



FabImage Library 5.3

Introduction

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Overview

Introduction

FabImage Library is a machine vision library for C++ and .NET programmers. It provides a comprehensive set of functions for creating industrial image analysis applications – from standard-based image acquisition interfaces, through low-level image processing routines, to ready-made tools such as template matching, measurements or barcode readers. The main strengths of the product include the highest performance, modern design and simple structure making it easy to integrate with the rest of your code.

The scope of the library encompasses:

- **Image Processing**
High performance, any-shape ROI operations for unary and binary image arithmetics, refinement, morphology, smoothing, spatial transforms, gradients, thresholding and color analysis.
- **Region Analysis**
Robust processing of pixel sets that correspond to foreground objects: extraction, set arithmetics, refinement, morphology, skeletonization, spatial transformations, feature extraction and measurements.
- **Path Analysis**
Subpixel-precise alternative to region analysis, particularly suitable for shape analysis. Provides methods for contour extraction, refinement, segmentation, smoothing, classification, global transformations, feature extraction and more.
- **Profiles**
Auxiliary toolset for analysis of one-dimensional sequences of values, e.g. image sections or path-related distances.
- **Histograms**
Auxiliary toolset for value distribution analysis.
- **Geometry 2D**
Exhaustive toolset of geometric operations compatible with other parts of the library. Provides operations for measuring distances and angles, determining intersections, tangents and feature.
- **1D Edge Detection**
Detection of edges, ridges and stripes (paired edges) by the means of 1D edge scanning, i.e. by extracting and analysing a profile along a specified path.
- **2D Edge Detection**
Detection of edges by the means of 2D edge tracing, i.e. by extracting and refining locally maximal image gradients.
- **Fourier Analysis**
Suitable both for educational experimentation and industrial application, this toolset provides methods for Fourier transform and image processing in the frequency domain.
- **Template Matching**
Efficient, robust and easy to use methods for localizing objects using a gray-based or an edge-based model.
- **Barcodes**
Detection and recognition of many types of 1D codes.
- **Datacodes**
Detection and recognition of QR codes and DataMatrix codes.
- **Hough Transform**
Detection of analytical shapes using the Hough transform.
- **Image Segmentation**
Automated extraction of object regions using gray or edge information.
- **Multilayer Perceptron**
Artificial neural networks.
- **Optical Character Recognition**
Text recognition or validation, including dot print.
- **Shape Fitting**
Subpixel-precise detection of analytical shapes, whose rough locations are known.

Relation between FabImage Library and FabImage Studio

Each function of the FabImage Library is the basis for the corresponding filter available in **FabImage Studio**. Therefore, it is possible (and advisable) to use the FabImage Studio as a convenient, drag & drop prototyping tool, even if one intends to develop the final solution in C++ using FabImage Library. Moreover, for extended information about how to use advanced image analysis techniques, one can refer to [Machine Vision Guide](#) from the documentation of **FabImage Studio**.

In the table below we compare the [ThresholdImage](#) function with the [ThresholdImage](#) filter:

FabImage Library:

```
void ThresholdImage
(
    const Image&    inImage,
    Optional<const Region&> inRoi,
    Optional<real>   inMinValue,
    Optional<real>   inMaxValue,
    real            inFuzziness,
    Image&          outMonoImage
);
```

FabImage Studio:

ThresholdImage		
inImage		inMinValue
inRoi		inMaxValue
outMonoImage		

Key Features

Performance

In FabImage Library careful design of algorithms goes hand in hand with extensive hardware optimizations, resulting in performance that puts the library among the fastest in the world. Our implementations make use of **SSE instructions** and **parallel computations** on multicore processors.

Modern Design

All types of data feature **automatic memory management**, errors are handled explicitly with **exceptions** and **optional types** are used for type-safe special values. All functions are **thread-safe** and use **data parallelism** internally, when possible.

Consistency

The library is a simple collection of types and functions, provided as a single DLL file with appropriate headers. For maximum readability function follow consistent naming convention (e.g. the VERB + NOUN form as in: [ErodelImage](#), [RotateVector](#)). All results are returned via reference output parameters, so that many outputs are always possible.

Example Program

A simple program based on the FabImage Library may look as follows:

```
#include <FIL.h>

using namespace ftl;
using namespace fil;

int main()
{
    try
    {
        InitLibrary();
        Image input, output;
        LoadImage("input.bmp", false, input);
        ThresholdImage(input, NIL, 128, NIL, 0, output);
        SaveImage(output, NIL, "output.bmp", false);
        return 0;
    }
    catch (const ftl::Error&)
    {
        return -1;
    }
}
```

Please note that FabImage Library is distributed with a set of example programs, which are available after installation.

