Universidade de Brasilia

É só Fazer

Ruan Petrus, Eduardo Freire, Arthur Botelho

2024-06-21

Contest (1)

template.cpp

26 lines

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

using namespace std;

#define int long long
#define endl '\n'
#define rep(i, a, b) for(int i = (a); i < (b); ++i)
#define all(x) begin(x), end(x)
#define sz(x) (int)(x).size()
#define debug(var) cerr << #var << ": " << var << endl
#define pb push_back
#define eb emplace_back
typedef long long ll;
typedef pair<int, int> pii;
typedef vector<int> vi;

void solve() {
}

int32_t main() {
  ios_base::sync_with_stdio(0); cout.tie(0); cin.tie(0);
  int t = 1;
  while(t--) solve();

  return 0;
}
```

.bashrc

3 lines

```
alias c='g++ -Wall -Wconversion -Wfatal-errors -g -std=c++17 \
  -fsanitize=undefined,address'
xmodmap -e 'clear lock' -e 'keycode 66=less greater' #caps = <>
```

.vimrc

4 lines

```
set cin ai is ts=4 sw=4 nu rnu
" Select a region and then type :Hash
ca Hash w !cpp -dD -P -fpreprocessed \| tr -d '[:space:]' \
 \| md5sum \| cut -c-6
```

hash.sh

3 lines

```
# Hashes a file, ignoring all whitespace and comments. Use for
# verifying that code was correctly typed.
cpp -dD -P -fpreprocessed | tr -d '[:space:]'| md5sum |cut -c-6
```

troubleshoot.txt

52 lines

```
Pre-submit:
Write a few simple test cases if sample is not enough.
Are time limits close? If so, generate max cases.
Is the memory usage fine?
Could anything overflow?
Make sure to submit the right file.

Wrong answer:
Print your solution! Print debug output, as well.
Are you clearing all data structures between test cases?
Can your algorithm handle the whole range of input?
Read the full problem statement again.
Do you handle all corner cases correctly?
Have you understood the problem correctly?
Any uninitialized variables?
Any overflows?
Confusing N and M, i and j, etc.?
Are you sure your algorithm works?
What special cases have you not thought of?
Are you sure the STL functions you use work as you think?
Add some assertions, maybe resubmit.
Create some testcases to run your algorithm on.
Go through the algorithm for a simple case.
Go through this list again.
Explain your algorithm to a teammate.
Ask the teammate to look at your code.
Go for a small walk, e.g. to the toilet.
Is your output format correct? (including whitespace)
Rewrite your solution from the start or let a teammate do it.

Runtime error:
Have you tested all corner cases locally?
Any uninitialized variables?
Are you reading or writing outside the range of any vector?
Any assertions that might fail?
Any possible division by 0? (mod 0 for example)
Any possible infinite recursion?
Invalidated pointers or iterators?
Are you using too much memory?
Debug with resubmits (e.g. remapped signals, see Various).

Time limit exceeded:
Do you have any possible infinite loops?
What is the complexity of your algorithm?
Are you copying a lot of unnecessary data? (References)
How big is the input and output? (consider scanf)
Avoid vector, map. (use arrays/unordered_map)
What do your teammates think about your algorithm?

Memory limit exceeded:
What is the max amount of memory your algorithm should need?
Are you clearing all data structures between test cases?
```

Data structures (2)

SegTree.h

Description: Iterative SegTree Can be changed by modifying Spec
Time: $\mathcal{O}(\log N)$

0386e5, 37 lines

```
template<typename Spec>
struct SegTree {
  using LS = Spec;
  using S = typename LS::S;
  using K = typename LS::K;
  int n;
  vector<S> seg;

  SegTree(const vector<S> & v)
    : n(sz(v)), seg(2*n) {
    rep(i, 0, n) seg[i+n] = v[i];
    for(int i = n-1; i >= 1; i--) seg[i] = LS::op(seg[i*2], seg
        [i*2+1]);
  }

  void update(int no, K val) {
    no += n;
    seg[no] = LS::update(val, seg[no]);
    while (no > 1) no /= 2, seg[no] = LS::op(seg[no*2], seg[no
        *2+1]);
  }

