if (low[u]>low[v])
23                  low[u]=low[v];
24          }
25
26          else if (ins[v]==1&&low[u]>dfn[v])
27              low[u]=dfn[v];
28      }
29
30      if (low[u]==dfn[u])
31      {
32          c++;
33
34          do
35          {
36              v=stack[top--];
37              color[v]=c;
38              cnt[c]++;
39              ins[v]=0;
40          }
41          while (u!=v);
42      }
43  }
44
45  void solve()
46  {
47      int i;
48
49      for (i=1;i<=n;i++)
50          if (dfn[i]==0)
51              tarjan(i);
52  }
```

4.2.2 求割点、点双联通分支

```
1  #define N 2000 // 注意缩点后新建的图的顶点数最大可能达到 2*n-1
2  #define M 600000
3  using namespace std;
```

```

4
5 struct Edge
6 {
7     int u,v;
8
9     Edge(){}
10    Edge(int a,int b):u(a),v(b){}
11 };
12
13 int first[N],next[M],end[M];
14 int cnt_edge;
15 int dfn[N],low[N],color[N];
16 int cut[N]; // cut[i]>0表示i是割点, 删掉i点后原图将分成cut[i]+1个联通块
17 Edge stack[M];
18 int idx,c,b,top;
19 vector<int>dpt[N]; // 保存每个点双联通分支中的点。注意割点会包含在多个点双联通分支中
20 int qfir[N],qnex[M],qend[M]; // 保存缩点后的图
21 int cnt_Qedge;
22
23 void addEdge(int u,int v)
24 {
25     end[cnt_edge]=v;
26     next[cnt_edge]=first[u];
27     first[u]=cnt_edge++;
28 }
29
30 void addQedge(int u,int v)
31 {
32     qend[cnt_Qedge]=v;
33     qnex[cnt_Qedge]=qfir[u];
34     qfir[u]=cnt_Qedge++;
35 }
36
37 void tarjan(int u)
38 {
39     int i,v,flag;
40     Edge e;
41
42     dfn[u]=low[u]=++idx;
43     flag=0;
44
45     for (i=first[u];i;i=next[i])
46     {
47         v=end[i];
48
49         if (dfn[v]==0)
50         {
51             stack[++top]=Edge(u,v);
52
53             tarjan(v);
54
55             low[u]=min(low[u],low[v]);
56
57             if (dfn[u]<=low[v])
58             {
59                 cut[u]++;
60                 c++;
61
62                 do
63                 {
64                     e=stack[top--];
65
66                     if (color[e.u]!=c)

```

```

67         {
68             color[e.u]=c;
69             dpt[c].push_back(e.u);
70         }
71         if (color[e.v]!=c)
72         {
73             color[e.v]=c;
74             dpt[c].push_back(e.v);
75         }
76
77         }while (e.u!=u||e.v!=v);
78     }
79 }
80 else
81 {
82     low[u]=min(low[u],dfn[v]);
83     if (dfn[u]>dfn[v])
84         stack[++top]=Edge(u,v);
85 }
86 }
87 }
88
89 main()
90 {
91     int n,m,i,j,u,v;
92
93     while (scanf("%d%d",&n,&m)!=EOF)
94     {
95         memset(first,0,sizeof(first));
96         memset(qfir,0,sizeof(qfir));
97         memset(dfn,0,sizeof(dfn));
98         memset(cut,0,sizeof(cut));
99         memset(color,0,sizeof(color));
100         cnt_edge=1;
101         cnt_Qedge=1;
102         idx=top=c=0;
103
104         for (i=0;i<N;i++)
105             dpt[i].clear();
106
107         for (i=0;i<m;i++)
108         {
109             scanf("%d%d",&u,&v);
110             addEdge(u,v);
111             addEdge(v,u);
112         }
113
114         for (i=1;i<=n;i++)
115             if (dfn[i]==0)
116             {
117                 tarjan(i);
118                 cut[i]--;
119             }
120
121         b=c;
122
123         for (i=1;i<=n;i++)
124             if (cut[i])
125                 color[i]=++c;    // 缩点后新图中割点形成的点的编号>b, 联通分支形成的点的
                                   编号<=b
126
127         for (i=1;i<=b;i++)
128             for (j=0;j<dpt[i].size();j++)

```

```

129         {
130             u=dpt[i][j];
131
132             if (cut[u])
133             {
134                 addQedge(color[u],i); // 缩点建图，每个割点形成的点向周围联通分量
                                     形成的点双向连边
135                 addQedge(i,color[u]);
136             }
137         }
138
139         for (i=1;i<=b;i++)
140         {
141             for (j=0;j<dpt[i].size();j++)
142                 printf("%d ",dpt[i][j]);
143             printf("\n");
144         }
145     }
146
147     return 0;
148 }

```

4.2.3 求桥

```

1  #include<stdio.h>
2  #include<string.h>
3  #define N 5005
4  #define M 20005
5
6  typedef struct
7  {
8      int u,v;
9  }Edge;
10
11  Edge bridge[M];
12  int first[N],next[M],end[M],dfn[N],low[N],degree[N],father[N];
13  int idx,cnt;
14
15  void reset(int n)
16  {
17      int i;
18
19      for (i=0;i<=n;i++)
20          father[i]=i;
21  }
22
23  int find(int a)
24  {
25      if (father[a]==a)
26          return a;
27      else
28          return father[a]=find(father[a]);
29  }
30
31  void merge(int a,int b)
32  {
33      int fa=find(a);
34      int fb=find(b);
35
36      if (fa!=fb)
37          father[fa]=fb;
38  }
39
40  int tarjan(int u,int fu)

```

```

41 {
42     int i,v,flag;
43
44     dfn[u]=low[u]=++idx;
45     flag=0;
46
47     for (i=first[u];i;i=next[i])
48     {
49         v=end[i];
50
51         if (flag==0&&v==fu)    // 处理返祖边的影响
52         {
53             flag=1;
54             continue;
55         }
56
57         if (dfn[v]==0)
58         {
59             tarjan(v,u);
60
61             if (low[u]>low[v])
62                 low[u]=low[v];
63
64             if (dfn[u]<low[v])    //dfn[u]<low[v]说明u v为桥
65             {
66                 bridge[cnt].u=u;
67                 bridge[cnt].v=v;
68                 cnt++;
69             }
70             else
71                 merge(u,v);
72         }
73         else if (low[u]>dfn[v])
74             low[u]=dfn[v];
75     }
76 }
77
78 main()
79 {
80     int n,m,i,u,v,ans;
81
82     scanf("%d%d",&n,&m);
83
84     memset(first,0,sizeof(first));
85     memset(dfn,0,sizeof(dfn));
86     memset(degree,0,sizeof(degree));
87     reset(n);
88     cnt=idx=0;
89
90     for (i=1;i<=m+m;)
91     {
92         scanf("%d%d",&u,&v);
93         end[i]=v;
94         next[i]=first[u];
95         first[u]=i;
96         i++;
97         end[i]=u;
98         next[i]=first[v];
99         first[v]=i;
100        i++;
101    }
102
103    tarjan(1,0);

```

```

104
105     for (i=0;i<cnt;i++)
106     // 求最少需要添加多少条边, 使原图无桥: 缩点后度为1 (叶子) 的点的个数为ans, 则需添
        加(ans+1)/2条边。
107     {
108         u=bridge[i].u;
109         v=bridge[i].v;
110
111         degree[find(u)]++;
112         degree[find(v)]++;
113     }
114
115     ans=0;
116
117     for (i=1;i<=n;i++)
118         if (degree[i]==1)
119             ans++;
120
121     printf("%d\n", (ans+1)/2);
122
123     return 0;
124 }

```

4.2.4 求LCA

```

1  #include<stdio.h>
2  #include<string.h>
3  #define N 1000
4  #define M 1000000
5  int father[N],mark[N],res[N],ans[N];
6  int first[N],next[N],end[N],degree[N],qhead[N],qnext[M],qtail[M],qnum[M];
7  int find(int a)
8  {
9      if (father[a]==a)
10         return a;
11     else
12         return father[a]=find(father[a]);
13 }
14
15 void merge(int a,int b)
16 {
17     father[b]=a;
18 }
19
20 void LCA(int u)
21 {
22     int i,v,num;
23
24     father[u]=u;
25
26     for (i=first[u];i;i=next[i])
27     {
28         v=end[i];
29         LCA(v);
30         merge(u,v);
31     }
32
33     mark[u]=1;
34     for (i=qhead[u];i;i=qnext[i])
35     {
36         v=qtail[i];
37         num=qnum[i];
38

```

```

39 |         if (mark[v]==1)
40 |         {
41 |             ans[num]=find(v);
42 |             res[find(v)]++;
43 |         }
44 |     }
45 | }

```


4.3 网络流

4.3.1 EK

```
1  # include <cstring>
2  # include <cstdio>
3  # include <cstdlib>
4  # include <iostream>
5  # include <queue>
6  # define N 20500
7  # define M 4000500
8  # define oo 200000000
9  using namespace std;
10 struct EDGE
11 {
12     int val,v,next;
13 }edge[M];
14 struct DOT
15 {
16     int x,y,c;
17 }dot[110];
18 int vis[110],map[110][110];
19 int first[N],prev[N],curedge[N];
20 int m,w,n,d,cnt_edge;
21 void addedge(int u,int v,int c)
22 {
23     edge[cnt_edge].next=first[u];
24     edge[cnt_edge].v=v;
25     edge[cnt_edge].val=c;
26     first[u]=cnt_edge++;
27
28     edge[cnt_edge].next=first[v];
29     edge[cnt_edge].v=u;
30     edge[cnt_edge].val=0;
31     first[v]=cnt_edge++;
32 }
33 int sqr(int x)
34 {
35     return x*x;
36 }
37 int EK_MaxFlow(int st,int en)
38 {
39     int maxflow=0;
40     queue<int>q;
41     while (1)
42     {
43         while (!q.empty())
44             q.pop();
45         memset(prev,-1,sizeof(prev));
46         q.push(st);
47         curedge[st]=oo;
48         while (!q.empty())
49         {
50             int x=q.front();
51             q.pop();
52             for (int cur=first[x];cur!=-1;cur=edge[cur].next)
53             {
54                 int v=edge[cur].v;
55                 if (prev[v]==-1 && edge[cur].val)
56                 {
57                     prev[v]=x;
58                     curedge[v]=cur;
59                     q.push(v);
60                 }
```

```

61         }
62         if (prev[en] != -1)
63             break;
64     }
65     if (prev[en] == -1)
66         return maxflow;
67     int minflow = oo;
68     for (int v = en; v != st; v = prev[v])
69         minflow = min(minflow, edge[curedge[v]].val);
70     for (int v = en; v != st; v = prev[v])
71     {
72         edge[curedge[v]].val -= minflow;
73         edge[curedge[v]^1].val += minflow;
74     }
75     maxflow += minflow;
76 }
77 return maxflow;
78 }
79 int bfs(void)
80 {
81     queue<int> q;
82     int x;
83     q.push(0);
84     while (!q.empty())
85     {
86         x = q.front();
87         q.pop();
88         for (int i = 1; i <= n + 1; i++)
89             if (map[x][i] && !vis[i])
90             {
91                 vis[i] = 1;
92                 q.push(i);
93             }
94     }
95     return vis[n + 1];
96 }
97 int main (void)
98 {
99     cin >> n >> m >> d >> w;
100     for (int i = 1; i <= n; i++)
101         scanf("%d%d%d", &dot[i].x, &dot[i].y, &dot[i].c);
102     if (d >= w)
103     {
104         printf("1\n");
105         return 0;
106     }
107     for (int i = 1; i <= n; i++)
108     {
109         if (dot[i].c == 0)
110             continue;
111         if (dot[i].y <= d)
112             map[0][i] = 1;
113         if (w - dot[i].y <= d)
114             map[i][n + 1] = 1;
115         for (int j = i; j <= n; j++)
116             if (dot[j].c)
117                 if (sqr(dot[i].x - dot[j].x) + sqr(dot[i].y - dot[j].y) <= d * d)
118                     map[i][j] = map[j][i] = 1;
119     }
120     if (!bfs())
121     {
122         printf("IMPOSSIBLE\n");
123         return 0;

```

```

124     }
125     cnt_edge=0;
126     memset(first,-1,sizeof(first));
127     int st=0,en=1,tot=1,ans=0,cnt=0;
128     for (;cnt<m;cnt+=EK_MaxFlow(st,en))
129     {
130         ans++;
131         for (int i=1;i<=n;i++)
132         {
133             if (dot[i].c==0)
134                 continue;
135             addedge(i+tot,i+n+tot,dot[i].c);
136             if (ans>1)
137             {
138                 for (int j=1;j<=n;j++)
139                     if (map[j][i])
140                         addedge(tot-n+j,tot+i,dot[i].c);
141                 if (map[i][n+1])
142                     addedge(tot-n+i,en,dot[i].c);
143             }
144             if (map[0][i])
145                 addedge(st,i+tot,dot[i].c);
146         }
147         tot+=n+n;
148     }
149     cout<<ans<<endl;
150     return 0;
151 }

```

4.3.2 Sap

```

1  # include <cstring>
2  # include <cstdlib>
3  # include <cstdio>
4  # include <iostream>
5  using namespace std;
6  # define M 485000
7  # define N 20500
8  # define oo 200000000
9  struct EDGE
10 {
11     int v,val,next;
12 }edge[M];
13 int first[N],dis[N],gap[N],pre[N],cur[N];
14 int cnt_edge,NP0;
15 inline void addedge(int u,int v,int c1,int c2)
16 {
17     edge[cnt_edge].next=first[u];
18     edge[cnt_edge].v=v;
19     edge[cnt_edge].val=c1;
20     first[u]=cnt_edge++;
21
22     edge[cnt_edge].next=first[v];
23     edge[cnt_edge].v=u;
24     edge[cnt_edge].val=c2;
25     first[v]=cnt_edge++;
26 }
27 int Sap(int st,int en)
28 {
29     memset(dis,0,sizeof(int)*(NP0+1));
30     memset(gap,0,sizeof(int)*(NP0+1));
31     for (int i=0;i<NP0;i++)
32         cur[i]=first[i];
33     int u=pre[st]=st,maxflow=0,aug=oo;

```

```

34     gap[0]=NPO;
35     while (dis[st]<NPO)
36     {
37 loop:   for (int &i=cur[u];i!=-1;i=edge[i].next)
38         {
39             int v=edge[i].v;
40             if (edge[i].val && dis[u]==dis[v]+1)
41             {
42                 aug=min(aug,edge[i].val);
43                 pre[v]=u;
44                 u=v;
45                 if (v==en)
46                 {
47                     maxflow+=aug;
48                     for (u=pre[u];v!=st;u=pre[u])
49                     {
50                         edge[cur[u]].val-=aug;
51                         edge[cur[u]^1].val+=aug;
52                         v=u;
53                     }
54                     aug=0;
55                 }
56                 goto loop;
57             }
58         }
59     int mindis=NPO;
60     for (int i=first[u];i!=-1;i=edge[i].next)
61     {
62         int v=edge[i].v;
63         if (edge[i].val && mindis>dis[v])
64         {
65             cur[u]=i;
66             mindis=dis[v];
67         }
68     }
69     if (--gap[dis[u]]==0)
70         break;
71     gap[dis[u]=mindis+1]++;
72     u=pre[u];
73 }
74 return maxflow;
75 }
76 int main (void)
77 {
78     int n,m,x,y,z;
79     cin>>n>>m;
80     int st=0,en=n+1;
81     NPO=en+1;
82     memset(first,-1,sizeof(first));
83     cnt_edge=0;
84     for (int i=1;i<=n;i++)
85     {
86         scanf("%d%d",&x,&y);
87         addedge(st,i,x,0);
88         addedge(i,en,y,0);
89     }
90     for (int i=1;i<=m;i++)
91     {
92         scanf("%d%d%d",&x,&y,&z);
93         addedge(x,y,z,z);
94     }
95     cout<<Sap(st,en)<<endl;
96     return 0;

```

97 | }

4.3.3 sap邻接表

```
1 //memset(first,-1,sizeof(first));
2 //cnt_edge=0
3 struct EDGE
4 {
5     int v,val;
6 }edge[M];
7 int next[M];
8 int first[N],d[N],gap[N];
9 int cnt_edge,NPO,ok;
10 void addedge(LOL u,LOL v,LOL c)
11 {
12     next[cnt_edge]=first[u];
13     edge[cnt_edge].v=v;
14     edge[cnt_edge].val=c;
15     first[u]=cnt_edge++;
16
17     next[cnt_edge]=first[v];
18     edge[cnt_edge].v=u;
19     edge[cnt_edge].val=0;
20     first[v]=cnt_edge++;
21 }
22 LOL MIN(LOL x,LOL y)
23 {
24     return x>y?y:x;
25 }
26 LOL relable(LOL x)
27 {
28     LOL mm=bignum;
29     for (int i=first[x];i!=-1;i=next[i])
30         if (edge[i].val)
31             mm=MIN(mm,d[edge[i].v]+1);
32     return mm==bignum?NPO:mm;
33 }
34 LOL solve(int cur ,int t,LOL min)
35 {
36     if (cur==t && min!=bignum)
37         return min;
38     for (int i=first[cur];i!=-1;i=next[i])
39     {
40         int u=edge[i].v;
41         if (edge[i].val && d[cur]==d[u]+1)
42         {
43             LOL p=MIN(solve(u,t,MIN(min,edge[i].val)),min);
44             if (p)
45             {
46                 edge[i].val-=p;
47                 edge[i^1].val+=p;
48                 return p;
49             }
50         }
51     }
52     LOL x=reliable(cur);
53     gap[x]++;
54     if (--gap[d[cur]]==0)
55         ok=1;
56     d[cur]=x;
57     return 0;
58 }
59 int maxflow(int s,int t)
60 {
```

```

61     int ans=0;
62     ok=0;
63     memset(gap,0,sizeof(gap));
64     memset(d,0,sizeof(d));
65     while (d[s]<NPO && !ok)
66         ans+=solve(s,t,bignum);
67     return ans;
68 }

```

4.3.4 费用流

```

1  struct EDGE
2  {
3      int val,v,cost;
4  }edge[M];
5  int vis[N],pv[N],pe[N],q[N],dis[N],first[N];
6  int next[M];
7  int NPO,cnt_edge;
8  int MIN(int x,int y)
9  {
10     return x>y?y:x;
11 }
12 void addedge(int u,int v,int c,int cost)
13 {
14     next[cnt_edge]=first[u];
15     edge[cnt_edge].val=c;
16     edge[cnt_edge].v=v;
17     edge[cnt_edge].cost=cost;
18     first[u]=cnt_edge++;
19
20     next[cnt_edge]=first[v];
21     edge[cnt_edge].val=0;
22     edge[cnt_edge].v=u;
23     edge[cnt_edge].cost=-cost;
24     first[v]=cnt_edge++;
25 }
26 int mincost (int s,int t)
27 {
28     int x,u,cur;
29     int head,tail;
30     int flow,cost,min;
31     for (flow=0,cost=0;;)
32     {
33         memset(pv,-1,sizeof(int)*(NPO+10));
34         memset(vis,0,sizeof(int)*(NPO+10));
35         for (int i=0;i<=NPO;i++)
36             dis[i]=bignum;
37         dis[s]=0;
38         q[1]=s;
39         vis[s]=1;
40         for (head=0,tail=1;head++<tail;)
41         {
42             x=q[head%N];
43             vis[x]=0;
44             for (cur=first[x];cur!=-1;cur=next[cur])
45             {
46                 u=edge[cur].v;
47                 if (edge[cur].val && dis[x]+edge[cur].cost<dis[u])
48                 {
49                     dis[u]=dis[x]+edge[cur].cost;
50                     if (!vis[u])
51                     {
52                         vis[u]=1;
53                         q[(++tail)%N]=u;

```

```

54         }
55         pv[u]=x;
56         pe[u]=cur;
57     }
58 }
59 }
60 if (pv[t]==-1)
61     break;
62 for (cur=t,min=bignum;cur!=s;cur=pv[cur])
63     min=MIN(min,edge[pe[cur]].val);
64 for (cur=t;cur!=s;cur=pv[cur])
65 {
66     edge[pe[cur]].val-=min;
67     edge[pe[cur]^1].val+=min;
68 }
69 flow+=min;
70 cost+=dis[t]*min;
71 }
72 return cost;
73 }

```

4.3.5 无源无汇上下界网络流

z oj 2314

主要思想：每一个点流进来的流=流出去的流

对于每一个点i，令

$M_i = \text{sum}(i\text{点所有流进来的下界流}) - \text{sum}(i\text{点所有流出去的下界流})$

如果 M_i 大于0，代表此点必须还要流出去 M_i 的自由流，那么我们从源点连一条 M_i 的边到该点。

如果 M_i 小于0，代表此点必须还要流进来 M_i 的自由流，那么我们从该点连一条 M_i 的边到汇点。

如果求S到T的最大流，看是否满流(S的相邻边都流满)

```

1  # include <cstring>
2  # include <cstdlib>
3  # include <cstdio>
4  # include <iostream>
5  using namespace std;
6  # define N 400
7  # define M 500000
8  # define oo 2000000000
9  struct EDGE
10 {
11     int v,val,next;
12 }edge[M];
13 int low[M];
14 int w[N],first[N],dis[N],gap[N],preV[N],curE[N];
15 int cnt_edge,NP0;
16 inline void addedge(int u,int v,int c)
17 {
18     edge[cnt_edge].next=first[u];
19     edge[cnt_edge].v=v;
20     edge[cnt_edge].val=c;
21     first[u]=cnt_edge++;
22
23     edge[cnt_edge].next=first[v];
24     edge[cnt_edge].v=u;
25     edge[cnt_edge].val=0;
26     first[v]=cnt_edge++;
27 }
28 int Sap(int st,int en)
29 {
30     memset(dis,0,sizeof(int)*(NP0+1));
31     memset(gap,0,sizeof(int)*(NP0+1));
32     for (int i=0;i<NP0;i++)
33         curE[i]=first[i];
34     int u=preV[st]=st,maxflow=0,minflow=oo;

```

```

35 gap[0]=NPO;
36 while (dis[st]<NPO)
37 {
38     loop:
39     for (int &i=curE[u];i!=-1;i=edge[i].next)
40     {
41         int v=edge[i].v;
42         if (edge[i].val && dis[u]==dis[v]+1)
43         {
44             minflow=min(minflow,edge[i].val);
45             preV[v]=u;
46             u=v;
47             if (v==en)
48             {
49                 maxflow+=minflow;
50                 for (u=preV[u];v!=st;u=preV[u])
51                 {
52                     edge[curE[u]].val-=minflow;
53                     edge[curE[u]^1].val+=minflow;
54                     v=u;
55                 }
56                 minflow=oo;
57             }
58             goto loop;
59         }
60     }
61     int mindis=NPO;
62     for (int i=first[u];i!=-1;i=edge[i].next)
63     {
64         int v=edge[i].v;
65         if (edge[i].val && mindis>dis[v])
66         {
67             curE[u]=i;
68             mindis=dis[v];
69         }
70     }
71     if (--gap[dis[u]]==0)
72         break;
73     gap[dis[u]=mindis+1]++;
74     u=preV[u];
75 }
76 return maxflow;
77 }
78 int main (void)
79 {
80     int t,n,m;
81     cin>>t;
82     while (t--)
83     {
84         cin>>n>>m;
85         int u,v,l,h;
86         cnt_edge=0;
87         memset(first,-1,sizeof(first));
88         memset(w,0,sizeof(w));
89         int st=0,en=n+1,sum=0;
90         NPO=en+1;
91         for (int i=1;i<=m;i++)
92         {
93             scanf("%d%d%d%d",&u,&v,&l,&h);
94             addedge(u,v,h-1);
95             low[i]=1;
96             w[v]+=1;
97             w[u]-=1;

```



```

98     }
99     for (int i=1;i<=n;i++)
100         if (w[i]<0)
101         {
102             sum-=w[i];
103             addedge(i,en,-w[i]);
104         }
105         else
106             addedge(st,i,w[i]);
107     if (Sap(st,en)<sum)
108         printf("NO\n");
109     else
110     {
111         printf("YES\n");
112         for (int i=1;i<=m;i++)
113             printf("%d\n",edge[i+i-1].val+low[i]);
114     }
115 }
116 return 0;
117 }

```

4.3.6 有源有汇上下界网络流

poj_2396

有源有汇上下界网络流

由汇向源连一条 $(0, \infty)$ 的边，下界为0，上界为 ∞

然后转化成无源无汇上下界网络流问题

```

1  # include <cstring>
2  # include <cstdlib>
3  # include <cstdio>
4  # include <iostream>
5  # include <algorithm>
6  # include <queue>
7  # include <vector>
8  # include <map>
9  # include <cmath>
10 # include <time.h>
11 # include <set>
12 using namespace std;
13 # define N 400
14 # define M 500000
15 # define oo 2000000
16 struct EDGE
17 {
18     int v,val,next;
19 }edge[M];
20 int w[N],first[N],dis[N],gap[N],preV[N],curE[N];
21 int low[N][N],high[N][N],num[N][N];
22 int row[N],col[N];
23 int cnt_edge,NPO,flag;
24 inline void addedge(int u,int v,int c)
25 {
26     edge[cnt_edge].next=first[u];
27     edge[cnt_edge].v=v;
28     edge[cnt_edge].val=c;
29     first[u]=cnt_edge++;
30
31     edge[cnt_edge].next=first[v];
32     edge[cnt_edge].v=u;
33     edge[cnt_edge].val=0;
34     first[v]=cnt_edge++;
35 }

```