Programming Conventions

Organization of the Library

FabImage Library is a collection of C++ functions that process machine vision related types of data. Each function corresponds to a single data processing operation, e.g. `DetectEdges_AsPaths` performs a Canny-like 2D edge detection. As a data processing library, it is not particularly object-oriented. It does use, however, modern approach to C++ programming with automatic memory management, exception handling, thread safety and the use of templates where appropriate.

Namespaces

There are two namespaces used:

- **ftl** – the namespace of types and functions related to [Fab Template Library](#).
- **fil** – the namespace of types and functions related to FabImage Library as the whole.
- **fis** – FabImage Studio Code Generator equivalents of FabImage Library functions. Not recommended to use.

Enumeration Types

All enumeration types in FabImage Library use C++0x-like namespaces, for example:

```
namespace EdgeFilter
{
    enum Type
    {
        Canny,
        Deriche,
        Lanser
    };
}
```

This has two advantages: (1) some identifiers can be shared between different enumeration types; (2) after typing "EdgeFilter::" IntelliSense will display all possible elements of the given enumeration type.

Example:

```
ftl::Array<fil::Path> edges;
fil::Image image, gradientImage;

fil::DetectEdges_AsPaths(image, ftl::NIL, fil::EdgeFilter::Canny,
    2.0f, ftl::NIL, 60.0f, 30.0f, ftl::NIL, 30.0f, 0.0f, ftl::NIL, 0.0f, edges, gradientImage);
```

Function Parameters

Contrary to standard C++ libraries, machine vision algorithms tend to have many parameters and often compute not single, but many output values. Moreover, diagnostic information is highly important for effective work of a machine vision software engineer. For these reasons, function parameters in FabImage Library are organized as follows:

1. First come **input parameters**, which have "in" prefix.
2. Second come **output parameters**, which have "out" prefix and denote the results.
3. The last come **diagnostic output parameters**, which have "diag" prefix and contain information that is useful for optimizing parameters (not computed when the diagnostic mode is turned off).

For example, the following function invocation has a number of input parameters, a single output parameter (*edges*) and a single diagnostic output parameter (*gradientImage*).

```
ftl::Array<fil::Path> edges;
fil::Image image, gradientImage;

fil::DetectEdges_AsPaths(image, ftl::NIL, fil::EdgeFilter::Canny,
    2.0f, ftl::NIL, 60.0f, 30.0f, ftl::NIL, 30.0f, 0.0f, ftl::NIL, 0.0f, edges, gradientImage);
```

Diagnostic Output Parameters

Due to efficiency reasons the diagnostic outputs are only computed when the diagnostic mode is turned on. This can be done by calling:

```
fil::EnableFilDiagnosticOutputs(true);
```

In your code you can check if the diagnostic mode is turned on by calling:

```
if (fil::GetFilDiagnosticOutputsEnabled())
{
  //...
}
```

Optional Outputs

Due to efficiency reasons computation of some outputs can be skipped. In function `TestImage` user can inform function that computation of `outMonoImage` is not necessary and function can omit computation of this data.

the `TestImage` Header with last two optional parameters:

```
void fil::TestImage
(
  fil::TestImageId::Type inImageId,
  ftl::Optional<fil::Image&> outRgbImage = ftl::NIL,
  ftl::Optional<fil::Image&> outMonoImage = ftl::NIL
)
```

Example of using optional outputs:

```
fil::Image rgb, mono;

// Both outputs are computed
fil::TestImage(fil::TestImageId::Baboon, rgb, mono);

// Only RGB image is computed
fil::TestImage(fil::TestImageId::Baboon, rgb);

// Only mono image is computed
fil::TestImage(fil::TestImageId::Baboon, ftl::NIL, mono);
```

In-Place Data Processing

Some functions can process data *in-place*, i.e. modifying the input objects instead of computing new ones. There are two approaches used for such functions:

1. Some filters, e.g. the image `drawing routines`, use "io" parameters, which work simultaneously as inputs and outputs. For example, the following function invocation draws red circles on the `image1` object:

```
fil::DrawCircle(image1, circle, ftl::NIL, fil::Pixel(255, 0, 0), style);
```

2. Some filters, e.g. `image point transforms`, can be given the same object on the input and on the output. For example, the following function invocation negates pixel values without allocating any additional memory:

```
fil::NegateImage(image1, ftl::NIL, image1);
```

Please note, that simple functions like `NegateImage` can be executed even 3 times faster in-place than when computing a new output object.

