Gungnir's Standard Code Library

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Chapter 1 计算几何

1.1 二维

1.1.1 基础

```cpp
typedef double DB;
const DB eps = 1e-8;

int sign(DB x) {
    return x < -eps ? -1 : ( x > eps ? 1 : 0 );
}
DB msqrt(DB x) {
    return sign(x) > 0 ? sqrt(x) : 0;
}

struct Point {
    DB x, y;
    Point(): x(0), y(0) {}
    Point(DB x, DB y): x(x), y(y) {}
    Point operator+(const Point &rhs) const {
        return Point(x + rhs.x, y + rhs.y);
    }
    Point operator-(const Point &rhs) const {
        return Point(x - rhs.x, y - rhs.y);
    }
    Point operator*(DB k) const {
        return Point(x * k, y * k);
    }
    Point operator/(DB k) const {
        assert(sign(k));
        return Point(x / k, y / k);
    }
    Point rotate(DB ang) const {  // 逆时针旋转 ang 弧度
        return Point(cos(ang) * x - sin(ang) * y,
                cos(ang) * y + sin(ang) * x);
    }
    Point turn90() const {  // 逆时针旋转 90 度
        return Point(-y, x);
    }
};
DB dot(const Point& a, const Point& b) {
    return a.x * b.x + a.y * b.y;
}
DB det(const Point& a, const Point& b) {
    return a.x * b.y - a.y * b.x;
}
bool isLL(const Line& l1, const Line& l2, Point& p) {  // 直线与直线交点
    DB s1 = det(l2.b - l2.a, l1.a - l2.a),
       s2 = -det(l2.b - l2.a, l1.b - l2.a);
    if (!sign(s1 + s2)) return false;
    p = (l1.a * s2 + l1.b * s1) / (s1 + s2);
    return true;
}
bool onSeg(const Line& l, const Point& p) {  // 点在线段上
    return sign(det(p - l.a, l.b - l.a)) == 0 && sign(dot(p - l.a, p - l.b)) <= 0;
}
DB disToLine(const Line& l, const Point& p) {  // 点到直线距离
    return fabs(det(p - l.a, l.b - l.a) / (l.b - l.a).len());
}
DB disToSeg(const Line& l, const Point& p) {  // 点到线段距离
    return sign(dot(p - l.a, l.b - l.a)) * sign(dot(p - l.b, l.a - l.b)) == 1 ? disToLine(l, p) : std::min((p - l.a).len(), (p - l.b).len());
}
// 圆与直线交点
bool isCL(Circle a, Line l, Point& p1, Point& p2) {
    DB x = dot(l.a - a.o, l.b - l.a),
       y = (l.b - l.a).len2(),
       d = x * x - y * ((l.a - a.o).len2() - a.r * a.r);
    if (sign(d) < 0) return false;
    Point p = l.a - ((l.b - l.a) * (x / y)), delta = (l.b - l.a) * (msqrt(d) / y);
    p1 = p + delta; p2 = p - delta;
    return true;
}
// 求凸包
std::vector<Point> convexHull(std::vector<Point> ps) {
    int n = ps.size(); if (n <= 1) return ps;
    std::sort(ps.begin(), ps.end());
    std::vector<Point> qs;
    for (int i = 0; i < n; qs.push_back(ps[i ++]))
        while (qs.size() > 1 && sign(det(qs[qs.size() - 2], qs.back(), ps[i])) <= 0)
            qs.pop_back();
    for (int i = n - 2, t = qs.size(); i >= 0; qs.push_back(ps[i --]))
        while ((int)qs.size() > t && sign(det(qs[qs.size() - 2], qs.back(), ps[i])) <= 0)
            qs.pop_back();
    return qs;
}
```

