ParallelKmeansImageCompressor

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Chapter 1

Parallel Kmeans Images Compressor

This program compresses images by reducing the number of colors using k-means clustering. It offers enhanced performance through the implementation of several parallelization techniques. By clustering pixels into k color groups, the program reduces the image's color palette, thereby compressing the image while maintaining visual quality.

1.1 Doxygen Documentation

The documentation of the project can be found `here`.

1.2 Prerequisites

In order to be able to compile and run the program, there are a few programs that need to be installed.

1.2.1 OpenCV C++ Library

A comprehensive library for computer vision and image processing tasks.

You can refer to the `official page` to download.

1.2.2 Mpicc

A C compiler wrapper for parallel programming with the MPI library.

1.2.3 OpenMP

A C++ API for parallel programming on shared-memory systems.

1.3 Getting Started

To compile the project, navigate to the project root directory in your terminal and run the following command:

```
make
```

Once you have compiled you can execute the main program by:

```
./exe
```

1.4 What to expect

Once the program is started, the following screen appears, through which it is possible to compress a new image or decompress an already compressed image.

Figure 1.1 alt text

If you choose the "Compress an image" option you can select one type of compressor (sequential, MPI or OpenMP), the type of compression and the path of the original image.

The result image will be created in the output folder and you can rerun `./exe` selecting the decoding function to decode it.

1.5 Project Structure

The project is organized as follows:

1.5.0.1 Folders

- `benchmarkImages`: This folder contains the images used for benchmarking the program. It can be used to test the program's performance.
- `outputs`: This folder contains the compressed images. After installing the program, you may notice that the outputs folder is not present. However, don't worry! It will be automatically created during the first execution of the program.
- `include`: This folder contains the header files of the project. These define the classes and functions that are used in the program.
- `src`: This folder contains the source files of the project. These files contain the implementation of the classes and functions defined in the header files.
- `build`: This folder contains the object files generated during the compilation process.

1.5.0.2 Files and Executables

- `exe`: This is the executable file generated after compiling the project. It is the main program that can be executed to compress or decompress images.
- `Makefile`: This file contains the instructions for compiling the project. It specifies the dependencies and the commands to compile the project.
- `.config`: This file contains the configuration of the program. It is used to store some hyperparameters that can be modified to change the behavior of the program.

1.6 How does it work?

The program compresses images by reducing the number of colors in the image. It does this by clustering the pixels into k color groups using the k-means clustering algorithm. The k-means algorithm is an unsupervised learning algorithm that partitions the data into k clusters based on the similarity of the data points. In the context of image compression, the data points are the pixels of the image, and the clusters are the colors that represent the image.

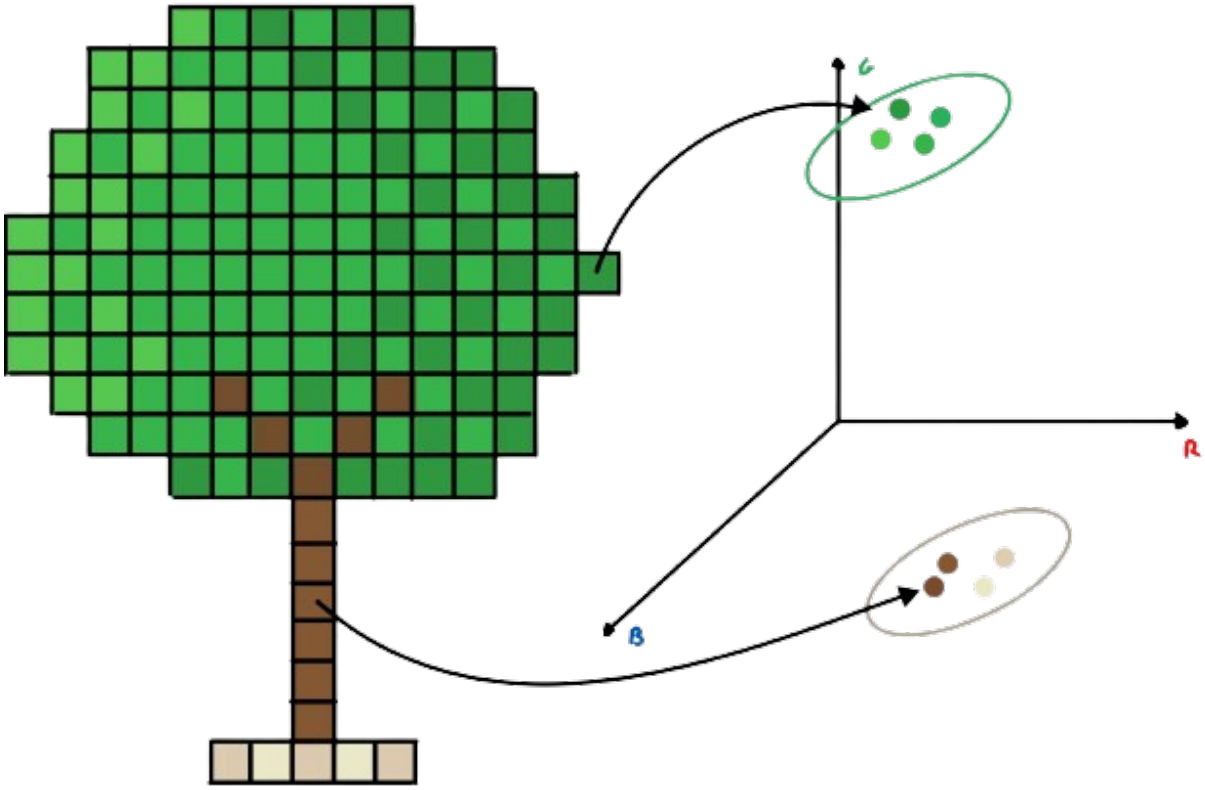

Figure 1.2 tree

The k-means algorithm works as follows:

1. Initialize k centroids randomly.
2. Assign each data point to the nearest centroid.
3. Recompute the centroids based on the data points assigned to them.
4. Repeat steps 2 and 3 until convergence.

The k-means algorithm is an iterative algorithm that converges to a local minimum. The quality of the compression depends on the value of k, the number of clusters. A higher value of k will result in a better representation of the image but will require more memory to store the centroids.

1.7 Parallelization Techniques

The program uses several parallelization techniques to enhance performance. These techniques include:

- **OpenMP**: OpenMP is an API for parallel programming on shared-memory systems. It allows the program to parallelize the computation of the k-means algorithm by distributing the work among multiple threads.
- **MPI**: MPI is a message-passing library for parallel programming on distributed-memory systems. It allows the program to parallelize the computation of the k-means algorithm by distributing the work among multiple processes running on different nodes.

1.8 Benchmarking

The program includes a benchmarking feature that allows you to test the performance of the program on different images. The benchmarking feature measures the time taken to compress an image using different compression techniques and different values of k. The benchmarking results are displayed in a table that shows the time taken to compress the image for each value of k and each compression technique.

1.9 Authors

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- Francesco Rosnati

Chapter 2

Namespace Documentation

2.1 km Namespace Reference

Main namespace for the project.

Namespaces

- namespace filesUtils
  Provides utility functions for file handling.
- namespace imageUtils
  Provides utility functions for image processing.
- namespace utilsCLI
  Provides utility functions for the command-line interface.

Classes

- class ConfigReader
  Reads and stores configuration values from a file.
- class KMeansBase
- class KMeansCUDA
- class KMeansMPI
- class KMeansOMP
- class KMeansSequential
- class Performance
  Represents the performance evaluation.
- class Point
  Represents a point in a feature space.

2.1.1 Detailed Description

Main namespace for the project.

The `km` namespace encapsulates various functionalities related to data clustering, file manipulation, and image processing. It is designed to organize core utilities and algorithms used across different modules of the project.

2.2 km::filesUtils Namespace Reference

Provides utility functions for file handling.

Functions

- auto createOutputDirectories () -> void

  Creates output directories.
- auto writeBinaryFile (std::string &outputPath, int &width, int &height, int &k, std::vector< Point > points, std::vector< Point > centroids) -> void

  Writes data to a binary file.
- auto isCorrectExtension (const std::filesystem::path &filePath, const std::string &correctExtension) -> bool

  Checks if a file has the correct extension.
- auto createDecodingMenu (std::filesystem::path &decodeDir, std::vector< std::filesystem::path > &imageNames) -> void

  Creates a decoding menu.
- auto readBinaryFile (std::string &path, cv::Mat &imageCompressed) -> int

  Reads a binary file and reconstructs the compressed image.

2.2.1 Detailed Description

Provides utility functions for file handling.

The filesUtils namespace within the km namespace offers a set of utility functions designed to handle various file operations crucial for image processing and data management. It includes functionalities to create necessary output directories, ensuring that the required directory structure is in place before any file operations are performed. The namespace provides a function to write data to a binary file, which includes parameters for the file path, image dimensions, the number of clusters, and vectors of points and centroids. This is particularly useful for saving compressed image data or related binary information. Additionally, it includes a function to verify whether a file has the correct extension, which is essential for validating file types before processing. The createDecodingMenu function facilitates the creation of a decoding menu by accepting a directory path and a vector of image names, which may be used for setting up decoding options. Lastly, the readBinaryFile function reads from a binary file to reconstruct a compressed image into an OpenCV matrix, returning the number of clusters present in the file. This set of functions is designed to streamline and manage file-related tasks, particularly in the context of image processing.

2.2.2 Function Documentation

2.2.2.1 createDecodingMenu()

```
void km::filesUtils::createDecodingMenu (
              std::filesystem::path & decodeDir,
              std::vector< std::filesystem::path > & imageNames) -> void
```

Creates a decoding menu.

Parameters

decodeDir	Directory for decoding
imageNames	Vector of image names

Here is the call graph for this function:

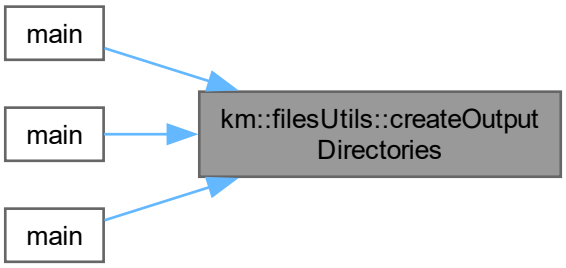
Here is the caller graph for this function:

2.2.2.2 createOutputDirectories()

```
void km::filesUtils::createOutputDirectories () -> void
```

Creates output directories.

Here is the caller graph for this function:



2.2.2.3 isCorrectExtension()

```
auto km::filesUtils::isCorrectExtension (
              const std::filesystem::path & filePath,
              const std::string & correctExtension) -> bool
```

Checks if a file has the correct extension.

Parameters

filePath	Path of the file
correctExtension	Correct extension to check

Returns

True if the file has the correct extension, false otherwise

Here is the caller graph for this function:

2.2.2.4 readBinaryFile()

```
auto km::filesUtils::readBinaryFile (
              std::string & path,
              cv::Mat & imageCompressed) -> int
```

Reads a binary file and reconstructs the compressed image.

Parameters

path	Path of the binary file
imageCompressed	Compressed image matrix

Returns

Number of clusters

Here is the caller graph for this function:

2.2.2.5 writeBinaryFile()

```
void km::filesUtils::writeBinaryFile (
              std::string & outputPath,
              int & width,
              int & height,
              int & k,
              std::vector< Point > points,
              std::vector< Point > centroids) -> void
```

Writes data to a binary file.

Parameters

outputPath	Path of the output file
width	Width of the image
height	Height of the image
k	Number of clusters
points	Vector of points
centroids	Vector of centroids

Here is the caller graph for this function:

2.3 km::imageUtils Namespace Reference

Provides utility functions for image processing.

Functions

- void preprocessing (cv::Mat &image, int &typeCompressionChoice)

  Performs preprocessing on an image.
- void defineKValue (int &k, int levelsColorsChoice, std::set< std::vector< unsigned char > > &different_colors)

  Defines the value of K based on the color levels choice.
- void pointsFromImage (cv::Mat &image, std::vector< Point > &points, std::set< std::vector< unsigned char > > &different_colors)

  Extracts points from an image.

2.3.1 Detailed Description

Provides utility functions for image processing.

The imageUtils namespace within the km namespace provides a suite of utility functions aimed at facilitating various image processing tasks. This namespace encompasses functions designed to preprocess images, determine the appropriate number of clusters for color-based compression, and extract points from images for further analysis.

The preprocessing function is responsible for preparing an image for subsequent processing steps, adjusting it according to the specified type of compression. The defineKValue function calculates the number of clusters, or K, based on the chosen levels of colors and the distinct colors present in the image. This function helps in determining the optimal number of clusters for tasks such as color quantization. Lastly, the pointsFromImage function extracts points from the image and organizes them into a vector, using the set of distinct colors found in the image to aid in this process. These functions collectively support various aspects of image processing, ensuring efficient handling and analysis of image data.

2.3.2 Function Documentation

2.3.2.1 defineKValue()

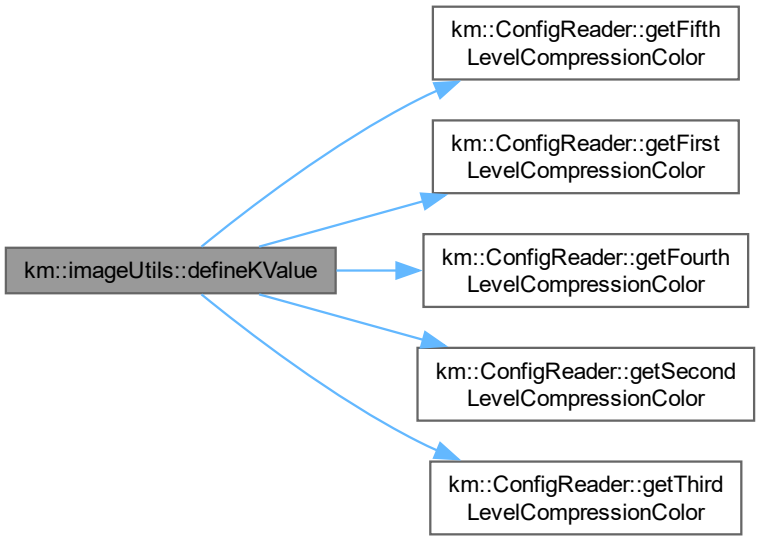
```
void km::imageUtils::defineKValue (
                int & k,
                int levelsColorsChoice,
                std::set< std::vector< unsigned char > > & different_colors)
```

Defines the value of K based on the color levels choice.

Parameters

k	Value of K
levelsColorsChoice	Levels of colors choice
different_colors	Set of different colors in the image

Here is the call graph for this function:



Here is the caller graph for this function:

2.3.2.2 pointsFromImage()

```
void km::imageUtils::pointsFromImage (
                cv::Mat & image,
                std::vector< Point > & points,
                std::set< std::vector< unsigned char > > & different_colors)
```

Extracts points from an image.

Parameters

image	Input image
points	Vector of points
different_colors	Set of different colors in the image

Here is the caller graph for this function:

2.3.2.3 preprocessing()

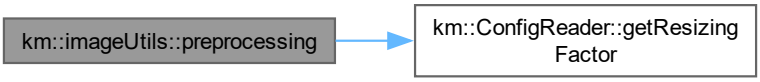
```
void km::imageUtils::preprocessing (
                cv::Mat & image,
                int & typeCompressionChoice)
```

Performs preprocessing on an image.

Parameters

image	Input image
typeCompressionChoice	Type of compression choice

Here is the call graph for this function:



Here is the caller graph for this function:

2.4 km::utilsCLI Namespace Reference

Provides utility functions for the command-line interface.

Functions

- void mainMenuHeader ()

  Displays the main menu header.
- void decoderHeader ()

  Displays the decoder header.
- void workDone ()

  Displays the work done message.
- void printCompressionInformations (int &originalWidth, int &originalHeight, int &width, int &height, int &k, size_t &different_colors_size)

  Prints the compression information.
- void displayDecodingMenu (std::string &path, std::vector< std::filesystem::path > &imageNames, std::filesystem::path &decodeDir)

  Displays the decoding menu.

