PBImgAnalysis

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March 2, 2019

Contents

Introduction

PBImgAnalysis is a C library providing structures and functions to perform various data analysis on images.

It implements the following algorithms:

- K-means clustering on the RGBA space of pixels in a user defined radius

- Intersection over Union (aka Jaccard index)

It uses the `PBErr`, `PBDataAnalaysis`, `GenBrush` libraries.

1 Interface

```
// ============ PBIMGANALYSIS.H ================

#ifndef PBIMGANALYSIS_H
#define PBIMGANALYSIS_H

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

#include <stdlib.h>
#include <stdio.h>
#include <stdbool.h>
#include <execinfo.h>
#include <errno.h>
#include <string.h>
#include "pberr.h"
#include "pbdataanalysis.h"
#include "genbrush.h"
#include "genalg.h"
#include "neuranet.h"
#include "gdataset.h"

// ------------------ ImgKMeansClusters ----------------------

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

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

typedef struct ImgKMeansClusters {
  // Image on which the clustering is applied
  // Uses the GBSurfaceFinalPixels
  const GenBrush* _img;
  // Clusters result of the search
  KMeansClusters _kmeansClusters;
  // Size of the considered cell in the image around a given position
  // is equal to (_size * 2 + 1)
  int _size;
} ImgKMeansClusters;

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

// Create a new ImgKMeansClusters for the image 'img' and with seed 'seed'
// and type 'type' and a cell size equal to 2*'size'+1
ImgKMeansClusters ImgKMeansClustersCreateStatic(
  const GenBrush* const img, const KMeansClustersSeed seed,
  const int size);

// Free the memory used by a ImgKMeansClusters
void ImgKMeansClustersFreeStatic(ImgKMeansClusters* const that);

// Get the GenBrush of the ImgKMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
const GenBrush* IKMCImg(const ImgKMeansClusters* const that);

// Set the GenBrush of the ImgKMeansClusters 'that' to 'img'
#if BUILDMODE != 0
inline
#endif
void IKMCSetImg(ImgKMeansClusters* const that, const GenBrush* const img);
```

```c
// Set the size of the cells of the ImgKMeansClusters 'that' to
// 2*'size'+1
#if BUILDMODE != 0
inline
#endif
void IKMCSetSizeCell(ImgKMeansClusters* const that, const int size);

// Get the number of cluster of the ImgKMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
int IKMCGetK(const ImgKMeansClusters* const that);

// Get the size of the cells of the ImgKMeansClusters 'that'
#if BUILDMODE != 0
inline
#endif
int IKMCGetSizeCell(const ImgKMeansClusters* const that);

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

// Search for the 'K' clusters in the image of the
// ImgKMeansClusters 'that'
void IKMCSearch(ImgKMeansClusters* const that, const int K);

// Print the ImgKMeansClusters 'that' on the stream 'stream'
void IKMCPrintln(const ImgKMeansClusters* const that,
  FILE* const stream);

// Get the index of the cluster at position 'pos' for the
// ImgKMeansClusters 'that'
int IKMCGetId(const ImgKMeansClusters* const that,
  const VecShort2D* const pos);

// Get the GBPixel equivalent to the cluster at position 'pos'
// for the ImgKMeansClusters 'that'
GBPixel IKMCGetPixel(const ImgKMeansClusters* const that,
  const VecShort2D* const pos);

// Convert the image of the ImageKMeansClusters 'that' to its clustered
// version
// IKMCSearch must have been called previously
void IKMCCluster(const ImgKMeansClusters* const that);

// Load the IKMC 'that' from the stream 'stream'
// There is no associated GenBrush object saved
// Return true upon success else false
bool IKMCLoad(ImgKMeansClusters* that, FILE* const stream);

// Save the IKMC 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// There is no associated GenBrush object saved
// Return true upon success else false
bool IKMCSave(const ImgKMeansClusters* const that,
  FILE* const stream, const bool compact);
```

```c
// Function which return the JSON encoding of 'that'
JSONNode* IKMCEncodeAsJSON(const ImgKMeansClusters* const that);

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

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

// ----------------- General functions ----------------------

// Return the Jaccard index (aka intersection over union) of the
// image 'that' and 'tho' for pixels of color 'rgba'
// 'that' and 'tho' must have same dimensions
float IntersectionOverUnion(const GenBrush* const that,
  const GenBrush* const tho, const GBPixel* const rgba);

// ----------------- ImgSegmentor ----------------------

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

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

typedef struct ImgSegmentor {
  // Set of criterion
  GSet _criteria;
  // Number of segmentation class
  int _nbClass;
  // Flag to apply or not the binarization on result of prediction
  // false by default
  bool _flagBinaryResult;
  // Threshold value for the binarization of result of prediction
  // If the result of prediction is above the threshold then
  // the result is considered equal to 1.0 else it is considered equal
  // to -1.0
  // 0.5 by default
  float _thresholdBinaryResult;
  // Nb of epoch for training, 1 by default
  unsigned int _nbEpoch;
  // Size pool for training
  // By default GENALG_NBENTITIES
  int _sizePool;
  // Nb elite for training
  // By default GENALG_NBELITES
  int _nbElite;
  // Threshold to stop the training once
  float _targetBestValue;
} ImgSegmentor;

typedef struct ImgSegmentorPerf {
  // Accuracy
  float _accuracy;
} ImgSegmentorPerf;

typedef struct ImgSegmentorTrainParam {
  // Nb of epochs
  int _nbEpoch;
} ImgSegmentorParam;

typedef enum ISCType {
  ISCType_RGB
```

```c
} ISCType;

typedef struct ImgSegmentorCriterion {
  // Type of criteriion
  ISCType _type;
  // Nb of class
  int _nbClass;
} ImgSegmentorCriterion;

typedef struct ImgSegmentorCriterionRGB {
  // ImgSegmentorCriterion
  ImgSegmentorCriterion _criterion;
  // NeuraNet model
  NeuraNet* _nn;
} ImgSegmentorCriterionRGB;

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

// Create a new static ImgSegmentor with 'nbClass' output
ImgSegmentor ImgSegmentorCreateStatic(int nbClass);

// Free the memory used by the static ImgSegmentor 'that'
void ImgSegmentorFreeStatic(ImgSegmentor* that);

// Return the nb of criterion of the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
long ISGetNbCriterion(const ImgSegmentor* const that);

// Add a new ImageSegmentorCriterionRGB to the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
void ISAddCriterionRGB(ImgSegmentor* const that);

// Return the nb of classes of the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
int ISGetNbClass(const ImgSegmentor* const that);

// Return the flag controlling the binarization of the result of
// prediction of the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
bool ISGetFlagBinaryResult(const ImgSegmentor* const that);

// Return the threshold controlling the binarization of the result of
// prediction of the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
float ISGetThresholdBinaryResult(const ImgSegmentor* const that);

// Return the threshold controlling the stop of the training
#if BUILDMODE != 0
inline
#endif
float ISGetTargetBestValue(const ImgSegmentor* const that);
```

```
// Set the threshold controlling the stop of the training to 'val'
// Clip the value to [0.0, 1.0]
#if BUILDMODE != 0
inline
#endif
void ISSetTargetBestValue(ImgSegmentor* const that, const float val);

// Set the flag controlling the binarization of the result of
// prediction of the ImgSegmentor 'that' to 'flag'
#if BUILDMODE != 0
inline
#endif
void ISSetFlagBinaryResult(ImgSegmentor* const that,
  const bool flag);

// Return the number of epoch for training the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
unsigned int ISGetNbEpoch(const ImgSegmentor* const that);

// Set the number of epoch for training the ImgSegmentor 'that' to 'nb'
#if BUILDMODE != 0
inline
#endif
void ISSetNbEpoch(ImgSegmentor* const that, unsigned int nb);

// Return the size of the pool for training the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
int ISGetSizePool(const ImgSegmentor* const that);

// Set the size of the pool for training the ImgSegmentor 'that' to 'nb'
#if BUILDMODE != 0
inline
#endif
void ISSetSizePool(ImgSegmentor* const that, int nb);

// Return the nb of elites for training the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
int ISGetNbElite(const ImgSegmentor* const that);

// Set the nb of elites for training the ImgSegmentor 'that' to 'nb'
#if BUILDMODE != 0
inline
#endif
void ISSetNbElite(ImgSegmentor* const that, int nb);

// Set the threshold controlling the binarization of the result of
// prediction of the ImgSegmentor 'that' to 'threshold'
#if BUILDMODE != 0
inline
#endif
void ISSetThresholdBinaryResult(ImgSegmentor* const that,
  const float threshold);

// Make a prediction on the GenBrush 'img' with the ImgSegmentor 'that'
// Return an array of pointer to GenBrush, one per output class, in
// greyscale, where the color of each pixel indicates the detection of
```

```
// the corresponding class at the given pixel, white equals no
// detection, black equals detection, 50% grey equals "don't know"
GenBrush** ISPredict(const ImgSegmentor* const that,
  const GenBrush* const img);

// Return the nb of criterion of the ImgSegmentor 'that'
#if BUILDMODE != 0
inline
#endif
const GSet* ISCriteria(const ImgSegmentor* const that);

// Train the ImageSegmentor 'that' on the data set 'dataSet' using
// the data of the first category in 'dataSet'
// srandom must have been caled before calling ISTrain
void ISTrain(ImgSegmentor* const that,
  const GDataSetGenBrushPair* const dataset);

// Create a new static ImgSegmentorCriterion with 'nbClass' output
// and the type of criterion 'type'
ImgSegmentorCriterion ImgSegmentorCriterionCreateStatic(int nbClass,
  ISCType type);

// Free the memory used by the static ImgSegmentorCriterion 'that'
void ImgSegmentorCriterionFreeStatic(ImgSegmentorCriterion* that);

// Make the prediction on the 'input' values by calling the appropriate
// function according to the type of criterion
// 'input' 's format is width*height*3, values in [0.0, 1.0]
// Return values are width*height*nbClass, values in [-1.0, 1.0]
VecFloat* ISCPredict(const ImgSegmentorCriterion* const that,
  const VecFloat* input, const VecShort2D* const dim);

// Return the nb of class of the ImgSegmentorCriterion 'that'
#if BUILDMODE != 0
inline
#endif
int _ISCGetNbClass(const ImgSegmentorCriterion* const that);

// Return the number of int parameters for the criterion 'that'
long _ISCGetNbParamInt(const ImgSegmentorCriterion* const that);

// Return the number of float parameters for the criterion 'that'
long _ISCGetNbParamFloat(const ImgSegmentorCriterion* const that);

// Set the bounds of int parameters for training of the criterion 'that'
void _ISCSetBoundsAdnInt(const ImgSegmentorCriterion* const that,
  GenAlg* const ga, const long shift);

// Set the bounds of float parameters for training of the criterion 'that'
void _ISCSetBoundsAdnFloat(const ImgSegmentorCriterion* const that,
  GenAlg* const ga, const long shift);

// Set the values of int parameters for training of the criterion 'that'
void _ISCSetAdnInt(const ImgSegmentorCriterion* const that,
  const GenAlgAdn* const adn, const long shift);

// Set the values of float parameters for training of the criterion 'that'
void _ISCSetAdnFloat(const ImgSegmentorCriterion* const that,
  const GenAlgAdn* const adn, const long shift);

// Create a new ImgSegmentorCriterionRGB with 'nbClass' output
ImgSegmentorCriterionRGB* ImgSegmentorCriterionRGBCreate(int nbClass);
```

```
// Free the memory used by the ImgSegmentorCriterionRGB 'that'
void ImgSegmentorCriterionRGBFree(ImgSegmentorCriterionRGB** that);

// Make the prediction on the 'input' values with the
// ImgSegmentorCriterionRGB that
// 'input' 's format is width*height*3, values in [0.0, 1.0]
// Return values are width*height*nbClass, values in [-1.0, 1.0]
VecFloat* ISCRGBPredict(const ImgSegmentorCriterionRGB* const that,
  const VecFloat* input, const VecShort2D* const dim);

// Return the number of int parameters for the criterion 'that'
long ISCRGBGetNbParamInt(const ImgSegmentorCriterionRGB* const that);

// Return the number of float parameters for the criterion 'that'
long ISCRGBGetNbParamFloat(const ImgSegmentorCriterionRGB* const that);

// Set the bounds of int parameters for training of the criterion 'that'
void ISCRGBSetBoundsAdnInt(const ImgSegmentorCriterionRGB* const that,
  GenAlg* const ga, const long shift);

// Set the bounds of float parameters for training of the criterion 'that'
void ISCRGBSetBoundsAdnFloat(const ImgSegmentorCriterionRGB* const that,
  GenAlg* const ga, const long shift);

// Set the values of int parameters for training of the criterion 'that'
void ISCRGBSetAdnInt(const ImgSegmentorCriterionRGB* const that,
  const GenAlgAdn* const adn, const long shift);

// Set the values of float parameters for training of the criterion 'that'
void ISCRGBSetAdnFloat(const ImgSegmentorCriterionRGB* const that,
  const GenAlgAdn* const adn, const long shift);

// Return the NeuraNet of the ImgSegmentorCriterionRGB 'that'
#if BUILDMODE != 0
inline
#endif
const NeuraNet* ISCRGBNeuraNet(
  const ImgSegmentorCriterionRGB* const that);

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

#define ISCGetNbClass(That) _Generic(That, \
  ImgSegmentorCriterion*: _ISCGetNbClass, \
  const ImgSegmentorCriterion*: _ISCGetNbClass, \
  ImgSegmentorCriterionRGB*: _ISCGetNbClass, \
  const ImgSegmentorCriterionRGB*: _ISCGetNbClass, \
  default: PBErrInvalidPolymorphism) ((const ImgSegmentorCriterion*)That)

#define ISCGetNbParamInt(That) _Generic(That, \
  ImgSegmentorCriterion*: _ISCGetNbParamInt, \
  const ImgSegmentorCriterion*: _ISCGetNbParamInt, \
  ImgSegmentorCriterionRGB*: ISCRGBGetNbParamInt, \
  const ImgSegmentorCriterionRGB*: ISCRGBGetNbParamInt, \
  default: PBErrInvalidPolymorphism) ((const ImgSegmentorCriterion*)That)

#define ISCGetNbParamFloat(That) _Generic(That, \
  ImgSegmentorCriterion*: _ISCGetNbParamFloat, \
  const ImgSegmentorCriterion*: _ISCGetNbParamFloat, \
  ImgSegmentorCriterionRGB*: ISCRGBGetNbParamFloat, \
  const ImgSegmentorCriterionRGB*: ISCRGBGetNbParamFloat, \
  default: PBErrInvalidPolymorphism) ((const ImgSegmentorCriterion*)That)
```

```
#define ISCSetBoundsAdnInt(That, GenAlg, Shift) _Generic(That, \
  ImgSegmentorCriterion*: _ISCSetBoundsAdnInt, \
  const ImgSegmentorCriterion*: _ISCSetBoundsAdnInt, \
  ImgSegmentorCriterionRGB*: ISCRGBSetBoundsAdnInt, \
  const ImgSegmentorCriterionRGB*: ISCRGBSetBoundsAdnInt, \
  default: PBErrInvalidPolymorphism) ( \
    (const ImgSegmentorCriterion*)That, GenAlg, Shift)

#define ISCSetBoundsAdnFloat(That, GenAlg, Shift) _Generic(That, \
  ImgSegmentorCriterion*: _ISCSetBoundsAdnFloat, \
  const ImgSegmentorCriterion*: _ISCSetBoundsAdnFloat, \
  ImgSegmentorCriterionRGB*: ISCRGBSetBoundsAdnFloat, \
  const ImgSegmentorCriterionRGB*: ISCRGBSetBoundsAdnFloat, \
  default: PBErrInvalidPolymorphism) ( \
    (const ImgSegmentorCriterion*)That, GenAlg, Shift)

#define ISCSetAdnInt(That, Adn, Shift) _Generic(That, \
  ImgSegmentorCriterion*: _ISCSetAdnInt, \
  const ImgSegmentorCriterion*: _ISCSetAdnInt, \
  ImgSegmentorCriterionRGB*: ISCRGBSetAdnInt, \
  const ImgSegmentorCriterionRGB*: ISCRGBSetAdnInt, \
  default: PBErrInvalidPolymorphism) ( \
    (const ImgSegmentorCriterion*)That, Adn, Shift)

#define ISCSetAdnFloat(That, Adn, Shift) _Generic(That, \
  ImgSegmentorCriterion*: _ISCSetAdnFloat, \
  const ImgSegmentorCriterion*: _ISCSetAdnFloat, \
  ImgSegmentorCriterionRGB*: ISCRGBSetAdnFloat, \
  const ImgSegmentorCriterionRGB*: ISCRGBSetAdnFloat, \
  default: PBErrInvalidPolymorphism) ( \
    (const ImgSegmentorCriterion*)That, Adn, Shift)

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

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

#endif
```

