Contents

Basic

vimrc

Description

vimrc.

1. Be careful of the version (currently `gnu++20` for WF)
2. `setxkbmap` command should be executed in terminal or smt.

Test Status

No test needed

Debug Macro

Description

Debug code for dumping information.

Test Status

No test needed.

SVG Writer

Description

A helper to generate SVG. Support Line, Circle, and Text. Should adjust sizes properly.

Test Status

No Test

Pragma Optimization

Description

Magic Pragmas. It depends to choose Ofast or O3. For target related stuff, adding `arch=skylake` should work (no need for others). Also, a way to avoid denormal numbers. 0x8000 for FTZ and 0x0040 for DAZ. Intel Compiler Docs. Only works for SSE/AVX stuff.

Test Status

Rarely used, no test

IO Optimization

Description

I/O bounded program needs this sweet optimization.

Test Status

Rarely used, no test.

Increase Stack

Description

Increase the stack size

Test Status

Not even used

Data Structure

Dark Magic

Description

PBDS classes/functions. ordered set and mergable heap are the useful ones.

Test Status

No test.

Link-Cut Tree

Description

$O(Q \log N)$ operations on path query. Supports link or cut edge.

Subtree queries are tricky.

Test Status

CF 603E. Passed dynamic_tree_vertex_set_path_composite and dynamic_tree_vertex_add_subtree_sum.

LiChao Segment Tree

Description

Maintain the upper envelope of lines.

TODO: is extended version needed?

Test Status

Used in some contest.

Treap

Description

treap. For persistent, should not use `pri`.

Test Status

Rarely used. Need test?

Linear Basis

Description

Given a set of integers: - `query_kth` to find the k-th integer in the (sorted) set of XOR combination of the integers with v. - The `second` field is for range XOR basis query or smt, greedily maintained in `insert` function.

Test Status

- ABC223 H
- kth problem 1st Hunger Games S
- maybe need a combined problem?

Binary Search on Segtree

Description

Binary search on ZKW segtree. `sz` should be power of 2 (be careful of other parts!).

Test Status

Passed Quick Sort

Matching & Flow

HopcroftKarp

Description

An $O(|E|\sqrt{|V|})$ bipartite matching algorithm. Basically a low constant Dinic's algorithm.

Number of matching saved in `ans`, and the corresponding matching saved in `l` and `r`. ~~Not sure about what `a` and `p` does.~~ `a` and `p` are auxiliary array when doing BFS.

Test Status

Tested on Library Checker

Kuhn Munkres

Description

KM algo.

Test Status

Passed UOJ 80 and Library Checker.

Flow Models

Description

Some models. Need check.

Test Status

TODO

Dinic

Description

Dinic with capacity scaling. See this and this. $O(VE\log U)$ and $\Theta(acceptable)$ in practice.

Test Status

Passed luogu P3376. Passed VN-SPOJ FFLOW. Without scaling won't pass.

HLPP

Description

HLPP algo with gap heuristics.

Theoritical complexity is $O(V^2\sqrt{E})$. But heuristic is powerful!

Note: Lowest Label Push Relabel is $O(\sqrt{V}E)$ on bipartie matching graph.

Test Status

LOJ 127 and library checker bipartite matching. Passed Matching on Bipartite Graph.

Passed VN-SPOJ FFLOW.

Global Min-Cut

Description

Stoer-Wagner algorithm solves the minimum cut problem in undirected weighted graphs with non-negative weights. Our code looks like an $O(N^3)$ implementation.

Test Status

Passed luogu Didn't find a $O(VE+V^2\log V)$ version.

GomoryHu Tree

Description

For a given non-negative weighted tree, this algorithm returns a weighted tree (Gomory-Hu Tree). For any s, t, the minimum s-t cut in the original graph is equal to the minimum values among the path between s and t in the Gomory-Hu Tree.

Runs in $(|V|-1) \times O(\text{maflow})$.

Need to adapt current Dinic's algorithm.

Something I don't understand: In the Gomory-Hu tree, for any pair of vertices not just the size of the minimum cut between them is equal to the size of the minimum cut in the original graph (as Wikipedia claims), but also the minimum cut itself (as a partition of the vertex set into two). (Petr's blog)

Fun Fact: Gomory-Hu Tree can be computed in almost linear time. (see this)

Test Status

Passed CF 343E.

MCMF

Description

Successive Shortest Path Algorithm using SPFA (Bellman-Ford algorithm).