1.1.2 凸包

```cpp
// 凸包中的点按逆时针方向
struct Convex {
    int n;
    std::vector<Point> a, upper, lower;
    void make_shell(const std::vector<Point>& p,
            std::vector<Point>& shell) {  // p needs to be sorted.
        clear(shell); int n = p.size();
        for (int i = 0, j = 0; i < n; i++, j++) {
            for (; j >= 2 && sign(det(shell[j-1] - shell[j-2],
                            p[i] - shell[j-2])) <= 0; --j) shell.pop_back();
            shell.push_back(p[i]);
        }
    }
    void make_convex() {
        std::sort(a.begin(), a.end());
        make_shell(a, lower);
        std::reverse(a.begin(), a.end());
        make_shell(a, upper);
        a = lower; a.pop_back();
        a.insert(a.end(), upper.begin(), upper.end());
        if ((int)a.size() >= 2) a.pop_back();
        n = a.size();
    }
    void init(const std::vector<Point>& _a) {
        clear(a); a = _a; n = a.size();
        make_convex();
    }
    void read(int _n) {  // Won't make convex.
        clear(a); n = _n; a.resize(n);
        for (int i = 0; i < n; i++)
            a[i].read();
    }
    std::pair<DB, int> get_tangent(
            const std::vector<Point>& convex, const Point& vec) {
        int l = 0, r = (int)convex.size() - 2;
        assert(r >= 0);
        for (; l + 1 < r; ) {
            int mid = (l + r) / 2;
            if (sign(det(convex[mid + 1] - convex[mid], vec)) > 0)
                r = mid;
            else l = mid;
        }
        return std::max(std::make_pair(det(vec, convex[r]), r),
                std::make_pair(det(vec, convex[0]), 0));
    }
    int binary_search(Point u, Point v, int l, int r) {
        int s1 = sign(det(v - u, a[l % n] - u));
        for (; l + 1 < r; ) {
            int mid = (l + r) / 2;
            int smid = sign(det(v - u, a[mid % n] - u));
```

```cpp
            if (smid == s1) l = mid;
            else r = mid;
        }
        return l % n;
    }
    // 求凸包上和向量 vec 叉积最大的点，返回编号，共线的多个切点返回任意一个
    int get_tangent(Point vec) {
        std::pair<DB, int> ret = get_tangent(upper, vec);
        ret.second = (ret.second + (int)lower.size() - 1) % n;
        ret = std::max(ret, get_tangent(lower, vec));
        return ret.second;
    }
    // 求凸包和直线 u, v 的交点，如果不相交返回 false，如果有则是和 (i, next(i)) 的交点，交在点上不确定返回前后两条边其中之一
    bool get_intersection(Point u, Point v, int &i0, int &i1) {
        int p0 = get_tangent(u - v), p1 = get_tangent(v - u);
        if (sign(det(v - u, a[p0] - u)) * sign(det(v - u, a[p1] - u)) <= 0) {
            if (p0 > p1) std::swap(p0, p1);
            i0 = binary_search(u, v, p0, p1);
            i1 = binary_search(u, v, p1, p0 + n);
            return true;
        }
        else return false;
    }
};
```

1.2 三维

1.2.1 基础

```cpp
// 三维绕轴旋转，大拇指指向 axis 向量方向，四指弯曲方向转 w 弧度
Point rotate(const Point& s, const Point& axis, DB w) {
    DB x = axis.x, y = axis.y, z = axis.z;
    DB s1 = x * x + y * y + z * z, ss1 = msqrt(s1),
       cosw = cos(w), sinw = sin(w);
    DB a[4][4];
    memset(a, 0, sizeof a);
    a[3][3] = 1;
    a[0][0] = ((y * y + z * z) * cosw + x * x) / s1;
    a[0][1] = x * y * (1 - cosw) / s1 + z * sinw / ss1;
    a[0][2] = x * z * (1 - cosw) / s1 - y * sinw / ss1;
    a[1][0] = x * y * (1 - cosw) / s1 - z * sinw / ss1;
    a[1][1] = ((x * x + z * z) * cosw + y * y) / s1;
    a[1][2] = y * z * (1 - cosw) / s1 + x * sinw / ss1;
    a[2][0] = x * z * (1 - cosw) / s1 + y * sinw / ss1;
    a[2][1] = y * z * (1 - cosw) / s1 - x * sinw / ss1;
    a[2][2] = ((x * x + y * y) * cos(w) + z * z) / s1;
    DB ans[4] = {0, 0, 0, 0}, c[4] = {s.x, s.y, s.z, 1};
    for (int i = 0; i < 4; ++ i)
        for (int j = 0; j < 4; ++ j)
            ans[i] += a[j][i] * c[j];
    return Point(ans[0], ans[1], ans[2]);
}
```

Chapter 2 数论

2.1 求逆元

```cpp
void ex_gcd(long long a, long long b, long long &x, long long &y) {
    if (b == 0) {
        x = 1;
        y = 0;
        return;
    }
    long long xx, yy;
    ex_gcd(b, a % b, xx, yy);
    y = xx - a / b * yy;
    x = yy;
}

long long inv(long long x, long long MODN) {
    long long inv_x, y;
    ex_gcd(x, MODN, inv_x, y);
    return (inv_x % MODN + MODN) % MODN;
}
```