2.4.1 Detailed Description

Provides utility functions for the command-line interface.

The utilsCLI namespace within the km namespace provides a collection of utility functions for enhancing command-line interface (CLI) interactions. The mainMenuHeader function displays the main menu header, while decoderHeader shows the header for the decoder section. The workDone function outputs a completion message to indicate that work has been finished. The printCompressionInformations function prints detailed compression data, including the original and compressed image dimensions, the number of clusters, and the count of different colors. Lastly, the displayDecodingMenu function presents a menu for decoding, showing image names and the path of the decoding directory. These functions facilitate user interaction and provide essential information during CLI operations.

2.4.2 Function Documentation

2.4.2.1 decoderHeader()

```
void km::utilsCLI::decoderHeader ()
```

Displays the decoder header.

Here is the caller graph for this function:

2.4.2.2 displayDecodingMenu()

```
void km::utilsCLI::displayDecodingMenu (
                std::string & path,
                std::vector< std::filesystem::path > & imageNames,
                std::filesystem::path & decodeDir)
```

Displays the decoding menu.

Parameters

path	Path of the directory containing the compressed images
imageNames	Vector of image names
decodeDir	Path of the decoding directory

Here is the caller graph for this function:

2.4.2.3 mainMenuHeader()

```
void km::utilsCLI::mainMenuHeader ()
```

Displays the main menu header.

Here is the caller graph for this function:

2.4.2.4 printCompressionInformations()

```
void km::utilsCLI::printCompressionInformations (
                int & originalWidth,
                int & originalHeight,
                int & width,
                int & height,
                int & k,
                size_t & different_colors_size)
```

Prints the compression information.

Parameters

originalWidth	Original width of the image
originalHeight	Original height of the image
width	Width of the compressed image
height	Height of the compressed image
k	Number of clusters
different_colors_size	Number of different colors

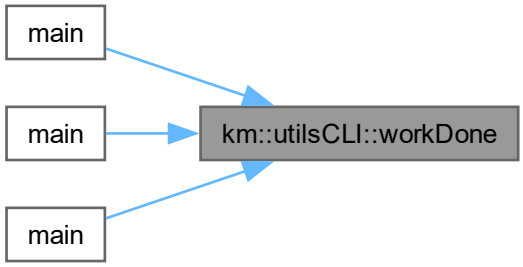
Here is the caller graph for this function:

2.4.2.5 workDone()

```
void km::utilsCLI::workDone ()
```

Displays the work done message.

Here is the caller graph for this function:



Chapter 3

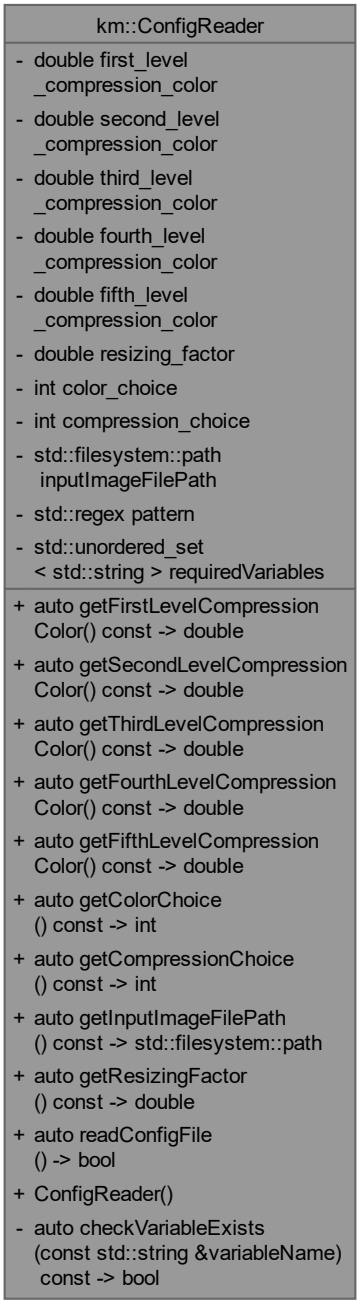
Class Documentation

3.1 km::ConfigReader Class Reference

Reads and stores configuration values from a file.

`#include <configReader.hpp>`

Collaboration diagram for km::ConfigReader:



Public Member Functions

- auto getFirstLevelCompressionColor () const -> double

  Gets the first level compression color value.
- auto getSecondLevelCompressionColor () const -> double

  Gets the second level compression color value.
- auto getThirdLevelCompressionColor () const -> double

Gets the third level compression color value.

- auto getFourthLevelCompressionColor () const -> double

  Gets the fourth level compression color value.
- auto getFifthLevelCompressionColor () const -> double

  Gets the fifth level compression color value.
- auto getColorChoice () const -> int

  Gets the color choice.
- auto getCompressionChoice () const -> int

  Gets the compression choice.
- auto getInputImageFilePath () const -> std::filesystem::path

  Gets the input image file path.
- auto getResizingFactor () const -> double

  Gets the resizing factor.
- auto readConfigFile () -> bool

  Reads the configuration file.
- ConfigReader ()

Private Member Functions

- auto checkVariableExists (const std::string &variableName) const -> bool

Private Attributes

- double first_level_compression_color = 0.

  First level compression color value.
- double second_level_compression_color = 0.

  Second level compression color value.
- double third_level_compression_color = 0.

  Third level compression color value.
- double fourth_level_compression_color = 0.

  Fourth level compression color value.
- double fifth_level_compression_color = 0.

  Fifth level compression color value.
- double resizing_factor = 0.

  Resizing factor.
- int color_choice = 0

  Color choice.
- int compression_choice = 0

  Compression choice.
- std::filesystem::path inputImageFilePath

  Input image file path.
- std::regex pattern

  Regular expression pattern.
- std::unordered_set< std::string > requiredVariables = {}

  Set of required variables.

3.1.1 Detailed Description

Reads and stores configuration values from a file.

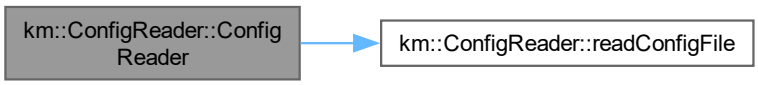
The ConfigReader class, located within the km namespace, is designed to handle the reading and storage of configuration settings from a file. This class is particularly focused on managing settings for image processing and compression. It holds various parameters such as compression color values for different levels, resizing factors, color choices, and compression choices, which are essential for tailoring the behavior of image processing operations. The class also manages the input image file path, allowing it to reference the specific files needed for processing. A regular expression pattern is included for validating or extracting configuration details, and a set of required variables is maintained to ensure that all necessary configuration options are present. The class provides several getter methods to access these stored settings, ensuring that they can be easily retrieved by other parts of the application. Additionally, it includes a method to read and validate the configuration file, ensuring that all required parameters are correctly set up before proceeding with any image processing tasks.

3.1.2 Constructor & Destructor Documentation

3.1.2.1 ConfigReader()

```
km::ConfigReader::ConfigReader ()
```

Here is the call graph for this function:



3.1.3 Member Function Documentation

3.1.3.1 checkVariableExists()

```
auto km::ConfigReader::checkVariableExists (
              const std::string & variableName) const -> bool  [nodiscard], [private]
```

3.1.3.2 getColorChoice()

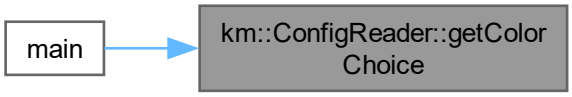
```
auto km::ConfigReader::getColorChoice () const -> int  [nodiscard]
```

Gets the color choice.

Returns

Color choice

Here is the caller graph for this function:



3.1.3.3 getCompressionChoice()

```
auto km::ConfigReader::getCompressionChoice () const -> int  [nodiscard]
```

Gets the compression choice.

Returns

Compression choice

Here is the caller graph for this function:

3.1.3.4 getFifthLevelCompressionColor()

```
auto km::ConfigReader::getFifthLevelCompressionColor () const -> double  [nodiscard]
```

Gets the fifth level compression color value.

Returns

Fifth level compression color value

Here is the caller graph for this function:

3.1.3.5 getFirstLevelCompressionColor()

```
auto km::ConfigReader::getFirstLevelCompressionColor () const -> double  [nodiscard]
```

Gets the first level compression color value.

Returns

First level compression color value

Here is the caller graph for this function:

3.1.3.6 getFourthLevelCompressionColor()

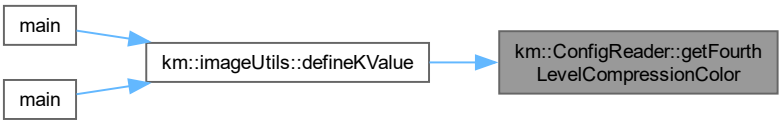
```
auto km::ConfigReader::getFourthLevelCompressionColor () const -> double  [nodiscard]
```

Gets the fourth level compression color value.

Returns

Fourth level compression color value

Here is the caller graph for this function:



3.1.3.7 getInputImageFilePath()

```
auto km::ConfigReader::getInputImageFilePath () const -> std::filesystem::path  [nodiscard]
```

Gets the input image file path.

Returns

Input image file path

Here is the caller graph for this function:

3.1.3.8 getResizingFactor()

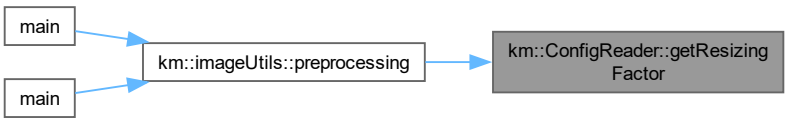
```
auto km::ConfigReader::getResizingFactor () const -> double  [nodiscard]
```

Gets the resizing factor.

Returns

Resizing factor

Here is the caller graph for this function:



3.1.3.9 getSecondLevelCompressionColor()

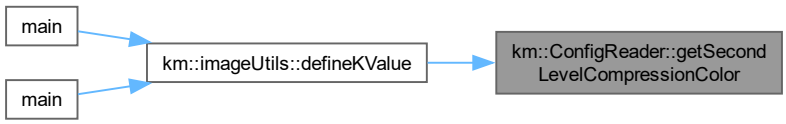
```
auto km::ConfigReader::getSecondLevelCompressionColor () const -> double  [nodiscard]
```

Gets the second level compression color value.

Returns

Second level compression color value

Here is the caller graph for this function:



3.1.3.10 getThirdLevelCompressionColor()

```
auto km::ConfigReader::getThirdLevelCompressionColor () const -> double  [nodiscard]
```

Gets the third level compression color value.

Returns

Third level compression color value

Here is the caller graph for this function:

3.1.3.11 readConfigFile()

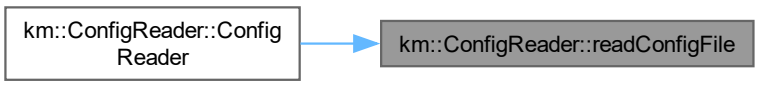
```
auto km::ConfigReader::readConfigFile () -> bool  [nodiscard]
```

Reads the configuration file.

Returns

True if the configuration file is read successfully, false otherwise

Here is the caller graph for this function:



3.1.4 Member Data Documentation

3.1.4.1 color_choice

```
int km::ConfigReader::color_choice = 0  [private]
```

Color choice.

3.1.4.2 compression_choice

```
int km::ConfigReader::compression_choice = 0  [private]
```

Compression choice.

3.1.4.3 fifth_level_compression_color

```
double km::ConfigReader::fifth_level_compression_color = 0.  [private]
```

Fifth level compression color value.

3.1.4.4 first_level_compression_color

```
double km::ConfigReader::first_level_compression_color = 0.  [private]
```

First level compression color value.

3.1.4.5 fourth_level_compression_color

```
double km::ConfigReader::fourth_level_compression_color = 0.  [private]
```

Fourth level compression color value.

3.1.4.6 inputImageFilePath

```
std::filesystem::path km::ConfigReader::inputImageFilePath  [private]
```

Input image file path.

3.1.4.7 pattern

```
std::regex km::ConfigReader::pattern  [private]
```

Regular expression pattern.

3.1.4.8 requiredVariables

```
std::unordered_set<std::string> km::ConfigReader::requiredVariables = {}  [private]
```

Set of required variables.

3.1.4.9 resizing_factor

```
double km::ConfigReader::resizing_factor = 0.  [private]
```

Resizing factor.

3.1.4.10 second_level_compression_color

```
double km::ConfigReader::second_level_compression_color = 0.  [private]
```

Second level compression color value.

3.1.4.11 third_level_compression_color

```
double km::ConfigReader::third_level_compression_color = 0.  [private]
```

Third level compression color value.

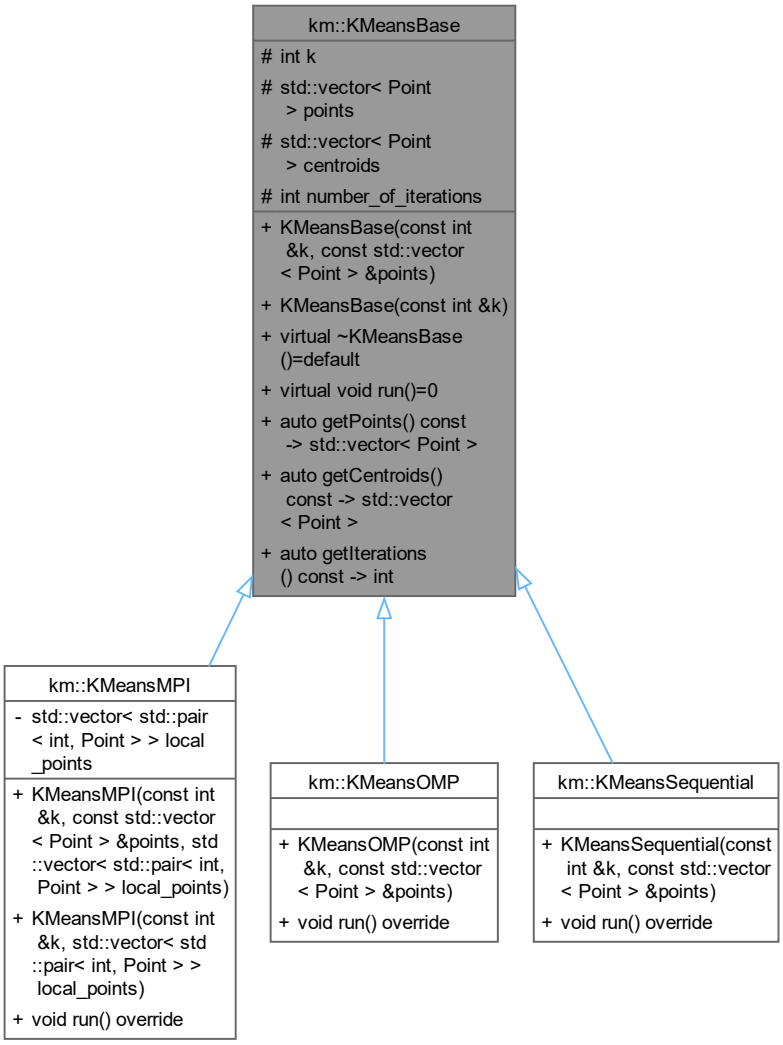
The documentation for this class was generated from the following files:

- include/configReader.hpp
- src/configReader.cpp

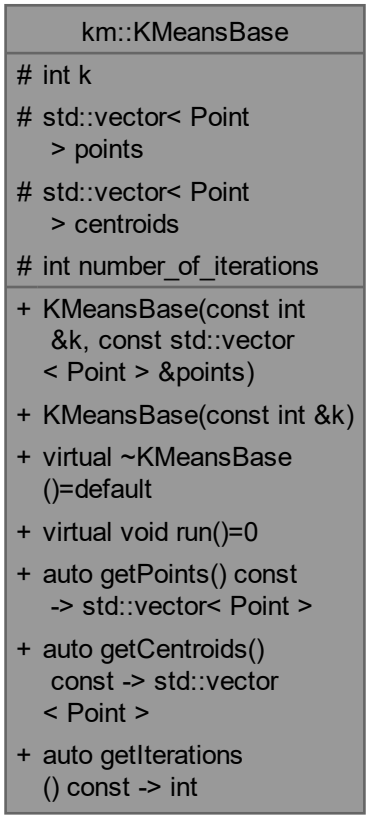
3.2 km::KMeansBase Class Reference

`#include <kMeansBase.hpp>`

Inheritance diagram for km::KMeansBase:



Collaboration diagram for km::KMeansBase:



Public Member Functions

- KMeansBase (const int &k, const std::vector< Point > &points)

  Constructor for KMeansBase.
- KMeansBase (const int &k)

  Constructs a KMeansBase object only with the specified number of clusters.
- virtual ~KMeansBase ()=default

  Virtual destructor for KMeansBase.
- virtual void run ()=0

  Runs the K-means clustering algorithm.
- auto getPoints () const -> std::vector< Point >

  Gets the poinots.
- auto getCentroids () const -> std::vector< Point >

  Gets the centroids.
- auto getIterations () const -> int

  Gets the number of iterations.