2 Code

2.1 pbimganalysis.c

```
// ============ PBIMGANALYSIS.C ===============

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

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

// ----------------- ImgKMeansClusters ---------------------

// ================= Define =================
```

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

// Get the input values for the pixel at position 'pos' according to
// the cell size of the ImgKMeansClusters 'that'
// The return is a VecFloat made of the sizeCell^2 pixels' value
// around pos ordered by (((r*256+g)*256+b)*256+a)
VecFloat* IKMCGetInputOverCell(const ImgKMeansClusters* const that,
  const VecShort2D* const pos);

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

// Create a new ImgKMeansClusters for the image 'img' and with seed 'seed'
// and type 'type' and a cell size equal to 2*'size'+1
ImgKMeansClusters ImgKMeansClustersCreateStatic(
  const GenBrush* const img, const KMeansClustersSeed seed,
  const int size) {
#if BUILDMODE == 0
  if (img == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'img' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (size < 0) {
    PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
    sprintf(PBImgAnalysisErr->_msg, "'size' is invalid (%d>=0)", size);
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare the new ImgKMeansClusters
  ImgKMeansClusters that;
  // Set properties
  that._img = img;
  that._kmeansClusters = KMeansClustersCreateStatic(seed);
  that._size = size;
  // Return the new ImgKMeansClusters
  return that;
}