```

36 int Sap(int st,int en)
37 {
38     memset(dis,0,sizeof(int)*(NPO+1));
39     memset(gap,0,sizeof(int)*(NPO+1));
40     for (int i=0;i<NPO;i++)
41         curE[i]=first[i];
42     int u=preV[st]=st,maxflow=0,minflow=oo;
43     gap[0]=NPO;
44     while (dis[st]<NPO)
45     {
46         loop:
47         for (int &i=curE[u];i!=-1;i=edge[i].next)
48         {
49             int v=edge[i].v;
50             if (edge[i].val && dis[u]==dis[v]+1)
51             {
52                 minflow=min(minflow,edge[i].val);
53                 preV[v]=u;
54                 u=v;
55                 if (v==en)
56                 {
57                     maxflow+=minflow;
58                     for (u=preV[u];v!=st;u=preV[u])
59                     {
60                         edge[curE[u]].val-=minflow;
61                         edge[curE[u]^1].val+=minflow;
62                         v=u;
63                     }
64                     minflow=oo;
65                 }
66                 goto loop;
67             }
68         }
69         int mindis=NPO;
70         for (int i=first[u];i!=-1;i=edge[i].next)
71         {
72             int v=edge[i].v;
73             if (edge[i].val && mindis>dis[v])
74             {
75                 curE[u]=i;
76                 mindis=dis[v];
77             }
78         }
79         if (--gap[dis[u]]==0)
80             break;
81         gap[dis[u]=mindis+1]++;
82         u=preV[u];
83     }
84     return maxflow;
85 }
86 void update(int x,int y,char ch,int z)
87 {
88     if (ch=='=')
89     {
90         if (!(low[x][y]<=z && high[x][y]>=z))
91             flag=0;
92         low[x][y]=high[x][y]=z;
93     }
94     else
95     if (ch=='<')
96     {
97         high[x][y]=min(high[x][y],z-1);
98         if (low[x][y]>high[x][y])

```

```

99         flag=0;
100     }
101     else
102     if (ch=='>')
103     {
104         low[x][y]=max(low[x][y],z+1);
105         if (low[x][y]>high[x][y])
106             flag=0;
107     }
108 }
109 int main (void)
110 {
111     int t,n,m,ys=0;
112     //~ freopen("a.in","r",stdin);
113     //~ freopen("a.out","w",stdout);
114     cin>>t;
115     while (t--)
116     {
117         int sum1=0,sum2=0;
118         cin>>n>>m;
119         for (int i=1;i<=n;i++)
120         {
121             cin>>row[i];
122             sum1+=row[i];
123         }
124         for (int i=1;i<=m;i++)
125         {
126             cin>>col[i];
127             sum2+=col[i];
128         }
129         for (int i=1;i<=n;i++)
130             for (int j=1;j<=m;j++)
131                 low[i][j]=0,high[i][j]=oo;
132         int q,x,y,z;
133         flag=1;
134         char s[10];
135         cin>>q;
136         while (q--)
137         {
138             cin>>x>>y>>s>>z;
139             if (x==0 && y==0)
140             {
141                 for (int i=1;i<=n;i++)
142                     for (int j=1;j<=m;j++)
143                         update(i,j,s[0],z);
144             }
145             else
146             if (x==0)
147             {
148                 for (int i=1;i<=n;i++)
149                     update(i,y,s[0],z);
150             }
151             else
152             if (y==0)
153             {
154                 for (int i=1;i<=m;i++)
155                     update(x,i,s[0],z);
156             }
157             else
158                 update(x,y,s[0],z);
159         }
160         if (ys)
161             cout<<endl;

```

```

162     else ys=1;
163     if (sum1!=sum2 || !flag)
164         cout<<"IMPOSSIBLE"<<endl;
165     else
166     {
167         int st=0,en=n+m+1,cnt=0;
168         int ss=en+1,ee=en+2;
169         NPO=en+3;
170         cnt_edge=0;
171         memset(first,-1,sizeof(first));
172         memset(w,0,sizeof(w));
173         for (int i=1;i<=n;i++)
174             for (int j=1;j<=m;j++)
175             {
176                 addedge(i,n+j,high[i][j]-low[i][j]);
177                 w[n+j]+=low[i][j];
178                 w[i]-=low[i][j];
179                 num[i][j]=++cnt;
180             }
181         for (int i=1;i<=n;i++)
182         {
183             addedge(st,i,0);
184             w[i]+=row[i];
185             w[st]-=row[i];
186         }
187         for (int i=1;i<=m;i++)
188         {
189             addedge(i+n,en,0);
190             w[en]+=col[i];
191             w[i+n]-=col[i];
192         }
193         //add a oo edge from en to st
194         addedge(en,st,oo);
195
196         int sum=0;
197         for (int i=0;i<=n+m+1;i++)
198         {
199             if (w[i]>0)
200             {
201                 addedge(ss,i,w[i]);
202                 sum+=w[i];
203             }
204             else
205                 addedge(i,ee,-w[i]);
206         }
207         if (Sap(ss,ee)!=sum)
208             cout<<"IMPOSSIBLE"<<endl;
209         else
210         {
211             for (int i=1;i<=n;i++)
212                 for (int j=1;j<=m;j++)
213                     printf("%d%c",low[i][j]+edge[num[i][j]+num[i][j]-1].
214                             val,j==m?'':' ');
215         }
216     }
217     return 0;
218 }

```

4.4 2-sat

2-sat模版

poj_3683

如果 i,j 矛盾, 则`addege(i,j+n),addege(j,i+n)`

$i,j+n$ 矛盾 `addege(i,j),addege(j+n,i+n)`

$i+n,j$ 矛盾 `addege(i+n,j+n),addege(j,i)`

$i+n,j+n$ 矛盾 `addege(i+n,j),addege(j+n,i)`

`pd()`调用2-sat判断是否合法

调用`initialize()`初始化

`print_solution()`输出方案, 如果`ans[i]==1`则选择左点, 否则选择右点

```
1 # include <cstring>
2 # include <iostream>
3 # include <cstdio>
4 # include <cstdlib>
5 # define N 2500
6 # define M 2000000
7 using namespace std;
8 struct EDGE
9 {
10     int u,v,next;
11 }edge[M],edge2[M];
12 struct node
13 {
14     int s,e,len;
15 }a[N];
16 int first[N],DFN[N],divi[N],LOW[N],instack[N],stack[N];
17 int cf[N],choice[N],ind[N],q[N],ans[N],first2[N];
18 int cnt,cnt_edge,cnt_edge2,top,nowt;
19 inline void addege(int u,int v)
20 {
21     edge[cnt_edge].u=u;
22     edge[cnt_edge].v=v;
23     edge[cnt_edge].next=first[u];
24     first[u]=cnt_edge++;
25 }
26 inline void addege2(int u,int v)
27 {
28     edge2[cnt_edge2].v=v;
29     edge2[cnt_edge2].next=first2[u];
30     first2[u]=cnt_edge2++;
31 }
32 void tarjan(int u)
33 {
34     int v;
35     DFN[u]=LOW[u]=++nowt;
36     stack[++top]=u;
37     instack[u]=1;
38     for (int cur=first[u];cur!=-1;cur=edge[cur].next)
39     {
40         v=edge[cur].v;
41         if (!DFN[v])
42         {
43             tarjan(v);
44             LOW[u]=min(LOW[v],LOW[u]);
45         }
46         else
47             if (instack[v])
48                 LOW[u]=min(LOW[u],DFN[v]);
49     }
50     if (DFN[u]==LOW[u])
51     {
52         ++cnt;
```

```

53         do
54         {
55             v=stack[top--];
56             instack[v]=0;
57             divi[v]=cnt;
58         }
59         while (u!=v);
60     }
61 }
62 void initialize(void)
63 {
64     memset(first,-1,sizeof(first));
65     memset(first2,-1,sizeof(first2));
66     memset(instack,0,sizeof(instack));
67     memset(divi,0,sizeof(divi));
68     memset(DFN,0,sizeof(DFN));
69     memset(LOW,0,sizeof(LOW));
70     memset(choice,0,sizeof(choice));
71     memset(ind,0,sizeof(ind));
72     memset(ans,0,sizeof(ans));
73     nowt=cnt=top=0;
74     cnt_edge=cnt_edge2=0;
75 }
76 bool pd(int n)
77 {
78     for (int i=1;i<=2*n;i++)
79         if (!DFN[i])
80             tarjan(i);
81     for (int i=1;i<=n;i++)
82         if (divi[i]==divi[i+n])
83             return false;
84     return true;
85 }
86 void print_solution(int n)
87 {
88     for (int i=1;i<=n;i++)
89     {
90         cf[divi[i]]=divi[i+n];
91         cf[divi[i+n]]=divi[i];
92     }
93     for (int i=0;i<cnt_edge;i++)
94         if (divi[edge[i].u]!=divi[edge[i].v])// 反向连边
95         {
96             addedge2(divi[edge[i].v],divi[edge[i].u]);
97             ind[divi[edge[i].u]]++;
98         }
99     int head=0,tail=0,x;
100     for (int i=1;i<=cnt;i++)//topsort
101         if (!ind[i])
102             q[++tail]=i;
103     while (head++<tail)
104     {
105         x=q[head];
106         if (!choice[x])
107         {
108             choice[x]=1;
109             choice[cf[x]]=-1;
110         }
111         for (int cur=first2[x];cur!=-1;cur=edge2[cur].next)
112             if (--ind[edge2[cur].v]==0)
113                 q[++tail]=edge2[cur].v;
114     }
115     for (int i=1;i<=n;i++)

```

```

116         if (choice[divi[i]]==1)
117             ans[i]=1;
118     }
119     bool intersect(int x1,int y1,int x2,int y2)
120     {
121         if ((x2<y1 && y2>x1) || (x1<y2 && y1>x2))
122             return true;
123         return false;
124     }
125     int main (void)
126     {
127         int n,x,y;
128         scanf("%d",&n);
129         initialize();
130         for (int i=1;i<=n;i++)
131         {
132             scanf("%d:%d",&x,&y);
133             a[i].s=x*60+y;
134             scanf("%d:%d",&x,&y);
135             a[i].e=x*60+y;
136             scanf("%d",&a[i].len);
137             if (a[i].s+a[i].len>a[i].e)
138             {
139                 printf("NO\n");
140                 return 0;
141             }
142         }
143         for (int i=1;i<=n;i++)
144             for (int j=i+1;j<=n;j++)
145             {
146                 if (intersect(a[i].s,a[i].s+a[i].len,a[j].s,a[j].s+a[j].len))
147                 {
148                     addedge(i,j+n);
149                     addedge(j,i+n);
150                 }
151                 if (intersect(a[i].s,a[i].s+a[i].len,a[j].e-a[j].len,a[j].e))
152                 {
153                     addedge(i,j);
154                     addedge(j+n,i+n);
155                 }
156                 if (intersect(a[i].e-a[i].len,a[i].e,a[j].s,a[j].s+a[j].len))
157                 {
158                     addedge(i+n,j+n);
159                     addedge(j,i);
160                 }
161                 if (intersect(a[i].e-a[i].len,a[i].e,a[j].e-a[j].len,a[j].e))
162                 {
163                     addedge(i+n,j);
164                     addedge(j+n,i);
165                 }
166             }
167         if (!pd(n))
168             printf("NO\n");
169         else
170         {
171             printf("YES\n");
172             print_solution(n);
173             for (int i=1;i<=n;i++)
174             {
175                 if (ans[i])
176                 {
177                     x=a[i].s;
178                     y=a[i].s+a[i].len;

```

```

179         }
180     else
181     {
182         x=a[i].e-a[i].len;
183         y=a[i].e;
184     }
185     printf ("%02d:%02d %02d:%02d\n",x/60,x%60,y/60,y%60);
186 }
187 }
188 return 0;
189 }

```


4.5 A*求最短路

```
1  # include <cstring>
2  # include <queue>
3  # include <cstdlib>
4  # include <cstdio>
5  # include <iostream>
6  # define oo 200000000
7  # define N 1050
8  # define M 105000
9  using namespace std;
10 struct EDGE
11 {
12     int v,w,next;
13 }E[M],E1[M];
14 int first[N],first1[N],dist[N],vis[N],deg[N];
15 struct Po
16 {
17     int v,w;
18     bool operator <(const Po &a)const
19     {
20         return w+dist[v]>a.w+dist[a.v];
21     }
22 }Point;
23
24 inline void addedge(EDGE E[],int first[],int i,int u,int v,int c)
25 {
26     E[i].next=first[u];
27     E[i].v=v;
28     E[i].w=c;
29     first[u]=i;
30 }
31 void Dij(EDGE E[],int first[],int s,int n)
32 {
33     priority_queue <Po> Q;
34     Po tem;
35     int u,now;
36     memset(vis,0,sizeof(vis));
37     for (int i=1;i<=n;i++)
38         dist[i]=oo;
39     dist[s]=0;
40     tem.v=s;
41     tem.w=0;
42     Q.push(tem);
43     while (!Q.empty())
44     {
45         now=Q.top().v;
46         Q.pop();
47         if (vis[now])
48             continue;
49         vis[now]=1;
50         for (int cur=first[now];cur!=-1;cur=E[cur].next)
51         {
52             u=E[cur].v;
53             if (dist[u]>dist[now]+E[cur].w)
54             {
55                 dist[u]=dist[now]+E[cur].w;
56                 tem.v=u;
57                 tem.w=dist[u];
58                 Q.push(tem);
59             }
60         }
61     }
```

```

62 }
63 int A_star(EDGE E[],int first[],int s,int t,int k)
64 {
65     priority_queue <Po> Q;
66     Po tem,now;
67     memset(deg,0,sizeof(deg));
68     tem.v=s;
69     tem.w=0;
70     Q.push(tem);
71     while (!Q.empty())
72     {
73         tem=Q.top();
74         Q.pop();
75         deg[tem.v]++;
76         if (deg[tem.v]==k)
77             return tem.w+dist[tem.v];
78         for (int cur=first[tem.v];cur!=-1;cur=E[cur].next)
79         {
80             now.v=E[cur].v;
81             now.w=tem.w+E[cur].w;
82             if (deg[now.v]<k)
83                 Q.push(now);
84         }
85     }
86     return -1;
87 }
88 int main (void)
89 {
90     int n,m,s,t,k;
91     int x,y,z;
92     cin>>n>>m;
93     memset(first,-1,sizeof(first));
94     memset(first1,-1,sizeof(first1));
95     for (int i=0;i<m;i++)
96     {
97         scanf ("%d%d%d",&x,&y,&z);
98         addedge(E,first,i,x,y,z);
99         addedge(E1,first1,i,y,x,z);
100     }
101     cin>>s>>t>>k;
102     if (s==t)
103         k++;
104     Dij(E1,first1,t,n);
105     cout<<A_star(E,first,s,t,k)<<endl;
106     return 0;
107 }

```

4.6 带花树

求一般图最大匹配数的带花树算法

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #define N 1000
5  #define M 800000
6  using namespace std;
7
8  int first[N],next[M],end[M];
9  int cnt_edge;
10 int n;
11
12 char mark[N],blossom[N];
13 int que[N],pre[N],base[N],match[N]; //match数组记录匹配点
14
15 void addEdge(int u,int v) // 无向图求最大匹配需要双向加边
16 {
17     end[cnt_edge]=v;
18     next[cnt_edge]=first[u];
19     first[u]=cnt_edge++;
20 }
21
22 void argument(int u)
23 {
24     int k,v;
25
26     while (~u)
27     {
28         v=pre[u];
29         k=match[v];
30         match[u]=v;
31         match[v]=u;
32         u=k;
33     }
34 }
35
36 void changeblossom(int b,int u)
37 {
38     int v;
39
40     while (base[u]!=b)
41     {
42         v=match[u];
43         blossom[base[v]]=blossom[base[u]]=1;
44         u=pre[v];
45
46         if (base[u]!=b)
47             pre[u]=v;
48     }
49 }
50
51 int findbase(int u,int v)
52 {
53     char inp[N];
54
55     memset(inp,0,sizeof(inp));
56
57     while (1)
58     {
59
60
```

```

61         inp[u]=1;
62         if (match[u]==-1)
63             break;
64
65         u=base[pre[match[u]]];
66     }
67
68     while (!inp[v])
69         v=base[pre[match[v]]];
70
71     return v;
72
73 }
74
75 int contract(int u,int v)
76 {
77     int b;
78
79     memset(blossom,0,sizeof(blossom));
80     b=findbase(base[u],base[v]);
81     changeblossom(b,u);
82     changeblossom(b,v);
83
84     if (base[u]!=b)
85         pre[u]=v;
86     if (base[v]!=b)
87         pre[v]=u;
88
89     return b;
90
91 }
92
93 int bfs(int p)
94 {
95     int i,j,head,tail,u,v,b;
96
97     memset(pre,-1,sizeof(pre));
98     memset(mark,0,sizeof(mark));
99
100     for (i=0;i<n;i++)
101         base[i]=i;
102
103     que[0]=p;
104     mark[p]=1;
105     head=0,tail=1;
106
107     while (head<tail)
108     {
109         u=que[head++];
110
111         for (i=first[u];i;i=next[i])
112         {
113             v=end[i];
114
115             if (base[u]!=base[v]&&v!=match[u])
116             {
117                 if (v==p|| (match[v]!=-1&&pre[match[v]]!=-1))
118                 {
119                     b=contract(u,v);
120
121                     for (j=0;j<n;j++)
122                         if (blossom[base[j]])
123                             {

```

```

124         base[j]=b;
125
126         if (mark[j]==0)
127         {
128             mark[j]=1;
129             que[tail++]=j;
130         }
131     }
132 }
133 else if (pre[v]==-1)
134 {
135     pre[v]=u;
136
137     if (match[v]==-1)
138     {
139         argument(v);
140         return 1;
141     }
142     else
143     {
144         que[tail++]=match[v];
145         mark[match[v]]=1;
146     }
147 }
148 }
149 }
150 }
151
152 return 0;
153 }
154
155
156 int max_match() // 返回最大匹配数
157 {
158     int i,res=0;
159
160     memset(match,-1,sizeof(match));
161
162     for (i=0;i<n;i++)
163         if (match[i]==-1)
164             res+=bfs(i);
165
166     return res;
167 }
168
169 //ural1099: n个点(编号范围0~n-1)的无向图, 求最大匹配数, 并输出最大匹配方案。单组数据, 读入边
    以EOF结束。
170 int main()
171 {
172     int i,u,v,ans;
173
174     memset(first,0,sizeof(first));
175     cnt_edge=1;
176
177     scanf("%d",&n);
178     while (scanf("%d%d",&u,&v)!=EOF)
179     {
180         u--,v--;
181         addEdge(u,v);
182         addEdge(v,u);
183     }
184
185     ans=max_match();

```

```

186 |
187 |     printf ("%d\n", ans*2);
188 |
189 |     for (i=0; i<n; i++)
190 |         if (match[i] != -1 && i < match[i])
191 |             printf ("%d %d\n", i+1, match[i]+1);
192 |
193 |     return 0;
194 | }

```

4.7 KM算法

```
1  #include<cstdio>
2  #include<cmath>
3  #include<cstring>
4  #define N 105
5  #define oo 0x7fffffff
6  using namespace std;
7  struct Point
8  {
9      int x;
10     int y;
11 };
12
13 char str[N][N],mx[N],my[N];
14 int r,c,n,nx,ny,map[N][N],lx[N],ly[N],slack[N],res[N];
15
16 int find(int u)
17 {
18     int i,v,t;
19
20     mx[u]=1;
21
22     for (i=1;i<=n;i++)
23         if (my[i]==0)
24         {
25             v=i;
26             t=lx[u]+ly[v]-map[u][v];
27
28             if (t==0)
29             {
30                 my[v]=1;
31                 if (res[v]==0||find(res[v]))
32                 {
33                     res[v]=u;
34                     return 1;
35                 }
36             }
37             else
38             {
39                 if (slack[v]>t)
40                     slack[v]=t;
41             }
42         }
43
44     return 0;
45 }
46
47 void KM()
48 {
49
50
51     int i,j,d;
52
53     memset(res,0,sizeof(res));
54     memset(lx,0,sizeof(lx));
55     memset(ly,0,sizeof(ly));
56
57     for (i=1;i<=n;i++)
58         for (j=1;j<=n;j++)
59             if (lx[i]<map[i][j])
60                 lx[i]=map[i][j];
61 }
```

```

62     for (i=1;i<=n;i++)
63     {
64         for (j=1;j<=n;j++)
65             slack[j]=oo;
66
67         while (1)
68         {
69             memset(mx,0,sizeof(mx));
70             memset(my,0,sizeof(my));
71
72             if (find(i))
73                 break;
74             else
75             {
76                 d=oo;
77                 for (j=1;j<=n;j++)
78                     if (my[j]==0&&d>slack[j])
79                         d=slack[j];
80
81                 for (j=1;j<=n;j++)
82                     if (mx[j])
83                         lx[j]-=d;
84
85                 for (j=1;j<=n;j++)
86                     if (my[j])
87                         ly[j]+=d;
88                 else
89                     slack[j]-=d;
90             }
91         }
92     }
93 }
94
95 main()
96 {
97     int i,j,r,c,ans;
98     Point px[N],py[N];
99     while (scanf("%d%d",&r,&c),r||c)
100     {
101         for (i=0;i<r;i++)
102             scanf("%s",str[i]);
103
104         n=nx=ny=0;
105         for (i=0;i<r;i++)
106             for (j=0;j<c;j++)
107                 if (str[i][j]=='m')
108                 {
109                     px[++nx].x=i+1;
110                     px[nx].y=j+1;
111                 }
112                 else if (str[i][j]=='H')
113                 {
114                     py[++ny].x=i+1;
115                     py[ny].y=j+1;
116                 }
117         n=nx;
118
119         for (i=1;i<=n;i++)
120             for (j=1;j<=n;j++)
121                 map[i][j]=- (abs(px[i].x-py[j].x)+abs(px[i].y-py[j].y));
122
123         KM();
124

```



```
125         for (ans=0,i=1;i<=n;i++)
126             ans+=map[res[i]][i];
127
128         printf("%d\n",-ans);
129     }
130     return 0;
131 }
```

4.8 欧拉回路通路

当图中存在欧拉回路（通路）时，使用USACO算法能够找到一个可行方案

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<stack>
5  #define N 20000
6  #define M 110000
7  using namespace std;
8
9  int first[N],next[M],end[M],vis[M];
10 int cnt_edge;
11 stack<int>ans;
12
13 void addEdge(int u,int v)
14 {
15     end[cnt_edge]=v;
16     next[cnt_edge]=first[u];
17     first[u]=cnt_edge++;
18 }
19
20 // 无向图需要双向加边，欧拉通路需要选好起点，最后逆序（弹栈）输出
21 void USACO(int u)
22 {
23     int i,v;
24
25     for (i=first[u];i;i=next[i])
26     {
27         v=end[i];
28
29         if (vis[i]==0)
30         {
31             vis[i]=1;
32             USACO(v);
33         }
34     }
35
36     ans.push(u);
37 }
38
39 //poj2230
40 int main()
41 {
42     int n,m,u,v,i,j;
43
44     memset(first,0,sizeof(first));
45     memset(vis,0,sizeof(vis));
46     cnt_edge=1;
47
48     scanf("%d%d",&n,&m);
49     for (i=0;i<m;i++)
50     {
51         scanf("%d%d",&u,&v);
52         addEdge(u,v);
53         addEdge(v,u);
54     }
55
56     USACO(1);
57
58     while (!ans.empty())
59     {
60         printf("%d\n",ans.top());
```

```
61 |         ans.pop();
62 |     }
63 |
64 |     return 0;
65 | }
```

4.9 汉密尔顿回路

哈密顿回路 Dirac's Theorem: 对于一张顶点个数为 n 的无向图, 若 $n \geq 3$ 且每个顶点的度不小于 $(n+1)/2$, 那么一定存在哈密顿回路。 以下为满足此性质的图中求哈密顿回路的算法, 时间复杂度为 $O(n^2)$ 。

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #define N 200
5  using namespace std;
6
7  struct node
8  {
9      int id;
10     node *next;
11
12     node (int u=0,node *x=NULL)
13     {
14         id=u;
15         next=x;
16     }
17 };
18
19 node *hs,*he,*cur; //hs为链的头指针, he为尾指针
20 char map[N][N],mark[N]; //map[u][v]为1则顶点u、v关联
21 int n,m,size;
22
23 void init()
24 {
25     memset(map,0,sizeof(map));
26     memset(mark,0,sizeof(mark));
27     hs=he=cur=NULL;
28 }
29
30 void reverse(node *v)
31 {
32     if (v==he)
33     {
34         cur=he;
35         return;
36     }
37
38     reverse(v->next);
39     cur->next=v;
40     cur=v;
41 }
42
43 void change(node *v1,node *v2)
44 {
45     v1->next=he;
46     reverse(v2);
47 }
48
49 void solve()
50 {
51     int i;
52
53     hs=new node(1,NULL);
54     mark[1]=1;
55
56     for (i=2;i<=n;i++)
57         if (map[i][1])
58         {
59             he=new node(i,NULL);
```

```

60
61         hs->next=he;
62         mark[i]=1;
63         break;
64     }
65
66     size=2;
67     while (1)
68     {
69         for (i=1;i<=n;i++)
70         {
71             if (mark[i])
72                 continue;
73
74             if (map[i][hs->id]&&mark[i]==0)
75             {
76                 mark[i]=1;
77                 size++;
78                 hs=new node(i,hs);
79             }
80
81             if (map[i][he->id]&&mark[i]==0)
82             {
83                 mark[i]=1;
84                 size++;
85                 node *tmp=he;
86                 he=new node(i,NULL);
87                 tmp->next=he;
88             }
89         }
90
91         if (map[hs->id][he->id]==0)
92         {
93             node *tmp=hs->next;
94
95             while (tmp->next!=he&&tmp!=he)
96             {
97                 if (map[hs->id][tmp->next->id]==1&&map[he->id][tmp->id]==1)
98                 {
99                     change(tmp,tmp->next);
100                     he=cur;
101                     he->next=NULL;
102                     cur=NULL;
103                     break;
104                 }
105                 tmp=tmp->next;
106             }
107         }
108
109         if (size==n)
110             break;
111
112         for (i=1;i<=n;i++)
113         {
114             if (mark[i])
115                 continue;
116
117             node *tmp=hs;
118
119             while (tmp!=NULL)
120             {
121                 if (map[i][tmp->id])
122                     {

