



UNIVERSITA
DEGLI STUDI
FIRENZE



Mid Term Presentation: K-means Algorithm

Parallel Programming

Gianluca Giuliani

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Dispositivo

Il dispositivo su cui viene eseguito il codice contiene un processore intel i7 con 14 cores e 20 processori logici

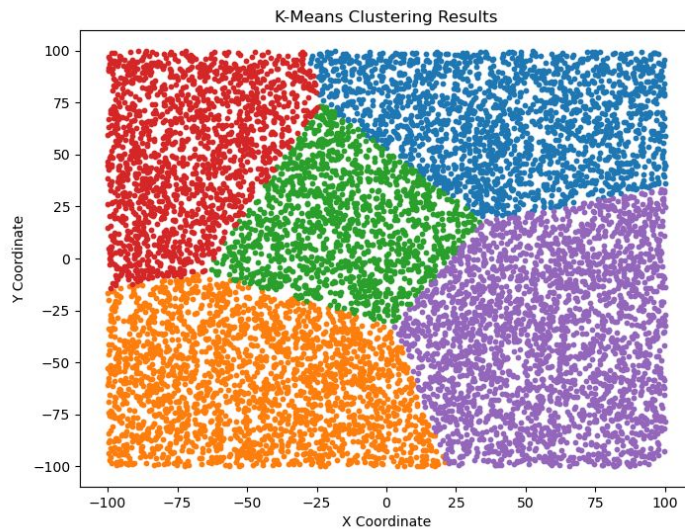
Processori fisici:	1
Cores:	14
Processori logici:	20

Algoritmo

- Inizializzazione
Inizializzo casualmente i centroidi dei cluster
- Assegnazione
Assegna ogni punto al centroide più vicino.
- Aggiornamento
Calcola nuovi centroidi come la media dei punti assegnati.

Ripeto Assegnazione e Aggiornamento per un certo numero, maxIteration , volte.

Risultati



Kmenas con 1000 punti e 5 cluster

Parametri

- Numero di Punti
- Numero di Cluster
- Numero massimo di iterazioni
- Numero di threads

SoA vs AoS

- In SoA, Structure of Arrays, i dati sono separati in array distinti, uno per ogni attributo.

Questo mi permette di ottimizzare operazioni SIMD e favorisce il parallelismo

- In AoS ogni elemento è una struttura che rappresenta un oggetto completo.

Di contro avrò un accesso alla cache più lento.

Code Snippets: AoS - Cluster Point.h

```
class Cluster {
    float x, y;
    float sum_x, sum_y;
    int size;

public:
    Cluster(float x_val = 0, float y_val = 0){
        std::random_device rd;
        std::mt19937 gen(rd());
        std::uniform_real_distribution<> dis(-100.0, 100.0);

        x = dis(gen);
        y = dis(gen);
        sum_x = 0;
        sum_y = 0;
        size = 0;
    }

    void updateCenter() {
        if (size > 0) {
            x = sum_x / size;
            y = sum_y / size;
        }
    }

    void reset() {
        sum_x = 0;
        sum_y = 0;
        size = 0;
    }

    void updateCenter(float sum_x, float sum_y, int count) {
        if (count > 0) {
            x = sum_x / count;
            y = sum_y / count;
        }
    }
}
```

Code Snippets: AoS - Cluster Point.h

```
class Point {  
    float x, y;  
    int cluster_id;
```



Code Snippets: AoS AoS.h

```
std::vector<Cluster> clusters(num_clusters);
for (int i = 0; i < num_clusters; ++i) {
    clusters[i] = Cluster();
}

#pragma omp parallel for
for (int iter = 0; iter < max_iterations; ++iter) {
    // Assignment Step
    #pragma omp parallel for schedule(dynamic, 1000)
    for (size_t i = 0; i < points.size(); ++i) {
        float min_distance = std::numeric_limits<float>::max();
        int best_cluster = -1;

        for (size_t j = 0; j < clusters.size(); ++j) {
            float distance = points[i].distanceTo(clusters[j].getX(), clusters[j].getY());
            if (distance < min_distance) {
                min_distance = distance;
                best_cluster = j;
            }
        }
        points[i].setClusterId(best_cluster);
    }

    float* cluster_sum_x = new float[clusters.size()]();
    float* cluster_sum_y = new float[clusters.size()]();
    int* cluster_count = new int[clusters.size()]();
}
```