2.2 中国剩余定理

```cpp
// 返回 (ans, M)，其中 ans 是模 M 意义下的解
std::pair<long long, long long> CRT(const std::vector<long long>& m, const std::vector<long long>& a) {
    long long M = 1, ans = 0;
    int n = m.size();
    for (int i = 0; i < n; i++) M *= m[i];
    for (int i = 0; i < n; i++) {
        ans = (ans + (M / m[i]) * a[i] % M * inv(M / m[i], m[i])) % M;  // 可能需要大整数相乘取模
    }
    return std::make_pair(ans, M);
}
```

Chapter 3 代数

3.1 快速傅里叶变换

```cpp
// n 必须是 2 的次幂
void fft(Complex a[], int n, int f) {
    for (int i = 0; i < n; ++i)
        if (R[i] < i) swap(a[i], a[R[i]]);
    for (int i = 1, h = 0; i < n; i <<= 1, h++) {
        Complex wn = Complex(cos(pi / i), f * sin(pi / i));
        Complex w = Complex(1, 0);
        for (int k = 0; k < i; ++k, w = w * wn) tmp[k] = w;
        for (int p = i << 1, j = 0; j < n; j += p) {
            for (int k = 0; k < i; ++k) {
                Complex x = a[j + k], y = a[j + k + i] * tmp[k];
                a[j + k] = x + y; a[j + k + i] = x - y;
            }
        }
    }
}
```

Chapter 4 字符串

4.1 后缀自动机

```cpp
struct Sam {
    static const int MAXL = MAXN * 2;  // MAXN is original length
    static const int alphabet = 26;  // sometimes need changing
    int l, last, cnt, trans[MAXL][alphabet], par[MAXL], sum[MAXL], seq[MAXL], mxl[MAXL], size[MAXL];  // mxl is maxlength, size is the size of right
    char str[MAXL];
    inline void init() {
        l = strlen(str + 1); cnt = last = 1;
        for (int i = 0; i <= l * 2; ++i) memset(trans[i], 0, sizeof(trans[i]));
        memset(par, 0, sizeof(*par) * (l * 2 + 1));
        memset(mxl, 0, sizeof(*mxl) * (l * 2 + 1));
        memset(size, 0, sizeof(*size) * (l * 2 + 1));
    }
    inline void extend(int pos, int c) {
        int p = last, np = last = ++cnt;
        mxl[np] = mxl[p] + 1; size[np] = 1;
        for (; p && !trans[p][c]; p = par[p]) trans[p][c] = np;
        if (!p) par[np] = 1;
        else {
            int q = trans[p][c];
            if (mxl[p] + 1 == mxl[q]) par[np] = q;
            else {
```

```cpp
                int nq = ++cnt;
                mxl[nq] = mxl[p] + 1;
                memcpy(trans[nq], trans[q], sizeof(trans[nq]));
                par[nq] = par[q];
                par[np] = par[q] = nq;
                for (; trans[p][c] == q; p = par[p]) trans[p][c] = nq;
            }
        }
    }
    inline void buildsam() {
        for (int i = 1; i <= l; ++i) extend(i, str[i] - 'a');
        memset(sum, 0, sizeof(*sum) * (l * 2 + 1));
        for (int i = 1; i <= cnt; ++i) sum[mxl[i]]++;
        for (int i = 1; i <= l; ++i) sum[i] += sum[i - 1];
        for (int i = cnt; i; --i) seq[sum[mxl[i]]--] = i;
        for (int i = cnt; i; --i) size[par[seq[i]]] += size[seq[i]];
    }
} sam;
```

Chapter 5 图论

5.1 基础

```cpp
struct Graph {  // Remember to call .init()!
    int e, nxt[M], v[M], adj[N], n;
    bool base;
    __inline void init(bool _base, int _n = 0) {
        assert(n < N);
        n = _n; base = _base;
        e = 0; memset(adj + base, -1, sizeof(*adj) * n);
    }
    __inline int new_node() {
        adj[n + base] = -1;
        assert(n + base + 1 < N);
        return n++ + base;
    }
    __inline void ins(int u0, int v0) {  // directional
        assert(u0 < n + base && v0 < n + base);
        v[e] = v0; nxt[e] = adj[u0]; adj[u0] = e++;
        assert(e < M);
    }
    __inline void bi_ins(int u0, int v0) {  // bi-directional
        ins(u0, v0); ins(v0, u0);
    }
};
```

