

LAPORAN TUGAS KECIL 2 IF2211

Mencari Pasangan Titik Terdekat 3D dengan *Algoritma Divide and Conquer*



Ditujukan untuk memenuhi salah satu tugas kecil mata kuliah IF2211 Strategi
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BAB I

ALGORITMA

1.1. Algoritma *Brute Force*

Algoritma *brute force* adalah suatu pendekatan algoritma yang lempang (*straightforward*) untuk memecahkan suatu persoalan. Algoritma ini memecahkan suatu persoalan dengan cara yang sangat sederhana, langsung (*direct*), dan jelas (*obvious*). Pendekatan *brute force* membutuhkan volume komputasi dan waktu penyelesaian yang relative cukup besar. Meskipun begitu, algoritma *brute force* dapat menyelesaikan hamper semua persoalan dan sangat cocok untuk persoalan-persoalan kecil.

1.2. Algoritma *Divide and Conquer*

Algoritma *divide and conquer* adalah suatu pendekatan algoritma untuk memecahkan suatu persoalan dengan cara yang membagi persoalan tersebut (*divide*) sehingga menjadi suatu bagian yang lebih kecil untuk dapat diselesaikan (*conquer*). Pendekatan *divide and conquer* ini memiliki 3 fase dalam implementasinya, yaitu fase *divide* atau membagi-bagi persoalan menjadi lebih kecil, fase *conquer* atau menyelesaikan persoalan yang sudah dibagi, dan terakhir fase *combine* atau menggabungkan solusi sehingga membentuk solusi persoalan semula. Algoritma ini lebih efisien dari algoritma *brute force*.

1.3. *Quicksort*

Quicksort merupakan salah satu algoritma pengurutan yang menggunakan pendekatan *divide and conquer*. Algoritma ini termasuk kedalam category *hard split/easy join* yang berarti pembagian persoalan relatif lebih susah dan penggabungan relatif lebih mudah. *Quicksort* ini diimplementasikan dengan cara membagi dua buah larik yang dipisahkan oleh sebuah *pivot* atau acuan dimana larik pertama terdiri dari bagian yang lebih kecil dari acuan, dan larik kedua terdiri dari bagian yang lebih besar dari acuan. Setelah dibagi-bagi hingga bagian yang lebih kecil, setiap potongan larik kemudian akan diurutkan dan digabungkan kembali.

BAB II

SOURCE

CODE

2.1 Point Class Header File (point.hpp)

```
#ifndef __POINT__HPP__
#define __POINT__HPP__

class Point
{
private:
    int x;
    int y;
    int z;
public:
    Point();
    Point(int, int, int);
    ~Point();

    void operator=(const Point&);

    int getX();
    int getY();
    int getZ();
    void setX(int);
    void setY(int);
    void setZ(int);

    double getDistance(Point);
    void printPoint();
    //void quicksort(array<Point, 1000>);
};

#endif
```

2.2. Point Class File (point.cpp)

```
#include "point.hpp"
#include <cstdlib>
#include <iostream>
#include <cmath>
using namespace std;

Point::Point() {
    x = 0;
    y = 0;
    z = 0;
}

Point::Point(int x, int y, int z) {
    this->x = x;
    this->y = y;
    this->z = z;
}

Point::~Point() {}

int Point::getX() {
    return x;
}

int Point::getY() {
    return y;
}

int Point::getZ() {
    return z;
}

void Point::setX(int x) {
    this->x = x;
}

void Point::setY(int y) {
    this->y = y;
}

void Point::setZ(int z) {
    this->z = z;
}

void Point::operator=(const Point& other) {
    this->x = other.x;
    this->y = other.y;
```

```

        this->z = other.z;
    }

    double Point::getDistance(Point other){
        int dX = pow(abs(this->x - other.getX()), 2);
        int dY = pow(abs(this->y - other.getY()), 2);
        int dZ = pow(abs(this->z - other.getZ()), 2);
        double d = sqrt(dX + dY + dZ);

        return d;
    }

    void Point::printPoint(){
        cout << "Coordinates - X: " << x << " | Y: " << y << " | Z: " << z << endl;
    }

```

2.3. Utilities Header File(utilities.hpp)

```

#ifndef __UTILITIES_HPP__
#define __UTILITIES_HPP__

#include "point.cpp"

#define MAX_ARR 1000
#define MIN_COOR -500
#define MAX__COOR 500

void quicksort(Point arr[], int n);

void BruteForce(Point arr[], int n);

void DivideAndConquer(Point arr[], int n);

void split(Point parent[], Point child1[], Point child2[], int n);

#endif