// Free the memory used by a ImgKMeansClusters
void ImgKMeansClustersFreeStatic(ImgKMeansClusters* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Reset the GenBrush associated to the IKMC
  that->_img = NULL;
  // Free the memory used by the KMeansClusters
  KMeansClustersFreeStatic((KMeansClusters*)IKMCKMeansClusters(that));
}

// Search for the 'K' clusters in the image of the
// ImgKMeansClusters 'that'
void IKMCSearch(ImgKMeansClusters* const that, const int K) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
```

```c
    if (K < 1) {
      PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
      sprintf(PBImgAnalysisErr->_msg, "'K' is invalid (%d>0)", K);
      PBErrCatch(PBImgAnalysisErr);
    }
#endif
  // Create a set to memorize the input over cells
  GSetVecFloat inputOverCells = GSetVecFloatCreateStatic();
  // Get the dimension of the image
  VecShort2D dim = GBGetDim(IKMCImg(that));
  // Loop on pixels
  VecShort2D pos = VecShortCreateStatic2D();
  do {
    // Get the KMeansClusters input over the cell
    VecFloat* inputOverCell = IKMCGetInputOverCell(that, &pos);
    // Add it to the inputs for the search
    GSetAppend(&inputOverCells, inputOverCell);
  } while (VecStep(&pos, &dim));
  // Search the clusters
  KMeansClustersSearch((KMeansClusters*)IKMCKMeansClusters(that),
    &inputOverCells, K);
  // Free the memory used by the input
  while (GSetNbElem(&inputOverCells) > 0) {
    VecFloat* v = GSetPop(&inputOverCells);
    VecFree(&v);
  }
}

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

// Get the index of the cluster at position 'pos' for the
// ImgKMeansClusters 'that'
int IKMCGetId(const ImgKMeansClusters* const that,
  const VecShort2D* const pos) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (pos == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'pos' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
```

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```
#endif
  // Get the KMeansClusters input over the cell
  VecFloat* inputOverCell = IKMCGetInputOverCell(that, pos);
  // Get the index of the cluster for this pixel
  int id = KMeansClustersGetId(IKMCKMeansClusters(that), inputOverCell);
  // Free memory
  VecFree(&inputOverCell);
  // Return the id
  return id;
}

// Get the GBPixel equivalent to the cluster at position 'pos'
// for the ImgKMeansClusters 'that'
// This is the average pixel over the pixel in the cell of the cluster
GBPixel IKMCGetPixel(const ImgKMeansClusters* const that,
  const VecShort2D* const pos) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (pos == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'pos' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare the result pixel
  GBPixel pix;
  // Get the id of the cluster for the input pixel
  int id = IKMCGetId(that, pos);
  // Get the 'id'-th cluster's center
  const VecFloat* center =
    KMeansClustersCenter(IKMCKMeansClusters(that), id);
  // Declare a variable to calculate the average pixel
  VecFloat* avgPix = VecFloatCreate(4);
  // Calculate the average pixel
  for (int i = 0; i < VecGetDim(center); i += 4) {
    for (int j = 4; j--;) {
      VecSet(avgPix, j, VecGet(avgPix, j) + VecGet(center, i + j));
    }
  }
  VecScale(avgPix, 1.0 / round((float)VecGetDim(center) / 4.0));
  // Update the returned pixel values and ensure the converted value
  // from float to char is valid
  for (int i = 4; i--;) {
    float v = VecGet(avgPix, i);
    if (v < 0.0)
      v = 0.0;
    else if (v > 255.0)
      v = 255.0;
    pix._rgba[i] = (unsigned char)v;
  }
  // Free memory
  VecFree(&avgPix);
  // Return the result pixel
  return pix;
}

// Convert the image of the ImageKMeansClusters 'that' to its clustered
// version
```

```
// IKMCSearch must have been called previously
void IKMCCluster(const ImgKMeansClusters* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Get the dimension of the image
  VecShort2D dim = GBGetDim(IKMCImg(that));
  // Loop on pixels
  VecShort2D pos = VecShortCreateStatic2D();
  do {
    // Get the clustered pixel for this pixel
    GBPixel clustered = IKMCGetPixel(that, &pos);
    // Replace the original pixel
    GBSetFinalPixel((GenBrush*)IKMCImg(that), &pos, &clustered);
  } while (VecStep(&pos, &dim));
}

// Get the input values for the pixel at position 'pos' according to
// the cell size of the ImgKMeansClusters 'that'
// The return is a VecFloat made of the sizeCell^2 pixels' value
// around pos ordered by (((r*256+g)*256+b)*256+a)
VecFloat* IKMCGetInputOverCell(const ImgKMeansClusters* const that,
  const VecShort2D* const pos) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (pos == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'pos' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Create two vectors to loop on the cell
  VecShort2D from = VecShortCreateStatic2D();
  VecSet(&from, 0, -that->_size);
  VecSet(&from, 1, -that->_size);
  VecShort2D to = VecShortCreateStatic2D();
  VecSet(&to, 0, that->_size + 1);
  VecSet(&to, 1, that->_size + 1);
  // Get the pixel at the center of the cell, will be used as default
  // if the cell goes over the border of the image
  const GBPixel* defaultPixel = GBFinalPixel(IKMCImg(that), pos);
  // Declare a set to memorize the pixels in the cell
  GSet pixels = GSetCreateStatic();
  // Loop over the pixels of the cell
  VecShort2D posCell = from;
  VecShort2D posImg = VecShortCreateStatic2D();
  do {
    // If the position in the cell is inside the radius of the cell
    VecFloat2D posCellFloat = VecShortToFloat2D(&posCell);
    if ((int)round(VecNorm(&posCellFloat)) <= that->_size) {
      // Get the position in the image
      posImg = VecGetOp(pos, 1, &posCell, 1);
      // Get the pixel at this position
      const GBPixel* pix = GBFinalPixelSafe(IKMCImg(that), &posImg);
```

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```
      if (pix == NULL)
        pix = defaultPixel;
      // Get the value to sort this pixel
      float valPix = 0.0;
      for (int iRgba = 4; iRgba--;)
        valPix += 256.0 * valPix + (float)(pix->_rgba[iRgba]);
      // Add the pixel to the set of pixels in the cell
      GSetAddSort(&pixels, pix, valPix);
    }
  } while (VecShiftStep(&posCell, &from, &to));
  // Declare the result vector
  VecFloat* res = VecFloatCreate(GSetNbElem(&pixels) * 4);
  // Loop over the sorted pixels of the cell
  int iPix = 0;
  while (GSetNbElem(&pixels)) {
    const GBPixel* pix = GSetDrop(&pixels);
    // Set the result value
    for (int i = 0; i < 4; ++i)
      VecSet(res, iPix * 4 + i, (float)(pix->_rgba[i]));
    ++iPix;
  }
  // Return the result
  return res;
}


// Load the IKMC 'that' from the stream 'stream'
// There is no associated GenBrush object saved
// Return true upon success else false
bool IKMCLoad(ImgKMeansClusters* that, FILE* const stream) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (stream == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'stream' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#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 (!IKMCDecodeAsJSON(that, json)) {
    return false;
  }
  // Free the memory used by the JSON
  JSONFree(&json);
  // Return success code
  return true;
}


// Save the IKMC 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// There is no associated GenBrush object saved
// Return true upon success else false
```

```c
bool IKMCSave(const ImgKMeansClusters* const that,
  FILE* const stream, const bool compact) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (stream == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'stream' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Get the JSON encoding
  JSONNode* json = IKMCEncodeAsJSON(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* IKMCEncodeAsJSON(const ImgKMeansClusters* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Create the JSON structure
  JSONNode* json = JSONCreate();
  // Declare a buffer to convert value into string
  char val[100];
  // Encode the size
  sprintf(val, "%d", that->_size);
  JSONAddProp(json, "_size", val);
  // Encode the KMeansClusters
  JSONAddProp(json, "_clusters",
    KMeansClustersEncodeAsJSON(IKMCKMeansClusters(that)));
  // Return the created JSON
  return json;
}


