IF2211 Strategi Algoritma

PROGRAM PENYELSAI PERMAINAN KARTU 24 DENGAN ALGORITMA BRUTE FORCE

Laporan Tugas Kecil

Disusun oleh

Rinaldy Adin 13521134

PROGRAM STUDI TEKNIK INFORMATIKA

SEKOLAH TEKNIK ELEKTRO DAN INFORMATIKA

INSTITUT TEKNOLOGI BANDUNG

DAFTAR ISI

BAB I

Pendahuluan dan Algoritma Penyelesaian

1. Pendahuluan

Permainan kartu 24 adalah permainan kartu aritmatika dengan tujuan mencari cara untuk mengubah 4 buah angka random sehingga mendapatkan hasil akhir sejumlah 24. Permainan Kartu 24 biasa dimainkan dengan menggunakan kartu remi. Kartu remi terdiri dari 52 kartu yang terbagi menjadi empat suit (sekop, hati, keriting, dan wajik) yang masing-masing terdiri dari 13 kartu (As, 2, 3, 4, 5, 6, 7, 8, 9, 10, Jack, Queen, dan King). Yang perlu diperhatikan hanyalah nilai kartu yang didapat (As, 2, 3, 4, 5, 6, 7, 8, 9, 10, Jack, Queen, dan King). As bernilai 1, Jack bernilai 11, Queen bernilai 12, King bernilai 13, sedangkan kartu bilangan memiliki nilai dari bilangan itu sendiri. Pada awal permainan moderator atau salah satu pemain mengambil 4 kartu dari dek yang sudah dikocok secara random. Permainan berakhir ketika pemain berhasil menemukan solusi untuk membuat kumpulan nilainya menjadi 24. Pengubahan nilai tersebut dapat dilakukan menggunakan operasi dasar matematika penjumlahan (+), pengurangan (-), perkalian (×), pembagian (/) dan tanda kurung (()). Tiap kartu harus digunakan tepat sekali dan urutan penggunaannya bebas.

2. Algoritma Penyelesaian

Program yang telah dibuat bertujuan menyelesaikan permasalahan ini dengan menampilkan semua kemungkinan persamaan/solusi dari pilihan kartu yang dapat dihasilkan secara acak oleh program atau didapatkan dari masukan pengguna. Untuk memperoleh semua kemungkinan solusi, program menggunakan algoritma dengan strategi *brute force*, yaitu algoritma yang mencoba semua kemungkinan yang ada hingga mendapatkan hasil yang diinginkan. Dalam kasus ini, semua kemungkinan yang ada merupakan semua kemungkinan/permutasi persamaan yang terdiri dari empat angka dan tiga operator, sedangkan hasil yang diinginkan adalah semua persamaan yang menghasilkan nilai 24. Oleh karena itu, algoritma penyelesaian dapat dibagi menjadi algoritma penghasil permutasi persamaan dan algoritma menghitung nilai dari suatu persamaan.

Dalam implementasi program ini, permasalahan memperoleh semua permutasi yang ada dipecahkan dengan mencari permutasi urutan angka, serta permutasi susunan angka dan operator yang direpresentasikan dalam bentuk prefix, karena urutan operasi dalam representasi prefix sudah inheren dan tidak perlu ditambahkan kurung seperti representasi infix. Oleh karena itu, algoritma penyelesaian program ini dapat dijabarkan sebagai berikut,

1. Pencarian permutasi persamaan, yang dapat dibagi menjadi
    a. Pencarian permutasi urutan angka, yang terdiri dari langkah-langkah
        i. Menerima masukan 4 angka yang dapat digunakan.
        ii. Melakukan nested looping dengan kedalaman 4 yang akan mencoba semua permutasi angka, program akan mencatat angka sebelumnya

yang sudah digunakan agar permutasi berupa acakan dari angka masukan.

iii. Permutasi yang dihasilkan akan dimasukkan ke dalam array hasil, tetapi sebelum dimasukkan ke dalam array, diperiksa terlebih dahulu apakah permutasi tersebut sudah tercatat dalam array atau belum, jika belum permutasi dimasukkan ke dalam array hasil.

b. Pencarian permutasi susunan angka dan operator, yang terdiri dari langkah-langkah:
   i. Memanggil fungsi rekursi yang akan menghasilkan persamaan prefix yang diawali dengan operator *op*. Dengan *op* berupa operator tambah (+), kurang (-), kali (×), dan bagi (/).
   ii. Dalam fungsi tersebut, akan terjadi rekursi yang akan menghasilkan kemungkinan susunan persamaan yang direpresentasikan secara prefix dengan variabel w, x, y, dan z sebagai placeholder/pengganti untuk angka. Contoh, "$+ - w\ x \times y\ z$".
   iii. Fungsi rekursi menerima masukan elemen yang ingin dimasukkan ke dalam susunan, variabel yang belum terpakai, urutan/index saat ini, susunan yang sedang dihasilkan, jumlah operator, dan jumlah variabel/angka.
   iv. Aturan pemasukkan elemen berdasarkan pengamatan bahwa dalam persamaan prefix, jumlah operator dari awal hingga suatu elemen, kecuali elemen terakhir, selalu lebih banyak atau sama dengan jumlah angka. Oleh karena itu, pemasukkan elemen mengikuti aturan berikut,
      1. Apabila jumlah operator kurang dari 3, masukkan operator ke dalam index berikutnya.
      2. Apabila jumlah angka kurang dari jumlah operator, masukkan angka ke dalam index berikutya.
      3. Apabila elemen berikutnya merupakan elemen terakhir, masukkan angka ke dalam index berikutya.
   v. Setiap permutasi susunan operator yang dihasilkan dimasukkan ke dalam array hasil susunan operator.