Protected Attributes

- int k
  Number of clusters.
- std::vector< Point > points
  Vector of points.
- std::vector< Point > centroids
  Vector of centroids.
- int number_of_iterations
  Number of iterations.

3.2.1 Detailed Description

```
@class KMeansBase
@brief Base class for K-means clustering algorithm
@details The KMeansBase class, part of the km namespace, serves as a foundational class for implementing the K-means cluste
```

The class includes several key functionalities: it allows for the construction of an object with either a predefined number of clusters and a set of points or just the number of clusters. The run method, which is a pure virtual function, must be implemented by any derived class to execute the K-means algorithm. This structure ensures that the base class can provide the essential setup and data management, while specific clustering logic is handled by subclasses.

The KMeansBase class also includes methods to retrieve the points used for clustering, the centroids calculated by the algorithm, and the number of iterations the algorithm has undergone. These methods provide access to the internal state of the clustering process, enabling users to inspect and analyze the results. Protected member variables include the number of clusters, the points to be clustered, the centroids resulting from the clustering process, and the count of iterations performed, allowing derived classes to access and manipulate these values as needed.

3.2.2 Constructor & Destructor Documentation

3.2.2.1 KMeansBase() [1/2]

```
km::KMeansBase::KMeansBase (
            const int & k,
            const std::vector< Point > & points)
```

Constructor for KMeansBase.

Parameters

k	Number of clusters
points	Vector of points

3.2.2.2 KMeansBase() [2/2]

```
km::KMeansBase::KMeansBase (
            const int & k)
```

Constructs a KMeansBase object only with the specified number of clusters.

Parameters

k	The number of clusters.

3.2.2.3 ~KMeansBase()

```
virtual km::KMeansBase::~KMeansBase ()  [virtual], [default]
```

Virtual destructor for KMeansBase.

3.2.3 Member Function Documentation

3.2.3.1 getCentroids()

```
std::vector< km::Point > km::KMeansBase::getCentroids () const -> std::vector<Point>  [nodiscard]
```

Gets the centroids.

Returns

Vector of centroids

Here is the caller graph for this function:

3.2.3.2 getIterations()

```
int km::KMeansBase::getIterations () const -> int  [nodiscard]
```

Gets the number of iterations.

Returns

Number of iterations

Here is the caller graph for this function:

3.2.3.3 getPoints()

```
std::vector< km::Point > km::KMeansBase::getPoints () const -> std::vector<Point>  [nodiscard]
```

Gets the poinots.

Returns

Vector of points

Here is the caller graph for this function:

3.2.3.4 run()

```
virtual void km::KMeansBase::run ()  [pure virtual]
```

Runs the K-means clustering algorithm.

Implemented in km::KMeansMPI, km::KMeansOMP, and km::KMeansSequential.

3.2.4 Member Data Documentation

3.2.4.1 centroids

```
std::vector<Point> km::KMeansBase::centroids  [protected]
```

Vector of centroids.

3.2.4.2 k

```
int km::KMeansBase::k  [protected]
```

Number of clusters.

3.2.4.3 number_of_iterations

```
int km::KMeansBase::number_of_iterations  [protected]
```

Number of iterations.

3.2.4.4 points

```
std::vector<Point> km::KMeansBase::points  [protected]
```

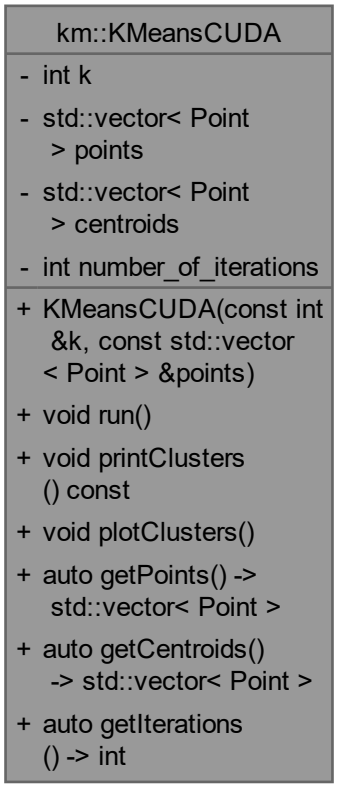
Vector of points.

The documentation for this class was generated from the following files:

- include/kMeansBase.hpp
- src/kMeansBase.cpp

3.3 km::KMeansCUDA Class Reference

Collaboration diagram for km::KMeansCUDA:



Public Member Functions

- KMeansCUDA (const int &k, const std::vector< Point > &points)

  Constructor for KMeans.
- void run ()

  Runs the K-means clustering algorithm using CUDA.

- void printClusters () const

  Prints the clusters.
- void plotClusters ()

  Plots the clusters.
- auto getPoints () -> std::vector< Point >

  Gets the points.
- auto getCentroids () -> std::vector< Point >

  Gets the centroids.
- auto getIterations () -> int

  Gets the number of iterations.

Private Attributes

- int k

  Number of clusters.
- std::vector< Point > points

  Vector of points.
- std::vector< Point > centroids

  Vector of centroids.
- int number_of_iterations

  Number of iterations.

3.3.1 Detailed Description

```
@class KMeansCUDA
@brief Represents the K-means clustering algorithm using CUDA
@details The KMeansCUDA class, located in the km namespace, is designed to implement the K-means clustering algorithm usin
```

The class provides a constructor that initializes the number of clusters and the vector of points to be clustered. It includes a run method that executes the K-means algorithm on the GPU, performing the clustering operations efficiently by taking advantage of parallel processing capabilities. Additionally, it offers methods to print and plot the clusters, allowing users to visualize the results of the clustering process. The getPoints, getCentroids, and getIterations methods provide access to the internal state of the clustering, including the input points, the resulting centroids, and the number of iterations the algorithm has undergone, respectively. This design ensures that users can both run and analyze the K-means clustering process using CUDA for improved performance.

3.3.2 Constructor & Destructor Documentation

3.3.2.1 KMeansCUDA()

```
km::KMeansCUDA::KMeansCUDA (
                const int & k,
                const std::vector< Point > & points)
```

Constructor for KMeans.

Parameters

k	Number of clusters
points	Vector of points

3.3.3 Member Function Documentation

3.3.3.1 getCentroids()

```
auto km::KMeansCUDA::getCentroids () -> std::vector<Point>
```

Gets the centroids.

Returns

Vector of centroids

Here is the caller graph for this function:

3.3.3.2 getIterations()

```
auto km::KMeansCUDA::getIterations () -> int
```

Gets the number of iterations.

Returns

Number of iterations

Here is the caller graph for this function:

3.3.3.3 getPoints()

```
auto km::KMeansCUDA::getPoints () -> std::vector<Point>
```

Gets the points.

Returns

Vector of points

Here is the caller graph for this function:

3.3.3.4 plotClusters()

```
void km::KMeansCUDA::plotClusters ()
```

Plots the clusters.

3.3.3.5 printClusters()

```
void km::KMeansCUDA::printClusters () const
```

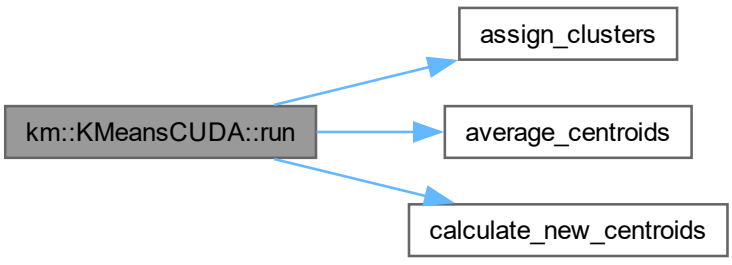
Prints the clusters.

3.3.3.6 run()

```
void km::KMeansCUDA::run ()
```

Runs the K-means clustering algorithm using CUDA.

Here is the call graph for this function:



Here is the caller graph for this function:

3.3.4 Member Data Documentation

3.3.4.1 centroids

```
std::vector<Point> km::KMeansCUDA::centroids  [private]
```

Vector of centroids.

3.3.4.2 k

```
int km::KMeansCUDA::k  [private]
```

Number of clusters.

3.3.4.3 number_of_iterations

```
int km::KMeansCUDA::number_of_iterations  [private]
```

Number of iterations.

3.3.4.4 points

```
std::vector<Point> km::KMeansCUDA::points  [private]
```

Vector of points.

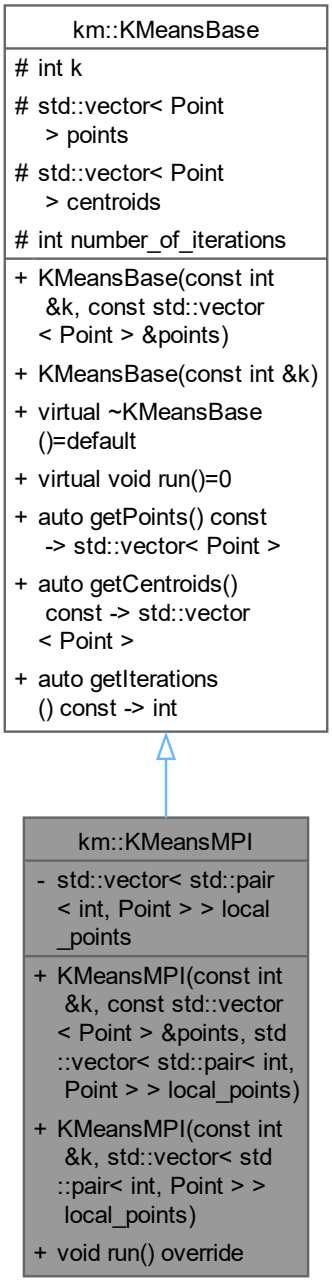
The documentation for this class was generated from the following files:

- include/kMeansCUDA.cuh
- src/kMeansCUDA.cu

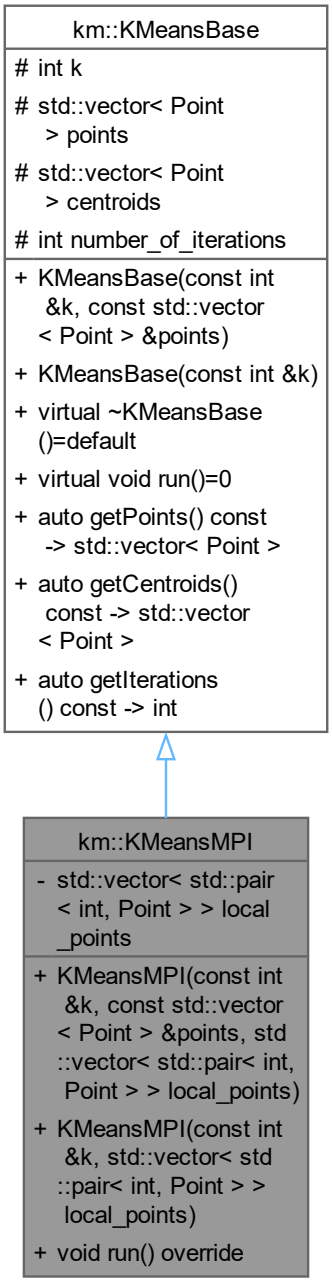
3.4 km::KMeansMPI Class Reference

`#include <kMeansMPI.hpp>`

Inheritance diagram for km::KMeansMPI:



Collaboration diagram for km::KMeansMPI:



Public Member Functions

- KMeansMPI (const int &k, const std::vector< Point > &points, std::vector< std::pair< int, Point > > local_points)

  Constructor for KMeansMPI.
- KMeansMPI (const int &k, std::vector< std::pair< int, Point > > local_points)

  Constructor for KMeansMPI.
- void run () override

  Runs the K-means clustering algorithm using MPI.

Public Member Functions inherited from km::KMeansBase

- KMeansBase (const int &k, const std::vector< Point > &points)
  Constructor for KMeansBase.
- KMeansBase (const int &k)
  Constructs a KMeansBase object only with the specified number of clusters.
- virtual ~KMeansBase ()=default
  Virtual destructor for KMeansBase.
- auto getPoints () const -> std::vector< Point >
  Gets the poinots.
- auto getCentroids () const -> std::vector< Point >
  Gets the centroids.
- auto getIterations () const -> int
  Gets the number of iterations.

Private Attributes

- std::vector< std::pair< int, Point > > local_points
  Vector of local points.

Additional Inherited Members

Protected Attributes inherited from km::KMeansBase

- int k
  Number of clusters.
- std::vector< Point > points
  Vector of points.
- std::vector< Point > centroids
  Vector of centroids.
- int number_of_iterations
  Number of iterations.

3.4.1 Detailed Description

```
@class KMeansMPI
@brief Represents the K-means clustering algorithm using MPI
@details The KMeansMPI class, located in the km namespace, is designed to implement the K-means clustering algorithm using
```

The class includes two constructors: one that initializes the number of clusters, a vector of points, and a vector of local points distributed across MPI processes; and another that initializes only the number of clusters and local points. The run method, overridden from KMeansBase, is responsible for executing the K-means clustering algorithm using MPI, coordinating the clustering process across different processes in a distributed computing environment.

The local_points member variable holds the points assigned to each MPI process, enabling the parallel execution of clustering tasks. This class is designed to handle clustering in a distributed setting, allowing for efficient processing of large datasets by distributing the workload across multiple computing nodes.

3.4.2 Constructor & Destructor Documentation

3.4.2.1 KMeansMPI() [1/2]

```
km::KMeansMPI::KMeansMPI (
            const int & k,
            const std::vector< Point > & points,
            std::vector< std::pair< int, Point > > local_points)
```

Constructor for KMeansMPI.

Parameters

k	Number of clusters
points	Vector of points

3.4.2.2 KMeansMPI() [2/2]

```
km::KMeansMPI::KMeansMPI (
              const int & k,
              std::vector< std::pair< int, Point > > local_points)
```

Constructor for KMeansMPI.

Parameters

k	Number of clusters

3.4.3 Member Function Documentation

3.4.3.1 run()

```
void km::KMeansMPI::run ()  [override], [virtual]
```

Runs the K-means clustering algorithm using MPI.

Implements km::KMeansBase.

3.4.4 Member Data Documentation

3.4.4.1 local_points

```
std::vector<std::pair<int, Point> > km::KMeansMPI::local_points  [private]
```

Vector of local points.