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

```
  }
#endif
  // Free the memory eventually used by the IKMC
  ImgKMeansClustersFreeStatic(that);
  // Get the size from the JSON
  JSONNode* prop = JSONProperty(json, "_size");
  if (prop == NULL) {
    return false;
  }
  that->_size = atoi(JSONLabel(JSONValue(prop, 0)));
  if (that->_size < 0) {
    return false;
  }
  // Decode the KMeansClusters
  prop = JSONProperty(json, "_clusters");
  if (!KMeansClustersDecodeAsJSON(
    (KMeansClusters*)IKMCKMeansClusters(that), prop)) {
    return false;
  }
  // Return the success code
  return true;
}


// ----------------- ImgSegmentor ---------------------

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

// Create a new static ImgSegmentor with 'nbClass' output
ImgSegmentor ImgSegmentorCreateStatic(int nbClass) {
#if BUILDMODE == 0
  if (nbClass <= 0) {
    PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
    sprintf(PBImgAnalysisErr->_msg, "'nbClass' is invalid (%d>0)",
      nbClass);
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare the new ImgSegmentor
  ImgSegmentor that;
  // Init properties
  that._nbClass = nbClass;
  that._criteria = GSetCreateStatic();
  that._flagBinaryResult = false;
  that._thresholdBinaryResult = 0.5;
  that._nbEpoch = 1;
  that._sizePool = GENALG_NBENTITIES;
  that._nbElite = GENALG_NBELITES;
  that._targetBestValue = 0.9999;
  // Return the new ImgSegmentor
  return that;
}

// Free the memory used by the static ImgSegmentor 'that'
void ImgSegmentorFreeStatic(ImgSegmentor* that) {
  if (that == NULL)
    return;
  while (ISGetNbCriterion(that) > 0) {
    ImgSegmentorCriterion* criterion = GSetPop(&(that->_criteria));
    switch (criterion->_type) {
      case ISCType_RGB:
        ImgSegmentorCriterionRGBFree(
          (ImgSegmentorCriterionRGB**)&criterion);
```

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```
          break;
        default:
          PBImgAnalysisErr->_type = PBErrTypeNotYetImplemented;
          sprintf(PBImgAnalysisErr->_msg,
            "Not yet implemented type of criterion");
          PBErrCatch(PBImgAnalysisErr);
          break;
      }
    }
}

// Make a prediction on the GenBrush 'img' with the ImgSegmentor 'that'
// Return an array of pointer to GenBrush, one per output class, in
// greyscale, where the color of each pixel indicates the detection of
// the corresponding class at the given pixel, white equals no
// detection, black equals detection, 50% grey equals "don't know"
GenBrush** ISPredict(const ImgSegmentor* const that,
  const GenBrush* const img) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (img == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'img' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Get the dimension of the input image
  VecShort2D dim = GBGetDim(img);
  // Calculate the area of the image
  long area = VecGet(&dim, 0) * VecGet(&dim, 1);
  // Create a temporary vector to convert the image into the input
  // of a criterion
  VecFloat* input = VecFloatCreate(area * 3);
  // Declare a vector to loop on position in the image
  VecShort2D pos = VecShortCreateStatic2D();
  // Convert the image's pixels into the input VecFloat
  do {
    GBPixel pix = GBGetFinalPixel(img, &pos);
    long iPos = GBPosIndex(&pos, &dim);
    for (int iRGB = 3; iRGB--;)
      VecSet(input, iPos * 3 + iRGB, (float)(pix._rgba[iRGB]) / 255.0);
  } while (VecStep(&pos, &dim));
  // Create temporary vectors to memorize the prediction of each criterion
  VecFloat** pred = PBErrMalloc(PBImgAnalysisErr,
    sizeof(VecFloat*) * ISGetNbCriterion(that));
  // Loop on criteria
  int iCrit = 0;
  GSetIterForward iter = GSetIterForwardCreateStatic(ISCriteria(that));
  do {
    ImgSegmentorCriterion* criterion = GSetIterGet(&iter);
    pred[iCrit] = ISCPredict(criterion, input, &dim);
    ++iCrit;
  } while(GSetIterStep(&iter));
  // Create temporary vectors to memorize the combined predictions
  VecFloat* combPred = VecFloatCreate(area * ISGetNbClass(that));
  VecFloat* finalPred = VecFloatCreate(area * ISGetNbClass(that));
  // Combine the predictions over criteria
  // The combination is the weighted average of prediction over criteria
```

```
// where the weight is the absolute value of the prediction
for (long i = area * (long)ISGetNbClass(that); i--;) {
  float sumWeight = 0.0;
  for (iCrit = ISGetNbCriterion(that); iCrit--;) {
    float v = VecGet(pred[iCrit], i);
    VecSetAdd(combPred, i, v * fabs(v));
    sumWeight += fabs(v);
  }
  if (sumWeight > PBMATH_EPSILON)
    VecSet(combPred, i, VecGet(combPred, i) / sumWeight);
  else
    VecSet(combPred, i, 0.0);
}
// Combine the predictions over classes
// The combination is calculated as follow:
// finalPred(i) = (pred(i)*abs(combPred(i) - sum_{j!=i}
//   combPred(j)*abs(combPred(j)) / (sum_i abs(combPred(i))
VecSetNull(&pos);
do {
  for (long iClass = ISGetNbClass(that); iClass--;) {
    float sumWeight = 0.0;
    long iPos = GBPosIndex(&pos, &dim) * ISGetNbClass(that) + iClass;
    for (long jClass = ISGetNbClass(that); jClass--;) {
      long jPos = GBPosIndex(&pos, &dim) * ISGetNbClass(that) + jClass;
      float v = VecGet(combPred, jPos);
      if (iClass == jClass) {
        VecSetAdd(finalPred, iPos, v * fabs(v));
      } else {
        VecSetAdd(finalPred, iPos, -1.0 * v * fabs(v));
      }
      sumWeight += fabs(v);
    }
    if (sumWeight > PBMATH_EPSILON)
      VecSet(finalPred, iPos, VecGet(finalPred, iPos) / sumWeight);
    else
      VecSet(finalPred, iPos, 0.0);
  }
} while(VecStep(&pos, &dim));
// Allocate memory for the results
GenBrush** res = PBErrMalloc(PBImgAnalysisErr,
  sizeof(GenBrush*) * ISGetNbClass(that));
// Declare a variable to convert the prediction into pixel
GBPixel pix = GBColorWhite;
// Loop on classes
for (int iClass = ISGetNbClass(that); iClass--;) {
  // Create the result GenBrush
  res[iClass] = GBCreateImage(&dim);
  // Loop on position in the image
  VecSetNull(&pos);
  do {
    // Get the prediction value for this class and this position
    // and convert it to rgb value
    long iPos = GBPosIndex(&pos, &dim);
    float p = VecGet(finalPred, iPos * ISGetNbClass(that) + iClass);
    if (ISGetFlagBinaryResult(that)) {
      if (p > ISGetThresholdBinaryResult(that))
        p = 1.0;
      else
        p = -1.0;
    }
    unsigned char pChar = 255 -
      (unsigned char)round(255.0 * (p * 0.5 + 0.5));
```

```
      // Convert the prediction to a pixel
      pix._rgba[GBPixelRed] = pix._rgba[GBPixelGreen] =
        pix._rgba[GBPixelBlue] = pChar;
      // Set the pixel in the result image
      GBSetFinalPixel(res[iClass], &pos, &pix);
    } while (VecStep(&pos, &dim));
  }
  // Free memory
  for (int iCrit = ISGetNbCriterion(that); iCrit--;) {
    VecFree(pred + iCrit);
  }
  free(pred);
  VecFree(&input);
  VecFree(&finalPred);
  // Return the result
  return res;
}


// Train the ImageSegmentor 'that' on the data set 'dataSet' using
// the data of the first category in 'dataSet'
// srandom must have been caled before calling ISTrain
void ISTrain(ImgSegmentor* const that,
  const GDataSetGenBrushPair* const dataset) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (dataset == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'dataset' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (ISGetNbClass(that) > GDSGetNbMask(dataset)) {
    PBImgAnalysisErr->_type = PBErrTypeInvalidData;
    sprintf(PBImgAnalysisErr->_msg,
      "Not enough masks in the dataset (%d<=%d)",
      ISGetNbClass(that), GDSGetNbMask(dataset));
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // If there is no criterion, nothing to do
  if (ISGetNbCriterion(that) == 0)
    return;
  // Memorize the current flag for binarization of results
  bool curFlagBinary = ISGetFlagBinaryResult(that);
  // Turn on the binarization
  ISSetFlagBinaryResult(that, true);
  // Create two vectors to memorize the number of int and float
  // parameters for each criterion
  VecLong* nbParamInt = VecLongCreate(ISGetNbCriterion(that));
  VecLong* nbParamFloat = VecLongCreate(ISGetNbCriterion(that));
  // Declare two variables to memorize the total number of int and
  // float parameters
  long nbTotalParamInt = 0;
  long nbTotalParamFloat = 0;
  // Decclare a varibale to memorize the color of the mask
  const GBPixel rgbaMask = GBColorBlack;
  // Get the number of int and float parameters for each criterion
  int iCrit = 0;
  GSetIterForward iter = GSetIterForwardCreateStatic(ISCriteria(that));
```