Code Snippets: AoS AoS.h

```
// Reset the clusters before accumulation
#pragma omp parallel for
for (size_t i = 0; i < clusters.size(); ++i) {
    clusters[i].reset();
}

// Accumulate
#pragma omp parallel for reduction(+:cluster_sum_x[:clusters.size()], cluster_sum_y[:clusters.size()], cluster_count[:clusters.size()])
for (size_t i = 0; i < points.size(); ++i) {
    int cluster_id = points[i].getClusterId();

    cluster_sum_x[cluster_id] += points[i].getX();
    cluster_sum_y[cluster_id] += points[i].getY();
    cluster_count[cluster_id]++;
}

// Update the cluster
#pragma omp parallel for
for (size_t i = 0; i < clusters.size(); ++i) {
    clusters[i].updateCenter(cluster_sum_x[i], cluster_sum_y[i], cluster_count[i]);
}

delete[] cluster_sum_x;
delete[] cluster_sum_y;
delete[] cluster_count;
```

Code Snippets: SoA Utility.h

```
struct alignas(64) PointsSoA {  
    std::vector<float> x;  
    std::vector<float> y;  
  
    PointsSoA(size_t numPoints) : x(numPoints), y(numPoints) {}  
  
    float getX(size_t index) const { return x[index]; }  
    float getY(size_t index) const { return y[index]; }  
  
    Codeium: Refactor | Explain | Generate Function Comment | ✕  
    void set(size_t index, float xVal, float yVal) {  
        x[index] = xVal;  
        y[index] = yVal;  
    }  
};
```

Code Snippets: SoA SoA.h

```
std::vector<float> centroidsX(k), centroidsY(k);
#pragma omp parallel
{
    std::random_device rd;
    std::mt19937 gen(rd() ^ omp_get_thread_num());
    std::uniform_real_distribution<float> dis(-100.0f, 100.0f);

    #pragma omp for
    for (int i = 0; i < k; i++) {
        centroidsX[i] = dis(gen);
        centroidsY[i] = dis(gen);
    }
}
```

Code Snippets: SoA SoA.h

```
#pragma omp parallel shared(newCentroidsX, newCentroidsY, counts)
{
    for (int iter = 0; iter < maxIterations; iter++) {

        // Parallelize point-to-centroid assignment
        #pragma omp for schedule(static,500)
        for (size_t i = 0; i < numPoints; i++) {
            int bestCluster = -1;
            float bestDistance = std::numeric_limits<float>::max();
            for (int j = 0; j < k; j++) {
                float d = distance(points, i, centroidsX[j], centroidsY[j]);
                if (d < bestDistance) {
                    bestDistance = d;
                    bestCluster = j;
                }
            }
            labels[i] = bestCluster;
        }
    }
}
```