  S query(int l, int r) { // [l, r)
    S vl = LS::id(), vr = LS::id();
    for (l += n, r += n; l < r; l /= 2, r /= 2) {
      if (l & 1) vl = LS::op(vl, seg[l++]);
      if (r & 1) vr = LS::op(seg[--r], vr);
    }
    return LS::op(vl, vr);
  }
};

struct Spec {
  using S = int;
  using K = int;
  static S op(S a, S b) { return max(a, b); }
  static S update(K f, S a) { return f + a; }
  static S id() { return 0; }
};
```

LazySeg.h

Description: Iterative Lazy SegTree Can be changed by modifying Spec
Time: $\mathcal{O}(\log N)$

ee5763, 96 lines

```
template<typename Spec>
struct LazySeg {
  using LS = Spec;
  using S = typename LS::S;
  using K = typename LS::K;
  int n;
  vector<S> seg;
  vector<K> lazy;
  vector<bool> has_lazy;
  // vector<int> lx, rx; // Aditional info

    LazySeg(vector<S> & v) : n(sz(v)), seg(2*n) , lazy(n),
        has_lazy(n) {
    rep(no, 0, n) seg[no+n] = v[no];
    for (int no = n-1; no >= 1; no--) pull(no);

    // Aditional info, n must be power of two
    /*
    lx.assign(2*n, 0); rx.assign(2*n, 0);
    lx[1] = 0; rx[1] = n;
    rep(no, 1, n) {
      int mid = (lx[no] + rx[no])/2;
      lx[no*2]   = lx[no]; rx[no*2] = mid;
      lx[no*2+1] = mid;    rx[no*2+1] = rx[no];
    }
    */
  }

  S query(int l, int r) { // [l, r)
    l += n;
    r += n;
    push_to(l); push_to(r-1);
    S vl = LS::id(), vr = LS::id();
    while(l < r) {
      if (l & 1) vl = LS::op(vl, seg[l++]);
      if (r & 1) vr = LS::op(seg[--r], vr);
      l >>= 1; r >>= 1;
    }
    return LS::op(vl, vr);
  }
```

```cpp
  void update(int l, int r, K val) {
    l += n;
    r += n;
    push_to(l); push_to(r-1);
    int lo = 1, ro = 1;
    while(l < r) {
      if (l & 1) lo = max(lo, l), apply(l++, val);
      if (r & 1) ro = max(ro, r), apply(--r, val);
      l >>= 1; r >>= 1;
    }
    pull_from(lo);
    pull_from(ro-1);
  }

  void apply(int no, K val) {
    seg[no] = LS::update(val, seg[no]);
    // seg[no] = LS::update(val, seg[no], lx[no], rx[no]);

    if (no < n) {
      if (has_lazy[no]) lazy[no] = LS::compose(val, lazy[no]);
      else lazy[no] = val;
      has_lazy[no] = true;
    }
  }

  void pull_from(int no) {
    while(no > 1) no >>= 1, pull(no);
  }

  void pull(int no) {
    seg[no] = LS::op(seg[no*2], seg[no*2+1]);
  }

  void push_to(int no) {
    int h = 0; int p2 = 1;
    while(p2 < no) p2 *= 2, h++;
    for (int i = h; i >= 1; i--) push(no >> i);
  }

  void push(int no) {
    if (has_lazy[no]) {
      apply(no*2, lazy[no]);
      apply(no*2+1, lazy[no]);
      has_lazy[no] = false;
    }
  }
};

struct Spec {
  using S = int;
  using K = int;
  static S op(S a, S b) { return max(a, b); }
  static S update(K f, S a) { return f + a; }
  static K compose(const K f, const K g) { return f + g; }
  static S id() { return 0; }
};
```

Psum.h

Description: Multidimensional Psum Requires Abelian Group S (op, inv, id)

Memory: $\mathcal{O}\left(N^D\right)$

Time: $\mathcal{O}\left(1\right)$

65f259, 29 lines