2. Menghitung nilai dari suatu persamaan yang dihasilkan, yang terdiri dari langkah-langkah
   a. Hasilkan permutasi persamaan dengan memasukkan permutasi angka ke dalam permutasi susunan operator.
   b. Evaluasi nilai dari persamaan tersebut dengan memanfaatkan struktur data stack. Program melakukan itertasi elemen persamaan dari akhir ke awal
      i. Jika elemen yang ditemukan merupakan angka, masukkan angka tersebut ke dalam stack.
      ii. Jika elemen yang ditemukan merupakan operator, jalan kan operasi tersebut terhadap 2 elemen teratas pada stack, hilangkan 2 elemen tersebut dari stack, dan masukkan hasil operasi ke dalam stack.

Misal ditemukan operator bagi (/) dan elemen teratas pada stack adalah x dan elemen kedua teratas adalah y, maka x dan y akan dihilangkan dari stack, lalu nilai dari y / x akan dimasukkan ke dalam stack.

c. Jika permutasi persamaan tersebut menghasilkan nilai 24, ubahlah terlebih dahulu persamaan tersebut ke dalam bentuk infix, untuk melakukan hal tersebut program menggunakan struktur data stack yang menyimpan data string dan akan melakukan itertasi elemen persamaan dari akhir ke awal
    i. Jika elemen yang ditemukan merupakan angka, *casting* angka tersebut menjadi string dan masukkan ke dalam stack.
    ii. Jika elemen yang ditemukan merupakan operator, hilangkan dan simpan nilai 2 elemen teratas pada stack, lakukan konkatenasi sehingga menghasilkan string persamaan infix antara dua elemen tersebut. Jika iterasi belum sampai elemen pertama tambahkan tanda kurung pada persamaan tersebut.
d. Masukkan string persamaan infix ke dalam list yang menyimpan persamaan-persamaan yang menghasilkan nilai 24.

BAB II

Source Code Program

Source code program disimpan dalam repository github https://github.com/Rinaldy-Adin/Tucil1_13521134. Source code serta file header adalah sebagai berikut,

main.cpp

```cpp
#include <chrono>
#include <iomanip>
#include <iostream>
#include <vector>

#include "cliui.h"
#include "evaluate_exp.h"
#include "generate_exp.h"
#include "generate_perms.h"

using std::cout;
using std::endl;
using std::vector;

int main() {
    // Splash screen on start
    splashScreen();
    cout << endl << endl;

    // Initialize loop variables
    bool programRunning = true;
    vector<string> menuChoices = {"User input", "Random", "Exit program"};

    while (programRunning) {
        // Input method menu
        header("Menu");
        cout << endl;
        int choice = menuPrompt("Choose card input method:", menuChoices);

        if (choice == 1 || choice == 2) {  // User chooses to continue
            // Initialize permutation variables
            int cardNums[4];
            int permutations[25][4];
            char possibleExpressions[400][7];

            int nPermutations;
            int nExpressions;

            for (int i = 0; i < 25; i++) {
                for (int j = 0; j < 4; j++) {
```

```
                permutations[i][j] = 0;
            }
        }

        for (int i = 0; i < 400; i++) {
            for (int j = 0; j < 7; j++) {
                possibleExpressions[i][j] = 0;
            }
        }

        if (choice == 1) {  // Cards chosen by user
            cout << "\nEnter 4 card values separated by spaces (A, 2, 3,
                     4, 5, 6, 7, 8, 9, 10, "
                    "J, Q, K):\n";
            readInput(cardNums);
            cout << endl;
        } else {  // Cards randomized
            for (int i = 0; i < 4; i++) {
                cardNums[i] = rand() % 13 + 1;
            }
            cout << endl << endl;
        }

        if (cardNums[0] != -1) {  // Input valid
            // Display cards chosen by user/random
            header("Cards");
            printCards(cardNums);
            waitForEnter();
            cout << endl << endl;

            // Start algorithm clock
            auto begin = std::chrono::high_resolution_clock::now();

            // Generate & evaluate expressions equal to 24
            generatePermutations(cardNums, permutations,
                                 &nPermutations);
            generateExpressions(possibleExpressions, &nExpressions);
            vector<string> expressions =
               evaluateExpressions(permutations,
               nPermutations, possibleExpressions, nExpressions);

            // End algorithm clock and calculate elapsed time
            auto end = std::chrono::high_resolution_clock::now();
            auto elapsed =
    std::chrono::duration_cast<std::chrono::nanoseconds>(end - begin);

            // Display solutions
            header("Solutions");
```

```
                cout << expressions.size() << " solutions found:" << endl <<
                        endl;
                for (string expression : expressions) {
                    cout << expression << endl;
                }

                // Display elapsed time
                cout << "\nSolution algorithm elapsed for " << std::fixed <<
                        std::setprecision(3)
                     << elapsed.count() * 1e-6 << " miliseconds\n";

                // Ask user to save to file
                askToSave(cardNums, expressions, elapsed.count());

            } else {  // Input Invalid
                // Return to menu
                cout << "\nInput invalid\n";
                waitForEnter();
            }
            cout << endl << endl;

        } else {  // User chooses to exit program
            programRunning = false;
        }
    }

    return 0;
}
```

cliui.h

```
#include <string>
#include <vector>

using std::string;
using std::vector;

// Read cards based off user input
void readInput(int cardNums[]);

// Display splash screen
void splashScreen();

// Display header with centered title
void header(string str);

// Display menu and recieve valid input
int menuPrompt(string prompt, vector<string> choices);
```

```
// Display cards
void printCards(int cardNums[]);

// Ask for user to press enter to continue program
void waitForEnter();

// Ask for user to save solution results into file
void askToSave(int cardNums[], vector<string> solutions, int nanoseconds);
```

