

Cuprins

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Fișiere comune

utils.h

```
1  #pragma once
2  #include <initializer_list>
3  #include <iostream>
4
5  constexpr size_t getSize(std::initializer_list<double> l) {
6      size_t n = 0;
7      auto it = l.begin();
8      auto end = l.end();
9      while (it++ != end) ++n;
10     return n;
11 }
12
13 constexpr void getSize(std::initializer_list<
14     std::initializer_list<double>> list,
15     int& s1, int& s2) {
16     constexpr int invalid = -1;
17     s1 = 0;
18     s2 = invalid;
19
20     for (const auto& l: list) {
21         int i = getSize(l);
22         ++s1;
23         if (s2 != invalid && i != s2) {
24             //std::cerr << i << "!=" << s2 << "\n";
25             throw std::logic_error("Fixed line size expected");
26         }
27         s2 = i;
28     }
29     //std::cerr << "size: " << s1 << ", " << s2 << "\n";
30 }
31 constexpr int MAX_SZ = 256;
32 inline size_t readSize(const char* name, int a = 1, int b = MAX_SZ) {
33     int res;
34     do {
35         std::cout << name << ": ";
36         std::cin >> res;
37     } while (res < a || res >= b);
38     return res;
39 }
```

```

40
41 inline void assert(bool cond, const char* msg) {
42     if (!cond) throw std::logic_error(msg);
43 }
44 template<typename T>
45 static T read(const char* name) {
46     T res;
47     std::cout << name << ": ";
48     std::cin >> res;
49     return res;
50 }

```

matrix.h

```

1  #pragma once
2  #include "utils.h"
3
4  #include <iostream>
5  #include <cmath>
6  #include <cstring>
7  #include <utility>
8
9  struct Mat {
10     int m, n;
11     double *data;
12     Mat() : m(0), n(0), data(nullptr) {}
13     Mat(int m, int n) : m(m), n(n) { data = new double[m*n]; }
14     //template<int m, int n>
15     Mat(std::initializer_list<std::initializer_list<double>> list) {
16         getSize(list, m, n);
17         data = new double[m*n];
18
19         auto it = begin();
20         for (const auto& l : list) {
21             for (const auto& v : l) *(it++) = v;
22         }
23     }
24     Mat(Mat&& rhs) noexcept :
25         m(rhs.m), n(rhs.n),
26         data(std::exchange(rhs.data, nullptr)) {
27         //rhs.n = rhs.m = 0;
28     }
29
30     Mat(const Mat& rhs) : Mat(rhs.m, rhs.n) {
31         std::memcpy(data, rhs.data, sizeof(double) * m*n);
32     }
33     Mat& operator=(const Mat& rhs) {
34         setSize(rhs.m, rhs.n);
35         std::memcpy(data, rhs.data, sizeof(double) * m*n);
36         return *this;

```

```

37 }
38 Mat& operator=(Mat&& rhs) noexcept {
39     this->~Mat();
40     m = rhs.m;
41     n = rhs.n;
42     data = std::exchange(rhs.data, nullptr);
43
44     return *this;
45 }
46
47 ~Mat() {
48     delete[] data;
49 }
50 double& at(int i, int j) {
51     assert(i < m && j < n, "out of range");
52     return data[i * n + j];
53 }
54 double at(int i, int j) const { return data[i * n + j]; }
55 double* begin() { return data; }
56 const double* begin() const { return data; }
57 double* end() { return data + m*n; }
58 const double* end() const { return data + m*n; }
59
60 void setSize(int m, int n) {
61     if (this->m == m && this->n == n) return;
62     this->~Mat();
63     new (this) Mat(m, n);
64 }
65
66 static Mat read() {
67     Mat res(readSize("m"), readSize("n"));
68     for (auto& i : res)
69         std::cin >> i;
70     return res;
71 }
72 void print(const char* name) const {
73     std::cout << name << " = Mat " << m << "x" << n << "{\n";
74
75     for (int i = 0; i < m; ++i) {
76         for (int j = 0; j < n; ++j) {
77             std::cout << at(i, j) << " ";
78         }
79         std::cout << "\n";
80     }
81     std::cout << "}\n";
82 }
83
84 friend std::ostream& operator<<(std::ostream& s, Mat& m) {
85     s << "Mat " << m.m << "x" << m.n << "{\n";
86     for (int i = 0; i < m.m; ++i) {