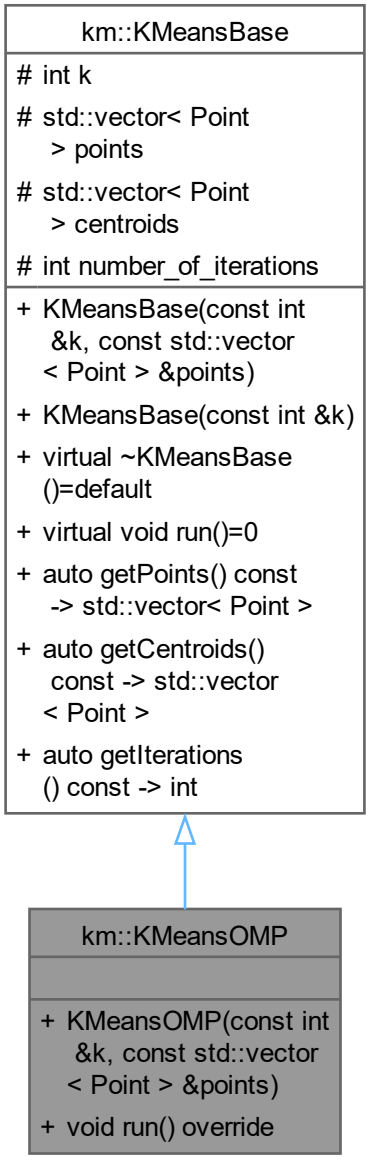
The documentation for this class was generated from the following files:

- include/kMeansMPI.hpp
- src/kMeansMPI.cpp

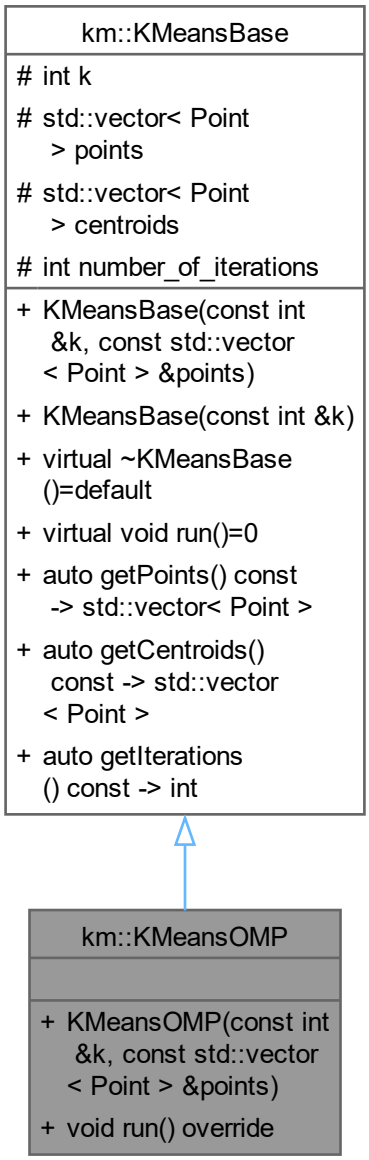
3.5 km::KMeansOMP Class Reference

`#include <kMeansOMP.hpp>`

Inheritance diagram for km::KMeansOMP:



Collaboration diagram for km::KMeansOMP:



Public Member Functions

- KMeansOMP (const int &k, const std::vector< Point > &points)

  Constructor for KMeansOMP.
- void run () override

  Runs the K-means clustering algorithm using OpenMP.

Public Member Functions inherited from km::KMeansBase

- KMeansBase (const int &k, const std::vector< Point > &points)

Constructor for KMeansBase.

- KMeansBase (const int &k)

  Constructs a KMeansBase object only with the specified number of clusters.
- virtual ~KMeansBase ()=default

  Virtual destructor for KMeansBase.
- auto getPoints () const -> std::vector< Point >

  Gets the poinots.
- auto getCentroids () const -> std::vector< Point >

  Gets the centroids.
- auto getIterations () const -> int

  Gets the number of iterations.

Additional Inherited Members

Protected Attributes inherited from km::KMeansBase

- int k

  Number of clusters.
- std::vector< Point > points

  Vector of points.
- std::vector< Point > centroids

  Vector of centroids.
- int number_of_iterations

  Number of iterations.

3.5.1 Detailed Description

```
@class KMeansOMP
@brief Represents the K-means clustering algorithm using OpenMP
@details The KMeansOMP class, part of the km namespace, is designed to implement the K-means clustering algorithm using Ope
```

The class features a constructor that initializes the number of clusters and the vector of points to be clustered. The run method, which overrides the base class method, is responsible for executing the K-means clustering algorithm with parallelization support provided by OpenMP. This allows the algorithm to handle clustering operations more efficiently by distributing computational tasks across multiple threads.

By integrating OpenMP, the KMeansOMP class aims to enhance the performance of the K-means clustering algorithm, making it suitable for processing larger datasets and improving computational efficiency in environments with multi-core CPUs.

3.5.2 Constructor & Destructor Documentation

3.5.2.1 KMeansOMP()

```
km::KMeansOMP::KMeansOMP (
            const int & k,
            const std::vector< Point > & points)
```

Constructor for KMeansOMP.

Parameters

k	Number of clusters
points	Vector of points

3.5.3 Member Function Documentation

3.5.3.1 run()

```
void km::KMeansOMP::run ()  [override], [virtual]
```

Runs the K-means clustering algorithm using OpenMP.

Implements km::KMeansBase.

Here is the caller graph for this function:

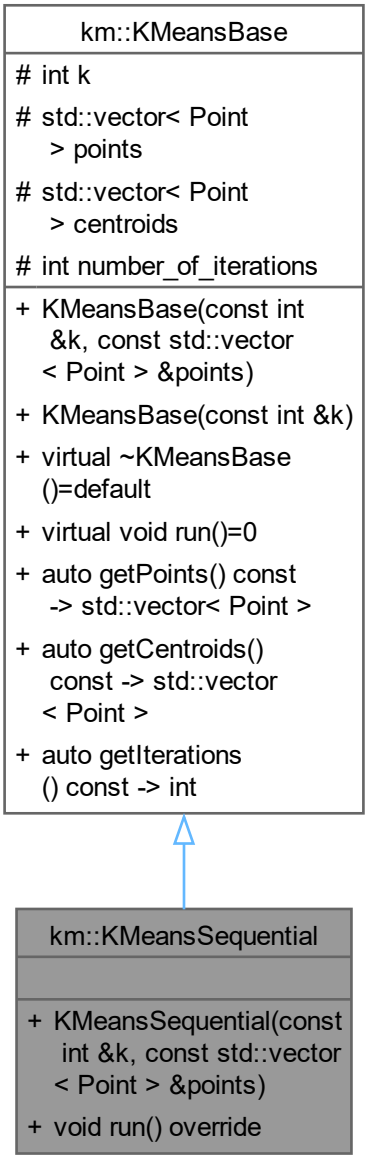
The documentation for this class was generated from the following files:

- include/kMeansOMP.hpp
- src/kMeansOMP.cpp

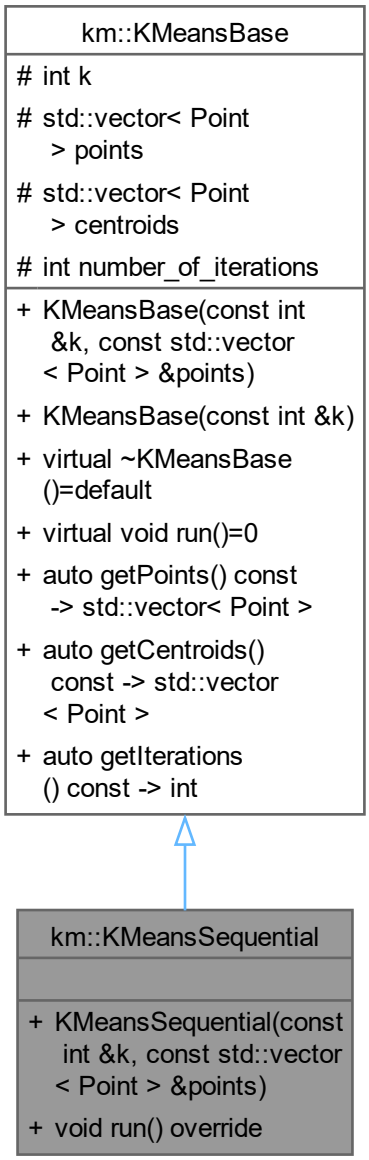
3.6 km::KMeansSequential Class Reference

```
#include <kMeansSequential.hpp>
```

Inheritance diagram for km::KMeansSequential:



Collaboration diagram for km::KMeansSequential:



Public Member Functions

- KMeansSequential (const int &k, const std::vector< Point > &points)

  Constructor for KMeansSequential.
- void run () override

  Runs the K-means clustering algorithm.

Public Member Functions inherited from km::KMeansBase

- KMeansBase (const int &k, const std::vector< Point > &points)

Constructor for KMeansBase.

- KMeansBase (const int &k)

  Constructs a KMeansBase object only with the specified number of clusters.
- virtual ~KMeansBase ()=default

  Virtual destructor for KMeansBase.
- auto getPoints () const -> std::vector< Point >

  Gets the poinots.
- auto getCentroids () const -> std::vector< Point >

  Gets the centroids.
- auto getIterations () const -> int

  Gets the number of iterations.

Additional Inherited Members

Protected Attributes inherited from km::KMeansBase

- int k

  Number of clusters.
- std::vector< Point > points

  Vector of points.
- std::vector< Point > centroids

  Vector of centroids.
- int number_of_iterations

  Number of iterations.

3.6.1 Detailed Description

```
@class KMeansSequential
@brief Represents the K-means clustering algorithm
@details The KMeansSequential class, within the km namespace, provides a straightforward implementation of the K-means clus
```

The class includes a constructor that initializes the number of clusters and the vector of points to be clustered. The run method, which overrides the virtual method from KMeansBase, is responsible for executing the K-means clustering algorithm in a sequential, step-by-step process. This implementation is suitable for environments where parallel processing is not available or necessary, and it provides a foundational approach to K-means clustering that can be used for benchmarking or as a baseline for more complex implementations.

The KMeansSequential class serves as a basic and direct implementation of K-means clustering, focusing on clarity and correctness of the algorithm in a non-parallelized context.

3.6.2 Constructor & Destructor Documentation

3.6.2.1 KMeansSequential()

```
km::KMeansSequential::KMeansSequential (
            const int & k,
            const std::vector< Point > & points)
```

Constructor for KMeansSequential.

Parameters

k	Number of clusters
points	Vector of points

3.6.3 Member Function Documentation

3.6.3.1 run()

```
void km::KMeansSequential::run ()  [override], [virtual]
```

Runs the K-means clustering algorithm.

Implements km::KMeansBase.

Here is the caller graph for this function:

The documentation for this class was generated from the following files:

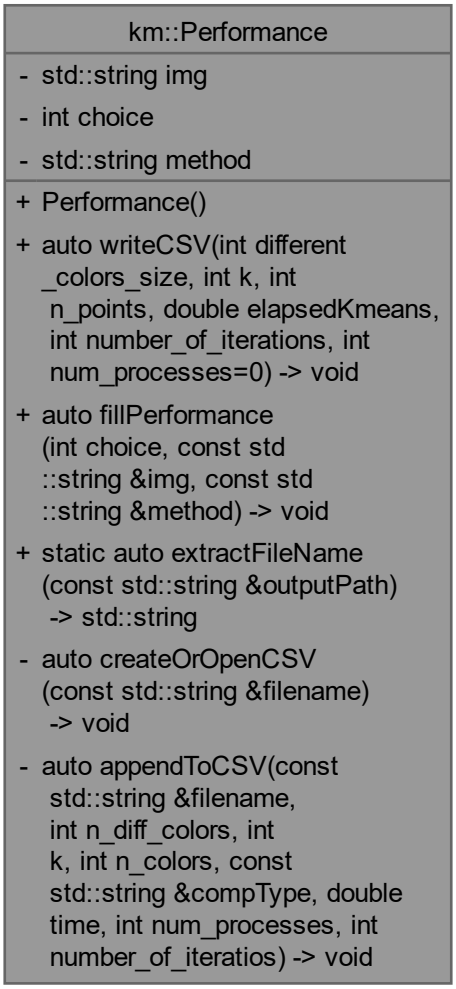
- include/kMeansSequential.hpp
- src/kMeansSequential.cpp

3.7 km::Performance Class Reference

Represents the performance evaluation.

```
#include <performanceEvaluation.hpp>
```

Collaboration diagram for km::Performance:



Public Member Functions

- Performance ()

  Default constructor.
- auto writeCSV (int different_colors_size, int k, int n_points, double elapsedKmeans, int number_of_iterations, int num_processes=0) -> void

  Writes performance data to a CSV file.
- auto fillPerformance (int choice, const std::string &img, const std::string &method) -> void

  Fills the performance data.

Static Public Member Functions

- static auto extractFileName (const std::string &outputPath) -> std::string

  Extracts the file name from the output path.

Private Member Functions

- auto createOrOpenCSV (const std::string &filename) -> void

  Creates or opens a CSV file.
- auto appendToCSV (const std::string &filename, int n_diff_colors, int k, int n_colors, const std::string &compType, double time, int num_processes, int number_of_iteratios) -> void

  Appends performance data to the CSV file.

Private Attributes

- std::string img

  Image name.
- int choice {}

  Choice of performance evaluation.
- std::string method

  Method used.

3.7.1 Detailed Description

Represents the performance evaluation.

The Performance class in the km namespace is designed for evaluating and recording the performance of clustering algorithms. It includes methods to write performance data to a CSV file, extract file names from paths, and fill in performance metrics based on various criteria. The class has a default constructor and methods for writing data to a CSV file, such as writeCSV for recording performance metrics, and fillPerformance for populating evaluation data. Private methods handle file operations, including creating or opening CSV files and appending data. The class manages internal details like image names and evaluation choices for performance analysis.

3.7.2 Constructor & Destructor Documentation

3.7.2.1 Performance()

```
km::Performance::Performance ()  [default]
```

Default constructor.

3.7.3 Member Function Documentation

3.7.3.1 appendToCSV()

```
void km::Performance::appendToCSV (
            const std::string & filename,
            int n_diff_colors,
            int k,
            int n_colors,
            const std::string & compType,
            double time,
            int num_processes,
            int number_of_iteratios) -> void  [private]
```

Appends performance data to the CSV file.

Parameters

filename	Name of the CSV file
n_diff_colors	Number of different colors
k	Number of clusters
n_colors	Number of colors
compType	Compression type
time	Elapsed time
num_processes	Number of processes

3.7.3.2 createOrOpenCSV()

```
void km::Performance::createOrOpenCSV (
            const std::string & filename) -> void  [private]
```

Creates or opens a CSV file.

Parameters

filename	Name of the CSV file

3.7.3.3 extractFileName()

```
auto km::Performance::extractFileName (
            const std::string & outputPath) -> std::string  [static]
```

Extracts the file name from the output path.

Parameters

outputPath	Output path

Returns

Extracted file name

Here is the caller graph for this function:

3.7.3.4 fillPerformance()

```
void km::Performance::fillPerformance (
                int choice,
                const std::string & img,
                const std::string & method) -> void
```

Fills the performance data.

Parameters

choice	Choice of performance evaluation
img	Image name
method	Method used

Here is the caller graph for this function:

3.7.3.5 writeCSV()

```
void km::Performance::writeCSV (
                int different_colors_size,
                int k,
                int n_points,
                double elapsedKmeans,
                int number_of_iterations,
                int num_processes = 0) -> void
```

Writes performance data to a CSV file.

Parameters

different_colors_size	Number of different colors
k	Number of clusters
n_points	Number of points
elapsedKmeans	Elapsed time for K-means clustering
num_processes	Number of processes (optional, default=0)

Here is the caller graph for this function:

3.7.4 Member Data Documentation

3.7.4.1 choice

```
int km::Performance::choice {}  [private]
```

Choice of performance evaluation.

3.7.4.2 img

```
std::string km::Performance::img  [private]
```

Image name.

3.7.4.3 method

```
std::string km::Performance::method  [private]
```

Method used.

