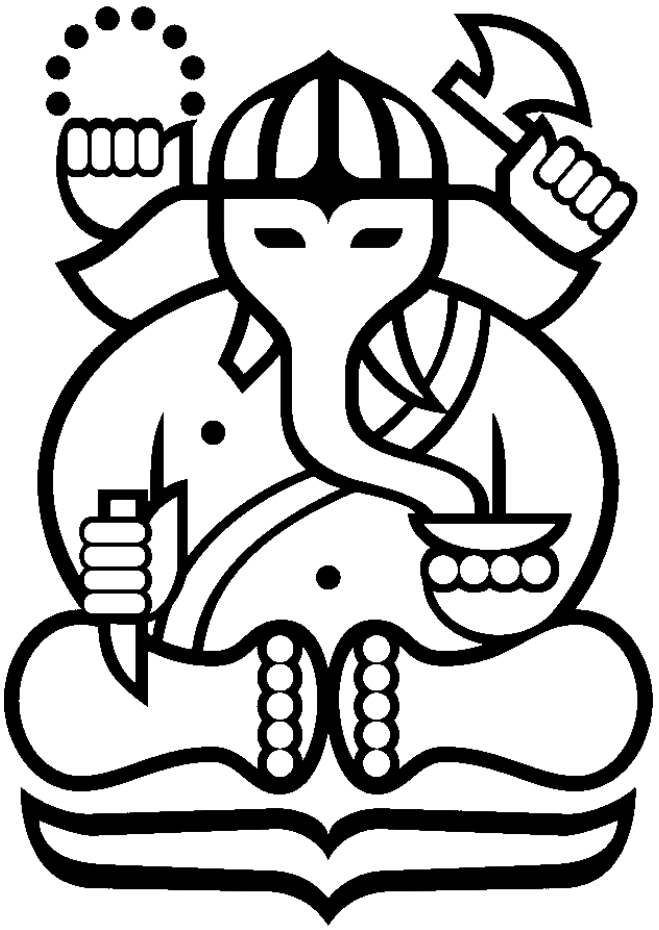
TUGAS KECIL 2 IF2211 STRATEGI ALGORITMA
SEMESTER II TAHUN 2022/2023

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



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

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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 Tucil 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 datu 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*

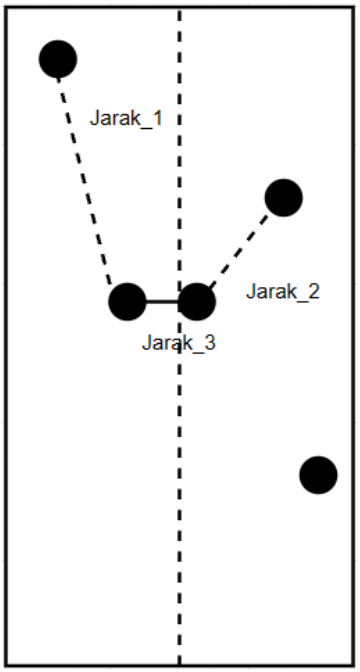
      Kita pertama-tama harus membagi daftar titik tersebut ke dalam beberapa daftar yang lebih kecil. Pembagian dapat dilakukan dengan cara mencari titik tengah pada daftar titik semula. Untuk mempermudah proses pembagian, kita dapat mengurutkan titik-titik tersebut secara menaik terhadap sumbu x-nya. Setelah diurutkan titik tengah dapat ditemukan dengan mengakses elemen ke-*mid* dari daftar titik, dimana $mid = banyak\_titik\ div\ 2$. 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.

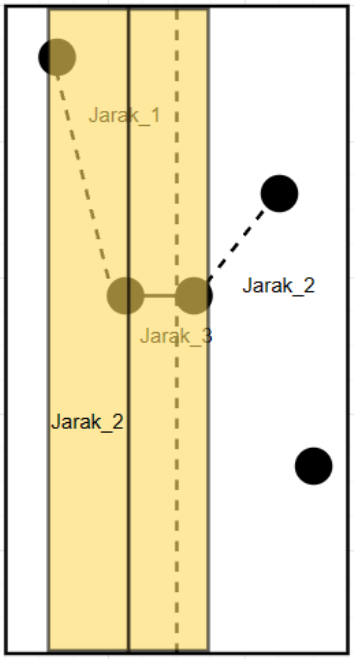
c. *Combine*

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 kan berinilai 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

```python
# 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 bruteforce
    ax.set_title("Hasil dari Divide and Conquer")
    bx.set_title("Hasil dari Bruteforce")
    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 titik"nya
    daftar_titik = sort_titik(x, 0)

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

    # algoritma bruteforce
    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:\n\nWaktu eksekusi: {exec_time_divide}s \nJumlah kalkulasi: {jumlahperhitungan_divide}\nJarak terdekat: {jarak}\nSolusi:\n{solution_to_strin
    ax.text2D(0.1, 0.1, info_divide, fontsize=9, transform=plt.gcf().transFigure)

    info_brute = f"Deskripsi hasil Bruteforce:\n\nWaktu eksekusi: {exec_time_brute}s \nJumlah kalkulasi: {jumlahperhitungan_brute}\nJarak terdekat: {jarak_brute}\nSolusi:\n{solution_to_string(pa
    bx.text2D(0.6, 0.1, info_brute, fontsize=9, transform=plt.gcf().transFigure)

    print(f"\nTitik yang digunakan: {x}\n")
    print(info_divide)
    print("\n")
    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)
                                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 bruteforce
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

```python
# 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

```python
# 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

```python
# 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

```python
# 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

```python
# 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
```

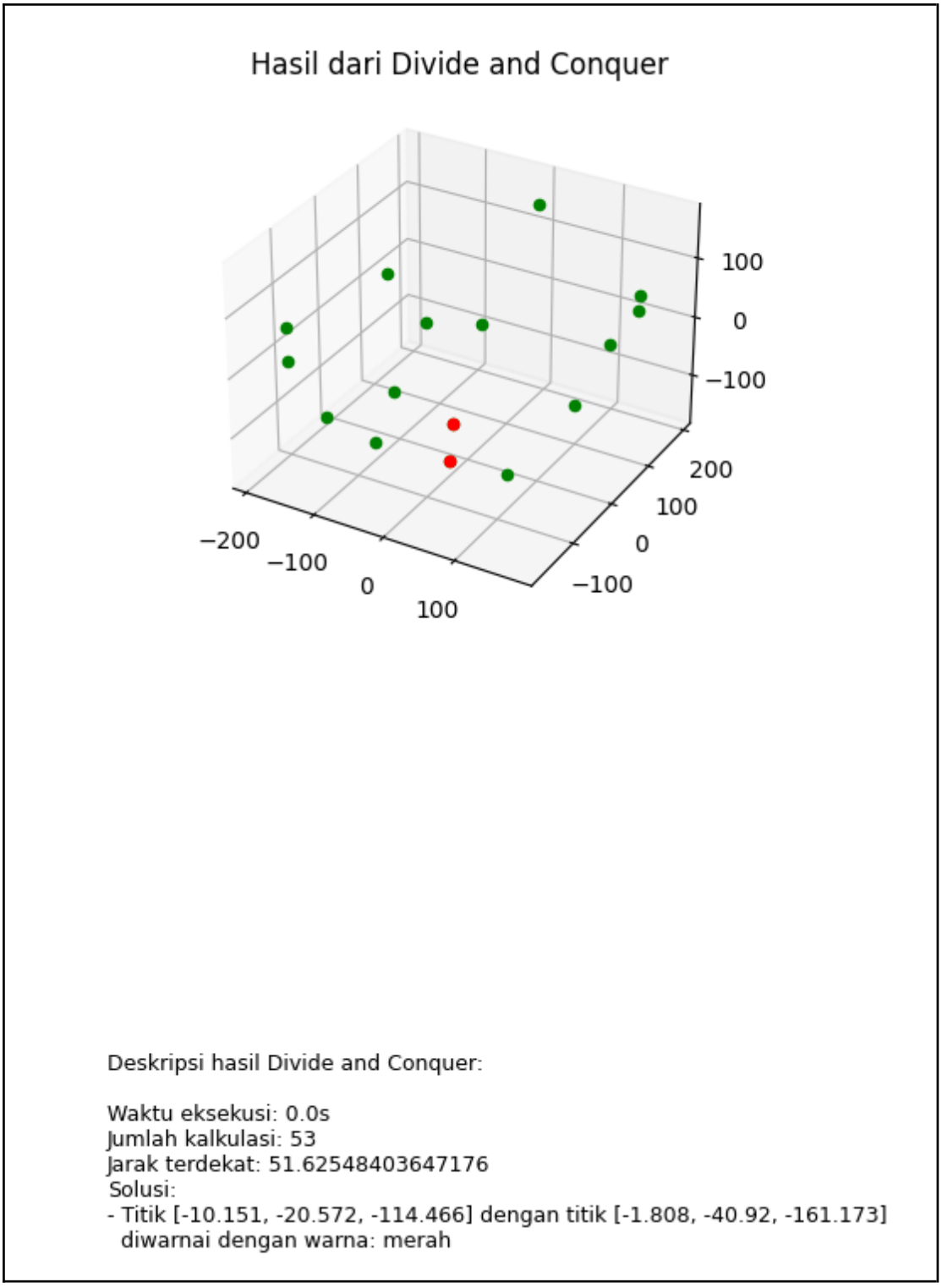
BAB IV EKSPERIMEN

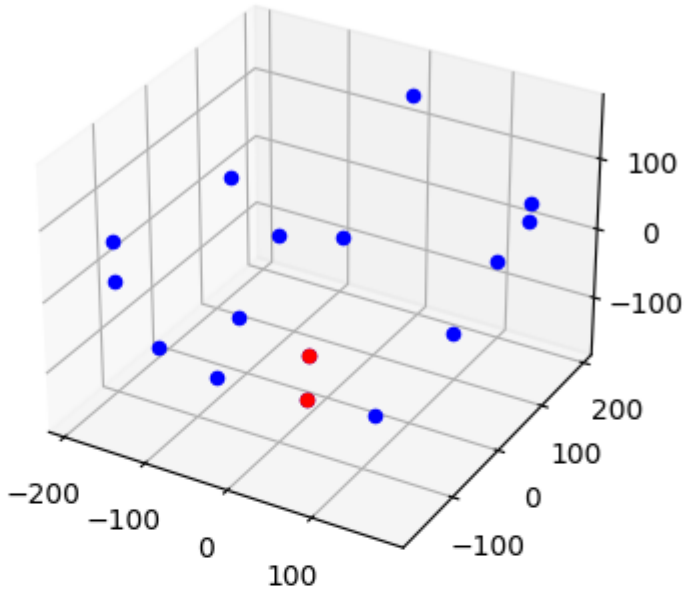
1. test case 1

input	n = 16, dimensi = 3, lowerbound = -200, upperbound = 200

output:

