

树套树 1

线段树/树状数组套名次树

简介

用于实现区间范围的名次树操作，空间复杂度 $O(n \log n)$

模板题

[洛谷p3380](#)

维护一种数集结构，支持以下操作：

1. 查询 k 在区间内的排名
2. 查询区间内排名为 k 的值
3. 修改某一位置上的数值
4. 查询 k 在区间内的前驱
5. 查询 k 在区间内的后继

线段树套名次树版本

线段树套名次树 rank update pre suf 操作和普通线段树类似 kth 操作需要二分 rank 操作。

rank update pre suf 操作时间复杂度为 $O(\log^2 n)$ kth 操作时间复杂度 $O(\log^2 n \log v)$

```
#include <iostream>
#include <cstdio>
#include <cstdlib>
#include <algorithm>
#include <string>
#include <sstream>
#include <cstring>
#include <cctype>
#include <cmath>
#include <vector>
#include <set>
#include <map>
#include <stack>
#include <queue>
#include <ctime>
#include <cassert>
#define _for(i,a,b) for(int i=(a);i<(b);++i)
#define _rep(i,a,b) for(int i=(a);i<=(b);++i)
```

```
#define mem(a,b) memset(a,b,sizeof(a))
using namespace std;
typedef long long LL;
inline int read_int(){
    int t=0;bool sign=false;char c=getchar();
    while(!isdigit(c)){sign|=c=='-';c=getchar();}
    while(isdigit(c)){t=(t<<1)+(t<<3)+(c&15);c=getchar();}
    return sign?-t:t;
}
inline LL read_LL(){
    LL t=0;bool sign=false;char c=getchar();
    while(!isdigit(c)){sign|=c=='-';c=getchar();}
    while(isdigit(c)){t=(t<<1)+(t<<3)+(c&15);c=getchar();}
    return sign?-t:t;
}
inline char get_char(){
    char c=getchar();
    while(c==' '||c=='\n'||c=='\r')c=getchar();
    return c;
}
inline void write(LL x){
    register char c[21],len=0;
    if(!x)return putchar('0'),void();
    if(x<0)x=-x,putchar('-');
    while(x)c[++len]=x%10,x/=10;
    while(len)putchar(c[len--]+48);
}
inline void space(LL x){write(x),putchar(' ');}
inline void enter(LL x){write(x),putchar('\n');}
const int MAXN=(5e4+5)*4,MAXS=MAXN*20,Inf=0x7fffffff;
template <typename T>
struct Treap{
    int pool[MAXS],top,tot;
    int root[MAXN],ch[MAXS][2],r[MAXS],sz[MAXS],cnt[MAXS];
    T val[MAXS];
    int new_node(T v){
        int id=top?pool[top--]:++tot;
        val[id]=v;r[id]=rand();sz[id]=cnt[id]=1;ch[id][0]=ch[id][1]=0;
        return id;
    }
    void push_up(int id){sz[id]=sz[ch[id][0]]+sz[ch[id][1]]+cnt[id];}
    void Rotate(int &id,int dir){
        int t=ch[id][dir^1];
        ch[id][dir^1]=ch[t][dir];ch[t][dir]=id;id=t;
        push_up(ch[id][dir]);push_up(id);
    }
    void Insert(int &id,T v){
        if(!id)
            return id=new_node(v),void();
        if(v==val[id])
            return;
```

```

    cnt[id]++;
    else{
        int dir=v<val[id]?0:1;
        Insert(ch[id][dir],v);
        if(r[id]<r[ch[id][dir]])
            Rotate(id,dir^1);
    }
    push_up(id);
}

void Erase(int &id,T v){
    if(!id)
        return;
    if(v==val[id]){
        if(cnt[id]>1)return cnt[id]--,push_up(id);
        else if(!ch[id][0])pool[++top]=id,id=ch[id][1];
        else if(!ch[id][1])pool[++top]=id,id=ch[id][0];
        else{
            int d=r[ch[id][0]]>r[ch[id][1]]?1:0;
            Rotate(id,d);Erase(ch[id][d],v);push_up(id);
        }
    }
    else{
        if(v<val[id])Erase(ch[id][0],v);
        else Erase(ch[id][1],v);
        push_up(id);
    }
}

int Rank(int id,T v){//有多少个数严格小于v
    if(!id)return 0;
    if(v==val[id])return sz[ch[id][0]];
    else if(v<val[id])return Rank(ch[id][0],v);
    else return sz[ch[id][0]]+cnt[id]+Rank(ch[id][1],v);
}

T Kth(int id,int rk){
    if(!id) return -1;//第rk小的节点不存在
    if(rk>sz[ch[id][0]]+cnt[id]) return Kth(ch[id][1],rk-sz[ch[id][0]]-cnt[id]);
    else if(rk>sz[ch[id][0]]) return val[id];
    else return Kth(ch[id][0],rk);
}

T Pre(int id,T v){
    int pos=id,ans=-Inf;
    while(pos){
        if(val[pos]<v){
            ans=ans<val[pos]?val[pos]:ans;
            pos=ch[pos][1];
        }
        else pos=ch[pos][0];
    }
    return ans;
}