```

```

87         for (int j = 0; j < m.n; ++j) {
88             s << m.at(i, j) << " ";
89         }
90         s << "\n";
91     }
92     return s<< "}\n";
93 }
94
95 double norm1() const { return normImpl<Type::Row>(n, m); }
96 double normInf() const { return normImpl<Type::Col>(m, n); }
97 double normF() const {
98     double res = 0;
99     for (int i = 0; i < m; ++i)
100         for (int j = 0; j < n; ++j)
101             res += at(i, j) * at(i, j);
102
103     return std::sqrt(res);
104 }
105 bool isStrictlyRowDiagonallyDominant() const {
106     return isStrictlyDiagonallyDominantImpl<Type::Row>();
107 }
108
109 bool isStrictlyColDiagonallyDominant() const {
110     return isStrictlyDiagonallyDominantImpl<Type::Col>();
111 }
112
113 private:
114
115     enum class Type { Row, Col };
116     template<Type type>
117     bool isStrictlyDiagonallyDominantImpl() const {
118         assert(m == n, "Matrix must be square");
119         for (int i = 0; i < m; ++i) {
120             double val = std::abs(at(i, i));
121             double sum = -val;
122             for (int j = 0; j < m; ++j) {
123                 sum += std::abs(type == Type::Col? at(j, i): at(i, j));
124             }
125             if (sum >= val) {
126                 std::cout << "(" << sum << ", " << val << ")";
127                 return false;
128             }
129         }
130         return true;
131     }
132     template<Type type>
133     double normImpl(int sz1, int sz2) const {
134         double max = -1;
135         for (int j = 0; j < sz1; ++j) {
136             double x = 0;

```

```

137         for (int i = 0; i < sz2; ++i) {
138             x += std::abs(type == Type::Col? at(j, i) : at(i, j));
139         }
140         if (x > max) max = x;
141     }
142     return max;
143 }
144 };
145
146 Mat& add(const Mat& a, const Mat& b, Mat& res) {
147     assert(a.m == b.m && a.n == b.n, "Sizes don't match, can't add");
148     res.setSize(a.m, a.n);
149     for (int i = 0; i < a.m; ++i)
150         for (int j = 0; j < a.n; ++j)
151             res.at(i, j) = a.at(i, j) + b.at(i, j);
152     return res;
153 }
154
155 Mat& mul(double a, const Mat& b, Mat& res) {
156     res.setSize(b.m, b.n);
157
158     for (int i = 0; i < res.m; ++i)
159         for (int j = 0; j < res.n; ++j)
160             res.at(i, j) = a * b.at(i, j);
161     return res;
162 }
163
164 Mat& neg(const Mat& a, Mat& res) {
165     return mul(-1, a, res);
166 }
167
168 Mat& sub(const Mat& a, const Mat& b, Mat& res) {
169     return add(a, neg(b, res), res);
170 }
171
172 Mat& mul(const Mat& a, const Mat& b, Mat& res) {
173     assert(a.n == b.m, "Sizes don't match, can't multiply");
174     res.setSize(a.m, b.n);
175
176     for (int i = 0; i < res.m; ++i)
177         for (int j = 0; j < res.n; ++j) {
178             res.at(i, j) = 0;
179             for (int k = 0; k < a.n; ++k)
180                 res.at(i, j) += a.at(i, k) * b.at(k, j);
181         }
182     return res;
183 }
184
185 Mat& trans(const Mat& a, Mat& res) {
186     assert(a.data != res.data, "Can't transpose inplace");
187     res.setSize(a.n, a.m);

```

```

187     for (int i = 0; i < res.m; ++i)
188         for (int j = 0; j < res.n; ++j)
189             res.at(i, j) = a.at(j, i);
190     return res;
191 }

```

vector.h

```

1  #pragma once
2  #include "utils.h"
3
4  #include <iostream>
5  #include <utility>
6  #include <cmath>
7
8  struct Vec {
9      double *_begin, *_end;
10
11      constexpr double* begin() { return _begin; }
12      constexpr const double* begin() const { return _begin; }
13
14      constexpr double* end() { return _end; }
15      constexpr const double* end() const { return _end; }
16
17      constexpr Vec() : _begin(nullptr), _end(nullptr) {}
18      explicit Vec(size_t n) : _begin(new double[n]), _end(_begin+n) {}
19      Vec(std::initializer_list<double> list) : Vec(getSize(list)) {
20          auto it = _begin;
21          for (const auto& v : list) *(it++) = v;
22      }
23      Vec(const Vec& rhs) : Vec(rhs.size()) {
24          auto it = _begin;
25          for (const auto& v : rhs) *(it++) = v;
26      }
27      Vec(Vec&& rhs) noexcept
28          : _begin(std::exchange(rhs._begin, nullptr)),
29            _end(std::exchange(rhs._end, nullptr)) {}
30
31      Vec& operator=(const Vec& rhs) {
32          if (size() != rhs.size()) {
33              this->~Vec();
34              new (this) Vec(rhs.size());
35          }
36          auto it = _begin;
37          for (const auto& v : rhs) *(it++) = v;
38          return *this;
39      }
40      Vec& operator=(Vec&& rhs) noexcept {
41          this->~Vec();
42          _begin = std::exchange(rhs._begin, nullptr);

