

# PBDataAnalysis

P. Baillehache

January 14, 2019

## Contents

<b>1</b>	<b>Definitions</b>	<b>2</b>
1.1	K-means clustering . . . . .	2
<b>2</b>	<b>Interface</b>	<b>2</b>
<b>3</b>	<b>Code</b>	<b>5</b>
3.1	pbdataanalysis.c . . . . .	5
<b>4</b>	<b>Makefile</b>	<b>13</b>
<b>5</b>	<b>Unit tests</b>	<b>14</b>
<b>6</b>	<b>Unit tests output</b>	<b>16</b>

## Introduction

PBDataAnalysis is a C library providing structures and functions to perform various data analysis.

It implements the following algorithms:

- K-means clustering (random, Forgy and plusplus seeds)

It uses the `PBErr`, `PBMath`, `PBJSon`, `GSet` libraries.

# 1 Definitions

## 1.1 K-means clustering

The goal of the K-means clustering algorithm is to find K Voronoi cells which clusters a data set in a way that for each cells the center of this cell is the nearest possible to the average value of the input data inside this cell.

The K-means algorithm is as follow, where 'seed' defines the way we initialise the algorithm: 'random', 'Forgy' or 'plusplus'.

```
if seed = random
    init the center of each cluster with a random value inside the bounds
    of the input data
else if seed = Forgy
    init the center of each cluster with one of the input data randomly
    choosen, one given input data can't be choosen twice
else if seed = pluspus
    choose one center uniformly at random from among the data points
    for each data point x, compute D(x), the distance between x and the
    nearest center that has already been chosen
    choose one new data point at random as a new center, using a weighted
    probability distribution where a point x is chosen with probability
    proportional to D(x)
    repeat the previous 2 steps until k centers have been chosen
loop until clusters' center have all converged
init K empty sets S[]
for each input data I
    ID = get the cluster containing I
    add I to S[ID]
for each set S[I]
    AVG = calculate the average value of the input in S[I]
    if AVG is equal to the center of the I-th cluster
        the center of the I-th cluster has converged
    else
        set the center of the I-th cluster to AVG
```

## 2 Interface

```
// ===== PBDATAANALYSIS.H =====

#ifndef PBDATAANALYSIS_H
#define PBDATAANALYSIS_H

// ===== Include =====

#include <stdlib.h>
#include <stdio.h>
#include <stdbool.h>
#include <execinfo.h>
#include <errno.h>
#include <string.h>
#include "pberr.h"
```

```

#include "pbmath.h"
#include "pbjson.h"
#include "gset.h"

// ===== Define =====

// ===== Data structure =====

typedef enum KMeansClustersSeed {
    KMeansClustersSeed_Random, KMeansClustersSeed_Forgy,
    KMeansClustersSeed_PlusPlus
} KMeansClustersSeed;
#define KMeansClustersSeed_Default KMeansClustersSeed_PlusPlus

typedef struct KMeansClusters {
    GSetVecFloat _centers;
    KMeansClustersSeed _seed;
} KMeansClusters;

// ===== Functions declaration =====

// Create a KMeansClusters for a K-means clustering initialized
// using the 'seed' technique
KMeansClusters KMeansClustersCreateStatic(const KMeansClustersSeed seed);

// Free the memory used by a PBDKMeansClusters
void KMeansClustersFreeStatic(KMeansClusters* const that);

// Create the set of 'K' clusters clustering the 'input' data according
// to the K-means algorithm
// 'K' must be inferior or equal to the number of input data
// srandom() must have been called before using this function
void KMeansClustersSearch(KMeansClusters* const that,
    const GSetVecFloat* const input, const int K);

// Get the set of clusters' center for the KMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
const GSetVecFloat* KMeansClustersCenters(
    const KMeansClusters* const that);

// Get the 'iCluster'-th cluster's center for the KMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
const VecFloat* _KMeansClustersCenterFromId(
    const KMeansClusters* const that, const int iCluster);

// Get the seed of the KMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
KMeansClustersSeed KMeansClustersGetSeed(const KMeansClusters* const that);

// Set the seed of the KMeansClusters 'that' to 'seed'
#if BUILDMODE != 0
inline
#endif
void KMeansClustersSetSeed(KMeansClusters* const that,
    const KMeansClustersSeed seed);

```

```

// Get the center of the cluster including the 'input' data for the
// KMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
const VecFloat* _KMeansClustersCenterFromPos(
    const KMeansClusters* const that, const VecFloat* input);

// Get the index of the cluster including the 'input' data for the
// KMeansClusters 'that'
int KMeansClustersGetId(const KMeansClusters* const that,
    const VecFloat* input);

// Get the seed of the KMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
int KMeansClustersGetK(const KMeansClusters* const that);

// Print the KMeansClusters 'that' on the stream 'stream'
void KMeansClustersPrintln(const KMeansClusters* const that,
    FILE* const stream);

// Load the KMeansClusters 'that' from the stream 'stream'
bool KMeansClustersLoad(KMeansClusters* that, FILE* const stream);

// Save the KMeansClusters 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true upon success else false
bool KMeansClustersSave(const KMeansClusters* const that,
    FILE* const stream, const bool compact);

// Function which return the JSON encoding of 'that'
JSONNode* KMeansClustersEncodeAsJSON(const KMeansClusters* const that);

// Function which decode from JSON encoding 'json' to 'that'
bool KMeansClustersDecodeAsJSON(KMeansClusters* that,
    const JSONNode* const json);

// ===== Polymorphism =====

#define KMeansClustersCenter(Cluster, Input) _Generic(Input, \
    VecFloat*: _KMeansClustersCenterFromPos, \
    const VecFloat*: _KMeansClustersCenterFromPos, \
    int: _KMeansClustersCenterFromId, \
    const int: _KMeansClustersCenterFromId, \
    default: PBErrInvalidPolymorphism)(Cluster, Input)

// ===== Inliner =====

#if BUILDMODE != 0
#include "pbdataanalysis-inline.c"
#endif

#endif

