

TUGAS KECIL 2 IF2211 STRATEGI ALGORITMA SEMESTER II TAHUN 2022/2023

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



Disusun oleh:

Louis Caesa Kesuma

13521069

**PROGRAM STUDI TEKNIK INFORMATIKA
SEKOLAH TEKNIK ELEKTRO DAN INFORMATIKA
INSTITUT TEKNOLOGI BANDUNG
2023**

BAB I DESKRIPSI MASALAH

Mencari sepasang titik terdekat dengan Algoritma Divide and Conquer sudah dijelaskan di dalam kuliah. Persoalan tersebut dirumuskan untuk titik pada bidang datar (2D). Pada Tugil 2 kali ini Anda diminta mengembangkan algoritma mencari sepasang titik terdekat pada bidang 3D. Misalkan terdapat n buah titik pada ruang 3D. Setiap titik P di dalam ruang dinyatakan dengan koordinat $P = (x, y, z)$. Carilah sepasang titik yang mempunyai jarak terdekat satu sama lain. Jarak dua buah titik $P_1 = (x_1, y_1, z_1)$ dan $P_2 = (x_2, y_2, z_2)$ dihitung dengan rumus Euclidean berikut:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

Buatlah program dalam Bahasa C/C++/Java/Python/Golang/Ruby/Perl (pilih salah satu) untuk mencari sepasang titik yang jaraknya terdekat satu sama lain dengan menerapkan Algoritma *Divide and Conquer* untuk penyelesaiannya, dan perbandingannya dengan Algoritma *Brute Force*.

BAB II TEORI DASAR

1. Algoritma *Divide and Conquer*

Algoritma *Divide and Conquer* adalah algoritma yang identik dengan membagi-bagi persoalan kedalam beberapa persoalan yang lebih kecil dan menghasilkan solusi yang sesuai dengan permasalahan skala kecil tersebut. Hasil-hasil dari persoalan-persoalan kecil tersebut kemudian digabungkan untuk menghasilkan solusi dari persoalan awal. *Divide and Conquer* dulunya adalah strategi militer yang dikenal dengan nama *divide ut imperes*, sekarang strategi tersebut menjadi salah satu strategi yang populer di dalam ilmu komputer dengan nama yang sama.

Umumnya pengimplementasian Algoritma *Divide and Conquer* berkaitan erat dengan algoritma rekursif. Basis-basis pada algoritma rekursif dapat dijadikan sebagai permasalahan terkecil dari persoalan, dan rekursi pada algoritma rekursif dapat digunakan untuk memecah permasalahan tersebut menjadi permasalahan yang lebih kecil serta menggabungkan hasil dari pemecahan masalah-masalah skala kecil tersebut.

Algoritma *Divide and Conquer* terdiri dari 3 tahapan, yaitu:

- a. *Divide*, yaitu tahapan dimana permasalahan yang besar dipecah menjadi permasalahan-permasalahan yang terkecil (*base case*)
- b. *Conquer*, yaitu tahapan dimana permasalahan terkecil tersebut diselesaikan dan dicari solusinya
- c. *Combine*, yaitu tahapan dimana solusi-solusi dari permasalahan-permasalahan terkecil yang telah didapat digabungkan menjadi solusi untuk permasalahan semula

2. Algoritma *Divide and Conquer* pada persoalan mencari pasangan titik terdekat

Algoritma *Divide and Conquer* tentunya dapat digunakan untuk mencari solusi dari masalah tersebut. Kita dapat membagi titik-titik tersebut ke dalam beberapa area yang lebih kecil, dan mencari pasangan titik terdekat di area tersebut. Hasil-hasil yang didapat kemudian dapat kita gabungkan untuk mendapatkan pasangan titik terdekat dari daftar semula.

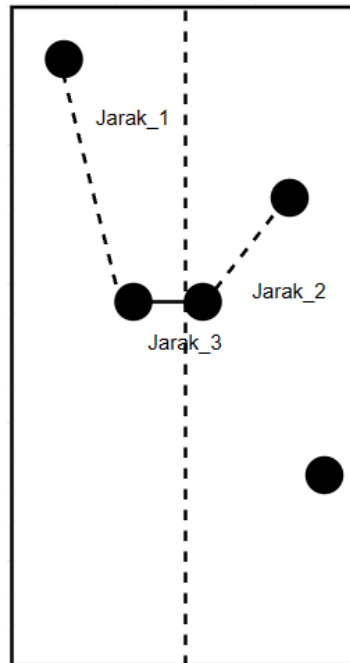
Tahapan dari pengimplementasiannya adalah:

- a. *Divide*
Kita pertama-tama harus membagi daftar titik tersebut ke dalam beberapa daftar yang lebih kecil. Pembagian dapat dilakukan dengan cara mencari titik tengah pada daftar titik semula. Untuk mempermudah proses pembagian, kita dapat mengurutkan titik-titik tersebut secara menaik terhadap sumbu x-nya. Setelah diurutkan titik tengah dapat ditemukan dengan mengakses elemen ke-*mid* dari daftar titik, dimana $mid = \text{banyak_titik} \div 2$. Titik-titik yang nilai x-nya bernilai lebih kecil sama dengan dari titik tengah dapat dimasukkan ke dalam daftar titik kiri dan sisanya ke dalam daftar titik kanan. Proses tersebut akan terus kita lakukan hingga tercapai *base case*-nya, yaitu jika jumlah titik pada daftar titik tersebut adalah 1, 2 atau 3.
- b. *Conquer*
Setelah *base case* tercapai, maka kita dapat mencari jarak terpendek dari titik-titik yang tersedia. Untuk *base case* dimana jumlah titiknya adalah 1, kita tidak perlu mencari jaraknya. Untuk *base case* dimana jumlah titiknya adalah 2, kita hanya perlu mencari jarak antara 2 titik tersebut dengan menggunakan rumus *Euclidean distance*.

Untuk *base case* dimana jumlah titiknya adalah 3, kita harus mencari jarak antara titik pertama dengan titik kedua, titik pertama dengan titik ketiga, dan titik kedua dengan titik ketiga. Kemudian jarak-jarak tersebut dibandingkan, dan dipilih titik-titik dengan jarak terkecil.

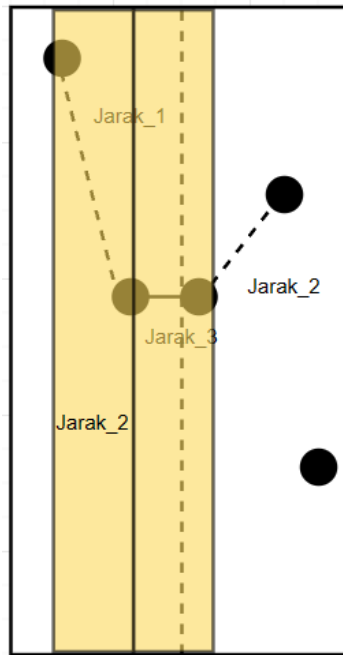
c. *Combine*

Proses penggabungan hasil dari *base case*-nya tidak bisa dilakukan secara langsung. Kita juga harus memikirkan kemungkinan dimana terdapat sepasang titik yang memiliki jarak yang lebih pendek dari hasil yang didapat sebelumnya ketika kita menggabungkan 2 daftar titik dari *base case*-nya. Ilustrasi sederhananya adalah sebagai berikut:



Bisa dilihat bahwa dari penggabungan titik-titik pada sisi kiri dan sisi kanan terdapat titik dengan jarak yang lebih kecil dari pada jarak yang didapat sebelumnya. Jarak_1 yang didapat dari sisi kiri dan Jarak_2 yang didapat dari sisi kanan bernilai lebih besar dari pada Jarak_3. Sehingga kita perlu memikirkan kemungkinan ini.

Untuk mempermudah kita dalam menangani kejadian ini, kita hanya perlu melihat area tertentu saja. Kita hanya perlu memilih titik-titik yang berada dalam area tertentu di sekitar titik tengah. Karena titik tengah bisa dibilang adalah titik yang terdekat dari sumbu penggabungan kedua sisi, maka kita hanya perlu mengambil titik-titik yang berada di sekitar titik tengah. Contohnya adalah sebagai berikut:



Dari ilustrasi tersebut kita hanya perlu mencari titik yang berada di area sekitar titik tengah. Area tersebut dapat kita temukan dengan cara mencari jarak yang lebih kecil antara sisi kanan dan sisi kiri, karena kita hanya ingin mencari titik yang berkemungkinan berjarak lebih pendek dari hasil yang didapat sebelumnya. Pada ilustrasi tersebut Jarak_2 lebih pendek dibanding Jarak_1, jadi kita akan menggunakan Jarak_2 sebagai batas area dari titik tengah. Kita hanya akan mengambil titik-titik yang dimana posisinya pada sumbu x berada diantara posisi titik tengah pada sumbu x - Jarak_2 dan posisi titik tengah pada sumbu x + Jarak_2. Setelah penyaringan tersebut dilakukan, maka langkah berikutnya adalah mencari jarak terpendek serta titik-titik yang bersangkutan dari daftar titik tersebut. Hasil jarak terpendek dari daftar titik gabungan tersebut kemudian kita bandingkan dengan hasil yang didapat pada *base case*, dan titik-titik dengan jarak terpendek lah yang kita pilih. Hasil perbandingan tersebut kemudian dapat memvalidasi penggabungan *base case* kita.

Pembagian titik-titik berdasarkan sumbu x ini merupakan salah satu bentuk generalisasi yang mungkin agar kita juga dapat mencari titik-titik dengan jarak terpendek dari vektor R^n . Karena untuk setiap vektor dengan ruang n, pasti ada nilai pada sumbu x yang dapat digunakan untuk membaginya pada tahap *Divide*.

BAB III IMPLEMENTASI

1. main

```
# PROGRAM UTAMA
def main():
    # Inisialisasi
    fig = plt.figure(figsize=(15, 9))
    ax = fig.add_subplot(2, 3, 1, projection='3d') # visualisasi untuk divide and conquer
    bx = fig.add_subplot(2, 3, 3, projection='3d') # visualisasi untuk brute force
    ax.set_title("Hasil dari Divide and Conquer")
    bx.set_title("Hasil dari Brute force")
    n = int(input("Masukkan jumlah titik: "))
    while n < 2:
        n = int(input("Jumlah titik minimal 2, masukkan lagi jumlah titik: "))
    dimensi = int(input("Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal):\n"))
    while dimensi < 1:
        dimensi = int(input("Jumlah dimensi minimal 1, masukkan lagi jumlah dimensi: "))

    x = []

    lowerbound = float(input("Masukkan batas bawah nilai titik (note: maksimal -1000): "))
    upperbound = float(input("Masukkan batas atas nilai titik (note: maksimal 1000): "))
    while (upperbound <= lowerbound):
        print("Masukan salah!! batas bawah harus lebih kecil dari batas atas")
        lowerbound = float(input("Masukkan batas bawah nilai titik (note: maksimal -1000): "))
        upperbound = float(input("Masukkan batas atas nilai titik (note: maksimal 1000): "))
    for i in range(n):
        temp = []
        for j in range(dimensi):
            temp.append(round(random.uniform(lowerbound, upperbound), 3))
        x.append(temp)

    # sort terlebih dahulu titik2nya
    daftar_titik = sort_titik(x, 0)

    # algoritma divide and conquer
    jumlahperhitungan_divide = 0
    start_divide = time.time()
    pasangan_divide, jarak_divide, jumlahperhitungan_divide = find_minimum(daftar_titik, jumlahperhitungan_divide)
    end_divide = time.time()
    exec_time_divide = end_divide - start_divide

    # algoritma brute force
    jumlahperhitungan_brute = 0
    start_brute = time.time()
    pasangan_brute, jarak_brute, jumlahperhitungan_brute = find_minimum_gabungan(daftar_titik, jumlahperhitungan_brute)
    end_brute = time.time()
    exec_time_brute = end_brute - start_brute

    # semua data akan ditampilkan di terminal
    info_divide = f"Deskripsi hasil Divide and Conquer:\nWaktu eksekusi: {exec_time_divide}s \nJumlah kalkulasi: {jumlahperhitungan_divide}\nJarak terdekat: {jarak_divide}\nSolusi: {solution_to_string(pasangan_divide)}"
    info_brute = f"Deskripsi hasil Brute force:\nWaktu eksekusi: {exec_time_brute}s \nJumlah kalkulasi: {jumlahperhitungan_brute}\nJarak terdekat: {jarak_brute}\nSolusi: {solution_to_string(pasangan_brute)}"

    ax.text2D(0.1, 0.1, info_divide, fontsize=9, transform=plt.gcf().transFigure)
    bx.text2D(0.6, 0.1, info_brute, fontsize=9, transform=plt.gcf().transFigure)

    print(f"\nitik yang digunakan: {x}\n")

    my_system = platform.uname()
    print(f"System : {my_system.system}")
    print(f"Node Name : {my_system.node}")
    print(f"Release : {my_system.release}")
    print(f"Version : {my_system.version}")
    print(f"Machine : {my_system.machine}")
    print(f"Processor : {my_system.processor}\n")

    print([info_divide])
    print([info_brute])

    # VISUALISASI
    warna = ["red", "purple", "brown", "pink", "gray", "olive", "cyan", "orange", "black"]
    if dimensi == 3: # visualisasi hanya untuk dimensi 3
        for i in daftar_titik:
            ax.scatter(i[0], i[1], i[2], c='g', marker='o')

        color_cycle = 0
        for i in pasangan_divide:
            ax.scatter(i[0][0], i[0][1], i[0][2], c = warna[color_cycle % 9], marker='o')
            ax.scatter(i[1][0], i[1][1], i[1][2], c = warna[color_cycle % 9], marker='o')
            color_cycle += 1

        for i in daftar_titik:
            bx.scatter(i[0], i[1], i[2], c='b', marker='o')

        color_cycle = 0
        for i in pasangan_divide:
            bx.scatter(i[0][0], i[0][1], i[0][2], c = warna[color_cycle % 9], marker='o')
            bx.scatter(i[1][0], i[1][1], i[1][2], c = warna[color_cycle % 9], marker='o')
            color_cycle += 1

    plt.show()

if __name__ == "__main__":
    main()
```