```
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: [[72.511, 148.902, -157.03], [4.601, 172.522, 151.451], [-149.356, -176.516,
 39.32], [-23.795, -59.897, 77.833], [-56.277, -96.48, 166.149], [-1.808, -40.92, -161.173], [80.0
89, -39.519, -154.355], [-184.739, -42.727, -148.87], [178.715, 109.575, 66.576], [-192.526, -113.
955, 42.078], [100.84, 189.957, -65.074], [-78.159, 169.291, -78.143], [139.852, 192.344, 30.662],
 [-94.645, -68.772, -145.839], [-113.655, 8.035, -113.089], [-10.151, -20.572, -114.466]]

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.0s
Jumlah kalkulasi: 53
Jarak terdekat: 51.62548403647176
Solusi:
- Titik [-10.151, -20.572, -114.466] dengan titik [-1.808, -40.92, -161.173]
  diwarnai dengan warna: merah



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.0s
Jumlah kalkulasi: 106
Jarak terdekat: 51.62548403647176
Solusi:
- Titik [-10.151, -20.572, -114.466] dengan titik [-1.808, -40.92, -161.173]
  diwarnai dengan warna: merah
```


Hasil dari Divide and Conquer
100
0
−100
200
100
0
−100
−200
−100
0
100
Deskripsi hasil Divide and Conquer:
Waktu eksekusi: 0.0s
Jumlah kalkulasi: 53
Jarak terdekat: 51.62548403647176
Solusi:
- Titik [-10.151, -20.572, -114.466] dengan titik [-1.808, -40.92, -161.173]
diwarnai dengan warna: merah



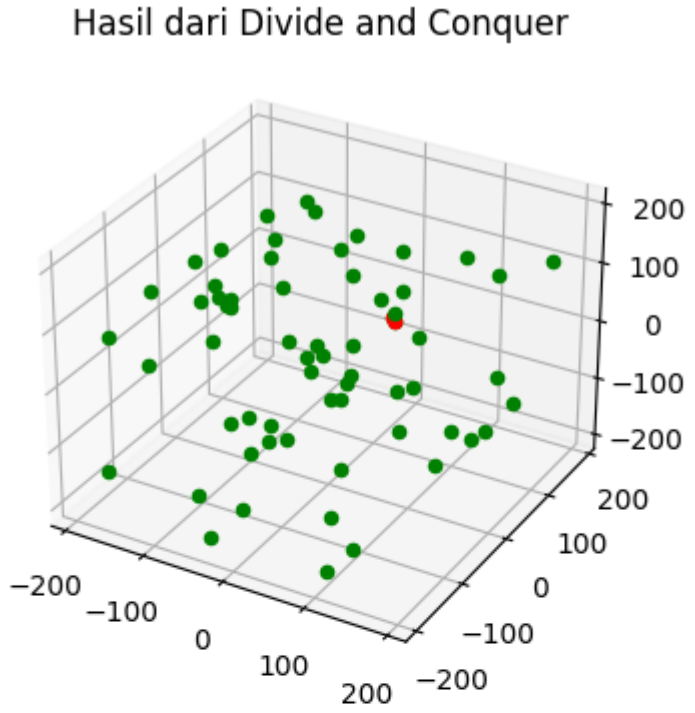
Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.0s
Jumlah kalkulasi: 106
Jarak terdekat: 51.62548403647176
Solusi:
- Titik [-10.151, -20.572, -114.466] dengan titik [-1.808, -40.92, -161.173]
  diwarnai dengan warna: merah

2. test case 2

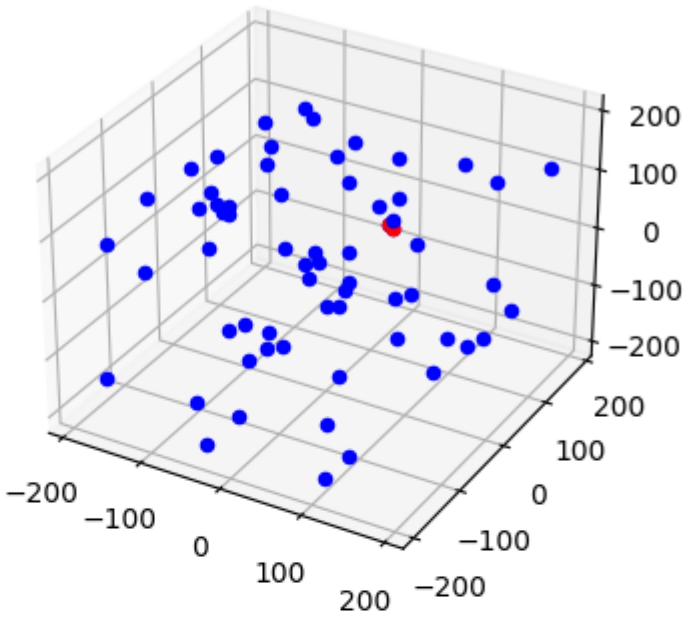
input	n = 64, dimensi = 3, lowerbound = -200, upperbound = 200
output:	