```

```

43     _end = std::exchange(rhs._end, nullptr);
44     return *this;
45 }
46
47 ~Vec() { delete[] _begin; }
48
49 constexpr size_t size() const { return _end - _begin; }
50
51 constexpr double& operator[](size_t i) { return _begin[i]; }
52 constexpr double operator[](size_t i) const { return _begin[i]; }
53
54 void setSize(size_t n) {
55     if (size() == n) return;
56     *this = Vec(n);
57 }
58
59 friend std::ostream& operator<<(std::ostream& s, const Vec& v) {
60     s << "(";
61     double* it = v._begin;
62     for (double* end = v._end - 1; it < end; ++it)
63         s << *it << ", ";
64
65     if (it < v._end) s << *it;
66
67     return s << ")";
68 }
69 static Vec read() {
70     Vec res(readSize("n"));
71     for (auto& v: res) std::cin >> v;
72     return res;
73 }
74 double norm() const;
75 };
76 void assertSizes(const Vec& a, const Vec& b) {
77     assert(a.size() == b.size(), "Sizes don't match");
78 }
79
80 Vec& add(const Vec& a, const Vec& b, Vec& res) {
81     assertSizes(a, b);
82     res.setSize(a.size());
83     auto aIt = a.begin();
84     auto bIt = b.begin();
85     for (auto& v : res) v = *(aIt++) + *(bIt++);
86     return res;
87 }
88
89 Vec& mul(double a, const Vec& b, Vec& res) {
90     res.setSize(b.size());
91     auto it = b.begin();
92     for (auto& v : res) v = a * *(it++);

```



```

93     return res;
94 }
95
96 Vec& neg(const Vec& b, Vec& res) { return mul(-1, b, res); }
97
98 Vec& sub(const Vec& a, const Vec& b, Vec& res) {
99     return add(a, neg(b, res), res);
100 }
101 double dot(const Vec& a, const Vec& b) {
102     double res = 0;
103     assertSizes(a, b);
104     auto bIt = b.begin();
105     for (auto& v : a) res += v * (*(bIt++));
106     return res;
107 }
108 double norm(const Vec& a) {
109     return std::sqrt(dot(a, a));
110 }
111 double Vec::norm() const {
112     return ::norm(*this);
113 }

```

Alocarea dinamică a memoriei.

Tipuri specifice.

Laborator 1

16. Scrieți funcții pentru implemetarea operațiilor specifice pe matrice de numere reale cu m linii și n coloane: suma, diferența și produsul al două matrice, produsul dintre o matrice și un scalar real, transpusa unei matrice, norme matriceale specifice¹, citirea de la tastatură a componentelor unei matrice, afișarea componentelor matricei. Pentru cazul particular al unei matrice patratice de ordin n , să se testeze dacă aceasta satisface criteriul de dominanță pe linii² sau pe coloane³. Se vor folosi tablouri bidimensionale alocate static.

```
1  #include "utils.h"
2
3  #include <iostream>
4  #include <cmath>
5
6  struct Mat {
7      double data[MAX_SZ][MAX_SZ] {};
8      int m, n;
9
10     Mat() : m(0), n(0) {}
11     Mat(int m, int n) : m(m), n(n) {}
12
13     static Mat read() {
14         Mat res(readSize("m"), readSize("n"));
15
16         for (int i = 0; i < res.m; ++i)
17             for (int j = 0; j < res.n; ++j)
18                 std::cin >> res.data[i][j];
19         return res;
20     }
21     void setSize(int m, int n) {
22         this->m = m;
23         this->n = n;
24     }
25 }
```

¹Dacă $A \in \mathcal{M}_{m \times n}(\mathbb{R})$, atunci $\|A\|_1 = \max_{1 \leq j \leq n} \sum_{i=1}^m |a_{ij}|$, $\|A\|_\infty = \max_{1 \leq i \leq m} \sum_{j=1}^n |a_{ij}|$, $\|A\|_F = \sqrt{\sum_{i=1}^m \sum_{j=1}^n a_{ij}^2}$.