Test Status

Passed LibreOJ 102. Testdata in LOJ is not strong in general.

Passed atcoder lib contest. QOJ 602 (random testcase).

Dijkstra Cost Flow

Description

Successive Shortest Path Algorithm using Dijkstra's algorithm.

Test Status

Tested on ARC122 F and LibreOJ 102

Passed atcoder lib contest. (??)

Min Cost Circulation

Description

Network simplex method. Exponential time complexity, but it runs not too slow in practice.

Test Status

Tested on UOJ #487, UOJ #680, and LibreOJ 102. min_cost_b_flow. QOJ 602 (random testcase). **Cannot** pass QOJ 7185

Capacity Scaling

Description

Test Status

min_cost_b_flow QOJ 602 (random testcase).

General Matching

Description

Matching in $O(|V|^3)$. ref-slide

Test Status

Tested on Library Checker.

Weighted Matching

Description

Weighted matching in $O(|V|^3)$. ref-slide

Test Status

Tested on Library Checker Passed UOJ #81.

Graph

SCC

Description

Tarjan algorithm. The constant is generally better than kosaraju.

TODO Kosaraju and bitset-optimized Kosaraju.

Test Status

Passed SCC.

2-SAT

Description

2-SAT construction.

To use 2-SAT with n variables, call constructor with $2n$. $2i$ and $2i+1$ represents x and $\neg x$. $x \vee x$ or $\neg x \vee \neg x$ is OK.

Test Status

Passed CSES Giant Pizza and CF Radio Stations. Passed 2 SAT.

BCC

Description

Gives AP and bridge and `bcc_id`. `bcc_id[edge_id]` is the bcc of the edge.

Test Status

Passed Two-Edge-Connected-Components and Biconnected Components. `is_ap` function is not tested.

Round Square Tree

Description

Or block-cut-tree. Useful tree for "simple path" queries. There will be at most $2N$ vertices in the new tree.

Test Status

Passed 2020 Shanghai K Passed Biconnected Components

Edge TCC

Description

Edge triconnected component.

Test Status

Passed yosupo library checker.

Bipolar Orientation

Description

Bipolar orientation algo

Test Status

Passed 1916F.

DMST

Description

Directed Minimum Spanning Tree in $O(E \log^2 E)$. Use mergable heap instead of small-to-big for better complexity?

Test Status

Passed yosupo library checker CF 100307 D

Dominator Tree

Description

Dominator tree in $O(E \log V)$. The ancestor relation on the tree is the "must-pass-from-source" relation in original graph.

Test Status

Passed yosupo library checker.

Edge Coloring

Description

Misra & Gries edge coloring algorithm. Runs in $O(NM)$

Test Status

Passed NCPC 2018 G.

Centroid Decomp.

Description

Mark a vertex or query the sum of distance from a vertex to all marked vertices.

Need rewrite or smt?

Test Status

Passed TIOJ 1171.

Lowbit Decomp.

Description

Some chain decomposition of tree.

Test Status

Passed Vertex Add Path Sum.

Virtual Tree

Description

Dependency: `lca`. Gives the critital nodes of given subset. Always include the original root. The edges are given in rooted tree format.

Test Status

Used in contest. TODO.

Tree Hashing

Description

Some PRNG random hash.

Test Status

Passed UOJ 763 and library checker. Passed QOJ 499.

Mo's Algo on Tree

Description

Pseudo code of mo's algo on tree. `push` means XOR the contribution.

Test Status

TODO

Count Cycles

Description

Count 3-cycle and 4-cycle in $O(M\sqrt{M})$.

Test Status

Passed CCPC Guangzhou.

Maximal Clique

Description

Enumerate maximal clique. Time complexity $O(n3^{n/3})$ or $O(nC)$ where C is the number of such cliques.

Test Status

Can run on $n = 80$ on TIOJ.

Maximum Clique

Description

MaxCliqueDyn algo Get maximum clique with ?? time complexity.

Test Status

kactl says it can run on $n = 155$. For $n = 100$ on POJ, runs in 32ms. Passed library checker.

Min Mean Cycle

Description

$O(V(V + E))$ find min mean cycle. Too rare to use so needs shorten.

Test Status

Passed a UVa problem with $n = 50$.

Math

Common Bounds

Description

Partition function, divisor function, catalan number, bell number

Test Status

No test.

Equations

Description

many equations. - Stirling Number - Derivatives - Extended Euler - Pentagonal number theorem

Test Status

No test.