```
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: [[-189.757, 69.092, 1.713], [-190.049, 29.722, 69.743], [190.289, 28.05, 17.
73], [-11.364, 183.568, -16.755], [-35.296, 84.823, 110.75], [112.305, -194.39, -180.525], [-24.98
1, -166.712, 186.929], [-174.284, -174.015, -146.427], [55.869, -132.711, 87.904], [194.148, -36.7
05, -37.609], [-120.994, 72.446, 145.782], [-84.17, -25.442, -187.456], [81.628, -152.86, 138.564]
, [-58.507, -24.471, -129.72], [-3.831, 154.687, -46.979], [-48.766, 126.009, -156.908], [43.646,
-24.747, 49.907], [-22.845, 41.203, -115.427], [-63.477, -95.467, 120.468], [-53.039, 61.627, 184.
949], [65.18, -156.416, 129.851], [71.407, -146.667, 144.005], [-1.904, -179.143, -135.509], [-15.
806, -64.839, -105.679], [-87.648, -57.128, 99.094], [-80.604, -140.38, -173.368], [-184.133, -69.
247, 85.213], [51.189, 66.689, -159.849], [161.213, 60.918, -111.484], [145.662, 9.554, -78.362],
[-12.837, 163.015, -48.725], [-117.23, -15.443, -157.048], [-188.92, -142.848, 54.176], [40.177, 8
7.984, 134.95], [-159.41, -5.155, 35.587], [126.517, -191.38, -1.91], [-149.162, 18.753, 112.328],
 [186.873, 33.524, 182.494], [-98.385, 49.185, 128.41], [4.017, 185.078, -184.9], [20.027, 111.213
, 2.781], [-59.472, 13.743, -8.167], [-127.207, 89.022, 61.358], [-34.21, -191.951, -188.787], [-6
5.35, 174.046, 66.516], [140.559, -54.602, 123.032], [17.754, -155.004, -30.594], [-6.103, -157.24
7, 1.916], [-114.682, -180.088, 62.792], [-23.809, 157.224, -18.988], [79.863, 166.691, 87.243], [
116.849, 30.408, -167.265], [101.006, -28.64, -0.436], [-62.763, 61.477, 196.603], [-96.773, 64.63
1, 36.183], [70.918, -95.203, 21.925], [-25.939, 96.0, 61.539], [-190.269, 63.774, -94.641], [-15.
672, 77.399, -95.756], [151.168, 146.03, -126.779], [68.031, -113.665, -168.879], [103.448, -127.2
25, -197.559], [-70.936, -106.486, 143.918], [182.168, 172.323, 112.93]]

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.00099658966064453125s
Jumlah kalkulasi: 466
Jarak terdekat: 12.390001452784402
Solusi:
- Titik [-12.837, 163.015, -48.725] dengan titik [-3.831, 154.687, -46.979]
  diwarnai dengan warna: merah



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.0034682750701904297s
Jumlah kalkulasi: 1954
Jarak terdekat: 12.390001452784402
Solusi:
- Titik [-12.837, 163.015, -48.725] dengan titik [-3.831, 154.687, -46.979]
  diwarnai dengan warna: merah
```



Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.0009965896606445312s
Jumlah kalkulasi: 466
Jarak terdekat: 12.390001452784402
Solusi:
- Titik [-12.837, 163.015, -48.725] dengan titik [-3.831, 154.687, -46.979]
  diwarnai dengan warna: merah



Deskripsi hasil Bruteforce:

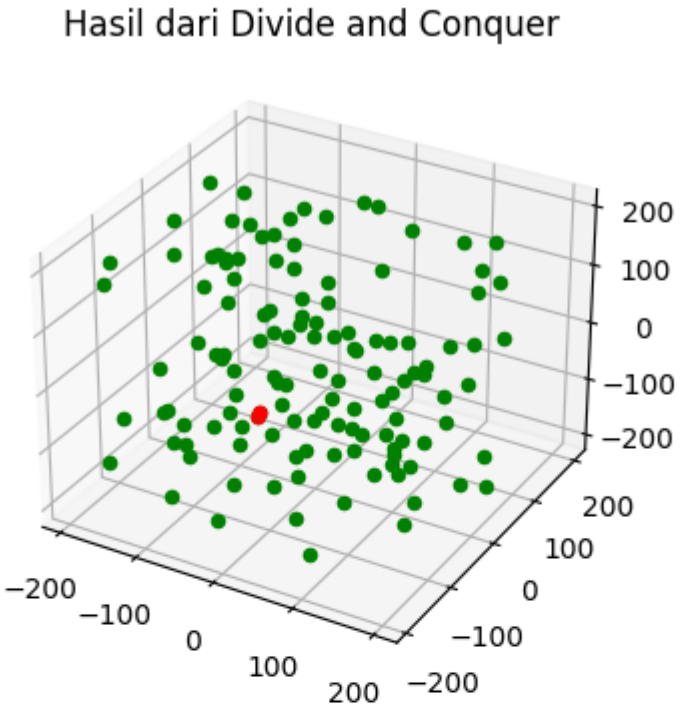
Waktu eksekusi: 0.0034682750701904297s
Jumlah kalkulasi: 1954
Jarak terdekat: 12.390001452784402
Solusi:
- Titik [-12.837, 163.015, -48.725] dengan titik [-3.831, 154.687, -46.979]
  diwarnai dengan warna: merah

3. test case 3

input	n = 128, dimensi = 3, lowerbound = -200, upperbound = 200
output:	

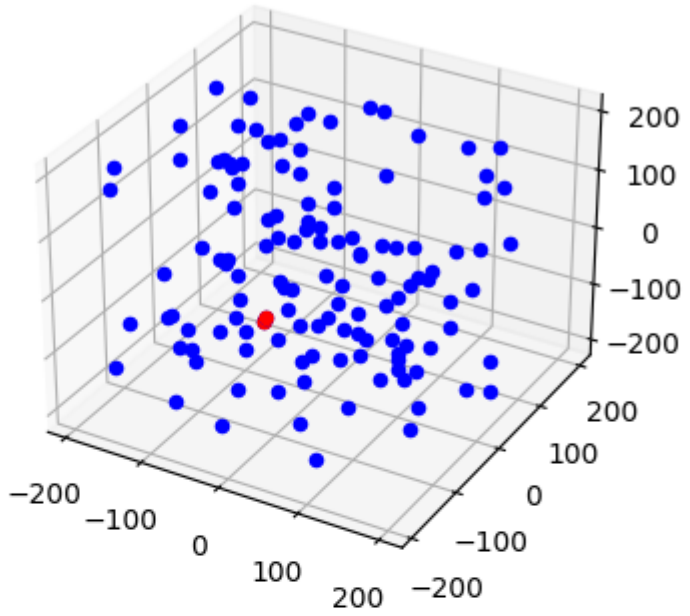
```
Masukkan jumlah titik: 128
Masukkan dimensi (note: visualisasi hanya akan diberikan untuk dimensi 3, selain itu hanya sebatas
 di terminal):
3
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[-179.555, -147.488, 158.025], [-146.643, 155.869, 62.682], [-30.097, -40.4
31, 62.034], [-114.559, -96.009, -90.064], [-92.553, 199.224, -126.469], [-164.166, -169.587, -125
.032], [-194.586, 117.134, -146.448], [-42.111, 25.586, 165.809], [0.995, 138.555, 173.312], [-6.9
92, 7.437, -113.267], [31.06, -145.969, -14.59], [-55.558, 19.921, -112.915], [136.332, -44.781, 4
8.801], [124.643, 25.584, -112.267], [52.217, 124.133, 160.075], [-184.877, 153.573, 126.892], [18
6.353, -146.852, -17.401], [-104.55, 150.496, 126.709], [45.706, -123.297, -167.62], [-112.836, 97
.511, -140.837], [-3.443, 55.154, -75.922], [-102.976, -49.717, -123.003], [85.645, -156.922, -189
.547], [-128.653, -191.345, -17.458], [-80.1, -180.744, 8.605], [-2.158, -154.82, -7.784], [-78.93
8, -178.889, -141.081], [58.952, -102.695, 131.517], [111.722, -23.817, -118.425], [109.948, -104.
972, -38.957], [-127.896, 5.954, -51.657], [121.623, 80.94, -115.558], [6.343, 125.848, -46.538],
[-92.161, 188.039, -23.076], [-87.262, -32.575, -31.523], [55.707, -137.801, -45.994], [153.075, -
58.972, -79.468], [-75.62, 13.391, 172.699], [-94.817, 131.347, -48.374], [49.632, 124.599, -35.97
], [3.904, -100.239, -149.125], [13.459, 80.034, -182.805], [-9.957, -65.135, 2.676], [182.143, -2
6.154, 111.632], [52.386, -146.873, 157.886], [-95.997, -56.441, 12.487], [174.982, 74.737, -151.4
58], [-180.19, 71.426, 192.45], [106.701, -40.546, -0.418], [199.706, 31.14, -162.553], [54.35, 15
1.506, -106.762], [159.125, 75.807, 36.941], [-144.408, 119.765, -101.924], [130.781, 174.43, 137.
442], [-19.261, -63.658, 119.81], [-88.236, 93.828, 152.001], [119.814, 136.65, -89.883], [-83.567
, 1.679, 199.309], [-114.773, 23.241, 116.317], [147.219, -126.948, -47.507], [85.603, -106.821, -
51.805], [193.373, -143.371, -100.877], [153.181, 143.695, 95.228], [-170.867, -56.921, -40.646],
[-61.973, -61.494, -129.093], [198.402, 5.776, 186.247], [-84.679, 20.18, -139.432], [-32.051, 164
.113, 154.178], [-133.005, 108.275, -43.732], [186.934, -116.07, 130.887], [26.877, -92.291, -29.4
86], [-52.228, -179.09, -60.882], [87.027, -112.453, 47.303], [-74.827, 61.035, -113.15], [-169.22
1, 101.382, -198.814], [-194.829, 109.104, 39.386], [35.506, 101.355, -186.859], [136.467, -155.23
3, 79.202], [87.284, -149.595, 196.907], [53.258, 161.873, -100.839], [63.851, -96.088, 1.118], [8
7.461, -9.188, 190.117], [-28.231, 101.261, -197.287], [-21.129, 6.073, 92.35], [-50.758, 116.496,
 2.17], [-179.403, -135.97, 189.126], [-122.728, -79.71, -139.651], [-80.051, -168.609, -55.475],
[-34.595, -156.211, -182.46], [-97.42, -25.306, -111.232], [124.493, 154.286, 100.55], [-146.467,
-88.341, -86.581], [-166.721, 53.302, 82.716], [102.051, -91.003, 118.029], [8.151, -4.412, -12.44
7], [144.673, 178.376, -27.196], [85.663, -165.865, -2.537], [104.937, -101.12, -3.74], [74.37, 47
.293, -169.554], [-169.493, 198.039, -18.465], [-45.559, -104.197, -161.405], [23.031, 146.207, -1
94.507], [-86.411, 18.434, -144.875], [-174.357, -14.852, 124.419], [-189.913, 10.352, 163.543], [
119.181, -145.768, -91.583], [134.407, -67.858, 44.675], [-189.028, 68.616, 10.325], [-17.308, -17
.523, 159.865], [129.369, 100.084, 182.097], [-10.67, 190.528, -100.502], [113.569, -7.416, -89.80
2], [66.983, -30.162, 66.642], [8.615, -53.94, -163.369], [-113.0, 10.784, 188.146], [164.817, -70
.611, -129.352], [-143.025, 42.268, 94.493], [167.749, -10.594, 12.122], [24.727, 27.092, 38.976],
 [-25.138, 64.209, 195.668], [188.035, -6.78, -135.837], [-132.654, 42.108, 64.465], [-127.855, 18
2.475, -107.444], [125.305, -46.869, -70.221], [162.355, -159.545, 152.025], [-128.797, -41.039, 9
.851], [-154.768, 63.598, 69.438], [-36.523, -122.017, 163.575]]