2. find_minimum

```
def find_minimum(daftar_titik, counter):
    if (len(daftar_titik) == 1):
        return None, None, counter
    elif (len(daftar_titik) == 2):
        return [[daftar_titik[0], daftar_titik[1]], euclidean_distance(daftar_titik[0], daftar_titik[1]), counter+1]
    elif (len(daftar_titik) == 3):
        jarak1 = euclidean_distance(daftar_titik[0], daftar_titik[1])
        jarak2 = euclidean_distance(daftar_titik[0], daftar_titik[2])
        jarak3 = euclidean_distance(daftar_titik[1], daftar_titik[2])
        if jarak1 == min(jarak1, jarak2, jarak3):
            return [[daftar_titik[0], daftar_titik[1]], jarak1, counter+3]
        elif jarak2 == min(jarak1, jarak2, jarak3):
            return [[daftar_titik[0], daftar_titik[2]], jarak2, counter+3]
        else:
            return [[daftar_titik[1], daftar_titik[2]], jarak3, counter+3]
    else:
        daftar_titik_kiri, daftar_titik_kanan = bagi_titik(daftar_titik)
        # tidak bisa dibagi lagi
        if (daftar_titik_kiri == daftar_titik):
            return find_minimum_gabungan(daftar_titik, counter)
        else:
            titik_kiri, delta_kiri, counter = find_minimum(daftar_titik_kiri, counter)
            titik_kanan, delta_kanan, counter = find_minimum(daftar_titik_kanan, counter)

            if delta_kanan is None or delta_kiri is None:
                if delta_kanan is None and delta_kiri is None:
                    return None, None, None, counter
                else:
                    if delta_kanan is None:
                        return titik_kiri, delta_kiri, counter
                    else:
                        return titik_kanan, delta_kanan, counter
            else:
                delta = min(delta_kanan, delta_kiri)
                # gabung
                daftar_titik_gabungan = bagi_titik_gabungan(daftar_titik, delta)

                if len(daftar_titik_gabungan) > 1:
                    titik_gabungan, delta_gabungan, counter = find_minimum_gabungan(daftar_titik_gabungan, counter)

                    if delta_gabungan is not None:
                        if delta_gabungan < delta:
                            return titik_gabungan, delta_gabungan, counter
                        elif delta_gabungan == delta:
                            if delta_kanan > delta_kiri:
                                for i in titik_gabungan:
                                    if i not in titik_kiri:
                                        titik_kiri.append(i)
                            elif delta_kiri > delta_kanan:
                                for i in titik_gabungan:
                                    if i not in titik_kanan:
                                        titik_kanan.append(i)
                            else:
                                return titik_kiri, delta_kiri, counter
                            elif delta_kanan < delta_kiri:
                                for i in titik_gabungan:
                                    if i not in titik_kanan:
                                        titik_kanan.append(i)
                                return titik_kanan, delta_kanan, counter
                            else:
                                for i in titik_gabungan:
                                    if i not in titik_kanan:
                                        titik_kanan.append(i)
                                for i in titik_kiri:
                                    if i not in titik_kanan:
                                        titik_kanan.append(i)
                                return titik_kanan, delta_kanan, counter

            if delta_kanan > delta_kiri:
                return titik_kiri, delta_kiri, counter
            elif delta_kanan == delta_kiri:
                for i in titik_kiri:
                    if i not in titik_kanan:
                        titik_kanan.append(i)
                return titik_kanan, delta_kanan, counter
            else:
                return titik_kanan, delta_kanan, counter
```

3. find_minimum_gabungan

```
# fungsi untuk mencari minimum distance dengan metode brute force
def find_minimum_gabungan(daftar_titik, counter):
    min = euclidean_distance(daftar_titik[0], daftar_titik[1])
    titik_gabungan = [[daftar_titik[0], daftar_titik[1]]]
    counter += 1

    for i in range(len(daftar_titik)-1):
        for j in range(i+1, len(daftar_titik)):
            if i != 0 and j != 1:
                counter += 1
                temp = euclidean_distance(daftar_titik[i], daftar_titik[j])
                if min > temp:
                    min = temp
                    titik_gabungan = [[daftar_titik[i], daftar_titik[j]]]
                elif min == temp:
                    if (daftar_titik[i], daftar_titik[j]) not in titik_gabungan:
                        titik_gabungan.append((daftar_titik[i], daftar_titik[j]))

    return titik_gabungan, min, counter
```

4. copy_titik

```
# fungsi untuk menyalin daftar titik
def copy_titik(daftar_awal):
    daftar_awal_copy = []
    for i in daftar_awal:
        daftar_awal_copy.append(i)

    return daftar_awal_copy
```

5. sort_titik

```
# fungsi untuk mengurutkan titik-titik yang tersedia
def sort_titik(daftar_awal, based_on):
    daftar_awal_copy = copy_titik(daftar_awal)

    daftar_titik = []
    while (len(daftar_awal_copy) != 0):
        correct = False
        i = 0

        if len(daftar_titik) != 0:
            while not correct:
                if i == len(daftar_titik) or daftar_awal_copy[0][based_on] <= daftar_titik[i][based_on]:
                    correct = True
                else:
                    i += 1

            daftar_titik.insert(i, daftar_awal_copy[0])

        daftar_awal_copy.remove(daftar_awal_copy[0])
    return daftar_titik
```

6. euclidean_distance

```
# fungsi untuk mencari jarak euclidean
def euclidean_distance(titik1, titik2):
    temp = 0
    for i in range(len(titik1)):
        temp += pow(titik1[i] - titik2[i], 2)

    return math.sqrt(temp)
```

7. bagi_titik

```
# fungsi untuk membagi titik-titik pada daftar titik menjadi 2 buah daftar titik baru yang berisikan titik di sebelah kiri dan di sebelah kanan
def bagi_titik(daftar_awal):
    daftar_kiri = []
    daftar_kanan = []

    mid = len(daftar_awal) // 2
    mid_point = daftar_awal[mid]

    for i in range(len(daftar_awal)):
        if (daftar_awal[i][0] <= mid_point[0]):
            daftar_kiri.append(daftar_awal[i])
        else:
            daftar_kanan.append(daftar_awal[i])

    return daftar_kiri, daftar_kanan
```

8. bagi_titik_gabungan


```
# fungsi untuk mendapatkan titik-titik yang berada di sekitar batas penggabungan 2 buah area
def bagi_titik_gabungan(daftar_awal, delta):
    titik_gabungan = []

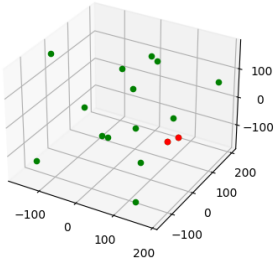
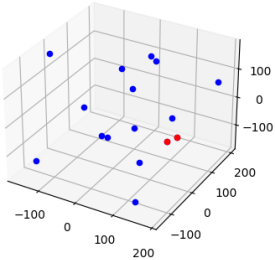
    mid = len(daftar_awal) // 2
    mid_point = daftar_awal[mid]

    for i in range(len(daftar_awal)):
        if (daftar_awal[i][0] <= mid_point[0] + delta) and (daftar_awal[i][0] >= mid_point[0] - delta):
            titik_gabungan.append(daftar_awal[i])

    return titik_gabungan
```

BAB IV EKSPERIMEN

1. test case 1

input	n = 16, dimensi = 3, lowerbound = -200, upperbound = 200
<p>output:</p> <pre> Masukkan jumlah titik: 16 Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal): 3 Masukkan batas bawah nilai titik (note: maksimal -1000): -200 Masukkan batas atas nilai titik (note: maksimal 1000): 200 Titik yang digunakan: [[17.744, 8.002, 165.435], [177.426, -14.258, 4.858], [-159.926, -88.404, -163.322], [186.069, 166.166, 80.918], [-10.889, 197.128, 81.878], [1 43.347, -126.728, -17.023], [169.187, -49.393, 12.339], [7.063, -37.903, -46.131], [5.303, 80.743, 44.186], [-102.643, 36.714, -31.928], [180.171, -46.201, 94.145], [140.326, -144.173, 108.916], [-153.923, -24.0, 175.97], [21.989, 164.163, 96.237], [25.999, -94.976, 6.82], [129.698, -123.319, -161.914]] System : Windows Node Name : DESKTOP-7GFDHFG Release : 10 Version : 10.0.22621 Machine : AMD64 Processor : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD Deskripsi hasil Divide and Conquer: Waktu eksekusi: 0.0s Jumlah kalkulasi: 59 Jarak terdekat: 36.85532128472088 Solusi: - Titik [169.187, -49.393, 12.339] dengan titik [177.426, -14.258, 4.858] diwarnai dengan warna: merah Deskripsi hasil Bruteforce: Waktu eksekusi: 0.0s Jumlah kalkulasi: 106 Jarak terdekat: 36.85532128472088 Solusi: - Titik [169.187, -49.393, 12.339] dengan titik [177.426, -14.258, 4.858] diwarnai dengan warna: merah </pre> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Hasil dari Divide and Conquer</p>  <p>Deskripsi hasil Divide and Conquer:</p> <p>Waktu eksekusi: 0.0s Jumlah kalkulasi: 59 Jarak terdekat: 36.85532128472088 Solusi: - Titik [169.187, -49.393, 12.339] dengan titik [177.426, -14.258, 4.858] diwarnai dengan warna: merah</p> </div> <div style="text-align: center;"> <p>Hasil dari Bruteforce</p>  <p>Deskripsi hasil Bruteforce:</p> <p>Waktu eksekusi: 0.0s Jumlah kalkulasi: 106 Jarak terdekat: 36.85532128472088 Solusi: - Titik [169.187, -49.393, 12.339] dengan titik [177.426, -14.258, 4.858] diwarnai dengan warna: merah</p> </div> </div>	

2. test case 2

input	n = 64, dimensi = 3, lowerbound = -200, upperbound = 200
output:	