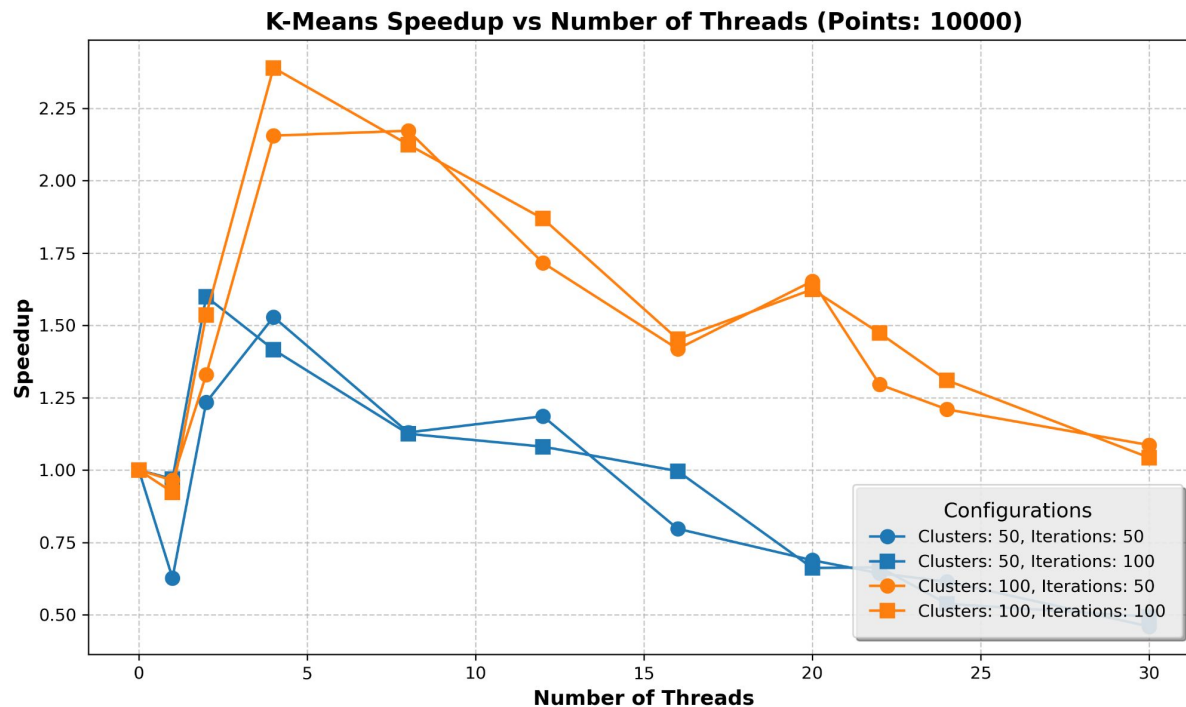


Code Snippets: SoA SoA.h

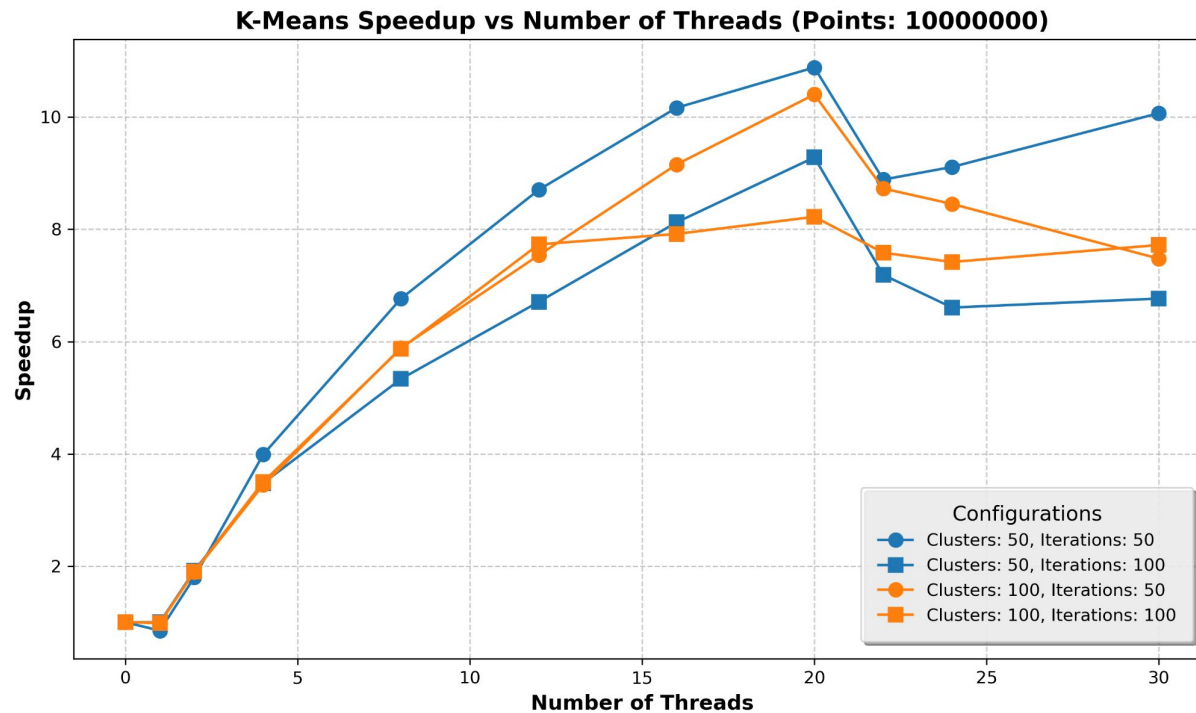
```
// Parallelize centroid update with reduction
#pragma omp for reduction(+:newCentroidsX, newCentroidsY, counts)
for (size_t i = 0; i < numPoints; i++) {
    int cluster = labels[i];
    newCentroidsX[cluster] += points.getX(i);
    newCentroidsY[cluster] += points.getY(i);
    counts[cluster]++;
}

// Update centroids after parallel computation
#pragma omp for
for (int j = 0; j < k; j++) {
    if (counts[j] > 0) {
        centroidsX[j] = newCentroidsX[j] / counts[j];
        centroidsY[j] = newCentroidsY[j] / counts[j];
    }
}
}
```