```

2.4. Utilities File(utilities.cpp)

```

#include "utilities.hpp"

void quicksort(Point arr[], int n){

```

```

Point pivot = arr[0];
//cout << "Begin Quicksort " << endl << endl;
//pivot.printPoint();
if(n == 1){

}

else if(n == 2){
    if(arr[0].getX() > arr[1].getX()){
        arr[0] = arr[1];
        arr[1] = pivot;
    }

}

else{
    int p = 1;
    int q = n - 1;
    bool flagBigger = false;
    bool flagSmaller = false;
    int count1 = 0;
    int count2 = 0;

    //Run positioning for splitting
    while(p < q){
        for(; p < n; p++){
            if(arr[p].getX() > pivot.getX()){
                //arr[p].printPoint();
                //cout << "Is bigger than pivot" << endl;
                flagBigger = true;
                count1++;
                break;
            }else{
                //arr[p].printPoint();
                //cout << "Is not bigger than pivot" << endl;
            }
        }

        // Case if pivot is the biggest
        if(!flagBigger){
            p = 0;
        }

        for(; q >= 1; q--){
            if(arr[q].getX() <= pivot.getX()){
                //arr[q].printPoint();
            }
        }
    }
}

```

```

        //cout << "Is smaller than pivot" << endl;
        flagSmaller = true;
        count2++;
        break;
    }
}

// Break out loop if q and p already cross
if(q <= p){
    break;
}

// Case if pivot is the smallest
if(!flagSmaller){
    q = 0;
}

//Swap q and p (smaller and bigger)
if(flagBigger && flagSmaller){
    swap(arr[p], arr[q]);

    p++;
    q--;
}else{ //if pivot is the biggest or smallest
    break;
}

}

//Swap the pivot if it's not the smallest
if(flagSmaller){
    arr[0] = arr[q];
    arr[q] = pivot;
}

Point firstHalf[MAX_ARR];
Point secondHalf[MAX_ARR];

//Create the first half of points (if pivot is not smallest)

```

```

int i = 0;
if(flagSmaller){
    //cout << "FIRST HALF" << endl;
    for(i = 0; i < q; i++){
        firstHalf[i] = arr[i];
        // firstHalf[i].printPoint();
    }

}

i++;

//Create the second half of points (if pivot is not biggest)
if(flagBigger){
    //cout << "SECOND HALF" << endl;
    for(int j = 0; i < n; j++){
        secondHalf[j] = arr[i];
        // secondHalf[j].printPoint();
        i++;
    }
}

//Recursive for bot halves
if(flagSmaller){
    quicksort(firstHalf, q);
}
if(flagBigger){
    quicksort(secondHalf, n - (q + 1));
}

//Merging all the ordered halves
Point result[MAX_ARR];
int j = 0;
if(flagSmaller){
    //cout << "First merge\n";
    for(j = 0; j < q; j++){
        arr[j] = firstHalf[j];
        //arr[j].printPoint();
    }
}

arr[j] = pivot;
j++;

```



```

        if(flagBigger){
            //cout << "second merge\n";
            for(int k = 0; j < n; k++){
                arr[j] = secondHalf[k];
                //arr[j].printPoint();
                j++;
            }
        }
    }
}

void BruteForce(Point arr[], int n){
    //Brute Force Way
    double MIN = arr[0].getDistance(arr[1]);
    Point T1 = arr[0];
    Point T2 = arr[1];
    int calculation = 0;

    for(int i = 0; i < n; i++){
        for(int j = 0; j < n; j++){
            if(i != j && arr[i].getDistance(arr[j]) < MIN){
                MIN = arr[i].getDistance(arr[j]);
                calculation++;
                T1 = arr[i];
                T2 = arr[j];
            }
            calculation++;
        }
    }

    cout << "BRUTE FORCE: " << MIN << endl;
    cout << "Jumlah perhitungan Euclidean: " << calculation << endl;
    cout << "Titik 1: (" << T1.getX() << ", " << T1.getY() << ", " << T1.getZ() <<
    ")" << endl;
    cout << "Titik 2: (" << T2.getX() << ", " << T2.getY() << ", " << T2.getZ() <<
    ")" << endl;

}

void DivideAndConquer(Point arr[], int n){
    Point leftSide[MAX_ARR / 2];
    Point rightSide[MAX_ARR / 2];