The documentation for this class was generated from the following files:

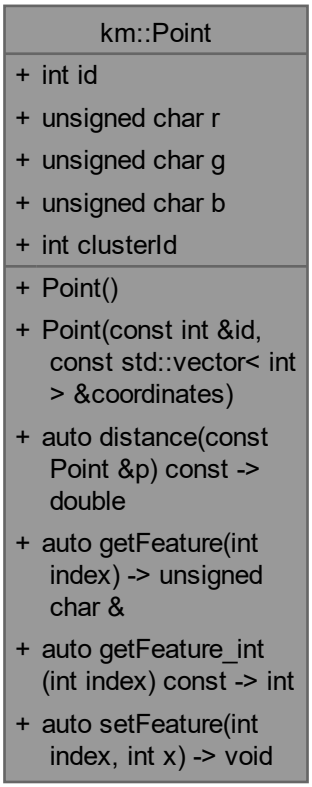
- include/performanceEvaluation.hpp
- src/performanceEvaluation.cpp

3.8 km::Point Class Reference

Represents a point in a feature space.

`#include <point.hpp>`

Collaboration diagram for km::Point:



Public Member Functions

- Point ()
  Constructor for Point.
- Point (const int &id, const std::vector< int > &coordinates)
  Constructor for Point.
- auto distance (const Point &p) const -> double
  Calculates the distance between this point and another point.
- auto getFeature (int index) -> unsigned char &
  Gets a feature value at the specified index.
- auto getFeature_int (int index) const -> int
  Gets a feature value as an integer at the specified index.
- auto setFeature (int index, int x) -> void
  Sets a feature value at the specified index.

Public Attributes

- int id {0}
  ID of the point.
- unsigned char r {0}
  Red component.
- unsigned char g {0}
  Green component.
- unsigned char b {0}
  Blue component.
- int clusterId {-1}
  ID of the cluster the point belongs to.

3.8.1 Detailed Description

Represents a point in a feature space.

The Point class in the km namespace represents a point in a feature space, with attributes including an ID, RGB color components, and a cluster ID. It features a default constructor and a parameterized constructor for initializing points with specific IDs and coordinates. The class includes methods to compute the distance between two points, retrieve and set feature values, and access feature values as integers. These functionalities facilitate the manipulation and analysis of points within clustering algorithms and other feature-based computations.

3.8.2 Constructor & Destructor Documentation

3.8.2.1 Point() [1/2]

```
km::Point::Point ()  [default]
```

Constructor for Point.

Parameters

features_size	Number of features

3.8.2.2 Point() [2/2]

```
km::Point::Point (
            const int & id,
            const std::vector< int > & coordinates)
```

Constructor for Point.

Parameters

id	ID of the point
coordinates	Coordinates of the point

3.8.3 Member Function Documentation

3.8.3.1 distance()

```
auto km::Point::distance (
            const Point & p) const -> double  [nodiscard]
```

Calculates the distance between this point and another point.

Parameters

p	Other point

Returns

Distance between the points

3.8.3.2 getFeature()

```
auto km::Point::getFeature (
               int index) -> unsigned char &
```

Gets a feature value at the specified index.

Parameters

index	Index of the feature

Returns

Feature value

3.8.3.3 getFeature_int()

```
auto km::Point::getFeature_int (
               int index) const -> int  [nodiscard]
```

Gets a feature value as an integer at the specified index.

Parameters

index	Index of the feature

Returns

Feature value as an integer

3.8.3.4 setFeature()

```
void km::Point::setFeature (
               int index,
               int x) -> void
```

Sets a feature value at the specified index.

Parameters

index	Index of the feature
x	Feature value

3.8.4 Member Data Documentation

3.8.4.1 b

```
unsigned char km::Point::b {0}
```

Blue component.

3.8.4.2 clusterId

```
int km::Point::clusterId {-1}
```

ID of the cluster the point belongs to.

3.8.4.3 g

```
unsigned char km::Point::g {0}
```

Green component.

3.8.4.4 id

```
int km::Point::id {0}
```

ID of the point.

3.8.4.5 r

```
unsigned char km::Point::r {0}
```

Red component.

The documentation for this class was generated from the following files:

- include/point.hpp
- src/point.cpp

Chapter 4

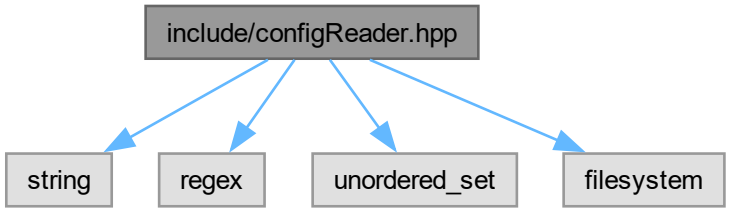
File Documentation

4.1 include/configReader.hpp File Reference

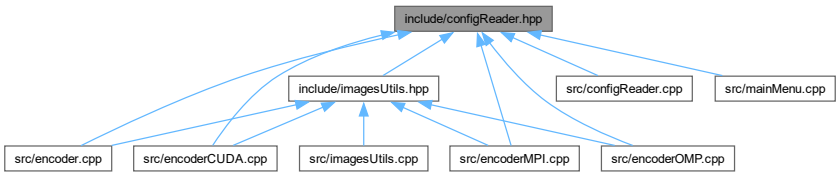
ConfigReader class declaration.

```
#include <string>
#include <regex>
#include <unordered_set>
#include <filesystem>
```

Include dependency graph for configReader.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::ConfigReader

  Reads and stores configuration values from a file.

Namespaces

- namespace km

  Main namespace for the project.

4.1.1 Detailed Description

ConfigReader class declaration.

4.2 configReader.hpp

Go to the documentation of this file.

```
00001
00006 #ifndef CONFIG_READER_HPP
00007 #define CONFIG_READER_HPP
00008
00009 #include <string>
00010 #include <regex>
00011 #include <unordered_set>
00012 #include <filesystem>
00013
00014 namespace km
00015 {
00022     class ConfigReader
00023     {
00024     private:
00025         double first_level_compression_color = 0.;
00026         double second_level_compression_color = 0.;
00027         double third_level_compression_color = 0.;
00028         double fourth_level_compression_color = 0.;
00029         double fifth_level_compression_color = 0.;
00030         double resizing_factor = 0.;
00031         int color_choice = 0;
00032         int compression_choice = 0;
00033         std::filesystem::path inputImageFilePath;
00034         std::regex pattern;
00035         std::unordered_set<std::string> requiredVariables = {};
00036
00037         [[nodiscard]] auto checkVariableExists(const std::string &variableName) const -> bool;
00038
00044     public:
00045         [[nodiscard]] auto getFirstLevelCompressionColor() const -> double;
00046
00051         [[nodiscard]] auto getSecondLevelCompressionColor() const -> double;
00052
00057         [[nodiscard]] auto getThirdLevelCompressionColor() const -> double;
00058
00063         [[nodiscard]] auto getFourthLevelCompressionColor() const -> double;
00064
00069         [[nodiscard]] auto getFifthLevelCompressionColor() const -> double;
00070
00075         [[nodiscard]] auto getColorChoice() const -> int;
00076
00081         [[nodiscard]] auto getCompressionChoice() const -> int;
00082
00087         [[nodiscard]] auto getInputImageFilePath() const -> std::filesystem::path;
00088
00093         [[nodiscard]] auto getResizingFactor() const -> double;
00094
00099         [[nodiscard]] auto readConfigFile() -> bool;
00100
00101         ConfigReader();
00102     };
00103 } // namespace km
00104
00105 #endif // CONFIG_READER_HPP
```

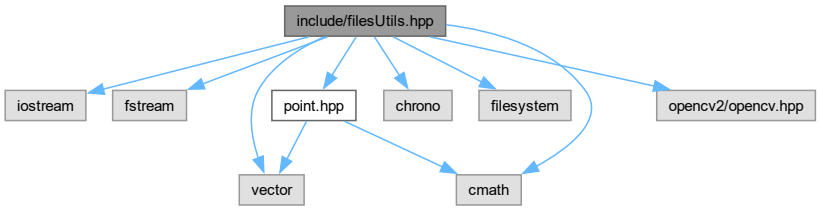
4.3 include/filesUtils.hpp File Reference

Utility functions for file handling.

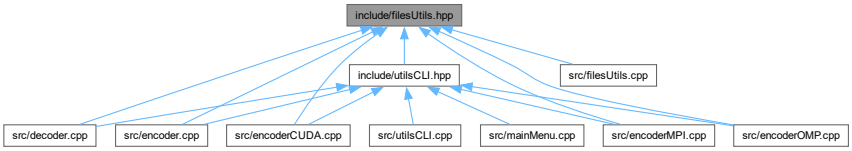
```
#include <iostream>
#include <fstream>
#include <vector>
#include <cmath>
#include <chrono>
```

```
#include <filesystem>
#include <point.hpp>
#include <opencv2/opencv.hpp>
```

Include dependency graph for filesUtils.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- namespace km::filesUtils

  Provides utility functions for file handling.
- namespace km

  Main namespace for the project.

Functions

- auto km::filesUtils::createOutputDirectories () -> void

  Creates output directories.
- auto km::filesUtils::writeBinaryFile (std::string &outputPath, int &width, int &height, int &k, std::vector< Point > points, std::vector< Point > centroids) -> void

  Writes data to a binary file.
- auto km::filesUtils::isCorrectExtension (const std::filesystem::path &filePath, const std::string &correctExtension) -> bool

  Checks if a file has the correct extension.
- auto km::filesUtils::createDecodingMenu (std::filesystem::path &decodeDir, std::vector< std::filesystem::path > &imageNames) -> void

  Creates a decoding menu.
- auto km::filesUtils::readBinaryFile (std::string &path, cv::Mat &imageCompressed) -> int

  Reads a binary file and reconstructs the compressed image.

4.3.1 Detailed Description

Utility functions for file handling.

4.4 filesUtils.hpp

Go to the documentation of this file.

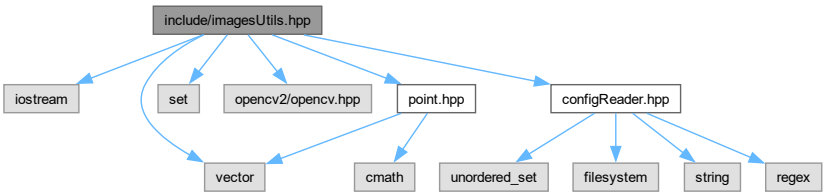
```
00001
00006 #ifndef FILESUTILS_HPP
00007 #define FILESUTILS_HPP
00008
00009 #include <iostream>
00010 #include <fstream>
00011 #include <vector>
00012 #include <cmath>
00013 #include <chrono>
00014 #include <filesystem>
00015 #include <point.hpp>
00016 #include <opencv2/opencv.hpp>
00017
00024 namespace km
00025 {
00026     namespace filesUtils
00027     {
00031         auto createOutputDirectories() -> void;
00032
00042         auto writeBinaryFile(std::string &outputPath, int &width, int &height, int &k, std::vector<Point> points,
      std::vector<Point> centroids) -> void;
00043
00050         auto isCorrectExtension(const std::filesystem::path &filePath, const std::string &correctExtension) -> bool;
00051
00057         auto createDecodingMenu(std::filesystem::path &decodeDir, std::vector<std::filesystem::path> &imageNames) ->
      void;
00058
00065         auto readBinaryFile(std::string &path, cv::Mat &imageCompressed) -> int;
00066     };
00067 }
00068
00069 #endif // FILESUTILS_HPP
```

4.5 include/imagesUtils.hpp File Reference

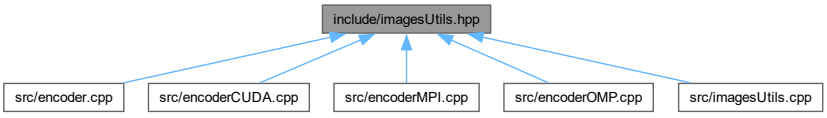
Utility functions for image processing.

```
#include <iostream>
#include <vector>
#include <set>
#include <opencv2/opencv.hpp>
#include <configReader.hpp>
#include <point.hpp>
```

Include dependency graph for imagesUtils.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- namespace km::imageUtils

  Provides utility functions for image processing.
- namespace km

  Main namespace for the project.

Functions

- void km::imageUtils::preprocessing (cv::Mat &image, int &typeCompressionChoice)

  Performs preprocessing on an image.
- void km::imageUtils::defineKValue (int &k, int levelsColorsChoice, std::set< std::vector< unsigned char > > &different_colors)

  Defines the value of K based on the color levels choice.
- void km::imageUtils::pointsFromImage (cv::Mat &image, std::vector< Point > &points, std::set< std::vector< unsigned char > > &different_colors)

  Extracts points from an image.

4.5.1 Detailed Description

Utility functions for image processing.

4.6 imagesUtils.hpp

Go to the documentation of this file.

```
00001
00006 #ifndef IMAGEUTILS_HPP
00007 #define IMAGEUTILS_HPP
00008
00009 #include <iostream>
00010 #include <vector>
00011 #include <set>
00012 #include <opencv2/opencv.hpp>
00013 #include <configReader.hpp>
00014 #include <point.hpp>
00015
00024 namespace km
00025 {
00026     namespace imageUtils
00027     {
00033         void preprocessing(cv::Mat& image, int& typeCompressionChoice);
00034
00041         void defineKValue(int& k, int levelsColorsChoice, std::set<std::vector<unsigned char»& different_colors);
00042
00049         void pointsFromImage(cv::Mat& image, std::vector<Point>& points, std::set<std::vector<unsigned char»&
      different_colors);
00050     };
00051
00052 }
00053
00054 #endif // IMAGEUTILS_HPP
```

4.7 include/kmDocs.hpp File Reference

Documentation for the km namespace.

Namespaces

- namespace km

  Main namespace for the project.

4.7.1 Detailed Description

Documentation for the km namespace.

This file provides comprehensive documentation for the km namespace, which includes utilities for clustering algorithms, file handling, image processing, etc. The km namespace serves as the main container for core functionalities and tools used throughout the project.

4.8 kmDocs.hpp

Go to the documentation of this file.

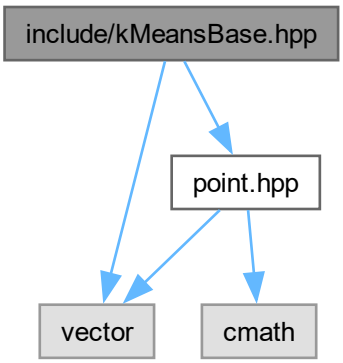
```
00001
00017 namespace km {
00018     // This file is for Doxygen documentation purposes only.
00019 }
```

4.9 include/kMeansBase.hpp File Reference

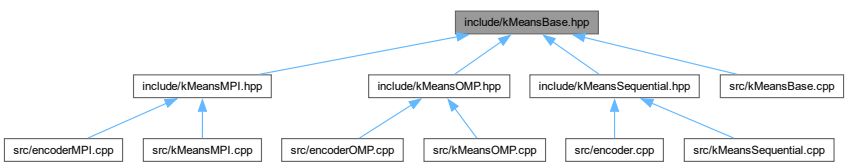
Base class for K-means clustering algorithm.

```
#include <vector>
#include "point.hpp"
```

Include dependency graph for kMeansBase.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::KMeansBase

Namespaces

- namespace km

  Main namespace for the project.

4.9.1 Detailed Description

Base class for K-means clustering algorithm.

4.10 kMeansBase.hpp

Go to the documentation of this file.