cliui.cpp

```
#include "cliui.h"

#include <cstdio>
#include <fstream>
#include <iomanip>
#include <iostream>
#include <limits>
#include <string>

using std::cin;
using std::cout;
using std::endl;
using std::getline;
using std::ifstream;
using std::ofstream;
using std::string;

// Read cards based off user input
void readInput(int cardNums[]) {
    // Initialize variables
    int i = 0;
    int idx = 0;
    bool spaceSeparated = true;

    // Read line from input as string
    string str;
    getline(cin >> std::ws, str);

    char c;
    // Iterate over string to ensure valid input
    while (idx < str.length()) {
        c = str[idx];

        if (c > '1' && c <= '9' && spaceSeparated) {  // Card values under
10
            cardNums[i % 4] = c - '0';
            spaceSeparated = false;
        } else if (c == '1' && spaceSeparated) {  // Handle 10
```

```
            idx++;
            c = str[idx];
            if (c == '0') {
                cardNums[i % 4] = 10;
                spaceSeparated = false;
            } else {
                cardNums[0] = cardNums[1] = cardNums[2] = cardNums[3] = -1;
                return;
            }
        } else {  // Handle A J Q K and space character
            if ((c == 'A' || c == 'a') && spaceSeparated) {
                cardNums[i % 4] = 1;
                spaceSeparated = false;
            } else if ((c == 'J' || c == 'j') && spaceSeparated) {
                cardNums[i % 4] = 11;
                spaceSeparated = false;
            } else if ((c == 'Q' || c == 'q') && spaceSeparated) {
                cardNums[i % 4] = 12;
                spaceSeparated = false;
            } else if ((c == 'K' || c == 'k') && spaceSeparated) {
                cardNums[i % 4] = 13;
                spaceSeparated = false;
            } else if (c == ' ') {
                spaceSeparated = true;
                i--;
            } else {
                cardNums[0] = cardNums[1] = cardNums[2] = cardNums[3] = -1;
            }
        }
        i++;
        idx++;
    }

    // Return invalid input if the number of cards given is not 4
    if (i != 4 || idx < str.length()) {
        cardNums[0] = cardNums[1] = cardNums[2] = cardNums[3] = -1;
        return;
    }
}

// Display splash screen
void splashScreen() {
    cout << R"(
.___  ___.      ___       __  ___  _______     __  .___________.    ___     _
 _
|   \/   |     /   \     |  |/  / |   ____|   |  | |           |   |__ \  |
|| |
```

```
|  \  /  |    /  ^  \    |  '  /  |  |__      |  |`---|  |----`      ) | |
|| |_
|  |\/|  |   /  /_\  \   |    <   |   __|     |  |     |  |          /
/  |__   _|
|  |  |  |  /  _____  \  |  .  \  |  |___     |  |     |  |         /
/_     | |
|__|  |__| /__/     \__\ |__|\__\
|_______|   |__|     |__|        |____|    |_|
    )" << endl;
}

// Display header with centered title
void header(string str) {
    for (int i = 0; i < 20; i++) {
        cout << "=";
    }
    cout << "\n";

    cout << "==";
    for (int i = 2; i < 10 - (str.length() / 2); i++) {
        cout << " ";
    }
    cout << str;

    for (int i = 10 - (str.length() / 2) + str.length(); i < 18; i++) {
        cout << " ";
    }
    cout << "==\n";
    for (int i = 0; i < 20; i++) {
        cout << "=";
    }
    cout << "\n";
}

// Display menu and recieve valid input
int menuPrompt(string prompt, vector<string> choices) {
    while (true) {
        cout << prompt << endl;

        for (int i = 1; i <= choices.size(); i++) {
            cout << i << ". ";
            cout << choices[i - 1] << endl;
        }

        cout << endl;
        cout << "Enter command (";

        for (int i = 1; i <= choices.size(); i++) {
```

```
            cout << i;
            if (i != choices.size())
                cout << "/";
        }
        cout << "):" << endl;

        int choice;
        cin >> choice;

        if (choice < 1 || choice > choices.size()) {
            cout << endl << "Invalid input" << endl << endl;
        } else {
            cin.ignore(std::numeric_limits<std::streamsize>::max(), '\n');
            return choice;
        }
    }
}

// Display cards
void printCards(int cardNums[]) {
    cout << "----- ----- ----- -----" << endl;
    cout << "|   | |   | |   | |   |" << endl;

    for (int i = 0; i < 4; i++) {
        cout << "|";
        if (cardNums[i] == 11) {
            cout << " J";
        } else if (cardNums[i] == 1) {
            cout << " A";
        } else if (cardNums[i] == 12) {
            cout << " Q";
        } else if (cardNums[i] == 13) {
            cout << " K";
        } else if (cardNums[i] == 10) {
            cout << "10";
        } else {
            cout << " " << cardNums[i];
        }
        cout << " | ";
    }
    cout << endl;

    cout << "|   | |   | |   | |   |" << endl;
    cout << "----- ----- ----- -----" << endl;
}

// Ask for user to press enter to continue program
void waitForEnter() {
```

```
    cout << "Continue? (press enter)";
    cin.ignore(INT_MAX, '\n');
}

// Ask for user to save solution results into file
void askToSave(int cardNums[], vector<string> solutions, int nanoseconds) {
    string str;
    do {  // Validate input
        cout << "\nWould you like to save your results to a file?(y/n): ";
        getline(cin >> std::ws, str);
    } while (str[0] != 'y' && str[0] != 'Y' && str[0] != 'n' && str[0] !=
'N');

    // Write to file if user inputs Y
    if (str[0] == 'y' && str[0] != 'Y') {
        do {
            cout << "Enter the path to your file: ";
            getline(cin >> std::ws, str);
            ofstream outfile;

            try {
                outfile.open(str);
                outfile << "Cards: ";

                for (int i = 0; i < 4; i++) {
                    switch (cardNums[i]) {
                        case 1:
                            outfile << "A ";
                            break;
                        case 11:
                            outfile << "J ";
                            break;
                        case 12:
                            outfile << "Q ";
                            break;
                        case 13:
                            outfile << "K ";
                            break;
                        default:
                            outfile << cardNums[i] << " ";
                            break;
                    }
                }
                outfile << endl << endl;

                outfile << solutions.size() << " solutions found" << endl <<
endl;
                for (string solution : solutions) {
```

```
                    outfile << solution << endl;
                }

                outfile << "\nSolution algorithm elapsed for " << std::fixed
<< std::setprecision(3)
                        << nanoseconds * 1e-6 << " miliseconds" << endl;

                outfile.close();
                break;
            } catch (const ofstream::failure& e) {
                outfile.close();
                cout << "Filepath not valid" << endl;
            }
        } while (true);

        cout << "\nFile successfully written!" << endl;
    }
}
```