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.003501892089843755
Jumlah kalkulasi: 1417
Jarak terdekat: 5.972820857852689
```

```
Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.010529994964599615
Jumlah kalkulasi: 8002
Jarak terdekat: 5.972820857852689
Solusi:
- Titik [-86.411, 18.434, -144.875] dengan titik [-84.679, 20.18, -139.432]
  diwarnai dengan warna: merah
```



Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.003501892089843755
Jumlah kalkulasi: 1417
Jarak terdekat: 5.972820857852689
Solusi:
- Titik [-86.411, 18.434, -144.875] dengan titik [-84.679, 20.18, -139.432]
  diwarnai dengan warna: merah



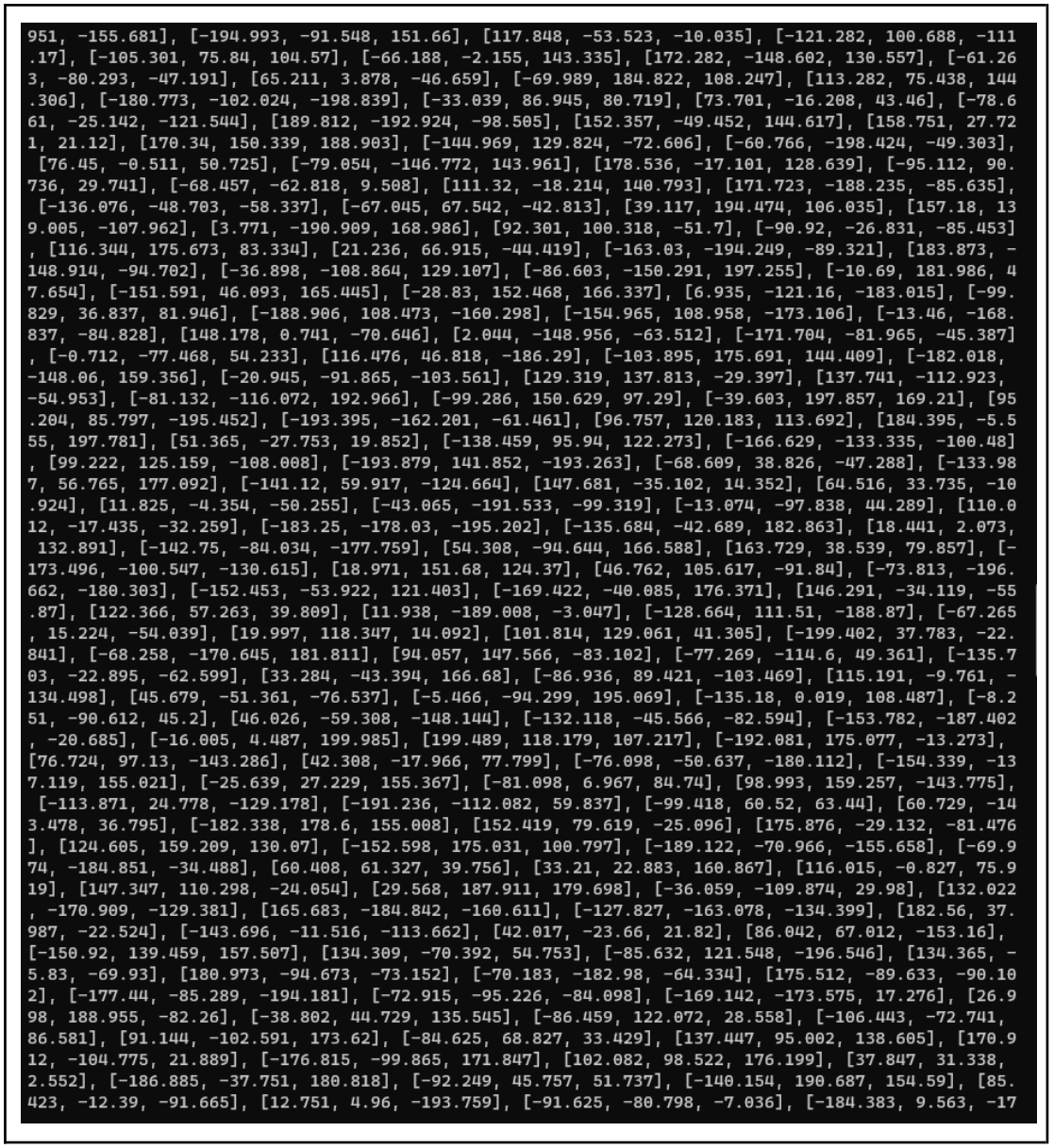
Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.01052999496459961s
Jumlah kalkulasi: 8002
Jarak terdekat: 5.972820857852689
Solusi:
- Titik [-86.411, 18.434, -144.875] dengan titik [-84.679, 20.18, -139.432]
  diwarnai dengan warna: merah

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
                                                                                                s
 di terminal):
3
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[61.425, -43.308, -59.584], [191.185, 155.031, 176.732], [90.057, -88.15, 7
5.946], [-146.001, -12.099, 12.827], [-130.05, -126.018, -87.367], [147.969, -144.341, -19.782], [
-22.482, -163.571, 82.285], [32.25, 181.634, 34.633], [-118.841, 40.424, 63.305], [-5.12, 2.052, 4
5.675], [113.473, -115.815, 175.688], [-165.871, 121.713, -141.31], [176.053, 97.166, 199.272], [-
190.24, 110.715, -114.225], [172.304, 142.63, -98.335], [-2.959, 20.093, 3.411], [-113.448, -39.27
2, -88.533], [153.358, -178.994, -64.979], [26.556, 86.116, -123.471], [100.942, 6.218, 173.75], [
-47.512, -131.653, -182.892], [153.26, -118.014, 54.911], [163.697, 47.433, -91.726], [-157.589, 6
7.359, -66.615], [-42.747, -40.073, 173.564], [144.88, 156.139, -15.527], [-187.318, -116.717, 114
.912], [41.502, -144.99, 190.967], [127.881, -169.18, -73.047], [181.156, 145.502, 173.867], [138.
937, 150.286, -182.757], [-172.274, 28.907, 21.22], [96.046, 152.582, -20.362], [-149.44, 69.358,
-146.836], [-167.141, 44.721, -3.146], [169.763, 74.542, 80.134], [-25.597, -189.967, 197.049], [-
90.75, 91.708, 41.897], [-38.525, 114.694, -80.693], [-55.72, 66.091, 116.5], [-150.32, -190.758,
-45.165], [189.358, -71.353, 125.79], [-3.708, -146.242, 76.103], [-9.706, -34.44, -177.336], [-69
.793, 145.925, 75.968], [145.178, -86.456, 48.828], [17.673, 149.118, -199.924], [-146.896, 147.53
6, 185.432], [36.206, -29.587, -33.771], [47.838, -184.715, -129.418], [-112.42, 34.246, 107.424],
 [181.334, -57.444, -155.399], [-114.103, -175.848, -58.429], [-59.478, 59.211, 163.787], [51.535,
 -128.277, 63.943], [182.53, 199.585, 24.432], [174.671, -158.839, 194.546], [138.733, 140.501, 59
.296], [73.848, -74.335, -85.05], [82.725, 182.622, 133.404], [-179.207, 163.66, 170.974], [154.84
1, -57.865, -161.676], [-4.479, 91.429, 54.119], [-121.476, 3.154, 21.11], [-163.412, 145.286, 186
.799], [38.714, -117.224, 107.93], [-102.434, 148.335, -31.121], [-11.375, -76.309, -103.314], [-6
7.47, -198.586, -163.352], [86.723, -48.251, -117.583], [-40.076, -6.1, 83.973], [-57.477, -36.702
, 131.944], [-72.109, 99.492, 31.098], [124.668, 104.237, 37.706], [-127.185, 96.568, -133.382], [
-37.545, -71.633, 121.364], [81.22, -112.156, -5.784], [-84.668, -109.98, -40.999], [6.197, 28.085
, -73.229], [57.472, 25.386, 144.179], [-197.763, -108.579, 159.108], [-4.884, -2.106, 133.303], [
132.09, 180.62, -103.528], [-114.422, -159.128, -46.345], [136.209, -112.032, -130.188], [-159.863
, 118.359, -9.97], [-36.076, -135.721, 26.191], [-81.734, -161.504, -78.885], [117.534, 22.177, 11
4.338], [-5.654, 164.218, 45.681], [18.548, 45.856, -189.555], [101.08, 78.906, 26.622], [-113.174
, 91.157, -25.623], [185.83, -8.347, 7.04], [-117.111, 185.872, -28.687], [72.034, -157.335, 81.70
1], [-169.822, 156.122, 136.983], [-179.524, 92.041, 70.961], [46.866, 112.875, -27.213], [-29.55,
 181.02, -144.121], [-40.371, 120.932, -177.861], [62.364, 181.173, -38.001], [-101.299, -29.19, -
41.18], [-1.922, 22.885, -196.42], [-92.447, 195.842, -176.535], [-65.773, -97.335, -101.669], [61
.198, 11.54, -22.926], [-124.457, -1.747, -85.988], [-187.967, -140.084, -42.288], [-27.112, -123.
783, 48.015], [-174.319, -48.376, -91.797], [-21.02, -50.974, -20.325], [-176.72, -16.294, -121.14
9], [162.027, -81.963, -163.822], [149.12, 179.103, -15.538], [107.235, -153.269, -103.276], [98.0
5, -32.046, -33.935], [57.875, -76.644, 150.194], [25.79, 76.068, 63.362], [152.538, 185.081, -22.