```

## 3 Code

### 3.1 pbdataanalysis.c

```
// ===== PBDATAANALYSIS.C =====

// ===== Include =====

#include "pbdataanalysis.h"
#if BUILDMODE == 0
#include "pbdataanalysis-inline.c"
#endif

// ===== Define =====

// ===== Functions declaration =====

void KMeansClustersInitRandom(KMeansClusters* const that,
    const GSetVecFloat* const input);

void KMeansClustersInitForgy(KMeansClusters* const that,
    const GSetVecFloat* const input);

void KMeansClustersInitPlusPlus(KMeansClusters* const that,
    const GSetVecFloat* const input);

// ===== Functions implementation =====

// Create a KMeansClusters for a K-means clustering initialized
// using the 'seed' technique
// srandom() must have been called before using this function
KMeansClusters KMeansClustersCreateStatic(const KMeansClustersSeed seed) {
    // Declare the KMeansClusters
    KMeansClusters clusters;
    // Init the properties
    clusters._seed = seed;
    clusters._centers = GSetVecFloatCreateStatic();
    // Return the KMeansClusters
    return clusters;
}

// Free the memory used by a PBDKMeansClusters
void KMeansClustersFreeStatic(KMeansClusters* const that) {
    #if BUILDMODE == 0
        if (that == NULL) {
            PBDataAnalysisErr->_type = PBErrTypeNullPointer;
            sprintf(PBDataAnalysisErr->_msg, "'that' is null");
            PBErrCatch(PBDataAnalysisErr);
        }
    #endif
    // Free the memory used by the cluster centers
    while (GSetNbElem(&(that->_centers)) > 0) {
        VecFloat* v = GSetPop((GSetVecFloat*)(KMeansClustersCenters(that)));
        free(v);
    }
}

// Create the set of 'K' clusters clustering the 'input' data according
// to the K-means algorithm
// 'K' must be inferior or equal to the number of input data
// srandom() must have been called before using this function
```

```

void KMeansClustersSearch(KMeansClusters* const that,
    const GSetVecFloat* const input, const int K) {
    #if BUILDMODE == 0
        if (that == NULL) {
            PBDataAnalysisErr->_type = PBErrTypeNullPointer;
            sprintf(PBDataAnalysisErr->_msg, "'that' is null");
            PBErrCatch(PBDataAnalysisErr);
        }
        if (input == NULL) {
            PBDataAnalysisErr->_type = PBErrTypeNullPointer;
            sprintf(PBDataAnalysisErr->_msg, "'input' is null");
            PBErrCatch(PBDataAnalysisErr);
        }
        if (K < 1) {
            PBDataAnalysisErr->_type = PBErrTypeInvalidArg;
            sprintf(PBDataAnalysisErr->_msg, "'K' is invalid (%d>=1)", K);
            PBErrCatch(PBDataAnalysisErr);
        }
        if (GSetNbElem(input) < K) {
            PBDataAnalysisErr->_type = PBErrTypeInvalidArg;
            sprintf(PBDataAnalysisErr->_msg, "'K' is invalid (%d<=%ld)", K,
                GSetNbElem(input));
            PBErrCatch(PBDataAnalysisErr);
        }
    #endif
    // If there are already computed clusters,
    // free the memory used by the cluster centers
    while (GSetNbElem(&(that->_centers)) > 0) {
        VecFloat* v = GSetPop((GSetVecFloat*)(KMeansClustersCenters(that)));
        free(v);
    }
    // Allocate an array of sets used for computation
    GSetVecFloat* inputsByCluster =
        PBErrMalloc(PBDataAnalysisErr, sizeof(GSetVecFloat) * K);
    // Get the dimension of the input
    long dim = VecGetDim(GSetGet(input, 0));
    // Allocate memory for the clusters' center and sets used for
    // computation
    for (int iCenter = K; iCenter--;) {
        // The dimension of the means is the same as the one of the input
        // data
        VecFloat* v = VecFloatCreate(dim);
        GSetAppend((GSetVecFloat*)(KMeansClustersCenters(that)), v);
        inputsByCluster[iCenter] = GSetVecFloatCreateStatic();
    }
    // Initialise the means according to the seed
    switch(KMeansClustersGetSeed(that)) {
        case KMeansClustersSeed_Random:
            KMeansClustersInitRandom(that, input);
            break;
        case KMeansClustersSeed_Forgy:
            KMeansClustersInitForgy(that, input);
            break;
        case KMeansClustersSeed_PlusPlus:
            KMeansClustersInitPlusPlus(that, input);
            break;
        default:
            break;
    }
    // Create a vector used for computation
    VecFloat* w = VecFloatCreate(dim);
    // Loop until the clusters' center are aligned with their

