Saint Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO University)
Faculty of Informational Technologies and Programming

REPORT

about laboratory work № 3

« The degree of objects similarity »

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Report

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k- .

2

1. DBSCAN *k*- .
2. , ( ) *k*-, , .

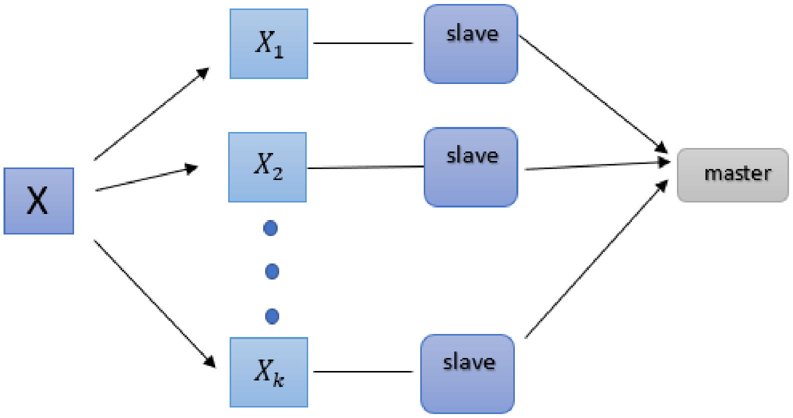
3

, , .

3.1 DBSCAN

DBSCAN (Density-based spatial clustering of applications with noise) - , . DBSCAN ,
.

DBSCAN , k-d tree, r-tree, vintage-point tree. X X_i, $i = 1, \dots, k$. DBSCAN master-slave. , . , . , . .



3.2 K-

k- *X* *K* $S_1, S_2, \ldots, S_k$, . , *d*- *k* , *d*- . *d*- *K* , .
, *n* , , . .
, .re , . ( ) *K*- , .