Work Cancellation

Most of long-working functions can be cancelled using `CancelCurrentWork` function. Cancellation technique is thread-safe, so function `CancelCurrentWork` can be called from different thread.

To check cancellation status use the `IsCurrentWorkCancelled` function.

```

void ProcessingThread()
{
    while (!fil::IsCurrentWorkCancelled())
    {
        std::cout << "Iteration start" << std::endl;
        fil::Delay(10000); // Function with cancellation support
        std::cout << "Iteration complete" << std::endl;
    }
    std::cout << "Processing thread stop" << std::endl;
}

int main()
{
    fil::InitLibrary();
    std::thread thread {ProcessingThread};

    std::cout << "Press Enter to stop execution." << std::endl;
    std::cin.get();

    // Cancel work in ProcessingThread and in fil::Delay
    fil::CancelCurrentWork();

    thread.join();

    return 0;
}

```

Library Initialization

For reasons related to efficiency and thread-safety, before any other function of the FIL library is called, the [InitLibrary](#) function should be called first:

```

int main()
{
    fil::InitLibrary();
    //...
}

```

Debug Preview

For diagnostic purposes it is useful to be able to preview data of types `Image` and `Region`. You can achieve this by using functions from the [Debug Preview](#) category. They can be helpful in debugging programs and displaying both intermediate and final data of such types.

```

fil::Image image;
fil::LoadImage("hello.png", false, image);

// Show loaded image in new window.
fil::DebugPreviewShowNewImage(image);

// Wait until window is closed.
fil::DebugPreviewWaitForWindowsClose();

```

Fab Template Library

FabImage Library is based on the Fab Template Library – a simplified counterpart of the C++ Standard Template Library, which avoids advanced templating techniques mainly by using raw pointers instead of abstract iterators. This makes FabImage Library portable to embedded platforms, including the ones that do not support C++ templates fully.

Please note, that the following types should only be parametrized with fundamental types (int, float, etc.) or [types from fil or ftl namespace](#). Const and/or reference types are also allowed, as long as template type accepts such type (e.g. Array<T> cannot be parametrized with reference type).

Array<T>

The Array<T> type strictly corresponds to std::vector<T>. It is a random-access, sequential container with automatic memory reallocation when growing.

Here is a simplified version of the public interface is depicted: [Array.h](#)

Optional<T>

The Optional<T> type provides a consistent way of representing an optional value, something for which NULL pointers or special values (such as -1) are often used. Many APIs provide optional values using default values of parameters. This type is inspired by [boost::optional<T>](#) class from the Boost Library, but is designed mostly for input parameters, not only for function results.

In FabImage Library it is used to represent optional regions of interest in image processing operations and many other input parameters that can be determined automatically when not provided by a user.

Documentation for this type is presented in [Optional.h](#).

Sample use:

```
ftl::Optional<fil::Point2D> p;
p = fil::Point2D(10, 25); // normal value
p = ftl::NIL;           // NIL value
if (p != ftl::NIL)
{
    fil::Point2D q = p.Get(); // access to a non-nil value
    p.Get().x = 15;         // direct access to a field
}
```

Conditional<T>

This type of data is especially used to determine invalid results. Many functions in C return special value as -1 or NULL when their result is invalid. Type Conditional<T> is very similar to Optional<T>, but it is mostly used in outputs.

Documentation for this type is presented in [Conditional.h](#).

Sample use:

```
ftl::Conditional<int> result;
fil::ParseInteger("Test1", fil::NumberSystemBase::Base_10, result); // Parsing textual data

if (result != ftl::NIL) // If textual data is not valid integer result has value ftl::NIL
    printf("Valid integer.");
else
    printf("Invalid integer. Value: %d", result.Get());
```

Dummy<T>

Dummy<T> class is used to create a temporary object that will be released after its use. It is mostly used to create a temporary object to pass its reference to a function. Such temporary objects are helpful when not all values returned by a function are important and we don't plan to use them.

Sample use:

```
fil::Region region;
fil::Circle2D circle = fil::Circle2D(50.0f, 50.0f, 50.0f);

fil::CreateCircleRegion(circle, ftl::NIL, 100, 100, region);

// Second parameter is not used.
fil::Segment2D minorAxis;
fil::RegionEllipticAxes(region, ftl::Dummy<fil::Segment2D>(), minorAxis);

std::cout << "Minor axis length: " << minorAxis.Length();
```



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