² $A \in \mathcal{M}_n(\mathbb{R})$ este strict diagonal dominantă pe linii dacă $|a_{ii}| > \sum_{\substack{j=1 \\ j \neq i}}^n |a_{ij}|$, pentru orice $i = 1, \dots, n$.

³ $A \in \mathcal{M}_n(\mathbb{R})$ este strict diagonal dominantă pe colonane dacă $|a_{jj}| > \sum_{\substack{i=1 \\ i \neq j}}^n |a_{ij}|$, pentru orice $j = 1, \dots, n$.

```

25     double& at(int i, int j) { return data[i][j]; }
26     double at(int i, int j) const { return data[i][j]; }
27
28     void print(const char* name) const {
29         std::cout << name << " = Mat " << m << "x" << n << "{\n";
30         for (int i = 0; i < m; ++i) {
31             for (int j = 0; j < n; ++j)
32                 std::cout << at(i, j) << " ";
33             std::cout << "\n";
34         }
35         std::cout << "}\n";
36     }
37 private:
38     enum class Type { Row, Col };
39     template<Type type>
40     bool isStrictlyDiagonallyDominantImpl() const {
41         assert(m == n, "Matrix must be square");
42         for (int i = 0; i < m; ++i) {
43             double val = std::abs(at(i, i));
44             double sum = -val;
45             for (int j = 0; j < m; ++j)
46                 sum += std::abs(type == Type::Col ? at(j, i) : at(i, j));
47             if (sum >= val) return false;
48         }
49         return true;
50     }
51
52     template<Type type>
53     double normImpl(int sz1, int sz2) const {
54         double max = -1;
55         for (int j = 0; j < sz1; ++j) {
56             double x = 0;
57             for (int i = 0; i < sz2; ++i)
58                 x += std::abs(type == Type::Col ? at(j, i) : at(i, j));
59             if (x > max) max = x;
60         }
61         return max;
62     }
63 public:
64     double norm1() const { return normImpl<Type::Row>(n, m); }
65     double normInf() const { return normImpl<Type::Col>(m, n); }
66     double normF() const {
67         double res = 0;
68         for (int i = 0; i < m; ++i)
69             for (int j = 0; j < n; ++j)
70                 res += at(i, j) * at(i, j);
71
72         return std::sqrt(res);
73     }
74     bool isStrictlyRowDiagonallyDominant() const {

```

```

75         return isStrictlyDiagonallyDominantImpl<Type::Row>();
76     }
77     bool isStrictlyColDiagonallyDominant() const {
78         return isStrictlyDiagonallyDominantImpl<Type::Col>();
79     }
80 };
81
82 Mat& add(const Mat& a, const Mat& b, Mat& res) {
83     assert(a.m == b.m && a.n == b.n, "Sizes don't match, can't add");
84     res.setSize(a.m, a.n);
85     for (int i = 0; i < a.m; ++i)
86         for (int j = 0; j < a.n; ++j)
87             res.at(i, j) = a.at(i, j) + b.at(i, j);
88     return res;
89 }
90 Mat& mul(double a, const Mat& b, Mat& res) {
91     res.setSize(b.m, b.n);
92
93     for (int i = 0; i < res.m; ++i)
94         for (int j = 0; j < res.n; ++j)
95             res.at(i, j) = a * b.at(i, j);
96     return res;
97 }
98 Mat& neg(const Mat& a, Mat& res) { return mul(-1, a, res); }
99 Mat& sub(const Mat& a, const Mat& b, Mat& res) {
100     return add(a, neg(b, res), res);
101 }
102 Mat& mul(const Mat& a, const Mat& b, Mat& res) {
103     assert(a.n == b.m, "Sizes don't match, can't multiply");
104     res.setSize(a.m, b.n);
105
106     for (int i = 0; i < res.m; ++i)
107         for (int j = 0; j < res.n; ++j) {
108             res.at(i, j) = 0;
109             for (int k = 0; k < a.n; ++k)
110                 res.at(i, j) += a.at(i, k) * b.at(k, j);
111         }
112     return res;
113 }
114 Mat& trans(const Mat& a, Mat& res) {
115     assert(a.data != res.data, "Can't calculate the transpose inplace");
116     res.setSize(a.n, a.m);
117
118     for (int i = 0; i < res.m; ++i)
119         for (int j = 0; j < res.n; ++j)
120             res.at(i, j) = a.at(j, i);
121     return res;
122 }