```cpp
#define MAs template<class... As> //multiple arguments
template<int D, class S>
struct Psum{ using T = typename S::T;
  int n;
  vector<Psum<D-1, S>> v;
  MAs Psum(int s, As... ds):n(s+1),v(n,Psum<D-1, S>(ds...)){}
  MAs void set(T x, int p, As... ps){v[p+1].set(x, ps...);}
  void push(Psum& p){rep(i, 1, n)v[i].push(p.v[i]);}
  void init(){rep(i, 1, n)v[i].init(),v[i].push(v[i-1]);}
  MAs T query(int l, int r, As... ps){
    return S::op(v[r+1].query(ps...),S::inv(v[l].query(ps...)))
        ;
  }
};

template<class S>
struct Psum<0, S>{ using T = typename S::T;
  T val=S::id;
  void set(T x){val=x;}
  void push(Psum& a){val=S::op(a.val,val);}
  void init(){}
  T query(){return val;}
};

struct G{
  using T = int;
  static constexpr T id = 0;
  static T op(T a, T b){return a+b;}
  static T inv(T a){return -a;}
};
```

MultiDSegTree.h

Description: Multidimensional SegTree Requires Monoid S (op, id)

Memory: $\mathcal{O}\left(N^D\right)$

Time: $\mathcal{O}\left((\log N)^D\right)$

53621d, 37 lines

```cpp
//#pragma once

#define MAs template<class... As> //multiple arguments
template<int D, class S>
struct SegTree{ using T = typename S::T;
  int n;
  vector<SegTree<D-1, S>> seg;
  MAs SegTree(int s, As... ds):n(s),seg(2*n, SegTree<D-1, S>(ds
      ...)){}
  MAs T get(int p, As... ps){return seg[p+n].get(ps...);}
  MAs void update(T x, int p, As... ps){
    p+=n; seg[p].update(x, ps...);
    for(p>>=1;p>=1;p>>=1)
    seg[p].update(S::op(seg[2*p].get(ps...),seg[2*p+1].get(ps
        ...)), ps...);
  }
  MAs T query(int l, int r, As... ps){
    T lv=S::id,rv=S::id;
    for(l+=n,r+=n+1;l<r;l>>=1,r>>=1){
      if (l&1)lv = S::op(lv,seg[l++].query(ps...));
      if (r&1)rv = S::op(seg[--r].query(ps...),rv);
    }
    return S::op(lv,rv);
  }
};

template<class S>
struct SegTree<0, S>{ using T = typename S::T;
  T val=S::id;
  T get(){return val;}
  void update(T x){val=x;}
  T query(){return val;}
};

struct M{ //monoid
  using T = int;
  static constexpr T id = 0;
  static T op(T a, T b){return max(a,b);}
};
```

SparseTable.h

Description: Multidimensional Sparse Table Requires Idempotent Monoid S (op, inv, id)

Memory: $\mathcal{O}\left((n \log n)^D\right)$

Time: $\mathcal{O}\left(1\right)$ query, $\mathcal{O}\left((n \log n)^D\right)$ build

c900f0, 39 lines

```cpp
#define MAs template<class...As> //multiple arguments
template<int D, class S>
struct SpTable{ using T = typename S::T;
  using isp = SpTable<D-1, S>;
  inline int lg(signed x){return __builtin_clz(1)-__builtin_clz
      (x);}
  int n;
  vector<vector<isp>> tab;
  MAs SpTable(int s, As... ds):n(s),
  tab(1+lg(n),vector<isp>(n,isp(ds...))){}
  MAs void set(T x, int p, As... ps){tab[0][p].set(x, ps...);}
  void join(SpTable& a, SpTable& b){
    rep(i, 0, 1+lg(n))rep(j, 0, n)
      tab[i][j].join(a.tab[i][j], b.tab[i][j]);
  }
  void init(){
    rep(i, 0, n)tab[0][i].init();
    rep(i, 0, lg(n))rep(j, 0, n-(1<<i))
      tab[i+1][j].join(tab[i][j], tab[i][j+(1<<i)]);
  }
  MAs T query(int l, int r, As... ps){
    int k = lg(r-l+1); r+=1-(1<<k);
    return S::op(tab[k][l].query(ps...),tab[k][r].query(ps...))
        ;
  }
};

template<class S>
struct SpTable<0, S>{ using T = typename S::T;
  T val=S::id;
  void set(T x){val=x;}
  void join(SpTable& a, SpTable& b){val=S::op(a.val,b.val);}
  void init(){}
  T query(){return val;}
};

struct IM{
  using T = int;
  static constexpr T id = 0;
  static T op(T a, T b){return max(a, b);}
};
```

BIT.h

Description: Multidimensional BIT/Fenwick Tree Requires Abelian Group "S" (op, inv, id)

Memory: $\mathcal{O}\left(N^D\right)$

Time: $\mathcal{O}\left((\log N)^D\right)$

778135, 31 lines