evaluate_exp.h

```
#include <string>
#include <vector>

using std::string;
using std::vector;

// Evaluate expressions based off generated card permutations and possible
prefix expressions
vector<string> evaluateExpressions(int permutations[][4], int nPerms, char
possibleExpressions[][7],
                                   int nExps);
```

evaluate_exp.cpp

```
#include "evaluate_exp.h"

#include <stack>
#include <string>
#include <vector>

using std::stack;
using std::string;
using std::to_string;
using std::vector;

// Return value of prefix equation
double evaluatePrefix(char mappedExp[]) {
    stack<double> Stack;
```

```
    // Iterate from back to front
    for (int i = 6; i >= 0; i--) {
        if (mappedExp[i] > '0' &&
            mappedExp[i] <= '9') {  // Push numericals into stack & cast to
double
            Stack.push((double)mappedExp[i] - '0');
        } else if (mappedExp[i] >= 'a' &&
                   mappedExp[i] < 'w') {  // Push numericals into stack &
cast to double
            Stack.push((double)mappedExp[i] - 'a' + 10);
        } else {  // Pop & calculate top two numericals and push result into
stack when operator
                  // found in
            double y = Stack.top();
            Stack.pop();
            double x = Stack.top();
            Stack.pop();

            if (mappedExp[i] == '*') {
                Stack.push(x * y);
            } else if (mappedExp[i] == '/') {
                Stack.push(x / y);
            } else if (mappedExp[i] == '+') {
                Stack.push(x + y);
            } else if (mappedExp[i] == '-') {
                Stack.push(x - y);
            }
        }
    }

    return Stack.top();
}

// Convert prefix array of chars into infix string
string convertToInfix(char prefix[]) {
    stack<string> Stack;

    // Iterate from back to front
    for (int i = 6; i >= 0; i--) {
        if (prefix[i] > '0' && prefix[i] <= '9') {  // Push numericals into
stack & cast to string
            string s(1, prefix[i]);
            Stack.push(s);
        } else if (prefix[i] >= 'a' &&
                   prefix[i] < 'w') {  // Push numericals into stack & cast
to string
            Stack.push(to_string(prefix[i] - 'a' + 10));
```

```
        } else {  // Pop top two numericals and push infix expressions into
stack when operator
                  // found in prefix
            string y = Stack.top();
            Stack.pop();
            string x = Stack.top();
            Stack.pop();

            string z;
            if (i != 0) {
                z = "(" + x + " " + prefix[i] + " " + y + ")";
            } else {
                z = x + " " + prefix[i] + " " + y;
            }

            Stack.push(z);
        }
    }

    return Stack.top();
}

// Evaluate expressions based off generated card permutations and possible
prefix expressions
vector<string> evaluateExpressions(int permutations[][4], int nPerms, char
possibleExpressions[][7],
                                   int nExps) {
    vector<string> infixes;

    // Iterate over permutations of cards and expressions
    for (int currPerm = 0; currPerm < nPerms; currPerm++) {
        for (int currExp = 0; currExp < nExps; currExp++) {
            char mappedExp[7];

            // Cast permutations of type int to characters representing
hexadecimals
            for (int k = 0; k < 7; k++) {
                char mappedOp = possibleExpressions[currExp][k];
                if (mappedOp >= 'w' && mappedOp <= 'z') {
                    mappedExp[k] = permutations[currPerm][mappedOp - 'w'] +
'0';

                    if (mappedExp[k] > '9') {
                        mappedExp[k] = mappedExp[k] - '9' - 1 + 'a';
                    }
                } else {
                    mappedExp[k] = mappedOp;
                }
            }
```

```
            // Evaluate permutation and append to solutions list if equals
24
            if (evaluatePrefix(mappedExp) == 24) {
                infixes.push_back(convertToInfix(mappedExp));
            }
        }
    }

    return infixes;
}
```

generate_exp.h

```
// Generate possible expressions
// with w, x, y, and z as placeholders for numerical values
void generateExpressions(char possibleExpressions[][7], int *nExpressions);
```