```

```

Point T1 = arr[0];
Point T2 = arr[1];
int leftMax = round(n / 2) - 1;
int count = 0;
int calculation = 0;

//Split array of points
split(arr, leftSide, rightSide, n);
double strip = (rightSide[0].getX() - leftSide[leftMax].getX()) +
leftSide[leftMax].getX();

//Shortest Distance on Left
double LeftMin = -1;
Point LeftT1 = Point();
Point LeftT2 = Point();
if(round(n / 1) > 1){
    LeftT1 = leftSide[0];
    LeftT2 = leftSide[1];
    LeftMin = leftSide[0].getDistance(leftSide[1]);
    calculation++;
    for(int i = 0; i < round(n / 2); i++){
        for(int j = 0; j < round(n / 2); j++){
            if(i < j && leftSide[i].getDistance(leftSide[j]) < LeftMin){
                LeftMin = leftSide[i].getDistance(leftSide[j]);
                calculation++;
                LeftT1 = leftSide[i];
                LeftT2 = leftSide[j];
            }
            calculation++;
        }
    }
}

//Shortest Distance on Right
double RightMin = rightSide[0].getDistance(rightSide[1]);
Point RightT1 = rightSide[0];
Point RightT2 = rightSide[1];
calculation++;
for(int i = 0; i < n - round(n / 2); i++){
    for(int j = 0; j < n - round(n / 2); j++){
        if(i < j && rightSide[i].getDistance(rightSide[j]) < RightMin){
            RightMin = rightSide[i].getDistance(rightSide[j]);
            calculation++;
        }
    }
}

```

```

        RightT1 = rightSide[i];
        RightT2 = rightSide[j];
    }
    calculation++;
}
}

//Shortest distance between left and right
double universalMin;
if(LeftMin == -1 || RightMin <= LeftMin){
    universalMin = RightMin;
    T1 = RightT1;
    T2 = RightT2;
}else{
    universalMin = LeftMin;
    T1 = LeftT1;
    T2 = LeftT2;
}
//Shortest distance near strip
count = 0;
for(int i = 0; i < round(n / 2); i++){
    if(leftSide[i].getX() >= strip - universalMin && leftSide[i].getX() <= strip
+ universalMin){
        for(int j = 0; j < n - round(n / 2); j++){
            if(rightSide[i].getX() >= strip - universalMin && rightSide[i].getX()
<= strip + universalMin && leftSide[i].getDistance(rightSide[j]) < universalMin){
                universalMin = leftSide[i].getDistance(rightSide[j]);
                calculation++;
                T1 = leftSide[i];
                T2 = rightSide[j];
            }
            calculation++;
        }
    }
}

cout << "DIVIDE & CONQUER: " << universalMin << endl;
cout << "Jumlah perhitungan Euclidean: " << calculation << endl;
cout << "Titik 1: (" << T1.getX() << ", " << T1.getY() << ", " << T1.getZ() <<
")" << endl;
cout << "Titik 2: (" << T2.getX() << ", " << T2.getY() << ", " << T2.getZ() <<
")" << endl;
}

```

```

void split(Point parent[], Point child1[], Point child2[], int n){
    int count = 0;
    // Left Points
    for(int i = 0; i < round(n/2); i++){
        child1[i] = parent[count];
        //leftSide[i].printPoint();
        count++;
    }
    //Right points
    for(int i = 0; i < n - round(n / 2); i++){
        child2[i] = parent[count];
        //rightSide[i].printPoint();
        count++;
    }
}

```

2.5. Main Driver File(main.cpp)

```

#include <iostream>
#include <time.h>
#include <ctime>
#include <chrono>
#include "utilities.cpp"

using namespace std;
using chrono::duration_cast;
using chrono::duration;
using chrono::milliseconds;

typedef chrono::high_resolution_clock Clock;

int main(){
    //Point p[MAX_ARR];
    int n;
    Point points[MAX_ARR];
    Point* pointsPtr = points;
    Point pointsByX[MAX_ARR];
    int Rx, Ry, Rz;
    srand(time(NULL));

    //Opening