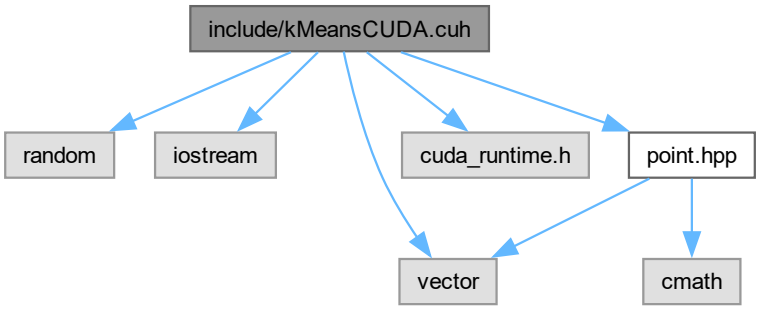
```
00001
00006 #ifndef KMEANS_BASE_HPP
00007 #define KMEANS_BASE_HPP
00008
00009 #include <vector>
00010 #include "point.hpp"
00011
00012 namespace km
00013 {
00024     class KMeansBase
00025     {
00026
00027     public:
00033         KMeansBase(const int &k, const std::vector<Point> &points);
00034
00040         KMeansBase(const int &k);
00041
00045         virtual ~KMeansBase() = default;
00046
00050         virtual void run() = 0;
00051
00056         [[nodiscard]] auto getPoints() const -> std::vector<Point>;
00057
00062         [[nodiscard]] auto getCentroids() const -> std::vector<Point>;
00063
00068         [[nodiscard]] auto getIterations() const -> int;
00069
00070     protected:
00071         int k;
00072         std::vector<Point> points;
00073         std::vector<Point> centroids;
00074         int number_of_iterations;
00075     };
00076 } // namespace k
00077
00078 #endif // KMEANS_BASE_HPP
```

4.11 include/kMeansCUDA.cuh File Reference

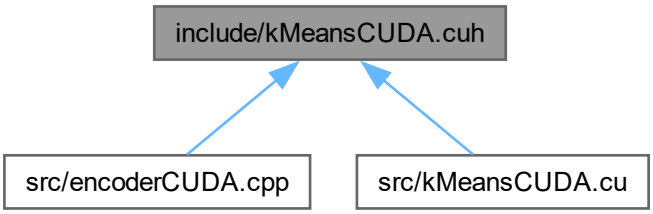
Implementation of the K-means clustering algorithm using CUDA.

```
#include <random>
#include <iostream>
#include <vector>
#include <cuda_runtime.h>
```

```
#include <point.hpp>
```
Include dependency graph for kMeansCUDA.cuh:



This graph shows which files directly or indirectly include this file:



Classes

- class km::KMeansCUDA

Namespaces

- namespace km

  Main namespace for the project.

Macros

- #define KMEANS_CUDA_HPP

4.11.1 Detailed Description

Implementation of the K-means clustering algorithm using CUDA.

4.11.2 Macro Definition Documentation

4.11.2.1 KMEANS_CUDA_HPP

```
#define KMEANS_CUDA_HPP
```

4.12 kMeansCUDA.cuh

Go to the documentation of this file.

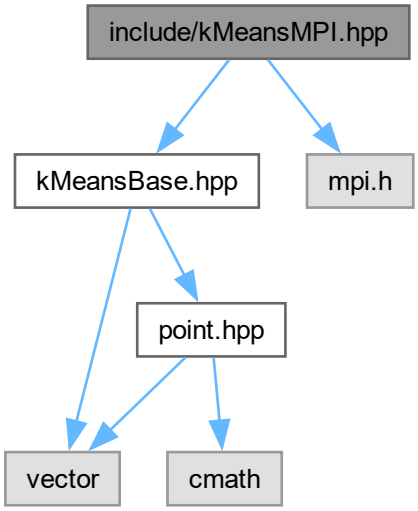
```
00001
00006 #ifndef KMEANS_CUDA_HPP
00007 #define KMEANS_CUDA_HPP
00008
00009 #include <random>
00010 #include <iostream>
00011 #include <vector>
00012 #include <cuda_runtime.h>
00013 #include <point.hpp>
00014
00015
00016 namespace km
00017 {
00026     class KMeansCUDA
00027     {
00028     public:
00035         KMeansCUDA(const int &k, const std::vector<Point> &points);
00036
00040         void run();
00041
00045         void printClusters() const;
00046
00050         void plotClusters();
00051
00056         auto getPoints() -> std::vector<Point>;
00057
00063         auto getCentroids() -> std::vector<Point>;
00064
00069         auto getIterations() -> int;
00070
00071     private:
00072         int k;
00073         std::vector<Point> points;
00074         std::vector<Point> centroids;
00075         int number_of_iterations;
00076     };
00077 } // namespace km
00078
00079 #endif // KMEANS_CUDA_HPP
```

4.13 include/kMeansMPI.hpp File Reference

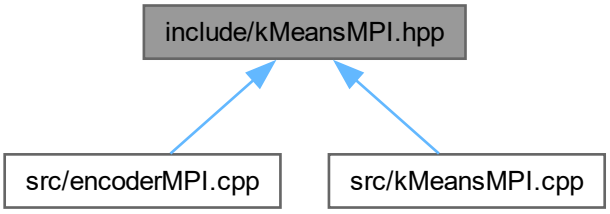
Implementation of the K-means clustering algorithm using MPI.

```
#include "kMeansBase.hpp"
#include <mpi.h>
```

Include dependency graph for kMeansMPI.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::KMeansMPI

Namespaces

- namespace km

  Main namespace for the project.

4.13.1 Detailed Description

Implementation of the K-means clustering algorithm using MPI.

4.14 kMeansMPI.hpp

Go to the documentation of this file.

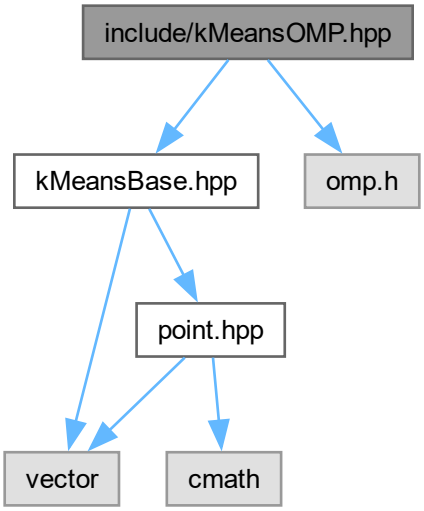
```
00001
00006 #ifndef KMEANS_MPI_HPP
00007 #define KMEANS_MPI_HPP
00008
00009 #include "kMeansBase.hpp"
00010 #include <mpi.h>
00011
00012 namespace km
00013 {
00024     class KMeansMPI : public KMeansBase
00025     {
00026     public:
00032         KMeansMPI(const int &k, const std::vector<Point> &points, std::vector<std::pair<int, Point» local_points);
00033
00038         KMeansMPI(const int &k, std::vector<std::pair<int, Point» local_points);
00039
00043         void run() override;
00044
00045     private:
00046         std::vector<std::pair<int, Point» local_points;
00047     };
00048 } // namespace k
00049
00050 #endif // KMEANS_MPI_HPP
```

4.15 include/kMeansOMP.hpp File Reference

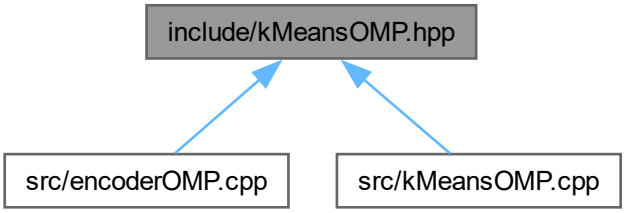
Implementation of the K-means clustering algorithm using OpenMP.

```
#include "kMeansBase.hpp"
#include <omp.h>
```

Include dependency graph for kMeansOMP.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::KMeansOMP

Namespaces

- namespace km

  Main namespace for the project.

4.15.1 Detailed Description

Implementation of the K-means clustering algorithm using OpenMP.

4.16 kMeansOMP.hpp

Go to the documentation of this file.

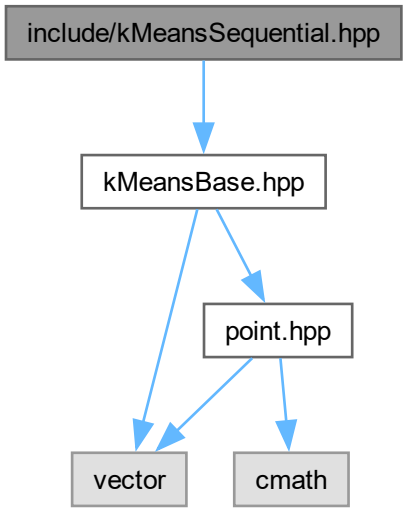
```
00001
00006 #ifndef KMEANS_OMP_HPP
00007 #define KMEANS_OMP_HPP
00008
00009 #include "kMeansBase.hpp"
00010 #include <omp.h>
00011
00012 namespace km
00013 {
00024     class KMeansOMP : public KMeansBase
00025     {
00026     public:
00032         KMeansOMP(const int &k, const std::vector<Point> &points);
00033
00037         void run() override;
00038     };
00039 } // namespace km
00040
00041 #endif // KMEANS_OMP_HPP
```

4.17 include/kMeansSequential.hpp File Reference

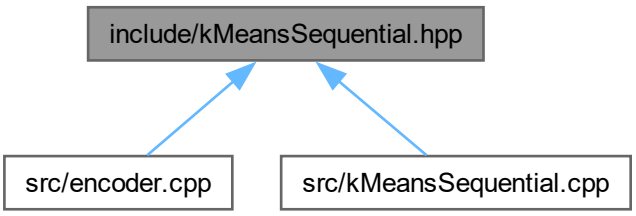
Implementation of the K-means clustering algorithm.

```
#include "kMeansBase.hpp"
```

Include dependency graph for kMeansSequential.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::KMeansSequential

Namespaces

- namespace km

  Main namespace for the project.

4.17.1 Detailed Description

Implementation of the K-means clustering algorithm.

4.18 kMeansSequential.hpp

Go to the documentation of this file.

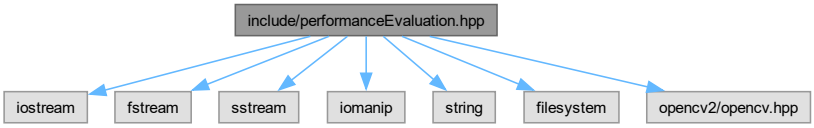
```
00001
00006 #ifndef KMEANS_SEQUENTIAL_HPP
00007 #define KMEANS_SEQUENTIAL_HPP
00008
00009 #include "kMeansBase.hpp"
00010
00011 namespace km
00012 {
00023     class KMeansSequential : public KMeansBase
00024     {
00025     public:
00031         KMeansSequential(const int &k, const std::vector<Point> &points);
00032
00036         void run() override;
00037     };
00038 }
00039
00040 #endif // KMEANS_SEQUENTIAL_HPP
```

4.19 include/performanceEvaluation.hpp File Reference

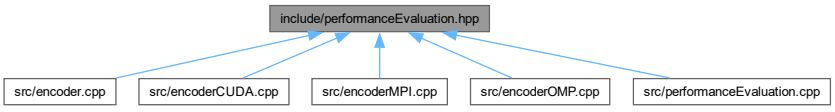
Performance evaluation class.

```
#include <iostream>
#include <fstream>
#include <sstream>
#include <iomanip>
#include <string>
#include <filesystem>
#include <opencv2/opencv.hpp>
```

Include dependency graph for performanceEvaluation.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::Performance

  Represents the performance evaluation.

Namespaces

- namespace km

  Main namespace for the project.

4.19.1 Detailed Description

Performance evaluation class.

4.20 performanceEvaluation.hpp

Go to the documentation of this file.

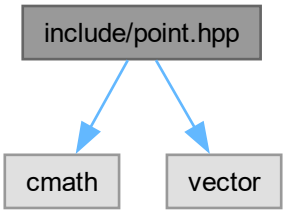
```
00001
00006 #ifndef PERFORMANCE_HPP
00007 #define PERFORMANCE_HPP
00008
00009 #include <iostream>
00010 #include <fstream>
00011 #include <sstream>
00012 #include <iomanip>
00013 #include <string>
00014 #include <filesystem>
00015 #include <opencv2/opencv.hpp>
00016
00017 namespace km
00018 {
00025     class Performance
00026     {
00027     public:
00031         Performance();
00032
00041         auto writeCSV(int different_colors_size, int k, int n_points, double elapsedKmeans, int number_of_iterations,
      int num_processes = 0) -> void;
00042
00048         static auto extractFileName(const std::string &outputPath) -> std::string;
00049
00056         auto fillPerformance(int choice, const std::string &img, const std::string &method) -> void;
00057
00058     private:
00063         auto createOrOpenCSV(const std::string &filename) -> void;
00064
00075         auto appendToCSV(const std::string &filename, int n_diff_colors, int k, int n_colors, const std::string
      &compType, double time, int num_processes, int number_of_iteratios) -> void;
00076
00077         std::string img;
00078         int choice{};
00079         std::string method;
00080     };
00081 }
00082
00083 #endif // PERFORMANCE_HPP
```

4.21 include/point.hpp File Reference

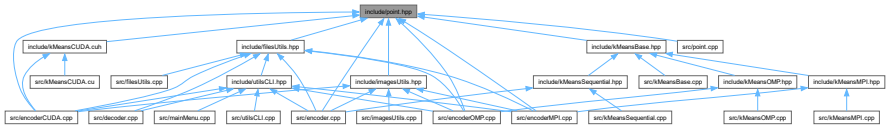
Point class representing a point in a feature space.

```
#include <cmath>
#include <vector>
```

Include dependency graph for point.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class km::Point

  Represents a point in a feature space.

Namespaces

- namespace km

  Main namespace for the project.

4.21.1 Detailed Description

Point class representing a point in a feature space.

4.22 point.hpp

Go to the documentation of this file.

```
00001
00006 #ifndef POINT_HPP
00007 #define POINT_HPP
00008
00009 #include <cmath>
00010 #include <vector>
00011
00012 namespace km
00013 {
00020     class Point
00021     {
00022     public:
```

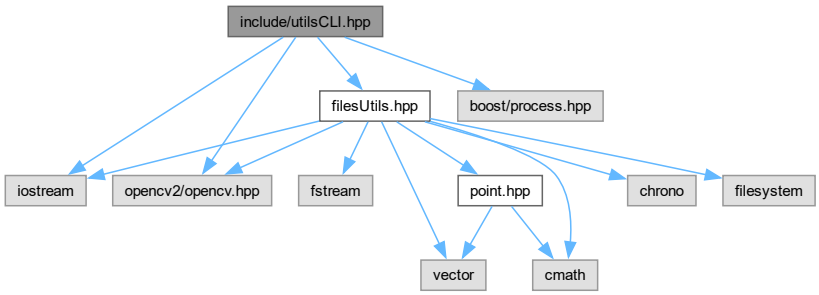
```
00023         int id{0};
00024         unsigned char r{0};
00025         unsigned char g{0};
00026         unsigned char b{0};
00027         int clusterId{-1};
00028
00033         Point();
00034
00040         Point(const int &id, const std::vector<int> &coordinates);
00041
00047         [[nodiscard]] auto distance(const Point &p) const -> double;
00048
00054         auto getFeature(int index) -> unsigned char &;
00055
00061         [[nodiscard]] auto getFeature_int(int index) const -> int;
00062
00068         auto setFeature(int index, int x) -> void;
00069     };
00070 } // namespace km
00071
00072 #endif // POINT_HPP
```

4.23 include/utilsCLI.hpp File Reference

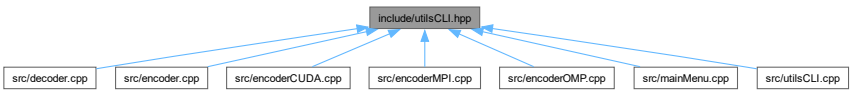
Utility functions for the command-line interface.

```
#include <iostream>
#include <opencv2/opencv.hpp>
#include <filesUtils.hpp>
#include <boost/process.hpp>
```

Include dependency graph for utilsCLI.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- namespace km::utilsCLI

  Provides utility functions for the command-line interface.
- namespace km

  Main namespace for the project.

Functions

- void km::utilsCLI::mainMenuHeader ()

  Displays the main menu header.
- void km::utilsCLI::decoderHeader ()

  Displays the decoder header.
- void km::utilsCLI::workDone ()

  Displays the work done message.
- void km::utilsCLI::printCompressionInformations (int &originalWidth, int &originalHeight, int &width, int &height, int &k, size_t &different_colors_size)

  Prints the compression information.
- void km::utilsCLI::displayDecodingMenu (std::string &path, std::vector< std::filesystem::path > &imageNames, std::filesystem::path &decodeDir)

  Displays the decoding menu.