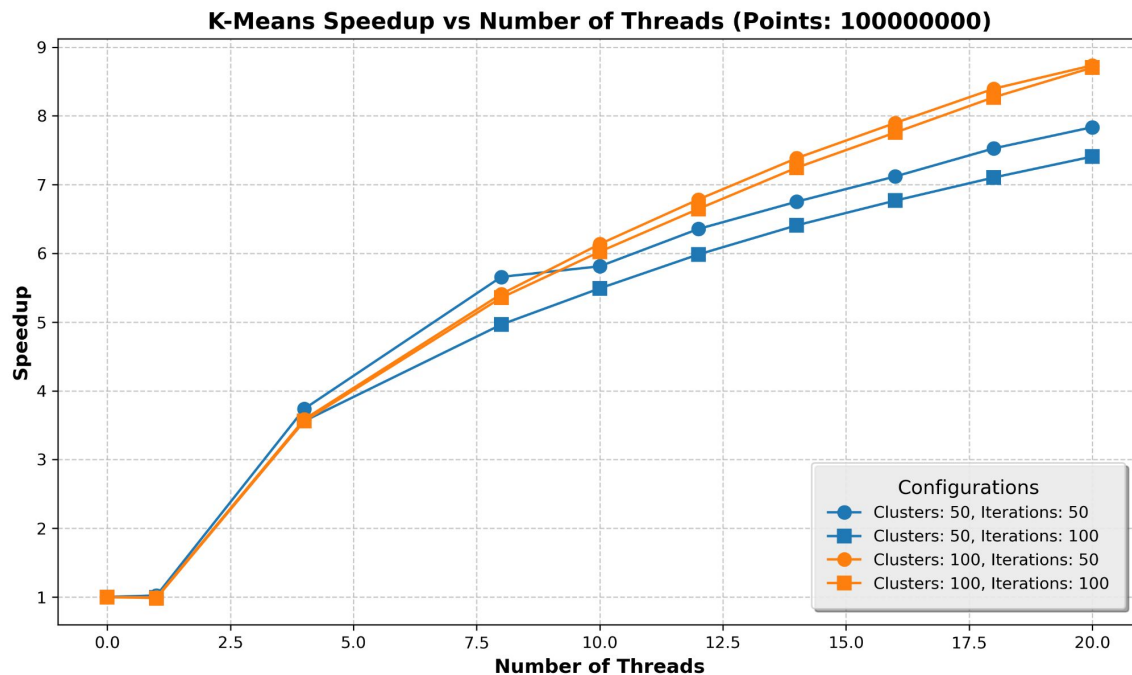
Plots SoA



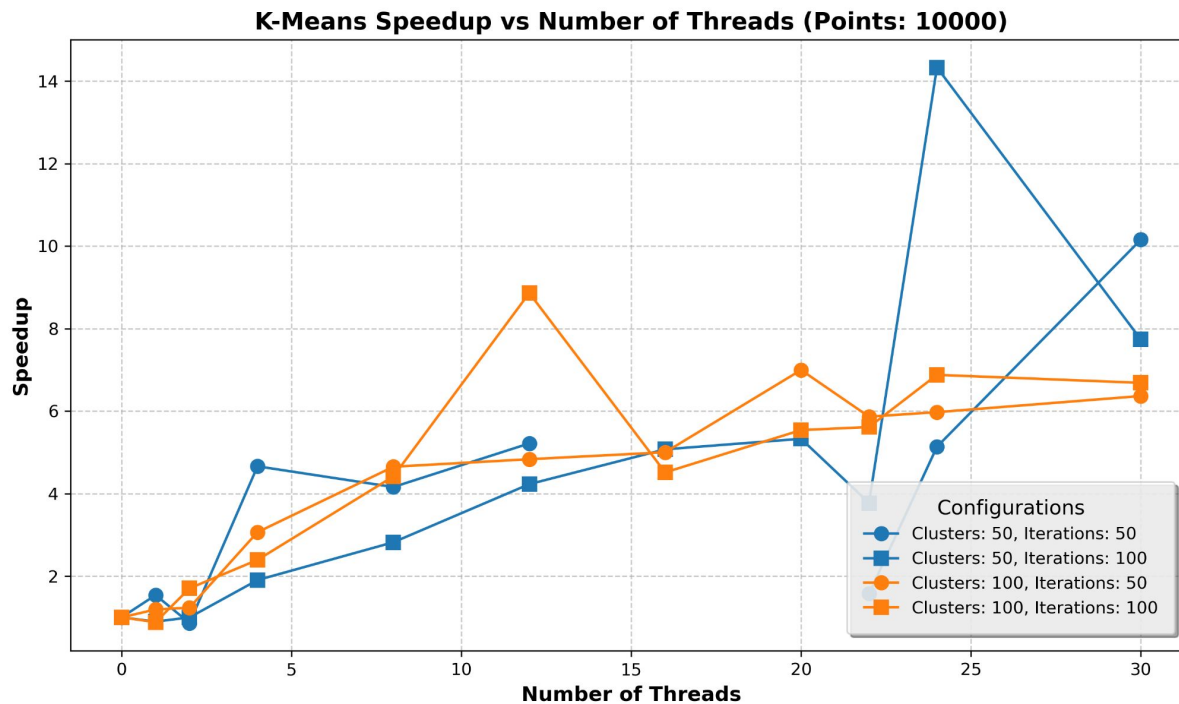