```

```

cout << "Selamat datang!\n" << endl;
cout << "Keterangan:" << endl;
cout << "1) Range Koordinat: (-500) - 500\n2) Maximum titik: 1000\n" << endl;
cout << "Masukan jumlah titik: ";
cin >> n;
cout << endl;

//Generate random points
for(int i = 0; i < n; i++){
    Rx = rand() % (MAX__COOR - MIN_COOR + 1) + MIN_COOR;
    Ry = rand() % (MAX__COOR - MIN_COOR + 1) + MIN_COOR;
    Rz = rand() % (MAX__COOR - MIN_COOR + 1) + MIN_COOR;

    points[i] = Point(Rx, Ry, Rz);
    //points[i].printPoint();

}

//Sort the array
quicksort(points, n);
// cout<<"RESULTS\n";
// for(int i = 0; i < n; i++){
//     pointsByX[i].printPoint();
// }

//Brute Force Way
auto start_s = Clock::now();
BruteForce(points, n);
auto stop_s = Clock::now();
duration<double, milli> exec = stop_s - start_s;
cout << "Execution time: " << exec.count() << " ms" << endl << endl;

//Divide and Conquer Way
start_s = Clock::now();
DivideAndConquer(points, n);
stop_s = Clock::now();
exec = stop_s - start_s;
cout << "Execution time: " << exec.count() << " ms" << endl << endl;

return 0;
}

```


BAB III

EKSPERIMEN

3.1. Hasil Input dan Output Program Saat $n = 16$

```
Selamat datang!

Keterangan:
1) Range Koordinat: (-500) - 500
2) Maximum titik: 1000

Masukan jumlah titik: 16

BRUTE FORCE: 92.2497
Jumlah perhitungan Euclidean: 260
Titik 1: (-361, -13, 211)
Titik 2: (-347, 20, 126)
Execution time: 2.287 ms

DIVIDE & CONQUER: 92.2497
Jumlah perhitungan Euclidean: 151
Titik 1: (-361, -13, 211)
Titik 2: (-347, 20, 126)
Execution time: 1.002 ms
```

3.2. Hasil Input dan Output Program Saat $n = 64$

```
Selamat datang!

Keterangan:
1) Range Koordinat: (-500) - 500
2) Maximum titik: 1000

Masukan jumlah titik: 64

BRUTE FORCE: 21.0713
Jumlah perhitungan Euclidean: 4104
Titik 1: (156, -496, -34)
Titik 2: (167, -496, -52)
Execution time: 1.985 ms

DIVIDE & CONQUER: 21.0713
Jumlah perhitungan Euclidean: 2223
Titik 1: (156, -496, -34)
Titik 2: (167, -496, -52)
Execution time: 2.427 ms
```

3.3. Hasil Input dan Output Program Saat $n = 128$

```
Selamat datang!

Keterangan:
1) Range Koordinat: (-500) - 500
2) Maximum titik: 1000

Masukan jumlah titik: 128

BRUTE FORCE: 31.8277
Jumlah perhitungan Euclidean: 16398
Titik 1: (438, -288, -272)
Titik 2: (452, -271, -295)
Execution time: 8.1 ms

DIVIDE & CONQUER: 31.8277
Jumlah perhitungan Euclidean: 8593
Titik 1: (438, -288, -272)
Titik 2: (452, -271, -295)
Execution time: 3.008 ms
```

3.4. Hasil Input dan Output Program Saat n = 1000

```
Selamat datang!

Keterangan:
1) Range Koordinat: (-500) - 500
2) Maximum titik: 1000

Masukan jumlah titik: 1000

BRUTE FORCE: 7.14143
Jumlah perhitungan Euclidean: 1000011
Titik 1: (390, 170, 1)
Titik 2: (391, 169, 8)
Execution time: 324.895 ms

DIVIDE & CONQUER: 7.14143
Jumlah perhitungan Euclidean: 502519
Titik 1: (390, 170, 1)
Titik 2: (391, 169, 8)
Execution time: 123.097 ms
```


REFERENSI

[https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-\(2021\)-Bagian1.pdf](https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-(2021)-Bagian1.pdf)

[https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-\(2021\)-Bagian2.pdf](https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-(2021)-Bagian2.pdf)

LAMPIRAN

Link github:

https://github.com/Ezaaan/Tucil2_13521141

Tabel pengerjaan:

Poin	Ya	Tidak
1. Program berhasil dikompilasi tanpa ada kesalahan.	✓	
2. Program berhasil <i>running</i>	✓	
3. Program dapat menerima masukan dan dan menuliskan luaran.	✓	
4. Luaran program sudah benar (solusi <i>closest pair</i> benar)	✓	
5. Bonus 1 dikerjakan		✓
6. Bonus 2 dikerjakan		✓