4.23.1 Detailed Description

Utility functions for the command-line interface.

4.24 utilsCLI.hpp

Go to the documentation of this file.

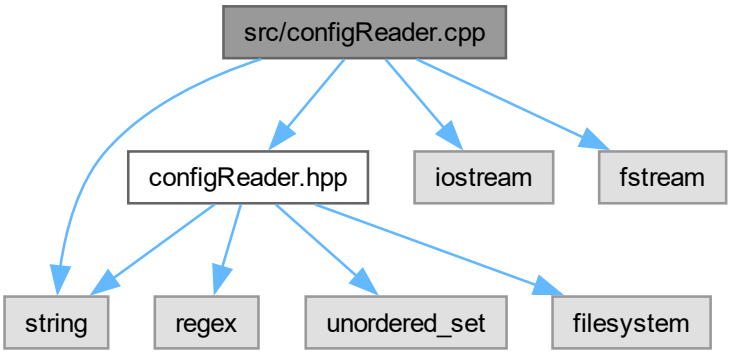
```
00001
00006 #ifndef UTILSCLI_HPP
00007 #define UTILSCLI_HPP
00008
00009 #include <iostream>
00010 #include <opencv2/opencv.hpp>
00011 #include <filesUtils.hpp>
00012 #include <boost/process.hpp>
00013
00020 namespace km
00021 {
00022     namespace utilsCLI
00023     {
00024
00028         void mainMenuHeader();
00029
00033         void decoderHeader();
00034
00038         void workDone();
00039
00049         void printCompressionInformations(int &originalWidth, int &originalHeight, int &width, int &height, int &k,
      size_t &different_colors_size);
00050
00057         void displayDecodingMenu(std::string &path, std::vector<std::filesystem::path> &imageNames,
      std::filesystem::path &decodeDir);
00058     };
00059 }
00060
00061 #endif // UTILSCLI_HPP
```

4.25 README.md File Reference

4.26 src/configReader.cpp File Reference

```
#include <configReader.hpp>
#include <iostream>
#include <fstream>
```

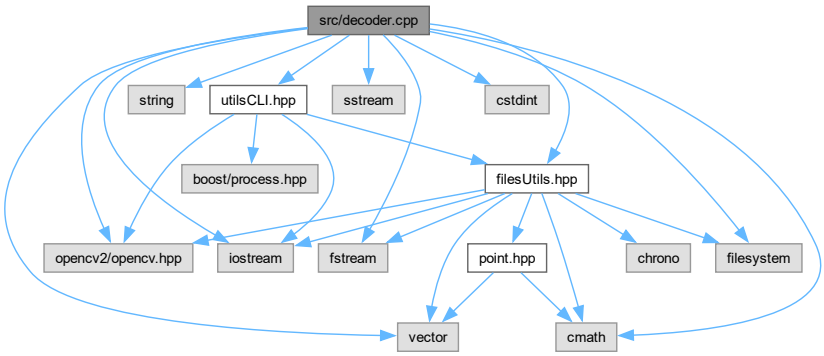
```
#include <string>
```
Include dependency graph for configReader.cpp:



4.27 src/decoder.cpp File Reference

The main program for decoding .kc files generated by the Encoder.

```
#include <opencv2/opencv.hpp>
#include <iostream>
#include <vector>
#include <string>
#include <fstream>
#include <sstream>
#include <cmath>
#include <cstdint>
#include <filesystem>
#include <filesUtils.hpp>
#include <utilsCLI.hpp>
```
Include dependency graph for decoder.cpp:



Functions

- auto main () -> int

  Main function for the Decoder program.

4.27.1 Detailed Description

The main program for decoding .kc files generated by the Encoder.

This program provides a command-line interface for decoding images that have been compressed by the Encoder. It allows users to load a compressed image, convert it to a viewable format, and optionally save it as a .jpg file.

The program makes use of OpenCV for image processing and the custom filesUtils and utilsCLI libraries for handling file operations and user interactions.

The Decoder program reads a .kc compressed file, decodes it into an image matrix, converts the color space for display, and allows the user to save a decompressed copy as a .jpg image. The program provides a simple command-line interface for selecting files and configuring output options.

4.27.2 Function Documentation

4.27.2.1 main()

```
auto main () -> int
```

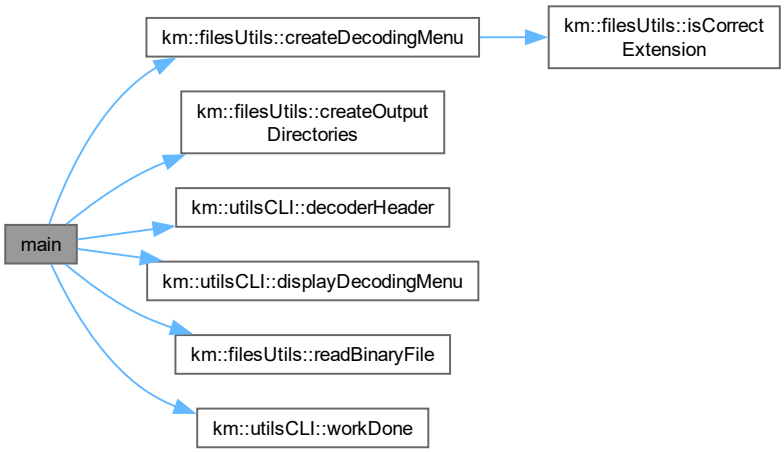
Main function for the Decoder program.

This function initializes the Decoder program, presents a menu for selecting the compressed image file, decodes the selected file, converts it for display, and provides the option to save the decoded image as a .jpg file.

Returns

Returns 0 on successful execution.

Here is the call graph for this function:

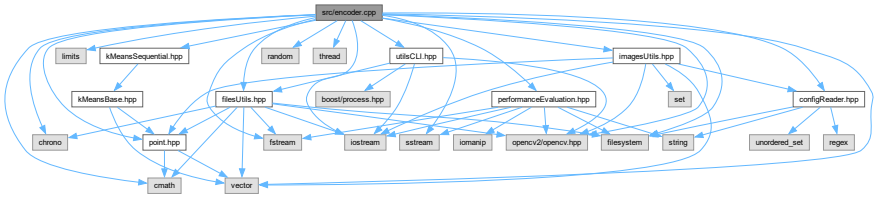


4.28 src/encoder.cpp File Reference

Main entry point for the image compression application.

```
#include <iostream>
#include <vector>
#include <cmath>
#include <limits>
#include <filesystem>
#include <fstream>
#include <sstream>
#include <random>
#include <thread>
#include <chrono>
#include <point.hpp>
#include <kMeansSequential.hpp>
#include <utilsCLI.hpp>
#include <imagesUtils.hpp>
#include <filesUtils.hpp>
#include <opencv2/opencv.hpp>
#include <configReader.hpp>
#include <performanceEvaluation.hpp>
```

Include dependency graph for encoder.cpp:



Functions

- auto main (int argc, char ∗argv[]) -> int

  Main function for the image compression application.

4.28.1 Detailed Description

Main entry point for the image compression application.

This program compresses an image using the K-means clustering algorithm in sequential mode. It reads input parameters from the command line, processes the image, applies compression, and saves the compressed image to a binary file. The program also evaluates performance metrics and writes them to a CSV file.

The application uses OpenCV for image processing and custom libraries for compression and file handling.

4.28.2 Function Documentation

4.28.2.1 main()

```
auto main (
              int argc,
              char * argv[]) -> int
```

Main function for the image compression application.

This function initializes the program, processes input arguments, reads the input image, performs preprocessing, applies K-means clustering for image compression, and saves the compressed image to a binary file. It also evaluates and logs the performance metrics.

Parameters

argc	The number of command-line arguments.
argv	The array of command-line arguments.

Returns

Returns 0 on successful execution, or 1 if an error occurs.

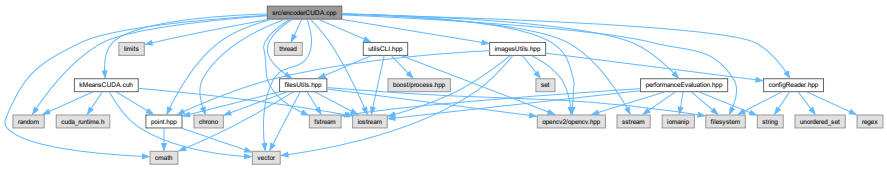
Here is the call graph for this function:

4.29 src/encoderCUDA.cpp File Reference

Main entry point for the CUDA-based image compression application.

```
#include <iostream>
#include <vector>
#include <cmath>
#include <limits>
#include <filesystem>
#include <fstream>
#include <sstream>
#include <random>
#include <thread>
#include <chrono>
#include <point.hpp>
#include <kMeansCUDA.cuh>
#include <utilsCLI.hpp>
#include <imagesUtils.hpp>
#include <filesUtils.hpp>
#include <opencv2/opencv.hpp>
#include <configReader.hpp>
#include <performanceEvaluation.hpp>
```

Include dependency graph for encoderCUDA.cpp:



Functions

- int main (int argc, char ∗argv[ ])

  Main function for the CUDA-based image compression application.

4.29.1 Detailed Description

Main entry point for the CUDA-based image compression application.

This program compresses an image using the K-means clustering algorithm, leveraging CUDA for GPU acceleration. It reads input parameters from the command line, processes the image, applies compression using the GPU, and saves the compressed image to a binary file. The program also evaluates performance metrics and logs them to a CSV file.

The application uses OpenCV for image processing and custom libraries for compression, file handling, and performance evaluation.

4.29.2 Function Documentation

4.29.2.1 main()

```
int main (
            int argc,
            char * argv[])
```

Main function for the CUDA-based image compression application.

This function initializes the program, processes input arguments, reads the input image, performs preprocessing, applies K-means clustering using CUDA for image compression, and saves the compressed image to a binary file. It also evaluates and logs the performance metrics.

Parameters

argc	The number of command-line arguments.
argv	The array of command-line arguments.

Returns

Returns 0 on successful execution, or 1 if an error occurs.

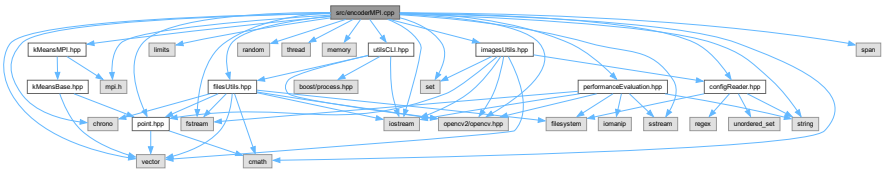
Here is the call graph for this function:

4.30 src/encoderMPI.cpp File Reference

Main entry point for the MPI-based image compression application.

```
#include <opencv2/opencv.hpp>
#include <iostream>
#include <string>
#include <vector>
#include <cmath>
#include <limits>
#include <fstream>
#include <sstream>
#include <random>
#include <thread>
#include <memory>
#include <set>
#include <chrono>
#include <point.hpp>
#include <kMeansMPI.hpp>
#include <configReader.hpp>
#include <utilsCLI.hpp>
#include <imagesUtils.hpp>
#include <filesUtils.hpp>
#include <mpi.h>
#include <performanceEvaluation.hpp>
#include <span>
```

Include dependency graph for encoderMPI.cpp:



Functions

- auto main (int argc, char ∗argv[ ]) -> int

  Main function for the MPI-based image compression application.

4.30.1 Detailed Description

Main entry point for the MPI-based image compression application.

This program compresses an image using the K-means clustering algorithm with MPI (Message Passing Interface) for parallel processing across multiple processors. It reads input parameters from the command line, processes the image, applies compression, and saves the compressed image to a binary file. The program also evaluates performance metrics and writes them to a CSV file.

The application uses OpenCV for image processing and custom libraries for compression, file handling, and performance evaluation.

4.30.2 Function Documentation

4.30.2.1 main()

```
auto main (
              int argc,
              char * argv[ ]) -> int
```

Main function for the MPI-based image compression application.

This function initializes MPI, processes input arguments, reads the input image, performs preprocessing, distributes data among MPI processes, applies K-means clustering for image compression, and saves the compressed image to a binary file. It also evaluates and logs the performance metrics.

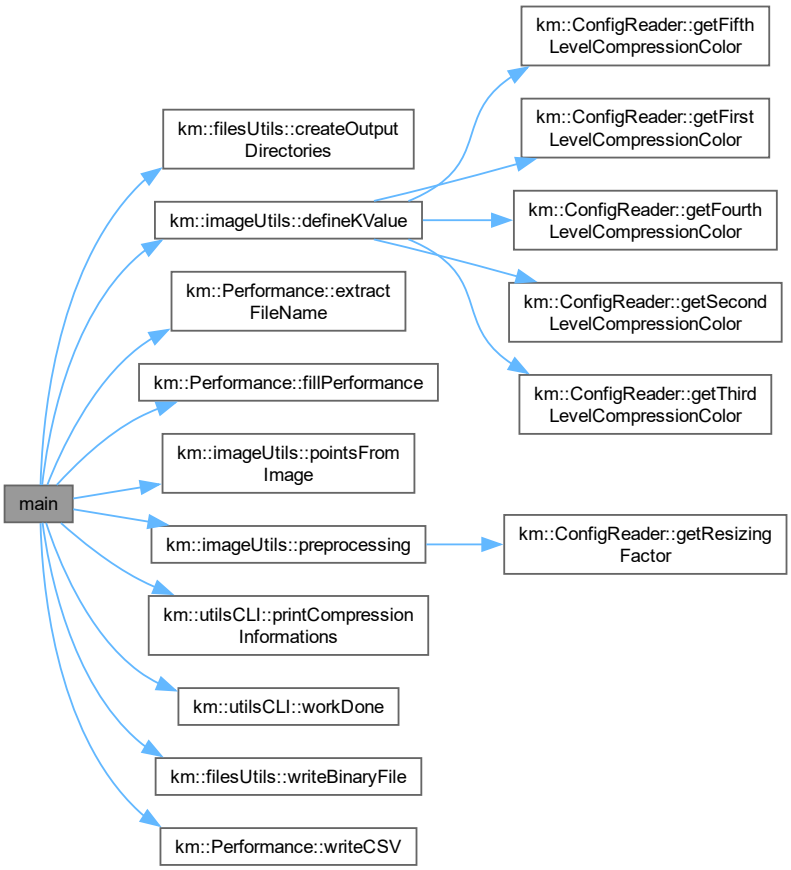
Parameters

argc	The number of command-line arguments.
argv	The array of command-line arguments.

Returns

Returns 0 on successful execution, or 1 if an error occurs.

Here is the call graph for this function:



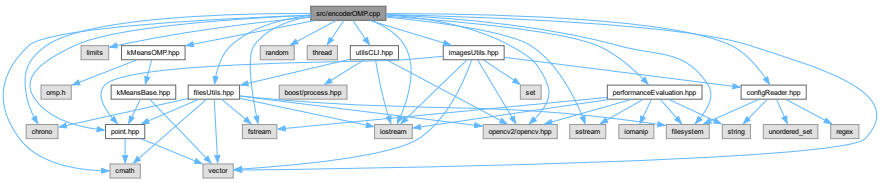
4.31 src/encoderOMP.cpp File Reference

Main entry point for the OpenMP-based image compression application.

```
#include <iostream>
#include <vector>
#include <cmath>
#include <limits>
#include <filesystem>
#include <fstream>
#include <sstream>
```

```
#include <random>
#include <thread>
#include <chrono>
#include <point.hpp>
#include <kMeansOMP.hpp>
#include <utilsCLI.hpp>
#include <imagesUtils.hpp>
#include <filesUtils.hpp>
#include <opencv2/opencv.hpp>
#include <configReader.hpp>
#include <performanceEvaluation.hpp>
```

Include dependency graph for encoderOMP.cpp:



Functions

- auto main (int argc, char ∗argv[ ]) -> int

  Main function for the OpenMP-based image compression application.