```

```

123         he->next=hs;
124         hs=tmp->next;
125         he=new node(i,NULL);
126         tmp->next=he;
127         mark[i]=1;
128         size++;
129         break;
130     }
131     tmp=tmp->next;
132 }
133
134     if (map[hs->id][he->id]==0)
135         break;
136 }
137 }
138 }
139
140 void print()
141 {
142     node *tmp=hs;
143
144     printf("%d",tmp->id);
145     tmp=tmp->next;
146
147     while (tmp!=NULL)
148     {
149         printf(" %d",tmp->id);
150         tmp=tmp->next;
151     }
152
153     printf("\n");
154 }
155
156 //hdu4337: 求满足Dirac's Theorem中条件的图 的哈密顿回路的方案
157 int main()
158 {
159     int i,u,v;
160
161     while (scanf("%d%d",&n,&m)!=EOF)
162     {
163         init();
164
165         for (i=0;i<m;i++)
166         {
167             scanf("%d%d",&u,&v);
168             map[u][v]=map[v][u]=1;
169         }
170
171         solve();
172         print();
173     }
174
175     return 0;
176 }

```

4.10 最小树形图

4.10.1 邻接表

```
1  #include<iostream>
2  #include<cstdio>
3  #include<cstring>
4  #include<cmath>
5  #define oo 1000000000
6  #define N 1005
7  #define M 2000100
8  using namespace std;
9
10 struct Point
11 {
12     int x,y,z;
13 };
14
15 struct Edge
16 {
17     int u,v,w;
18 };
19
20 Edge edge[M];
21 Point pt[N];
22 int pre[N],in[N],color[N],mark[N];
23 int cnt_edge;
24
25 void addEdge(int u,int v,int w)
26 {
27     edge[cnt_edge].u=u;
28     edge[cnt_edge].v=v;
29     edge[cnt_edge].w=w;
30     cnt_edge++;
31 }
32
33
34 int dis(Point a,Point b)
35 {
36     return abs(a.x-b.x)+abs(a.y-b.y)+abs(a.z-b.z);
37 }
38
39 int ZhuLiu(int root,int n,int m)
40 {
41     int i,j,u,v,w,cnt;
42     int res=0;
43
44     while (1)
45     {
46         for (i=1;i<=n;i++)
47             in[i]=oo;
48         for (i=0;i<m;i++)
49         {
50             u=edge[i].u;
51             v=edge[i].v;
52             w=edge[i].w;
53
54             if (in[v]>w&&u!=v)
55             {
56                 in[v]=w;
57                 pre[v]=u;
58             }
59         }
60     }
```

```

61     for (i=1;i<=n;i++)
62         if (i!=root&&in[i]==oo)
63             return -1;
64
65     memset(mark,0,sizeof(mark));
66     memset(color,0,sizeof(color));
67     mark[root]=1;
68     in[root]=0;
69     cnt=0;
70
71     for (i=1;i<=n;i++)
72     {
73         res+=in[i];
74         v=i;
75         while (mark[v]!=i&&color[v]==0&&v!=root)
76         {
77             mark[v]=i;
78             v=pre[v];
79         }
80
81         if (v!=root&&color[v]==0)
82         {
83             cnt++;
84             for (u=pre[v];u!=v;u=pre[u])
85                 color[u]=cnt;
86             color[v]=cnt;
87         }
88     }
89
90     if (cnt==0)
91         break;
92     for (i=1;i<=n;i++)
93         if (color[i]==0)
94             color[i]=++cnt;
95     for (i=0;i<m;i++)
96     {
97         v=edge[i].v;
98         edge[i].u=color[edge[i].u];
99         edge[i].v=color[edge[i].v];
100         if (edge[i].u!=edge[i].v)
101             edge[i].w-=in[v];
102     }
103
104     n=cnt;
105     root=color[root];
106 }
107
108 return res;
109 }
110
111 int main()
112 {
113     int n,m,i,u,v,w,mx,my,mz;
114
115     while (scanf("%d%d%d%d",&n,&mx,&my,&mz),n||mx||my||mz)
116     {
117         cnt_edge=0;
118         for (i=1;i<=n;i++)
119             scanf("%d%d%d",&pt[i].x,&pt[i].y,&pt[i].z);
120
121         for (i=1;i<=n;i++)
122         {
123             u=i;

```



```

124         scanf("%d",&m);
125         while (m--)
126         {
127             scanf("%d",&v);
128             if (u==v)
129                 continue;
130             w=dis(pt[u],pt[v])*my;
131             if (pt[u].z<pt[v].z)
132                 w+=mz;
133
134             addEdge(u,v,w);
135         }
136         addEdge(n+1,i,pt[i].z*mx);
137     }
138
139     printf("%d\n",ZhuLiu(n+1,n+1,cnt_edge));
140 }
141
142
143     return 0;
144 }

```

4.10.2 邻接矩阵

```

1  #include<iostream>
2  #include<cstdio>
3  #include<cstring>
4  #include<cmath>
5  #include<algorithm>
6  #define oo 1e15
7  #define eps 1e-6
8  #define N 105
9  #define M 10010
10 using namespace std;
11
12 struct Point
13 {
14     double x,y;
15 };
16 Point pt[N];
17
18 double dis(Point a,Point b)
19 {
20     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
21 }
22
23 double map[N][N];
24 int pre[N];
25 char mark[N],flag[N];
26 int n;
27 void dfs(int u)
28 {
29     int i;
30
31     mark[u]=1;
32     for (i=1;i<=n;i++)
33         if (mark[i]==0&&map[u][i]<oo)
34             dfs(i);
35 }
36
37 int connect(int root)
38 {
39     int i;
40

```

```

41     memset(mark,0,sizeof(mark));
42     dfs(root);
43
44     for (i=1;i<=n;i++)
45         if (mark[i]==0)
46             return 0;
47     return 1;
48 }
49
50 double ZhuLiu(int root)
51 {
52     int i,j,k;
53     double res=0;
54
55     memset(flag,0,sizeof(flag));
56
57     while (1)
58     {
59         for (i=1;i<=n;i++)
60         {
61             if (flag[i]||i==root)
62                 continue;
63
64             pre[i]=i;
65             map[i][i]=oo;
66             for (j=1;j<=n;j++)
67                 if (!flag[j]&&map[j][i]<map[pre[i]][i])
68                     pre[i]=j;
69         }
70
71         for (i=1;i<=n;i++)
72         {
73             if (flag[i]||i==root)
74                 continue;
75
76             memset(mark,0,sizeof(mark));
77             mark[root]=1;
78             j=i;
79
80             do
81             {
82                 mark[j]=1;
83                 j=pre[j];
84             }while (!mark[j]);
85
86             if (j==root)
87                 continue;
88
89             i=j;
90             res+=map[pre[i]][i];
91             for (j=pre[i];j!=i;j=pre[j])
92             {
93                 flag[j]=1;
94                 res+=map[pre[j]][j];
95             }
96
97             for (j=1;j<=n;j++)
98                 if (!flag[j]&&map[j][i]<oo)
99                     map[j][i]-=map[pre[i]][i];
100
101             for (j=pre[i];j!=i;j=pre[j])
102                 for (k=1;k<=n;k++)
103                     if (!flag[k])

```

```

104         {
105             map[i][k]=min(map[i][k],map[j][k]);
106             if (map[k][j]<oo)
107                 map[k][i]=min(map[k][i],map[k][j]-map[pre[j]][j]
108                     );
109         }
110         break;
111     }
112     if (i>n)
113     {
114         for (j=1;j<=n;j++)
115             if (!flag[j]&&j!=root)
116                 res+=map[pre[j]][j];
117         break;
118     }
119 }
120
121 return res;
122 }
123
124 int main()
125 {
126     int m,i,j,u,v;
127
128     while (scanf("%d%d",&n,&m)!=EOF)
129     {
130         for (i=0;i<=n;i++)
131             for (j=0;j<=n;j++)
132                 map[i][j]=oo;
133
134         for (i=1;i<=n;i++)
135             scanf("%lf%lf",&pt[i].x,&pt[i].y);
136         for (i=0;i<m;i++)
137         {
138             scanf("%d%d",&u,&v);
139             map[u][v]=min(map[u][v],dis(pt[u],pt[v]));
140         }
141
142         if (connect(1))
143             printf("%.2f\n",ZhuLiu(1));
144         else
145             printf("poor snoopy\n");
146     }
147
148     return 0;
149 }

```

4.11 稳定婚姻

解题思路：此题为一道典型的稳定婚姻问题，如果男A与女C匹配，男B与女D 匹配，但是A更喜欢D，D更喜欢A，那么这个婚姻就不是稳定的。稳定婚姻问题的算法步骤大致如下：（男士优先）

1.男士先选择自己最爱的人去求婚，如果有多个男士的最爱相同，那么女士就选择更爱的那位男士，那么其他的男士在这次求婚中失败。

2.上次求婚失败的男士再选择自己次爱的女士进行求婚，如果这位女士没有匹配男士，那么这两个人就进行匹配，如果这位女士有匹配的男士，但是如果这位女士更喜欢这位正在求婚的男士，那么这位女士就可以抛弃原有的男士而与这位她更爱的男士匹配。而原有的男士在这次匹配中失败。

3.上次求婚失败的男士(包括被女士抛弃的男士)再次选择自己次爱的女士求婚，知道所有的男士与女士全部匹配则结束。此算法被证明必定存在解，刚才所写的步骤是基于男士优先的。如果是女士向男士求婚，那么就是基于女士优先的，算法步骤和上面的基本相同，只要将男女调换就可以了。

```
1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  #include<map>
5  #include<string>
6  using namespace std;
7  const int N = 1010;
8  map<string,int> gmp,bmp;
9  string s;
10 int b[N][N],g[N][N],match[N],vis[N],v[N][N];
11 string boy[N],girl[N];
12 int n;
13 int num;
14 void find(int x)
15 {
16     int t=0;
17     for(int i=1;i<=n;i++){
18         if(!v[i][x]&&(t==0||g[x][t]>g[x][i])){
19             t=i;
20         }
21     }
22     v[t][x]=1;
23     if(!match[t]){
24         match[t]=x;vis[x]=1;num++;
25     }else{
26         if(b[t][x]<b[t][match[t]]){
27             vis[match[t]]=0;
28             match[t]=x;vis[x]=1;
29         }
30     }
31 }
32 void solve()
33 {
34     num=0;
35     memset(vis,0,sizeof(vis));
36     memset(v,0,sizeof(v));
37     memset(match,0,sizeof(match));
38     while(num<n){
39         for(int i=1;i<=n;i++){
40             if(!vis[i]) find(i);
41         }
42     }
43 }
44 int main(void)
45 {
46     while(scanf("%d",&n)!=EOF)
47     {
48         bmp.clear(),gmp.clear();
49         memset(g,0,sizeof(g));
50         memset(b,0,sizeof(b));
51         int k=0;
```

```

52     for(int i=1;i<=n;i++){
53         cin>>s;
54         boy[i]=s;
55         bmp[s]=i;
56         for(int j=1;j<=n;j++){
57             cin>>s;
58             if(gmp[s]==0){
59                 gmp[s]=++k;
60                 girl[k]=s;
61             }
62             b[i][gmp[s]]=j;
63         }
64     }
65     for(int i=1;i<=n;i++){
66         cin>>s;
67         int t=gmp[s];
68         for(int j=1;j<=n;j++){
69             cin>>s;
70             g[t][bmp[s]]=j;
71         }
72     }
73     solve();
74     for(int i=1;i<=n;i++){
75         cout<<boy[i]<<" "<<girl[match[i]]<<endl;
76     }
77 }
78 return 0;
79 }

```

4.12 最优比率生成树

poj_2728

dis[i][j]是i到j的距离

cost[i][j]修建i,j这条边的花费。

要求总花费比总距离最小（单位距离花费最小）

```
1  # include <cstdio>
2  # include <iostream>
3  # include <cstring>
4  # include <cmath>
5  # define N 1050
6  # define bignum 200000000
7  using namespace std;
8  double x[N],y[N],z[N],val[N],dis[N][N],cost[N][N],map[N][N];
9  int vis[N];
10 inline double prim(double x,int n)
11 {
12     for (int i=1;i<n;i++)
13         for (int j=i+1;j<=n;j++)
14             map[i][j]=map[j][i]=cost[i][j]-x*dis[i][j];
15     memset(vis,0,sizeof(int)*(n+10));
16     for (int i=2;i<=n;i++)
17         val[i]=map[1][i];
18     vis[1]=1;
19     double ans=0,Min;
20     int now;
21     for (int p=1;p<n;p++)
22     {
23         Min = bignum;
24         for (int i=2;i<=n;i++)
25             if (!vis[i] && val[i]<Min)
26             {
27                 now=i;
28                 Min=val[i];
29             }
30         vis[now]=1;
31         ans+=Min;
32         for (int i=2;i<=n;i++)
33             if (!vis[i])
34                 val[i]=min(val[i],map[now][i]);
35     }
36     return ans;
37 }
38 int main (void)
39 {
40     int n;
41     while (scanf("%d",&n)!=EOF && n)
42     {
43         double Min=bignum;
44         for (int i=1;i<=n;i++)
45         {
46             scanf("%lf%lf%lf",&x[i],&y[i],&z[i]);
47             for (int j=1;j<i;j++)
48             {
49                 cost[i][j]=cost[j][i]=fabs(z[i]-z[j]);
50                 dis[i][j]=dis[j][i]=sqrt((x[i]-x[j])*(x[i]-x[j])+(y[i]-y[j])
51                     *(y[i]-y[j]));
52                 if ( fabs(dis[i][j])>1e-2 && cost[i][j]/dis[i][j]<Min)
53                     Min=cost[i][j]/dis[i][j];
54             }
55         }
56         double left=Min,right,mid,sum1=0,sum2=0;
```

```

57     {
58         sum1+=cost[i][1];
59         sum2+=dis[i][1];
60     }
61     right=sum1/sum2;
62     while (right-left>1e-4)
63     {
64         mid=(right+left)/2;
65         if (prim(mid,n)>0)
66             left=mid;
67         else right=mid;
68     }
69     printf("%.3f\n",left);
70 }
71 return 0;
72 }

```

5 DP

5.1 插头DP

```
1  # include <cstring>
2  # include <cstdlib>
3  # include <cstdio>
4  # include <iostream>
5  # define HashMod 1999997
6  # define LEN 700000
7  # define N 15
8  using namespace std;
9  int HHash[HashMod];
10 int state[2][LEN],tot[2];
11 long long sum[2][LEN];
12 int a[N][N];
13 int n,m,nn,mm;
14 inline void Hash_in(int k,int s,long long data)
15 {
16     int hashpos=s%HashMod;
17     while (HHash[hashpos])
18     {
19         if (state[k][HHash[hashpos]]==s)
20         {
21             sum[k][HHash[hashpos]]+=data;
22             return;
23         }
24         hashpos++;
25         if (hashpos==HashMod) hashpos=0;
26     }
27     HHash[hashpos]=++tot[k];
28     state[k][tot[k]]=s;
29     sum[k][tot[k]]=data;
30 }
31 long long solve (void)
32 {
33     int k=0,jz[N];
34     int s,temps,p,q,bracket,w;
35     long long data,ans=0;
36     for (int i=0;i<N;i++)
37         jz[i]=i<1;
38     tot[0]=1;
39     state[0][1]=0;
40     sum[0][1]=1;
41     for (int i=1;i<=n;i++)
42     {
43         for (int j=1;j<=m;j++)
44         {
45             k^=1;
46             tot[k]=0;
47             memset(HHash,0,sizeof(HHash));
48             memset(state[k],0,sizeof(state[k]));
49             memset(sum[k],0,sizeof(sum[k]));
50             for (int now=1;now<=tot[k^1];now++)
51             {
52                 s=state[k^1][now];
53                 data=sum[k^1][now];
54                 p=(s>>jz[j-1])%4;
55                 q=(s>>jz[j])%4;
56                 if (!a[i][j])
57                 {
58                     if (p==0 && q==0)
59                         Hash_in(k,s,data);
```



```

60         continue;
61     }
62     if (p==2 && q==1)
63     {
64         temps=s-2*(1<<jz[j-1])-(1<<jz[j]);
65         Hash_in(k,temps,data);
66         continue;
67     }
68     if (p==1 && q==2)
69     {
70         if (i==nn && j==mm)
71             ans+=data;
72         continue;
73     }
74     if (p==1 && q==1)
75     {
76         bracket=1;
77         temps=s-(1<<jz[j-1])-(1<<jz[j]);
78         for (int x=j+1;x<=m;x++)
79         {
80             w=(s>>jz[x])%4;
81             if (w==1)
82                 bracket++;
83             if (w==2)
84                 bracket--;
85             if (bracket==0)
86             {
87                 temps=temps-(1<<jz[x]);
88                 break;
89             }
90         }
91         Hash_in(k,temps,data);
92         continue;
93     }
94     if (p==2 && q==2)
95     {
96         bracket=1;
97         temps=s-2*(1<<jz[j-1])-2*(1<<jz[j]);
98         for (int x=j-2;x>=0;x--)
99         {
100             w=(s>>jz[x])%4;
101             if (w==1)
102                 bracket--;
103             if (w==2)
104                 bracket++;
105             if (bracket==0)
106             {
107                 temps=temps+(1<<jz[x]);
108                 break;
109             }
110         }
111         Hash_in(k,temps,data);
112         continue;
113     }
114     if (p==0 && q==0)
115     {
116         if (a[i][j+1] && a[i+1][j])
117         {
118             temps=s+(1<<jz[j-1])+2*(1<<jz[j]);
119             Hash_in(k,temps,data);
120         }
121         continue;
122     }

```

```

123         if (p==0 && q>0)
124         {
125             if (a[i][j+1])
126                 Hash_in(k,s,data);
127             if (a[i+1][j])
128             {
129                 temps=s-q*(1<<jz[j])+q*(1<<jz[j-1]);
130                 Hash_in(k,temps,data);
131             }
132         }
133         if (p>0 && q==0)
134         {
135             if (a[i+1][j])
136                 Hash_in(k,s,data);
137             if (a[i][j+1])
138             {
139                 temps=s-p*(1<<jz[j-1])+p*(1<<jz[j]);
140                 Hash_in(k,temps,data);
141             }
142             continue;
143         }
144     }
145 }
146 for (int now=1;now<=tot[k];now++)
147     state[k][now]<=2;
148 }
149 return ans;
150 }
151 int main (void)
152 {
153     char ss[50];
154     memset(a,0,sizeof(a));
155     cin>>n>>m;
156     for (int i=1;i<=n;i++)
157     {
158         scanf("%s",ss+1);
159         for (int j=1;j<=m;j++)
160         {
161             a[i][j]=ss[j]=='.';
162             if (a[i][j])
163             {
164                 nn=i;
165                 mm=j;
166             }
167         }
168     }
169     cout<<solve()<<endl;
170     return 0;
171 }

```

5.2 数位DP

CF55D

```
1 #include<iostream>
2 #include<cstring>
3 #include<cstdio>
4 using namespace std;
5 #ifdef WINDOWS
6 #define LOL __int64
7 #else
8 #define LOL long long
9 #endif
10 LOL dp[50][2600][50];
11 int c[2600],g[2600][30];
12 int v[50];
13 int b[30],a[30];
14 int gcd(int a,int b)
15 {
16     if(b==0) return a;
17     return gcd(b,a%b);
18 }
19 int lcm(int a,int b)
20 {
21     if(a>b) swap(a,b);
22     if(a==0) return b;
23     return a*b/gcd(a,b);
24 }
25 LOL dfs(int l,int pre,int lcm,bool z)
26 {
27     if(l==0) return pre%lcm==0;
28     if(!z&&dp[l][pre][c[lcm]]!=-1) return dp[l][pre][c[lcm]];
29     LOL ans=0;
30     int u=z?a[l]:9;
31     for(int i=0;i<=u;i++)
32     {
33         int npre=(pre*10+i)%2520,nlcm=g[lcm][i];
34         ans+=dfs(l-1,npre,nlcm,i==u&&z);
35     }
36     if(!z)
37     {
38         dp[l][pre][c[lcm]]=ans;
39     }
40     return ans;
41 }
42 LOL solve(LOL x)
43 {
44     int n=0;
45     while(x!=0)
46     {
47         a[++n]=x%10;
48         x/=10;
49     }
50     return dfs(n,0,1,1);
51 }
52 int main(void)
53 {
54     memset(dp,0,sizeof(dp));
55     b[0]=1;
56     for(int i=1;i<=20;i++)
57     {
58         b[i]=(b[i-1]*10)%2520;
59     }
60     for(int i=1,r=-1;i<=2520;i++)
```

```

61     {
62         if (2520%i==0)
63         {
64             r++;
65             v[r]=i;
66         }
67         c[i]=r;
68     }
69     for(int j=0;j<10;++j){
70         for(int i=1;i<=2520;++i)
71             g[i][j]=j?i*j/gcd(i,j):i;
72     }
73     memset(dp,-1,sizeof(dp));
74     int T;
75     LOL a,b;
76     cin>>T;
77     while(T--)
78     {
79         cin>>a>>b;
80         cout<<solve(b)-solve(a-1)<<endl;
81     }
82     return 0;
83 }

```

5.3 最大平均子段和

```
1 # include <stdio>
2 # include <cstring>
3 # include <cmath>
4 # define N 1060000
5 using namespace std ;
6 __int64 sum [ N ] ,q[ N ];
7 int GetInt()
8 {
9     char ch=getchar();
10    while(ch<'0' || ch>'9')
11        ch=getchar();
12    int num=0;
13    while(ch>='0' && ch<='9')
14    {
15        num=num*10+ch-'0';
16        ch=getchar();
17    }
18    return num;
19 }
20 double MAX (double x , double y)
21 {
22     return x>y?x:y;
23 }
24 int main ( void )
25 {
26     __int64 x1,y1,x2,y2;
27     int head , tail ;
28     int n , k ,x;
29     while (scanf ("%d%d",&n,&k) !=EOF)
30     {
31         for (int i=1;i<=n;i++)
32         {
33             x=GetInt();
34             sum[i]=sum[i-1]+x;
35         }
36         tail = 0 ;
37         head = 1 ;
38         double ans = 0 ;
39         for (int i=k;i<=n;i++)
40         {
41             int now = i-k;
42             while (head<tail)
43             {
44                 x1=now-q[tail];
45                 y1=sum[now]-sum[q[tail]];
46                 x2=q[tail]-q[tail-1];
47                 y2=sum[q[tail]]-sum[q[tail-1]];
48                 if (x1*y2-x2*y1>=0)
49                     tail--;
50                 else break;
51             }
52             q[++tail]=now;
53             while (head<tail)
54             {
55                 x1=i-q[head+1];
56                 y1=sum[i]-sum[q[head+1]];
57                 x2=q[head+1]-q[head];
58                 y2=sum[q[head+1]]-sum[q[head]];
59                 if (x1*y2-x2*y1<=0)
60                     head++;
61                 else break ;
```

```

62         }
63         ans = MAX (ans,double(sum[i]-sum[q[head]])/double (i-q[head]));
64     }
65     printf("%.2lf\n",ans);
66 }
67 return 0 ;
68 }

```

5.4 斯坦纳树

```
1  # include <cstring>
2  # include <cstdio>
3  # include <cstdlib>
4  # include <iostream>
5  using namespace std;
6  # define oo 200000000
7  # define N 55
8  int dp[2000][N],val[2000];
9  int f[N][N],num[N],l[N],n,k;
10 inline int lowbit(int x)
11 {
12     return x&(-x);
13 }
14 int judge(int x)
15 {
16     int cnt1=0,cnt2=0;
17     for (int i=0;i<n;i++)
18     {
19         if (num[i]==-1) continue;
20         if (x&(1<<num[i]))
21         {
22             if (num[i]<k) cnt1++;
23             else cnt2++;
24         }
25     }
26     return (cnt1==cnt2);
27 }
28 int main (void)
29 {
30     int t,m,u,v,c;
31     scanf("%d",&t);
32     while (t--)
33     {
34         scanf("%d%d%d",&n,&m,&k);
35         for (int i=0;i<n;i++)
36             for (int j=0;j<n;j++)
37                 if (i!=j)
38                     f[i][j]=oo;
39         for (int i=1;i<=m;i++)
40         {
41             scanf("%d%d%d",&u,&v,&c);
42             u--,v--;
43             f[u][v]=min(f[u][v],c);
44             f[v][u]=min(f[v][u],c);
45         }
46         for (int p=0;p<n;p++)
47             for (int i=0;i<n;i++)
48                 for (int j=0;j<n;j++)
49                     f[i][j]=min(f[i][j],f[i][p]+f[p][j]);
50         memset(num,-1,sizeof(num));
51         memset(dp,-1,sizeof(dp));
52         int tot=0;
53         for (int i=0;i<k;i++)
54             num[i]=tot++;
55         for (int i=n-k;i<n;i++)
56             num[i]=tot++;
57         for (int i=0;i<n;i++)
58         {
59             int s=0;
60             if (num[i]!=-1)
```

```

62         s=(1<<num[i]);
63         dp[s][i]=0;
64     }
65     int all=(1<<(k<<1));
66     for (int i=1;i<all;i++)
67         val[i]=oo;
68     for (int i=1;i<all;i++)
69     {
70         for (int j=0;j<n;j++)
71         {
72             for (int s=(i-1)&i;s;s=(s-1)&i)
73             {
74                 if (dp[s][j]==-1 || dp[i^s][j]==-1) continue;
75                 if (dp[i][j]==-1 || dp[i][j]>dp[s][j]+dp[i^s][j])
76                     dp[i][j]=dp[s][j]+dp[i^s][j];
77             }
78             if (dp[i][j]==-1) continue;
79             val[i]=min(val[i],dp[i][j]);
80             for (int q=0;q<n;q++)
81                 if (f[j][q]<oo)
82                     if (dp[i][q]==-1 || dp[i][q]>dp[i][j]+f[j][q])
83                         dp[i][q]=dp[i][j]+f[j][q];
84         }
85     }
86     for (int i=0;i<all;i++)
87         if (judge(i))
88             for (int j=0;j<i;j++)
89                 if (judge(j) && ((i&j)==j))
90                     val[i]=min(val[i],val[j]+val[i^j]);
91     if (val[all-1]<oo)
92         printf("%d\n",val[all-1]);
93     else printf("No solution\n");
94 }
95 return 0;
96 }