```

```
T Suf(int id,T v){
    int pos=id,ans=Inf;
    while(pos){
        if(v<val[pos]){
            ans=ans<val[pos]?ans:val[pos];
            pos=ch[pos][0];
        }
        else pos=ch[pos][1];
    }
    return ans;
}

void insert(int root_id,T v){Insert(root[root_id],v);}
void erase(int root_id,T v){Erase(root[root_id],v);}
int rank(int root_id,T v){return Rank(root[root_id],v);}//如果需要,记得+1
T kth(int root_id,int rk){return Kth(root[root_id],rk);}
T pre(int root_id,T v){return Pre(root[root_id],v);}
T suf(int root_id,T v){return Suf(root[root_id],v);}
};

struct Tree{
    Treap<int> S;
    int a[MAXN],lef[MAXN],rig[MAXN];
    void build(int k,int L,int R){
        lef[k]=L,rig[k]=R;
        _rep(i,L,R)
        S.insert(k,a[i]);
        if(L==R)
            return;
        int M=L+R>>1;
        build(k<<1,L,M);
        build(k<<1|1,M+1,R);
    }
    void build(int n){build(1,1,n);}
    int Rank(int k,int L,int R,int v){
        if(L<=lef[k]&&rig[k]<=R)
            return S.rank(k,v);
        int mid=lef[k]+rig[k]>>1;
        if(mid>=R)
            return Rank(k<<1,L,R,v);
        else if(mid<L)
            return Rank(k<<1|1,L,R,v);
        else
            return Rank(k<<1,L,R,v)+Rank(k<<1|1,L,R,v);
    }
    int rank(int L,int R,int v){return Rank(1,L,R,v)+1;}
    int kth(int L,int R,int rk){
        int lef=0,rig=1e8,mid,trk,ans=0;
        while(lef<=rig){
            mid=lef+rig>>1;
            trk=rank(L,R,mid);
            if(trk<=rk){
```

```

        ans=mid;
        lef=mid+1;
    }
    else if(trk>rk)
        rig=mid-1;
    }
    return ans;
}
void update(int k,int pos,int v){
    S.erase(k,a[pos]);
    S.insert(k,v);
    if(lef[k]==rig[k]){
        a[pos]=v;
        return;
    }
    int mid=lef[k]+rig[k]>>1;
    if(pos<=mid)
        update(k<<1,pos,v);
    else
        update(k<<1|1,pos,v);
}
void update(int pos,int v){update(1,pos,v);}
int Pre(int k,int L,int R,int v){
    if(L<=lef[k]&&rig[k]<=R)
        return S.pre(k,v);
    int mid=lef[k]+rig[k]>>1;
    if(mid>=R)
        return Pre(k<<1,L,R,v);
    else if(mid<L)
        return Pre(k<<1|1,L,R,v);
    else
        return max(Pre(k<<1,L,R,v),Pre(k<<1|1,L,R,v));
}
int pre(int L,int R,int v){return Pre(1,L,R,v);}
int Suf(int k,int L,int R,int v){
    if(L<=lef[k]&&rig[k]<=R)
        return S.suf(k,v);
    int mid=lef[k]+rig[k]>>1;
    if(mid>=R)
        return Suf(k<<1,L,R,v);
    else if(mid<L)
        return Suf(k<<1|1,L,R,v);
    else
        return min(Suf(k<<1,L,R,v),Suf(k<<1|1,L,R,v));
}
int suf(int L,int R,int v){return Suf(1,L,R,v);}
}tree;
int main()
{
    int n=read_int(),m=read_int(),opt,l,r,pos,k,ans;
    _rep(i,1,n)