Generate_exp.cpp

```
#include "generate_exp.h"

// Generate prefix with 4 numbers and 3 operators, following the rule that
up until the last
// operand, there are more or equal operators than operands
void generatePrefix(char possibleExpressions[][7], char toInsert, char
unusedVar, char generated[],
                    int generatedIdx, int nOperators, int nNums, int
*nExpressions) {
    generated[generatedIdx] = toInsert;

    // Prefix expression is complete
    if (generatedIdx == 6) {
        // Insert into array
        for (int i = 0; i < 7; i++) {
            possibleExpressions[*nExpressions][i] = generated[i];
        }
        *nExpressions += 1;
    }

    if (nOperators < 3) {  // Generate operators
        generatePrefix(possibleExpressions, '*', unusedVar, generated,
                       generatedIdx + 1,
                      nOperators + 1, nNums, nExpressions);
        generatePrefix(possibleExpressions, '/', unusedVar, generated,
                       generatedIdx + 1,
                      nOperators + 1, nNums, nExpressions);
```

```
        generatePrefix(possibleExpressions, '+', unusedVar, generated,
                       generatedIdx + 1,
                       nOperators + 1, nNums, nExpressions);
        generatePrefix(possibleExpressions, '-', unusedVar, generated,
                       generatedIdx + 1,
                       nOperators + 1, nNums, nExpressions);
    }

    // Generate numbers when possible or when last operand
    if (nNums < nOperators || generatedIdx == 5)
        generatePrefix(possibleExpressions, unusedVar, unusedVar + 1,
                       generated, generatedIdx + 1,
                       nOperators, nNums + 1, nExpressions);
}

// Generate possible expressions with w, x, y, and z as placeholders for
numerical values
void generateExpressions(char possibleExpressions[][7], int *nExpressions) {
    char generated[7];
    *nExpressions = 0;

    generatePrefix(possibleExpressions, '*', 'w', generated, 0, 1, 0,
                   nExpressions);
    generatePrefix(possibleExpressions, '/', 'w', generated, 0, 1, 0,
                   nExpressions);
    generatePrefix(possibleExpressions, '+', 'w', generated, 0, 1, 0,
                   nExpressions);
    generatePrefix(possibleExpressions, '-', 'w', generated, 0, 1, 0,
                   nExpressions);
}
```

generate_perms.h

```
// Generate permutations of the recieved cards
void generatePermutations(int cardNums[], int permutations[][4], int
*nPermutations);
```

generate_perms.cpp

```
#include "generate_perms.h"

// Check if permutation is duplicate
bool isInPermutations(int permutation[], int permutations[][4], int
last_empty_idx) {
    int i = 0;
    // Iterate over generated permutations
    while (i < last_empty_idx) {
        if (permutation[0] == permutations[i][0] && permutation[1] ==
permutations[i][1] &&
```

```
            permutation[2] == permutations[i][2] && permutation[3] ==
permutations[i][3]) {
            return true;
        }
        i++;
    }

    return false;
}

// Generate permutations of the recieved cards
void generatePermutations(int cardNums[], int permutations[][4], int
*nPermutations) {
    *nPermutations = 0;

    for (int a = 0; a < 4; a++) {
        // Initialize generated to store generated permutation &
        // Initialize used to keep track of used cards
        int generated[4];
        bool used[4] = {0, 0, 0, 0};

        generated[0] = cardNums[a];
        used[a] = 1;

        for (int b = 0; b < 4; b++) {
            if (used[b])
                continue;

            generated[1] = cardNums[b];
            used[b] = 1;

            for (int c = 0; c < 4; c++) {
                if (used[c])
                    continue;

                generated[2] = cardNums[c];
                used[c] = 1;

                for (int d = 0; d < 4; d++) {
                    if (used[d])
                        continue;

                    generated[3] = cardNums[d];
                    used[d] = 1;

                    // Check if permutation is duplicate
                    if (!isInPermutations(generated, permutations,
                        *nPermutations)) {
```

```
                        // Insert to array if permutation is not duplicate
                        for (int i = 0; i < 4; i++) {
                            permutations[*nPermutations][i] = generated[i];
                        }

                        *nPermutations += 1;
                    }

                    used[d] = 0;
                }

                used[c] = 0;
            }

            used[b] = 0;
        }
    }
}
```

BAB III

Hasil Pengujian

Test Case #1

```
.---  ---.      ___       __  ___  _______     __  .___________.    ___    _  _
|   \/   |     /   \     |  |/  / |   ____|   |  | |           |   |__ \  | || |
|  \  /  |    /  ^  \    |  '  /  |  |__      |  | `---|  |----`      ) | | || |_
|  |\/|  |   /  /_\  \   |    <   |   __|     |  |     |  |          / /  |__   _|
|  |  |  |  /  _____  \  |  .  \  |  |____    |  |     |  |         / /_     | |
|__|  |__| /__/     \__\ |__|\__\ |_______|   |__|     |__|        |____|    |_|



====================
==      Menu      ==
====================

Choose card input method:
1. User input
2. Random
3. Exit program

Enter command (1/2/3):
1

Enter 4 card values separated by spaces (A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K):
6 6 6 6

====================
==      Cards     ==
====================
_____ _____ _____ _____
|   | |   | |   | |   |
| 6 | | 6 | | 6 | | 6 |
|   | |   | |   | |   |
_____ _____ _____ _____
Continue? (press enter)


====================
==    Solutions   ==
====================
7 solutions found:

6 + (6 + (6 + 6))
6 + ((6 + 6) + 6)
(6 + 6) + (6 + 6)
(6 + (6 + 6)) + 6
((6 + 6) + 6) + 6
(6 * 6) - (6 + 6)
((6 * 6) - 6) - 6

Solution algorithm elapsed for 0.327 miliseconds
```