```

```

// real center according to input data
float shift = 1.0;
while (shift > PBMATH_EPSILON) {
    // Reset the shift
    shift = 0.0;
    // Loop on input data
    GSetIterForward iterInput = GSetIterForwardCreateStatic(input);
    do {
        // Get the input data
        VecFloat* v = GSetIterGet(&iterInput);
        // Get the id of the cluster containing this data
        int clusterId = KMeansClustersGetId(that, v);
        // Add the input to the corresponding set
        GSetAppend(inputsByCluster + clusterId, v);
    } while(GSetIterStep(&iterInput));
    // For each cluster
    for (int iCenter = K; iCenter--;) {
        // Reset the vector used for computation
        VecSetNull(w);
        // Memorize the number of input associated to this cluster
        int nbInput = GSetNbElem(inputsByCluster + iCenter);
        // If there are data in this cluster
        if (nbInput > 0) {
            // Loop on the input contained by this cluster
            GSetIterForward iterSet =
                GSetIterForwardCreateStatic(inputsByCluster + iCenter);
            do {
                // Get the input data
                VecFloat* v = GSetIterGet(&iterSet);
                // Sum it to the temporary vector
                VecOp(w, 1.0, v, 1.0);
            } while(GSetIterStep(&iterSet));
            // Get the center (average) of the input contained by this
            // cluster
            VecScale(w, 1.0 / (float)nbInput);
            // Update the shift
            shift += VecDist(KMeansClustersCenter(that, iCenter), w);
            // Update the cluster center with the center of the input
            //VecPrint(KMeansClustersCenter(that, iCenter), stdout);printf(" ");
            VecCopy((VecFloat*)KMeansClustersCenter(that, iCenter), w);
            // Reset the sets of input data
            GSetFlush(inputsByCluster + iCenter);
        }
    }
    //printf("\n");
}
// Free the memory used by the vector and sets used for computation
free(inputsByCluster);
VecFree(&w);
}

void KMeansClustersInitRandom(KMeansClusters* const that,
    const GSetVecFloat* const input) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
    if (input == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'input' is null");
    }
#endif
}

```

```

        PBErrCatch(PBDataAnalysisErr);
    }
#endif
    // Get the bounds of the input data
    GSetVecFloat bounds = GSetGetBounds(input);
    VecFloat* boundMin = GSetGet(&bounds, 0);
    VecFloat* boundMax = GSetGet(&bounds, 1);
    // Get the dimension of the data
    int dim = VecGetDim(GSetGet(input, 0));
    // For each cluster's center
    for (int iCenter = KMeansClustersGetK(that); iCenter--;) {
        // Get the iCenter-th cluster center
        VecFloat* center = (VecFloat*)KMeansClustersCenter(that, iCenter);
        // Initialize randomly the components of the iCenter-th cluster's
        // center
        for (int iDim = dim; iDim--;) {
            VecSet(center, iDim, VecGet(boundMin, iDim) +
                rnd() * (VecGet(boundMax, iDim) - VecGet(boundMin, iDim)));
        }
    }
    // Free memory
    GSetFlush(&bounds);
    VecFree(&boundMin);
    VecFree(&boundMax);
}

void KMeansClustersInitForgy(KMeansClusters* const that,
    const GSetVecFloat* const input) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
    if (input == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'input' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
#endif
    // Create a set to select the seeds
    GSetVecFloat forgyInp = GSetVecFloatCreateStatic();
    // Get the number of inputs
    long nbInput = GSetNbElem(input);
    // Declare a variable to pick one input randomly
    VecFloat* inp = NULL;
    // For each cluster's center
    for (int iCenter = KMeansClustersGetK(that); iCenter--;) {
        // Pick an input while avoiding picking twice the same
        // Supposes K is far less than the number of inputs
        do {
            inp = GSetGet(input, (long)round(rnd() * (nbInput - 1)));
        } while (GSetFirstElem(&forgyInp, inp) != NULL);
        // Set the center of the iCenter-th cluster to this input
        VecCopy((VecFloat*)KMeansClustersCenter(that, iCenter), inp);
    }
    // Empty the set used to select the seeds
    GSetFlush(&forgyInp);
}

void KMeansClustersInitPlusPlus(KMeansClusters* const that,
    const GSetVecFloat* const input) {