```
do {
  ImgSegmentorCriterion* crit = GSetIterGet(&iter);
  long nb = ISCGetNbParamInt(crit);
  VecSet(nbParamInt, iCrit, nb);
  nbTotalParamInt += nb;
  nb = ISCGetNbParamFloat(crit);
  VecSet(nbParamFloat, iCrit, nb);
  nbTotalParamFloat += nb;
  ++iCrit;
} while (GSetIterStep(&iter));
// If there are parameters
if (nbTotalParamInt > 0 || nbTotalParamFloat > 0) {
  // Create the GenAlg to search parameters' value
  GenAlg* ga = GenAlgCreate(ISGetSizePool(that), ISGetNbElite(that),
    nbTotalParamFloat, nbTotalParamInt);
  // Loop on the criterion to initialise the parameters bound
  GSetIterReset(&iter);
  long shiftParamInt = 0;
  long shiftParamFloat = 0;
  do {
    ImgSegmentorCriterion* crit = GSetIterGet(&iter);
    ISCSetBoundsAdnInt(crit, ga, shiftParamInt);
    shiftParamInt += ISCGetNbParamInt(crit);
    ISCSetBoundsAdnFloat(crit, ga, shiftParamFloat);
    shiftParamFloat += ISCGetNbParamFloat(crit);
  } while (GSetIterStep(&iter));
  // Initialise the GenAlg
  GAInit(ga);
  // Declare a variable to memorize the current best value
  float bestValue = 0.0;
  // Loop over epochs
  do {
    // Loop over the GenAlg entities
    for (int iEnt = 0; iEnt < GAGetNbAdns(ga); ++iEnt) {
      // If this entity is a new one
      if (GAAdnIsNew(GAAdn(ga, iEnt))) {
        // Loop on the criterion to set the criteria parameters with
        // this entity's adn
        GSetIterReset(&iter);
        shiftParamInt = 0;
        shiftParamFloat = 0;
        do {
          ImgSegmentorCriterion* crit = GSetIterGet(&iter);
          ISCSetAdnInt(crit, GAAdn(ga, iEnt), shiftParamInt);
          shiftParamInt += ISCGetNbParamInt(crit);
          ISCSetAdnFloat(crit, GAAdn(ga, iEnt), shiftParamFloat);
          shiftParamFloat += ISCGetNbParamFloat(crit);
        } while (GSetIterStep(&iter));
        // Evaluate the ImgSegmentor for this entity's adn on the
        // dataset
        float value = 0.0;
        const int iCatTraining = 0;
        // Reset the iterator of the GDataSet
        GDSReset(dataset, iCatTraining);
        // Loop on the samples
        long iSample = 0;
        do {
          printf("Epoch %05ld/%05u ",
            GAGetCurEpoch(ga) + 1, ISGetNbEpoch(that));
          printf("Entity %03d/%03d ",
            iEnt + 1, GAGetNbAdns(ga));
          printf("Sample %05ld/%05ld ",
```

```
        iSample + 1, GDSGetSizeCat(dataset, iCatTraining));
      // Get the next sample
      GDSGenBrushPair* sample = GDSGetSample(dataset, iCatTraining);
      // Do the prediction on the sample
      GenBrush** pred = ISPredict(that, sample->_img);
      // Check the prediction against the masks
      float valMask = 0.0;
      for (int iMask = ISGetNbClass(that); iMask--;) {
        valMask += IntersectionOverUnion(
          sample->_mask[iMask], pred[iMask], &rgbaMask);
      }
      value += valMask / (float)GDSGetNbMask(dataset);
      // Free memory
      for (int iClass = ISGetNbClass(that); iClass--;)
        GBFree(pred + iClass);
      free(pred);
      GDSGenBrushPairFree(&sample);
      if (iSample + 1 < GDSGetSizeCat(dataset, iCatTraining))
        printf("\n");
      fflush(stdout);
      ++iSample;
    } while (GDSStepSample(dataset, iCatTraining));
    // Get the average value over all samples
    value /= (float)GDSGetSizeCat(dataset, iCatTraining);
    // Update the adn value of this entity
    GASetAdnValue(ga, GAAdn(ga, iEnt), value);
    // If the value is the best value
    if (value - bestValue > PBMATH_EPSILON) {
      bestValue = value;
    }
    printf("BestValue %f/%f\n", bestValue,
      ISGetTargetBestValue(that));
    }
  }
  // Step the GenAlg
  GAStep(ga);
} while (GAGetCurEpoch(ga) < ISGetNbEpoch(that) &&
  bestValue < ISGetTargetBestValue(that));
// Loop on the criterion to set the criteria to the best one
GSetIterReset(&iter);
shiftParamInt = 0;
shiftParamFloat = 0;
do {
  ImgSegmentorCriterion* crit = GSetIterGet(&iter);
  ISCSetAdnInt(crit, GABestAdn(ga), shiftParamInt);
  shiftParamInt += ISCGetNbParamInt(crit);
  ISCSetAdnFloat(crit, GABestAdn(ga), shiftParamFloat);
  shiftParamFloat += ISCGetNbParamFloat(crit);
} while (GSetIterStep(&iter));
  // Free memory
  GenAlgFree(&ga);
}
// Free memory
VecFree(&nbParamInt);
VecFree(&nbParamFloat);
// Put back the flag for binarization in its original state
ISSetFlagBinaryResult(that, curFlagBinary);
}

// Create a new static ImgSegmentorCriterion with 'nbClass' output
// and the type of criteria 'type'
ImgSegmentorCriterion ImgSegmentorCriterionCreateStatic(int nbClass,
```

```
    ISCType type) {
#if BUILDMODE == 0
  if (nbClass <= 0) {
    PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
    sprintf(PBImgAnalysisErr->_msg, "'nbClass' is invalid (%d>0)",
      nbClass);
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare the new ImgSegmentorCriterion
  ImgSegmentorCriterion that;
  // Set the properties
  that._nbClass = nbClass;
  that._type = type;
  // Return the new ImgSegmentorCriterion
  return that;
}

// Free the memory used by the static ImgSegmentorCriterion 'that'
void ImgSegmentorCriterionFreeStatic(ImgSegmentorCriterion* that) {
  if (that == NULL)
    return;
  // Nothing to do
}

// Make the prediction on the 'input' values by calling the appropriate
// function according to the type of criteria
// 'input' 's format is width*height*3, values in [0.0, 1.0]
// Return values are width*height*nbClass, values in [-1.0, 1.0]
VecFloat* ISCPredict(const ImgSegmentorCriterion* const that,
  const VecFloat* input, const VecShort2D* const dim) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (input == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'input' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare a variable to memorize the result
  VecFloat* res = NULL;
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      res = ISCRGBPredict((const ImgSegmentorCriterionRGB*)that,
        input, dim);
      break;
    default:
      break;
  }
  // Return the result
  return res;
}

// Return the number of int parameters for the criterion 'that'
long _ISCGetNbParamInt(const ImgSegmentorCriterion* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
```

```
      PBImgAnalysisErr->_type = PBErrTypeNullPointer;
      sprintf(PBImgAnalysisErr->_msg, "'that' is null");
      PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare a variable to memorize the result
  long res = 0;
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      res = ISCRGBGetNbParamInt((const ImgSegmentorCriterionRGB*)that);
      break;
    default:
      break;
  }
  // Return the result
  return res;
}


// Return the number of float parameters for the criterion 'that'
long _ISCGetNbParamFloat(const ImgSegmentorCriterion* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Declare a variable to memorize the result
  long res = 0;
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      res = ISCRGBGetNbParamFloat((const ImgSegmentorCriterionRGB*)that);
      break;
    default:
      break;
  }
  // Return the result
  return res;
}


// Create a new ImgSegmentorCriterionRGB with 'nbClass' output
ImgSegmentorCriterionRGB* ImgSegmentorCriterionRGBCreate(int nbClass) {
#if BUILDMODE == 0
  if (nbClass <= 0) {
    PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
    sprintf(PBImgAnalysisErr->_msg, "'nbClass' is invalid (%d>0)",
      nbClass);
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Allocate memory for the new ImgSegmentorCriterionRGB
  ImgSegmentorCriterionRGB* that = PBErrMalloc(PBImgAnalysisErr,
    sizeof(ImgSegmentorCriterionRGB));
  // Create the parent ImgSegmentorCriterion
  that->_criterion = ImgSegmentorCriterionCreateStatic(nbClass,
    ISCType_RGB);
  // Create the NeuraNet
  const int nbInput = 3;
  const int nbHidden = fsquare(nbInput) * nbClass;
  VecLong* hidden = VecLongCreate(1);
```

```
    VecSet(hidden, 0, nbHidden);
    that->_nn = NeuraNetCreateFullyConnected(nbInput, nbClass, hidden);
    VecFree(&hidden);
    // Return the new ImgSegmentorCriterionRGB
    return that;
}

// Free the memory used by the ImgSegmentorCriterionRGB 'that'
void ImgSegmentorCriterionRGBFree(ImgSegmentorCriterionRGB** that) {
    if (that == NULL || *that == NULL)
        return;
    // Free memory
    ImgSegmentorCriterionFreeStatic((ImgSegmentorCriterion*)(*that));
    NeuraNetFree(&((*that)->_nn));
    free(*that);
}