```


5.5 四边形不等式

状态转移方程如 $m(i, j) = m(i, k-1) + m(k, j) + w(i, j)$, 假设 $a \leq b < c \leq d$, 如果满足 $w(a, c) + w(b, d) \leq w(b, c) + w(a, d)$, 那么称 w 满足四边形不等式。若 w 满足四边形不等式, 则 m 也满足四边形不等式, 其决策 $s(i, j)$ 满足: $s(i, j-1) \leq s(i, j) \leq s(i+1, j)$

hdu3516 Consider a two-dimensional space with a set of points (x_i, y_i) that satisfy $x_i < x_j$ and $y_i > y_j$ for all $i < j$. We want to have them all connected by a directed tree whose edges go toward either right (x positive) or upward (y positive). Find a tree connecting all given points with the shortest total length of edges.

```
1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4 #define N 1010
5 #define oo 0x3fffffff
6 using namespace std;
7
8 int dp[N][N], s[N][N], x[N], y[N];
9
10 int main()
11 {
12     int n, i, j, k;
13
14     while (scanf("%d", &n) != EOF)
15     {
16         for (i=0; i<n; i++)
17             scanf("%d%d", &x[i], &y[i]);
18
19         if (n==1)
20         {
21             printf("0\n");
22             continue;
23         }
24
25         for (j=1; j<n; j++)
26         {
27             dp[j-1][j] = x[j] - x[j-1] + y[j-1] - y[j];
28             s[j-1][j] = j-1;
29
30             for (i=j-2; i>=0; i--)
31             {
32                 dp[i][j] = oo;
33
34                 for (k=s[i][j-1]; k<=s[i+1][j]; k++)
35                     if (dp[i][j] > dp[i][k] + dp[k+1][j] + x[k+1] - x[i] + y[k] - y[j])
36                     {
37                         dp[i][j] = dp[i][k] + dp[k+1][j] + x[k+1] - x[i] + y[k] - y[j];
38                         s[i][j] = k;
39                     }
40             }
41         }
42
43         printf("%d\n", dp[0][n-1]);
44     }
45
46     return 0;
47 }
```

```
1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4 #define N 301
5 #define M 32
6 #define oo 0x3fffffff
7 using namespace std;
```

```

8
9 int dp[M][N],s[M][N],w[N][N],p[N];
10
11 int main()
12 {
13     int n,m,i,j,k;
14
15     scanf("%d%d",&n,&m);
16
17     for (i=1;i<=n;i++)
18         scanf("%d",&p[i]);
19
20     for (i=1;i<=n;i++)
21     {
22         w[i][i]=0;
23         for (j=i+1;j<=n;j++)
24             w[i][j]=w[i][j-1]+p[j]-p[(i+j)/2];
25     }
26
27     memset(dp,0,sizeof(dp));
28
29     for (i=0;i<=n;i++)
30     {
31         dp[min(i,m+1)][i]=0;
32         s[min(i,m+1)][i]=i;
33     }
34
35     for (i=1;i<=n;i++)
36     {
37         dp[0][i]=oo;
38         for (j=min(i-1,m);j>0;j--)
39         {
40             dp[j][i]=oo;
41             for (k=s[j][i-1];k<=s[j+1][i];k++)
42                 if (dp[j][i]>dp[j-1][k-1]+w[k][i])
43                 {
44                     dp[j][i]=dp[j-1][k-1]+w[k][i];
45                     s[j][i]=k;
46                 }
47         }
48     }
49
50     printf("%d\n",dp[m][n]);
51
52     return 0;
53 }

```

6 数学

6.1 数学结论

当 $b \geq \phi(c)$ 时:

$$a^b = a^{b \% \phi(c) + \phi(c)} \pmod{c}$$

6.2 数论基础

```
1 #include <cstdio>
2 #include <cmath>
3 #include <cstring>
4 #include <iostream>
5 #define M 9901
6 using namespace std;
7 typedef __int64 typec;
8 ///teoy's number theory template
9 ///functions
10 /*****
11 gcd
12 *****/
13 typec gcd(typec a, typec b)
14 {
15     if(b==0) return a;
16     return gcd(b,a%b);
17 }
18 /*****
19 Extend_GCD
20 *****/
21 typec extendGCD(typec a, typec b, typec& x, typec& y)
22 {
23     if(!b) return x = 1, y = 0, a;
24     typec res = extendGCD(b, a % b, x, y), tmp = x;
25     x = y, y = tmp - (a / b) * y;
26     return res;
27 }
28 /*****求对的逆元
29 ap
30 *****/
31 typec inverse(typec a, typec p)
32 {
33     typec x, y;
34     y = extendGCD(a, p, x, y);
35     return x < 0 ? x += p : x;
36 }
37 /*****
38 abss for abs();
39 kgcd for quick gcd;
40 *****/
41 typec abss(typec a)
42 {
43     if(a<0) return -a;
44     return a;
45 }
46 typec kgcd(typec a,typec b)
47 {
48     if(a==0) return b;
49     if(b==0) return a;
50     if(!(a&1)&&!(b&1)) return kgcd(a>>1,b>>1)<<1;
51     else if(!(b&1)) return kgcd(a,b>>1);
52     else if(!(a&1)) return kgcd(a>>1,b);
53     else return kgcd(abss(a-b),min(a,b));
54 }
55
56
57 /*****
58 for x^k
59 *****/
60 typec power(typec x,typec k)
61 {
```

```

62     typec ans=1;
63     while(k)
64     {
65         if(k&1) ans*=x;
66         x*=x;
67         k>>=1;
68     }
69     return ans;
70 }
71 /*****
72 for (x^k)%mod
73 *****/
74 typec powermod(typec x,typec k,typec mod)
75 {
76     typec ans=1;
77     while(k)
78     {
79         if(k&1)
80         {
81             ans=(ans*x)%mod;
82         }
83         x=(x*x)%mod;
84         k>>=1;
85     }
86     return ans;
87 }
88 /*****
89 prime table
90 O(n)
91 prime[0] for the primes number in the PRIMERANGE
92 prime[i] for i th prime number
93 *****/
94 const int PRIMERANGE = 100000;
95 int prime[PRIMERANGE + 1];
96 int getPrime()
97 {
98     memset (prime, 0, sizeof (int) * (PRIMERANGE + 1));
99     for (int i = 2; i <= PRIMERANGE; i++)
100     {
101         if (!prime[i]) prime[++prime[0]] = i;
102         for (int j = 1; j <= prime[0] && prime[j] <= PRIMERANGE / i; j++)
103         {
104             prime[prime[j]*i] = 1;
105             if (i % prime[j] == 0) break;
106         }
107     }
108     return prime[0];
109 }
110 /*****
111 IsPrime table
112 IsPrime[i]==true if(i is not a prime)
113 Pmaxn is the range of numbers;
114 *****/
115 const int Pmaxn=20000000;
116 bool IsPrime[Pmaxn];
117 void Isprime()
118 {
119     memset(IsPrime,false,sizeof(IsPrime));
120     for(int i=2;i<=Pmaxn;i++)
121     {
122         if(!IsPrime[i])
123         {
124             for(int j=i;j<=Pmaxn;j++)

```

```

125         {
126             IsPrime[i*j]=true;
127         }
128     }
129 }
130 }
131 /*****
132 euler function
133 *****/
134 typec euler(typec x)
135 {
136     typec res=x;
137     for(int i=2;i*i<(typec)(x*1.0)+1;i++)
138     {
139         if(x%i==0)
140         {
141             res=res/i*(i-1);
142             while(x%i==0) x/=i;
143         }
144     }
145     if(x>1) res=res/x*(x-1);
146     return res;
147 }
148 ///you should init the prime table before
149 int factor[100][3], facCnt;
150 int getFactors(int x)
151 {
152     facCnt = 0;
153     int tmp = x;
154     for(int i = 1; prime[i] <= tmp / prime[i]; i++)
155     {
156         factor[facCnt][1] = 1, factor[facCnt][2] = 0;
157         if(tmp % prime[i] == 0)
158             factor[facCnt][0] = prime[i];
159         while(tmp % prime[i] == 0)
160             factor[facCnt][2]++, factor[facCnt][1] *= prime[i], tmp /= prime[i];
161         if(factor[facCnt][1] > 1) facCnt++;
162     }
163     if(tmp != 1)
164         factor[facCnt][0] = tmp, factor[facCnt][1] = tmp, factor[facCnt][2] = 1;
165     return facCnt;
166 }

```

6.3 筛法求素数

1. Pri数组中的素数是递增的,当i能整除Pri[j], 那么i*Pri[j+1]这个合数肯定被Pri[j]乘以某个数筛掉。 fir[i]代表i的最小素因子, 可以几乎线性的分解i. 2. 线性求1 n之间所有数的欧拉函数:

```
1   if ((i/fir[i])%fir[i]==0)
2       ouler[i]=ouler[i/fir[i]]*fir[i];
3   else ouler[i]=ouler[i/fir[i]]*(fir[i]-1);
```

3. 线性求1 n之间所有数约数个数 ei表示n的第i个质因数的个数.

```
1   if (i%Pri[j]==0)
2   {
3       divnum[i*Pri[j]]=divsum[i]/(e[i]+1)*(e[i]+2); //最小素因子次数加1
4       e[i*Pri[j]]=e[i]+1;
5   }
6   else
7   {
8       divnum[i*Pri[j]]=divnum[i]*2; //满足积性函数条件
9       e[i*Pri[j]]=1;
10  }
```

```
1  # define RANGE 100000
2  int init(void)
3  {
4      int cnt=0,x;
5      for (int i=2;i<=RANGE;i++)
6      {
7          if (!Pri[i])
8          {
9              fir[i]=Pri[++cnt]=i;
10             pos[i]=cnt;
11         }
12         for (int j=1;j<=cnt;j++)
13         {
14             x=i*Pri[j];
15             if (x>RANGE) break;
16             Pri[x]=1;
17             fir[x]=Pri[j];
18             if (i%Pri[j]==0) break;
19         }
20     }
21     return cnt;
22 }
```

6.4 同余方程

```
1  # include <cstring>
2  # include <cstdio>
3  # include <cstdlib>
4  # include <iostream>
5  using namespace std;
6  typedef long long LOL;
7  LOL extend_gcd(LOL a, LOL b, LOL &x, LOL &y)
8  {
9      if (!b)
10     {
11         x=1,y=0;
12         return a;
13     }
14     LOL tem,r;
15     r=extend_gcd(b,a%b,x,y);
16     tem=x;
17     x=y;
18     y=tem-a/b*y;
19     return r;
20 }
21 int main (void)
22 {
23     int n;
24     while (scanf("%d",&n)!=EOF)
25     {
26         LOL r=0,a=1,r1,a1,x,y,tem,t;
27         int flag=0;
28         for (int i=1;i<=n;i++)
29         {
30             scanf("%lld%lld",&a1,&r1);
31             if (flag) continue;
32             tem=extend_gcd(a,a1,x,y);
33             if ((r1-r)%tem)
34                 flag=1;
35             else
36             {
37                 t=a1/tem;
38
39                 x=((r1-r)/tem*x%t+t)%t;
40                 r+=x*a;
41                 a*=(a1/tem);
42                 r=(r%a+a)%a;
43             }
44         }
45         if (!flag)
46             printf("%lld\n",r);
47         else printf("-1\n");
48     }
49     return 0;
50 }
```


6.5 高次同余方程

poj 3243 hdu 2815 poj 2417

这个是求扩展离散对数问题。 $X^Y \bmod Z = K$, 给出X,Z,K,求Y。

当Z时素数的时候直接用baby-step 算法即可。

方程 $a^x = b \pmod{c}$, 可以进行一系列的转化。假设

$$d = \gcd(a, c)$$

由

$$a^{x-1} * a = b \pmod{c}$$

知道 a^{x-1} 要存在必须满足 $\gcd(a, c) \mid b$, 如果满足这个条件, 那么我们可以在方程两边同时除以d, 方程是不变的。因为

$$a^x = b + k * c$$

再除以公约数d, 得到方程

$$a^{x-1} * \frac{a}{d} = \frac{b}{d} + k * \frac{c}{d}$$

假设我们除了k次, 那么方程转化为

$$a^{x-k} * \frac{a^k}{d^k} = \frac{b}{d^k} + k * \frac{c}{d^k}$$

令 $d = \frac{a^k}{d^k}, b' = \frac{b}{d^k}, c' = \frac{c}{d^k}, x' = x - k$, 方程转化为:

$$a^{x'} * d = b' \pmod{c'}$$

得到:

$$a^{x'} = b' * d^{-1} \pmod{c'}$$

现在直接用baby-step解方程

$$a^{x'} = b' * d^{-1} \pmod{c'}$$

即可。注意到 $x = x' + k$, 如果存在x小于k的解, 那么x'小于0, 但是baby-step是不会求负的次数的, 所以需要先枚举一下是否存在小于k的解, 由于输入的数据不会超过 10^9 的, 假设k不超过50进行枚举即可了。

```
1  #include <iostream>
2  #include <stdio.h>
3  #include <cmath>
4  using namespace std;
5  typedef long long LOL;
6  const int maxn = 65535;
7  struct Hashh
8  {
9      int a,b,next;
10 }Hash[maxn<<1];
11
12 int flag[maxn+100]; //注意要赋初值0
13 int top,idx; //注意要赋初值maxn
14
15 void ins(int a,int b)
16 {
17     int k=b&maxn;
18     if(flag[k]!=idx) //第b&maxn个槽为空
19     {
20         flag[k]=idx;
21         Hash[k].a=a;
22         Hash[k].b=b;
23         Hash[k].next=-1;
24         return ;
25     }
26     //第b&maxn个槽不为空
27     while(Hash[k].next!=-1) // 到链表的最后一个
28     {
29         if(Hash[k].b==b) return; //若b已经存在, 返回
30         k=Hash[k].next;
31     }
```

```

32     Hash[k].next=++top;
33     Hash[top].next=-1;
34     Hash[top].a=a;
35     Hash[top].b=b;
36 }
37
38 int find(int b)
39 {
40     int k=b&maxn;
41     if(flag[k]!=idx) return -1;//为空
42     while(k!=-1)
43     {
44         if(Hash[k].b==b)
45             return Hash[k].a;
46         k=Hash[k].next;
47     }
48     return -1;
49 }
50
51 int gcd(int a,int b)
52 {
53     if(b==0) return a;
54     return gcd(b,a%b);
55 }
56
57 int exgcd(int a,int b,int &x,int &y)
58 {
59     if(0==b)
60     {
61         x=1;
62         y=0;
63         return a;
64     }
65     int d=exgcd(b,a%b,x,y);
66     int t=x;
67     x=y;
68     y=t-a/b*y;
69     return d;
70 }
71
72 int exmod(LOL a,int b,int c)
73 {
74     LOL ret=1%c;
75     a%=c;
76     while(b)
77     {
78         if(b&1) ret=ret*a%c;
79         a=a*a%c;
80         b>>=1;
81     }
82     return ret;
83 }
84
85 int invmod(int a,int b,int n)
86 {
87     int x,y,e;
88     exgcd(a,n,x,y);
89     e=(LOL)x*b%n;
90     return e<0?e+n:e;
91 }
92
93 int babystep(int a,int b,int c)
94 {

```

```

95     top=maxn;idx++;
96     LOL buf=1%c,K;
97     LOL D=buf;
98     int tmp,w,d=0;
99     for(int i=0;i<=100;i++)
100     {
101
102         if(buf==b) return i;
103         buf=buf*a%c;
104     }
105     while((tmp=gcd(a,c))!=1)
106     {
107         if(b%tmp) return -1;
108         ++d;
109         c/=tmp;
110         b/=tmp;
111         D=D*a/tmp%c;
112     }
113     int m=(int)ceil(sqrt((double)(c-1)));
114     buf=1%c;
115     for(int i=0;i<=m;i++)
116     {
117         ins(i,buf);
118         buf=buf*a%c;
119     }
120     K=exmod((LOL)a,m,c);
121     for(int i=0;i<=m;i++)
122     {
123         tmp=invmod((int)D,b,c);
124         w=find(tmp);
125         if(tmp>=0 && (w!=-1))
126             return i*m+w+d;
127         D=(D*K%c+c)%c;
128     }
129     return -1;
130 }
131
132
133 int main()
134 {
135     int a,b,c,tmp;
136     // a^X = b % c
137     while(scanf("%d%d%d",&c,&a,&b)!=EOF && (a||b||c))
138     {
139         //~ if(b>=c)
140         //~ {
141             //~ printf("no solution\n");
142             //~ continue;
143         //~ }
144         tmp=babystep(a,b,c);
145         if(tmp<0) printf("no solution\n");
146         else printf("%d\n",tmp);
147     }
148     return 0;
149 }

```

6.6 高斯消元

6.6.1 高斯消元解实数方程

```
1 int Gauss(int n, int m, double a[][N*N])
2 {
3     int i, j, r, c, pvt;
4     double maxp;
5     for (r=0, c=0; r<n && c<m; ++r, ++c)
6     {
7         for (maxp=0, i=r; i < n; ++i)
8             if (fabs(a[i][c])>fabs(maxp)) maxp = a[pvt=i][c];
9         if (sgn(maxp)==0)
10        {
11            r--;
12            continue;
13        }
14        if (pvt != r)
15            for (j = r; j <= m; ++j) swap(a[r][j], a[pvt][j]);
16        for (j = c+1; j <= m; ++j)
17        {
18            a[r][j] /= maxp;
19            for (i = r+1; i < n; ++i)
20                a[i][j] -= a[i][c]*a[r][j];
21        }
22    }
23    for (i = r; i < n; ++i)
24        if (sgn(a[i][m])) return -1;
25    if (r < m) return m-r;
26    for (i = m-1; i >= 0; --i)
27        for (j = i+1; j < m; ++j)
28            a[i][m] -= a[j][m]*a[i][j];
29    return 0;
30 }
```

6.6.2 高斯消元解异或方程组

高斯消元解异或方程+枚举变元

```
1 #include<iostream>
2 #include<cstdio>
3 #include<cstring>
4 #include<vector>
5 #define PB push_back
6 #define MP make_pair
7 using namespace std;
8 const int M = 16;
9 const int maxn=M*M;
10 typedef pair<int,int> PII;
11 char s[M][M];
12 int num[4];
13 int dx[4][8];
14 int dy[4][8];
15 int N;
16 int a[maxn][maxn],b[maxn][maxn],c[maxn],d[maxn];
17 int n,m;
18 int get(int x,int y)
19 {
20     return x*m+y;
21 }
22 void build(int op)
23 {
24     memset(a,0,sizeof(a));
25     for(int i=0;i<n;i++){
26         for(int j=0;j<m;j++){
```

```

27         int u=get(i,j);
28         if(s[i][j]=='1'){
29             a[u][N]=1;
30         }else{
31             a[u][N]=0;
32         }
33         for(int k=0;k<num[op];k++){
34             int tx=i+dx[op][k];
35             int ty=j+dy[op][k];
36             if(tx<0||tx>=n||ty<0||ty>=m) continue;
37             int v=get(tx,ty);
38             a[v][u]=1;
39         }
40     }
41 }
42 }
43 void debug(int a[maxn][maxn])
44 {
45     for(int i=0;i<N;i++){
46         for(int j=0;j<=N;j++){
47             printf("%d ",a[i][j]);
48         }
49         printf("\n");
50     }
51 }
52 int gauss()
53 {
54     int col,row;
55     vector<int>vec;
56     vector<PII>use;
57     int ans=n*m+1;
58     for(col=0,row=0;col<N&&row<N;col++){
59         int mark=row;
60         for(int i=row+1;i<N;i++){
61             if(a[i][col]){
62                 mark=i;
63             }
64         }
65         for(int i=0;i<N+1;i++){
66             swap(a[row][i],a[mark][i]);
67         }
68         if(!a[row][col]){
69             vec.PB(col);
70             continue;
71         }
72         use.PB(MP(row,col));
73         for(int i=row+1;i<N;i++){
74             if(!a[i][col]) continue;
75             for(int j=0;j<N+1;j++){
76                 a[i][j]^=a[row][j];
77             }
78         }
79         row++;
80     }
81     //debug(a);
82     for(int i=row;i<N;i++){
83         if(a[i][N]){
84             return n*m+1;
85         }
86     }
87     int sz=vec.size();
88     for(int i=0;i<(1<<sz);i++){
89         for(int j=0;j<N;j++){

```

```

90         for(int k=0;k<N+1;k++){
91             b[j][k]=a[j][k];
92         }
93     }
94     memset(d,0,sizeof(d));
95     int cnt=0;
96     for(int j=0;j<sz;j++){
97         int u;
98         if(i&(1<j)){
99             u=1;
100         }else u=0;
101         d[vec[j]]=u;cnt+=d[vec[j]];
102     }
103     for(int j=row-1;j>=0;j--){
104         int y=b[j][N];
105         for(int k=use[j].second+1;k<N;k++){
106             y^=(b[j][k]&& d[k]);
107         }
108         d[use[j].second]=y;
109         cnt+=d[use[j].second];
110     }
111     ans=min(ans,cnt);
112 }
113 return ans;
114 }

```

6.6.3 模意义下求行列式的值

```

1  #include<iostream>
2  #include<cstring>
3  #include<cstdio>
4  using namespace std;
5  const int N = 210;
6  typedef long long LOL;
7  LOL a[N][N];
8  LOL solve(int n,LOL p)
9  {
10     LOL ans=1;
11     for(int i=1;i<=n;i++){
12         for(int j=i+1;j<=n;j++){
13             while(a[j][i]!=0){
14                 LOL t=a[i][i]/a[j][i];
15                 for(int k=i;k<=n;k++){
16                     a[i][k]=a[i][k]-a[j][k]*t;
17                     a[i][k]%=p;
18                 }
19                 for(int k=i;k<=n;k++){
20                     swap(a[i][k],a[j][k]);
21                 }
22                 ans=-ans;
23             }
24         }
25         if(a[i][i]==0) return 0;
26         else ans=((ans*a[i][i])%p+p)%p;
27     }
28     return ans;
29 }
30 int main(void)
31 {
32     int n;
33     LOL p;
34     while(scanf("%d%lld",&n,&p)!=EOF){

```

```

35         for(int i=1;i<=n;i++){
36             for(int j=1;j<=n;j++){
37                 scanf("%lld",&a[i][j]);
38                 a[i][j]%=p;
39             }
40         }
41         LOL ans=solve(n,p);
42         ans=(ans%p+p)%p;
43         cout<<ans<<endl;
44     }
45     return 0;
46 }

```

6.7 POLYA

6.7.1 概念

定义 1 置换: 设 X 是一个有限集, 取 X 为包含前 n 个正整数的集合 $1, 2, \dots, n$, X 的每个置换 i_1, i_2, \dots, i_n 可视为 X 到其自身定义的一个一对一的函数

$$f: X \rightarrow X$$

其中 $f(1) = i_1, f(2) = i_2, \dots, f(n) = i_n$

定义 2 置换群: 如果 S_n 中的置换的非空子集 G 满足如下三条性质, 则定义它为 X 的一个置换群:

- 1) (合成运算的封闭性) 对 G 中所有的置换 f 与 g , $f \circ g$ 也属于 G 。
- 2) (单位元) S_n 中的恒等置换 τ 属于 G 。
- 3) (逆元的封闭性) 对 G 中的每一个置换 f , 它的逆 f^{-1} 也属于 G 。

定义 3 着色等价: 令 G 是作用在集合 X 上的一个置换群, 通常取 X 为前 n 个正整数的集合。令 C 是 X 的一个着色集合。设 c_1, c_2 是 C 中的两种着色, 如果 G 中存在一个置换 f , 使得

$$f * c_1 = c_2$$

则称 c_1 (在 G 的作用下) 等价于 c_2 。

定义 4 稳定核: 使着色 c 保持不变的所有置换的集合 $G(c)$ 称为 c 的稳定核。

定理 1 对于每一种着色 c , c 的稳定核 $G(c)$ 是一个置换群, 而且对 G 中任意置换 f 与 g , $g * c = f * c$ 当且仅当 $f^{-1} \circ g$ 属于 $G(c)$ 。

证明:

- 1) 因为 f 和 g 都使 c 保持不变, 则 $(g \circ f)(c) = c$, 满足合成运算的封闭性。
- 2) 显然单位元 τ 使所有着色不变。
- 3) 如果 f 使得 c 不变, 那么 f^{-1} 也使得 c 不变, 于是 $G(c)$ 具有对逆元的封闭性。所以 $G(c)$ 是一个置换群。
假设 $f * c = g * c$, 可得

$$(f^{-1} \circ g) * c = f^{-1} * (g * c) = f^{-1} * (f * c) = (f^{-1} \circ f) * c = \tau * c = c$$

6.7.2 题目

POJ1286 题目大意: 用红蓝绿三种颜色去染 n 元环, 问方案数。

解法: 旋转同构 $\sum_{i=1}^n 3^{\gcd(n,i)}$ 翻转同构, 如果 n 为奇数, $3^{n/2+1}$, 如果 n 为偶数, $(n/2) * 3^{n/2} + (n/2) * 3^{n/2+1}$

POJ2409 题目大意: 用 c 种颜色染 n 元环, 问方案数。

解法: 旋转同构 $\sum_{i=1}^n c^{\gcd(n,i)}$ 翻转同构, 如果 n 为奇数, $c^{n/2+1}$, 如果 n 为偶数, $(n/2) * c^{n/2} + (n/2) * c^{n/2+1}$

POJ2154 题目大意: 用 n 种颜色染 n 元环, $1 \leq n \leq 1000000000$, 并且有3500组数据。

解法: 解法和上一个相同, 但是因为 n 过大, 枚举 n 的复杂度会超时, 我们转过来想对于 x 有多少 $i (1 \leq i \leq n)$, 使得 $\gcd(n, i) = x$, 这个的个数为 $\phi(n/x)$ ($\phi(x)$ 表示 x 的欧拉函数, 即小于等于 x 的数有多少个)。这样枚举 n 的约数, 然后就能算出结果, 复杂度为 $O(\sqrt{n})$

```
1 for(int i=1;i*i<=n;i++){
2     if(n%i==0&&i*i!=n){
3         ans+=gao(n,i-1)*euler(n/i);
4         ans+=gao(n,n/i-1)*euler(i);
5         ans%=p;
6     }
7     if(i*i==n){
8         ans+=gao(n,i-1)*euler(i);
9         ans%=p;
10    }
11 }
```