Extended FloorSum

Description

A recursion formula.

Test Status

No test.

Integer Division

Description

C++ integer division to normal integer division.

Test Status

Copied from 8BQube

FloorSum

Description

Calculate $\sum_{i=0}^{n-1} \lfloor \frac{ai+b}{m} \rfloor$.

Test Status

Passed yosupo judge (negative coefficient not tested).

ModMin

Description

Return the minimum $x \geq 0$ such that $l \leq ax \mod m \leq r$.

Test Status

Tested on SEERC'20 G

Floor Monoid Product

Description

萬能歐幾里得 ref1 ref2

Test Status

https://judge.yosupo.jp/submission/185615 https://www.luogu.com.cn/record/144016921 https://loj.ac/s/1986411 https://qoj.ac/submission/327486

ax+by=gcd

Description

exgcd algorithm.

Test Status

See CRT section.

Chinese Remainder

Description

Solves $x \equiv r_1 \pmod{m_1}$ and $x \equiv r_2 \pmod{m_2}$. If no solution, returns false

Test Status

Passed luogu P4777.

DiscreteLog

Description

BSGS algorithm.

Test Status

Passed yosupo judge

Quadratic Residue

Description

Square root under modulo prime.

Test Status

Passed yosupo judge

FWT

Description

Bitwise XOR/AND/OR convolution.

Test Status

Passed yosupo judge, XOR and AND version.

Packed FFT

Description

`convolution` uses less times of FFT. `convolution_mod` decompose numbers to high and low part, make FFT precision better. reference: - 淺談 FFT - 題解 P4245

Test Status

Passed convolution mod with long double. For $N = 524288$, - normal NTT (998244353): ~230ms - three-mod-NTT: ~430ms - `convolution_mod` ~1000ms with long double (AC), 400ms with double (WA) - `convolution`: ~800ms with long double (WA)

The first function passed Because, art.

CRT for arbitrary mod

Description

CRT for three-mod-NTT.

Test Status

Passed yosupo judge.

NTT / FFT

Description

NTT. Can be modified to FFT easily.

Test Status

Passed yosupo judge. See also "CRT for arbitrary mod".

Formal Power Series

Description

Common Formal Power Series operations. Exp and Pow are relatively slow at yosupo library checker.

Do we need Consecutive Terms of Linear Recurrent Sequence?

Test Status

Inv Ln Exp Pow Sqrt Eval DivMod LinearRecursionKth

Partition Number

Description

Calculate first N partition number in $O(N\sqrt{N})$.

Test Status

Passed yosupo judge $N = 500000$ in 557ms.

Pi Count

Description

Count prime in sublinear time. The code is copied from 8BQube and simplified.

Test Status

Passed yosupo judge

Miller Rabin

Description

Prime detect. Be careful about mpow and mmul.

Test Status

Passed yosupo judge in 1632ms (10^5 tests). w/ Montgomery Multiplication runs in 219ms.

Pollard Rho

Description

Factorization. Be careful about mpow and mmul.

Test Status

Passed yosupo judge in 313ms (100 tests). w/ Montgomery Multiplication runs in 72ms.

Barrett Reduction

Description

Fast modulo operation of non-constexpr constant. Only able to handle int-size modulo.

Test Status

Copied from kactl. Guess it's ok to have no test.

Montgomery

Description

Montgomery multiplication. Fast modulo operation of non-constexpr constant. Only able to handle odd modulo.

Test Status

Tested with MillerRabin and PollardRho.

Berlekamp Massey

Description

BM algo.

Test Status

Passed yosupo judge.

Gauss Elimination

Description

Make RREF and solve system of linear equations.

Test status

library checker.

CharPoly

Description

Calculate the charateristic polynomial of matrix in $O(N^3)$.

Test Status

Passed 2021 PTZ Korea and library checker.

Simplex

Description

Linear programming.

Test Status

Passed Red and Black Tree. long double runs 3 times slower.

Simplex Construction

Description

Tips for simplex

Test Status

See simplex.

Adaptive Simpson

Description

Simpson integration method. Unknown time complexity.

Test Status

Passed Two Cylinders.

Golden Ratio Search

Description

Ternary search with less query number

Test Status

TODO copied from kactl.

Geometry

Basic Geometry

Description

- `sgn` `cross` `dot` `ori`
- `quad` `argCmp` all-integer angle compare.
- `area` be careful of type.
- `rot90` multiply by i (or left turn 90 degree)
- `project` projection onto a vector

Test Status

No test. Used extensively in other template. TODO Center of polygon needs test.