```



```

#if BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
    if (input == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'input' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
    if (GSetNbElem(input) < KMeansClustersGetK(that)) {
        PBDataAnalysisErr->_type = PBErrTypeInvalidArg;
        sprintf(PBDataAnalysisErr->_msg, "not enough inputs (%ld>=%d)",
            GSetNbElem(input), KMeansClustersGetK(that));
        PBErrCatch(PBDataAnalysisErr);
    }
#endif
    // Create a copy of the set of inputs to select the seeds
    GSetVecFloat remainInp = GSetVecFloatCreateStatic();
    // For each remaining inputs
    GSetIterForward iter = GSetIterForwardCreateStatic(input);
    do {
        GSetAppend(&remainInp, (VecFloat*)GSetIterGet(&iter));
    } while (GSetIterStep(&iter));
    // Declare a variable to pick one input randomly
    VecFloat* inp = NULL;
    // Pick one input randomly for the first cluster's center
    GSetShuffle((GSet*)&remainInp);
    inp = GSetPop(&remainInp);
    // Set the center of the 1st cluster to this input
    VecCopy((VecFloat*)KMeansClustersCenter(that, 0), inp);
    // For each following cluster
    for (int iCenter = 1; iCenter < KMeansClustersGetK(that); ++iCenter) {
        // Declare a variable to memorize the sum of square of distances
        float sumDist = 0.0;
        // For each remaining inputs
        iter = GSetIterForwardCreateStatic(&remainInp);
        do {
            // Calculate the minimum distance from this input to the center
            // of already choosen cluster's center
            inp = GSetIterGet(&iter);
            float dist = VecDist(inp, KMeansClustersCenter(that, 0));
            for (int iChoosenCluster = 1; iChoosenCluster < iCenter;
                ++iChoosenCluster) {
                float d = VecDist(inp,
                    KMeansClustersCenter(that, iChoosenCluster));
                if (d < dist)
                    dist = d;
            }
            GSetElemSetSortVal((GSetElem*)GSetIterGetElem(&iter),
                fsquare(dist));
            sumDist += fsquare(dist);
        } while (GSetIterStep(&iter));
        // Sort the remaining inputs by their distance
        GSetSort(&remainInp);
        // Select randomly one input according to its squared distance
        float r = rnd() * sumDist;
        GSetIterBackward iterBack = GSetIterBackwardCreateStatic(&remainInp);
        float sum = GSetElemGetSortVal(GSetIterGetElem(&iterBack));
        while (r > sum) {
            GSetIterStep(&iterBack);

```

```

        sum += GSetElemGetSortVal(GSetIterGetElem(&iterBack));
    }
    inp = GSetIterGet(&iterBack);
    GSetIterRemoveElem(&iterBack);
    // Set the center of the 1st cluster to this input
    VecCopy((VecFloat*)KMeansClustersCenter(that, iCenter), inp);
}
// Empty the set used to select the seeds
GSetFlush(&remainInp);
}

// Get the index of the cluster including the 'input' data for the
// KMeansClusters 'that'
int KMeansClustersGetId(const KMeansClusters* const that,
    const VecFloat* input) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
    if (input == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'input' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
#endif
    // Declare variables to memorize the id and distance to the input
    float dist = 0.0;
    int id = -1;
    int iCenter = 0;
    // Loop on the clusters' center
    GSetIterForward iter =
        GSetIterForwardCreateStatic(KMeansClustersCenters(that));
    do {
        // Get the center of the cluster
        VecFloat* center = GSetIterGet(&iter);
        // Calculate the distance to the input
        float d = VecDist(center, input);
        // If it's the first considered cluster or
        // if the distance is nearer
        if (id == -1 || dist > d) {
            id = iCenter;
            dist = d;
            // TODO: we can stop if the distance is less than half the
            // shortest distance between two clusters' center to make
            // this function faster
        }
        // Increment the center index
        ++iCenter;
    } while (GSetIterStep(&iter));
    // Return the id
    return id;
}

// Print the KMeansClusters 'that' on the stream 'stream'
void KMeansClustersPrintln(const KMeansClusters* const that,
    FILE* const stream) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
    }
#endif
}

```

```

        PBErCatch(PBDataAnalysisErr);
    }
    if (stream == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'stream' is null");
        PBErCatch(PBDataAnalysisErr);
    }
#endif
    // Loop on clusters' center
    GSetIterForward iter =
        GSetIterForwardCreateStatic(KMeansClustersCenters(that));
    do {
        // Get the cluster's center
        const VecFloat* v = GSetIterGet(&iter);
        // Print the cluster's center
        VecPrint(v, stream);
        printf("\n");
    } while (GSetIterStep(&iter));
}

// Load the KMeansClusters 'that' from the stream 'stream'
bool KMeansClustersLoad(KMeansClusters* that, FILE* const stream) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErCatch(PBDataAnalysisErr);
    }
    if (stream == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'stream' is null");
        PBErCatch(PBDataAnalysisErr);
    }
#endif
    // Declare a json to load the encoded data
    JSONNode* json = JSONCreate();
    // Load the whole encoded data
    if (!JSONLoad(json, stream)) {
        return false;
    }
    // Decode the data from the JSON
    if (!KMeansClustersDecodeAsJSON(that, json)) {
        return false;
    }
    // Free the memory used by the JSON
    JSONFree(&json);
    // Return success code
    return true;
}

// Save the KMeansClusters 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true upon success else false
bool KMeansClustersSave(const KMeansClusters* const that,
    FILE* const stream, const bool compact) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErCatch(PBDataAnalysisErr);
    }
#endif
}