5.2 KM

```cpp
struct KM {
    // Truly O(n^3)
    // 邻接矩阵，不能连的边设为 -INF，求最小权匹配时边权取负，但不能连的还是 -INF，使用时先对 1 -> n 调用 hungary() ，再 get_ans() 求值
    int w[N][N];
    int lx[N], ly[N], match[N], way[N], slack[N];
    bool used[N];
    void init() {
        for (int i = 1; i <= n; i++) {
            match[i] = 0;
            lx[i] = 0;
            ly[i] = 0;
            way[i] = 0;
        }
    }
    void hungary(int x) {
        match[0] = x;
        int j0 = 0;
        for (int j = 0; j <= n; j++) {
            slack[j] = INF;
            used[j] = false;
        }
        do {
            used[j0] = true;
            int i0 = match[j0], delta = INF, j1 = 0;
            for (int j = 1; j <= n; j++) {
                if (used[j] == false) {
                    int cur = -w[i0][j] - lx[i0] - ly[j];
                    if (cur < slack[j]) {
                        slack[j] = cur;
                        way[j] = j0;
                    }
                    if (slack[j] < delta) {
                        delta = slack[j];
                        j1 = j;
                    }
                }
            }
            for (int j = 0; j <= n; j++) {
                if (used[j]) {
                    lx[match[j]] += delta;
                    ly[j] -= delta;
                }
                else slack[j] -= delta;
            }
            j0 = j1;
        } while (match[j0] != 0);

        do {
            int j1 = way[j0];
            match[j0] = match[j1];
            j0 = j1;
        } while (j0);
    }

    int get_ans() {
        int sum = 0;
        for(int i = 1; i <= n; i++) {
            if (w[match[i]][i] == -INF) ; // 无解
            if (match[i] > 0) sum += w[match[i]][i];
        }
        return sum;
    }
} km;
```

5.3 点双连通分量

bcc.forest is a set of connected tree whose vertices are chequered with cut-vertex and BCC.

```cpp
const bool BCC_VERTEX = 0, BCC_EDGE = 1;
struct BCC {  // N = N0 + M0. Remember to call init(&raw_graph).
    Graph *g, forest; // g is raw graph ptr.
    int dfn[N], DFN, low[N];
    int stack[N], top;
    int expand_to[N];      // Where edge i is expanded to in expaned graph.
    // Vertex i expaned to i.
    int compress_to[N];  // Where vertex i is compressed to.
    bool vertex_type[N], cut[N], compress_cut[N], branch[M];
    //std::vector<int> BCC_component[N];  // Cut vertex belongs to none.
    __inline void init(Graph *raw_graph) {
        g = raw_graph;
    }
    void DFS(int u, int pe) {
        dfn[u] = low[u] = ++DFN; cut[u] = false;
        if (!~g->adj[u]) {
            cut[u] = 1;
            compress_to[u] = forest.new_node();
            compress_cut[compress_to[u]] = 1;
        }
        for (int e = g->adj[u]; ~e; e = g->nxt[e]) {
            int v = g->v[e];
```

```
            if ((e ^ pe) > 1 && dfn[v] > 0 && dfn[v] < dfn[u]) {
                stack[top++] = e;
                low[u] = std::min(low[u], dfn[v]);
            }
            else if (!dfn[v]) {
                stack[top++] = e; branch[e] = 1;
                DFS(v, e);
                low[u] = std::min(low[v], low[u]);
                if (low[v] >= dfn[u]) {
                    if (!cut[u]) {
                        cut[u] = 1;
                        compress_to[u] = forest.new_node();
                        compress_cut[compress_to[u]] = 1;
                    }
                    int cc = forest.new_node();
                    forest.bi_ins(compress_to[u], cc);
                    compress_cut[cc] = 0;
                    //BCC_component[cc].clear();
                    do {
                        int cur_e = stack[--top];
                        compress_to[expand_to[cur_e]] = cc;
                        compress_to[expand_to[cur_e^1]] = cc;
                        if (branch[cur_e]) {
                            int v = g->v[cur_e];
                            if (cut[v])
                                forest.bi_ins(cc, compress_to[v]);
                            else {
                                //BCC_component[cc].push_back(v);
                                compress_to[v] = cc;
                            }
                        }
                    } while (stack[top] != e);
                }
            }
        }
    }
    void solve() {
        forest.init(g->base);
        int n = g->n;
        for (int i = 0; i < g->e; i++) {
            expand_to[i] = g->new_node();
        }
        memset(branch, 0, sizeof(*branch) * g->e);
        memset(dfn + g->base, 0, sizeof(*dfn) * n); DFN = 0;
        for (int i = 0; i < n; i++)
            if (!dfn[i + g->base]) {
                top = 0;
                DFS(i + g->base, -1);
            }
    }
} bcc;

bcc.init(&raw_graph);
bcc.solve();
// Do something with bcc.forest ...
```