```

Laborator 2

18. Scrieți funcții pentru implementarea operațiilor specifice pe vectori din \mathbb{R}^n : suma, diferența și produsul scalar al doi vectori, produsul dintre un vector și un scalar real, negativarea unui vector, norma euclidiană a unui vector, citirea de la tastatură a celor n componente ale unui vector, afișarea componentelor vectorului sub forma unui n -uplu de elemente. Se vor folosi tablouri unidimensionale alocate dinamic.

```
1  #include "utils.h"
2
3  #include <iostream>
4  #include <utility>
5  #include <cmath>
6
7  struct Vec {
8      double *_begin, *_end;
9
10     constexpr double* begin() { return _begin; }
11     constexpr const double* begin() const { return _begin; }
12
13
14     constexpr double* end() { return _end; }
15     constexpr const double* end() const { return _end; }
16
17     constexpr Vec() : _begin(nullptr), _end(nullptr) {}
18     explicit Vec(size_t n) : _begin(new double[n]), _end(_begin+n) {}
19     Vec(std::initializer_list<double> list) : Vec(getSize(list)) {
20         auto it = _begin;
21         for (const auto& v : list) *(it++) = v;
22     }
23     Vec(const Vec&) = delete;
24     Vec(Vec&& rhs) noexcept
25         : _begin(std::exchange(rhs._begin, nullptr)),
26         _end(std::exchange(rhs._end, nullptr)) {}
27
28     Vec& operator=(const Vec&) = delete;
29     Vec& operator=(Vec&& rhs) noexcept {
30         this->~Vec();
31         _begin = std::exchange(rhs._begin, nullptr);
32         _end = std::exchange(rhs._end, nullptr);
33         return *this;
34     }
35
36     ~Vec() { delete[] _begin; }
37
38     constexpr size_t size() const { return _end - _begin; }
39
40     constexpr double& operator[](size_t i) { return _begin[i]; }
41     constexpr double operator[](size_t i) const { return _begin[i]; }
42
43     void setSize(size_t n) {
```

```

44         if (size() == n) return;
45         *this = Vec(n);
46     }
47
48     friend std::ostream& operator<<(std::ostream& s, const Vec& v) {
49         s << "(";
50         double* it = v._begin;
51         for (double* end = v._end - 1; it < end; ++it)
52             s << *it << ", ";
53
54         if (it < v._end) s << *it;
55
56         return s << ")";
57     }
58     static Vec read() {
59         Vec res(readSize("n"));
60         for (auto& v: res) std::cin >> v;
61         return res;
62     }
63     double norm() const;
64 };
65 void assertSizes(const Vec& a, const Vec& b) {
66     assert(a.size() == b.size(), "Sizes don't match");
67 }
68
69 Vec& add(const Vec& a, const Vec& b, Vec& res) {
70     assertSizes(a, b);
71     res.setSize(a.size());
72     auto aIt = a.begin();
73     auto bIt = b.begin();
74     for (auto& v : res) v = *(aIt++) + *(bIt++);
75     return res;
76 }
77
78 Vec& mul(double a, const Vec& b, Vec& res) {
79     res.setSize(b.size());
80     auto it = b.begin();
81     for (auto& v : res) v = a * (*(it++));
82     return res;
83 }
84
85 Vec& neg(const Vec& b, Vec& res) { return mul(-1, b, res); }
86
87 Vec& sub(const Vec& a, const Vec& b, Vec& res) {
88     return add(a, neg(b, res), res);
89 }
90 double dot(const Vec& a, const Vec& b) {
91     double res = 0;
92     assertSizes(a, b);
93     auto bIt = b.begin();

```

```
94     for (auto& v : a) res += v * (*(bIt++));
95     return res;
96 }
97 double norm(const Vec& a) {
98     return std::sqrt(dot(a, a));
99 }
100 double Vec::norm() const {
101     return ::norm(*this);
102 }
```

Tablouri

Laborator 3

7. Folosind structurile de date `VECTOR` și `MATRICE` definite la curs și funcțiile necesare, rezolvați următorul sistem algebric liniar cu n ecuații și n necunoscute folosind metoda lui Gauß de eliminare.