2D Convex Hull

Description

Returns strict convex hull of given points. The result is counter-clockwise and the first point is the lex-min point. Be carefule about edge case (0/1/2/3 points on CV)

Test Status

Used in some contest.

2D Farthest Pair

Description

Rotating caliper algorithm. Requires the input hull be strictly convex.

Test Status

Passed AOJ CGL.

MinMax Enclosing Rect

Description

Rotating caliper, but with more pointers.

Test Status

Passed UVA 819

Minkowski Sum

Description

Minkowski sum of two convex hulls.

Test Status

Used in some contest. TODO.

Segment Intersection

Description

Check whether the segment intersects. Touching at the ends counts. Be careful about edge case like parallel, does touching at ends count, ... Can be modified to `Ray` class or `Line` class.

To get the intersection point, check next part (HPI)

Test Status

Used in many contest. Passed AOJ CGL.

Halfplane Intersection

Description

Calculate the area of half-plane-intersection. The result lines will be in `q` (this is why we need the reference). Result lines maybe wrong if the intersection area doesn't have positive area.

Test Status

Passed 2020 Nordic NCPC Big brother. Used in many contest.

SegmentDist (Sausage)

Description

Distance from point to segment and segment to segment. Can be used in checking sausage intersection.

Test Status

Passed QOJ 2444 and PTZ 19 summer D3.

Rotating Sweep Line

Description

A skeleton of rotating sweep line. Support colinear cases.

Test Status

Passed NAIPC 2016 G

Hull Cut

Description

Cut convex polygon by a line.

Test Status

Copied from kactl. TODO.

Point In Hull

Description

Testing PIH in $O(\log N)$.

Test Status

Enclosure See tangent of points to hull Used in some contest.

Point In Polygon

Description

Testing PIP.

Test Status

Used in some contest. Passed CGL_3_C

Point In Polygon (Fast)

Description

Testing PIP offline and faster.

Test Status

Passed CGL_3_C

Cyclic Ternary Search

Description

Fine extreme point on cyclic good functions

Test Status

See tangent of points to hull

Tangent of Points to Hull

Description

Tangent of point to hull in $O(\log N)$. Requires the hull to be strictly convex. Can be modified to find extreme point on hull.

Test Status

Enclosure https://codeforces.com/gym/101201/submission/245757109

Circle Class & Intersection

Description

Definition of `Cir` and some intersection function.

Test Status

Passed AOJ CGL. CGL_7_E

Circle Common Tangent

Description

Common tangent point of circle.

Test Status

Passed AOJ CGL_7_F, CGL_7_G. Passed CF 128E.

Line-Circle Intersection

Description

The point of intersection of line and circle.

Test Status

Passed AOJ CGL_7_D.

Poly-Circle Intersection

Description

The intersection area of a circle and a simple polygon.

Test Status

Passed AOJ CGL_7_H. Copied from 8BQube and they say it passed HDU2892.

Min Covering Circle

Description

Get minimum covering circle in $O(N)$ expected time. Also gives the circumcenter formula.

Test Status

Passed TIOJ 1093, luogu P1742 TIOJ luogu

Circle Union

Description

Calculate the area that covered by at least k circle for each k. Time complexity $O(N^2 \log N)$.

Test Status

Passed SPOJ. CIRU (need 2d array instead of vector). CIRUT

Polygon Union

Description

Union area of simple polygon.

Test Status

https://codeforces.com/gym/101673/submission/244046248

3D Point

Description

Basic 3d point. - cross - triple product - rotate around an axis

Test Status

`rotate_around` is copied from NaCl. Others are tested by 3d hull.

3D Convex Hull

Description

Return the face of 3d convex hull of N points. There will be $O(N)$ faces and time complexity is $O(N^2)$. Be careful of degenerate cases.

Test Status

Passed SPOJ and stars in a can. Passed HDU 3662. (need to combine coplanar triangles to one face).

3D Projection

Description

Get the 2d coordinate of the projection of a point p onto plane $q^T x = 0$.

Test Status

Passed stars in a can.

Delaunay

Description

Delaunay triangulation.

Usage TODO.

Test Status

Passed Brazil subregional.

kd Tree (Nearest Point)

Description

KD Tree nearest point query.

Test Status

TODO

kd Closest Pair (3D ver.)

Description

3d closest pair

Test Status

Correct, but might be too slow. Can pass TIOJ using fast hash table.
Need more test.