5.4 边双连通分量

```
struct BCC {
    Graph *g, forest;
    int dfn[N], low[N], stack[N], tot[N], belong[N], vis[N], top, dfs_clock;
    // tot[] is the size of each BCC, belong[] is the BCC that each node belongs to
    pair<int, int > ori[M]; // bridge in raw_graph(raw node)
    bool is_bridge[M];
    __inline void init(Graph *raw_graph) {
        g = raw_graph;
        memset(is_bridge, false, sizeof(*is_bridge) * g -> e);
        memset(vis + g -> base, 0, sizeof(*vis) * g -> n);
    }
    void tarjan(int u, int from) {
        dfn[u] = low[u] = ++dfs_clock; vis[u] = 1; stack[++top] = u;
        for (int p = g -> adj[u]; ~p; p = g -> nxt[p]) {
            if ((p ^ 1) == from) continue;
            int v = g -> v[p];
            if (vis[v]) {
                if (vis[v] == 1) low[u] = min(low[u], dfn[v]);
            } else {
                tarjan(v, p);
                low[u] = min(low[u], low[v]);
                if (low[v] > dfn[u]) is_bridge[p / 2] = true;
            }
        }
        if (dfn[u] != low[u]) return;
        tot[forest.new_node()] = 0;
        do {
            belong[stack[top]] = forest.n;
            vis[stack[top]] = 2;
            tot[forest.n]++;
            --top;
        } while (stack[top + 1] != u);
    }
    void solve() {
        forest.init(g -> base);
        int n = g -> n;
        for (int i = 0; i < n; ++i)
            if (!vis[i + g -> base]) {
                top = dfs_clock = 0;
                tarjan(i + g -> base, -1);
            }
        for (int i = 0; i < g -> e / 2; ++i)
            if (is_bridge[i]) {
                int e = forest.e;
                forest.bi_ins(belong[g -> v[i * 2]], belong[g -> v[i * 2 + 1]], g -> w[i * 2]);
                ori[e] = make_pair(g -> v[i * 2 + 1], g -> v[i * 2]);
                ori[e + 1] = make_pair(g -> v[i * 2], g -> v[i * 2 + 1]);
            }
    }
} bcc;
```

Chapter 6 技巧

6.1 真正的释放 STL 容器内存空间

```
template <typename T>
__inline void clear(T& container) {
    container.clear();  // 或者删除了一堆元素
    T(container).swap(container);
}
```

6.2 无敌的大整数相乘取模

Time complexity $O(1)$.

```
// 需要保证 x 和 y 非负
long long mult(long long x, long long y, long long MODN) {
    long long t = (x * y - (long long)((long double)x / MODN * y + 1e-3) * MODN) % MODN;
    return t < 0 ? t + MODN : t;
}
```

6.3 无敌的读入优化

```
// getchar() 读入优化 << 关同步 cin << 此优化
// 用 isdigit() 会小幅变慢
// 返回 false 表示读到文件尾
namespace Reader {
    const int L = (1 << 15) + 5;
    char buffer[L], *S, *T;
```

```cpp
    __inline bool getchar(char &ch) {
        if (S == T) {
            T = (S = buffer) + fread(buffer, 1, L, stdin);
            if (S == T) {
                ch = EOF;
                return false;
            }
        }
        ch = *S++;
        return true;
    }
    __inline bool getint(int &x) {
        char ch; bool neg = 0;
        for (; getchar(ch) && (ch < '0' || ch > '9'); ) neg ^= ch == '-';
        if (ch == EOF) return false;
        x = ch - '0';
        for (; getchar(ch), ch >= '0' && ch <= '9'; )
            x = x * 10 + ch - '0';
        if (neg) x = -x;
        return true;
    }
}
```

6.4 控制 cout 输出实数精度

```cpp
std::cout << std::fixed << std::setprecision(5);
```

Chapter 7 提示

7.1 线性规划转对偶

$$\begin{array}{ll} \text{maximize } \mathbf{c}^T\mathbf{x} \\ \text{subject to } \mathbf{A}\mathbf{x} \le \mathbf{b}, \mathbf{x} \ge 0 \end{array} \iff \begin{array}{ll} \text{minimize } \mathbf{y}^T\mathbf{b} \\ \text{subject to } \mathbf{y}^T\mathbf{A} \ge \mathbf{c}^T, \mathbf{y} \ge 0 \end{array}$$

7.2 32-bit/64-bit 随机素数

32-bit	64-bit
73550053	1249292846855685773
148898719	1701750434419805569
189560747	3605499878424114901
459874703	5648316673387803781
1202316001	6125342570814357977
1431183547	6215155308775851301
1438011109	6294606778040623451
1538762023	6347330550446020547
1557944263	7429632924303725207
1981315913	8524720079480389849