Masukkan jumlah titik: 64
Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal):
3
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[52.155, 9.974, -191.647], [109.862, -62.759, 39.04], [-135.573, -122.692, -142.151], [138.901, -5.432, 80.716], [-17.066, -168.788, 62.936], [43.592, 141.766, -11.363], [35.172, 30.954, -179.301], [18.929, 137.395, -35.402], [-44.517, -49.365, 157.724], [166.186, 40.352, 191.475], [136.839, -0.407, 90.062], [-66.057, 158.56, -30.237], [-49.636, -196.596, 56.755], [183.598, -61.427, 59.454], [22.18, -6.922, 81.003], [199.267, -186.059, 164.448], [-185.154, -95.366, -71.331], [168.775, 180.651, 189.326], [-88.807, -148.615, 119.413], [-72.29, 149.175, -107.319], [-121.791, -161.193, 7.82], [-171.984, -72.025, 67.676], [-137.235, 139.146, -19.931], [134.455, 131.603, 56.567], [-188.197, -37.228, 65.438], [-151.391, -30.736, -112.754], [-144.866, -164.948, 14.852], [169.086, 181.888, -0.698], [-111.542, 108.904, 177.904], [123.56, 95.222, 20.359], [-102.025, 66.007, -84.346], [-88.103, -104.575, 90.045], [66.916, -96.302, -70.454], [145.103, -169.329, 115.287], [128.462, 191.701, -34.771], [-192.503, -85.2, 77.737], [-17.234, -106.528, -188.133], [174.591, 11.082, 90.425], [-1.741, -52.256, 127.42], [-16.622, -49.343, 152.435], [-65.817, 21.179, -64.144], [46.179, -15.895, 129.429], [99.428, -130.874, 128.873], [82.964, -28.915, 174.744], [-170.191, -140.329, 122.084], [-59.624, -47.298, -9.837], [-24.104, 133.015, 45.205], [-37.203, -3.059, -33.573], [-109.388, -96.791, 72.756], [-12.773, -64.011, -60.722], [-189.201, 116.48, 64.32], [-22.135, -14.042, -129.57], [22.507, -145.868, -81.138], [-191.814, -6.491, 54.977], [-133.003, -135.205, 120.483], [148.322, 84.905, -27.645], [59.113, -138.854, 37.11], [195.454, 166.751, -63.948], [-197.284, 82.74, -9.050], [-152.819, -138.639, -21.324], [36.316, -146.645, -175.221], [52.221, 170.619, 120.995], [131.811, -102.357, -49.204], [-98.411, -33.789, -176.174]]

System : Windows
Node Name : DESKTOP-7GFDHFG
Release : 10
Version : 10.0.22621
Machine : AMD64
Processor : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD

Deskripsi hasil Divide and Conquer:
Waktu eksekusi: 0.0023338794708251953s
Jumlah kalkulasi: 450
Jarak terdekat: 10.8097264072686
Solusi:
- Titik [136.839, -0.407, 90.062] dengan titik [138.901, -5.432, 80.716]
diwarnai dengan warna: merah

Deskripsi hasil Bruteforce:
Waktu eksekusi: 0.003000974655151367s
Jumlah kalkulasi: 1954
Jarak terdekat: 10.8097264072686
Solusi:
- Titik [136.839, -0.407, 90.062] dengan titik [138.901, -5.432, 80.716]
diwarnai dengan warna: merah

Hasil dari Divide and Conquer

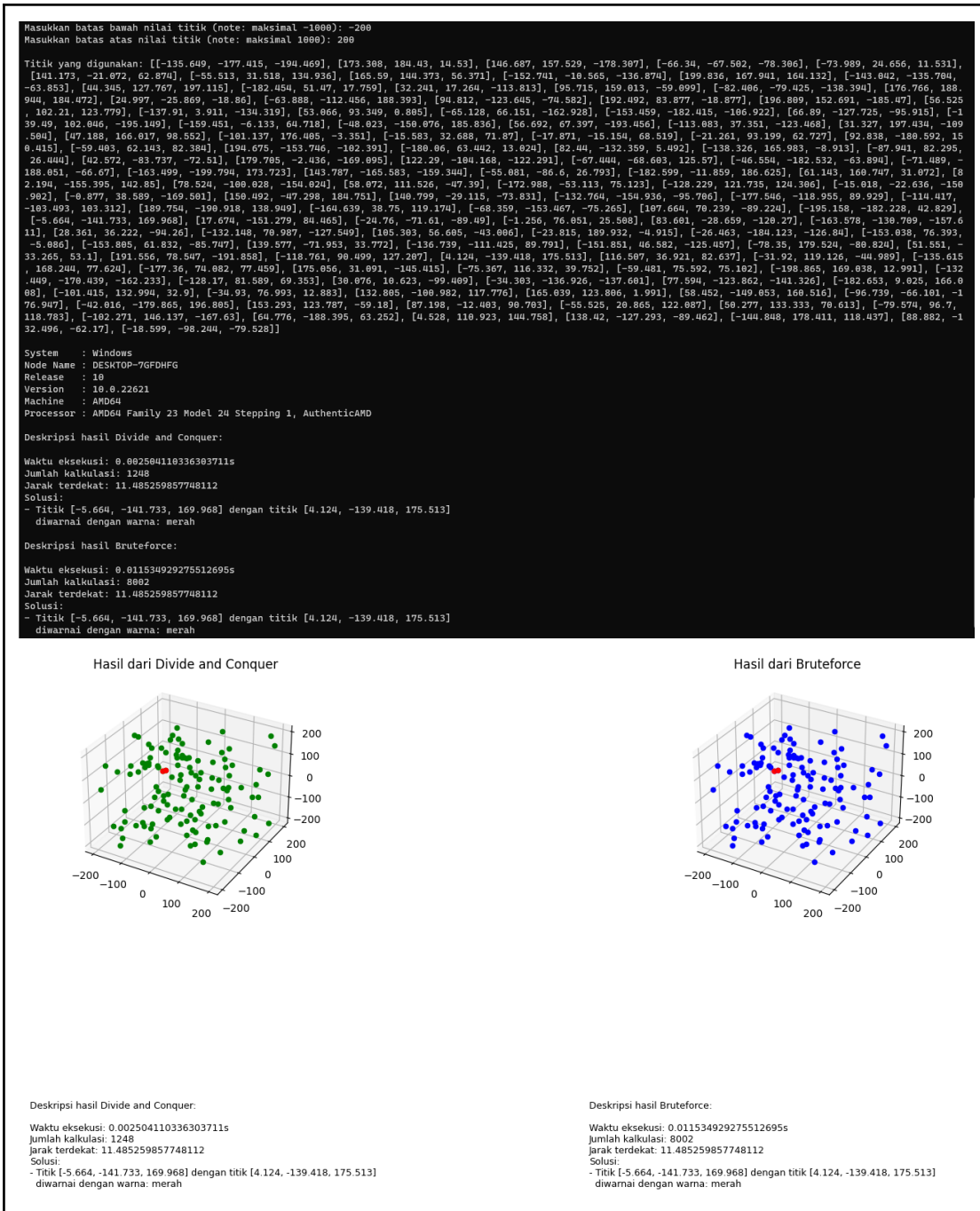
Hasil dari Bruteforce

Deskripsi hasil Divide and Conquer:
Waktu eksekusi: 0.0023338794708251953s
Jumlah kalkulasi: 450
Jarak terdekat: 10.8097264072686
Solusi:
- Titik [136.839, -0.407, 90.062] dengan titik [138.901, -5.432, 80.716]
diwarnai dengan warna: merah

Deskripsi hasil Bruteforce:
Waktu eksekusi: 0.003000974655151367s
Jumlah kalkulasi: 1954
Jarak terdekat: 10.8097264072686
Solusi:
- Titik [136.839, -0.407, 90.062] dengan titik [138.901, -5.432, 80.716]
diwarnai dengan warna: merah

3. test case 3

input	n = 128, dimensi = 3, lowerbound = -200, upperbound = 200
output:	Masukkan jumlah titik: 128 Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal): 3



4. test case 4

input	n = 1000, dimensi = 3, lowerbound = -200, upperbound = 200
output:	