```

```
tree.a[i]=read_int();
tree.build(n);
while(m--){
    opt=read_int();
    if(opt==3){
        pos=read_int(),k=read_int();
        tree.update(pos,k);
    }
    else{
        l=read_int(),r=read_int(),k=read_int();
        switch(opt){
            case 1:
                ans=tree.rank(l,r,k);
                break;
            case 2:
                ans=tree.kth(l,r,k);
                break;
            case 4:
                ans=tree.pre(l,r,k);
                break;
            case 5:
                ans=tree.suf(l,r,k);
                break;
        }
        enter(ans);
    }
}
return 0;
}
```

树状数组套名次树版本

树状数组套名次树 rank 操作和普通树状数组类似 kth 操作需要二分 pre suf 操作需要 $\text{rank} + \text{kth}$

rank update 操作时间复杂度为 $O(\log^2 n)$
 pre suf kth 操作时间复杂度 $O(\log^2 n \log v)$

```
#include <iostream>
#include <cstdio>
#include <cstdlib>
#include <algorithm>
#include <string>
#include <sstream>
#include <cstring>
#include <cctype>
#include <cmath>
#include <vector>
```

```

#include <set>
#include <map>
#include <stack>
#include <queue>
#include <ctime>
#include <cassert>
#define _for(i,a,b) for(int i=(a);i<(b);++i)
#define _rep(i,a,b) for(int i=(a);i<=(b);++i)
#define mem(a,b) memset(a,b,sizeof(a))
using namespace std;
typedef long long LL;
inline int read_int(){
    int t=0;bool sign=false;char c=getchar();
    while(!isdigit(c)){sign|=c=='-';c=getchar();}
    while(isdigit(c)){t=(t<<1)+(t<<3)+(c&15);c=getchar();}
    return sign?-t:t;
}
inline LL read_LL(){
    LL t=0;bool sign=false;char c=getchar();
    while(!isdigit(c)){sign|=c=='-';c=getchar();}
    while(isdigit(c)){t=(t<<1)+(t<<3)+(c&15);c=getchar();}
    return sign?-t:t;
}
inline char get_char(){
    char c=getchar();
    while(c==' '||c=='\n'||c=='\r')c=getchar();
    return c;
}
inline void write(LL x){
    register char c[21],len=0;
    if(!x)return putchar('0'),void();
    if(x<0)x=-x,putchar('-');
    while(x)c[++len]=x%10,x/=10;
    while(len)putchar(c[len--]+48);
}
inline void space(LL x){write(x),putchar(' ');}
inline void enter(LL x){write(x),putchar('\n');}
const int MAXN=5e4+5,MAXS=MAXN*20,Inf=0x7fffffff;
template <typename T>
struct Treap{
    int pool[MAXS],top,tot;
    int root[MAXN],ch[MAXS][2],r[MAXS],sz[MAXS],cnt[MAXS];
    T val[MAXS];
    int new_node(T v){
        int id=top?pool[top--]:++tot;
        val[id]=v;r[id]=rand();sz[id]=cnt[id]=1;ch[id][0]=ch[id][1]=0;
        return id;
    }
    void push_up(int id){sz[id]=sz[ch[id][0]]+sz[ch[id][1]]+cnt[id];}
    void Rotate(int &id,int dir){
        int t=ch[id][dir^1];