Plots SoA



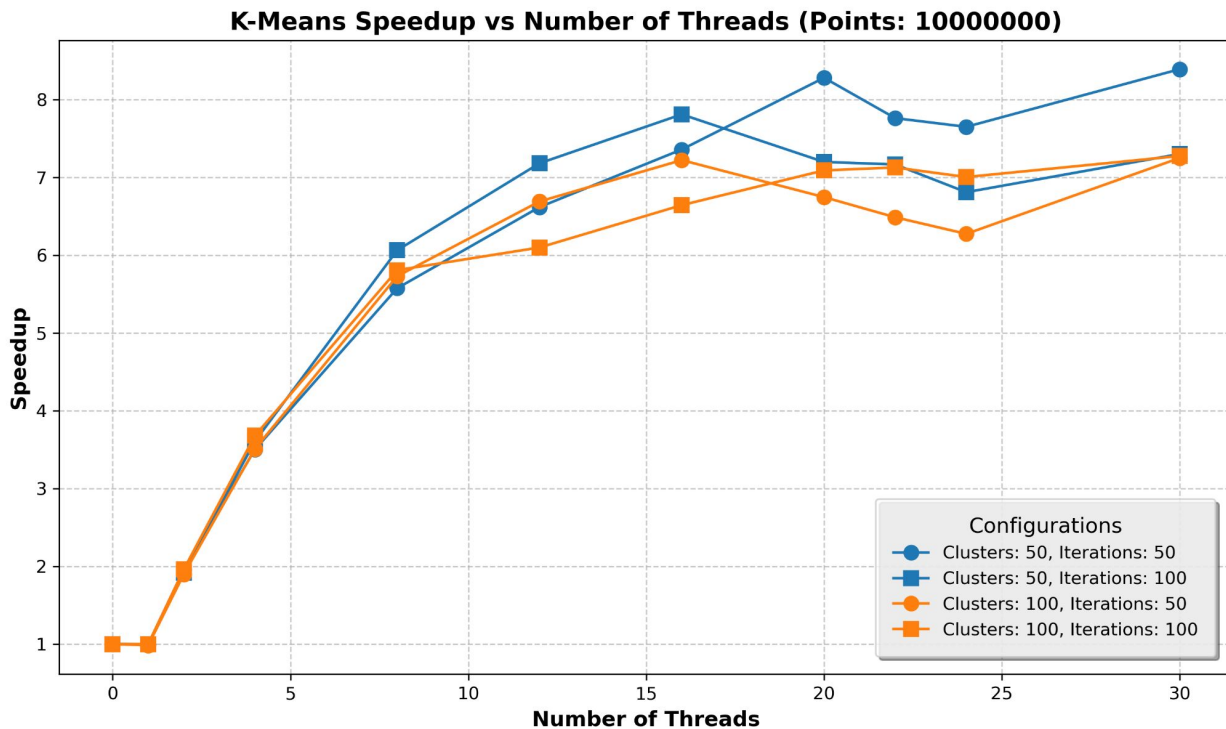
Plots SoA



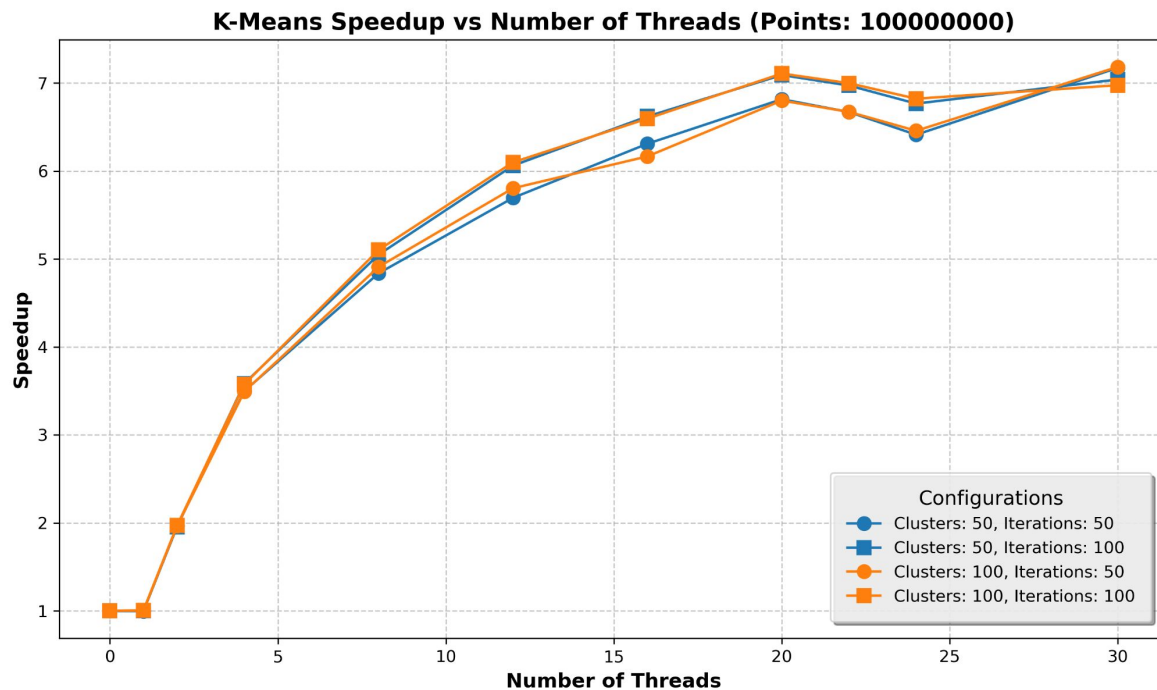
Plots AoS



Plots AoS



Plots AoS



Plots SoA vs AoS execution times