// Make the prediction on the 'input' values with the
// ImgSegmentorCriterionRGB that
// 'input' 's format is width*height*3, values in [0.0, 1.0]
// Return values are width*height*nbClass, values in [-1.0, 1.0]
VecFloat* ISCRGBPredict(const ImgSegmentorCriterionRGB* const that,
    const VecFloat* input, const VecShort2D* const dim) {
#if BUILDMODE == 0
    if (that == NULL) {
        PBImgAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBImgAnalysisErr->_msg, "'that' is null");
        PBErrCatch(PBImgAnalysisErr);
    }
    if (input == NULL) {
        PBImgAnalysisErr->_type = PBErrTypeNullPointer;
        sprintf(PBImgAnalysisErr->_msg, "'input' is null");
        PBErrCatch(PBImgAnalysisErr);
    }
    if ((VecGetDim(input) % 3) != 0) {
        PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
        sprintf(PBImgAnalysisErr->_msg,
            "'input' 's dim is not multiple of 3 (%ld)", VecGetDim(input));
        PBErrCatch(PBImgAnalysisErr);
    }
#endif
    // Calculate the area of the input image
    long area = VecGet(dim, 0) * VecGet(dim, 1);
    // Allocate memory for the result
    VecFloat* res = VecFloatCreate(area * (long)ISCGetNbClass(that));
    // Declare variables to memorize the input/output of the NeuraNet
    VecFloat3D in = VecFloatCreateStatic3D();
    VecFloat* out = VecFloatCreate(ISCGetNbClass(that));
    // Apply the NeuraNet on inputs
    for (long iInput = area; iInput--;) {
        for (long i = 3; i--;)
            VecSet(&in, i, VecGet(input, iInput * 3L + i));
        NNEval(that->_nn, (VecFloat*)&in, out);
        for (long i = ISCGetNbClass(that); i--;)
            VecSet(res, iInput * (long)ISCGetNbClass(that) + i,
                VecGet(out, i));
    }
    // Free memory
    VecFree(&out);
    // Return the result
    return res;
}
```

```c
// Return the number of int parameters for the criterion 'that'
long ISCRGBGetNbParamInt(const ImgSegmentorCriterionRGB* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  (void)that;
  return 0;
}

// Return the number of float parameters for the criterion 'that'
long ISCRGBGetNbParamFloat(const ImgSegmentorCriterionRGB* const that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  return NNGetGAAdnFloatLength(that->_nn);
}

// Set the bounds of int parameters for training of the criterion 'that'
void _ISCSetBoundsAdnInt(const ImgSegmentorCriterion* const that,
  GenAlg* const ga, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (ga == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      ISCRGBSetBoundsAdnInt((const ImgSegmentorCriterionRGB*)that,
        ga, shift);
      break;
    default:
      break;
  }
}

// Set the bounds of float parameters for training of the criterion
// 'that'
void _ISCSetBoundsAdnFloat(const ImgSegmentorCriterion* const that,
  GenAlg* const ga, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
```

```c
    if (ga == NULL) {
      PBImgAnalysisErr->_type = PBErrTypeNullPointer;
      sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
      PBErrCatch(PBImgAnalysisErr);
    }
#endif
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      ISCRGBSetBoundsAdnFloat((const ImgSegmentorCriterionRGB*)that,
        ga, shift);
      break;
    default:
      break;
  }
}

// Set the bounds of int parameters for training of the criterion 'that'
void ISCRGBSetBoundsAdnInt(const ImgSegmentorCriterionRGB* const that,
  GenAlg* const ga, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (ga == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Nothing to do
  (void)that;(void)ga;(void)shift;
}

// Set the bounds of float parameters for training of the criterion
// 'that'
void ISCRGBSetBoundsAdnFloat(const ImgSegmentorCriterionRGB* const that,
  GenAlg* const ga, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (ga == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  VecFloat2D bounds = VecFloatCreateStatic2D();
  VecSet(&bounds, 0, -1.0);
  VecSet(&bounds, 1, 1.0);
  for (long iParam = ISCRGBGetNbParamFloat(that); iParam--;) {
    GASetBoundsAdnFloat(ga, iParam + shift, &bounds);
  }
}

// Set the values of int parameters for training of the criterion 'that'
void _ISCSetAdnInt(const ImgSegmentorCriterion* const that,
```

```
    const GenAlgAdn* const adn, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (adn == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      ISCRGBSetAdnInt((const ImgSegmentorCriterionRGB*)that,
        adn, shift);
      break;
    default:
      break;
  }
}


// Set the values of float parameters for training of the criterion
// 'that'
void _ISCSetAdnFloat(const ImgSegmentorCriterion* const that,
  const GenAlgAdn* const adn, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (adn == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Call the appropriate function based on the type
  switch(that->_type) {
    case ISCType_RGB:
      ISCRGBSetAdnFloat((const ImgSegmentorCriterionRGB*)that,
        adn, shift);
      break;
    default:
      break;
  }
}


// Set the values of int parameters for training of the criterion 'that'
void ISCRGBSetAdnInt(const ImgSegmentorCriterionRGB* const that,
  const GenAlgAdn* const adn, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (adn == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
```

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```
      sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
      PBErrCatch(PBImgAnalysisErr);
  }
#endif
  // Nothing to do
  (void)that;(void)adn;(void)shift;
}


// Set the values of float parameters for training of the criterion
// 'that'
void ISCRGBSetAdnFloat(const ImgSegmentorCriterionRGB* const that,
  const GenAlgAdn* const adn, const long shift) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (adn == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'ga' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
#endif
  const VecFloat* adnF = GAAdnAdnF(adn);
  VecFloat* bases = VecFloatCreate(ISCRGBGetNbParamFloat(that));
  for (int i = ISCRGBGetNbParamFloat(that); i--;)
    VecSet(bases, i, VecGet(adnF, shift + i));
  NNSetBases((NeuraNet*)ISCRGBNeuraNet(that), bases);
  VecFree(&bases);
}


// ----------------- General functions ---------------------

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

// Return the Jaccard index (aka intersection over union) of the
// image 'that' and 'tho' for pixels of color 'rgba'
// 'that' and 'tho' must have same dimensions
float IntersectionOverUnion(const GenBrush* const that,
  const GenBrush* const tho, const GBPixel* const rgba) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'that' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (tho == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'tho' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (rgba == NULL) {
    PBImgAnalysisErr->_type = PBErrTypeNullPointer;
    sprintf(PBImgAnalysisErr->_msg, "'rgba' is null");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (!VecIsEqual(GBDim(that), GBDim(tho))) {
    PBImgAnalysisErr->_type = PBErrTypeInvalidArg;
    sprintf(PBImgAnalysisErr->_msg,
      "'that' and 'tho' have different dimensions");
    PBErrCatch(PBImgAnalysisErr);
```

```c
  }
#endif
  // Declare two variables to count the number of pixels in
  // intersection and union
  long nbUnion = 0;
  long nbInter = 0;
  // Declare a variable to loop through pixels
  VecShort2D pos = VecShortCreateStatic2D();
  // Loop through pixels
  do {
    // If the pixel is in the intersection
    if (GBPixelIsSame(GBFinalPixel(that, &pos), rgba) &&
      GBPixelIsSame(GBFinalPixel(tho, &pos), rgba)) {
      // Increment the number of pixels in intersection
      ++nbInter;
    }
    // If the pixel is in the union
    if (GBPixelIsSame(GBFinalPixel(that, &pos), rgba) ||
      GBPixelIsSame(GBFinalPixel(tho, &pos), rgba)) {
      // Increment the number of pixels in union
      ++nbUnion;
    }
  } while (VecStep(&pos, GBDim(that)));
  // Calcaulte the intersection over union
  float iou = (float)nbInter / (float)nbUnion;
  // Return the result
  return iou;
}
```