Simulated Annealing

Description

A skeleton of simulated annealing

Test Status

TODO.

Triangle Centers

Description

Triangle centers formula.

Test Status

No test.

Stringology

Hash

Description

Rolling-hash algorithm

Test Status

Used in some contests. Passed Z-algo.

Suffix Array

Description

SA-IS algorithm. Complexity: $O(N + C)$

Test Status

Tested on Suffix Array and Number of Substrings and Longest Common Substring.

QOJ 956 with $N = 1e6$ and Σ is alphabet and number, 144ms.

Suffix Array Tools

Description

Some LCP array related operation.

Test Status

TODO

Ex SAM

Description

Don't know how to use.

Test Status

Copied from 8bq

KMP

Description

Knuth-Morris-Pratt algo

Test Status

TIOJ 1306 QOJ 464

Z value

Description

Z algorithm

Test Status

Tested on Library Checker

Manacher

Description

Find maximal palindrome for each index.

Test Status

Tested on Library Checker

Lyndon Factorization

Description

A string is called simple (or a Lyndon word), if it is strictly smaller than any of its own nontrivial suffixes. The Lyndon factorization of the string s is a factorization $s = w_1 w_2 ... w_k$, where all strings w_i are simple, and they are in non-increasing order $w_1 \geq w_2 \geq ... \geq w_k$.

Duval algorithm: $O(N)$.

Test Status

Tested @ luogu 6114, 1368 & UVA 719. Passed Library Checker

Main Lorentz

Description

A repetition is two occurrences of a string in a row. The challenge is to find all repetitions in a given string s.

The algorithm described here was published in 1982 by Main and Lorentz.

Time complexity: $O(N \log N)$

Every $[l, r]$ in rep$[i]$ satisfies that if $p \in [l, r]$ then $s[p, p + i) = s[p + i, p + 2i)$.

Test Status

TODO: pass library checker?

Passed CF 104508J. This problem is prepared with this code, but some SA solutions also passes.

BWT

Description

Burrows-Wheeler transform is done by sorting all the circular shifts of a text in lexicographic order and by extracting the last column and the index of the original string in the set of sorted permutations of S.

Good for run-length encoding?

Test Status

Passed UVa 632 and UVa 741

Palindromic Tree

Description

Check OI Wiki

Don't know how to use.

Test Status

TODO

Misc

Theorems

Description

Theorems.

Test Status

No test.

Stable Marriage

Description

Stable Marriage algo.

Test Status

No test needed.

Weight Matroid Intersection

Description

Almost an implementation.

Test Status

Copied from NaCl

Bitset LCS

Description

$O(n^2/w)$. need hand-written bitset (needs subtraction) TODO: Find a way to recove the answer. Prob

Test Status

Passed LibreOJ #6564

Prefix Substring LCS

Description

Calculate the LCS of a prefix of S and a substring of T in $O((|S||T| + Q) \log |T|)$

Test Status

Passed yosupo library checker. Copied from 8BQube.

Convex 1D/1D DP

Description

1D/1D optimization.

Test Status

TIOJ 烏龜疊疊樂

ConvexHull Optimization

Description

Maintain upper envelope of lines.

Test Status

Passed yosupo library checker.

Min Plus Convolution

Description

Monotone minima method of min plus convolution.

Test Status

Passed library checker.

SMAWK

Description

SMAWK algo. ref: maspy and abc

Test Status

Passed min plus convolution.

De-Bruijn

Description

De-Bruijn sequence construction

Test Status

Passed CSES, regional prob and local test.

Josephus Problem

Description

Josephus problem $O(N)$ and faster algo ($O(M \log N)$).

Test Status

Passed 2018 Asia Nanjing.

N Queens Problem

Description

N Queens Problem construction

Test Status

Not even used or tested.

Tree Knapsack

Description

TODO don't know its usage

Test Status

Not even used or tested.

Manhattan MST

Description

Minimum Spanning Tree of manhattan distance.

Test Status

Passed yosupo library checker.

Binary Search On Fraction

Description

Binary search on stern-borcot tree, binary search over p/q such that $0 \leq p, q \leq N$.

Test Status

TODO. Copied from NaCl.

Cartesian Tree

Description

ref: https://github.com/yosupo06/library-checker-problems/tree/master/graph/cartesian_tree

Test Status

Passed library checker.

Nim Product

Description

Nim product ref: ecnerwala and correct.cpp.

Test Status

Passed library checker. Relatively slow.