优化: 通过DFS直接枚举出 n 的所有约数和约数的欧拉函数。

```
1 int ans=0;
2 void dfs(int now,int euler,int val)
3 {
4     if(now>=facCnt){
5         ans=(ans+(gao(n,n/val-1)*euler)%mod;
6         ans%=mod;
7     }
```



```

7         return ;
8     }
9     int pre=1,sum=1;
10    for(int i=0;i<=fac[now][1];i++){
11        dfs(now+1,euler*pre%mod,val*sum);
12        if(i==0){
13            pre*=(fac[now][0]-1);
14        }else{
15            pre*=fac[now][0];
16        }
17        sum*=fac[now][0];
18    }
19 }

```

立方体染色 立方体面: $1*1^6 + 6*1^2*4^1 + 3*1^2*2^2 + 8*3^2 + 6*2^3$

立方体楞: $1*1^{12} + 6*4^3 + 3*2^6 + 8*3^4 + 6*2^5*1^2$

立方体点: $1*1^8 + 6*4^2 + 9*2^4 + 8*1^2*3^2$

对立方体面来说: 如果用三种颜色染色,

$$I = (3^6 + 6*3^3 + 3*3^4 + 8*3^2 + 6*3^3)/24 = 57$$

如果限定每种颜色用两次, 那么

$$I = (r+b+g)^6 + 6*(r+g+b)^2*(r^4+b^4+g^4) + 3*(r+b+g)^2*(r^2+b^2+g^2)^2 + 8*(r^3+b^3+g^3)^2 + 6*(r^2+b^2+g^2)^3 \quad (1)$$

然后方案数就是 $r^2 * b^2 * g^2$ 的系数

UVA11255 题目大意: 用三种颜色, 每种a,b,c个去染 $n = a + b + c$ 的环, 问方案数。

解法: 同上, 用dfs求系数。

```

1  int a[3],n;
2  LOL com[45][45];
3  LOL gao(int g,int t)
4  {
5      if(a[0]%t!=0||a[1]%t!=0||a[2]%t!=0) return 0;
6      LOL ans=0;
7      int ta=a[0]/t,tb=a[1]/t,tc=a[2]/t;
8      ans=com[ta+tb+tc][ta]*com[tb+tc][tb];
9      return ans;
10 }
11 int main(void)
12 {
13     int T;
14     for(int i=0;i<=40;i++){
15         com[i][0]=1;
16     }
17     for(int i=1;i<=40;i++){
18         for(int j=1;j<=i;j++){
19             com[i][j]=com[i-1][j]+com[i-1][j-1];
20         }
21     }
22     scanf("%d",&T);
23     while(T--){
24         n=0;
25         for(int i=0;i<3;i++){
26             scanf("%d",&a[i]);
27             n+=a[i];
28         }
29         LOL ans=0;
30         for(int i=1;i<=n;i++){
31             int g=gcd(i,n);
32             ans+=gao(g,n/g);
33         }
34         if(n%2==0){
35             ans+=n/2*gao(n/2,2);

```

```

36         for(int i=0;i<3;i++){
37             for(int j=0;j<3;j++){
38                 a[i]--;a[j]--;
39                 ans+=n/2*gao((n-2)/2,2);
40                 a[i]++;a[j]++;
41             }
42         }
43     }
44     else{
45         for(int i=0;i<3;i++){
46             a[i]--;
47             ans+=n*gao(n/2,2);
48             a[i]++;
49         }
50     }
51     cout<<ans/(2*n)<<endl;
52 }
53 return 0;
54 }
55 }

```

7 计算几何

7.1 几何基础

7.1.1 求两向量的叉积

```
1 | int cross(int x1,int y1,int x2,int y2) //int型
2 | {
3 |     return x1*y2-x2*y1;
4 | }
5 |
6 | double cross(double x1,double y1,double x2,double y2) //double型
7 | {
8 |     return x1*y2-x2*y1;
9 | }
10 |
11 | double cross(Point a,Point b) // 向量叉积
12 | {
13 |     return a.x*b.y-b.x*a.y;
14 | }
```

7.1.2 求平面两点欧氏距离

```
1 | double distance(Point a,Point b)
2 | {
3 |     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
4 | }
```

7.1.3 判断点是否在线段上

```
1 | int on_segment(Segment seg,Point k)
2 | {
3 |     Point a=seg.s,Point b=seg.e;
4 |
5 |     if (cross(k.x-a.x,k.y-a.y,b.x-a.x,b.y-a.y)==0&&
6 |         k.x>=min(a.x,b.x)&&k.x<=max(a.x,b.x)&&
7 |         k.y>=min(a.y,b.y)&&k.y<=max(a.y,b.y))
8 |
9 |         return 1;
10 |
11 |     else
12 |         return 0;
13 | }
```

7.1.4 判断两线段是否相交 (快速排斥+跨立实验)

```
1 | int segment_intersect(Segment seg1,Segment seg2) //endpoint exclusive
2 | {
3 |     Point s1=seg1.s,e1=seg1.e,s2=seg2.s,e2=seg2.e;
4 |
5 |     if (max(s1.x,e1.x)>min(s2.x,e2.x)&&
6 |         max(s2.x,e2.x)>min(s1.x,e1.x)&&
7 |         max(s1.y,e1.y)>min(s2.y,e2.y)&&
8 |         max(s2.y,e2.y)>min(s1.y,e1.y)&&
9 |         cross(e1.x-s1.x,e1.y-s1.y,s2.x-s1.x,s2.y-s1.y)*cross(e1.x-s1.x,e1.y-
10 |             s1.y,e2.x-s1.x,e2.y-s1.y)<0&&
11 |         cross(e2.x-s2.x,e2.y-s2.y,s1.x-s2.x,s1.y-s2.y)*cross(e2.x-s2.x,e2.y-
12 |             s2.y,e1.x-s2.x,e1.y-s2.y)<0)
13 |
14 |         return 1;
15 |
16 |     else
17 |         return 0;
18 | }
```

```

18 int segment_intersect(Segment seg1,Segment seg2) //endpoint inclusive
19 {
20     Point s1=seg1.s,e1=seg1.e,s2=seg2.s,e2=seg2.e;
21
22     if (max(s1.x,e1.x)>=min(s2.x,e2.x)&&
23         max(s2.x,e2.x)>=min(s1.x,e1.x)&&
24         max(s1.y,e1.y)>=min(s2.y,e2.y)&&
25         max(s2.y,e2.y)>=min(s1.y,e1.y)&&
26         cross(e1.x-s1.x,e1.y-s1.y,s2.x-s1.x,s2.y-s1.y)*cross(e1.x-s1.x,e1.y-
            s1.y,e2.x-s1.x,e2.y-s1.y)<=0&&
27         cross(e2.x-s2.x,e2.y-s2.y,s1.x-s2.x,s1.y-s2.y)*cross(e2.x-s2.x,e2.y-
            s2.y,e1.x-s2.x,e1.y-s2.y)<=0)
28
29         return 1;
30
31     else
32         return 0;
33 }

```

7.1.5 判断double型变量的符号

```

1 #define eps 1e-8
2 int dlcmp(double x)
3 {
4     return x<-eps?-1:x>eps;
5 }

```

7.1.6 求点到线段的最短距离(此做法过于naive,可用点积+叉积来求)

```

1 #include<cmath>
2 #include<algorithm>
3 #define eps 1e-6
4 struct Point
5 {
6     double x,y;
7 };
8
9 struct Segment
10 {
11     Point s,e;
12 };
13
14 struct Line //ax+by+c=0;
15 {
16     double a,b,c;
17     Line(double d1=1,double d2=-1,double d3=0) {a=d1;b=d2;c=d3;}
18 };
19
20 int dlcmp(double x)
21 {
22     return x<-eps?-1:x>eps;
23 }
24 double dis(Point a,Point b)
25 {
26     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
27 }
28
29 Line make_line(Point a,Point b)
30 {
31     Line l;
32     int sign=1;
33
34     l.a=b.y-a.y;
35

```

```

36     if (l.a<0)
37     {
38         sign=-1;
39         l.a=l.a*sign;
40     }
41
42     l.b=sign*(a.x-b.x);
43     l.c=sign*(a.y*b.x-a.x*b.y);
44     return l;
45 }
46
47 double dis_point_segment(Point a,Segment seg)
48 {
49     double A=dis(a,seg.s);
50     double B=dis(a,seg.e);
51     double C=dis(seg.s,seg.e);
52
53     if (!dlcmp(A+B-C))
54         return 0;
55
56     if (!dlcmp(A+C-B)||!dlcmp(B+C-A))
57         return min(A,B);
58
59     if (dlcmp(A*A+C*C-B*B)<=0||dlcmp(B*B+C*C-A*A)<=0)
60         return min(A,B);
61
62     Line l=make_line(seg.s,seg.e);
63     double t=fabs(a.x*l.a+a.y*l.b+l.c);
64     t/=sqrt(l.a*l.a+l.b*l.b);
65
66     return t;
67 }
68 }

```

7.1.7 求两线段间最短距离

```

1 double dis_segments(Segment seg1,Segment seg2)
2 {
3     double m1=dis_point_segment(seg1.s,seg2);
4
5     double m2=dis_point_segment(seg1.e,seg2);
6     double m3=dis_point_segment(seg2.s,seg1);
7     double m4=dis_point_segment(seg2.e,seg1);
8
9     return min(min(m1,m2),min(m3,m4));
10 }

```

7.1.8 判断两直线是否相交（共线及平行，若相交则求出交点）

```

1 #include<math.h>
2 #define eps 1e-8
3 struct Point
4 {
5     double x;
6     double y;
7 };
8
9 struct Line
10 {
11     Point s;
12     Point e;
13     Point v;
14 };
15

```

```

16 | Line l1,l2;
17 |
18 | double x,y交点坐标;//
19 |
20 | int line_intersect(Line l1,Line l2)
21 | {
22 |     Point vec;
23 |     double r;
24 |
25 |     vec.x=l1.s.x-l2.s.x;
26 |     vec.y=l1.s.y-l2.s.y;
27 |
28 |     if (fabs(l1.v.x*l2.v.y-l2.v.x*l1.v.y)<eps)
29 |     {
30 |         if (fabs(l1.v.x*vec.y-vec.x*l1.v.y)<eps)
31 |             return 2;    //共线
32 |         else
33 |             return 0;    //平行
34 |     }
35 |     else
36 |     {
37 |         r=((l1.s.x-l2.s.x)*l2.v.y-(l1.s.y-l2.s.y)*l2.v.x)/(l1.v.x*l2.v.y-l1.
38 |             v.y*l2.v.x);
39 |         x=-r*l1.v.x+l1.s.x;
40 |         y=-r*l1.v.y+l1.s.y;
41 |         return 1;        //相交
42 |     }
43 | }

```

7.1.9 求两直线交点

```

1 | Point line_intersect(Point s1,Point e1,Point s2,Point e2)
2 | {
3 |     Point v1,v2,res;
4 |     double r;
5 |
6 |     v1=s1-e1;
7 |     v2=s2-e2;
8 |
9 |     r=((s1.x-s2.x)*v2.y-(s1.y-s2.y)*v2.x)/(v1.x*v2.y-v1.y*v2.x);
10 |     res.x=-r*v1.x+s1.x;
11 |     res.y=-r*v1.y+s1.y;
12 |
13 |     return res;
14 | }

```

7.1.10 求两线段交点

```

1 | Point line_intersect(Point s1,Point e1,Point s2,Point e2)
2 | {
3 |     Point res;
4 |
5 |     double cs=fabs(cross(s2,e1,s1));
6 |     double ce=fabs(cross(e2,e1,s1));
7 |
8 |     res.x=(ce*s2.x+cs*e2.x)/(cs+ce);
9 |     res.y=(ce*s2.y+cs*e2.y)/(cs+ce);
10 |
11 |     return res;
12 | }

```

7.2 多边形

7.2.1 判断线段是否与矩形相交（包括线段在矩形内部）

```
1 struct Rectangle
2 {
3     Point lt;//lefttop
4     Point rb;//rightbottom
5 };
6
7 int segment_rectangle_intersect(Segment l,Rectangle r)
8 {
9     Segment d1,d2;//rectangle's diagonal
10
11     d1.s=r.lt;
12     d1.e=r.rb;
13     d2.s.x=d1.e.x;
14     d2.s.y=d1.s.y;
15     d2.e.x=d1.s.x;
16     d2.e.y=d1.e.y;
17
18     if (l.s.x>=r.lt.x&& l.s.x<=r.rb.x&&
19         l.s.y<=r.lt.y&& l.s.y>=r.rb.y||
20         l.e.x>=r.lt.x&& l.e.x<=r.rb.x&&
21         l.e.y<=r.lt.y&& l.e.y>=r.rb.y)
22
23         return 1;
24
25     if (segment_intersect(l,d1)|| segment_intersect(l,d2)) //
26         segment_intersect(endpoint inclusive)
27         return 1;
28
29     return 0;
30 }
```

7.2.2 判断点是否在多边形内部（包含在边上）,射线法

```
1 int point_on_segment(Point o,Point a,Point b)//点在线段上
2 {
3     if (dlcmp(cross(a-o,b-o))==0&&
4         o.x>=min(a.x,b.x)&&o.x<=max(a.x,b.x)&&
5         o.y>=min(a.y,b.y)&&o.y<=max(a.y,b.y))
6
7         return 1;
8     else
9         return 0;
10 }
11
12 int point_in_polygon(Point o,Point pln[],int n)//判断点在多边形内部
13 {
14     int i,j,cnt=0;
15     Point far(o,o.y);
16     int d1,d2,d3,d4;
17
18     for (i=0;i<n;i++)
19     {
20         j=(i+1)%n;
21         if (point_on_segment(o,pln[i],pln[j]))
22             return 1;
23
24         d1=dlcmp(cross(far-o,pln[i]-o));
25         d2=dlcmp(cross(far-o,pln[j]-o));
26         d3=dlcmp(cross(pln[j]-pln[i],o-pln[i]));
27         d4=dlcmp(cross(pln[j]-pln[i],far-pln[i]));
```

```

28
29         if (d1*d2<0&& d3*d4<0)
30             cnt++;
31         else if ((d1*d2==0&& d3*d4<0)&&
32                 dlcmp(o.y-max(pln[i].y,pln[j].y))==0)
33             cnt++;
34     }
35
36     if (cnt&1)
37         return 1;
38     else
39         return 0;
40 }

```

7.2.3 求简单多边形重心

```

1 Point get_center(Point pt[],int n)
2 {
3     double sum,area;
4     Point res(0,0),o(0,0);
5     int i;
6
7     sum=0;
8     for (i=0;i<n;i++)
9     {
10         area=cross(pt[i]-o,pt[(i+1)%n]-o);
11         res=res+(pt[i]+pt[(i+1)%n])/3*area;
12         sum+=area;
13     }
14
15     res=res/sum;
16     return res;
17 }

```

7.2.4 graham_scan求凸包

测试报告: hdu1348 1392

```

1 #include<cmath>
2 #include<algorithm>
3 #define eps 1e-6
4 #define N 50005
5 using namespace std;
6
7 struct Point
8 {
9     double x,y;
10 };
11
12 Point pt[N],pln[N];
13
14 int dlcmp(double x)
15 {
16     return x<-eps?-1:x>eps;
17 }
18
19 double cross(Point a,Point b,Point s)
20 {
21     double x1=a.x-s.x,y1=a.y-s.y;
22     double x2=b.x-s.x,y2=b.y-s.y;
23
24     return x1*y2-x2*y1;
25 }
26
27 double dis(Point a,Point b)

```



```

28 {
29     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
30 }
31
32 int cmp(Point a,Point b)
33 {
34     if (dlcmp(cross(a,b,pt[0]))==1||
35         dlcmp(cross(a,b,pt[0]))==0&&
36         dis(pt[0],a)<dis(pt[0],b))
37
38         return 1;
39     else
40         return 0;
41 }
42
43 int graham_scan(int n)
44 {
45     int i,top,t;
46
47     if (n<=1)
48         return n;
49
50     for (t=0,i=1;i<n;i++)
51         if (dlcmp(pt[i].y-pt[t].y)==-1||
52             dlcmp(pt[i].y-pt[t].y)==0&&
53             dlcmp(pt[i].x-pt[t].x)==-1)
54
55             t=i;
56
57     swap(pt[0],pt[t]);
58
59     sort(pt+1,pt+n,cmp);
60
61     top=2;
62     for (i=0;i<2;i++)
63         pln[i]=pt[i];
64
65     for (i=2;i<n;i++)
66     {
67         while (top>1&&dlcmp(cross(pln[top-1],pt[i],pln[top-2]))<=0)
68             top--;
69         pln[top++]=pt[i];
70     }
71
72     return top;
73 }

```

7.2.5 旋转卡壳求凸包直径

测试报告: poj2187

```

1 double rotating_calipers(Point pln[],int n)
2 {
3     int p,q;
4     double res;
5
6     pln[n]=pln[0];
7     res=0;
8
9     for (p=0,q=1;p<n;p++)
10    {
11        while (cross(pln[p+1],pln[q],pln[p])<
12              cross(pln[p+1],pln[q+1],pln[p]))

```

```

13
14         q=(q+1)%n;
15
16         res=max(res,max(dis(pln[p],pln[q]),dis(pln[p+1],pln[q+1])));
17     }
18
19     return res;
20 }

```

7.2.6 凸包间最短距离 (旋转卡壳)

测试报告: poj3608

```

1  const double eps=1e-6;
2  const double oo=1e100;
3  const double PI=3.141592657589793;
4
5  struct Point
6  {
7      double x,y;
8  };
9
10
11 struct Segment
12 {
13     Point s,e;
14 };
15
16 struct Line    //ax+by+c=0;
17 {
18     double a,b,c;
19
20     Line(double d1=1,double d2=-1,double d3=0) {a=d1;b=d2;c=d3;}
21 };
22
23 double dis(Point a,Point b)
24 {
25     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
26 }
27
28 double cross1(double x1,double y1,double x2,double y2)
29 {
30     return x1*y2-x2*y1;
31 }
32
33 double cross2(Point a,Point b)
34 {
35     return a.x*b.y-b.x*a.y;
36 }
37
38 double cross3(Point a,Point b,Point s)
39 {
40
41     double x1=a.x-s.x,y1=a.y-s.y;
42     double x2=b.x-s.x,y2=b.y-s.y;
43
44     return x1*y2-x2*y1;
45 }
46
47 int dlcmp(double x)
48 {
49     return x<-eps?-1:x>eps;
50 }

```

```

51
52 double polygon_area(Point pln[],int n)
53 {
54     double sum=0;
55     int i;
56
57     for (i=0;i<n;i++)
58         sum+=cross2(pln[i],pln[(i+1)%n]);
59
60     return sum/2;
61 }
62
63 void reverse_clockwise(Point pln[],int n)
64 {
65     int i;
66
67     for (i=0;i<=(n-1)/2;i++)
68         swap(pln[i],pln[n-i-1]);
69 }
70
71 double calculate_degree(Point a,Point b,double cur)
72 {
73     double ang,res;
74     Point p;
75
76     p.x=b.x-a.x;
77     p.y=b.y-a.y;
78
79     if (!dlcmp(p.x))
80     {
81         if (p.y>0)
82             ang=PI/2;
83         else
84             ang=3*PI/2;
85     }
86     else
87     {
88         ang=atan(p.y/p.x);
89         if (p.x<0)
90             ang+=PI;
91     }
92
93     while (ang<0)
94         ang+=2*PI;
95
96     if (ang>=PI)
97         cur+=PI;
98
99     if (ang>cur)
100         res=ang-cur;
101     else
102         res=PI-(cur-ang);
103
104     while (res>=PI)
105         res-=PI;
106
107     if (!dlcmp(res-PI))
108         res=0;
109
110     return res;
111 }
112
113

```

```

114
115 Line make_line(Point a,Point b)
116 {
117     Line l;
118     int sign=1;
119
120     l.a=b.y-a.y;
121
122     if (l.a<0)
123     {
124         sign=-1;
125         l.a=l.a*sign;
126     }
127
128     l.b=sign*(a.x-b.x);
129     l.c=sign*(a.y*b.x-a.x*b.y);
130
131     return l;
132 }
133
134 double dis_point_segment(Point a,Segment seg)
135 {
136     double A=dis(a,seg.s);
137     double B=dis(a,seg.e);
138     double C=dis(seg.s,seg.e);
139
140     if (!dlcmp(A+B-C))
141         return 0;
142
143     if (!dlcmp(A+C-B)||!dlcmp(B+C-A))
144         return min(A,B);
145
146     if (dlcmp(A*A+C*C-B*B)<=0||dlcmp(B*B+C*C-A*A)<=0)
147         return min(A,B);
148
149     Line l=make_line(seg.s,seg.e);
150     double t=fabs(a.x*l.a+a.y*l.b+l.c);
151     t/=sqrt(l.a*l.a+l.b*l.b);
152
153     return t;
154 }
155
156 double dis_segments(Segment seg1,Segment seg2)
157 {
158     double m1=dis_point_segment(seg1.s,seg2);
159     double m2=dis_point_segment(seg1.e,seg2);
160     double m3=dis_point_segment(seg2.s,seg1);
161     double m4=dis_point_segment(seg2.e,seg1);
162
163     return min(min(m1,m2),min(m3,m4));
164 }
165
166
167 double dis_polygons(Point pln1[],int n1,Point pln2[],int n2)
168 {
169     int i,j,k,p1=0,p2=0;
170     double res=oo,arg=0,cur=0;
171     double ang1,ang2,tmp;
172     Segment seg1,seg2;
173
174     if (polygon_area(pln1,n1)<0)
175         reverse_clockwise(pln1,n1);
176     if (polygon_area(pln2,n2)<0)

```

```

177         reverse_clockwise(pln2,n2);
178
179     for (i=1;i<n1;i++)
180         if (pln1[i].y<pln1[p1].y)
181             p1=i;
182
183     for (i=1;i<n2;i++)
184         if (pln2[i].y>pln2[p2].y)
185             p2=i;
186
187     while (arg<=360)
188     {
189         while (cur>=PI)
190             cur-=PI;
191
192         if (!dlcmp(cur-PI))
193             cur=0;
194
195         ang1=calculate_degree(pln1[p1],pln1[(p1+1)%n1],cur);
196         ang2=calculate_degree(pln2[p2],pln2[(p2+1)%n2],cur);
197
198         if (!dlcmp(ang1-ang2))
199         {
200             cur+=ang1;
201             arg+=ang1;
202
203             seg1.s=pln1[p1],seg1.e=pln1[(p1+1)%n1];
204             seg2.s=pln2[p2],seg2.e=pln2[(p2+1)%n2];
205
206             tmp=dis_segments(seg1,seg2);
207             res=min(res,tmp);
208
209             p1=(p1+1)%n1;
210             p2=(p2+1)%n2;
211         }
212         else if (dlcmp(ang1-ang2)>0)
213         {
214             cur+=ang2;
215             arg+=ang2;
216
217             seg2.s=pln2[p2],seg2.e=pln2[(p2+1)%n2];
218             tmp=dis_point_segment(pln1[p1],seg2);
219             res=min(tmp,res);
220
221             p2=(p2+1)%n2;
222         }
223         else
224         {
225             cur+=ang1;
226             arg+=ang1;
227             seg1.s=pln1[p1],seg1.e=pln1[(p1+1)%n1];
228             tmp=dis_point_segment(pln2[p2],seg1);
229
230             res=min(tmp,res);
231             p1=(p1+1)%n1;
232         }
233     }
234
235     return res;
236 }
237
238 main()
239 {

```

```

240     int n1,n2,i;
241     double ans;
242     Point pln1[N],pln2[N];
243
244     while (scanf("%d%d",&n1,&n2),n1||n2)
245     {
246         for (i=0;i<n1;i++)
247             scanf("%lf%lf",&pln1[i].x,&pln1[i].y);
248         for (i=0;i<n2;i++)
249             scanf("%lf%lf",&pln2[i].x,&pln2[i].y);
250
251         ans=dis_polygons(pln1,n1,pln2,n2);
252
253         printf("%.5lf\n",ans);
254     }
255
256     return 0;
257 }

```

7.2.7 判断两凸多边形是否相交 (graham_scan求凸包+枚举边、点)

```

1  #include<iostream>
2  #include<cstdio>
3  #include<algorithm>
4  #define N 110
5  using namespace std;
6
7  struct Point
8  {
9      int x,y;
10 };
11
12 struct Polygon
13 {
14     Point p[N];
15     int n;
16 };
17
18 Point pt[N];
19 int stack[N];
20
21 int cross(Point a,Point b,Point s)
22 {
23     return (a.x-s.x)*(b.y-s.y)-(b.x-s.x)*(a.y-s.y);
24 }
25
26 int dist(Point a,Point b)
27 {
28     return (a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y);
29 }
30
31 int cmp(Point a,Point b)
32 {
33     if (cross(a,b,pt[0])>0||cross(a,b,pt[0])==0&&dist(a,pt[0])<dist(b,pt[0]))
34         return 1;
35     else
36         return 0;
37 }
38
39 int on_segment(Point s,Point e,Point o)
40 {

```

```

41     if (cross(s,e,o)==0&&o.x>=min(s.x,e.x)&&
42         o.x<=max(s.x,e.x)&&o.y>=min(s.y,e.y)&&o.y<=max(s.y,e.y))
43
44         return 1;
45     else
46         return 0;
47 }
48
49 int graham_scan(int n)
50 {
51     int i,top,t;
52
53     if (n<=1)
54     {
55         stack[0]=0;
56         return n;
57     }
58
59     for (t=0,i=1;i<n;i++)
60         if (pt[i].y<pt[t].y||pt[i].y==pt[t].y&&pt[i].x<pt[t].x)
61             t=i;
62
63     swap(pt[0],pt[t]);
64
65     sort(pt+1,pt+n,cmp);
66
67     top=2;
68     for (i=0;i<2;i++)
69         stack[i]=i;
70
71     for (i=2;i<n;i++)
72     {
73         while (top>1&&cross(pt[stack[top-1]],pt[i],pt[stack[top-2]])<=0)
74             top--;
75         stack[top++]=i;
76     }
77
78     return top;
79 }
80
81 int segment_intersect(Point s1,Point e1,Point s2,Point e2)
82 {
83     if (max(s1.x,e1.x)>=min(s2.x,e2.x)&&
84         max(s2.x,e2.x)>=min(s1.x,e1.x)&&
85         max(s1.y,e1.y)>=min(s2.y,e2.y)&&
86         max(s2.y,e2.y)>=min(s1.y,e1.y)&&
87         (double)cross(s2,e1,s1)*(double)cross(e2,e1,s1)<=0&&
88         (double)cross(s1,e2,s2)*(double)cross(e1,e2,s2)<=0)
89
90         return 1;
91     else
92         return 0;
93 }
94
95 int point_inside(Point o,Polygon pln)
96 {
97     int i,a1=0,a2=0,n=pln.n;
98
99     pln.p[n]=pln.p[0];
100
101     for (i=0;i<n;i++)
102         a1+=abs(cross(pln.p[i],pln.p[i+1],o));
103     for (i=1;i<n;i++)