Masukkan jumlah titik: 1000
Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal):
3
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[-144.917, 168.344, 6.999], [-53.467, 82.827, -165.199], [183.44, -140.193, 166.377], [-91.51, 54.395, -76.444], [-57.625, 146.376, 174.21], [-183.297, 149.343, -180.026], [-91.845, 29.457, 73.573], [58.08, 144.811, 107.099], [-180.727, -161.345, 46.518], [14.436, -140.764, -140.994], [-105.389, -188.668, 58.704], [49.844, 92.56, -2.429], [-133.983, 135.881, -188.968], [-7.831, 28.405, 88.577], [69.585, -55.527, -98.589], [-91.881, -153.483, 153.841], [66.832, -180.46, 42.384], [192.358, -156.562, 86.356], [32.527, 49.823, 3.825], [50.385, 116.553, 93.786], [-127.81, -22.372, 72.885], [-196.502, 9.267, -68.744], [-145.173, -165.067, 72.674], [-48.485, -39.173, -152.524], [-177.096, -180.196, -198.39], [104.21, 181.935, -157.457], [143.84, -198.802, -110.13], [126.819, -83.821, -23.895], [-1.21.326, 63.617, 135.834], [-40.212, -93.001, -70.707], [-54.687, 40.411, 5.878], [-112.681, -184.793, 199.892], [30.633, 139.17, 15.822], [82.216, -126.321, 105.085], [133.383, 36.472, -22.994], [136.859, 98.747, 41.186], [-150.848, -67.724, 45.776], [-57.615, -128.621, 1.487], [-13.574, 104.458, 183.893], [16.188, -141.354, 39.107], [-192.569, 159.427, -161.901], [46.39, 140.522, 25.493], [-152.668, 127.929, 6.588], [174.134, 189.931, -119.006], [137.767, 28.991, 101.692], [11.498, 17.445, 199.406], [100.366, 190.617, -28.222], [156.58, -186.857, -111.019], [-187.726, 17.591, 0.575], [-113.834, -134.784, -90.793], [77.288, -21.524, 102.686], [-12.839, -75.679, -55.585], [-26.912, 151.861, -86.664], [-107.828, 154.041, -12.417], [-178.875, -183.725, -108.251], [-94.588, 125.194, -65.924], [158.217, -93.894, 157.99, 11], [5.225, 147.162, 169.649], [154.232, 186.174, 14.562], [9.981, 168.945, -32.756], [188.6, -107.435, -109.73], [128.479, 22.012, -28.775], [11.113, -188.786, 27.423], [31.942, -40.037, -132.351], [40.875, -85.436, -198.750], [-5.802, -114.498, -176.081], [-12.686, 127.842, -183.489], [126.991, 51.537, -198.429], [193.988, 37.971, -36.377], [-61.772, -198.375, -52.935], [-133.414, -66.408, 168.635], [-168.041, -95.629, 33.557], [-40.143, -71.715, 165.826], [-105.630, -132.641, -187.733], [153.569, -14.016, -117.579], [129.325, -17.138, -85.556], [-43.62, -141.478, 178.783], [85.69, -92.854, -184.740], [-94.299, -2.567, -31.093], [-199.569, 1.832, -83.954], [-35.418, -35.14, -145.593], [-111.101, 194.503, -198.754], [-139.9, 131.184, 65.478], [-109.184, -143.09, 130.389], [35.618, -150.127, -102.555], [108.916, 1.278, -147.025], [-0.945, 23.274, 21.107], [-146.754, -197.465, 21.68], [131.818, 170.439, 174.095], [60.485, 8.406, 105.3], [-163.578, 25.763, 128.058], [-69.253, 1.429, 59.451], [-89.626, -96.006, 12.336], [-73.962, -111.723, -169.022], [132.659, 169.888, -191.729], [50.358, 87.577, -171.505], [109.231, -158.639, 86.374], [10.093, 183.74, 29.387], [-186.611, 156.747, 146.44], [25.691, -108.527, -130.254], [-28.455, -14.708, -170.599], [121.401, 37.494, -33.429], [-10.272, 128.888, 187.35, 2], [-3.391, 133.184, -129.001], [189.739, 130.831, -156.198], [151.649, 64.988, -43.860], [-94.48, -68.631, -161.604], [-146.81, -52.172, 154.586], [-199.491, -191.09, 30.020], [-30.020], [-156.282, -175.007, 19.479], [112.335, -191.248, -160.831], [-129.202, -179.973, 67.405], [136.072, 20.765, -85.408], [-118.777, -160.695, 111.152], [52.001, -22.779, 17.004], [151.219, 96.416, 79.82], [78.101, 105.076, -32.433], [-27.149, -198.903, -65.849], [132.437, -156.94, 36.827], [57.849, 18.507, -45.218], [-164.405, 6.102, -66.812], [108.565, 19.703, 106.657], [-26.31, -74.933, 105.728], [117.299, 91.745, 14.994], [56.876, 24.766, -152.518], [166.356, 4.3, 164.016], [-7.4555, 7.788, 76.703], [63.057, 68.371, -77.959], [-61.52, 83.37, -153.388], [95.117, 162.632, -62.079], [107.737, -128.294, -48.909], [-193.963, -180.797, 75.021], [-98.002, 68.723, -190.798], [109.765, -154.621, -35.684], [-20.814, 11.826, -180.898], [143.485, 96.276, 4.839], [-189.275, -187.719, 24.004], [-78.584, 190.98, 192.033], [124.068, -156.306, 193.799], [102.888, 130.172, -98.003], [-172.46, 119.138, 158.8], [-61.542, 139.344, 151.835], [-43.975, 42.688, 68.706], [6.601, -132.19, 1.33.126], [-154.996, 56.583, -50.532], [52.453, -35.18, -24.81], [23.302, 0.131, 20.904], [-35.114, -40.52, 44.653], [26.271, -2.002, -20.857], [-156.857, -191.794, -30.020], [-16.959], [137.022, 33.361, 51.064], [-133.238, -134.965, 37.664], [-128.701, 141.796, 25.856], [48.094, -139.816, -177.807], [-170.514, 160.268, 67.247], [-133.581, 190.04, 173.215], [-125.294, -150.922, 21.058], [-118.836, -129.568, -20.361], [3.305, 44.847, 155.462], [-83.124, 3.824, -197.809], [-42.774, -16.366, -83.918], [-79.731, -194.914, 126.779], [-142.58, -21.345, 159.551], [-161.712, 35.58, 72.951], [-129.41, 42.346, 184.05], [-137.169, 189.373, 158.596], [-166.549, -146.898, -14.348], [122.697, -17.032, -197.677], [17.998, -118.32, -146.632], [22.426, -22.393, 99.196], [-76.285, -5.792, -172.859], [115.486, -108.744, -154.342], [0.246, -35.562, 126.983], [4.278, -153.737, -142.803], [44.667, -78.86, 22.733], [54.295, 106.283, 38.006], [63.314, 139.678, 62.724], [-87.815, 195.026, -148.075], [189.253, 1.0552, 77.51], [-2.178, -23.21, -41.905], [112.551, -83.95, -75.495], [-72.225, -73.024, -14.986], [-67.523, -76.808, -66.12], [-192.545, -160.834, -73.266], [-194.52, 5.115.859, 105.407], [-44.834, -95.003, 107.462], [168.462, -22.296, 30.857], [22.005, -52.599, -20.121], [-140.594, 109.004, -39.65], [166.320, -107.505, 16.934], [-16.959], [-182.838, 18.965, 55.82], [83.661, -142.382, -23.584], [-85.289, 138.964, -76.545], [27.096, 116.172, 164.515], [78.848, -120.846, 183.161], [168.527, -101.702, 133.693], [140.853, 36.701, -61.918], [164.521, -44.31, -183.2], [-108.851, 41.748, -147.495], [78.408, 154.665, 108.848], [-116.412, -189.658, 160.981], [-125.43, -15.344, 45.725], [-17.995, 5.417, 142.042], [-93.548, -34.72, -135.119], [-3.836, 109.864, -66.59], [87.526, 107.286, 48.363], [5.887, 175.355, -162.361], [183.235, -10.4.166, -17.412], [112.975, 114.016, 95.577], [-88.446, -148.476, -76.468], [179.167, -168.623, 145.957], [167.991, 131.371, 111.737], [65.313, -20.367, -75.983], [-1.52.754, 1.075, -149.859], [-82.293, -86.535, -165.062], [28.402, -20.892, 68.476], [-26.37, 115.387, 56.703], [69.052, 135.515, -155.661], [-141.336, 87.626, -10.945], [-4.182], [-49.729, -1.205], [-145.712, -164.138, 81.311], [168.877, -179.174, 82.561], [173.2, 126.229, -61.181], [-86.465, 124.666, 15.169], [-39.737, 48.523, -17.870], [-11.983, 111.479, -20.02], [-137.381, 42.293, -193.659], [-89.429, 123.116, -101.731], [62.093, 68.824, -91.690], [-128.459, 141.577, 90.204], [52.369, -126.004, -168.508], [169.118, -51.017, 61.409], [-11.705, -185.213, 27.443], [-127.71, -168.82, 78.734], [-26.23, 129.557, 12.092], [96.135, 126.33, -42.737], [-95.562, 66.296, -22.008], [12.151, -30.75, -55.577], [110.289, -31.582, -97.062], [-188.005, -143.634, 44.61], [62.901, 58.405, -139.094], [-49.124, -103.915, 61.345], [-42.64, 7.68.094, 172.335], [91.574, -108.12, -10.266], [-118.078, -175.988, -77.222], [36.07, 141.768, -63.422], [-66.821, 107.929, -76.149], [186.793, 199.598, -108.035], [-25.76, -31.62, -173.611], [-195.835, -50.773, 96.993], [164.42, -129.073, -123.559], [-92.232, 165.714, 15.509], [-194.626, 41.684, 80.897], [-162.624, 182.714, -117.944], [152.645, -92.943, -69.355], [-66.722, -119.34, -45.004], [167.022, -104.67, 196.687], [-164.138, -48.351, 182.562], [39.493, -166.759, 162.780], [25.258, -180.341, -56.790], [-174.311, -51.508, -150.304], [-179.295, 110.702, 72.463], [-189.87, 72.784, -136.707], [-44.836, 107.466, -189.332], [0.359, 191.215, -118.409], [-105.916, -99.81, -48.699], [-98.325, -52.093, -172.020], [154.486, -104.471, 191.355], [189.206, -176.817, 84.11], [-154.55, 181.406, -148.059], [123.217, -122.4.171.978], [-39.825, -5.929, -2.515], [-14.709, 14.172, -44.848], [-68.962, -78.894, -180.179], [131.276, 192.615, 88.766], [7.037, -121.841, -66.359], [192.782, 2.8.449, 166.934], [49.801, -180.389, -88.802], [-120.794, -94.892, 2.359], [47.519, 162.004, 61.212], [162.292, 58.583, -32.838], [84.696, -95.219, -91.695], [-68.283, 39.524, 45.414], [32.405, 76.166, -148.434], [-71.564, -90.149, -152.699], [135.88, -58.2, 90.204], [-0.217, -23.733, 148.479], [-176.522, 193.318, 131.293], [159.388, -159.387, 182.557], [-45.258, -178.302, 84.934], [-72.447, -45.615, -49.903], [-45.933, -161.194, -46.218], [-47.026, -26.098, -101.225], [-79.851, -1.122, 160.112], [191.666, -188.095, -126.56], [143.271, -153.587, 144.545], [-103.211, 46.718, -189.511], [-122.058, -183.721, 16.51], [-129.522, 85.338, 67.776], [21.574, -6.7.04, -92.415], [171.34, 115.835, -119.701], [-10.009, 108.169, -52.039], [190.472, 35.409, -20.121], [-140.594, 109.004, -39.65], [166.320, -107.505, 16.934], [6.298, 115.770, -116.172], [157.205, -177.746, 191.361], [141.241, -199.596, 120.279], [183.437, 194.215, 58.369], [24.669, -43.405, -175.907], [-99.562, -1.259, 184.637], [-35.733, -118.338, 165.591], [156.401, 44.872, 93.811], [-113.48, 46.405, -86.493], [-65.585, -79.145, 162.28], [159.73, 2.572, 114.123], [118.899, -132.299, -5.575], [-153.918, -68.73, -144.153], [54.964, 192.584, 110.119], [196.335, 64.165, 185.037], [-73.199, -58.45, -100.434], [135.391, -163.652, 50.871], [158.847, 53.637, -128.124], [161.641, 162.24, 18.692], [140.155, 135.973, 168.835], [-36.883, -141.92, 46.828], [69.611, -62.61, -137.178], [188.764, -51.647, -51.358], [-142.083, 51.065, 187.569], [29.142, -28.984, 1.607], [63.022, -191.257, -1.252], [-183.627, -72.541, 189.239], [117.61, 43.26, 110.577], [-172.774, -139.663, -7.965], [179.454, 96.866, -143.382], [142.486, 15.69, -67.634], [-0.761, -15.114, 152.234], [-89.933, -144.944, 54.934], [-161.837, 6.207, 164.277], [28.811, 134.612, 18.684], [-160.308, 151.658, -122.722], [-19.634, 9.102, -10.903], [-113.261, -154.277, 65.304], [-70.837, -66.162, 70.562], [136.998, -51.367, 83.525], [134.304, 176.425, 153.369], [-139.1, -74.081, 74.954], [-134.421, 101.481, -25.12], [-18.076, 44.728, -177.609], [-102.068, -121.839, 141.331], [18.615, 8.222, -131.452], [-169.368, 5.125, 18.036], [-145.888, -2.787, 153.281], [-78.559, 99.475, -81.189], [-159.136, -4.978, -131.919], [-176.383, -69.326, 83.518], [4.936, 4.088, -13.767], [-63.07, -139.992, 144.478], [97.644, 87.297, 15.789], [174.021, 117.507, -124.754], [82.455, -130.233, 86.427], [-139.197, 133.691, 38.21], [-137.712, 24.733, -113.993], [154.207, 115.912, -126.866], [100.519, 50.105, 20.952], [24.582, -129.345, 189.241], [-163.827, 105.618, 54.432], [188.839, -64.755, 49.237], [-167.354, 45.424, 182.239], [-123.085, 189.93, 92.325], [-88.761, -21.409, -136.175], [154.555, 17.891, -46.299], [112.964, -47.832, -107.221], [-43.114, 25.768, 45.046], [101.133, 93.9, 129.618], [177.437, 185.465, 134.136], [-63.026, 41.807, -36.415], [-63.659, -18.400, 1.407], [189.24, 117.459, 24.951], [-181.329, 115.485, -11.238], [126.888, 169.284, -89.382], [52.696, -185.097, -80.708], [-77.959, -198.635, 64.443], [170.881, 129.518, -55.469], [102.194, 41.586, -104.836], [51.567, 107.109, 76.157], [70.676, 44.806, -134.826], [-170.295, 40.12, -62.497], [-7.323, 199.893, 84.888], [-118.851, 84.622, 82.775], [-67.18, 128.865, 27.203], [-88.648, 32.914, 103.125], [-179.101, -55.416, 7.725], [-127.995, -179.541, 134.102], [26.758, 104.754, 189.092], [-42.903, 17.378, -167.551], [33.798, -165.541, 157.678], [-136.2, 191.417, 103.793], [5.241, 61.984, -195.473], [-2.206, -161.906, -80.885], [159.861, -12.545, 98.094], [-188.251, 24.071, 40.964], [13.697, 188.766, 12.374], [-153.093, -156.509, -47.481], [85.562, -47.915, -96.384], [-182.54, -172.051, 44.714], [53.298, 146.351, 111.302], [-130.758, 45.854, 3.198], [95.593, -85.888, -13.294], [187.919, -179.053, 180.388], [-125.647, 167.625, 51.772], [22.233, -149.577, -139.775], [-113.112, 75.089, -156.687], [-162.926, 166.257, 37.761], [-165.978, 79.314, -77.405], [88.52, 6.167, 135, 58.801], [35.539, -107.522, 52.408], [134.623, 192.953, 111.011], [-119.181, -110.697, -89.653], [102.946, -6.385, -68.006], [133.274, 143.695, -109.884], [190.329, 61.879, 112.752], [155.631, 130.409, -61.762], [117.551, -6.52, 36.163], [234.694, 58.608, -135.976], [131.474, -181.093, 64.960], [-153.179, 191.089, -74.85, 4], [87.585, -58.859, 104.137], [-27.544, -92.931, 113.37], [-169.197, 118.878, -111.992], [-13.86, -79.578, 100.622], [3.528, -96.365, 193.837], [194.143, 109.584, -2.1], [156.792, -187.096, 164.72], [-198.913, 101.786, -87.128], [141.127, -133.557, 6.165], [198.945, 195.128, 107.529], [121.263, -191.995, -161.137], [-97.341, -38.803, 30.672], [66.666, 90.213, -99.8], [134.693, -174.864, 58.953], [22.845, -20.71, 25.949], [-119.007, 185.339, -92.054], [44.657, 160.018, -13.41], [159.096, 1.43.261, -124.121], [117.958, -125.803, -162.979], [107.978, 58.046, 115.54], [61.683, -2.529, 186.756], [-44.766, -143.747, -108.874], [185.406, 5.06, -198.416], [3.07, -179.223, -42.6], [-187.83, -139.832, -136.503], [-194.601, 93.15, 139.356], [19.225, -122.471, 47.198], [46.165, -142.153, 65.469], [-129.751, -74.319, 104.761], [-131.43, 115.081, -107.263], [-93.622, -101.927, 108.985], [-45.172, -107.827, -76.031], [-101.723, -122.906, 135.481], [-161.219, -91.946, -146.455], [-140.261, 176.409, 113.537], [172.934, -1.8, -144.129], [190.594, 107.975, -72.541], [156.672, -39.272, -36.6], [12.06, 107.674, 37.998], [193.061, 49.339, -158.402], [-16.009, 186.507, -92.635], [-65.643, -143.233, -179.161], [-54.977, -123.537, 12.168], [47.684, 50.647, 110.721], [68.153, -137.388, 191.194], [195.604, 15.755, 75.889], [2.9.035, 99.424, 155.854], [160.191, -189.753, 83.326], [126.972, 99.459, -52.069], [-162.478, 108.666, 23.624], [-142.186, -164.454, -186.642], [-178.555, -10.156, 11.1.35], [167.821, -130.163, -55.798], [56.248, 39.807, -10.881], [73.774, 89.586, 197.687], [-170.468, 95.098, -193.13], [36.895, 158.831, 129.582], [-165.27, 106.138, 1.92], [-165.666, -96.362, 131.359], [141.073, 31.838, -121.261], [-26.094, -12