532], [-46.953, -173.61, 129.987], [-5.384, -85.744, 31.795], [-35.824, -98.08, 41.684], [-198.665
, 111.655, 43.224], [-142.309, -83.054, -185.003], [24.209, 170.453, 189.356], [104.83, -93.9, 10.
758], [172.897, 139.753, -177.272], [80.467, -22.932, -152.054], [-180.433, 70.955, 93.17], [4.987
, -0.197, -60.829], [-193.122, 79.876, -117.757], [-99.767, 126.952, 198.288], [-12.887, 199.574,
-89.126], [91.225, -118.957, 58.202], [125.258, -191.008, -125.346], [82.64, 71.502, 72.067], [6.5
11, -105.334, 96.355], [-27.474, 50.823, -13.846], [101.154, -48.962, -49.873], [168.179, 25.764,
-80.668], [196.366, -146.073, 181.599], [-199.18, -172.59, -50.777], [-75.54, 181.269, 16.909], [8
4.841, 192.819, -17.164], [172.67, -116.813, -30.921], [27.385, -92.794, 179.794], [-171.433, 107.
```


951, -155.681], [-194.993, -91.548, 151.66], [117.848, -53.523, -10.035], [-121.282, 100.688, -111
.17], [-105.301, 75.84, 104.57], [-66.188, -2.155, 143.335], [172.282, -148.602, 130.557], [-61.26
3, -80.293, -47.191], [65.211, 3.878, -46.659], [-69.989, 184.822, 108.247], [113.282, 75.438, 144
.306], [-180.773, -102.024, -198.839], [-33.039, 86.945, 80.719], [73.701, -16.208, 43.46], [-78.6
61, -25.142, -121.544], [189.812, -192.924, -98.505], [152.357, -49.452, 144.617], [158.751, 27.72
1, 21.12], [170.34, 150.339, 188.903], [-144.969, 129.824, -72.606], [-60.766, -198.424, -49.303],
[76.45, -0.511, 50.725], [-79.054, -146.772, 143.961], [178.536, -17.101, 128.639], [-95.112, 90.
736, 29.741], [-68.457, -62.818, 9.508], [111.32, -18.214, 140.793], [171.723, -188.235, -85.635],
[-136.076, -48.703, -58.337], [-67.045, 67.542, -42.813], [39.117, 194.474, 106.035], [157.18, 13
9.005, -107.962], [3.771, -190.909, 168.986], [92.301, 100.318, -51.7], [-90.92, -26.831, -85.453]
, [116.344, 175.673, 83.334], [21.236, 66.915, -44.419], [-163.03, -194.249, -89.321], [183.873, -
148.914, -94.702], [-36.898, -108.864, 129.107], [-86.603, -150.291, 197.255], [-10.69, 181.986, 4
7.654], [-151.591, 46.093, 165.445], [-28.83, 152.468, 166.337], [6.935, -121.16, -183.015], [-99.
829, 36.837, 81.946], [-188.906, 108.473, -160.298], [-154.965, 108.958, -173.106], [-13.46, -168.
837, -84.828], [148.178, 0.741, -70.646], [2.044, -148.956, -63.512], [-171.704, -81.965, -45.387]
, [-0.712, -77.468, 54.233], [116.476, 46.818, -186.29], [-103.895, 175.691, 144.409], [-182.018,
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1, -67.856], [-179.603, -199.822, -22.196], [4.467, -151.585, 143.641], [132.048, 121.83, 134.87],
 [-17.514, 36.33, 79.424], [31.733, -10.141, -106.042], [-34.082, 180.916, -43.516], [72.216, -113
.658, 73.18], [-19.318, -152.144, 176.592], [76.002, -119.105, 67.607], [-134.392, -171.137, -179.
042], [39.302, 181.854, 18.676], [5.126, -199.22, 99.962], [-148.38, -157.827, 173.385], [189.971,
 -119.425, 49.219], [-165.717, 13.416, -111.478], [117.007, -183.447, -177.656], [72.809, -136.008
, 182.178], [-144.866, -121.449, 137.605], [-165.136, -119.141, 128.352], [88.155, -37.46, -77.838
], [181.445, -81.276, 131.129], [0.057, 51.398, 82.657], [178.635, 180.852, -24.804], [-34.705, -1
13.914, -153.701], [129.306, -181.522, 47.209], [-183.261, 98.43, 84.835], [-33.397, 199.46, 153.7
01], [-16.201, 48.852, 44.634], [-72.769, 85.581, -30.354], [-58.169, 144.433, 67.019], [28.838, -
176.452, 21.346], [180.774, -149.508, 96.981], [-50.853, -34.066, -167.646], [95.042, -132.697, 87
.828], [-77.856, -12.826, 164.698], [50.797, 8.688, 141.505], [98.784, -36.866, 191.794], [172.63,
 -138.829, 73.569], [127.865, -105.365, -29.973], [-153.935, 151.695, -84.641], [-66.129, -113.285
, -104.325], [-88.97, -184.925, -195.427], [-79.37, 108.187, 159.924], [-171.257, 195.986, -2.476]
, [157.079, -25.31, -93.631], [157.861, -113.437, -114.707], [99.618, 53.249, -28.624], [-175.739,
 -76.36, -90.474], [85.358, -97.009, 134.313], [136.555, 165.7, -88.379], [-18.757, 141.923, -115.
175], [149.918, -110.21, 6.487], [125.126, -156.51, -58.627], [-46.167, -48.784, 88.251], [-23.781
, -56.031, -121.454], [57.405, -37.934, 36.828], [165.618, 54.212, 71.567], [-60.952, -89.436, -14
6.19], [-52.759, -40.758, 94.612], [-59.637, 105.094, 84.78], [-68.996, -73.995, -196.277], [135.4
6, 85.079, -59.251], [159.268, 164.899, -187.352], [-5.751, -30.539, -32.298], [164.589, 169.064,
-189.259], [78.719, 25.234, -157.447], [-150.183, -12.952, 86.663], [-132.398, -46.918, 80.402], [
-5.576, 76.391, 186.692], [5.277, 16.072, 95.273], [76.04, -27.678, 80.629], [20.045, -108.529, -1
34.33], [168.489, -145.583, 167.309], [-79.478, -90.914, 25.588], [-79.588, -73.757, 103.751], [11
.874, 59.991, 58.812], [199.545, -75.315, 19.314], [-68.89, 106.409, 56.084]]