```

```

    if (stream == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'stream' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
#endif
    // Get the JSON encoding
    JSONNode* json = KMeansClustersEncodeAsJSON(that);
    // Save the JSON
    if (!JSONSave(json, stream, compact)) {
        return false;
    }
    // Free memory
    JSONFree(&json);
    // Return success code
    return true;
}

// Function which return the JSON encoding of 'that'
JSONNode* KMeansClustersEncodeAsJSON(const KMeansClusters* const that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
#endif
    // Create the JSON structure
    JSONNode* json = JSONCreate();
    // Declare a buffer to convert value into string
    char val[100];
    // Encode the seed
    sprintf(val, "%u", that->_seed);
    JSONAddProp(json, "_seed", val);
    // Encode the centers
    JSONArrayStruct setCenters = JSONArrayStructCreateStatic();
    // If there are clusters
    if (KMeansClustersGetK(that) > 0) {
        // For each cluster
        GSetIterForward iter =
            GSetIterForwardCreateStatic(KMeansClustersCenters(that));
        do {
            VecFloat* center = GSetIterGet(&iter);
            JSONArrayStructAdd(&setCenters, VecEncodeAsJSON(center));
        } while (GSetIterStep(&iter));
        JSONAddProp(json, "_centers", &setCenters);
    }
    // Free memory
    JSONArrayStructFlush(&setCenters);
    // Return the created JSON
    return json;
}

// Function which decode from JSON encoding 'json' to 'that'
bool KMeansClustersDecodeAsJSON(KMeansClusters* that,
    const JSONNode* const json) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBDataAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBDataAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBDataAnalysisErr);
    }
}

```

```

if (json == NULL) {
    PBDataAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBDataAnalysisErr->_msg, "'json' is null");
    PBErrCatch(PBDataAnalysisErr);
}
#endif
// Free the memory eventually used by the clusters
KMeansClustersFreeStatic(that);
// Get the seed from the JSON
JSONNode* prop = JSONProperty(json, "_seed");
if (prop == NULL) {
    return false;
}
int seed = atoi(JSONLabel(JSONValue(prop, 0)));
if (seed < 0 || seed > KMeansClustersSeed_PlusPlus) {
    return false;
}
that->_seed = (KMeansClustersSeed)seed;
// Decode the centers
prop = JSONProperty(json, "_centers");
if (prop == NULL) {
    return false;
}
// For each cluster
for (int iCluster = 0; iCluster < JSONGetNbValue(prop); ++iCluster) {
    // Decode the center of the cluster
    JSONNode* center = JSONValue(prop, iCluster);
    VecFloat* v = NULL;
    if (!VecDecodeAsJSON(&v, center))
        return false;
    GSetAppend((GSet*)KMeansClustersCenters(that), v);
}
// Return the success code
return true;
}

```

## 4 Makefile

```

# Build mode
# 0: development (max safety, no optimisation)
# 1: release (min safety, optimisation)
# 2: fast and furious (no safety, optimisation)
BUILD_MODE?=0

all: pbmake_wget main

# Automatic installation of the repository PBMake in the parent folder
pbmake_wget:
if [ ! -d ../PBMake ]; then wget https://github.com/BayashiPascal/PBMake/archive/master.zip; unzip master.zip; rm -f

# Makefile definitions
MAKEFILE_INC=../PBMake/Makefile.inc
include $(MAKEFILE_INC)

# Rules to make the executable
repo=pbdataanalysis
$($(repo)_EXENAME): \

```

```

$$($(repo)_EXENAME).o \
$$($(repo)_EXE_DEP) \
$$($(repo)_DEP)
$(COMPILER) 'echo "$($(repo)_EXE_DEP) $$($(repo)_EXENAME).o" | tr ' ' '\n' | sort -u' $(LINK_ARG) $$($(repo)_LINK_ARG)

$$($(repo)_EXENAME).o: \
$$($(repo)_DIR)/$$($(repo)_EXENAME).c \
$$($(repo)_INC_H_EXE) \
$$($(repo)_EXE_DEP)
$(COMPILER) $(BUILD_ARG) $$($(repo)_BUILD_ARG) 'echo "$($(repo)_INC_DIR)" | tr ' ' '\n' | sort -u' -c $$($(repo)_DIR)/

```

## 5 Unit tests

```

#include <stdlib.h>
#include <stdio.h>
#include <time.h>
#include <string.h>
#include <math.h>
#include "pbdataanalysis.h"

void UnitTestKMean() {
    srandom(3);
    GSetVecFloat input = GSetVecFloatCreateStatic();
    int K = 3;
    float mean = 0.0;
    float sigma = 3.0;
    Gauss gauss = GaussCreateStatic(mean, sigma);
    int nbData = 100;
    VecFloat2D tgtMean[3];
    FILE* csvFile = fopen("./kmeancluster.csv", "w");
    for (int iInput = 0; iInput < K; ++iInput) {
        tgtMean[iInput] = VecFloatCreateStatic2D();
        VecSet(tgtMean + iInput, 0, rnd() * 50.0);
        VecSet(tgtMean + iInput, 1, rnd() * 50.0);
        printf("Target #%d: ", iInput);
        VecPrint(tgtMean + iInput, stdout);
        printf("\n");
        fprintf(csvFile, "%f %f\n",
            VecGet(tgtMean + iInput, 0),
            VecGet(tgtMean + iInput, 1));
    }
    fprintf(csvFile, "\n");
    for (int iData = 0; iData < nbData; ++iData) {
        for (int iInput = 0; iInput < K; ++iInput) {
            VecFloat* vFloat = VecFloatCreate(2);
            GSetAppend(&input, vFloat);
            VecSet(vFloat, 0, VecGet(tgtMean + iInput, 0) +
                GaussRnd(&gauss));
            VecSet(vFloat, 1, VecGet(tgtMean + iInput, 1) +
                GaussRnd(&gauss));
            fprintf(csvFile, "%f %f ",
                VecGet(vFloat, 0), VecGet(vFloat, 1));
        }
        fprintf(csvFile, "\n");
    }
    fprintf(csvFile, "\n");
    printf("--- Seed: random\n");
    KMeansClustersSeed seed = KMeansClustersSeed_Random;
}