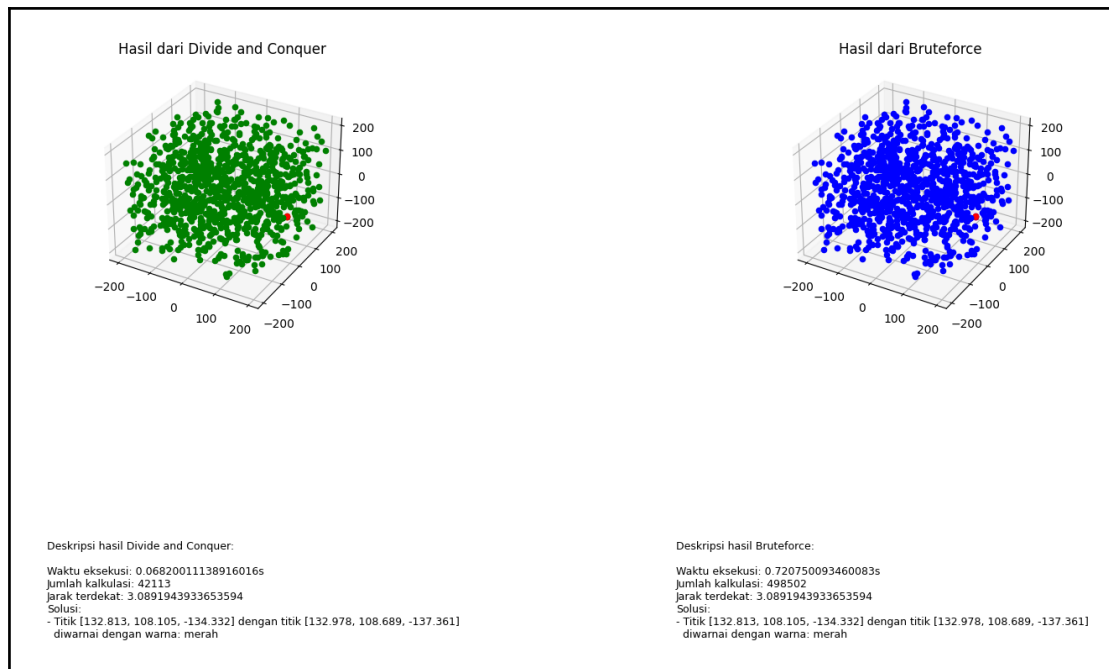
74, 181.627], [73.069, -76.498, 104.168], [-67.135, -128.143, -20.311], [107.886, 98.845, -43.171], [126.685, 183.554, -194.092], [-128.222, 137.927, -50.545], [67.8
36, -5.275, -10.959], [-98.88, -160.39, 144.164], [127.402, 7.131, 160.457], [169.578, -158.582, 53.695], [-140.265, 50.959, -183.781], [111.74, -188.147, -179.821],
[192.487, 157.442, 188.495], [-32.632, 152.447, -12.134], [-142.453, -101.439, 163.848], [-194.825, -38.666, 189.48], [-0.349, 47.924, -151.111], [-167.221, -11.672
-, -104.031], [-119.341, 147.814, 65.962], [16.835, 112.187, -24.415], [24.236, -172.653, -71.385], [130.97, -185.437, 185.874], [-60.165, -5.365, 27.84], [43.774, -1
39.651, 10.318], [-129.717, 38.912, -150.349], [-81.872, 77.688, -178.05], [-82.598, 39.598, 48.224], [3.527, 37.719, -85.889], [186.993, 3.067, 25.578], [3.934, -98
826, 134.003], [61.972, -5.954, 167.126], [19.438, 58.832, 16.355], [-92.931, 129.115, -40.878], [-49.117, 91.793, 158.912], [144.265, -124.955, 64.445], [-51.658,
173.246, 191.639], [-88.934, -114.081, 67.574], [-179.82, -0.035, 65.522], [-18.882, 25.714, 118.481], [-16.171, -182.595, 128.826], [-95.793, -174.778, -162.08], [-
95.285, -120.629, 169.907], [-150.588, 131.54, -7.428], [-63.751, -42.921, -88.352], [48.824, 109.992, 191.533], [24.304, 190.555, 65.695], [-122.997, -178.656, -35.
39], [24.602, 41.32, -33.018], [-113.902, -89.949, -66.237], [-58.6, -97.221, -186.573], [164.245, -140.864, -7.877], [-154.668, 2.238, -48.947], [20.284, 197.071, -
146.126], [106.764, 46.69, -68.981], [-91.959, 135.062, -199.999], [-15.356, 162.774, -162.253], [-32.03, 55.556, 111.102], [-197.812, -165.262, 76.584], [-188.486,
-84.076, -182.319], [-45.823, -173.781, 53.484], [178.659, 27.419, -196.29], [-40.627, -89.415, 157.221], [71.596, -3.0, 32.549], [-139.96, 154.135, 64.437], [-134.2
83, 68.417, 123.273], [195.837, -53.817, -42.01], [-9.819, -105.958, -52.722], [-74.992, -51.558, 102.466], [-115.421, 192.409, -8.404], [71.532, 95.66, 134.877], [-1
229, -49.595, -140.889], [-72.19, -173.489, -154.914], [93.249, 95.18, -120.56], [-160.737, 88.618, 95.413], [69.531, -13.705, 113.22], [-179.993, 195.707, -35.528]
[101.189, -153.262, 13.246], [-118.186, -61.215, -67.094], [180.373, 46.4, -6.468], [-5.358, -79.334, -77.32], [65.586, -164.389, 12.887], [-51.831, 135.116, -4.57
2], [183.847, -10.726, -187.825], [-174.331, 192.034, -93.111], [123.669, 98.155, -139.047], [-74.024, -163.125, -43.369], [164.68, 89.842, -11.68], [10.852, -9.777,
-126.302], [45.101, -63.041, -10.829], [192.277, 95.022, -82.736], [41.256, -148.536, 154.05], [-101.666, 123.248, -135.131], [-48.511, 83.17, -38.698], [-9.713, -
35.683, -102.932], [152.084, 154.571, 64.515], [-136.254, -74.41, 27.264], [183.544, -82.974, 33.064], [131.571, -60.934, -168.344], [131.233, -139.983, [-188.486,
-77.069, 94.464, -27.814], [-175.213, 140.386, -138.251], [62.273, 132.757, -134.987], [-113.944, -117.633, -12.417], [-143.927, -38.585, -171.178], [-30.218, 21.906,
132.409], [-122.824, -64.069, -162.009], [89.466, 19.354, 0.608], [-405.604, 21.604, 23.030], [61.097, 127.203, 177.408], [188.423, 151.655, -34.715], [-30.526, 42.9
08, 181.958], [-167.671, 27.769, -139.525], [188.324, 88.289, -18.482], [-188.052, 143.588, 191.49], [-42.879, 47.118, -0.279], [199.039, -140.624, 172.441], [-26.91
4, -78.069, 184.515], [-119.424, -42.324, 118.931], [-91.748, -70.075, 132.394], [-195.433, 88.875, -90.522], [-5.107, -78.396, 160.166], [-94.666, 77.671, 125.098],
[-142.571, -165.6, -38.44], [-149.476, -169.844, -33.712], [-133.731, -7.39, 110.993], [6.03, 80.954, -71.919], [192.16, -51.946, -156.883], [18.999, -122.139, -53.
137], [-95.053, 189.452, 17.905], [97.335, 64.489, -148.232], [-39.609, -76.422, -182.66], [-69.849, -113.345, 82.117], [154.899, -111.832, 4.15], [-194.14, -183.824
, 154.15], [-23.312, 122.839, 184.934], [-30.465, -163.445, -64.219], [-51.681, 198.218, -188.703], [21.887, -74.233, -42.964], [-136.583, 46.133, 190.787], [68.137,
-110.056, -40.128], [-180.464, 128.446, -61.002], [3.702, -148.373, -65.099], [121.229, 27.378, -47.738], [-46.035, -19.01, 119.245], [154.863, -92.768, -110.163],
[60.704, 104.233, -47.557], [81.076, -72.943, -1.18], [-120.236, -26.309, -67.669], [-118.821, -3.537, -120.85], [-47.289, -79.423, 87.763], [-199.482, -121.017, -18
3.93], [132.978, 108.689, -137.361], [-2.383, 173.308, 1.877], [-126.382, 54.248, -8.743], [-66.544, 190.736, -165.874], [-111.345, 183.323, 109.427], [-33.093, 130.8
833, -60.016], [-104.572, -82.139, 164.828], [-47.537, 61.619, -106.192], [193.693, 179.131, 155.654], [-125.458, 31.034, 185.664], [44.68, 142.094, 89.892], [188.4
43, -185.673, 158.126], [-125.862, -9.4, 24.152], [-27.324, -96.875, -10.403], [42.923, 184.706, -157.322], [-189.326, 194.85, -86.984], [-189.326, 194.85, -86.984], [1
44.636, 91.738, 174.259], [57.421, -5.323, -19.175], [-56.911, -0.604, 68.457], [81.188, -161.325, -59.453], [-197.685, -65.688, 190.691], [-67.349, -117.556, 181.2
3], [-59.586, 28.884, -76.923], [36.65, -183.272, -58.355], [171.807, 13.626, -197.66], [81.814, 152.663, -170.894], [-69.541, 165.964, 51.744], [128.964, 175.465, 9
0.057], [133.836, -157.51, 70.424], [87.295, -168.605, 65.562], [-73.627, -163.783, 175.108], [-126.214, -72.505, 132.727], [172.34, 104.94, 137.562], [124.99, -101.
553, -170.307], [-71.302, 177.596, 122.219], [9.561, 45.042, 115.256], [41.334, -72.718, 116.531], [196.965, 38.691, 133.391], [29.436, 172.991, -5.522], [0.375, -89
409, -48.807], [20.837, -15.888, -118.368], [-123.797, -33.101, 168.868], [-136.881, -95.809, -0.196], [-65.214, 117.919, 25.106], [-110.525, -78.623, -111.632], [-1
174.938, 191.127, -41.112], [-4.256, 87.564, -191.286], [156.951, 80.522, -20.121], [-24.273, 29.243, 40.76], [172.989, -89.66, -3.035], [-40.443, 77.898, -48.658],
[27.355, 68.389, 87.751], [197.539, 133.271, -172.141], [-37.637, -108.515, -27.369], [11.64, -26.256, -77.849], [39.426, -121.937, -17.732], [-80.798, -166.229, -42
.647], [-109.253, 104.385, 169.052], [149.615, -87.99, -160.153], [84.728, -23.086, 24.31], [-87.475, 126.541, -120.425], [134.693, -60.769, 98.373], [-96.207, -116.08
3, 1.87], [-181.221, -101.634, -26.739], [-83.532, 28.228, 198.977], [-185.081, 148.536, -53.033], [-165.493, 64.068, 171.151], [114.537, -107.102, 23.209], [-9.124,
145.603, 87.106.978], [-132.706, 164.878, -150.911], [194.409, 188.926, -129.061], [-126.023, 60.106, -157.090], [-108.921, 83.871, -14.304], [-105.286, -119.477, 106.8
14], [132.813, 108.105, -134.332], [39.453, 22.11, 184.684], [-38.353, -81.019, -139.447], [105.272, -55.942, 148.047], [27.476, -164.543, 73.042], [-68.278, 113.830
, 155.185], [-16.260, 30.363, 20.841], [186.601, 13.392, 185.725], [157.314, -41.726, 24.218], [0.478, -197.741, 82.996], [-111.26, 81.833, 63.428], [-121.823, 118.9
04, 142.837], [-155.931, -114.434, -32.655], [-52.516, 87.869, -125.38], [-159.976, -28.496, -66.26], [140.423, 151.542, -178.454], [-78.809, 91.672, -152.571], [-135
.089, 194.225, -47.003], [-62.785, -67.892, 184.149], [-69.615, -53.007, 62.058], [-25.259, -41.995, -175.428], [53.514, 41.563, 163.557], [-174.292, -117.423, -166.
448], [-47.556, 28.596, -55.857], [134.439, 171.849, 2.697], [-66.864, -66.412, 13.621], [-79.162, -173.39, 54.434], [-92.163, 109.476, -17.331], [199.716, 156.878, 7
0.167], [71.052, 102.183, 186.898], [122.638, -105.586, -168.815], [-185.105, -170.389, 21.522], [-106.97, 41.129, -162.881], [-97.709, -122.827, -96.153], [59.007,
155.908, 199.918], [-45.98, -166.891, -71.099], [193.281, -72.652, 94.272], [38.26, -30.991, -167.63], [47.43, 89.371, -74.437], [113.439, 108.418, 105.722], [-51.53
-, -184.781, -179.141], [-129.704, 129.217, 60.843], [183.151, -22.903, 115.455], [94.684, 176.27, 16.913], [60.043, 126.089, 108.981], [99.004, 2.39, 58.056], [162.
678, -44.008, -80.398], [103.384, -1.211, -64.382], [82.895, 99.282, 118.518], [176.375, 175.327, 65.359], [-45.11, -37.296, 122.105], [-165.968, 16.845, 115.704], [-
15.808, -122.432, 130.09], [55.052, -38.107, -163.256], [174.266, -133.229, 121.676], [-35.812, 44.422, 88.46], [98.332, 102.727, 133.417], [161.023, -18.439, 135.0
9], [49.507, 117.899, -107.393], [69.722, -184.161, 65.974], [-168.155, -162.82, -122.06], [-159.473, -159.328, -116.581], [132.543, -168.521, -78.513], [-34.235,
-41.622, 83.368], [-171.078, -136.214, 62.055], [94.313, 14.869, 86.473], [-8.085, 73.112, 80.673], [-182.428, -19.104, -112.188], [92.565, 185.073, 108.043], [-51.5