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[1]:

```
%cat example2.c
```

```
#include <math.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <sys/time.h>


#include <assert.h>
#include <float.h>
#include <math.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

#include <omp.h>

#define KMEANS_NULL_CLUSTER -1

/*
* If the algorithm doesn't converge within this number of iterations,
* it will return with a failure error code.
*/
#define KMEANS_MAX_ITERATIONS 1000

#define kmeans_malloc(size) malloc(size)
#define kmeans_free(ptr) free(ptr)

typedef void * Pointer;

typedef enum {
        KMEANS_OK,
        KMEANS_EXCEEDED_MAX_ITERATIONS,
        KMEANS_ERROR
} kmeans_result;


typedef double (*kmeans_distance_method) (const Pointer a, const Pointer b);
typedef void (*kmeans_centroid_method) (const Pointer * objs, const int *
clusters, size_t num_objs, int cluster, Pointer centroid);

typedef struct kmeans_config
{
        /* Function returns the "distance" between any pair of objects */
        kmeans_distance_method distance_method;

        /* Function returns the "centroid" of a collection of objects */
        kmeans_centroid_method centroid_method;

        /* An array of objects to be analyzed. User allocates this array */
        /* and is responsible for freeing it. */
        /* For objects that are not capable of participating in the distance */
        /* calculations, but for which you still want included in the process */
        /* (for examples, database nulls, or geometry empties) use a NULL */
        /* value in this list. All NULL values will be returned in the */
        /* KMEANS_NULL_CLUSTER. */
        Pointer * objs;

        /* Number of objects in the preceding array */
        size_t num_objs;

        /* An array of inital centers for the algorithm */
        /* Can be randomly assigned, or using proportions, */
        /* unfortunately the algorithm is sensitive to starting */
        /* points, so using a "better" set of starting points */
        /* might be wise. User allocates and is responsible for freeing. */
        Pointer * centers;

        /* Number of means we are calculating, length of preceding array */
        unsigned int k;

        /* Maximum number of times to iterate the algorithm, or 0 for */
        /* library default */
        unsigned int max_iterations;

        /* Iteration counter */
        unsigned int total_iterations;

        /* Array to fill in with cluster numbers. User allocates and frees. */
        int * clusters;

} kmeans_config;

static void
update_r(kmeans_config *config)
```

```
{
        int i;

        #pragma omp parallel for
        for (i = 0; i < config->num_objs; i++)
        {
                double distance, curr_distance;
                int cluster, curr_cluster;
                Pointer obj;

                assert(config->objs != NULL);
                assert(config->num_objs > 0);
                assert(config->centers);
                assert(config->clusters);

                obj = config->objs[i];


                /*
                * Don't try to cluster NULL objects, just add them
                * to the "unclusterable cluster"
                */
                if (!obj)
                {
                        config->clusters[i] = KMEANS_NULL_CLUSTER;
                        continue;
                }
                // printf("It2\n");
                /* Initialize with distance to first cluster */
                curr_distance = (config->distance_method)(obj,
config->centers[0]);
                curr_cluster = 0;

                /* Check all other cluster centers and find the nearest */
                for (cluster = 1; cluster < config->k; cluster++)
                {
                        distance = (config->distance_method)(obj,
config->centers[cluster]);
                        if (distance < curr_distance)
                        {
                                curr_distance = distance;
                                curr_cluster = cluster;
                        }
                }

                /* Store the nearest cluster this object is in */
                config->clusters[i] = curr_cluster;
        }
```

```
}

static void
update_means(kmeans_config *config)
{
        int i;

        for (i = 0; i < config->k; i++)
        {
                /* Update the centroid for this cluster */
                (config->centroid_method)(config->objs, config->clusters,
config->num_objs, i, config->centers[i]);
        }
}



kmeans_result
kmeans(kmeans_config *config)
{
        int iterations = 0;
        int *clusters_last;
        size_t clusters_sz = sizeof(int)*config->num_objs;

        assert(config);
        assert(config->objs);
        assert(config->num_objs);
        assert(config->distance_method);
        assert(config->centroid_method);
        assert(config->centers);
        assert(config->k);
        assert(config->clusters);
        assert(config->k <= config->num_objs);

        /* Zero out cluster numbers, just in case user forgets */
        memset(config->clusters, 0, clusters_sz);

        /* Set default max iterations if necessary */
        if (!config->max_iterations)
                config->max_iterations = KMEANS_MAX_ITERATIONS;

        /*
         * Previous cluster state array. At this time, r doesn't mean anything
         * but it's ok
         */
        clusters_last = kmeans_malloc(clusters_sz);

        while (1)
        {
                /* Store the previous state of the clustering */
                memcpy(clusters_last, config->clusters, clusters_sz);

                update_r(config);
                update_means(config);
                /*
                 * if all the cluster numbers are unchanged since last time,
                 * we are at a stable solution, so we can stop here
                 */
                if (memcmp(clusters_last, config->clusters, clusters_sz) == 0)
                {
                        kmeans_free(clusters_last);
                        config->total_iterations = iterations;
                        return KMEANS_OK;
                }

                if (iterations++ > config->max_iterations)
                {
                        kmeans_free(clusters_last);
                        config->total_iterations = iterations;
                        return KMEANS_EXCEEDED_MAX_ITERATIONS;
                }
        }

        kmeans_free(clusters_last);
        config->total_iterations = iterations;
        return KMEANS_ERROR;
}

typedef struct point
{
        double x;
        double y;
} point;


static double pt_distance(const Pointer a, const Pointer b)
{
        point *pa = (point*)a;
        point *pb = (point*)b;

        double dx = (pa->x - pb->x);
        double dy = (pa->y - pb->y);

        return dx*dx + dy*dy;
}
```

```
static void pt_centroid(const Pointer * objs, const int * clusters, size_t
num_objs, int cluster, Pointer centroid)
{
        int i;
        int num_cluster = 0;
        point sum;
        double sum_x, sum_y;
        point **pts = (point**)objs;
        point *center = (point*)centroid;

        sum_x = sum_y = 0.0;

        if (num_objs <= 0) return;

        #pragma omp parallel for reduction(+:sum_x,sum_y,num_cluster)
        for (i = 0; i < num_objs; i++)
        {
                /* Only process objects of interest */
                if (clusters[i] != cluster) continue;

                sum_x += pts[i]->x;
                sum_y += pts[i]->y;
                num_cluster+=1;
        }
        if (num_cluster)
        {
                sum_x /= num_cluster;
                sum_y /= num_cluster;
                center->x = sum_x;
                center->y = sum_y;
        }
        return;
}

int
main(int nargs, char **args)
{
        kmeans_config config;
        kmeans_result result;
        int i, j;
        int spread = 3;
        point *pts;
        point *init;
        int print_results = 0;
        unsigned long start;

        int k = 10;
```

```
srand(1234);

/* Constants */
config.k = k;
config.num_objs = 100000; // config.k * nptsincluster;
config.max_iterations = 200;
config.distance_method = pt_distance;
config.centroid_method = pt_centroid;

/* Inputs for K-means */
config.objs = calloc(config.num_objs, sizeof(Pointer));
config.centers = calloc(config.k, sizeof(Pointer));
config.clusters = calloc(config.num_objs, sizeof(int));

/* Storage for raw data */
pts = calloc(config.num_objs, sizeof(point));
init = calloc(config.k, sizeof(point));

/* Create test data! */
/* Populate with K gaussian clusters of data */

FILE *file = fopen("birch3.txt", "r");
int n = 0, x, y;
while ( fscanf(file, "    %d    %d\n", &x , &y) != EOF ) {
        pts[n].x = (double)x, pts[n].y = (double) y;
        config.objs[n] = &(pts[n]);

        n += 1;
        if( n > config.num_objs ) {
                printf("Too many objects");
                exit(1);
        }
}

/* Populate the initial means vector with random start points */
for (i = 0; i < config.k; i++)
{
        int r = floor(config.num_objs * (1.0 * rand() / RAND_MAX));
        /* Populate raw data */
        init[i] = pts[r];
        /* Pointers to raw data */
        config.centers[i] = &(init[i]);

        if (print_results)
                printf("center[%d]\t%g\t%g\n", i, init[i].x, init[i].y);
}
```

```
        /* run k-means! */
        start = time(NULL);
        result = kmeans(&config);

        printf("\n");
        printf("Iteration count: %d\n", config.total_iterations);
        printf("     Time taken: %ld seconds\n", (time(NULL) - start));
        printf(" Iterations/sec: %.3g\n",
(1.0*config.total_iterations)/(time(NULL) - start));
        printf("\n");

        /* print results */
        if (print_results)
        {
                for (i = 0; i < config.num_objs; i++)
                {
                        point *pt = (point*)(config.objs[i]);

                        if (config.objs[i])
                                printf("%g\t%g\t%d\n", pt->x, pt->y,
config.clusters[i]);
                        else
                                printf("N\tN\t%d\n", config.clusters[i]);
                }
        }

        free(config.objs);
        free(config.clusters);
        free(config.centers);

        free(init);
        free(pts);

}
```