```

```

KMeansClusters clusters = KMeansClustersCreateStatic(seed);
KMeansClustersSearch(&clusters, &input, K);
if (GSetNbElem(KMeansClustersCenters(&clusters)) != K) {
    PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBDataAnalysisErr->_msg, "_GetKMeansClusterFloat NOK");
    PBErrCatch(PBDataAnalysisErr);
}
for (int iCenter = 0; iCenter < K; ++iCenter) {
    const VecFloat* vFloat = KMeansClustersCenter(&clusters, iCenter);
    printf("Cluster #d: ", iCenter);
    VecPrint(vFloat, stdout);
    printf("\n");
    fprintf(csvFile, "%f %f\n",
        VecGet(vFloat, 0), VecGet(vFloat, 1));
}
KMeansClustersFreeStatic(&clusters);
printf("--- Seed: forgy\n");
seed = KMeansClustersSeed_Forgy;
clusters = KMeansClustersCreateStatic(seed);
KMeansClustersSearch(&clusters, &input, K);
if (GSetNbElem(KMeansClustersCenters(&clusters)) != K) {
    PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBDataAnalysisErr->_msg, "_GetKMeansClusterFloat NOK");
    PBErrCatch(PBDataAnalysisErr);
}
for (int iCenter = 0; iCenter < K; ++iCenter) {
    const VecFloat* vFloat = KMeansClustersCenter(&clusters, iCenter);
    printf("Cluster #d: ", iCenter);
    VecPrint(vFloat, stdout);
    printf("\n");
    fprintf(csvFile, "%f %f\n",
        VecGet(vFloat, 0), VecGet(vFloat, 1));
}
KMeansClustersFreeStatic(&clusters);
printf("--- Seed: plusplus\n");
seed = KMeansClustersSeed_PlusPlus;
clusters = KMeansClustersCreateStatic(seed);
KMeansClustersSearch(&clusters, &input, K);
if (GSetNbElem(KMeansClustersCenters(&clusters)) != K) {
    PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBDataAnalysisErr->_msg, "_GetKMeansClusterFloat NOK");
    PBErrCatch(PBDataAnalysisErr);
}
for (int iCenter = 0; iCenter < K; ++iCenter) {
    const VecFloat* vFloat = KMeansClustersCenter(&clusters, iCenter);
    printf("Cluster #d: ", iCenter);
    VecPrint(vFloat, stdout);
    printf("\n");
    fprintf(csvFile, "%f %f\n",
        VecGet(vFloat, 0), VecGet(vFloat, 1));
}
FILE* fd = fopen("./kmeancluster.txt", "w");
if (!KMeansClustersSave(&clusters, fd, false)) {
    PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBDataAnalysisErr->_msg, "KMeansClustersSave NOK");
    PBErrCatch(PBDataAnalysisErr);
}
fclose(fd);
KMeansClusters loadClusters =
    KMeansClustersCreateStatic(KMeansClustersSeed_Default);
fd = fopen("./kmeancluster.txt", "r");
if (!KMeansClustersLoad(&loadClusters, fd)) {

```

```

    PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBDataAnalysisErr->_msg, "KMeansClustersLoad NOK");
    PBErrCatch(PBDataAnalysisErr);
}
fclose(fd);
if (clusters._seed != loadClusters._seed ||
    GSetNbElem(KMeansClustersCenters(&clusters)) !=
    GSetNbElem(KMeansClustersCenters(&loadClusters))) {
    PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBDataAnalysisErr->_msg, "KMeansClustersLoad NOK");
    PBErrCatch(PBDataAnalysisErr);
}
GSetIterForward iter =
    GSetIterForwardCreateStatic(KMeansClustersCenters(&clusters));
GSetIterForward iterLoad =
    GSetIterForwardCreateStatic(KMeansClustersCenters(&loadClusters));
do {
    VecFloat* u = GSetIterGet(&iter);
    VecFloat* v = GSetIterGet(&iterLoad);
    if (VecIsEqual(u, v) == false) {
        PBDataAnalysisErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBDataAnalysisErr->_msg, "KMeansClustersLoad NOK");
        PBErrCatch(PBDataAnalysisErr);
    }
} while (GSetIterStep(&iter) && GSetIterStep(&iterLoad));
KMeansClustersFreeStatic(&loadClusters);
KMeansClustersFreeStatic(&clusters);
fclose(csvFile);
while (GSetNbElem(&input) > 0) {
    VecFloat* v = GSetPop(&input);
    VecFree(&v);
}
printf("UnitTestKMean OK\n");
}

void UnitTestAll() {
    UnitTestKMean();
}

int main(void) {
    UnitTestAll();
    return 0;
}