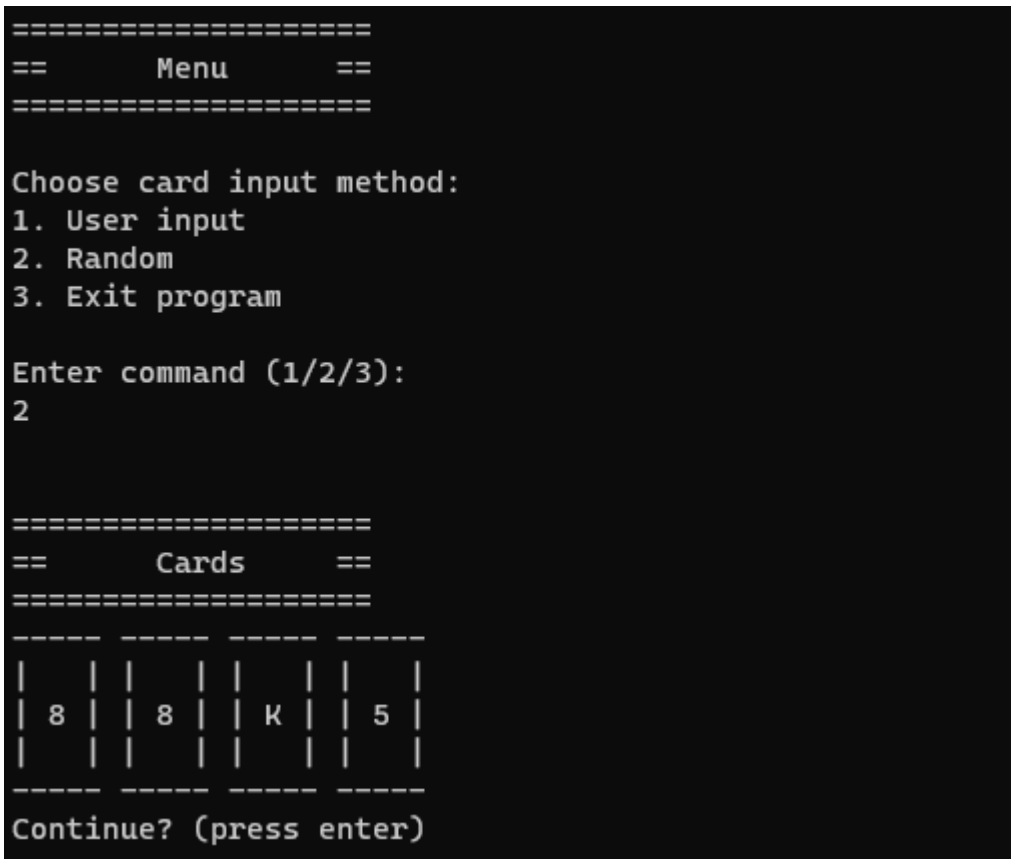
Test Case #2

```
====================
==      Menu      ==
====================

Choose card input method:
1. User input
2. Random
3. Exit program

Enter command (1/2/3):
2


====================
==      Cards     ==
====================
_____ _____ _____ _____
|   | |   | |   | |   |
| 3 | | 8 | | 4 | | 7 |
|   | |   | |   | |   |
_____ _____ _____ _____
Continue? (press enter)


====================
==    Solutions   ==
====================
6 solutions found:

8 + (4 * (7 - 3))
(4 * (7 - 3)) + 8
((7 - 3) * 4) + 8
8 + ((7 - 3) * 4)
8 - ((3 - 7) * 4)
8 - (4 * (3 - 7))

Solution algorithm elapsed for 6.697 miliseconds
```

Test Case #3

```
====================
==      Menu      ==
====================

Choose card input method:
1. User input
2. Random
3. Exit program

Enter command (1/2/3):
1

Enter 4 card values separated by spaces (A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K):
A A  A A

====================
==      Cards     ==
====================
_____ _____ _____ _____
|   | |   | |   | |   |
| A | | A | | A | | A |
|   | |   | |   | |   |
_____ _____ _____ _____
Continue? (press enter)


====================
==    Solutions   ==
====================
0 solutions found:


Solution algorithm elapsed for 0.291 miliseconds
```

Test Case #4


==========
== Menu ==
==========
Choose card input method:
1. User input
2. Random
3. Exit program
Enter command (1/2/3):
2
==========
== Cards ==
==========
8 8 K 5
Continue? (press enter)

```
====================
==    Solutions   ==
====================
45 solutions found:

(13 - 5) + (8 + 8)
((13 - 5) + 8) + 8
(13 - (5 - 8)) + 8
13 - (5 - (8 + 8))
13 - ((5 - 8) - 8)
(8 - 5) + (13 + 8)
((8 - 5) + 13) + 8
(8 - (5 - 13)) + 8
8 - (5 - (13 + 8))
8 - ((5 - 13) - 8)
13 + ((8 - 5) + 8)
13 + (8 - (5 - 8))
(13 + (8 - 5)) + 8
((13 + 8) - 5) + 8
(13 + 8) - (5 - 8)
8 + ((13 - 5) + 8)
8 + (13 - (5 - 8))
(8 + (13 - 5)) + 8
((8 + 13) - 5) + 8
(8 + 13) - (5 - 8)
(8 - 5) + (8 + 13)
((8 - 5) + 8) + 13
(8 - (5 - 8)) + 13
8 - (5 - (8 + 13))
8 - ((5 - 8) - 13)
8 + ((8 - 5) + 13)
8 + (8 - (5 - 13))
(8 + (8 - 5)) + 13
((8 + 8) - 5) + 13
(8 + 8) - (5 - 13)
13 + (8 + (8 - 5))
13 + ((8 + 8) - 5)
(13 + 8) + (8 - 5)
(13 + (8 + 8)) - 5
((13 + 8) + 8) - 5
8 + (13 + (8 - 5))
8 + ((13 + 8) - 5)
(8 + 13) + (8 - 5)
(8 + (13 + 8)) - 5
((8 + 13) + 8) - 5
8 + (8 + (13 - 5))
8 + ((8 + 13) - 5)
(8 + 8) + (13 - 5)
(8 + (8 + 13)) - 5
((8 + 8) + 13) - 5
```

```
Solution algorithm elapsed for 5.196 miliseconds
```