2, 149.446, -154.283], [-23.889, 94.65, -50.235], [-152.404, -190.061, -114.608], [-130.477, 9.23, 57.201], [61.033, 23.705, -184.243], [-93.405, -24.880, 134.393],
[-157.152, -71.111, 99.423], [193.577, -71.82, 116.636], [21.095, 18.004, -137.208], [56.903, 65.185, -94.79], [-70.477, 107.474, -73.637], [33.048, -45.962, -140.99
9], [-86.712, 43.666, 39.543], [60.002, 141.602, -32.004], [125.87, 71.809, 18.750], [-60.406, 111.518, 42.781], [112.863, 189.164, 134.215], [189.55, -31.881, 65.06
9], [41.095, 93.613, 20.183], [-43.502, 56.058, 27.207], [-115.366, -101.33, -197.923], [-12.805, 183.657, 93.826], [99.409, -82.519, -13.611], [-74.634, 170.214, -2
0.141], [196.882, 54.238, -132.551], [172.125, 180.668, -49.005], [118.877, -139.993, 158.904], [97.737, 123.851, -179.338], [17.793, 72.56, 25.237], [47.118, -82.87
0, 168.341], [-1.897, -35.883, -3.995], [-167.1, -34.354, -132.718], [189.619, -41.925, -108.144], [179.511, -178.768, 182.585], [136.194, -10.776, -24.459], [188.62
5, 185.05, -41.204], [115.394, -180.321, 131.979], [-76.52, 0.532, -110.51], [107.694, 157.362, -123.023], [-166.123, -407.226, -183.749], [184.724, -109.497, -49.740],
[7.904, 70.804, 93.523], [61.798, -31.251, 0.012], [176.375, 191.104, 2.473], [-125.994, -62.139, -102.335], [180.664, -115.119, -42.265], [176.308, 14.664, 72.352
1], [-114.281, -49.424, 37.593], [24.048, 30.799, 12.939], [-138.483, -56.951, 97.849], [38.077, 46.328, 146.32], [-121.421, 117.732, -81.14], [107.111, -59.539, -67.
295], [151.519, 162.54, 86.376], [161.71, -160.207, -97.586], [110.091, -94.448, 110.719], [-95.478, -158.009, 127.716], [-95.478, -158.009, 127.716], [-132.516, -17.41
8, -172.104], [-190.034, 162.718, -11.041], [144.468, 69.711, -21.464], [85.507, 36.317, 165.259], [190.686, -112.288, 17.258], [28.957, -109.961, -33.097], [-6.573,
-140.138, -91.701], [-28.018, 107.169, 29.079], [185.996, -21.547, -28.363], [-156.361, 21.075, -115.381], [167.564, 156.073, 85.254], [-111.022, -119.211, 79.245],
[-169.165, 7.258, 157.936], [-165.916, 145.783, 10.645], [157.828, -77.831, 182.581], [35.724, 93.024, 190.958], [-91.566, -62.241, 127.075], [21.771, -36.288, 165.
621], [-95.007, -54.472, -151.232], [52.832, 16.072, 130.133], [-175.981, 41.324, 111.971], [-101.555, -56.304, -188.401], [50.707, -57.724, 141.422], [-39.627, -167.
828, -91.785], [-74.778, 197.412, 100.892], [49.648, 144.71, -40.121], [-40.077, -50.819, 169.158], [-101.353, 14.831, -32.602], [170.808, 45.113, 106.206], [-139.89
4, -97.598, 166.779], [-67.741, -47.71, -62.971], [-69.813, 170.796, 155.966], [195.938, -45.409, -57.805], [105.097, 87.131, 147.764], [50.266, 155.433, -127.668],
[-89.224, 125.722, 149.941], [-3.855, -83.597, 79.903], [-191.978, -137.064, 81.821], [137.412, -75.37, 91.278], [177.016, -114.494, -131.714], [170.923, 48.238, 52.
839], [164.059, -40.33, -9.499], [104.612, -5.111, -158.322], [-176.579, -18.079, 125.387], [-17.962, 94.016, 41.866], [-131.047, 132.4, 173.332], [-74.13, 196.698,
-194.364], [24.23, 25.382, -70.099], [16.142, -131.784, 171.931], [-184.89, 152.039, -135.212], [-136.584, -30.068, 176.877], [89.249, -183.003, -35.184], [64.277, -
100.283, 90.71], [113.798, -99.447, 182.817], [-191.636, 66.775, 187.876], [-180.643, 25.362, 54.309], [-187.419, 39.741, 178.248], [-136.008, 111.908, -185.475], [92
186, -6.908, 144.09], [173.562, -86.902, 178.428], [137.102, 132.871, 20.572], [91.066, 7.94, -188.046], [67.393, -125.625, 101.338], [152.538, 164.749, 41.297], [-
161.329, -189.825, -153.373], [-176.086, 41.625, -113.978], [-18.079, -162.431, 176.792], [20.749, -169.223, 86.625], [-36.242, 5.537, -18.669], [-28.225, -0.619, -
25.723], [-2.3, -56.958, 106.753], [195.37, -65.28, 16.854], [-23.601, 46.459, 173.463], [20.908, -106.194, -24.776], [-133.117, -167.986, -110.792], [86.935, 18.934
, 26.405], [199.929, -171.333, 93.449], [160.269, -127.337, -157.956], [154.798, 120.264, 48.241], [135.824, 62.138, 19.074], [-147.648, 123.799, -80.689], [102.806,
89.299, 111.238], [23.569, -170.208, -5.586], [-76.272, 18.148, -93.931], [2.292, -186.411, 36.237], [101.962, 128.421, 76.051], [-33.756, 64.065, -187.077], [-93.4
16, -198.136, 127.749], [-169.007, 51.804, 74.576], [-155.79, -151.716, -76.407], [164.171, 21.589, 190.544], [-64.228, -52.325, 144.776], [197.943, 101.681, -13.876
1], [-60.568, -0.804, -88.392]

System : Windows
Node Name : DESKTOP-7GDFHFG
Release : 10
Version : 10.0.22621
Machine : AMD64
Processor : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD

Deskripsi hasil Divide and Conquer:
Waktu eksekusi: 0.0602001138916016s
Jumlah kalkulasi: 42113
Jarak terdekat: 3.0891943933653594
Solusi:
- Titik [132.813, 108.105, -134.332] dengan titik [132.978, 108.689, -137.361]
diwarnai dengan warna: merah

Deskripsi hasil BruteForce:
Waktu eksekusi: 0.72750093460083s
Jumlah kalkulasi: 498502
Jarak terdekat: 3.0891943933653594
Solusi:
- Titik [132.813, 108.105, -134.332] dengan titik [132.978, 108.689, -137.361]
diwarnai dengan warna: merah



5. test case 5

input	n = 100, dimensi = 1, lowerbound = -200, upperbound = 200
<p>output:</p> <pre> Masukkan jumlah titik: 100 Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal): 1 Masukkan batas bawah nilai titik (note: maksimal -1000): -200 Masukkan batas atas nilai titik (note: maksimal 1000): 200 Titik yang digunakan: [[-44.148], [-188.715], [40.731], [11.315], [-114.945], [179.981], [88.729], [74.633], [-99.526], [50.53], [-145.997], [86.595], [44.996], [-19 6.19], [-88.518], [-134.121], [105.458], [160.088], [-157.426], [-120.822], [-169.496], [-87.77], [-67.639], [47.289], [-74.486], [-177.96], [-69.469], [64.751], [-6 1.059], [-138.456], [129.582], [146.99], [185.026], [-185.225], [180.192], [116.79], [55.326], [51.927], [46.074], [-71.01], [168.401], [114.402], [186.894], [-174.0 39], [-65.426], [49.69], [-12.166], [186.758], [16.320], [-120.807], [1.665], [-16.209], [-87.381], [-111.603], [10.532], [-131.404], [-78.268], [-53.632], [-187.709], [-27.43], [-86.331], [-94.805], [-88.971], [43.590], [-102.495], [-111.888], [104.603], [81.253], [10.929], [-88.938], [-149.236], [101.894], [22.660], [63.398], [-88.273], [37.432], [-57.165], [-187.454], [40.892], [157.281], [-175.935], [42.729], [-45.33], [-148.217], [-119.405], [199.326], [-193.643], [-189.283], [86.983], [120.274], [50.77], [4.826], [-54.772], [12.084], [12.742], [81.422], [94.581], [-132.137], [86.394], [154.729]] System : Windows Node Name : DESKTOP-7GFDHFG Release : 10 Version : 18.0.22621 Machine : AMD64 Processor : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD Deskripsi hasil Divide and Conquer: Waktu eksekusi: 0.0s Jumlah kalkulasi: 92 Jarak terdekat: 0.0150000000000000568 Solusi: - Vektor [-120.822] dengan vektor [-120.807] Deskripsi hasil Bruteforce: Waktu eksekusi: 0.005006074905395508s Jumlah kalkulasi: 4852 Jarak terdekat: 0.0150000000000000568 Solusi: - Vektor [-120.822] dengan vektor [-120.807] </pre>	