Deskripsi hasil Divide and Conquer:

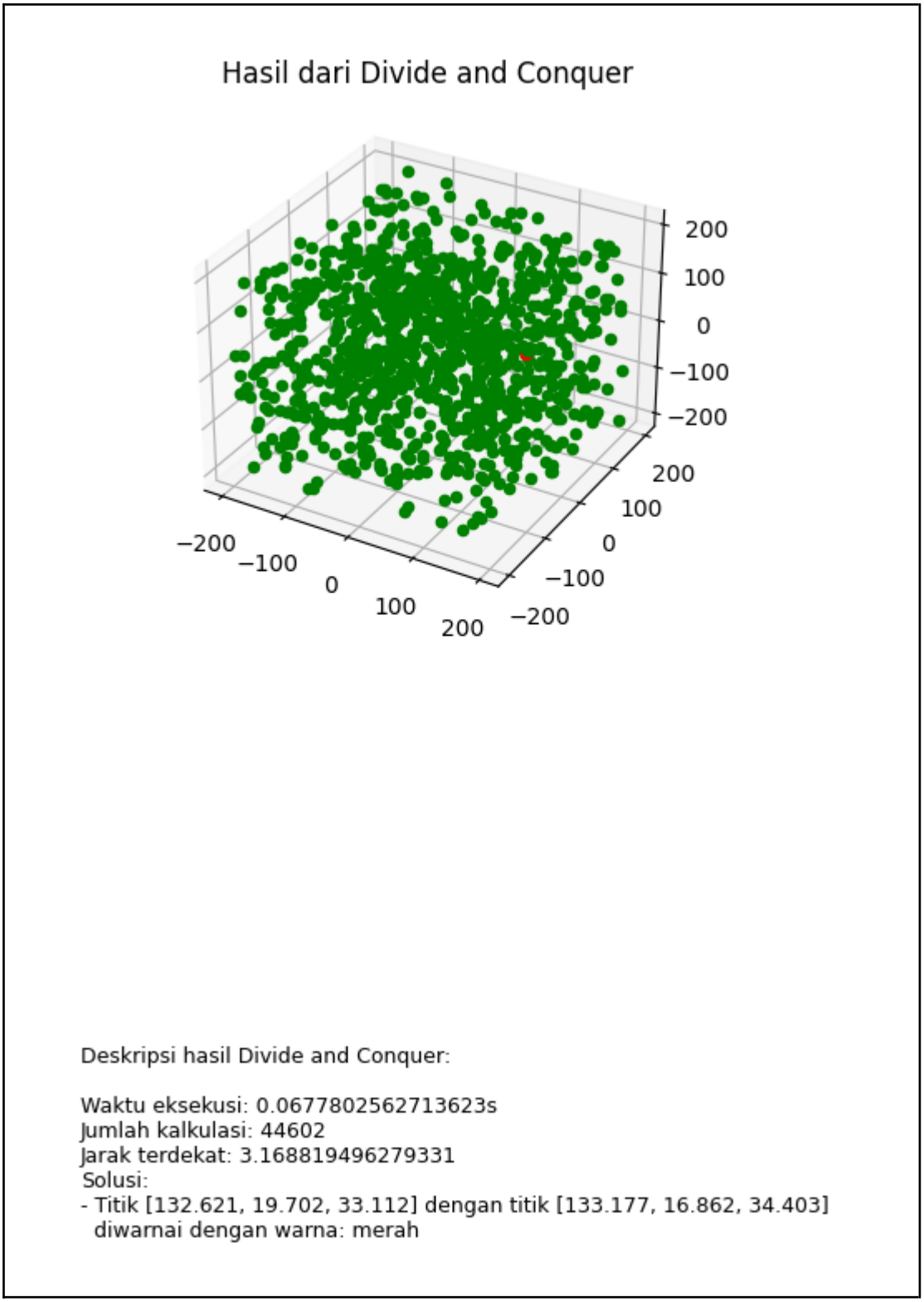
Waktu eksekusi: 0.0677802562713623s
Jumlah kalkulasi: 44602
Jarak terdekat: 3.168819496279331
Solusi:
```

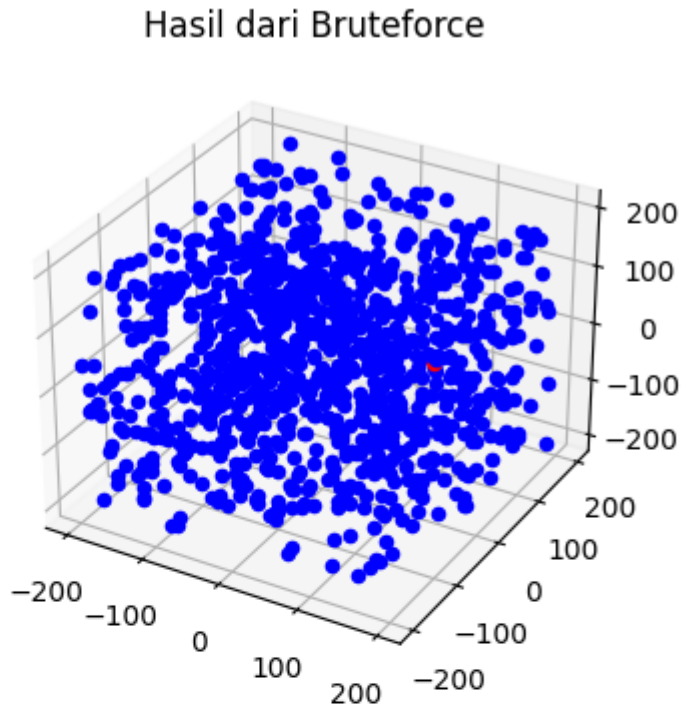
```
- Titik [132.621, 19.702, 33.112] dengan titik [133.177, 16.862, 34.403]
  diwarnai dengan warna: merah