```

## 6 Unit tests output

```

Target #0: <28.069,11.249>
Target #1: <19.655,22.197>
Target #2: <14.252,7.239>
--- Seed: random
Cluster #0: <19.957,21.695>
Cluster #1: <13.881,7.343>
Cluster #2: <28.442,11.917>
--- Seed: forgy
Cluster #0: <28.442,11.917>
Cluster #1: <19.957,21.695>
Cluster #2: <13.881,7.343>
--- Seed: plusplus

```



Cluster #0: <28.442,11.917>  
Cluster #1: <13.881,7.343>  
Cluster #2: <19.957,21.695>  
UnitTestKMean OK

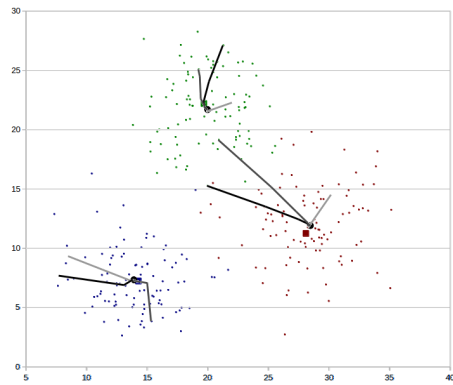
kmeanscluster.csv:

28.069008 11.249166  
19.654589 22.196920  
14.252063 7.239053

28.633823 12.292907 19.235598 18.823492 12.592678 3.948273  
26.052284 19.234270 18.743282 24.418528 10.458279 5.078588  
26.130377 12.850240 22.535856 21.906000 10.845601 13.083977  
26.455097 8.574337 18.511803 20.898256 14.739879 4.883637  
28.733614 10.599995 23.665422 25.562561 14.357016 6.407752  
28.550997 10.792174 15.249710 18.156441 20.529245 7.550764  
29.843285 10.751228 20.759161 25.732025 9.862355 9.238699  
29.386349 10.359576 22.475607 19.885624 14.946790 11.217808  
28.227690 11.757756 22.867130 25.741074 14.902649 10.882385  
28.538338 19.813602 18.626719 26.148878 11.498481 5.557252  
23.947056 8.374683 20.750635 24.407253 13.187488 6.842857  
28.845385 11.675117 22.477848 25.658518 16.712572 6.494166  
28.240320 6.265765 18.270994 16.920401 12.141680 9.390920  
24.723717 8.320883 22.146622 22.992455 11.246556 7.748080  
26.633812 6.446450 13.803344 20.392096 18.239250 9.086374  
30.953035 9.323502 21.829857 21.131969 16.259020 7.211296  
31.116953 12.879289 23.409569 22.789968 14.732009 6.460821  
20.959503 12.602968 17.141291 23.852451 14.999218 8.711921  
27.956499 13.609019 18.733019 22.014162 15.527146 10.999743  
31.872864 8.943518 18.358654 24.653770 8.360085 10.208816  
26.097677 16.264061 24.531662 23.721464 12.468403 6.878686  
26.388678 11.445029 20.422182 25.463303 14.714397 3.323504  
24.513933 7.059963 18.509027 22.554037 18.467571 4.957978  
29.366932 10.861627 17.426935 22.157187 14.995366 8.656789  
31.595938 14.901086 19.876196 26.168688 12.279941 6.107559  
27.047731 18.721298 17.749092 27.143915 17.660381 4.754192  
24.668179 13.485799 21.459522 22.727383 13.219142 7.327538  
30.785263 15.390684 23.087008 21.896502 11.119055 6.156090  
25.330399 12.283073 18.255594 22.551985 12.758935 11.746021  
24.778790 12.417658 15.977521 20.013983 17.043211 8.389001  
31.640587 12.987787 17.524673 20.441366 14.605970 4.453372  
29.095758 11.579761 22.153564 18.537165 14.559906 8.431289  
32.779095 15.358913 20.257149 25.212011 13.068298 10.726461  
35.030907 6.639762 21.238081 25.346832 16.072897 6.441304  
26.896448 16.172876 14.700457 27.644926 8.433315 7.357404  
32.441208 13.260548 18.330910 24.867006 14.426729 3.567520  
19.391371 12.997995 15.806515 19.831161 15.215398 5.320875  
28.895748 9.814054 20.318626 23.252077 7.718215 7.693003  
27.068031 10.696910 16.536890 22.733471 15.396071 5.993648  
32.208397 16.384439 25.096729 21.963247 11.924290 10.051946  
26.491650 6.049950 20.415474 22.120098 10.869869 5.957185  
26.589045 10.089059 18.382231 22.843460 14.501829 10.078506  
26.485561 12.192287 19.841579 19.588705 13.052887 9.544924  
24.927652 12.940019 17.671413 26.235970 15.761093 6.421089  
31.238827 18.318321 19.240604 25.089767 11.164451 6.369447  
28.939318 12.142779 18.180834 20.816853 12.375098 5.505887  
27.630131 10.561348 22.605457 19.463205 14.375712 7.359557  
27.850735 13.993544 15.209973 21.950428 14.728844 5.261156  
30.143599 11.337689 15.328620 22.779089 8.273642 8.736053  
30.769220 12.207006 19.299946 24.585787 17.362402 4.612987