6. test case 6

input	n = 100, dimensi = 2, lowerbound = -200, upperbound = 200
output:	

```
Masukkan jumlah titik: 100
Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal):
2
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[-5.493, 92.616], [-44.119, -6.274], [-39.267, 133.094], [-91.244, 155.82], [-107.947, -143.935], [184.61, -138.819], [-164.332, 187.63], [-12
9.952, 185.438], [182.363, 59.552], [91.886, -181.535], [157.681, 74.932], [165.739, -108.965], [199.334, 120.434], [2.53, -126.74], [124.347, -196.711], [-161.602,
-196.189], [153.898, -162.172], [-181.573, 138.893], [158.218, -90.662], [156.222, -174.875], [-48.776, 60.856], [-81.476, -170.818], [-69.527, 74.916], [-87.039, 18
9.976], [116.452, 11.166], [-196.618, -115.588], [-54.472, 178.619], [134.464, -30.091], [-35.447, -11.559], [-186.109, -82.446], [186.546, 193.03], [-3.973, 101.217
1], [119.712, -157.422], [-45.565, 53.881], [170.401, -37.909], [32.844, -186.576], [1.637, -57.483], [-137.909, 93.297], [37.848, -14.824], [-2.958, 168.426], [-151.
098, -180.815], [-18.208, -90.880], [-182.269, 112.572], [162.7, -80.179], [149.456, -109.940], [-159.405, -81.995], [92.018, 199.951], [-89.301, 147.386], [-100.372
, -107.884], [-124.297, -6.872], [-172.933, 148.24], [-133.359, 149.344], [51.552, 80.018], [-171.257, 178.788], [85.638, -142.396], [77.563, 141.825], [18.232, -59.
952], [21.31, -90.207], [196.926, 151.688], [71.216, 164.963], [-63.937, 74.784], [-121.354, -69.039], [-155.974, 184.146], [-112.281, -95.264], [-44.406, -120.011],
[190.733, 94.056], [-143.637, -14.827], [29.743, -185.454], [-118.388, 7.876], [103.706, 143.275], [192.825, 41.568], [-41.37, 122.186], [-99.361, -166.844], [-131.
102, -114.364], [-147.497, -169.791], [39.393, 123.69], [169.489, 76.631], [18.824, -136.076], [159.824, -52.94], [106.56, 15.934], [-74.661, -15.148], [143.968, 17.
846], [74.443, 37.087], [-108.531, -148.497], [-179.666, -197.29], [-61.431, 22.938], [-22.399, 185.538], [-4.322, -162.456], [-98.421, 63.347], [72.166, 50.24], [19
8.703, 189.317], [-12.246, 6.893], [141.723, 141.362], [113.397, -55.502], [-140.851, 146.722], [152.311, -60.679], [73.581, 178.271], [-70.659, -153.105], [19.869,
-114.302], [-108.626, -57.483]]

System      : Windows
Node Name   : DESKTOP-7GFDHFG
Release     : 10
Version     : 10.0.22621
Machine     : AMD64
Processor    : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.000997304916381836s
Jumlah kalkulasi: 409
Jarak terdekat: 4.599228196121618
Solusi:
- Vektor [-108.531, -148.497] dengan vektor [-107.947, -143.935]

Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.00600433349609375s
Jumlah kalkulasi: 4852
Jarak terdekat: 4.599228196121618
Solusi:
- Vektor [-108.531, -148.497] dengan vektor [-107.947, -143.935]
```

7. test case 7

input	n = 100, dimensi = 4, lowerbound = -200, upperbound = 200
output:	
<pre>Masukkan jumlah titik: 100 Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal): 4 Masukkan batas bawah nilai titik (note: maksimal -1000): -200 Masukkan batas atas nilai titik (note: maksimal 1000): 200 Titik yang digunakan: [[-97.208, -72.094, -27.866, 95.043], [-165.799, -98.574, 195.399, -112.356], [-53.102, 1.806, -126.279, -87.455], [-57.404, 109.706, -113.711, 95.585], [165.956, 43.805, 175.496, 69.948], [-138.937, 0.33, -34.821, 170.344], [-29.263, 53.33, -109.539, -99.21], [118.033, -47.471, -129.161, -59.685], [4.928, -100.468, 192.543, 7.734], [120.209, 30.471, 195.148, -186.787], [88.192, 70.451, -64.003, -37.306], [-196.813, 138.787, -197.742, 136.946], [77.766, 187.18, -52.487 , -108.05], [108.021, -109.072, 96.978, 169.787], [-20.791, -107.714, 96.301, 173.872], [24.201, -106.644, 154.513, 55.684], [-51.926, 103.186, 104.838, -104.664], [5 7.227, -100.51, -54.705, 37.869], [59.263, 32.811, 101.919, 25.01], [-71.953, -132.034, 177.804, -119.05], [25.50, -97.032, -32.993, 103.223], [-108.211, -197.552, -6 5.157, -196.409], [87.612, -174.678, -5.747, -52.89], [198.033, -85.018, -169.269, 3.136], [69.411, 14.969, 28.087, 49.525], [-62.313, 104.021, 131.663, 75.416], [5. 328, 193.48, 168.482, -133.142], [55.542, -109.265, 5.494, -57.412], [198.936, -68.116, -139.165, 106.646], [144.363, -16.112, -24.065, 77.962], [29.695, 123.252, 14 9.738, -120.633], [-68.283, -14.661, 144.66, 165.882], [132.811, -93.975, 5.858, -135.758], [63.261, -19.143, 56.201, -186.615], [50.116, -76.141, 124.269, 78.645], [-101.564, 142.028, 33.52, 145.621], [-24.596, -183.637, 111.202, 37.819], [64.321, 179.884, 129.881, -182.069], [-84.745, 120.99, -86.59, -22.893], [-156.212, 7.611, 121.945, 115.56], [19.743, -188.219, -144.833, -82.828], [-91.758, -77.237, 161.628, 98.353], [184.431, -8.167, -80.814, 30.277], [-62.893, 18.115, 157.824, -73.74 5], [-83.62, -64.081, 173.189, 4.563], [-23.717, -100.608, 111.308, 107.859], [-43.331, -143.398, 119.624, -63.973], [-101.968, 69.672, 143.261, -1.179], [-58.596, - 109.595, 194.954, 25.174], [88.72, -78.44, -169.413, -186.230], [64.918, 174.683, -120.216, 20.778], [-107.538, -31.814, 104.746, -108.315], [-152.079, 91.338, 100.0 82, 111.426], [-63.534, -2.860, -71.67, 169.419], [198.323, -195.719, 137.887, 115.589], [-181.13, 70.83, -76.925, -79.540], [65.621, 89.038, 100.163, 143.382], [-17 8.157, -15.349, 130.159, -74.244], [-94.437, 36.104, 63.003, 87.213], [-56.666, -134.076, 118.793, -148.574], [-81.303, 115.315, 27.371, -162.833], [61.527, -127.103 , -85.400, 190.107], [-150.675, 70.662, -21.742, 123.852], [51.594, 91.86, -68.681, -136.202], [54.372, -194.426, 104.376, 120.008], [-182.209, -142.503, 161.734, -6 0.813], [-91.115, -134.289, 159.773, 171.91], [177.388, 105.425, -136.083, 189.01], [90.211, 44.702, 10.879, -86.254], [145.364, 83.374, -116.427, -129.916], [156.97 7, -126.481, 93.101, -4.710], [23.488, -83.307, 76.002, 45.816], [-83.353, -176.052, -109.223, 179.018], [177.231, 106.812, -83.635, 110.476], [-128.081, 63.361, -17 3.306, 50.817], [169.040, 150.607, -174.304, 115.621], [0.891, -150.559, -96.052, 55.209], [37.456, -15.91, -110.917, -181.711], [-121.938, 0.631, -9.554, -17.505], [-50.573, 95.089, 59.062, 120.763], [-24.602, 103.174, 103.829, -164.077], [-24.623, -189.052, -7.957, 119.419], [-53.985, 104.244, -192.395, 174.151], [-129.57, 21. 886, -159.114, 150.364], [-39.906, 195.564, -17.494, 144.197], [41.859, -6.401, 99.996, -126.332], [186.366, 122.350, -78.775, 191.849], [-11.797, -188.239, -50.677, 185.676], [-5.678, 71.847, 155.928, -185.401], [-29.117, 85.629, -104.692, 142.089], [33.347, 166.962, 195.405, 190.168], [-23.096, -97.357, 161.931, 28.715], [-20. 517, -138.043, -153.556, -137.054], [04.021, 103.454, -38.543, -160.718], [-156.917, 0.788, 136.565, -93.361], [113.839, 91.188, 78.108, -30.950], [112.149, -177.04, 52.648, 139.533], [-196.121, 135.386, -144.589, -6.56], [-189.598, 103.269, -174.281, -28.636], [112.506, -190.44, -13.464, -27.411]] System : Windows Node Name : DESKTOP-7GFDHFG Release : 10 Version : 10.0.22621 Machine : AMD64 Processor : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD Deskripsi hasil Divide and Conquer: Waktu eksekusi: 0.003908027572631036s Jumlah kalkulasi: 1663 Jarak terdekat: 21.906686878667887 Solusi: - Vektor [-23.717, -100.608, 111.308, 107.859] dengan vektor [-20.791, -107.714, 96.301, 173.872] Deskripsi hasil Bruteforce: Waktu eksekusi: 0.0008536815643310547s Jumlah kalkulasi: 4852 Jarak terdekat: 21.906686878667887 Solusi: - Vektor [-23.717, -100.608, 111.308, 107.859] dengan vektor [-20.791, -107.714, 96.301, 173.872]</pre>	