```

```

104         a2+=abs(cross(pln.p[i],pln.p[i+1],pln.p[0]));
105
106     if (a1==a2)
107         return 1;
108
109     else
110         return 0;
111 }
112
113 int convex_polygon_intersect(Polygon pln1,Polygon pln2)
114 {
115     int i,j;
116
117     pln1.p[pln1.n]=pln1.p[0];
118     pln2.p[pln2.n]=pln2.p[0];
119
120     for (i=0;i<pln1.n;i++)
121         for (j=0;j<pln2.n;j++)
122             if (segment_intersect(pln1.p[i],pln1.p[i+1],pln2.p[j],pln2.p[j
123                                     +1]))
124                 return 1;
125
126     if (point_inside(pln1.p[0],pln2)||point_inside(pln2.p[0],pln1))
127         return 1;
128
129     return 0;
130 }
131
132 int main()
133 {
134     int n,m,i,vertexnum,ans;
135     Polygon pln1,pln2;
136
137     while (cin>>n>>m,n||m)
138     {
139         for (i=0;i<n;i++)
140             cin>>pt[i].x>>pt[i].y;
141         vertexnum=graham_scan(n);
142         pln1.n=vertexnum;
143
144         for (i=0;i<vertexnum;i++)
145             pln1.p[i]=pt[stack[i]];
146
147         for (i=0;i<m;i++)
148             cin>>pt[i].x>>pt[i].y;
149
150         vertexnum=graham_scan(m);
151         pln2.n=vertexnum;
152
153         for (i=0;i<vertexnum;i++)
154             pln2.p[i]=pt[stack[i]];
155
156         if (pln1.n==1&&pln2.n==1)
157             ans=1;
158         else if (pln1.n==1&&pln2.n==2)
159         {
160             if (on_segment(pln2.p[0],pln2.p[1],pln1.p[0]))
161                 ans=0;
162             else
163                 ans=1;
164         }
165         else if (pln1.n==2&&pln2.n==1)
166         {

```



```

166         if (on_segment(pln1.p[0],pln1.p[1],pln2.p[0]))
167             ans=0;
168         else
169             ans=1;
170     }
171     else if (pln1.n==2&&pln2.n==2)
172     {
173         if (segment_intersect(pln1.p[0],pln1.p[1],pln2.p[0],pln2.p[1]))
174             ans=0;
175         else
176             ans=1;
177     }
178     else if (pln1.n==1)
179     {
180         if (point_inside(pln1.p[0],pln2))
181             ans=0;
182         else
183             ans=1;
184     }
185     else if (pln2.n==1)
186     {
187         if (point_inside(pln2.p[0],pln1))
188             ans=0;
189         else
190             ans=1;
191     }
192     else
193     {
194         if (convex_polygon_intersect(pln1,pln2)==0)
195             ans=1;
196         else
197             ans=0;
198     }
199
200     if (ans==0)
201         cout<<"NO"<<endl;
202     else
203         cout<<"YES"<<endl;
204 }
205
206 return 0;
207 }

```

7.3 半平面交

7.3.1 求多边形内核

测试报告: poj3130 3335 3384

复杂度 $O(n^2)$

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<cmath>
5  #define eps 1e-8
6  #define N 1010
7  using namespace std;
8
9  struct Point
10 {
11     double x,y;
12
13     Point(){};
14     Point(double a,double b):x(a),y(b){}
15
16     Point operator - (const Point a) const {return Point(x-a.x,y-a.y);}
17 };
18 Point kernel[N],pt[N];
19
20 int dlcmp(double x)
21 {
22     if (x<=-eps)
23         return -1;
24     else
25         return x>eps?1:0;
26 }
27
28 double cross(Point v1,Point v2) //向量叉积
29 {
30     return v1.x*v2.y-v2.x*v1.y;
31 }
32
33 Point line_intersect(Point s1,Point e1,Point s2,Point e2) //求两点所在直线的交点
34 {
35     Point v1,v2,res;
36     double r;
37
38     v1=s1-e1;
39     v2=s2-e2;
40
41     r=((s1.x-s2.x)*v2.y-(s1.y-s2.y)*v2.x)/(v1.x*v2.y-v1.y*v2.x);
42     res.x=-r*v1.x+s1.x;
43     res.y=-r*v1.y+s1.y;
44
45     return res;
46 }
47
48 void rev_points(Point p[],int n)
49 {
50     int i;
51
52     for (i=0;i<n/2;i++)
53         swap(p[i],p[n-i-1]);
54 }
55
56 double polygon_area(Point pln[],int n) //求多边形有向面积,顺时针为负,逆时针为正
```

```

58 {
59     int i;
60     double res=0;
61
62     for (i=0;i<n;i++)
63         res+=cross(pln[i],pln[(i+1)%n]);
64
65     return res/2.0;
66 }
67
68 void cut_polygon(Point org[],int on,Point des[],int &dn,Point s,Point e) //多
    边形切割
69 {
70     int i;
71     int d1,d2;
72
73     dn=0;
74
75     for (i=0;i<on;i++)
76     {
77         d1=dlcmp(cross(e-s,org[i]-s));
78         d2=dlcmp(cross(e-s,org[(i+1)%on]-s));
79
80         if (d1>=0)
81             des[dn++]=org[i];
82         if (d1*d2<0)
83             des[dn++]=line_intersect(s,e,org[i],org[(i+1)%on]);
84     }
85 }
86
87 void polygon_kernel(Point org[],int on,Point kernel[],int &kn) //求多边形内核
88 {
89     int i,j,dn;
90     Point des[N];
91
92     if (dlcmp(polygon_area(org,on))<0)
93         rev_points(org,on);
94
95     for (i=0;i<on;i++)
96         kernel[i]=org[i];
97     kn=on;
98
99     for (i=0;i<on;i++)
100     {
101         cut_polygon(kernel,kn,des,dn,org[i],org[(i+1)%on]);
102
103         for (j=0;j<dn;j++)
104             kernel[j]=des[j];
105         kn=dn;
106     }
107 }
108
109 //poj3335
110 int main()
111 {
112     int t,i,pn,kn;
113
114     scanf("%d",&t);
115     while (t--)
116     {
117         scanf("%d",&pn);
118
119         for (i=0;i<pn;i++)

```

```

120         scanf("%lf%lf",&pt[i].x,&pt[i].y);
121
122         polygon_kernel(pt,pn,kernel,kn);
123
124         if (kn==0)
125             printf("NO\n");
126         else
127             printf("YES\n");
128     }
129
130     return 0;
131 }

```

7.3.2 zzyO($n \cdot \log n$)做法

测试报告: poj2451

```

1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<vector>
5  #include<string>
6  #include<queue>
7  #include<cmath>
8  #define N 60000
9  #define eps 1e-8
10 using namespace std;
11
12 int dlcmp(double x)
13 {
14     return x<-eps?-1:x>eps;
15 }
16
17 struct Point
18 {
19     double x,y;
20
21     Point(){}
22     Point(double a,double b):x(a),y(b){}
23
24     Point operator + (const Point a) const {return Point(x+a.x,y+a.y);}
25     Point operator - (const Point a) const {return Point(x-a.x,y-a.y);}
26 };
27
28 double cross(Point v1,Point v2)
29 {
30     return v1.x*v2.y-v2.x*v1.y;
31 }
32
33 Point line_intersect(Point s1,Point e1,Point s2,Point e2)
34 {
35     Point v1,v2,res;
36     double r;
37
38     v1=s1-e1;
39     v2=s2-e2;
40     r=((s1.x-s2.x)*v2.y-(s1.y-s2.y)*v2.x)/(v1.x*v2.y-v1.y*v2.x);
41
42     res.x=-r*v1.x+s1.x;
43     res.y=-r*v1.y+s1.y;
44
45     return res;
46 }

```

```

47
48 struct Vector
49 {
50     Point s,e;
51     double ang;
52
53     Vector(){}
54     Vector(Point a,Point b):s(a),e(b){ang=atan2(e.y-s.y,e.x-s.x);}
55
56     bool operator == (const Vector &v) const
57     {
58         return dlcmp(ang-v.ang)==0;
59     }
60
61     bool operator < (const Vector &v) const
62     {
63         if (dlcmp(ang-v.ang)==0)
64             return dlcmp(cross(v.e-v.s,e-v.s))>=0;
65         else
66             return dlcmp(ang-v.ang)<0;
67     }
68 };
69
70 struct HalfPlane
71 {
72     Vector plane[N];
73     int n;
74
75     HalfPlane():n(0){}
76
77     void add(Vector v)
78     {
79         plane[n++]=v;
80     }
81
82     void add(Point s,Point e)
83     {
84         Vector v(s,e);
85         plane[n++]=v;
86     }
87
88     int check(Vector &v1,Vector &v2,Vector &v0)
89     {
90         Point o=line_intersect(v1.s,v1.e,v2.s,v2.e);
91
92         return dlcmp(cross(o-v0.s,v0.e-v0.s))>0;
93     }
94
95     //首先需要保证存在交集
96     void work(Point pln[],int &pn)
97     {
98         int i,cnt,head,tail;
99         Vector deque[N];
100
101         sort(plane,plane+n);
102         for (cnt=i=1;i<n;i++)
103             if (!(plane[i]==plane[i-1]))
104                 plane[cnt++]=plane[i];
105         n=cnt;
106
107         head=1,tail=2;
108         deque[head]=plane[0];
109         deque[tail]=plane[1];

```

```

110
111     for (i=2;i<n;i++)
112     {
113         while (head<tail&&check(deque[tail-1],deque[tail],plane[i]))
114             tail--;
115         while (head<tail&&check(deque[head+1],deque[head],plane[i]))
116             head++;
117         deque[++tail]=plane[i];
118     }
119
120     while (head<tail&&check(deque[tail-1],deque[tail],deque[head]))
121         tail--;
122     while (head<tail&&check(deque[head+1],deque[head],deque[tail]))
123         head++;
124     deque[--head]=deque[tail];
125
126     for (pn=0,i=head+1;i<=tail;i++)
127         pln[pn++]=line_intersect(deque[i-1].s,deque[i-1].e,deque[i].s,
128                                   deque[i].e);
129 };
130
131 Point pln[N];
132 HalfPlane w;
133
134 double get_area(Point pln[],int n)
135 {
136     int i;
137     double res=0;
138
139     for (i=1;i<n-1;i++)
140         res+=cross(pln[i]-pln[0],pln[i+1]-pln[0]);
141
142     return fabs(res/2);
143 }
144
145 //poj2451
146 int main()
147 {
148     int n,pn,i;
149     Point s,e;
150     double ans;
151
152     s=Point(0,0);e=Point(10000,0);w.add(s,e);
153     s=Point(10000,0);e=Point(10000,10000);w.add(s,e);
154     s=Point(10000,10000);e=Point(0,10000);w.add(s,e);
155     s=Point(0,10000);e=Point(0,0);w.add(s,e);
156
157     scanf("%d",&n);
158     for (i=0;i<n;i++)
159     {
160         scanf("%lf%lf%lf%lf",&s.x,&s.y,&e.x,&e.y);
161         w.add(s,e);
162     }
163
164     w.work(pln,pn);
165     ans=get_area(pln,pn);
166
167     printf("%.1f\n",ans);
168
169     return 0;
170 }

```

7.3.3 两个简单多边形求面积并、交

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<cmath>
5  #define eps 1e-8
6  #define N 550
7  using namespace std;
8
9  struct Point
10 {
11     double x,y;
12
13     Point (){}
14     Point (double a,double b):x(a),y(b){}
15
16     Point operator - (const Point a) const {return Point(x-a.x,y-a.y);}
17 };
18
19 Point zero(0,0);
20 int dlcmp(double x) {return x<-eps?-1:x>eps;}
21 double cross(Point v1,Point v2) {return v1.x*v2.y-v2.x*v1.y;}
22
23 struct Polygon
24 {
25     Point p[N];
26     int n;
27
28     Polygon():n(0){}
29     void clear(){n=0;}
30     void add(Point a){p[n++]=a;}
31
32     double area()
33     {
34         double res=0;
35         for (int i=1;i<n-1;i++)
36             res+=cross(p[i]-p[0],p[i+1]-p[0]);
37         return fabs(res/2);
38     }
39 };
40
41 Polygon A,B,rec;
42
43
44 Point line_intersect(Point s1,Point e1,Point s2,Point e2) //两直线交点
45 {
46     Point v1,v2,res;
47     double r;
48
49     v1=s1-e1;
50     v2=s2-e2;
51     r=((s1.x-s2.x)*v2.y-(s1.y-s2.y)*v2.x)/(v1.x*v2.y-v1.y*v2.x);
52     res.x=-r*v1.x+s1.x;
53     res.y=-r*v1.y+s1.y;
54
55     return res;
56 }
57
58 void cut(Point s,Point e) //半平面交
59 {
60     int i,j,d1,d2;
61     Polygon ker;
```

```

62
63     for (i=0;i<rec.n;i++)
64     {
65         j=(i+1)%rec.n;
66         d1=dlcmp(cross(e-s,rec.p[i]-s));
67         d2=dlcmp(cross(e-s,rec.p[j]-s));
68
69         if (d1>=0)
70             ker.add(rec.p[i]);
71         if (d1*d2<0)
72             ker.add(line_intersect(s,e,rec.p[i],rec.p[j]));
73     }
74
75     rec=ker;
76 }
77
78 double calc(Point p1,Point p2,Point q1,Point q2)
79 {
80     int dp=dlcmp(cross(p1,p2)),dq=dlcmp(cross(q1,q2));
81     int sgn=dp*dq;
82
83     if (sgn==0)
84         return 0;
85
86     rec.clear();
87     rec.add(zero); rec.add(p1); rec.add(p2);
88     if (dp<0)
89         swap(rec.p[1],rec.p[2]);
90     if (dq>0)
91     {
92         cut(zero,q1);
93         cut(q1,q2);
94         cut(q2,zero);
95     }
96     else
97     {
98         cut(zero,q2);
99         cut(q2,q1);
100        cut(q1,zero);
101    }
102
103    return sgn*rec.area();
104 }
105
106 double solve()
107 {
108     double res=A.area()+B.area();
109     double sum=0;
110     int i,j;
111
112     //对两个多边形三角剖分，分别求两个三角形的面积交
113     for (i=0;i<A.n;i++)
114         for (j=0;j<B.n;j++)
115             sum+=calc(A.p[i],A.p[(i+1)%A.n],B.p[j],B.p[(j+1)%B.n]);
116     res-=fabs(sum); //fabs(sum)为两个多边形的面积交
117
118     return res; //面积并
119 }
120 //hdu3060(题目数据有误)
121 int main()
122 {
123     int n,m,i;
124     Point pt;

```



```

125     double ans;
126
127     while (scanf("%d%d",&n,&m)!=EOF)
128     {
129         A.clear();B.clear();
130         for (i=0;i<n;i++)
131         {
132             scanf("%lf%lf",&pt.x,&pt.y);
133             A.add(pt);
134         }
135         for (i=0;i<m;i++)
136         {
137             scanf("%lf%lf",&pt.x,&pt.y);
138             B.add(pt);
139         }
140
141         ans=solve();
142
143         printf("%.2f\n",ans+eps);
144     }
145
146     return 0;
147 }

```

7.4 圆

7.4.1 点类

```
1 struct Point
2 {
3     double x,y;
4
5     Point(){}
6     Point(double a,double b):x(a),y(b){}
7     Point operator + (const Point a) const {return Point(x+a.x,y+a.y);}
8     Point operator - (const Point a) const {return Point(x-a.x,y-a.y);}
9     Point operator * (const double a) const {return Point(x*a,y*a);}
10    Point operator / (const double a) const {return Point(x/a,y/a);}
11
12    bool operator < (const Point a) const
13    {
14        if (dlcmp(x-a.x)==0)
15            return dlcmp(x-a.y)<0;
16        else
17            return dlcmp(x-a.x)<0;
18    }
19    bool operator == (const Point a) const
20    {
21        return !dlcmp(x-a.x)&&!dlcmp(y-a.y);
22    }
23
24    //向量长度定为d
25    Point trunc(double d)
26    {
27        double dis(Point,Point);
28        double len=dis(*this,Point(0,0));
29        return Point(x*d/len,y*d/len);
30    }
31
32    //坐标逆时针旋转a度
33    Point rotate(double a)
34    {
35        return Point(x*cos(a)-y*sin(a),y*cos(a)+x*sin(a));
36    }
37 };
38
39 double dis(Point a,Point b)
40 {
41     return sqrt(sqr(a.x-b.x)+sqr(a.y-b.y));
42 }
43
44 double cross(Point a,Point b,Point s)
45 {
46     double x1=a.x-s.x,y1=a.y-s.y;
47     double x2=b.x-s.x,y2=b.y-s.y;
48
49     return x1*y2-x2*y1;
50 }
51
52 double cross(Point a,Point b)
53 {
54     return a.x*b.y-b.x*a.y;
55 }
56
57 double dot(Point a,Point b,Point s)
58 {
59     double x1=a.x-s.x,y1=a.y-s.y;
```

```

60     double x2=b.x-s.x,y2=b.y-s.y;
61
62     return x1*x2+y1*y2;
63 }
64
65 double dot(Point a,Point b)
66 {
67     return a.x*b.x+a.y*b.y;
68 }

```

7.4.2 圆类

```

1 struct Circle
2 {
3     Point o;
4     double r;
5
6
7     Circle(){}
8     Circle(Point a,double l):o(a),r(l){}
9
10    double area(){return sqr(r)*PI;}
11 };
12
13 //判断圆a是否含于圆b
14 int inner_circle(Circle a,Circle b)
15 {
16     if (dlcmp(a.r-b.r)>0)
17         return 0;
18     return dlcmp(dis(a.o,b.o)+a.r-b.r)<=0;
19 }
20
21 //以base点为基点，极角排序，排序前base需赋初值
22 Point base;
23 int cmp(const Point a,const Point b)
24 {
25     return atan2(a.y-base.y,a.x-base.x)<atan2(b.y-base.y,b.x-base.x);
26 }
27
28 //向量a,b的夹角
29 double vec_angle(Point a,Point b)
30 {
31     double tmp=dot(a,b)/(dis(a,Point(0,0))*dis(b,Point(0,0)));
32     if (dlcmp(tmp-1)>=0) tmp=1;
33     if (dlcmp(tmp+1)<=0) tmp=-1;
34
35     return acos(tmp);
36 }
37
38 //计算由a到b逆时针方向的弓形面积
39 double arc_area(Point a,Point b,Circle c)
40 {
41     double theta=vec_angle(a-c.o,b-c.o);
42     double sf=sqr(c.r)*theta/2.0;
43     double st=sqr(c.r)*sin(theta)/2.0;
44
45     if (dlcmp(cross(a,b,c.o))>0)
46         return sf-st;
47     else
48         return c.area()-sf+st;
49 }
50
51 double arc_area(double th,double r)

```

```

52 | {
53 |     return 0.5*sqr(r)*(th-sin(th));
54 | }

```

7.4.3 圆面积交、并

测试报告: sgu435 hdu3239 spojCRCU spojCRCUT

```

1 | //求两圆交点, 排除相切的情况, 不考虑内含
2 | int inter_circle_or(Circle c1,Circle c2,Point &p1,Point &p2)
3 | {
4 |     double len=dis(c1.o,c2.o);
5 |
6 |     if (dlcmp(len-c1.r-c2.r)>=0)
7 |         return 0;
8 |
9 |     double s=(sqr(c1.r)-sqr(c2.r)+sqr(len))/len/2;
10 |    double h=sqrt(sqr(c1.r)-sqr(s));
11 |    Point vec=c2.o-c1.o;
12 |    Point p0=c1.o+vec.trunc(s);
13 |
14 |    p1=p0+vec.rotate(PI/2).trunc(h);
15 |    p2=p0-vec.rotate(PI/2).trunc(h);
16 |    return 1;
17 | }
18 |
19 | //求两圆交点, 不排除相切的情况, 不考虑内含
20 | int inter_circle_and(Circle c1,Circle c2,Point &p1,Point &p2)
21 | {
22 |     double len=dis(c1.o,c2.o);
23 |
24 |     if (dlcmp(len-c1.r-c2.r)>0)
25 |         return 0;
26 |
27 |     double s=(sqr(c1.r)-sqr(c2.r)+sqr(len))/len/2;
28 |    double h=sqrt(sqr(c1.r)-sqr(s));
29 |    Point vec=c2.o-c1.o;
30 |    Point p0=c1.o+vec.trunc(s);
31 |
32 |    p1=p0+vec.rotate(PI/2).trunc(h);
33 |    p2=p0-vec.rotate(PI/2).trunc(h);
34 |    return 1;
35 | }
36 |
37 | struct Circles
38 | {
39 |     int n;
40 |     Circle c[MAXN];
41 |
42 |     Circles():n(0){}
43 |     void add(Circle cc) {c[n++]=cc;}
44 |     void clear() {n=0;}
45 |
46 |     //初始化圆的面积并, 去掉能被其他圆覆盖的圆
47 |     void init_or()
48 |     {
49 |         char mark[MAXN]={0};
50 |
51 |         int i,j,cnt=0;
52 |
53 |         for (i=0;i<n;i++)
54 |             for (j=0;j<n;j++)
55 |                 if (i!=j&&!mark[j]&&inner_circle(c[i],c[j]))
56 |                     {

```

```

57         mark[i]=1;
58         break;
59     }
60
61     for (i=0;i<n;i++)
62         if (!mark[i])
63             c[cnt++]=c[i];
64     n=cnt;
65 }
66
67 //初始化圆的面积并，去掉能把其他圆覆盖的圆
68 void init_and()
69 {
70     char mark[MAXN]={0};
71
72     int i,j,cnt=0;
73
74     for (i=0;i<n;i++)
75         for (j=0;j<n;j++)
76             if (i!=j&&!mark[j]&&inner_circle(c[j],c[i]))
77             {
78                 mark[i]=1;
79                 break;
80             }
81
82     for (i=0;i<n;i++)
83         if (!mark[i])
84             c[cnt++]=c[i];
85     n=cnt;
86 }
87
88 //判断圆弧是否被其他圆覆盖
89 int isvalid_or(Point a,Point b,int num)
90 {
91     Point vec,p;
92     int i;
93
94     vec=a-b;
95     p=c[num].o+vec.rotate(PI/2).trunc(c[num].r);
96
97     for (i=0;i<n;i++)
98         if (i!=num&&dlcmp(dis(p,c[i].o)-c[i].r)<0)
99             return 0;
100     return 1;
101 }
102
103 //判断点是否被其他圆覆盖
104 int isvalid_and(Point a)
105 {
106     int i;
107
108     for (i=0;i<n;i++)
109         if (dlcmp(dis(a,c[i].o)-c[i].r)>0)
110             return 0;
111     return 1;
112 }
113
114 //判断圆弧是否被其他圆覆盖
115 int isvalid_and(Point a,Point b,int num)
116 {
117     Point vec,p;
118     int i;
119

```

```

120         vec=a-b;
121         p=c[num].o+vec.rotate(PI/2).trunc(c[num].r);
122
123         return isvalid_and(p);
124     }
125
126     //计算圆的面积并
127     double area_or()
128     {
129         int i,j,k;
130         vector<Point>s[MAXN];
131         Point a,b;
132         double sa=0,sp=0;
133
134         init_or();
135
136         for (i=0;i<n;i++)
137             for (j=i+1;j<n;j++)
138                 if (inter_circle_or(c[i],c[j],a,b))
139                 {
140                     s[i].push_back(a);
141                     s[i].push_back(b);
142                     s[j].push_back(a);
143                     s[j].push_back(b);
144                 }
145
146
147         for (i=0;i<n;i++)
148         {
149             if (s[i].empty())
150             {
151                 sa+=c[i].area();
152                 continue;
153             }
154
155             base=c[i].o;
156             sort(s[i].begin(),s[i].end(),cmp);
157             s[i].resize(unique(s[i].begin(),s[i].end())-s[i].begin());
158             if (s[i].front()==s[i].back())
159                 s[i].pop_back();
160
161             for (j=0;j<s[i].size();j++)
162             {
163                 k=(j+1)%s[i].size();
164
165                 if (isvalid_or(s[i][j],s[i][k],i))
166                 {
167                     sa+=arc_area(s[i][j],s[i][k],c[i]);
168                     sp+=cross(s[i][j],s[i][k],Point(0,0));
169                 }
170             }
171         }
172
173         return sa+fabs(sp)/2.0;
174     }
175
176     //计算圆的面积交，若交集为空，返回-1.0，若交集为一点，保存交点到res中
177     double area_and(Point &res)
178     {
179         int i,j,k;
180         vector<Point>s[MAXN];
181         Point a,b;
182         double sa=0,sp=0;