32.244652 10.282434 17.320114 19.385283 12.901281 2.647302  
 24.538588 11.602779 17.704199 17.823856 18.038988 7.197000  
 32.762169 13.371628 17.284149 17.552122 8.941116 7.436787  
 22.792772 10.254848 22.606411 20.504032 16.266470 4.143282  
 29.497095 8.332836 20.680696 21.482531 7.318890 12.883151  
 25.626740 11.106087 21.263109 27.102179 13.899856 5.798704  
 29.959078 5.556306 17.444815 18.728331 13.491052 3.413284  
 29.565657 11.146928 16.102915 18.778042 12.468431 7.059418  
 20.874537 9.183593 20.529369 20.739050 11.255786 9.527601  
 28.047850 10.108035 23.392248 19.218472 16.328957 9.925616  
 28.980659 13.423824 25.531322 18.621786 21.656321 8.177464  
 23.947527 13.464624 20.417976 25.766447 13.998024 8.555392  
 20.401991 15.498606 20.430428 24.843374 12.270667 5.141373  
 28.698526 13.782323 23.226360 18.814350 18.963131 14.917116  
 24.172115 14.940063 20.003445 25.918982 12.409090 5.246104  
 28.780060 12.445168 17.376379 16.831505 10.603637 5.899348  
 29.091532 14.746472 17.044893 23.312666 17.813711 4.991867  
 29.301987 14.153702 18.020756 25.616367 11.686535 7.868994  
 31.022701 8.606833 22.743259 17.513430 15.340607 3.845795  
 29.180979 11.557543 23.135773 22.946238 16.151800 5.273566  
 27.930099 14.438169 22.556080 24.529539 12.015292 9.173822  
 33.846203 16.903858 18.179155 16.632879 12.875151 9.295219  
 25.154898 11.033173 23.341743 19.887142 16.519030 10.240064  
 35.106670 13.242561 21.428787 21.090490 12.723807 7.010818  
 25.209135 12.850850 25.295937 18.056234 13.486193 7.795741  
 29.438828 15.266409 23.976778 24.548758 9.845288 4.550106  
 29.725252 6.946030 18.197956 24.123976 15.505687 5.925257  
 27.486713 8.837636 20.891312 19.136850 13.277709 6.045727  
 29.519789 14.146199 23.007465 22.318642 13.021230 13.619496  
 26.245506 13.107677 21.434750 21.703260 13.752280 5.025379  
 33.955357 7.920842 19.684978 21.106571 7.609594 6.834551  
 27.990343 10.415890 16.665651 17.502064 14.444242 7.779035  
 26.135830 12.700714 22.301006 19.147243 17.841988 9.468630  
 25.933100 15.111071 22.559328 21.635067 12.447936 10.128994  
 27.279961 15.185240 15.790156 16.344282 15.927351 5.365943  
 25.760311 13.632949 20.413557 18.830910 11.671001 7.179329  
 31.429111 14.423276 19.958885 15.272199 17.757336 3.014699  
 32.629345 10.570017 18.707993 22.012554 14.535404 3.854448  
 28.192547 8.295099 16.633928 24.252712 16.008110 5.620173  
 26.773861 9.202416 23.548534 18.603050 13.867304 5.248979  
 29.160664 10.902171 20.796232 18.358614 11.421997 3.795157  
 30.813576 8.899913 23.060558 15.621967 10.409031 16.299700  
 20.219097 13.715732 20.710800 25.666639 17.539631 7.110938  
 33.206272 13.169051 21.665442 26.510429 16.426327 8.984314  
 33.969456 18.170853 23.012854 21.830002 15.478644 7.657965  
 29.226646 9.814377 22.302011 19.372135 11.912398 8.626127  
 26.332895 2.736907 19.141897 28.252583 17.338530 8.767639  
 31.999931 13.560342 18.478439 22.093273 20.308399 7.575285  
 24.406387 14.606756 15.232427 18.946995 14.076594 8.607273  
 33.677944 15.398574 16.708639 20.123032 11.821822 5.521711  
  
 19.956741 21.694563  
 13.880673 7.343436  
 28.442356 11.917128  
 28.442356 11.917128  
 19.956741 21.694563  
 13.880673 7.343436  
 28.442356 11.917128  
 13.880673 7.343436  
 19.956741 21.694563

random seed in grey, Forge seed in black, plusplus in dark grey:



kmeancluster.txt:

```
{
  "_seed": "2",
  "_centers": [
    {
      "_dim": "2",
      "_val": ["28.442356", "11.917128"]
    },
    {
      "_dim": "2",
      "_val": ["13.880673", "7.343436"]
    },
    {
      "_dim": "2",
      "_val": ["19.956741", "21.694563"]
    }
  ]
}
```