```cpp
#define MAs template<class... As> //multiple arguments
template<int D, class S>
struct BIT{ using T = typename S::T;
  int n;
  vector<BIT<D-1, S>> bit;
  MAs BIT(int s, As... ds):n(s),bit(n+1, BIT<D-1, S>(ds...)){}
  inline int lastbit(int x){return x&(-x);}
  MAs void add(T x, int p, As... ps){
    for(p++;p<=n;p+=lastbit(p))bit[p].add(x, ps...);
  }
```

```
  MAs T query(int l, int r, As... ps){
    T lv=S::id,rv=S::id; r++;
    for(;r>=1;r-=lastbit(r))rv=S::op(rv,bit[r].query(ps...));
    for(;l>=1;l-=lastbit(l))lv=S::op(lv,bit[l].query(ps...));
    return S::op(rv,S::inv(lv));
  }
};

template<class S>
struct BIT<0, S>{ using T = typename S::T;
  T val=S::id;
  void add(T x){val=S::op(val,x);}
  T query(){return val;}
};

struct AG{ //abelian group analogous to int addition
  using T = int;
  static constexpr T id = 0;
  static T op(T a, T b){return a+b;}
  static T inv(T a){return -a;}
};
```

MoQueries.h

Description: Solve queries offline Can be changed by modifying Spec
Time: $\mathcal{O}\left(n * \sqrt(q)\right)$

cf6ecd, 23 lines

```
vi mo(vector<pii> Q, vector<int> V) { // Queries in Q are [l, r
    )
  int L = 0, R = 0, blk = 350; // N/sqrt (Q)

  vi s(sz(Q)), res = s;
  auto K = [&](pii x) {return pii(x.first/blk, x.second ^ -(x.
      first/blk & 1)); };
  iota(all(s), 0);
  sort(all(s), [&](int s, int t){ return K(Q[s]) < K(Q[t]); });

  int sum = 0;
  auto add =  [&](int ind, int end) { sum += V[ind]; }; // add
      a [ ind ] (end = 0 or 1)
  auto del =  [&](int ind, int end) { sum -= V[ind]; }; //
      remove a [ ind ]
  auto calc = [&]() { return sum; };                      //
      compute current answer

  for (int qi : s) {
    pii q = Q[qi];
    while (L > q.first) add(--L, 0);
    while (R < q.second) add(R++, 1);
    while (L < q.first) del(L++, 0);
    while (R > q.second) del(--R, 1);
    res[qi] = calc();
  }
  return res;
}
```

Matching (3)

OnlineMatching.h

Description: Modified khun developed for specific question able to run $2 * 10^6$ queries, in $2 * 10^6$ x 10^6 graph in 3 seconds codeforces
Time: $\mathcal{O}\left(confia\right)$

6ac539, 42 lines

```
struct OnlineMatching {
    int n = 0, m = 0;
    vector<int> vis, match, dist;
    vector<vector<int>> g;
  vector<int> last;
  int t = 0;

    OnlineMatching(int n_, int m_) : n(n_), m(m_),
    vis(n, 0), match(m, -1), dist(n, n+1), g(n), last(n, -1)
    {}

    void add(int a, int b) {
        g[a].pb(b);
    }

    bool kuhn(int a) {
    vis[a] = t;
    for(int b: g[a]) {
        int c = match[b];
        if (c == -1) {
        match[b] = a;
        return true;
        }
        if (last[c] != t || (dist[a] + 1 < dist[c]))
        dist[c] = dist[a] + 1, last[c] = t;
    }
    for (int b: g[a]) {
      int c = match[b];
      if (dist[a] + 1 == dist[c] && vis[c] != t && kuhn(c)) {
        match[b] = a;
        return true;
      }
    }
        return false;
    }
  bool can_match(int a) {
    t++;
    last[a] = t;
    dist[a] = 0;
    return kuhn(a);
  }
};
```

Math (4)

LinearDiophantineEquation.h

Description: Find a solution to equation a*x + b*y = c
Time: $\mathcal{O}\left(log(a)\right)$

538f05, 14 lines