3 Makefile

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

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=pbimganalysis
$($(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)/$
```

4 Unit tests

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

void UnitTestImgKMeansClusters() {
  srandom(1);
  for (int size = 0; size < 6; ++size) {
    for (int K = 2; K <= 6; ++K) {
      char* fileName = "./ImgKMeansClustersTest/imgkmeanscluster.tga";
      GenBrush* img = GBCreateFromFile(fileName);
      ImgKMeansClusters clusters = ImgKMeansClustersCreateStatic(
        img, KMeansClustersSeed_Forgy, size);
      IKMCSearch(&clusters, K);

      FILE* fd = fopen("./imgkmeanscluster.txt", "w");
      if (!IKMCSave(&clusters, fd, false)) {
        PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBImgAnalysisErr->_msg, "IKMCSave NOK");
        PBErrCatch(PBImgAnalysisErr);
      }
      fclose(fd);
      fd = fopen("./imgkmeanscluster.txt", "r");
      if (!IKMCLoad(&clusters, fd)) {
        PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBImgAnalysisErr->_msg, "IKMCLoad NOK");
        PBErrCatch(PBImgAnalysisErr);
      }
      IKMCSetImg(&clusters, img);
      fclose(fd);

      printf("%s size K=%d cell=%d:\n",
        fileName, K, IKMCGetSizeCell(&clusters));
      IKMCPrintln(&clusters, stdout);
      IKMCCluster(&clusters);
      char fileNameOut[50] = {'\0'};
      sprintf(fileNameOut,
        "./ImgKMeansClustersTest/imgkmeanscluster%02d-%02d.tga", K, size);
      GBSetFileName(img, fileNameOut);
      GBRender(img);
      GBFree(&img);
      ImgKMeansClustersFreeStatic(&clusters);
    }
  }
  printf("UnitTestImgKMeansClusters OK\n");
}

void UnitTestIntersectionOverUnion() {
  char* fileNameA = "./iou1.tga";
  GenBrush* imgA = GBCreateFromFile(fileNameA);
  char* fileNameB = "./iou2.tga";
```

```
    GenBrush* imgB = GBCreateFromFile(fileNameB);
    GBPixel rgba = GBColorBlack;
    float iou = IntersectionOverUnion(imgA, imgB, &rgba);
    if (!ISEQUALF(iou, 6.0 / 10.0)) {
      PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBImgAnalysisErr->_msg, "IntersectionOverUnion failed");
      PBErrCatch(PBImgAnalysisErr);
    }
    GBFree(&imgA);
    GBFree(&imgB);
    printf("UnitTestIntersectionOverUnion OK\n");
}

void UnitTestImgSegmentorRGB() {
    int nbClass = 2;
    ImgSegmentorCriterionRGB* criterion =
      ImgSegmentorCriterionRGBCreate(nbClass);
    if (ISCGetNbClass(criterion) != nbClass) {
      PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBImgAnalysisErr->_msg,
        "ImgSegmentorCriterionRGBCreate failed");
      PBErrCatch(PBImgAnalysisErr);
    }
    int imgArea = 4;
    VecFloat* input = VecFloatCreate(imgArea * 3);
    VecShort2D dim = VecShortCreateStatic2D();
    VecSet(&dim, 0, 2);
    VecSet(&dim, 1, 2);
    VecFloat* output = ISCRGBPredict(criterion, input, &dim);
    if (VecGetDim(output) != imgArea * nbClass) {
      PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBImgAnalysisErr->_msg, "ISCRGBPredict failed");
      PBErrCatch(PBImgAnalysisErr);
    }
    VecFree(&input);
    VecFree(&output);
    ImgSegmentorCriterionRGBFree(&criterion);
    printf("UnitTestImgSegmentorRGB OK\n");
}

void UnitTestImgSegmentorCreateFree() {
    int nbClass = 2;
    ImgSegmentor segmentor = ImgSegmentorCreateStatic(nbClass);
    if (segmentor._nbClass != nbClass ||
      segmentor._flagBinaryResult != false ||
      segmentor._nbEpoch != 1 ||
      !ISEQUALF(segmentor._thresholdBinaryResult, 0.5) ||
      !ISEQUALF(segmentor._targetBestValue, 0.9999)) {
      PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBImgAnalysisErr->_msg, "ImgSegmentorCreateStatic failed");
      PBErrCatch(PBImgAnalysisErr);
    }
    ImgSegmentorFreeStatic(&segmentor);
    printf("UnitTestImgSegmentorCreateFree OK\n");
}

void UnitTestImgSegmentorAddCriterionGetSet() {
    int nbClass = 2;
    ImgSegmentor segmentor = ImgSegmentorCreateStatic(nbClass);
    if (ISCriteria(&segmentor) != &(segmentor._criteria)) {
      PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBImgAnalysisErr->_msg, "ISCriteria failed");
```

```
    PBErrCatch(PBImgAnalysisErr);
}
if (ISGetNbClass(&segmentor) != nbClass) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetNbClass failed");
  PBErrCatch(PBImgAnalysisErr);
}
if (ISGetNbCriterion(&segmentor) != 0) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetNbCriterion failed");
  PBErrCatch(PBImgAnalysisErr);
}
ISAddCriterionRGB(&segmentor);
if (GSetNbElem(&(segmentor._criteria)) != 1 ||
  ((ImgSegmentorCriterion*)GSetGet(&(segmentor._criteria),
    0))->_type != ISCType_RGB) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISAddCriterion failed");
  PBErrCatch(PBImgAnalysisErr);
}
if (ISGetNbCriterion(&segmentor) != 1) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetNbCriterion failed");
  PBErrCatch(PBImgAnalysisErr);
}
ISSetFlagBinaryResult(&segmentor, true);
if (segmentor._flagBinaryResult != true) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISSetFlagBinaryResult failed");
  PBErrCatch(PBImgAnalysisErr);
}
if (ISGetFlagBinaryResult(&segmentor) != true) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetFlagBinaryResult failed");
  PBErrCatch(PBImgAnalysisErr);
}
ISSetThresholdBinaryResult(&segmentor, 1.0);
if (!ISEQUALF(segmentor._thresholdBinaryResult, 1.0)) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISSetThrehsoldBinaryResult failed");
  PBErrCatch(PBImgAnalysisErr);
}
if (!ISEQUALF(ISGetThresholdBinaryResult(&segmentor), 1.0)) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetThresholdBinaryResult failed");
  PBErrCatch(PBImgAnalysisErr);
}
if (ISGetSizePool(&segmentor) != GENALG_NBENTITIES) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetSizePool failed");
  PBErrCatch(PBImgAnalysisErr);
}
ISSetSizePool(&segmentor, GENALG_NBENTITIES + 100);
if (ISGetSizePool(&segmentor) != GENALG_NBENTITIES + 100) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISSetSizePool failed");
  PBErrCatch(PBImgAnalysisErr);
}
if (ISGetNbElite(&segmentor) != GENALG_NBELITES) {
  PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBImgAnalysisErr->_msg, "ISGetNbElite failed");
  PBErrCatch(PBImgAnalysisErr);
```

```
  }
  ISSetNbElite(&segmentor, GENALG_NBELITES + 10);
  if (ISGetNbElite(&segmentor) != GENALG_NBELITES + 10) {
    PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBImgAnalysisErr->_msg, "ISSetNbElite failed");
    PBErrCatch(PBImgAnalysisErr);
  }
  if (!ISEQUALF(ISGetTargetBestValue(&segmentor), 0.9999)) {
    PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBImgAnalysisErr->_msg, "ISGetTargetBestValue failed");
    PBErrCatch(PBImgAnalysisErr);
  }
  ISSetTargetBestValue(&segmentor, 0.5);
  if (!ISEQUALF(ISGetTargetBestValue(&segmentor), 0.5)) {
    PBImgAnalysisErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBImgAnalysisErr->_msg, "ISSetTargetBestValue failed");
    PBErrCatch(PBImgAnalysisErr);
  }
  ImgSegmentorFreeStatic(&segmentor);
  printf("UnitTestImgSegmentorAddCriterionGetSet OK\n");
}

void UnitTestImgSegmentorPredict() {
  int nbClass = 2;
  ImgSegmentor segmentor = ImgSegmentorCreateStatic(nbClass);
  ISAddCriterionRGB(&segmentor);
  char* fileNameIn = "ISPredict-in.tga";
  char fileNameOut[20];
  GenBrush* img = GBCreateFromFile(fileNameIn);
  GenBrush** res = ISPredict(&segmentor, img);
  for (int iClass = nbClass; iClass--;) {
    sprintf(fileNameOut, "ISPredict-out%02d.tga", iClass);
    GBSetFileName(res[iClass], fileNameOut);
    GBRender(res[iClass]);
  }
  ImgSegmentorFreeStatic(&segmentor);
  for (int iClass = nbClass; iClass--;)
    GBFree(res + iClass);
  free(res);
  GBFree(&img);
  printf("UnitTestImgSegmentorPredict OK\n");
}

void UnitTestImgSegmentorTrain() {
  srandom(0);
  int nbClass = 2;
  ImgSegmentor segmentor = ImgSegmentorCreateStatic(nbClass);
  ISAddCriterionRGB(&segmentor);
  char* cfgFilePath = PBFSJoinPath(
    ".", "UnitTestImgSegmentorTrain", "dataset.json");
  GDataSetGenBrushPair dataSet =
    GDataSetGenBrushPairCreateStatic(cfgFilePath);
  ISSetSizePool(&segmentor, 20);
  ISSetNbElite(&segmentor, 5);
  ISSetNbEpoch(&segmentor, 100);
  ISSetTargetBestValue(&segmentor, 0.9);
  ISTrain(&segmentor, &dataSet);
  char* imgFilePath = PBFSJoinPath(
    ".", "UnitTestImgSegmentorTrain", "img000.tga");
  GenBrush* img = GBCreateFromFile(imgFilePath);
  GenBrush** pred = ISPredict(&segmentor, img);
  for (int iClass = nbClass; iClass--;) {
```

```
        char outPath[100];
        sprintf(outPath, "pred000-%03d.tga", iClass);
        char* predFilePath = PBFSJoinPath(
          ".", "UnitTestImgSegmentorTrain", outPath);
        GBSetFileName(pred[iClass], predFilePath);
        GBRender(pred[iClass]);
        GBFree(pred + iClass);
        free(predFilePath);
    }
    free(pred);
    GBFree(&img);
    free(cfgFilePath);
    free(imgFilePath);
    GDataSetGenBrushPairFreeStatic(&dataSet);
    ImgSegmentorFreeStatic(&segmentor);
    printf("UnitTestImgSegmentorTrain OK\n");
}

void UnitTestImgSegmentor() {
    UnitTestImgSegmentorCreateFree();
    UnitTestImgSegmentorAddCriterionGetSet();
    UnitTestImgSegmentorPredict();
    UnitTestImgSegmentorTrain();
    printf("UnitTestImgSegmentor OK\n");
}

void UnitTestAll() {
    UnitTestImgKMeansClusters();
    UnitTestIntersectionOverUnion();
    UnitTestImgSegmentorRGB();
    UnitTestImgSegmentor();
}

int main(void) {
    //UnitTestAll();
    UnitTestImgSegmentorTrain();
    return 0;
}
```