```

```

183
184     init_and();
185     if (n==1)
186         return c[0].area();
187
188     for (i=0;i<n;i++)
189         for (j=i+1;j<n;j++)
190             if (inter_circle_and(c[i],c[j],a,b))
191             {
192                 s[i].push_back(a);
193                 s[i].push_back(b);
194                 s[j].push_back(a);
195                 s[j].push_back(b);
196             }
197             else
198                 return -1.0;
199
200     for (i=0;i<n;i++)
201     {
202         base=c[i].o;
203         sort(s[i].begin(),s[i].end(),cmp);
204
205         s[i].resize(unique(s[i].begin(),s[i].end())-s[i].begin());
206         if (s[i].front()==s[i].back())
207             s[i].pop_back();
208
209         if (s[i].size()==1)
210         {
211             if (isvalid_and(s[i][0]))
212                 res=s[i][0];
213             continue;
214         }
215
216         for (j=0;j<s[i].size();j++)
217         {
218             if (isvalid_and(s[i][j]))
219                 res=s[i][j];
220
221             k=(j+1)%s[i].size();
222
223             if (isvalid_and(s[i][j],s[i][k],i))
224             {
225                 sa+=arc_area(s[i][j],s[i][k],c[i]);
226                 sp+=cross(s[i][j],s[i][k],Point(0,0));
227             }
228         }
229     }
230
231     return sa+fabs(sp)/2.0;
232 }
233
234
235 //计算被覆盖i次的面积
236 double ans[MAXN],pre[MAXN]; //ans[i]保存被覆盖i次的面积
237
238 void get_area()
239 {
240     int i,j,k;
241
242     memset(ans,0,sizeof(ans));
243
244     vector<pair<double,int> >v;
245

```

```

246     for (i=0;i<n;i++)
247     {
248         v.clear();
249         v.push_back(make_pair(-PI,1));
250         v.push_back(make_pair(PI,-1));
251
252         for (j=0;j<n;j++)
253             if (i!=j)
254             {
255                 Point q=c[j].o-c[i].o;
256                 double ab=dis(q,Point(0,0)),ac=c[i].r,bc=c[j].r;
257
258                 if (dlcmp(ab+ac-bc)<=0)
259                 {
260                     v.push_back(make_pair(-PI,1));
261                     v.push_back(make_pair(PI,-1));
262                     continue;
263                 }
264
265                 if (dlcmp(ab+bc-ac)<=0||dlcmp(ab-ac-bc)>0)
266                     continue;
267
268                 double th=atan2(q.y,q.x);
269                 double fai=acos((ac*ac+ab*ab-bc*bc)/(2.0*ac*ab));
270
271                 double a0=th-fai;
272                 if (dlcmp(a0+PI)<0)
273                     a0+=2*PI;
274                 double a1=th+fai;
275                 if (dlcmp(a1-PI)>0)
276                     a1-=2*PI;
277
278                 if (dlcmp(a0-a1)>0)
279                 {
280                     v.push_back(make_pair(a0,1));
281                     v.push_back(make_pair(PI,-1));
282                     v.push_back(make_pair(-PI,1));
283                     v.push_back(make_pair(a1,-1));
284                 }
285                 else
286                 {
287                     v.push_back(make_pair(a0,1));
288                     v.push_back(make_pair(a1,-1));
289                 }
290             }
291
292         sort(v.begin(),v.end());
293
294         int cur=0;
295
296         for (j=0;j<v.size();j++)
297         {
298             if (cur&&dlcmp(v[j].first-pre[cur]))
299             {
300                 ans[cur]+=arc_area(v[j].first-pre[cur],c[i].r);
301                 Point pa(c[i].o.x+c[i].r*cos(pre[cur]),c[i].o.y+c[i].r*
302                     sin(pre[cur]));
303                 Point pb(c[i].o.x+c[i].r*cos(v[j].first),c[i].o.y+c[i].r*
304                     sin(v[j].first));
305                 ans[cur]+=0.5*cross(pa,pb);
306             }
307             cur+=v[j].second;
308             pre[cur]=v[j].first;

```



```

307         }
308     }
309
310     for (i=1;i<=n;i++)
311         ans[i]-=ans[i+1];
312 }
313 };

```

7.4.4 简单多边形与圆求面积交

```

1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<cmath>
5  #define N 200
6  #define eps 1e-8
7  using namespace std;
8
9  const double PI=acos(-1.0);
10
11 struct Point
12 {
13     double x,y;
14 };
15
16 Point pt[N];
17 int n;
18
19 int dlcmp(double x)
20 {
21     return x<-eps?-1:x>eps;
22 }
23
24 double sqr(double x)
25 {
26     return x*x;
27 }
28
29 double dis(Point a,Point b)
30 {
31     return sqrt(sqr(a.x-b.x)+sqr(a.y-b.y));
32 }
33
34 double outer(Point a,Point b,Point c)
35 {
36     return (a.x-c.x)*(b.y-c.y)-(a.y-c.y)*(b.x-c.x);
37 }
38
39 double inner(Point a,Point b,Point c)
40 {
41     return (a.x-c.x)*(b.x-c.x)+(a.y-c.y)*(b.y-c.y);
42 }
43
44 double calc_area(Point a,Point b,Point c,double r)
45 {
46     double A,B,C,x,y,tS;
47
48     A=dis(b,c);
49     B=dis(a,c);
50     C=dis(b,a);
51
52     if (A<r&&B<r)
53         return outer(a,b,c)/2;

```

```

54
55     else if (A<r&&B>=r)
56     {
57         x=(inner(a,c,b)+sqrt(sqr(r)*sqr(C)-sqr(outer(a,c,b))))/C;
58         tS=outer(a,b,c)/2;
59
60         return asin(tS*(1-x/C)*2/r/B)*sqr(r)/2+tS*x/C;
61     }
62     else if (A>=r&&B<r)
63     {
64         y=(inner(b,c,a)+sqrt(sqr(r)*sqr(C)-sqr(outer(b,c,a))))/C;
65         tS=outer(a,b,c)/2;
66
67         return asin(tS*(1-y/C)*2/r/A)*sqr(r)/2+tS*y/C;
68     }
69     else if (fabs(outer(a,b,c))>=r*C||inner(b,c,a)<=0||inner(a,c,b)<=0)
70     {
71         if (inner(a,b,c)<0)
72         {
73             if (outer(a,b,c)<0)
74                 return (-PI-asin(outer(a,b,c)/A/B))*sqr(r)/2;
75             else
76                 return (PI-asin(outer(a,b,c)/A/B))*sqr(r)/2;
77         }
78         else
79             return asin(outer(a,b,c)/A/B)*sqr(r)/2;
80     }
81     else
82     {
83         x=(inner(a,c,b)+sqrt(sqr(r)*sqr(C)-sqr(outer(a,c,b))))/C;
84         y=(inner(b,c,a)+sqrt(sqr(r)*sqr(C)-sqr(outer(b,c,a))))/C;
85         tS=outer(a,b,c)/2;
86
87         return (asin(tS*(1-x/C)*2/r/B)+asin(tS*(1-y/C)*2/r/A))*sqr(r)/2+tS
            *((y+x)/C-1);
88     }
89 }
90
91 //计算一般多边形与圆的交面积 (将多边形划分为三角形, 然后有向三角形与圆求有向面积交)
92 double solve(Point o,double r)
93 {
94     int i,j;
95     double res,sum;
96     Point tri[3];
97
98     res=0;
99     for (i=1;i<n-1;i++)
100     {
101         tri[0]=pt[0];
102         tri[1]=pt[i];
103         tri[2]=pt[i+1];
104         sum=0;
105
106         for (j=0;j<3;j++)
107             sum+=calc_area(tri[j],tri[(j+1)%3],o,r);
108
109         //sum为三角形与圆交的有向面积
110         res+=sum;
111     }
112
113     return fabs(res);
114 }
115

```

```

116 //poj3675
117 int main()
118 {
119     double x0,y0,v,vx,vy,g,r,t,theta,ans;
120     Point o;
121     int i;
122
123     o.x=o.y=0;
124
125     while (scanf("%lf",&r)!=EOF)
126     {
127         scanf("%d",&n);
128         for (i=0;i<n;i++)
129             scanf("%lf%lf",&pt[i].x,&pt[i].y);
130
131         ans=solve(o,r);
132
133         printf("%.2f\n",ans);
134     }
135
136     return 0;
137 }

```

7.4.5 求线段与圆的交点

若求直线与圆的交点类似，无需讨论 k_1 、 k_2 的取值范围

```

1 int inter_circle_segment(Circle c,Point a,Point b,Point &p1,Point &p2)
2 {
3     Point vec=b-a;
4     double A=sqr(vec.x)+sqr(vec.y);
5     double B=2*(vec.x*(a.x-c.o.x)+vec.y*(a.y-c.o.y));
6     double C=sqr(a.x-c.o.x)+sqr(a.y-c.o.y)-sqr(c.r);
7     double delta=sqr(B)-4*A*C;
8
9     if (dlcmp(delta)<0)
10         return 0;
11
12     double k1=(-B-sqrt(fabs(delta)))/(2*A);
13     double k2=(-B+sqrt(fabs(delta)))/(2*A);
14     int res=0;
15
16
17     if (dlcmp(k1)>=0&&dlcmp(k1-1)<=0)
18     {
19         res++;
20         p1=a+vec*k1;
21     }
22
23     if (dlcmp(k2)>=0&&dlcmp(k2-1)<=0)
24     {
25         res++;
26
27         if (res==1)
28             p1=a+vec*k2;
29         else
30             p2=a+vec*k2;
31     }
32
33     return res;
34 }

```

7.4.6 求两圆公切线

```

1 //求两相离的圆的两条内共切线
2 void get_InCommonTangent(Circle c1,Circle c2,Point &s1,Point &e1,Point &s2,
   Point &e2)
3 {
4     double l=dis(c1.o,c2.o);
5     double d=l*c1.r/(c1.r+c2.r);
6     double tmp=c1.r/d;
7     tmp=fix(tmp);
8     double theta=acos(tmp);
9     Point vec=c2.o-c1.o;
10
11     vec=vec.trunc(c1.r);
12     s1=c1.o+vec.rotate(theta);
13     s2=c1.o+vec.rotate(-theta);
14
15     vec=c1.o-c2.o;
16     vec=vec.trunc(c2.r);
17     e1=c2.o+vec.rotate(theta);
18     e2=c2.o+vec.rotate(-theta);
19 }
20
21 //求两相离的圆的两条外公切线
22 void get_OutCommonTangent(Circle c1,Circle c2,Point &s1,Point &e1,Point &s2,
   Point &e2)
23 {
24     double l=dis(c1.o,c2.o);
25     double d=fabs(c1.r-c2.r);
26     double theta=acos(d/l);
27
28     if (dlcmp(c1.r-c2.r)>0)
29         swap(c1,c2);
30
31     Point vec=c1.o-c2.o;
32     vec=vec.trunc(c1.r);
33     s1=c1.o+vec.rotate(theta);
34     s2=c1.o+vec.rotate(-theta);
35     vec=vec.trunc(c2.r);
36     e1=c2.o+vec.rotate(theta);
37     e2=c2.o+vec.rotate(-theta);
38 }

```

7.4.7 最小圆覆盖

测试报告: zoj1450 hysbz1336 1337 hdu3007 3932

```

1 #define eps 1e-8
2 #define MAX_P 2000
3 struct Point
4 {
5     double x,y;
6
7     Point operator-(Point &a)
8     {
9         Point t;
10
11         t.x=x-a.x;
12         t.y=y-a.y;
13
14         return t;
15     }
16 };
17
18 struct Circle
19 {
20     double r;

```

```

21     Point center;
22 };
23
24 struct Triangle
25 {
26     Point t[3];
27 };
28
29 Point pt[MAX_P];    //点集
30 Circle c;           //最小圆
31
32 double distance(Point a,Point b)
33 {
34     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
35 }
36
37 double cross(Point a,Point b)
38 {
39     return a.x*b.y-b.x*a.y;
40 }
41
42 double triangle_area(Triangle tri)    //三角形面积
43 {
44     Point v1=tri.t[1]-tri.t[0];
45     Point v2=tri.t[2]-tri.t[0];
46
47     return fabs(cross(v1,v2))/2;
48 }
49
50 Circle circumcircle_triangle(Triangle tri)    //三角形外接圆
51 {
52     Circle res;
53
54     double a,b,c,c1,c2;
55     double xA,yA,xB,yB,xC,yC;
56
57     a=distance(tri.t[0],tri.t[1]);
58     b=distance(tri.t[1],tri.t[2]);
59     c=distance(tri.t[2],tri.t[0]);
60
61     res.r=a*b*c/triangle_area(tri)/4;
62
63     xA=tri.t[0].x; yA=tri.t[0].y;
64     xB=tri.t[1].x; yB=tri.t[1].y;
65     xC=tri.t[2].x; yC=tri.t[2].y;
66
67     c1=(xA*xA+yA*yA-xB*xB-yB*yB)/2;
68     c2 = (xA*xA+yA*yA-xC*xC-yC*yC)/2;
69
70     res.center.x=(c1*(yA-yC)-c2*(yA-yB))/ ((xA-xB)*(yA-yC)-(xA-xC)*(yA-yB));
71     res.center.y = (c1*(xA-xC)-c2*(xA-xB))/ ((yA-yB)*(xA-xC)-(yA-yC)*(xA-xB));
72
73     return res;
74 }
75
76 Circle mincircle_triangle(int trinum,Triangle tri)
77 {
78     Circle res;
79
80     if (trinum==0)
81         res.r=-2;
82     else if (trinum==1)

```

```

83     {
84         res.center=tri.t[0];
85         res.r=0;
86     }
87     else if (trinum==2)
88     {
89         res.center.x=(tri.t[0].x+tri.t[1].x)/2;
90         res.center.y=(tri.t[0].y+tri.t[1].y)/2;
91         res.r=distance(tri.t[0],tri.t[1])/2;
92     }
93     else if (trinum==3)
94         res=circumcircle_triangle(tri);
95
96     return res;
97 }
98
99 void mincircle_pointset(int m,int trinum,Triangle tri) //求点集的最小覆盖圆
100 {
101     int i,j;
102     Point tmp;
103
104     c=mincircle_triangle(trinum,tri);
105
106     if (trinum==3)
107         return;
108
109     for (i=0;i<m;i++)
110         if (distance(pt[i],c.center)>c.r)
111         {
112             tri.t[trinum]=pt[i];
113
114             mincircle_pointset(i,trinum+1,tri);
115
116             tmp=pt[i];
117
118             for (j=i;j>=1;j--)
119                 pt[j]=pt[j-1];
120
121             pt[0]=tmp;
122         }
123 }
124
125 main()
126 {
127     int n,i,f1,f2;
128     Triangle tri;
129
130     while (scanf("%d%d%d",&f1,&f2,&n)!=EOF)
131     {
132         for (i=0;i<n;i++)
133             scanf("%lf%lf",&pt[i].x,&pt[i].y);
134
135         mincircle_pointset(n,0,tri);
136         printf("%lf %lf %lf\n",c.center.x,c.center.y,c.r);
137     }
138     return 0;
139 }

```

7.4.8 单位圆覆盖

测试报告: poj1981

```
1 #include<math.h>
```

```

2 #define eps 1e-8
3 #define MAX_P 505
4 const double r=1.0;//单位圆半径
5
6 struct Point
7 {
8     double x,y;
9 };
10
11 Point pt[MAX_P];
12
13 double distance(Point a,Point b)
14 {
15     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
16     //sqrt函数速度较慢，应尽量避免出现，此处可优化为距离的平方和的形式
17 }
18
19 Point find_center(Point a,Point b)
20 {
21     Point v,mid,center;
22     double d,s,ang;
23
24     v.x=a.x-b.x;
25     v.y=a.y-b.y;
26
27     mid.x=(a.x+b.x)/2;
28     mid.y=(a.y+b.y)/2;
29
30     d=distance(a,mid);
31     s=sqrt(r*r-d*d);      //优化为s=sqrt(r*r-d);
32
33     if (fabs(v.y)<eps)
34     {
35         center.x=mid.x;
36         center.y=mid.y+s;
37     }
38     else
39     {
40         ang=atan(-v.x/v.y);
41         center.x=mid.x+s*cos(ang);
42         center.y=mid.y+s*sin(ang);
43     }
44
45     return center;
46 }
47
48 main()
49 {
50
51     int n,i,j,k,ans,cnt;
52     double tmp;
53     Point center;
54
55     while (scanf("%d",&n),n)
56     {
57         for (i=0;i<n;i++)
58             scanf("%lf%lf",&pt[i].x,&pt[i].y);
59
60         ans=1;
61         for (i=0;i<n;i++)
62             for (j=i+1;j<n;j++)
63             {

```

```

64 |         if (distance(pt[i],pt[j])>2*r)    //优化
        为distance(pt[i],pt[j])>2*2*r*r
65 |         continue;
66 |
67 |         cnt=0;
68 |         center=find_center(pt[i],pt[j]);
69 |
70 |         for (k=0;k<n;k++)
71 |             if (distance(pt[k],center)<=r+eps)
72 |                 cnt++;
73 |
74 |         if (ans<cnt)
75 |             ans=cnt;
76 |     }
77 |
78 |     printf("%d\n",ans);
79 | }
80 |
81 | return 0;
82 | }

```


7.5 模拟退火

7.5.1 求多边形费马点

测试报告: poj2420

```
1  #include<iostream>
2  #include<cstdio>
3  #include<cmath>
4  #define eps 1e-6
5  #define N 105
6  using namespace std;
7
8  struct Point
9  {
10     double x,y;
11 };
12
13
14 double point_dis(Point a,Point b)
15 {
16     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
17 }
18
19
20 double sum_dis(Point pt[],int n,Point o)
21 {
22     double res=0;
23     int i;
24
25     for (i=0;i<n;i++)
26         res+=point_dis(pt[i],o);
27
28     return res;
29 }
30
31 double polygon_Fermatpoint(Point pln[],int n)
32 {
33     Point cp,np,tmp;
34     double min,step,d;
35     int flag;
36
37     cp=pln[0];          //cp保存当前更新后最优的费马点
38     min=sum_dis(pln,n,cp);
39     step=10000;          //选取坐标范围的最大值
40
41     while (step>eps)
42     {
43         flag=1;
44         while (flag)
45         {
46             flag=0;
47             np=cp;
48
49             tmp=cp,tmp.x+=step;
50             d=sum_dis(pln,n,tmp);
51
52             if (min>d)
53                 min=d, np=tmp, flag=1;
54
55             tmp=cp,tmp.x-=step;
56             d=sum_dis(pln,n,tmp);
57
58             if (min>d)
```

```

59         min=d, np=tmp,flag=1;
60
61         tmp=cp,tmp.y+=step;
62         d=sum_dis(pln,n,tmp);
63
64         if (min>d)
65             min=d, np=tmp,flag=1;
66
67         tmp=cp,tmp.y-=step;
68         d=sum_dis(pln,n,tmp);
69
70         if (min>d)
71             min=d, np=tmp,flag=1;
72
73         cp=np;
74     }
75
76     step*=0.98;    //系数根据精度要求修改
77 }
78
79 return min;
80 }
81
82 main()
83 {
84     int n,i;
85     double min;
86     Point pt[N];
87
88     cin>>n;
89
90     for (i=0;i<n;i++)
91         cin>>pt[i].x>>pt[i].y;
92
93     min=polygon_Fermatpoint(pt,n);
94
95     printf("%.0f\n",min);
96
97     return 0;
98 }

```

7.5.2 最小球覆盖

测试报告: poj2069 cf106E

```

1  #include<iostream>
2  #include<cstdio>
3  #include<cmath>
4  #define oo 1e20
5  #define eps 1e-10
6  #define N 105
7  using namespace std;
8
9  struct Point
10 {
11     double x,y,z;
12 };
13
14 double dis(Point a,Point b)
15 {
16     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y)+(a.z-b.z)*(a.z-b.z));
17 }

```

```

18
19 int max_dis(Point pt[],int n,Point o)
20 {
21     int i,res;
22     double max,tmp;
23
24     max=0;
25     res=0;
26
27     for (i=0;i<n;i++)
28     {
29         tmp=dis(pt[i],o);
30
31         if (max<tmp)
32         {
33             max=tmp;
34             res=i;
35         }
36     }
37
38     return res;
39 }
40
41 int main()
42 {
43     Point pt[N],o;
44     int n,i,t;
45     double dx,dy,dz,step,r,tmp;
46
47     cin>>n;
48
49     for (i=0;i<n;i++)
50         cin>>pt[i].x>>pt[i].y>>pt[i].z;
51
52     step=10000;    //step选取最大的坐标范围
53     r=0;
54
55     if (n==1)
56     {
57         o.x=pt[0].x;
58         o.y=pt[0].y;
59         o.z=pt[0].z;
60     }
61     else
62     {
63         o.x=o.y=o.z=0;
64         while (step>eps)
65         {
66             t=max_dis(pt,n,o);
67             tmp=dis(pt[t],o);
68
69             if (r>tmp)
70                 r=tmp;
71
72             dx=(pt[t].x-o.x)/tmp;
73             dy=(pt[t].y-o.y)/tmp;
74             dz=(pt[t].z-o.z)/tmp;
75
76             o.x+=step*dx;
77             o.y+=step*dy;
78             o.z+=step*dz;
79
80             step*=0.9993;    //系数的选取根据具体精度调整

```

```
81 |         }
82 |     }
83 |     printf("%.6f %.6f %.6f\n",o.x,o.y,o.z);
84 |
85 |     return 0;
86 | }
```

7.6 三维几何

7.6.1 三维凸包

测试报告: hdu3662 poj3528

```
1 #include<iostream>
2 #include<cstdio>
3 #include<cstring>
4 #include<cmath>
5 #include<algorithm>
6 #define N 505
7 #define eps 1e-8
8 using namespace std;
9
10 struct Point
11 {
12     double x,y,z;
13     Point(){}
14     Point (double px,double py,double pz):x(px),y(py),z(pz){}
15     Point operator - (const Point p)
16     {
17         return Point(x-p.x,y-p.y,z-p.z);
18     }
19     Point operator * (const Point p)
20     {
21         return Point(y*p.z-z*p.y,z*p.x-x*p.z,x*p.y-y*p.x);
22     }
23     double operator ^ (const Point p)
24     {
25         return x*p.x+y*p.y+z*p.z;
26     }
27 };
28
29 struct ConvexPolygon3D
30 {
31     struct Face
32     {
33         int a,b,c;
34         bool flag;
35     };
36
37     int n;
38     Point pt[N];
39     int tri_num;
40     Face face[8*N];
41     int g[N][N];
42
43     double veclen(const Point &p)
44     {
45         return sqrt(p.x*p.x+p.y*p.y+p.z*p.z);
46     }
47
48     Point cross(const Point &a, const Point &b, const Point &c)
49     {
50         return Point((b.y-a.y)*(c.z-a.z)-(b.z-a.z)*(c.y-a.y),-((b.x-a.x)*(c.
51             z-a.z)-(b.z-a.z)*(c.x-a.x)),(b.x-a.x)*(c.y-a.y)-(b.y-a.y)*(c.x-a.
52             x));
53     }
54
55     double tri_area(Point a,Point b,Point c)
56     {
57         return veclen((a-c)*(b-c))/2;
```

```

58 double tetrahedron_volume(Point a,Point b,Point c,Point d)
59 {
60     return ((b-a)*(c-a)^(d-a))/6;
61 }
62
63 double dlcmp(Point &p,Face &f)
64 {
65     Point m=pt[f.b]-pt[f.a];
66     Point n=pt[f.c]-pt[f.a];
67     Point t=p-pt[f.a];
68
69     return (m*n)^t;
70 }
71
72 void deal(int a,int b,int p)
73 {
74     int f=g[a][b];
75     Face add;
76
77     if (face[f].flag)
78     {
79         if (dlcmp(pt[p],face[f])>eps)
80             dfs(p,f);
81         else
82         {
83             add.a=b;
84             add.b=a;
85             add.c=p;
86             add.flag=1;
87             g[p][b]=g[a][p]=g[b][a]=tri_num;
88             face[tri_num++]=add;
89         }
90     }
91 }
92
93 void dfs(int p,int now)
94 {
95     face[now].flag=0;
96     deal(face[now].b,face[now].a,p);
97     deal(face[now].c,face[now].b,p);
98     deal(face[now].a,face[now].c,p);
99 }
100
101 bool same(int s,int t)
102 {
103     Point &a=pt[face[s].a];
104     Point &b=pt[face[s].b];
105     Point &c=pt[face[s].c];
106
107     bool res=fabs(tetrahedron_volume(a,b,c,pt[face[t].a]))<eps&&
108             fabs(tetrahedron_volume(a,b,c,pt[face[t].b]))<eps&&
109             fabs(tetrahedron_volume(a,b,c,pt[face[t].c]))<eps;
110
111     return res;
112 }
113
114 void solve()
115 {
116     int i,j,tmp;
117     Face add;
118     bool flag;
119
120     tri_num=0;

```

```

121
122     if (n<4)
123         return;
124
125     flag=true;
126     for (i=1;i<n;i++)
127         if (veclen((pt[0]-pt[1])*(pt[1]-pt[i]))>eps)
128             {
129                 swap(pt[2],pt[i]);
130                 flag=false;
131                 break;
132             }
133
134     if (flag)
135         return;
136
137     flag=true;
138     for (i=2;i<n;i++)
139         if (fabs((pt[0]-pt[1])*(pt[1]-pt[2])^(pt[0]-pt[i]))>eps)
140             {
141                 swap(pt[3],pt[i]);
142                 flag=false;
143                 break;
144             }
145
146     if (flag)
147         return;
148
149     flag=true;
150     for (i=3;i<n;i++)
151         if (veclen(pt[0]-pt[i])>eps)
152             {
153                 swap(pt[1],pt[i]);
154                 flag=false;
155                 break;
156             }
157
158     if (flag)
159         return;
160
161     for (i=0;i<4;i++)
162     {
163         add.a=(i+1)%4;
164         add.b=(i+2)%4;
165         add.c=(i+3)%4;
166         add.flag=true;
167
168         if (dlcmp(pt[i],add)>0)
169             swap(add.b,add.c);
170
171         g[add.a][add.b]=g[add.b][add.c]=g[add.c][add.a]=tri_num;
172         face[tri_num++]=add;
173     }
174
175     for (i=4;i<n;i++)
176         for (j=0;j<tri_num;j++)
177             if (face[j].flag&&dlcmp(pt[i],face[j])>eps)
178                 {
179                     dfs(i,j);
180                     break;
181                 }
182
183     tmp=tri_num;