$$\left\{ \begin{array}{l} 2x_1 - x_2 = 1 \\ -x_1 + 2x_2 - x_3 = 1 \\ -x_2 + 2x_3 - x_4 = 1 \\ \dots\dots\dots \\ -x_{n-2} + 2x_{n-1} - x_n = 1 \\ -x_{n-1} + 2x_n = 1, \quad n \in \mathbb{N}, 2 \leq n \leq 50 \end{array} \right. .$$

```
1  #include "utils.h"
2
3  #include "vector.h"
4  #include "matrix.h"
5
6  #include <iostream>
7  #include <cmath>
8
9  constexpr double eps = 1e-7;
10
11 Vec& mul(const Mat& m, const Vec& v, Vec& res) {
12     assert(v.begin() != res.begin(), "Can't multiply inplace");
13     assert(v.size() == size_t(m.n), "Sizes don't match");
14     res.setSize(m.m);
15
16
17     for (size_t i = 0; i < res.size(); ++i) {
18         res[i] = 0;
19         for (size_t k = 0; k < v.size(); ++k)
20             res[i] += m.at(i, k) * v[k];
21     }
22     return res;
23 }
24
25 // A * X = b
26 struct System {
27     Mat A;
```



```

28 Vec b;
29
30 System(int n, int m) : A(n, m), b(n) {}
31
32 System(std::initializer_list<std::initializer_list<double>> A,
33         std::initializer_list<double> b) : A(A), b(b) {
34     assert(std::size_t(this->A.m) == this->b.size(),
35            "sizes don't match");
36 }
37
38 friend std::ostream& operator<<(std::ostream& s, const System& sys) {
39     s << "System " << sys.A.m << "x" << sys.A.n << ": \n";
40     auto& A = sys.A;
41     for (int i = 0; i < A.m; ++i) {
42         s << "{";
43         for (int j = 0; j < A.n; ++j) {
44             //showpos shows a '+' in front of positive numbers
45             if (std::abs(A.at(i, j)) > eps)
46                 s << std::showpos << A.at(i, j)
47                 << std::noshowpos << "*x" << (j+1) << " ";
48         }
49         s<< "= " << sys.b[i] << "\n";
50     }
51
52     return s;
53 }
54
55 // L_i += f * L_j
56 void addLines(int i, double f, int j) {
57     for (int k = 0; k < A.n; ++k) {
58         A.at(i, k) += f * A.at(j, k);
59     }
60     b[i] += f * b[j];
61 }
62
63 // L_i *= f
64 void multiplyLine(int i, double f) {
65     for (int k = 0; k < A.n; ++k) {
66         A.at(i, k) *= f;
67     }
68     b[i] *= f;
69 }
70
71 Vec solveTriangulated() {
72     for (int i = A.m-1; i > 0; --i) {
73         addLines(i-1, -A.at(i-1, i), i);
74         multiplyLine(i, 1 / A.at(i, i));
75     }
76     return b;
77 }

```

```

78
79 bool checkSolution(const Vec& x) const {
80     Vec r;
81     mul(A, x, r);
82     sub(b, r, r);
83     for (auto& v : r) {
84         if (std::abs(v) > eps) return false;
85     }
86     return true;
87 }
88
89 static Vec solveCustom(int n) {
90     System s(n, n);
91     for (auto& v : s.A) v = 0;
92     s.A.at(0,0) = 2;
93     s.A.at(0,1) = -1;
94     s.b[0] = 1;
95     for (int i = 1; i < n - 1; ++i) {
96         s.b[i] = 1;
97
98         s.A.at(i,i-1) = -1;
99         s.A.at(i,i) = 2;
100        s.A.at(i,i+1) = -1;
101    }
102    s.b[n-1] = 1;
103    s.A.at(n-1, n-2) = -1;
104    s.A.at(n-1, n-1) = 2;
105    s.customTriangulate();
106    return s.solveTriangulated();
107 }
108 void customTriangulate() {
109     multiplyLine(0, 1 / A.at(0, 0));
110     for (int i = 1; i < A.m; ++i) {
111         addLines(i, 1, i-1);
112         multiplyLine(i, 1 / A.at(i, i));
113     }
114 }
115 };
116
117 int main() {
118     try {
119         int n = readSize("n", 2, 51);
120         std::cout << "x = " << System::solveCustom(n) << "\n";
121     } catch (std::exception& e) {
122         std::cerr << "Error" << e.what() << "\n";
123         return 1;
124     }
125     return 0;
126 }

```