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.7169990539550781s
Jumlah kalkulasi: 498502
Jarak terdekat: 3.168819496279331
Solusi:
- Titik [132.621, 19.702, 33.112] dengan titik [133.177, 16.862, 34.403]
  diwarnai dengan warna: merah
```


Hasil dari Divide and Conquer
200
100
0
−100
−200
200
100
0
−100
−200
−200
−100
0
100
200
Deskripsi hasil Divide and Conquer:
Waktu eksekusi: 0.0677802562713623s
Jumlah kalkulasi: 44602
Jarak terdekat: 3.168819496279331
Solusi:
- Titik [132.621, 19.702, 33.112] dengan titik [133.177, 16.862, 34.403]
diwarnai dengan warna: merah



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.7169990539550781s
Jumlah kalkulasi: 498502
Jarak terdekat: 3.168819496279331
Solusi:
- Titik [132.621, 19.702, 33.112] dengan titik [133.177, 16.862, 34.403]
  diwarnai dengan warna: merah

5. test case 5

input	n = 100, dimensi = 1, 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):
1
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[-55.001], [137.645], [36.158], [63.738], [1.886], [83.74], [14.739], [38.8
84], [156.44], [182.581], [7.13], [29.547], [-116.061], [-150.49], [-145.012], [61.128], [64.723],
 [193.074], [38.789], [-117.259], [23.749], [-81.434], [70.746], [127.043], [-92.382], [-42.141],
[30.228], [132.523], [64.321], [-159.773], [177.39], [131.596], [184.048], [45.124], [32.744], [11
3.162], [-79.852], [-128.995], [-87.138], [133.356], [136.997], [-127.754], [-148.457], [-79.769],
 [-181.522], [-155.696], [98.585], [46.875], [-185.56], [168.452], [71.896], [-8.313], [183.659],
[114.859], [-170.955], [-162.826], [31.235], [-64.579], [-66.393], [-73.445], [68.098], [-49.696],
 [190.892], [-124.582], [-181.062], [-66.524], [123.52], [-192.236], [194.089], [90.317], [100.372
], [130.188], [-133.96], [54.476], [-165.905], [85.444], [-132.642], [45.965], [-87.426], [-20.792
], [4.059], [5.422], [12.627], [130.56], [174.203], [31.919], [181.815], [-89.368], [-182.388], [-
44.283], [-132.226], [105.975], [-9.192], [-97.007], [-159.447], [103.253], [22.15], [164.424], [-
8.872], [192.438]]

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.00101327896118164065
Jumlah kalkulasi: 89
Jarak terdekat: 0.08299999999999841
Solusi:
- Vektor [-79.852] dengan vektor [-79.769]



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.0035607814788818365
Jumlah kalkulasi: 4852
Jarak terdekat: 0.08299999999999841
Solusi:
- Vektor [-79.852] dengan vektor [-79.769]
```

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: [[-103.33, -34.982], [93.387, 174.757], [-165.289, -169.932], [65.892, -186.
818], [36.754, -56.237], [-172.767, 37.182], [-133.943, -2.245], [-22.453, -4.347], [76.47, -28.04
4], [-5.291, 14.225], [-30.46, -125.156], [-150.393, -148.238], [-135.493, -72.198], [-23.51, -53.
83], [70.083, 26.436], [133.616, 67.463], [-106.856, -127.909], [-42.169, -153.252], [-196.41, -14
7.269], [107.311, -20.571], [-122.202, 141.721], [-179.147, -100.007], [-134.19, -42.153], [132.17
4, -56.604], [-90.718, -146.725], [-101.302, -99.682], [-75.115, -114.645], [172.777, 147.367], [1
25.162, -174.231], [51.055, -158.293], [-162.328, 25.991], [-106.568, 43.274], [-119.005, 26.495],
 [105.925, -171.472], [-37.194, 60.795], [32.859, 25.71], [155.885, -179.749], [188.728, 111.985],
 [-193.701, 72.55], [-98.125, -20.62], [-87.422, -128.173], [8.172, 11.281], [21.65, 114.252], [-5
1.555, 186.844], [158.385, 163.546], [178.31, -23.398], [-64.141, -151.37], [190.051, 20.202], [80
.463, 45.407], [140.364, -192.533], [-24.534, -92.07], [-72.5, 157.827], [-76.526, 90.805], [191.3
66, -111.476], [-9.415, 147.501], [41.921, 163.565], [-152.141, -185.703], [-54.402, -140.317], [-
34.216, -57.009], [-106.322, 199.083], [-11.908, -166.987], [-43.279, 149.02], [-191.071, 142.056]
, [-121.268, 6.979], [-67.769, -104.624], [129.968, -51.345], [152.648, 102.851], [98.447, -38.697
], [-53.176, -160.467], [-195.093, 42.787], [152.481, 106.854], [22.062, 113.951], [-57.014, 164.7
7], [-2.886, 144.03], [40.379, -172.432], [-80.95, 143.267], [120.451, -192.297], [197.876, 135.11
7], [127.114, 143.636], [6.097, 175.457], [-37.263, -164.712], [-145.302, 118.109], [38.542, -115.
757], [-79.063, -41.968], [134.983, -9.623], [-177.879, -97.131], [153.925, 192.978], [28.231, -33
.994], [-14.075, 20.062], [-19.601, 145.988], [72.744, 117.438], [-191.564, 67.365], [35.099, -173
.809], [31.141, -110.524], [-146.64, 172.289], [-136.901, 148.398], [-117.784, 21.52], [172.52, 72
.939], [187.486, 102.758], [-171.322, -76.841]]

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.00100016593933105475
Jumlah kalkulasi: 312
Jarak terdekat: 0.5102401395421604
Solusi:
- Vektor [21.65, 114.252] dengan vektor [22.062, 113.951]