5   Unit tests output

```
./ImgKMeansClustersTest/imgkmeanscluster.tga size K=2 cell=1:
<190.271,188.622,189.519,255.874>
<57.922,71.614,92.852,255.544>
./ImgKMeansClustersTest/imgkmeanscluster.tga size K=3 cell=1:
<197.903,195.060,194.940,255.852>
<46.857,55.700,72.989,255.384>
<129.141,141.318,156.154,255.440>
./ImgKMeansClustersTest/imgkmeanscluster.tga size K=4 cell=1:
<49.314,59.658,46.134,255.156>
<156.342,159.087,163.036,255.568>
<56.903,76.562,152.418,255.000>
<201.616,198.516,198.111,255.828>
./ImgKMeansClustersTest/imgkmeanscluster.tga size K=5 cell=1:
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UnitTestImgKMeansClusters OK
UnitTestIntersectionOverUnion OK
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5.1   K-Means clustering on RGBA space
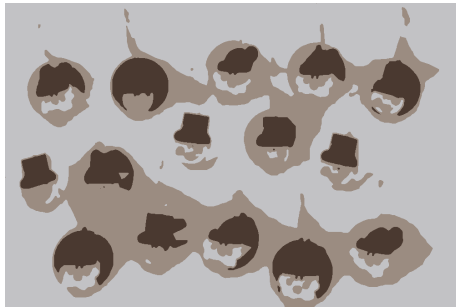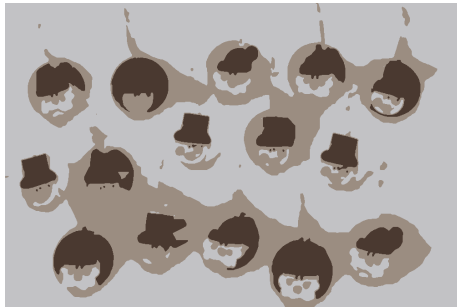
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clustering for K equals 2 to 6 and radius equals 0 to 5:
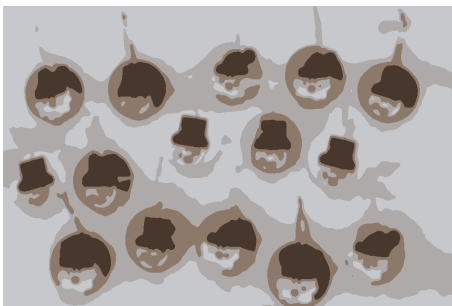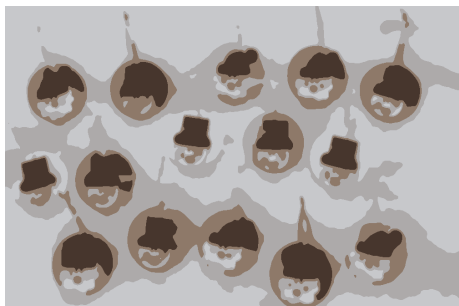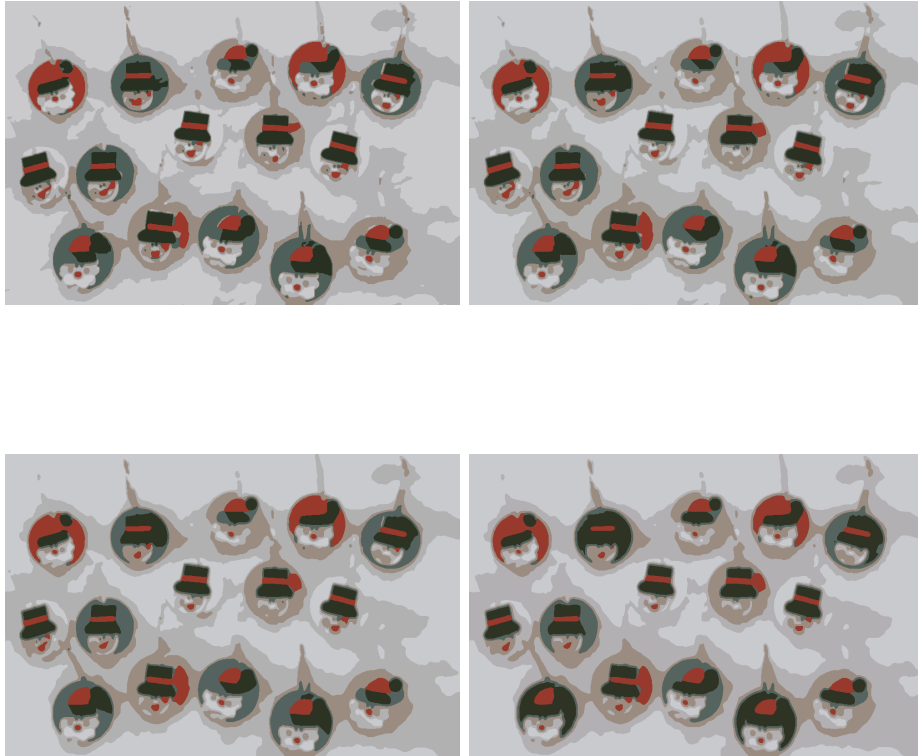K=2:
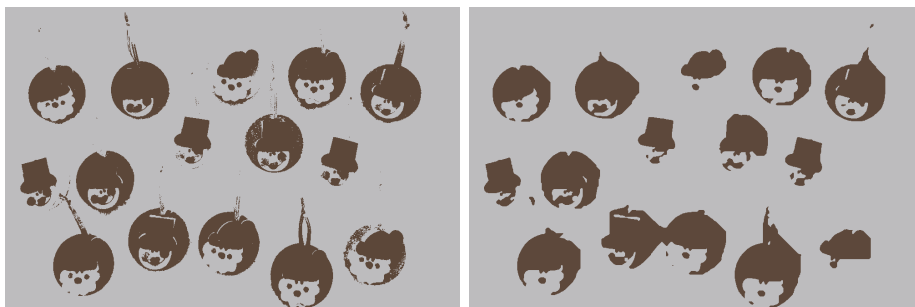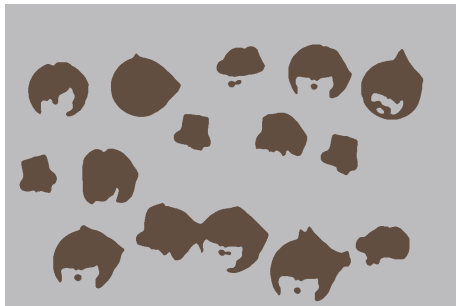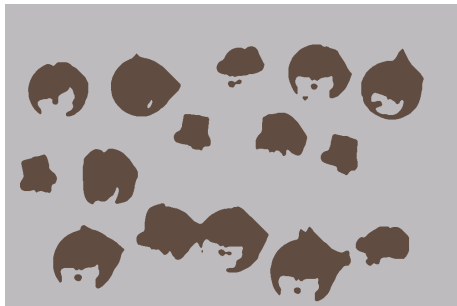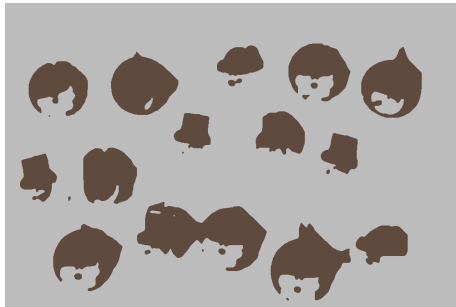
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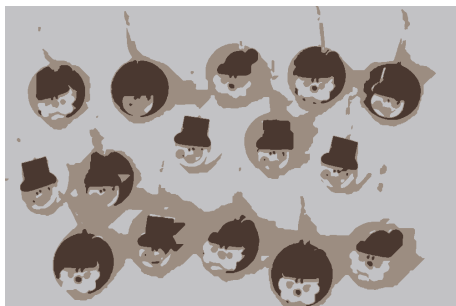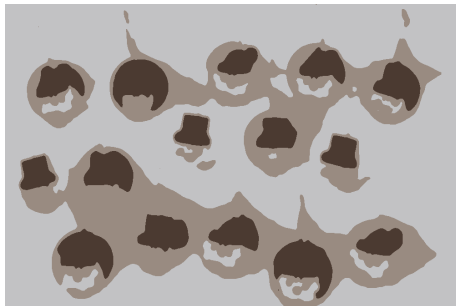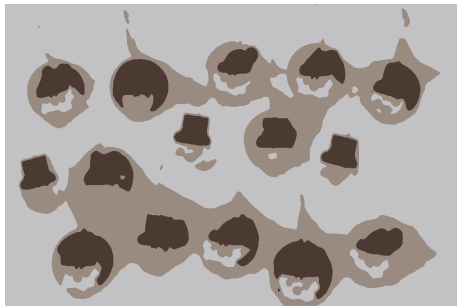
K=4:

K=5:

K=6:

imgkmeanscluster.txt:

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  "_clusters":{
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      },
      {
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      },
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        "_dim":"388",
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}
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