Test Case #5

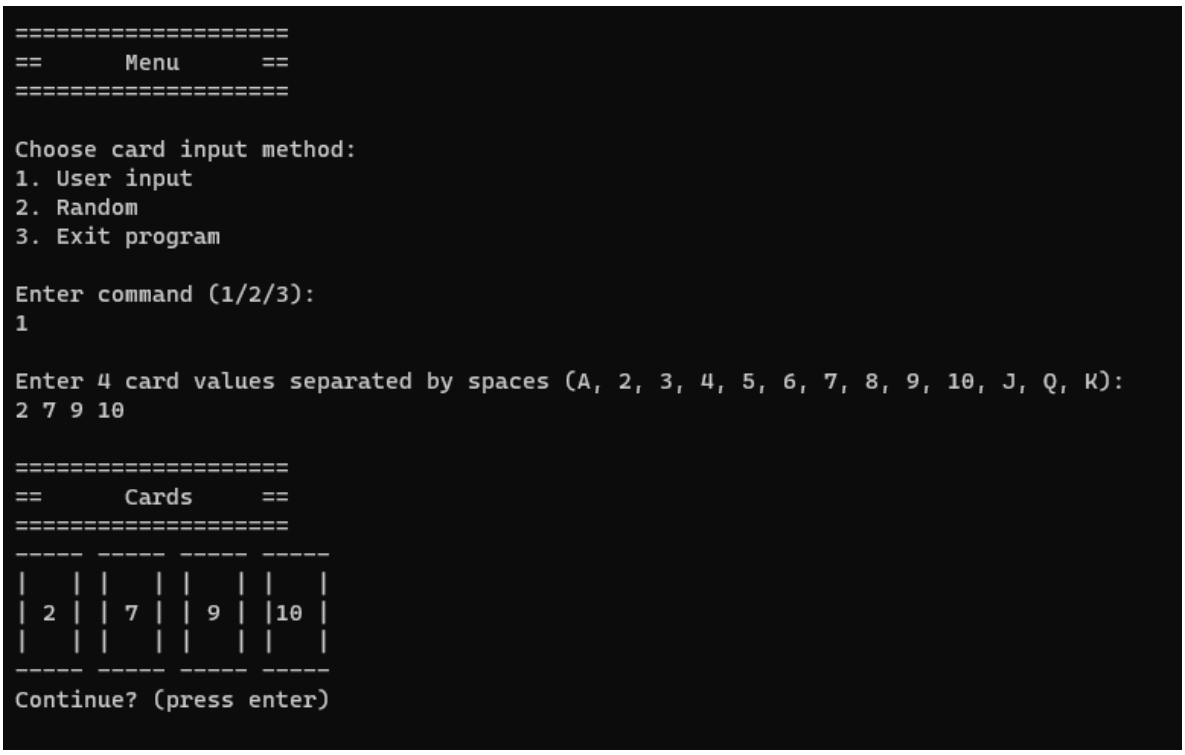
```
====================
==      Menu      ==
====================

Choose card input method:
1. User input
2. Random
3. Exit program

Enter command (1/2/3):
1

Enter 4 card values separated by spaces (A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K):
K Q J 10

====================
==      Cards     ==
====================
_____ _____ _____ _____
|   | |   | |   | |   |
| K | | Q | | J | |10 |
|   | |   | |   | |   |
_____ _____ _____ _____
Continue? (press enter)
```

```
====================
==    Solutions   ==
====================
90 solutions found:

(10 - 11) + (12 + 13)
((10 - 11) + 12) + 13
(10 - (11 - 12)) + 13
10 - (11 - (12 + 13))
10 - ((11 - 12) - 13)
10 + ((12 - 11) + 13)
10 + (12 - (11 - 13))
(10 + (12 - 11)) + 13
((10 + 12) - 11) + 13
(10 + 12) - (11 - 13)
12 + ((10 - 11) + 13)
12 + (10 - (11 - 13))
(12 + (10 - 11)) + 13
((12 + 10) - 11) + 13
(12 + 10) - (11 - 13)
(12 - 11) + (10 + 13)
((12 - 11) + 10) + 13
(12 - (11 - 10)) + 13
12 - (11 - (10 + 13))
12 - ((11 - 10) - 13)
(10 - 11) + (13 + 12)
((10 - 11) + 13) + 12
(10 - (11 - 13)) + 12
10 - (11 - (13 + 12))
10 - ((11 - 13) - 12)
10 + ((13 - 11) + 12)
10 + (13 - (11 - 12))
(10 + (13 - 11)) + 12
((10 + 13) - 11) + 12
(10 + 13) - (11 - 12)
13 + ((10 - 11) + 12)
13 + (10 - (11 - 12))
(13 + (10 - 11)) + 12
((13 + 10) - 11) + 12
(13 + 10) - (11 - 12)
(13 - 11) + (10 + 12)
((13 - 11) + 10) + 12
(13 - (11 - 10)) + 12
13 - (11 - (10 + 12))
13 - ((11 - 10) - 12)
10 + (12 + (13 - 11))
10 + ((12 + 13) - 11)
(10 + 12) + (13 - 11)
```

```
(10 + (12 + 13)) - 11
((10 + 12) + 13) - 11
12 + (10 + (13 - 11))
12 + ((10 + 13) - 11)
(12 + 10) + (13 - 11)
(12 + (10 + 13)) - 11
((12 + 10) + 13) - 11
10 + (13 + (12 - 11))
10 + ((13 + 12) - 11)
(10 + 13) + (12 - 11)
(10 + (13 + 12)) - 11
((10 + 13) + 12) - 11
13 + (10 + (12 - 11))
13 + ((10 + 12) - 11)
(13 + 10) + (12 - 11)
(13 + (10 + 12)) - 11
((13 + 10) + 12) - 11
12 + (13 + (10 - 11))
12 + ((13 + 10) - 11)
(12 + 13) + (10 - 11)
(12 + (13 + 10)) - 11
((12 + 13) + 10) - 11
13 + (12 + (10 - 11))
13 + ((12 + 10) - 11)
(13 + 12) + (10 - 11)
(13 + (12 + 10)) - 11
((13 + 12) + 10) - 11
(12 - 11) + (13 + 10)
((12 - 11) + 13) + 10
(12 - (11 - 13)) + 10
12 - (11 - (13 + 10))
12 - ((11 - 13) - 10)
(13 - 11) + (12 + 10)
((13 - 11) + 12) + 10
(13 - (11 - 12)) + 10
13 - (11 - (12 + 10))
13 - ((11 - 12) - 10)
12 + ((13 - 11) + 10)
12 + (13 - (11 - 10))
(12 + (13 - 11)) + 10
((12 + 13) - 11) + 10
(12 + 13) - (11 - 10)
13 + ((12 - 11) + 10)
13 + (12 - (11 - 10))
(13 + (12 - 11)) + 10
((13 + 12) - 11) + 10
(13 + 12) - (11 - 10)
```

```
Solution algorithm elapsed for 6.619 miliseconds
```