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.004990339279174805s
Jumlah kalkulasi: 4852
Jarak terdekat: 0.5102401395421604
Solusi:
- Vektor [21.65, 114.252] dengan vektor [22.062, 113.951]
```

7. test case 7

input	n = 100, dimensi = 4, 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):
4
Masukkan batas bawah nilai titik (note: maksimal -1000): -200
Masukkan batas atas nilai titik (note: maksimal 1000): 200

Titik yang digunakan: [[171.178, 50.165, -169.765, 179.21], [-177.74, -40.215, -25.85, -64.406], [
160.247, 192.689, 161.379, 30.982], [-42.032, -81.214, -95.191, 38.867], [-191.649, 117.193, 107.1
41, -46.617], [12.565, 110.627, -106.615, 147.996], [-68.749, -173.52, 62.67, 96.551], [-56.619, 1
16.848, 79.189, 43.378], [133.337, -156.135, -191.406, 109.208], [-55.629, -15.735, 166.336, 118.1
56], [95.784, 42.458, -142.682, -166.361], [11.957, 8.617, -82.765, 72.648], [-84.922, -11.141, -3
.558, -185.994], [-197.702, -57.17, -97.744, 60.359], [-160.757, 75.993, 97.542, -58.316], [-103.8
1, -190.685, -161.199, 183.417], [-5.789, 86.12, 143.719, 7.931], [35.439, 160.949, 78.158, 94.946
], [34.17, 65.719, -123.299, -119.023], [65.818, -6.365, 151.624, 3.841], [-56.835, -105.882, -148
.988, 132.18], [51.203, -161.344, 107.767, 149.67], [-170.572, 58.344, 136.418, 155.11], [34.434,
191.877, 98.704, 50.817], [62.52, 65.919, 188.309, 153.774], [-109.377, 60.485, 101.732, 99.89], [
37.713, -65.944, -140.798, -54.657], [84.46, 136.778, 124.235, 43.589], [195.714, 176.35, 63.456,
120.92], [-89.26, -198.154, -104.944, 130.711], [-105.306, -123.095, -172.865, -55.907], [93.894,
-72.358, -90.79, 11.214], [98.549, -154.417, 154.674, -143.925], [35.507, 175.986, -172.073, 19.56
2], [181.823, 199.932, 77.841, -41.092], [111.219, -155.172, -8.943, 81.193], [-32.242, -51.086, 1
25.961, -68.566], [-26.0, 95.225, 120.155, -142.247], [36.973, 79.557, 91.118, -180.52], [193.708,
 -56.74, 158.232, 39.957], [46.478, 165.902, -9.761, 9.144], [-183.44, -15.052, 44.154, 153.684],
[-190.943, 170.361, -164.498, 189.915], [34.766, -21.774, 131.715, -66.626], [-121.04, 30.316, -14
4.555, -145.274], [-153.511, -51.397, -13.107, -160.796], [-104.428, 79.552, 153.067, 198.842], [5
0.64, 126.044, -183.265, -42.314], [37.439, -119.012, -101.324, 184.307], [-34.511, 52.791, -69.76
7, 42.664], [56.211, -135.129, -74.432, 29.472], [125.549, 114.682, 84.123, -165.968], [-20.192, -
180.432, 51.086, -197.007], [-133.319, -92.729, 26.578, -69.273], [44.814, -54.474, 127.035, -165.
348], [-16.087, 12.16, -116.904, 136.622], [-130.452, -134.164, -80.538, 100.86], [-50.008, 29.749
, -35.233, -177.511], [-152.365, 143.878, -156.274, 176.549], [-123.94, -103.605, 134.594, -91.563
], [-184.18, 106.501, -32.052, 34.67], [-16.853, -44.381, -178.593, 126.502], [63.264, 9.381, 56.5
19, -168.697], [29.6, -102.075, -186.878, -161.796], [-114.905, 9.904, -91.53, -45.489], [-176.584
, -162.922, -57.91, -183.968], [-28.385, 25.577, 94.444, 119.001], [-61.874, -126.722, 196.601, 34
.877], [21.588, -50.07, -94.119, 93.583], [-88.414, -114.038, -64.847, -87.781], [-137.631, -122.4
3, 39.927, 129.194], [-25.975, -166.546, 69.114, -155.695], [-88.531, 46.909, 14.578, 10.743], [-1
30.793, -87.019, 92.496, 110.341], [-62.254, -142.193, -141.524, -55.194], [-1.401, -135.092, 68.9
01, 77.618], [-36.451, 31.507, 172.547, -132.165], [-184.274, 13.713, -54.822, 60.139], [26.355, -
180.486, -104.54, -188.956], [64.015, 102.165, 165.862, -51.066], [178.699, 58.67, 109.796, 84.794
], [-83.64, -31.335, -164.79, 196.395], [187.334, -108.118, 189.234, -137.409], [-15.705, 146.379,
 62.147, -30.253], [169.936, -160.846, 11.139, -73.983], [135.751, 184.846, 162.412, -160.021], [-
99.846, -98.472, -66.282, -87.993], [147.408, 169.866, 41.954, 135.071], [-139.514, 132.276, 162.8
76, -177.129], [85.455, 80.55, -93.407, 143.547], [-34.777, -149.915, -164.434, -135.688], [-73.84
, -43.02, -13.938, -114.347], [15.502, -66.037, -89.73, -161.98], [-50.48, -44.57, 184.729, -116.2
22], [-67.528, 2.728, 37.666, 198.135], [-176.944, -134.206, -100.238, 26.143], [23.871, 97.034, -
86.103, 107.655], [128.068, 197.395, -2.669, 169.797], [141.263, 1.183, 92.952, 56.102], [-53.426,
 -94.525, -80.454, -96.821]]

Deskripsi hasil Divide and Conquer:

Waktu eksekusi: 0.00450110435485839845
Jumlah kalkulasi: 2361
```

```
Jarak terdekat: 19.367373311835557
Solusi:
- Vektor [-99.846, -98.472, -66.282, -87.993] dengan vektor [-88.414, -114.038, -64.847, -87.781]



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.008009195327758789s
Jumlah kalkulasi: 4852
Jarak terdekat: 19.367373311835557
Solusi:
- Vektor [-99.846, -98.472, -66.282, -87.993] dengan vektor [-88.414, -114.038, -64.847, -87.781]
```

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: [[-79.335, 89.518, 174.471, -86.501, 161.443, 4.147, 47.039, -14.948, -151.1
96, 66.209], [129.127, 178.223, -25.224, -137.247, 2.884, -145.265, -150.481, 105.331, 96.867, -14
9.292], [135.152, 42.48, 175.105, 153.629, -192.674, -32.81, 68.935, 117.257, -124.093, -194.413],
 [174.864, -110.906, 51.21, 130.812, -19.775, 158.331, -177.98, 149.533, -56.775, 177.424], [100.2
32, 168.811, -143.178, -99.505, -125.833, -149.438, 152.275, -92.354, -199.223, 127.115], [-6.236,
 -50.824, -47.341, -2.286, -116.187, 2.266, -113.01, 82.914, -159.721, 153.831], [196.281, -89.073
, -115.149, -27.62, -115.252, 96.113, -173.777, -194.922, 27.955, 171.861], [-90.167, -31.144, -15
9.857, -192.298, -102.259, 47.63, -6.455, 57.814, 165.189, 116.171], [-60.85, -7.378, 94.023, 83.2
23, -191.769, -85.36, -101.694, -161.058, 143.436, 152.374], [90.223, 157.858, -165.264, -97.67, -
108.858, 185.698, 5.818, 36.423, 28.145, -80.96], [109.85, -0.146, 14.579, -3.509, -193.394, -90.9
07, -126.659, -24.369, 102.371, -89.87], [-128.944, 56.966, 20.359, 4.01, -171.087, -74.038, -26.8
41, -152.192, 54.583, -98.805], [50.765, 100.347, -176.686, 32.807, -51.404, -73.808, 189.519, -37
.671, 148.558, 39.366], [-180.981, 171.011, 109.816, 186.832, 21.955, 23.799, -186.857, 153.289, -
52.616, -35.445], [121.719, 133.533, 70.726, -119.407, -192.238, 62.116, 180.567, -101.103, 72.767
, 79.8], [26.706, 113.421, 97.942, -91.742, 185.656, 94.808, -111.15, -58.59, 89.778, 150.238], [-
80.037, 150.497, -108.053, 179.466, 111.175, -186.745, -145.975, 43.198, -58.629, 151.257], [-171.
418, -140.266, 173.795, 13.26, 168.48, 93.453, 159.113, 56.666, -28.835, 15.877], [-117.866, 158.2
24, -35.485, -195.76, 191.859, 46.797, -82.131, -94.036, -184.193, 183.714], [150.59, -176.101, 15
6.476, -110.36, -105.185, -154.361, -10.78, 150.679, 61.375, -188.693], [167.272, 140.628, 103.202
, 147.957, -129.45, 138.261, -196.421, 197.934, -175.986, -169.285], [-137.013, 127.453, 157.655,
-62.087, -113.523, 107.636, -101.513, -198.703, 110.67, 185.206], [-163.151, -140.842, 175.569, 10
2.649, -138.433, 58.982, 195.61, 67.99, 195.143, -34.438], [-95.059, -28.853, -196.6, 44.224, 167.
525, 17.87, -1.066, -81.359, 39.155, -70.836], [-5.597, -22.922, 190.908, -13.916, 134.201, 15.013
, -48.573, -187.543, -178.4, 3.23], [-163.9, 31.463, 52.278, 119.186, 163.555, -180.948, -22.48, 2
.836, -22.334, -178.32], [154.892, -75.273, -111.065, 107.896, -155.894, 142.708, -78.165, 6.114,
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Deskripsi hasil Divide and Conquer:
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Waktu eksekusi: 0.028561115264892578s
Jumlah kalkulasi: 8902
Jarak terdekat: 201.7007008664075
Solusi:
- Vektor [117.64, 21.913, -116.694, -3.024, -68.352, 78.32, 181.502, -100.251, 44.652, 105.931] de
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164]



Deskripsi hasil Bruteforce:

Waktu eksekusi: 0.0150306224822998055
Jumlah kalkulasi: 4852
Jarak terdekat: 201.7007008664075
Solusi:
- Vektor [117.64, 21.913, -116.694, -3.024, -68.352, 78.32, 181.502, -100.251, 44.652, 105.931] de
ngan vektor [155.054, 50.158, -190.146, -22.684, -15.935, 187.965, 130.031, -122.031, -74.067, 79.
164]
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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

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, 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, 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, diakses 12 Februari 2023.