```
array<ll, 3> exgcd(ll a, ll b) {
  if (a == 0) return {0, 1, b};
  auto [x, y, g] = exgcd(b % a, a);
  return {y - b / a * x , x, g};
}

array<ll, 4> find_any_solution(ll a, ll b, ll c) {
  assert(a != 0 || b != 0);
  auto[x, y, g] = exgcd(a, b);
  if (c % g) return {false, 0, 0, 0};
  x *= c / g;
  y *= c / g;
  return {true, x, y, g};
}
```

Techniques (A)

techniques.txt

159 lines

```
Recursion
Divide and conquer
  Finding interesting points in N log N
Algorithm analysis
  Master theorem
  Amortized time complexity
Greedy algorithm
  Scheduling
  Max contiguous subvector sum
  Invariants
  Huffman encoding
Graph theory
  Dynamic graphs (extra book-keeping)
  Breadth first search
  Depth first search
  * Normal trees / DFS trees
  Dijkstra's algorithm
  MST: Prim's algorithm
  Bellman-Ford
  Konig's theorem and vertex cover
  Min-cost max flow
  Lovasz toggle
  Matrix tree theorem
  Maximal matching, general graphs
  Hopcroft-Karp
  Hall's marriage theorem
  Graphical sequences
  Floyd-Warshall
  Euler cycles
  Flow networks
  * Augmenting paths
  * Edmonds-Karp
  Bipartite matching
  Min. path cover
  Topological sorting
  Strongly connected components
  2-SAT
  Cut vertices, cut-edges and biconnected components
  Edge coloring
  * Trees
  Vertex coloring
  * Bipartite graphs (=> trees)
  * 3^n (special case of set cover)
  Diameter and centroid
  K'th shortest path
  Shortest cycle
Dynamic programming
  Knapsack
  Coin change
  Longest common subsequence
  Longest increasing subsequence
  Number of paths in a dag
  Shortest path in a dag
  Dynprog over intervals
  Dynprog over subsets
  Dynprog over probabilities
  Dynprog over trees
  3^n set cover
  Divide and conquer
  Knuth optimization
  Convex hull optimizations
  RMQ (sparse table a.k.a 2^k-jumps)
  Bitonic cycle
  Log partitioning (loop over most restricted)
Combinatorics
  Computation of binomial coefficients
  Pigeon-hole principle
  Inclusion/exclusion
  Catalan number
  Pick's theorem
Number theory
  Integer parts
  Divisibility
  Euclidean algorithm
  Modular arithmetic
  * Modular multiplication
  * Modular inverses
  * Modular exponentiation by squaring
  Chinese remainder theorem
  Fermat's little theorem
  Euler's theorem
  Phi function
  Frobenius number
  Quadratic reciprocity
  Pollard-Rho
  Miller-Rabin
  Hensel lifting
  Vieta root jumping
Game theory
  Combinatorial games
  Game trees
  Mini-max
  Nim
  Games on graphs
  Games on graphs with loops
  Grundy numbers
  Bipartite games without repetition
  General games without repetition
  Alpha-beta pruning
Probability theory
Optimization
  Binary search
  Ternary search
  Unimodality and convex functions
  Binary search on derivative
Numerical methods
  Numeric integration
  Newton's method
  Root-finding with binary/ternary search
  Golden section search
Matrices
  Gaussian elimination
  Exponentiation by squaring
Sorting
  Radix sort
Geometry
  Coordinates and vectors
  * Cross product
  * Scalar product
  Convex hull
  Polygon cut
  Closest pair
  Coordinate-compression
  Quadtrees
  KD-trees
  All segment-segment intersection
Sweeping
  Discretization (convert to events and sweep)
  Angle sweeping
  Line sweeping
  Discrete second derivatives
Strings
  Longest common substring
  Palindrome subsequences
  Knuth-Morris-Pratt
  Tries
  Rolling polynomial hashes
  Suffix array
  Suffix tree
  Aho-Corasick
  Manacher's algorithm
  Letter position lists
Combinatorial search
  Meet in the middle
  Brute-force with pruning
  Best-first (A*)
  Bidirectional search
  Iterative deepening DFS / A*
Data structures
  LCA (2^k-jumps in trees in general)
  Pull/push-technique on trees
  Heavy-light decomposition
  Centroid decomposition
  Lazy propagation
  Self-balancing trees
  Convex hull trick (wcipeg.com/wiki/Convex_hull_trick)
  Monotone queues / monotone stacks / sliding queues
  Sliding queue using 2 stacks
  Persistent segment tree
```