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birch3.txt http://cs.joensuu.fi/sipu/datasets/. , .

[2]:

```
import subprocess
import os
from pathlib import Path

if Path('kmeans').exists():
    %cd kmeans/
```

```
def compile():

    _cmd = 'make -B example2'.split()
    # print(' '.join(_cmd))
    cmd = subprocess.run(_cmd, stdout=subprocess.PIPE, stderr=subprocess.PIPE)

    # if(cmd.stdout): print('cmd.stdout', cmd.stdout)
    if(cmd.stderr): print('cmd.stderr', cmd.stderr)

def run(env=None):
    cmd = subprocess.run('./example2', stdout=subprocess.PIPE,␣
 ↪stderr=subprocess.PIPE, env=env)
```

[3]:

```
compile()

for th in [1, 2, 4, 8, 16]:
    env = os.environ.copy()
    env['OMP_NUM_THREADS'] = str(th)

    print(f"Executing kmeans with {th} threads", end="\n\t")
    %timeit run(env)
    print()
```

```
Executing kmeans with 1 threads
        488 ms ś 5.54 ms per loop (mean ś std. dev. of 7 runs, 1 loop each)

Executing kmeans with 2 threads
        282 ms ś 12.7 ms per loop (mean ś std. dev. of 7 runs, 1 loop each)

Executing kmeans with 4 threads
        1.48 s ś 43.5 ms per loop (mean ś std. dev. of 7 runs, 1 loop each)

Executing kmeans with 8 threads
        304 ms ś 21.2 ms per loop (mean ś std. dev. of 7 runs, 1 loop each)

Executing kmeans with 16 threads
        314 ms ś 7.97 ms per loop (mean ś std. dev. of 7 runs, 1 loop each)
```

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k- . OpenMP.