Test Case #6


==========
== Menu ==
==========
Choose card input method:
1. User input
2. Random
3. Exit program
Enter command (1/2/3):
1
Enter 4 card values separated by spaces (A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K):
2 7 9 10
==========
== Cards ==
==========
| 2 | | 7 | | 9 | |10 |
Continue? (press enter)

```
====================
==    Solutions   ==
====================
110 solutions found:

(10 + (9 - 7)) * 2
((10 + 9) - 7) * 2
10 + (9 + (7 - 2))
10 + ((9 + 7) - 2)
(10 + 9) + (7 - 2)
(10 + (9 + 7)) - 2
((10 + 9) + 7) - 2
(9 + (10 - 7)) * 2
((9 + 10) - 7) * 2
9 + (10 + (7 - 2))
9 + ((10 + 7) - 2)
(9 + 10) + (7 - 2)
(9 + (10 + 7)) - 2
((9 + 10) + 7) - 2
((10 - 7) + 9) * 2
(10 - (7 - 9)) * 2
10 + (7 + (9 - 2))
10 + ((7 + 9) - 2)
(10 + 7) + (9 - 2)
(10 + (7 + 9)) - 2
((10 + 7) + 9) - 2
7 + (10 + (9 - 2))
7 + ((10 + 9) - 2)
(7 + 10) + (9 - 2)
(7 + (10 + 9)) - 2
((7 + 10) + 9) - 2
(9 - 7) * (10 + 2)
((9 - 7) + 10) * 2
(9 - (7 - 10)) * 2
9 + (7 + (10 - 2))
9 + ((7 + 10) - 2)
(9 + 7) + (10 - 2)
(9 + (7 + 10)) - 2
((9 + 7) + 10) - 2
7 + (9 + (10 - 2))
7 + ((9 + 10) - 2)
(7 + 9) + (10 - 2)
(7 + (9 + 10)) - 2
((7 + 9) + 10) - 2
10 + ((9 - 2) + 7)
10 + (9 - (2 - 7))
(10 + (9 - 2)) + 7
((10 + 9) - 2) + 7
(10 + 9) - (2 - 7)
9 + ((10 - 2) + 7)
```

```
9 + (10 - (2 - 7))
(9 + (10 - 2)) + 7
((9 + 10) - 2) + 7
(9 + 10) - (2 - 7)
(10 + 2) * (9 - 7)
(10 - 2) + (9 + 7)
((10 - 2) + 9) + 7
(10 - (2 - 9)) + 7
10 - (2 - (9 + 7))
10 - ((2 - 9) - 7)
2 * (10 + (9 - 7))
2 * ((10 + 9) - 7)
(2 + 10) * (9 - 7)
(9 - 2) + (10 + 7)
((9 - 2) + 10) + 7
(9 - (2 - 10)) + 7
9 - (2 - (10 + 7))
9 - ((2 - 10) - 7)
2 * (9 + (10 - 7))
2 * ((9 + 10) - 7)
10 + ((7 - 2) + 9)
10 + (7 - (2 - 9))
(10 + (7 - 2)) + 9
((10 + 7) - 2) + 9
(10 + 7) - (2 - 9)
7 + ((10 - 2) + 9)
7 + (10 - (2 - 9))
(7 + (10 - 2)) + 9
((7 + 10) - 2) + 9
(7 + 10) - (2 - 9)
(10 - 2) + (7 + 9)
((10 - 2) + 7) + 9
(10 - (2 - 7)) + 9
10 - (2 - (7 + 9))
10 - ((2 - 7) - 9)
2 * ((10 - 7) + 9)
2 * (10 - (7 - 9))
(7 - 2) + (10 + 9)
((7 - 2) + 10) + 9
(7 - (2 - 10)) + 9
7 - (2 - (10 + 9))
7 - ((2 - 10) - 9)
(9 - 7) * (2 + 10)
9 + ((7 - 2) + 10)
9 + (7 - (2 - 10))
(9 + (7 - 2)) + 10
((9 + 7) - 2) + 10
(9 + 7) - (2 - 10)
```

```
7 + ((9 - 2) + 10)
7 + (9 - (2 - 10))
(7 + (9 - 2)) + 10
((7 + 9) - 2) + 10
(7 + 9) - (2 - 10)
(9 - 2) + (7 + 10)
((9 - 2) + 7) + 10
(9 - (2 - 7)) + 10
9 - (2 - (7 + 10))
9 - ((2 - 7) - 10)
2 * ((9 - 7) + 10)
2 * (9 - (7 - 10))
(7 - 2) + (9 + 10)
((7 - 2) + 9) + 10
(7 - (2 - 9)) + 10
7 - (2 - (9 + 10))
7 - ((2 - 9) - 10)

Solution algorithm elapsed for 6.311 miliseconds
```

BAB IV

Cek List Program

No	Poin	Ya	Tidak
1	Program berhasil dikompilasi tanpa Kesalahan	✓	
2	Program berhasil *running*	✓	
3	Program dapat membaca input / generate sendiri dan memberikan luaran	✓	
4	Solusi yang diberikan program memenuhi (berhasil mencapai 24)	✓	
5	Program dapat menyimpan solusi dalam file teks	✓	

LAMPIRAN

Repositori Github :
https://github.com/Rinaldy-Adin/Tucil1_13521134