8. test case 8

input	n = 100, dimensi = 10, lowerbound = -200, upperbound = 200
output:	


```
Masukkan jumlah titik: 100
Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas di terminal):
10
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[172.671, 70.334, 72.133, 139.475, 87.582, 137.402, 139.173, 181.086, 182.645, 116.199], [-83.869, 185.733, 194.559, 59.625, 72.115, -7.597, 1
60.151, 72.451, 55.563, 112.341], [-193.091, -143.878, 155.868, -156.251, 19.677, 46.712, 17.182, -87.444, 18.573, -40.283], [-52.676, 94.275, -110.652, -23.066, -14
3.397, 23.157, -175.286, -103.452, -183.883, -128.501], [97.687, 126.913, -101.173, -126.876, -18.078, -37.434, -3.47, 15.433, -172.369, 144.175], [-55.851, 167.702,
-117.296, -193.49, 132.21, -87.785, -164.513, 70.784, -3.645, 159.517], [-34.594, 35.912, -25.003, -12.272, -72.189, 82.388, -93.893, -113.391, -78.713, -177.829],
[75.876, 196.783, 162.529, -16.959, 82.426, 198.893, 170.417, 97.693, 178.553, -191.822], [192.363, 97.927, -115.962, -196.519, 118.698, 122.265, 171.403, 172.937, 1
55.915, 64.545], [-9.315, 107.274, 83.59, -140.857, -100.37, 110.869, 104.543, -195.386, -195.189, 102.795], [103.397, -91.936, 66.616, -47.683, -20.445, 127.633, 91
841, -45.683, 167.701, -111.707], [11.97, 155.148, -198.213, 153.889, 110.23, 124.917, -36.626, 97.835, -197.361, 50.582], [-69.2, -5.625, -17.777, 186.994, 32.891,
198.308, 77.007, 161.473, -82.455, 22.253], [-152.068, -188.92, 61.125, -33.272, 75.39, 69.975, 136.335, 15.887, 24.431, -36.327], [-58.814, -193.449, -65.116, -101
.751, -9.087, 129.782, 79.145, 70.415, -198.503, -36.887], [-104.37, 158.764, 147.994, -155.191, 126.295, 74.991, 95.264, 9.193, 153.596, -65.884], [-105.433, 165.41
6, 81.822, -181.43, 155.625, -51.651, 31.326, -176.496, -69.728, -40.338], [158.466, -11.192, 126.672, -59.209, -133.078, -171.336, -161.174, -13.144, 6.837, -120.537
], [-22.765, -154.17, 139.825, -42.747, 22.939, -47.112, -17.897, 125.892, 37.491, -23.365], [133.529, 131.58, -150.96, -24.118, -16.776, 176.524, 173.223, 1
55.518, -108.321], [21.731, -109.4, -82.042, 193.079, 91.111, 2.771, -153.974, 441.295, -141.235, -67.403], [76.804, 23.525, -125.61, 64.704, 164.751, 63.755, -59.47
4, -173.395, 137.001, -37.112], [99.331, 185.316, -62.125, -50.613, 109.05, 41.71, 186.889, -82.209, 69.536, 88.163], [99.527, -127.655, -109.991, 10.656, -105.652,
179.187, 148.457, -184.554, 161.851, 69.785], [66.421, 182.07, 11.17, -199.809, 129.571, 182.332, -53.096, 137.329, -170.281, -45.899], [107.466, 100.018, 32.635, 9
3.87, -106.46, -107.136, -91.611, 8.438, 182.082, -144.194], [-198.344, -61.592, -4.933, -68.823, 148.402, -79.913, 116.919, 158.244, 31.973, -126.01], [-70.854, 98.
615, -101.273, -11.995, 100.184, -160.456, 141.735, 190.55, 129.574, -170.023], [-129.656, 70.107, 152.204, -127.035, -168.624, -45.394, 156.721, 84.667, 166.245, -9
6.12], [-4.544, 44.91, 28.29, -50.782, -92.305, 90.234, -7.952, -123.273, 171.182, -114.106], [99.316, 33.599, 1.002, -195.981, -68.847, -163.948, -100.641, 116.223,
109.781, 99.281], [-143.749, -82.387, 52.243, 16.412, -50.022, 151.982, 62.035, 191.658, 117.625, 44.907], [-49.949, 75.404, 101.877, 28.042, -12.943, -181.196, 143
.233, -60.109, 69.007, 19.505], [97.908, 6.297, -126.937, 189.528, 156.223, 118.848, -40.019, -45.724, -74.825, -100.810], [-125.502, -87.871, -57.979, 192.954, 91.6
27, -179.244, -129.856, 73.077, 90.859, -39.382], [-76.888, 15.577, -97.754, 139.039, 112.688, 197.906, -8.355, 69.079, 138.622, -115.249], [-167.744, -13.911, 51.78
8, 187.145, 44.994, -184.782, -54.206, -65.615, 103.653, 10.495], [-61.223, -82.226, 122.895, -28.726, -85.943, 108.04, 105.08, -49.731, -43.6, 135.577], [95.165, -9
1.036, -105.353, -6.35, 62.43, 172.025, -196.032, 14.118, -71.197, 50.222], [-38.829, 60.924, -193.617, -71.095, -73.857, 14.731, 169.51, -40.799, -3.209, -129.757], [
77.948, 102.689, -125.468, -26.115, 71.492, 199.236, -30.248, 120.682, -148.195, 93.515], [117.35, 25.225, -101.47, 94.464, -108.669, 99.589, -158.04, 21.42, 37.88
7, 131.241], [-189.007, 42.177, -76.228, -173.987, 86.794, -122.65, 134.677, -77.616, 37.634, 144.359], [-90.176, 179.93, -14.491, 92.715, 8.018, -60.851, 154.23, -4
9.997, 50.288, 153.243], [148.409, -97.56, -149.269, -116.775, 38.199, -66.394, -119.148, 73.204, 48.161, -51.183], [146.159, 75.62, -106.795, -181.443, 10.514, -148
.046, -70.674, 29.901, 43.328, -0.711], [66.838, 4.071, -3.495, -108.151, 107.87, -193.83, 128.221, -64.324, -1.405, 74.351], [-120.566, 45.048, -31.543, 27.936, -73
.115, -186.384, -22.945, -99.694, -12.332, 168.546], [-60.653, 37.987, -189.117, 93.183, 179.751, -105.406, -40.995, 120.588, 170.033, 112.428], [-187.062, 8.9, 15.2
44, 25.077, 72.606, -53.856, 95.706, 97.937, 123.838, -21.269], [-161.629, -2.199, 128.943, 85.672, 144.767, 16.441, 191.086, 120.426, -148.532, -72.103], [-173.516,
173.264, -195.293, -183.694, -2.021, -178.029, 53.047, 80.902, 31.184, 92.465], [117.84, 114.889, 107.198, 128.216, 14.051, 51.56, 69.304, 142.101, 117.979, -16.258
], [77.948, 102.689, -125.468, -26.115, 71.492, 199.236, -30.248, 120.682, -148.195, 93.515], [117.35, 25.225, -101.47, 94.464, -108.669, 99.589, -158.04, 21.42, 37.88
7, 131.241], [-189.007, 42.177, -76.228, -173.987, 86.794, -122.65, 134.677, -77.616, 37.634, 144.359], [-90.176, 179.93, -14.491, 92.715, 8.018, -60.851, 154.23, -4
9.997, 50.288, 153.243], [148.409, -97.56, -149.269, -116.775, 38.199, -66.394, -119.148, 73.204, 48.161, -51.183], [146.159, 75.62, -106.795, -181.443, 10.514, -148
.046, -70.674, 29.901, 43.328, -0.711], [66.838, 4.071, -3.495, -108.151, 107.87, -193.83, 128.221, -64.324, -1.405, 74.351], [-120.566, 45.048, -31.543, 27.936, -73
.115, -186.384, -22.945, -99.694, -12.332, 168.546], [-60.653, 37.987, -189.117, 93.183, 179.751, -105.406, -40.995, 120.588, 170.033, 112.428], [-187.062, 8.9, 15.2
44, 25.077, 72.606, -53.856, 95.706, 97.937, 123.838, -21.269], [-161.629, -2.199, 128.943, 85.672, 144.767, 16.441, 191.086, 120.426, -148.532, -72.103], [-173.516,
173.264, -195.293, -183.694, -2.021, -178.029, 53.047, 80.902, 31.184, 92.465], [117.84, 114.889, 107.198, 128.216, 14.051, 51.56, 69.304, 142.101, 117.979, -16.258
], [-28.152, -86.672, 7.178, 106.17, 161.822, -100.707, 25.508, 181.456, 21.298, -85.577], [-23.617, -128.378, 67.994, -90.802, 166.319, 157.329, 174.031, 88.286, 39
.347, 157.106], [-48.231, -68.777, 18.589, -119.035, 102.137, -100.102, 154.743, 186.193, -59.859, 128.153], [91.964, 124.945, 18.28, -75.584, 83.152, -160.345, 64.6
7, -18.200, 25.931, -6.004], [5.125, -105.811, 123.396, -157.641, -169.76, 103.809, -136.692, -9.687, 49.688, 186.474], [-157.909, -136.463, -80.833, 109.127, -25.4
32, 153.528, 149.701, -42.997, 154.842, -65.238], [-74.405, 110.898, 126.406, 39.822, -148.869, 32.218, 104.405, -169.835, 175.517, 30.925], [-5.76, 128.719, -95.86
4, -57.879, 58.883, -56.423, -115.426, 152.461, -37.924, -96.291], [195.572, 101.334, 59.241, 104.866, -120.5, -117.75, -117.237, 141.023, 123.708, 74.612], [-23.947,
169.564, 68.709, 2.334, 19.537, -13.746, -46.802, 102.643, 165.642, -147.463], [78.207, -23.79, 54.62, 135.859, -188.489, -182.589, -188.558, 118.381, -169.982, -8
.425], [191.056, 169.403, 54.751, 166.974, 95.759, 3.857, -146.522, 176.042, -166.706, -48.731], [-124.402, 20.658, 118.615, -67.196, -176.319, -41.097, 189.186, 11
4.333, -172.988, -112.287], [-168.195, 138.789, -122.194, -132.826, 70.109, 106.752, 61.221, -13.469, 117.006, 123.596], [-149.761, -183.089, 27.985, 184.331, -149.1
24, -131.194, -152.719, 184.61, -150.211, 86.855], [77.848, 111.55, -191.951, -109.185, 39.579, -129.215, 50.626, 27.414, 76.431, 72.276], [-80.363, -84.386, 67.83,
-106.202, -59.208, -97.504, -82.376, -113.795, 22.534, 41.527], [-41.401, -133.670, -51.01, -1.014, -167.091, 186.43, 47.232, 128.058, -62.740, 63.855], [131.508, 49
310, -86.262, -100.108, -168.147, 8.539, 42.514, 101.262, 113.535, -101.927], [131.677, 196.007, -113.739, 163.73, -101.624, -140.609, -22.471, 73.151, 52.23, -24.2
44], [133.689, 25.202, -121.044, -46.442, 89.889, -163.519, 5.351, -163.514, 20.157, -54.269], [-137.318, -118.664, -43.746, 53.077, -76.692, 38.434, 75.472, -81.414
, 66.102, 189.026], [-48.911, 176.81, -79.237, 190.962, -62.39, 40.785, -126.106, -176.205, 186.503], [-77.71, 79.627, -109.06, 21.894, 94.457, -163.512, -12
6.925, -100.959, 105.516, 28.401], [-141.239, 156.485, -170.698, -5.516, 176.087, -179.246, -97.257, 179.567, -89.839, 52.974], [-168.819, -197.245, -89.899, -51.351
, 102.255, -128.438, 76.981, 68.41, -93.475, -78.261], [-152.281, -131.246, -34.654, -185.222, 20.743, 22.673, 194.877, -161.508, 76.189, -37.31], [-84.889, -199.669
, 116.263, -101.755, -139.566, -130.623, 127.845, 23.96, 87.688, 160.092], [-107.397, -56.889, -32.323, 34.62, 40.836, -49.468, 141.378, 72.219, -25.789, 124.895], [
142.087, 14.988, -150.607, 166.894, 133.325, 196.919, 148.132, 80.232, -176.379, 156.856], [149.574, 161.875, -10.187, 61.912, 127.444, -85.006, -143.66, -39.626, -1
00.877, 49.212], [-93.383, -123.943, 182.802, -109.576, 174.489, 62.407, -7.374, -43.078, -66.498, -27.573], [-80.595, -86.423, 54.94, 1.947, -199.717, 10.726, -86.4
1, 24.968, 137.404, -23.654], [-121.883, 71.474, -116.909, -55.664, 173.876, 97.335, 112.839, 148.912, 7.913, -127.798], [137.196, 176.773, 133.237, 29.101, 38.056,
60.198, -58.339, 6.59, 150.159, 190.443], [-100.578, -45.222, -138.189, -159.582, 188.883, -112.893, -14.691, -19.168, -3.018, 30.759], [-115.254, -139.43, -155.527,
-196.832, -2.341, -154.589, -71.184, 156.114, -170.964, -62.159], [-120.105, 107.456, -164.302, 3.747, -181.066, -77.251, -146.812, -123.385, 135.499, -21.581], [3.
283, 126.559, 90.884, -126.114, -3.34, 170.061, 174.89, -149.362, 46.722, 5.130], [-69.687, 164.583, -36.209, 24.784, 34.855, 143.407, 31.266, -163.143, 15.150, -175
.188], [21.594, -33.214, 61.734, -81.583, -85.667, 123.959, -53.346, -33.743, 144.833, -161.309], [129.182, 15.2, -154.009, -47.064, -31.979, 98.666, -129.26, -197.2
89, -113.903, -27.337], [146.578, 77.629, -14.049, -58.405, -197.789, 105.845, -61.595, -100.828, -31.903, 162.506], [07.401, 117.624, 75.788, -61.453, -45.193, 113.
207, -170.661, 75.494, 148.63, -105.375], [177.202, -44.49, 140.485, 89.991, -182.16, 178.586, 186.945, -110.071, 52.481, 7.067], [13.123, 2.81, -93.251, -188.998, -
103.998, 100.384, 37.678, -191.854, 11.704, -70.822], [58.183, -90.399, -28.442, -41.055, -106.81, -92.369, -45.955, 04.752, -149.591, 25.001]
```

```
System : Windows
Node Name : DESKTOP-7GFDHFG
Release : 10
Version : 10.0.22621
Machine : AMD64
Processor : AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD

Deskripsi hasil Divide and Conquer:
Waktu eksekusi: 0.0255715804701538080s
Jumlah kalkulasi: 7172
Jarak terdekat: 151.79388608241112
Solusi:
- Vektor [-4.544, 44.91, 28.29, -50.782, -92.305, 90.234, -7.952, -123.273, 171.182, -114.106] dengan vektor [21.594, -33.214, 61.734, -81.583, -85.667, 123.959, -53
.346, -33.743, 144.833, -161.309]

Deskripsi hasil BruteForce:
Waktu eksekusi: 0.014058828353881830s
Jumlah kalkulasi: 4852
Jarak terdekat: 151.79388608241112
Solusi:
- Vektor [-4.544, 44.91, 28.29, -50.782, -92.305, 90.234, -7.952, -123.273, 171.182, -114.106] dengan vektor [21.594, -33.214, 61.734, -81.583, -85.667, 123.959, -53
.346, -33.743, 144.833, -161.309]
```

BAB V KESIMPULAN, SARAN, DAN REFLEKSI

1. Kesimpulan

Penggunaan Algoritma *Divide and Conquer* dalam pencarian pasangan titik terdekat bisa dibilang lebih efisien dibandingkan algoritma *bruteforce*. Akan tetapi, seiring dengan bertambahnya dimensi pada titiknya, maka akan jauh lebih efisien algoritma *bruteforce*.

2. Saran

Untuk visualisasi sebenarnya penggunaan library matplotlib sudah terbilang cukup. Namun jika ingin visualisasi yang lebih interaktif dan lebih ringan, bisa mencoba-coba library lain atau mungkin bahasa pemrograman lain.

3. Refleksi

Visualisasi sangatlah terbatas jika menggunakan library matplotlib.

LAMPIRAN

Link github: https://github.com/Ainzw0rth/Tucil2_13521069.git

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

REFERENSI

edunex.itb.ac.id (Diakses pada tanggal 12 Februari 2023)

Munir, Rinaldi. 2021. “Algoritma Divide and Conquer (Bagian 1)”.
[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), diakses 12 Februari 2023.

Munir, Rinaldi. 2021. “Algoritma Divide and Conquer (Bagian 2)”.
[https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-\(2021\)-Bag2.pdf](https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-(2021)-Bag2.pdf), diakses 12 Februari 2023.

Munir, Rinaldi. 2021. “Algoritma Divide and Conquer (Bagian 3)”.
[https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-\(2021\)-Bagian3.pdf](https://informatika.stei.itb.ac.id/~rinaldi.munir/Stmik/2020-2021/Algoritma-Divide-and-Conquer-(2021)-Bagian3.pdf), diakses 12 Februari 2023.