4.31.1 Detailed Description

Main entry point for the OpenMP-based image compression application.

This program compresses an image using the K-means clustering algorithm with OpenMP for parallel processing across multiple threads. It reads input parameters from the command line, processes the image, applies compression, and saves the compressed image to a binary file. The program also evaluates performance metrics and writes them to a CSV file.

The application uses OpenCV for image processing and custom libraries for compression, file handling, and performance evaluation.

4.31.2 Function Documentation

4.31.2.1 main()

```
auto main (
              int argc,
              char * argv[ ]) -> int
```

Main function for the OpenMP-based image compression application.

This function initializes the program, processes input arguments, reads the input image, performs preprocessing, applies K-means clustering using OpenMP for image compression, and saves the compressed image to a binary file. It also evaluates and logs the performance metrics.

Parameters

argc	The number of command-line arguments.
argv	The array of command-line arguments.

Returns

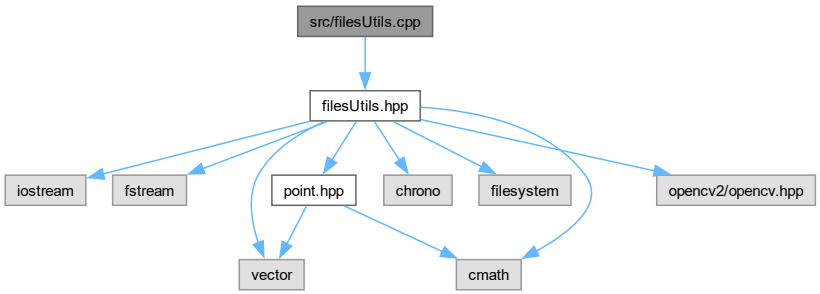
Returns 0 on successful execution, or 1 if an error occurs.

Here is the call graph for this function:

4.32 src/filesUtils.cpp File Reference

```
#include <filesUtils.hpp>
```

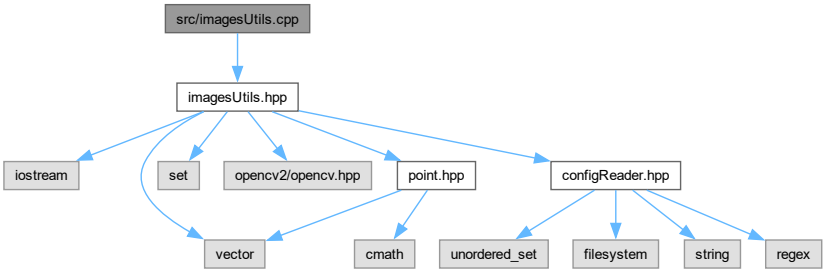
Include dependency graph for filesUtils.cpp:



4.33 src/imagesUtils.cpp File Reference

```
#include <imagesUtils.hpp>
```

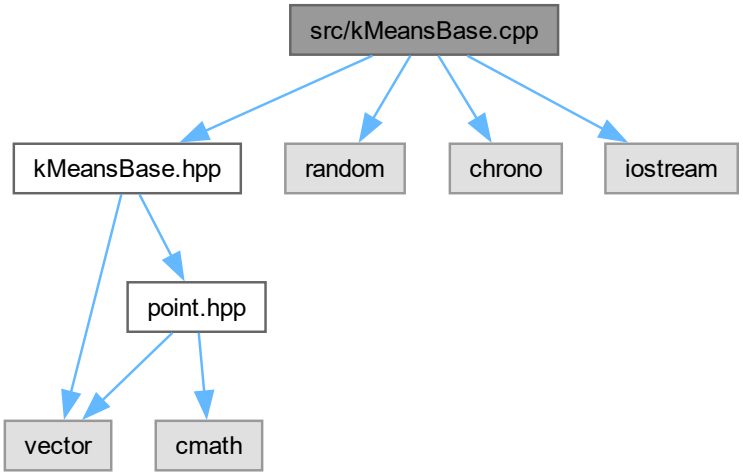
Include dependency graph for imagesUtils.cpp:



4.34 src/kMeansBase.cpp File Reference

```
#include "kMeansBase.hpp"
#include <random>
#include <chrono>
#include <iostream>
```

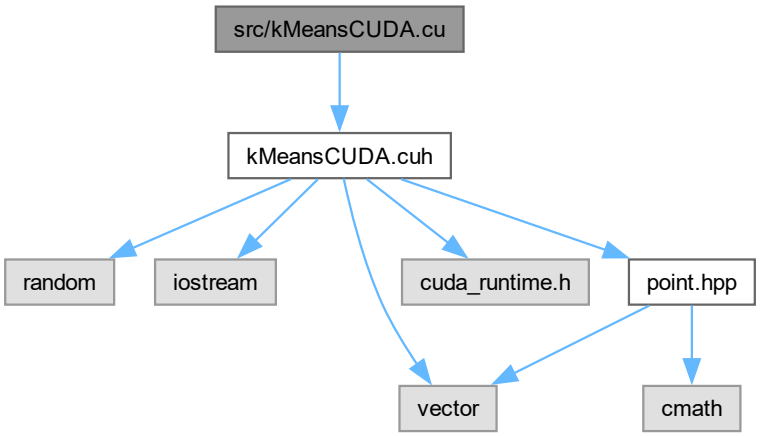
Include dependency graph for kMeansBase.cpp:



4.35 src/kMeansCUDA.cu File Reference

```
#include <kMeansCUDA.cuh>
```

Include dependency graph for kMeansCUDA.cu:



Functions

- __global__ void assign_clusters (int *data, int *centroids, int *labels, int n, int k, int dim)
- __global__ void calculate_new_centroids (int *data, int *centroids, int *labels, int *counts, int n, int k, int dim)
- __global__ void average_centroids (int *centroids, int *counts, int k, int dim)

4.35.1 Function Documentation

4.35.1.1 assign_clusters()

```
__global__ void assign_clusters (
                int * data,
                int * centroids,
                int * labels,
                int n,
                int k,
                int dim)
```

Here is the caller graph for this function:

4.35.1.2 average_centroids()

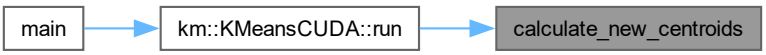
```
__global__ void average_centroids (
                int * centroids,
                int * counts,
                int k,
                int dim)
```

Here is the caller graph for this function:

4.35.1.3 calculate_new_centroids()

```
__global__ void calculate_new_centroids (
                int * data,
                int * centroids,
                int * labels,
                int * counts,
                int n,
                int k,
                int dim)
```

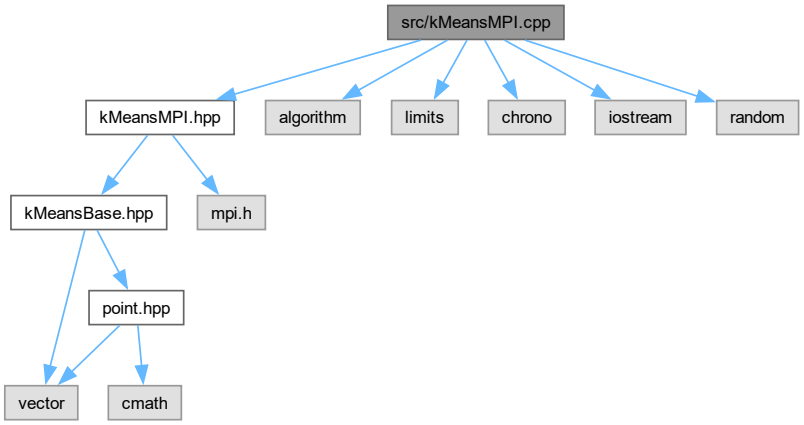
Here is the caller graph for this function:



4.36 src/kMeansMPI.cpp File Reference

```
#include "kMeansMPI.hpp"
#include <algorithm>
#include <limits>
#include <chrono>
#include <iostream>
#include <random>
```

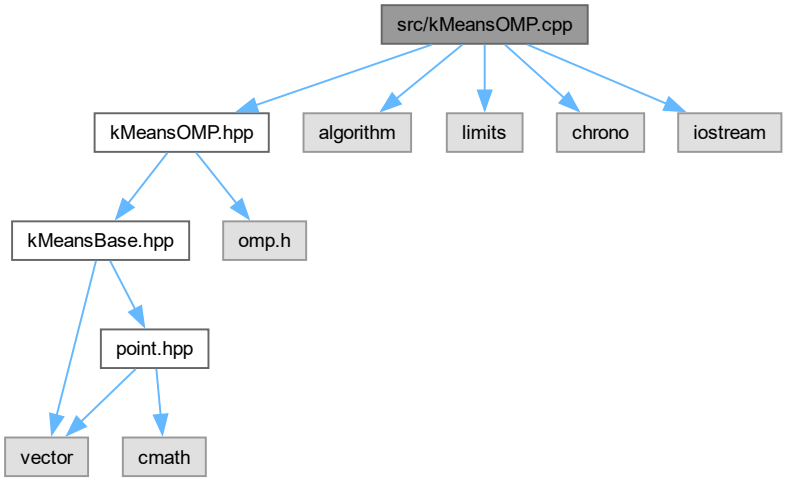
Include dependency graph for kMeansMPI.cpp:



4.37 src/kMeansOMP.cpp File Reference

```
#include "kMeansOMP.hpp"
#include <algorithm>
#include <limits>
#include <chrono>
#include <iostream>
```

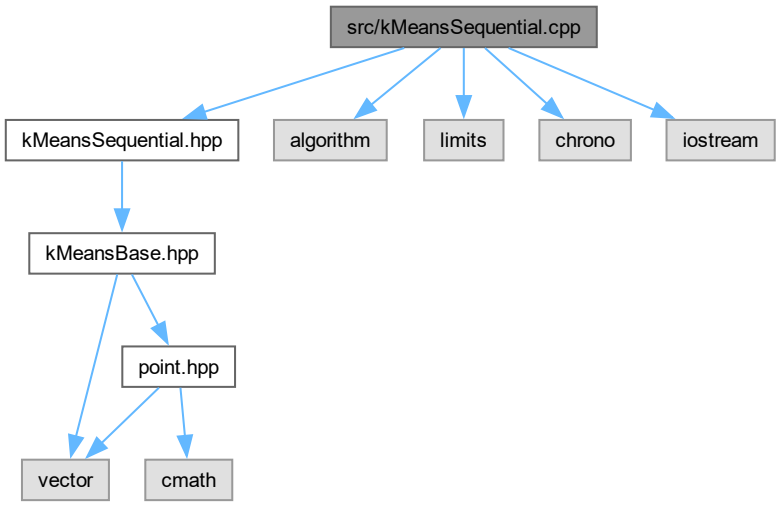
Include dependency graph for kMeansOMP.cpp:



4.38 src/kMeansSequential.cpp File Reference

```
#include "kMeansSequential.hpp"
#include <algorithm>
#include <limits>
#include <chrono>
#include <iostream>
```

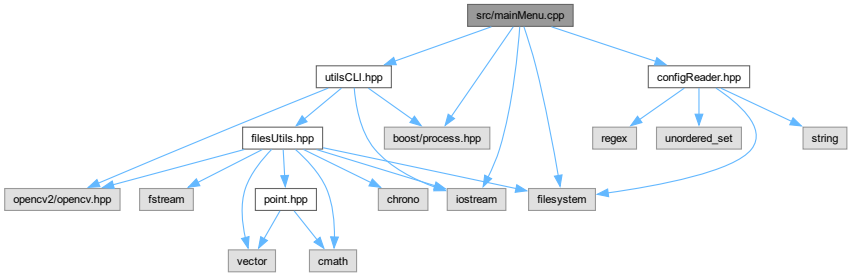
Include dependency graph for kMeansSequential.cpp:



4.39 src/mainMenu.cpp File Reference

```
#include <iostream>
#include <utilsCLI.hpp>
#include <filesystem>
#include <configReader.hpp>
#include <boost/process.hpp>
```

Include dependency graph for mainMenu.cpp:



Functions

- auto main () -> int

  Main function that runs the Image Compressor application.

4.39.1 Function Documentation

4.39.1.1 main()

```
auto main () -> int
```

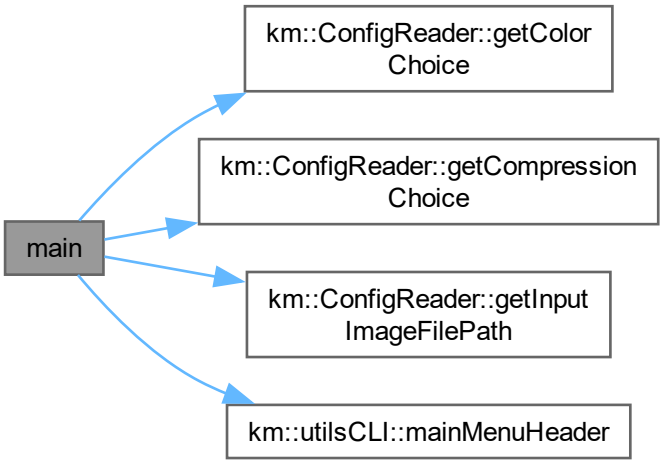
Main function that runs the Image Compressor application.

This function initializes necessary components, reads configuration settings, and provides a command-line interface for users to choose image compression or decompression options.

Returns

Returns 0 on successful execution.

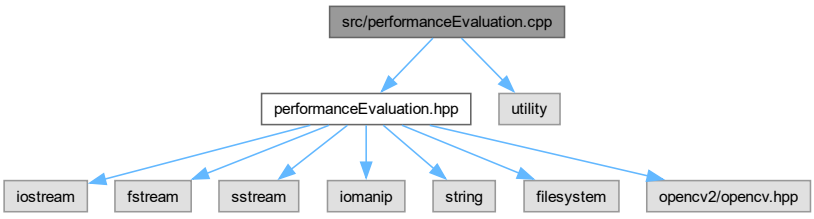
Here is the call graph for this function:



4.40 src/performanceEvaluation.cpp File Reference

```
#include <performanceEvaluation.hpp>
#include <utility>
```

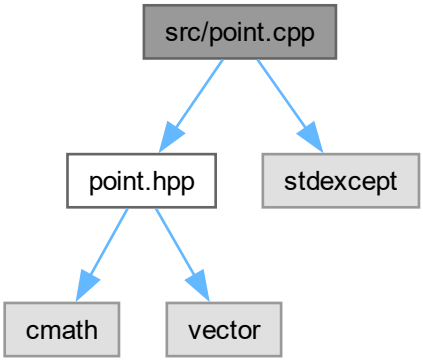
Include dependency graph for performanceEvaluation.cpp:



4.41 src/point.cpp File Reference

```
#include <point.hpp>
#include <stdexcept>
```

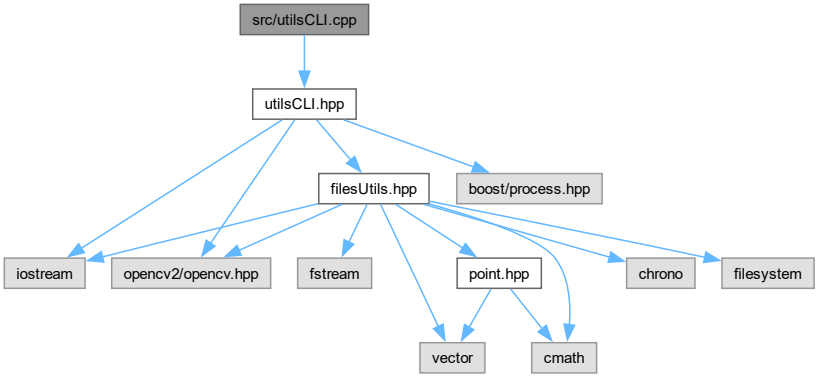
Include dependency graph for point.cpp:



4.42 src/utilsCLI.cpp File Reference

```
#include <utilsCLI.hpp>
```

Include dependency graph for utilsCLI.cpp:



Index