```

```
    ch[id][dir^1]=ch[t][dir];ch[t][dir]=id;id=t;
    push_up(ch[id][dir]);push_up(id);
}
void Insert(int &id,T v){
    if(!id)
        return id=new_node(v),void();
    if(v==val[id])
        cnt[id]++;
    else{
        int dir=v<val[id]?0:1;
        Insert(ch[id][dir],v);
        if(r[id]<r[ch[id][dir]])
            Rotate(id,dir^1);
    }
    push_up(id);
}
void Erase(int &id,T v){
    if(!id)
        return;
    if(v==val[id]){
        if(cnt[id]>1)return cnt[id]--,push_up(id);
        else if(!ch[id][0])pool[++top]=id,id=ch[id][1];
        else if(!ch[id][1])pool[++top]=id,id=ch[id][0];
        else{
            int d=r[ch[id][0]]>r[ch[id][1]]?1:0;
            Rotate(id,d);Erase(ch[id][d],v);push_up(id);
        }
    }
    else{
        if(v<val[id])Erase(ch[id][0],v);
        else Erase(ch[id][1],v);
        push_up(id);
    }
}
int Rank(int id,T v){//有多少个数严格小于v
    if(!id)return 0;
    if(v==val[id])return sz[ch[id][0]];
    else if(v<val[id])return Rank(ch[id][0],v);
    else return sz[ch[id][0]]+cnt[id]+Rank(ch[id][1],v);
}
T Kth(int id,int rk){
    if(!id) return -1;//第rk小的节点不存在
    if(rk>sz[ch[id][0]]+cnt[id]) return Kth(ch[id][1],rk-sz[ch[id][0]]-cnt[id]);
    else if(rk>sz[ch[id][0]]) return val[id];
    else return Kth(ch[id][0],rk);
}
T Pre(int id,T v){
    int pos=id,ans=-Inf;
    while(pos){
```

```

        if(val[pos]<v){
            ans=ans<val[pos]?val[pos]:ans;
            pos=ch[pos][1];
        }
        else pos=ch[pos][0];
    }
    return ans;
}
T Suf(int id,T v){
    int pos=id,ans=Inf;
    while(pos){
        if(v<val[pos]){
            ans=ans<val[pos]?ans:val[pos];
            pos=ch[pos][0];
        }
        else pos=ch[pos][1];
    }
    return ans;
}
int Count(int id,T v){
    int pos=id;
    while(pos){
        if(v<val[pos])
            pos=ch[pos][0];
        else if(val[pos]<v)
            pos=ch[pos][1];
        else
            return cnt[pos];
    }
    return 0;
}
void insert(int root_id,T v){Insert(root[root_id],v);}
void erase(int root_id,T v){Erase(root[root_id],v);}
int rank(int root_id,T v){return Rank(root[root_id],v);}//如果需要,记得+1
T kth(int root_id,int rk){return Kth(root[root_id],rk);}
T pre(int root_id,T v){return Pre(root[root_id],v);}
T suf(int root_id,T v){return Suf(root[root_id],v);}
int count(int root_id,T v){return Count(root[root_id],v);}
};
#define lowbit(x) x&(-x)
struct Tree{
    Treap<int> S;
    int n,a[MAXN];
    void build(int pos,int v){
        while(pos<=n){
            S.insert(pos,v);
            pos+=lowbit(pos);
        }
    }
    void build(int n){
        this->n=n;
    }
}

```

```
_rep(i,1,n)
build(i,a[i]);
}
int Rank(int L,int R,int v){
    int ans=0,pos1=L-1,pos2=R;
    while(pos1){
        ans-=S.rank(pos1,v);
        pos1-=lowbit(pos1);
    }
    while(pos2){
        ans+=S.rank(pos2,v);
        pos2-=lowbit(pos2);
    }
    return ans;
}
int rank(int L,int R,int v){return Rank(L,R,v)+1;}
int kth(int L,int R,int rk){
    int lef=0,rig=1e8,mid,trk,ans=0;
    while(lef<=rig){
        mid=lef+rig>>1;
        trk=rank(L,R,mid);
        if(trk<=rk){
            ans=mid;
            lef=mid+1;
        }
        else if(trk>rk)
            rig=mid-1;
    }
    return ans;
}
void update(int pos,int v){
    int t=pos;
    while(t<=n){
        S.erase(t,a[pos]);
        S.insert(t,v);
        t+=lowbit(t);
    }
    a[pos]=v;
}
int count(int L,int R,int v){
    int ans=0,pos1=L-1,pos2=R;
    while(pos1){
        ans-=S.count(pos1,v);
        pos1-=lowbit(pos1);
    }
    while(pos2){
        ans+=S.count(pos2,v);
        pos2-=lowbit(pos2);
    }
    return ans;
}
```

```
}
int pre(int L,int R,int v){
    int rk=Rank(L,R,v);
    if(rk)
        return kth(L,R,rk);
    else
        return -Inf;
}
int suf(int L,int R,int v){
    int rk=rank(L,R,v)+count(L,R,v);
    if(rk<=R-L+1)
        return kth(L,R,rk);
    else
        return Inf;
}
}tree;
int main()
{
    int n=read_int(),m=read_int(),opt,l,r,pos,k,ans;
    _rep(i,1,n)
        tree.a[i]=read_int();
    tree.build(n);
    while(m--){
        opt=read_int();
        if(opt==3){
            pos=read_int(),k=read_int();
            tree.update(pos,k);
        }
        else{
            l=read_int(),r=read_int(),k=read_int();
            switch(opt){
                case 1:
                    ans=tree.rank(l,r,k);
                    break;
                case 2:
                    ans=tree.kth(l,r,k);
                    break;
                case 4:
                    ans=tree.pre(l,r,k);
                    break;
                case 5:
                    ans=tree.suf(l,r,k);
                    break;
            }
            enter(ans);
        }
    }
    return 0;
}
```

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