```

```

184         for (i=tri_num=0;i<tmp;i++)
185             if (face[i].flag)
186                 face[tri_num++]=face[i];
187     }
188
189     double area()
190     {
191         double res=0;
192
193         if (n==3)
194         {
195             Point p=cross(pt[0],pt[1],pt[2]);
196             res=veclen(p)/2;
197         }
198         else
199         {
200             for (int i=0;i<tri_num;i++)
201                 res+=tri_area(pt[face[i].a],pt[face[i].b],pt[face[i].c]);
202         }
203
204         return res;
205     }
206
207     double volume()
208     {
209         double res=0;
210         Point tmp(0,0,0);
211
212         for (int i=0;i<tri_num;i++)
213             res+=tetrahedron_volume(tmp,pt[face[i].a],pt[face[i].b],pt[face[i].c]);
214
215         return fabs(res);
216     }
217
218     Point get_center() //凸包重心
219     {
220         Point res(0,0,0),o(0,0,0),p;
221         double sum,vol;
222         int i;
223
224         sum=0;
225         for (i=0;i<tri_num;i++)
226         {
227             vol=tetrahedron_volume(o,pt[face[i].a],pt[face[i].b],pt[face[i].c]);
228             sum+=vol;
229             p=(pt[face[i].a]+pt[face[i].b]+pt[face[i].c])/4;
230             p.x*=vol; p.y*=vol; p.z*=vol;
231             res=res+p;
232         }
233
234         res=res/sum;
235         return res;
236     }
237
238     int triangle_num()
239     {
240         return tri_num;
241     }
242
243     int polygon_num()
244     {

```



```

245         int i,j,res,flag;
246
247         res=0;
248         for (i=0;i<tri_num;i++)
249         {
250             flag=1;
251             for (j=0;j<i;j++)
252                 if (same(i,j))
253                 {
254                     flag=0;
255                     break;
256                 }
257             res+=flag;
258         }
259
260         return res;
261     }
262 };
263
264 ConvexPolygon3D hull;
265
266 //点p到平面abc的距离
267 double dis_point_face(Point p,Point a,Point b,Point c)
268 {
269     Point vec=(b-a)*(c-a);
270     Point t=a-p;
271     double tmp=(vec^t)/(vec.len()*t.len());
272
273     return fabs(t.len()*tmp);
274 }
275
276 int main()
277 {
278     int i;
279
280     while(scanf("%d",&hull.n)!=EOF)
281     {
282
283         for(i=0;i<hull.n;i++)
284             scanf("%lf%lf%lf",&hull.pt[i].x,&hull.pt[i].y,&hull.pt[i].z);
285         hull.solve();
286
287         printf("%.3f\n",hull.area());
288     }
289
290     return 0;
291 }

```

7.6.2 求两球体积并

测试报告: zoj3500

```

1  #define PI (acos(-1.0))
2
3  struct Point
4  {
5      double x,y,z;
6  };
7
8  double dis(Point a,Point b)
9  {
10     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y)+(a.z-b.z)*(a.z-b.z))
        ;

```

```

11 }
12
13 double ball_volume_combination(Point o1,double r1,Point o2,double r2)
14 {
15     double d,R,r,p,l,H,h,res;
16     R=max(r1,r2),r=min(r1,r2);
17     d=dis(o1,o2);
18     res=PI*(R*R*R+r*r*r)*4/3;
19
20     if (R+r>d)
21     {
22         if (R-r<=d)
23         {
24             p=(R+r+d)/2;
25             l=sqrt(p*(p-R)*(p-r)*(p-d))*2/d;
26             H=sqrt(R*R-l*l);
27             h=sqrt(r*r-l*l);
28
29             res-=PI*(R*R*R*2/3-R*R*H+H*H*H/3);
30
31             if (R*R-r*r<=d*d)
32                 res-=PI*(r*r*r*2/3-r*r*h+h*h*h/3);
33             else
34                 res-=PI*r*r*r*4/3-PI*(r*r*r*2/3-r*r*h+h*h*h/3);
35         }
36         else
37             res-=PI*r*r*r*4/3;
38     }
39
40     return res;
41 }

```

7.7 三维仿射变换

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<vector>
5  #include<stack>
6  #include<cmath>
7  #define eps 1e-6
8  #define SZ 10
9  using namespace std;
10
11 const double PI=acos(-1.0);
12 int dlcmp(double x) {return x<-eps?-1:x>eps;}
13 double sqr(double x) {return x*x;}
14
15 struct Matrix
16 {
17     double m[SZ][SZ];
18
19     void Identity()
20     {
21         for (int i=0;i<SZ;i++)
22             for (int j=0;j<SZ;j++)
23                 m[i][j]=(i==j?1.0:0.0);
24     }
25
26     Matrix (){Identity();}
27
28     Matrix operator * (const Matrix &a)
29     {
30         Matrix res;
31
32         for (int i=0;i<SZ;i++)
33             for (int j=0;j<SZ;j++)
34             {
35                 res.m[i][j]=0;
36                 for (int k=0;k<SZ;k++)
37                     res.m[i][j]+=m[i][k]*a.m[k][j];
38             }
39
40         return res;
41     }
42 };
43
44 struct Point
45 {
46     double x,y,z;
47
48     Point (){}
49     Point (double a,double b,double c):x(a),y(b),z(c){}
50
51     Point operator + (const Point &a) const {return Point(x+a.x,y+a.y,z+a.z)}
52     Point operator - (const Point &a) const {return Point(x-a.x,y-a.y,z-a.z)}
53
54     Point operator * (const Matrix &a) const
55     {
56         Point res;
57
58         res.x=x*a.m[0][0]+y*a.m[1][0]+z*a.m[2][0]+a.m[3][0];
59         res.y=x*a.m[0][1]+y*a.m[1][1]+z*a.m[2][1]+a.m[3][1];
```

```

60         res.z=x*a.m[0][2]+y*a.m[1][2]+z*a.m[2][2]+a.m[3][2];
61
62         return res;
63     }
64
65     void norm()
66     {
67         double len=sqrt(sqr(x)+sqr(y)+sqr(z));
68         x/=len; y/=len; z/=len;
69     }
70 };
71
72 stack<Matrix>sm;
73 stack<int>sn;
74
75 Matrix pow(Matrix a,int k)
76 {
77     Matrix res;
78
79     while (k)
80     {
81         if (k&1)
82             res=res*a;
83         a=a*a;
84         k/=2;
85     }
86
87     return res;
88 }
89
90 Matrix get_trans(Point v)
91 {
92     Matrix res;
93     res.m[3][0]=v.x; res.m[3][1]=v.y; res.m[3][2]=v.z;
94
95     return res;
96 }
97
98 Matrix get_scale(Point v)
99 {
100     Matrix res;
101     res.m[0][0]=v.x; res.m[1][1]=v.y; res.m[2][2]=v.z;
102
103     return res;
104 }
105
106 Matrix get_rotate(Point v,double ang)
107 {
108     Matrix res;
109     double d=ang/180*PI;
110     v.norm();
111
112     res.m[0][0]=(1-cos(d))*v.x*v.x+cos(d);
113     res.m[0][1]=(1-cos(d))*v.x*v.y+sin(d)*v.z;
114     res.m[0][2]=(1-cos(d))*v.x*v.z-sin(d)*v.y;
115     res.m[1][0]=(1-cos(d))*v.y*v.x-sin(d)*v.z;
116     res.m[1][1]=(1-cos(d))*v.y*v.y+cos(d);
117     res.m[1][2]=(1-cos(d))*v.y*v.z+sin(d)*v.x;
118     res.m[2][0]=(1-cos(d))*v.z*v.x+sin(d)*v.y;
119     res.m[2][1]=(1-cos(d))*v.z*v.y-sin(d)*v.x;
120     res.m[2][2]=(1-cos(d))*v.z*v.z+cos(d);
121
122     return res;

```

```

123 }
124
125 int main()
126 {
127     int i,n,m;
128     Matrix cur,tmp;
129     double ang;
130     Point p,v;
131     char str[100];
132
133     while (scanf("%d",&n),n)
134     {
135         while (!sm.empty())
136             sm.pop();
137         while (!sn.empty())
138             sn.pop();
139
140         sm.push(Matrix());
141         sn.push(-1);
142
143         while (!sm.empty() && !sn.empty())
144         {
145             scanf("%s",str);
146
147             if (!strcmp(str,"translate"))
148             {
149                 scanf("%lf%lf%lf",&v.x,&v.y,&v.z);
150                 tmp=get_trans(v);
151                 sm.top()=sm.top()*tmp;
152             }
153             else if (!strcmp(str,"scale"))
154             {
155                 scanf("%lf%lf%lf",&v.x,&v.y,&v.z);
156                 tmp=get_scale(v);
157                 sm.top()=sm.top()*tmp;
158             }
159             else if (!strcmp(str,"rotate"))
160             {
161                 scanf("%lf%lf%lf%lf",&v.x,&v.y,&v.z,&ang);
162                 tmp=get_rotate(v,ang);
163                 sm.top()=sm.top()*tmp;
164             }
165             else if (!strcmp(str,"repeat"))
166             {
167                 scanf("%d",&m);
168                 sn.push(m);
169                 sm.push(Matrix());
170             }
171             else if (!strcmp(str,"end"))
172             {
173                 m=sn.top();
174                 sn.pop();
175                 tmp=sm.top();
176                 sm.pop();
177                 if (m!=-1)
178                     cur=tmp;
179                 else
180                 {
181                     tmp=pow(tmp,m);
182                     sm.top()=sm.top()*tmp;
183                 }
184             }
185         }
186     }

```

```

186     }
187
188     for (i=0;i<n;i++)
189     {
190         scanf ("%lf%lf%lf",&p.x,&p.y,&p.z);
191         p=p*cur;
192         printf("%.2f %.2f %.2f\n",p.x+eps,p.y+eps,p.z+eps);
193     }
194     printf("\n");
195 }
196
197 return 0;
198 }

```

8 其他

8.1 矩阵乘

注意初始化sz的大小

```
1 | const int N = 60;
2 | typedef long long LOL;
3 | LOL mod=1000000007ll;
4 | LOL c[N][N],a[N][N],b[N][N],g[N][N];
5 | int sz;
6 | void matcopy(LOL a[N][N],LOL b[N][N])
7 | {
8 |     for(int i=1;i<=sz;i++){
9 |         for(int j=1;j<=sz;j++){
10 |             a[i][j]=b[i][j];
11 |         }
12 |     }
13 | }
14 | void matmul(LOL a[N][N],LOL b[N][N])
15 | {
16 |     memset(c,0,sizeof(c));
17 |     for(int i=1;i<=sz;i++){
18 |         for(int j=1;j<=sz;j++){
19 |             if(a[i][j]){
20 |                 for(int k=1;k<=sz;k++){
21 |                     c[i][k]+=a[i][j]*b[j][k];
22 |                     if(c[i][k]>mod) c[i][k]%=mod;
23 |                 }
24 |             }
25 |         }
26 |     }
27 |     matcopy(a,c);
28 | }
29 | void matpow(LOL a[N][N],LOL x)
30 | {
31 |     memset(b,0,sizeof(b));
32 |     for(int i=1;i<=sz;i++){
33 |         b[i][i]=1;
34 |     }
35 |     while(x!=0)
36 |     {
37 |         if(x%2) matmul(b,a);
38 |         matmul(a,a);
39 |         x/=2;
40 |     }
41 |     matcopy(a,b);
42 | }
```

8.2 平面最近点对

测试报告: poj3714 hdu1007

```
1 #include<iostream>
2 #include<cstdio>
3 #include<cmath>
4 #include<algorithm>
5 #define oo 1e30
6 #define eps 1e-8
7 #define N 100005
8 using namespace std;
9 int stack[N];
10
11 struct Point
12 {
13     double x,y;
14 };
15
16 Point pt[N];
17
18 double dis(Point a,Point b)
19 {
20     return sqrt((a.x-b.x)*(a.x-b.x)+(a.y-b.y)*(a.y-b.y));
21 }
22
23 bool cmp_x(Point a,Point b)
24 {
25     if (fabs(a.x-b.x)<eps)
26         return a.y<b.y;
27     else
28         return a.x<b.x;
29 }
30
31 bool cmp_y(int a,int b)
32 {
33     return pt[a].y<pt[b].y;
34 }
35
36 double find_minimum_points(Point pt[],int l,int r)
37 {
38     int i,j,top,mid;
39     double d1,d2,res;
40
41     if (r-l==1)
42         return dis(pt[l],pt[r]);
43     else if (r-l==2)
44         return min(dis(pt[l],pt[l+1]),min(dis(pt[l],pt[r]),dis(pt[l+1],pt[r]
45         ])));
46     else
47     {
48         mid=(l+r)/2;
49         d1=find_minimum_points(pt,l,mid);
50         d2=find_minimum_points(pt,mid+1,r);
51         res=min(d1,d2);
52
53         top=0;
54         for (i=mid;i>=l&&fabs(pt[mid+1].x-pt[i].x)<=res;i--)
55             stack[top++]=i;
56         for (i=mid+1;i<=r&&fabs(pt[mid].x-pt[i].x)<=res;i++)
57             stack[top++]=i;
58
59         if (top>0)
60             sort(stack,stack+top,cmp_y);
```



```

60
61     for (i=0;i<top;i++)
62         for (j=i+1;pt[stack[j]].y-pt[stack[i]].y<=res&& j<top;j++)
63             res=min(res,dis(pt[stack[i]],pt[stack[j]]));
64
65     return res;
66 }
67 }
68
69 double minimum_distance_pointset(Point pt[],int n)
70 {
71     int i;
72
73     sort(pt,pt+n,cmp_x);
74     for (i=1;i<n;i++)
75
76         if (fabs(pt[i].x-pt[i-1].x)<eps&&fabs(pt[i].y-pt[i-1].y)<eps)
77             return 0.0;
78
79     return find_minimum_points(pt,0,n-1);
80 }
81
82 int main()
83 {
84     int i,n;
85     double ans;
86
87     while (cin>>n,n)
88     {
89
90         for (i=0;i<n;i++)
91             scanf("%lf%lf",&pt[i].x,&pt[i].y);
92
93         ans=minimum_distance_pointset(pt,n);
94         printf("%.2f\n",ans/2);
95     }
96
97     return 0;
98 }

```

8.3 读入外挂

```
1 inline int ScanInt(void) {
2     int r = 0, c, d;
3     while (!isdigit(c = getchar()) && c != '-');
4     if (c != '-') r = c - '0'; d = c;
5     while (isdigit(c = getchar())) r = r * 10 + c - '0';
6     return d=='-'?-r:r;
7 }
8
9 inline Int64 ScanInt(void) {
10    Int64 r = 0, c, d;
11    while (!isdigit(c = getchar()) && c != '-');
12    if (c != '-') r = c - '0'; d = c;
13    while (isdigit(c = getchar())) r = r * 10ll + c - '0';
14    return d=='-'?-r:r;
15 }
```

8.4 JAVA分数类

```
1 import java.io.*;
2 import java.util.*;
3 import java.math.*;
4
5 class BigFraction {
6
7     BigFraction() {
8         numerator = BigInteger.ZERO;
9         Denominator = BigInteger.ONE;
10    }
11
12    BigFraction(BigInteger _numerator, BigInteger _Denominator) {
13        numerator = _numerator;
14        Denominator = _Denominator;
15    }
16
17    public BigFraction add(BigFraction bf) {
18        BigInteger n = numerator.multiply(bf.Denominator).add(Denominator.
19            multiply(bf.numerator));
20        BigInteger d = Denominator.multiply(bf.Denominator);
21
22        BigFraction ret = new BigFraction(n, d);
23        ret.simplify();
24
25        return ret;
26    }
27
28    public BigFraction subtract(BigFraction bf) {
29        BigInteger n = numerator.multiply(bf.Denominator).subtract(
30            Denominator.multiply(bf.numerator));
31        BigInteger d = Denominator.multiply(bf.Denominator);
32
33        BigFraction ret = new BigFraction(n, d);
34        ret.simplify();
35
36        return ret;
37    }
38
39    public BigFraction multiply(BigFraction bf) {
40        BigInteger n = numerator.multiply(bf.numerator);
41        BigInteger d = Denominator.multiply(bf.Denominator);
42
43        BigFraction ret = new BigFraction(n, d);
44        ret.simplify();
45
46        return ret;
47    }
48
49    public BigFraction divide(BigFraction bf) {
50        BigInteger n = numerator.multiply(bf.Denominator);
51        BigInteger d = Denominator.multiply(bf.numerator);
52
53        BigFraction ret = new BigFraction(n, d);
54        ret.simplify();
55
56        return ret;
57    }
58
59    public int compareTo(BigFraction bf) {
60        BigInteger ret = numerator.multiply(bf.Denominator).subtract(
61            Denominator.multiply(bf.numerator));
```

```

59         return ret.compareTo(BigInteger.ZERO);
60     }
61
62
63     public BigFraction abs() {
64         BigFraction ret = new BigFraction(numerator.abs(), Denominator.abs()
65         );
66         return ret;
67     }
68
69     public BigFraction negate() {
70         numerator = numerator.negate();
71         return this;
72     }
73
74     public boolean isInteger() {
75         return Denominator.equals(BigInteger.ONE);
76     }
77
78     // for simplify numerator and Denominator
79     private void simplify() {
80         BigInteger g = numerator.gcd(Denominator);
81         numerator = numerator.divide(g);
82         Denominator = Denominator.divide(g);
83         if (Denominator.compareTo(BigInteger.ZERO) < 0) {
84             numerator = numerator.negate();
85             Denominator = Denominator.negate();
86         }
87     }
88
89     public BigInteger numerator;
90     public BigInteger Denominator;
91     public static BigFraction ZERO = new BigFraction(BigInteger.ZERO,
92     BigInteger.ONE);
93     public static BigFraction ONE = new BigFraction(BigInteger.ONE,
94     BigInteger.ONE);
95 }
96
97 public class Main
98 {
99     static BigFraction c[][]=new BigFraction[120][120];
100     static BigFraction b[][]=new BigFraction[120][120];
101     public static void main(String args[])
102     {
103         for(int i=0;i<=101;i++){
104             for(int j=0;j<=101;j++){
105                 c[i][j]=BigFraction.ZERO;
106                 b[i][j]=BigFraction.ZERO;
107             }
108         }
109         for(int i=0;i<=101;i++){
110             c[i][0]=BigFraction.ONE;
111         }
112         for(int i=1;i<=101;i++){
113             for(int j=1;j<=i;j++){
114                 c[i][j]=c[i-1][j-1].add(c[i-1][j]);
115             }
116         }
117         b[0][1]=BigFraction.ONE;
118         for(int i=1;i<=100;i++){
119             for(int j=1;j<=i+1;j++){
120                 b[i][j]=c[i+1][j];
121             }
122             for(int j=0;j<i;j++){

```

```

119         for(int k=1;k<=j+1;k++){
120             b[i][k]=b[i][k].subtract(c[i+1][i+1-j].multiply(b[j][k])
121             );
122         }
123     }
124     for(int j=1;j<=i+1;j++){
125         b[i][j]=b[i][j].divide(c[i+1][1]);
126     }
127     Scanner cin=new Scanner(new BufferedInputStream(System.in));
128     BigInteger n;
129     int m;
130     while(cin.hasNext())
131     {
132         n=cin.nextBigInteger();
133         m=cin.nextInt();
134         BigFraction ans=BigFraction.ZERO;
135         BigInteger tmp=n;
136         for(int i=1;i<=m+1;i++){
137             BigFraction tx = BigFraction.ONE;
138             tx.numerator=tmp;
139             tx.Denominator=BigInteger.ONE;
140             ans=ans.add(tx.multiply(b[m][i]));
141             tmp=tmp.multiply(n);
142         }
143         System.out.println(ans.numerator);
144     }
145 }
146
147 }

```

8.5 魔方

```
1  #include<cstdio>
2  #include<cstring>
3  #include<algorithm>
4  #include<vector>
5  #include<string>
6  #include<queue>
7  #include<cmath>
8  using namespace std;
9
10 int rubik[55];
11
12 //魔方初始化。根据题目要求决定是每个面的每个格子一个编号，还是每个面的格子标同一个编号
13 void init() {for (int i=1;i<=54;i++) rubik[i]=i;}
14
15 //对每个面进行顺时针旋转度90
16 void rotate(int x1,int x2,int x3,int x4,int x5,int x6,int x7,int x8,int x9)
17 {
18     int a[55];
19
20     memcpy(a,rubik,sizeof(a));
21     rubik[x1]=a[x7]; rubik[x2]=a[x4]; rubik[x3]=a[x1];
22     rubik[x4]=a[x8]; rubik[x5]=a[x5]; rubik[x6]=a[x2];
23     rubik[x7]=a[x9]; rubik[x8]=a[x6]; rubik[x9]=a[x3];
24 }
25
26 //侧边顺时针选装度90
27 void trans(int x1,int x2,int x3,int x4,int x5,int x6,int x7,int x8,int x9,
28            int x10,int x11,int x12)
29 {
30     int a[55];
31
32     memcpy(a,rubik,sizeof(a));
33     rubik[x1]=a[x10]; rubik[x2]=a[x11]; rubik[x3]=a[x12];
34     rubik[x4]=a[x1]; rubik[x5]=a[x2]; rubik[x6]=a[x3];
35     rubik[x7]=a[x4]; rubik[x8]=a[x5]; rubik[x9]=a[x6];
36     rubik[x10]=a[x7]; rubik[x11]=a[x8]; rubik[x12]=a[x9];
37 }
38 //从上面看去，顺时针旋转第一层
39 void turn_U()
40 {
41     rotate(1,2,3,4,5,6,7,8,9);
42     trans(30,29,28,21,20,19,12,11,10,39,38,37);
43 }
44 //从上面看去，顺时针旋转第二层
45 void turn_X()
46 {
47     trans(33,32,31,24,23,22,15,14,13,42,41,40);
48 }
49 //从上面看去，顺时针旋转第三层
50 void turn_D()
51 {
52     rotate(48,47,46,51,50,49,54,53,52);
53     trans(36,35,34,27,26,25,18,17,16,45,44,43);
54 }
55 //从右面看去，顺治针旋转第一层
56 void turn_R()
57 {
58     rotate(19,20,21,22,23,24,25,26,27);
59     trans(9,6,3,28,31,34,46,49,52,18,15,12);
```

```

60 }
61 //从右面看去, 顺治针旋转第二层
62 void turn_Y()
63 {
64     trans(8,5,2,29,32,35,47,50,53,17,14,11);
65 }
66 //从右面看去, 顺治针旋转第三层
67 void turn_L()
68 {
69     rotate(39,38,37,42,41,40,45,44,43);
70     trans(7,4,1,30,33,36,48,51,54,16,13,10);
71 }
72 //从前面看去, 顺治针旋转第一层
73 void turn_F()
74 {
75     rotate(10,11,12,13,14,15,16,17,18);
76     trans(7,8,9,19,22,25,52,53,54,45,42,39);
77 }
78 //从前面看去, 顺治针旋转第二层
79 void turn_Z()
80 {
81     trans(4,5,6,20,23,26,49,50,51,44,41,38);
82 }
83 //从前面看去, 顺治针旋转第三层
84 void turn_B()
85 {
86     rotate(30,29,28,33,32,31,36,35,34);
87     trans(1,2,3,21,24,27,46,47,48,43,40,37);
88 }
89
90 //hdu4397: 询问操作后是否与初始状态完全相同 (每个面的每个格子都完全一样)
91 int main()
92 {
93     int i,j,ans,ys;
94     char str[1000];
95
96     ys=0;
97     freopen("data.in","r",stdin);
98     while (scanf("%s",str)!=EOF)
99     {
100         init();
101         for (i=0;str[i];i++)
102             switch (str[i])
103             {
104                 case 'U':
105                     turn_U();
106                     break;
107                 case 'u':
108                     turn_U();turn_U();turn_U();
109                     break;
110                 case 'X':
111                     turn_X();
112                     break;
113                 case 'x':
114                     turn_X();turn_X();turn_X();
115                     break;
116                 case 'D':
117                     turn_D();turn_D();turn_D();
118                     break;
119                 case 'd':
120                     turn_D();
121                     break;

```

```

122         case 'R':
123             turn_R();
124         break;
125         case 'r':
126             turn_R();turn_R();turn_R();
127         break;
128         case 'Y':
129             turn_Y();
130         break;
131         case 'y':
132             turn_Y();turn_Y();turn_Y();
133         break;
134         case 'L':
135             turn_L();turn_L();turn_L();
136         break;
137         case 'l':
138             turn_L();
139         break;
140         case 'F':
141             turn_F();
142         break;
143         case 'f':
144             turn_F();turn_F();turn_F();
145         break;
146         case 'Z':
147             turn_Z();turn_Z();turn_Z();
148         break;
149         case 'z':
150             turn_Z();
151         break;
152         case 'B':
153             turn_B();turn_B();turn_B();
154         break;
155         case 'b':
156             turn_B();
157         break;
158     }
159
160     ans=1;
161     for (i=1;i<=54;i++)
162         if (rubik[i]!=i)
163             {
164                 ans=0;
165                 break;
166             }
167
168     ys++;
169     if (ys>1)
170         printf("\n");
171
172     if (ans)
173         printf("Yes\n");
174     else
175         printf("No\n");
176 }
177
178 return 0;
179 }

```


8.6 Hashmap

GCC中的hash_map定义在<ext/hash_map>文件，namespace __gnu_cxx中。要定义一个hash_map<int, int>非常简单：

```
1 #include <ext/hash_map>
2 using namespace __gnu_cxx;
3 hash_map<int, int> hm;
```

在使用map时，如果我们想要改变元素顺序，或以自定义的struct/class作为key的时候，可以设定map第三个模板参数（默认是less<Key>，即operator<）。对于hash_map，我们需要设定其第三个(hash<Key>)和第四个模板参数(equal_to<Key>, operator==)。

```
1 typedef long long my_type;
2 typedef int any_type;
3 struct my_hash {
4     size_t operator()(const my_type& key) const {
5         return (key >> 32) ^ key;
6     }
7 };
8 struct my_equal_to {
9     bool operator()(const my_type& lhs, const my_type& rhs) const {
10         return lhs == rhs;
11     }
12 };
13 hash_map<my_type, any_type, my_hash, my_equal_to> my_hash_map;
```