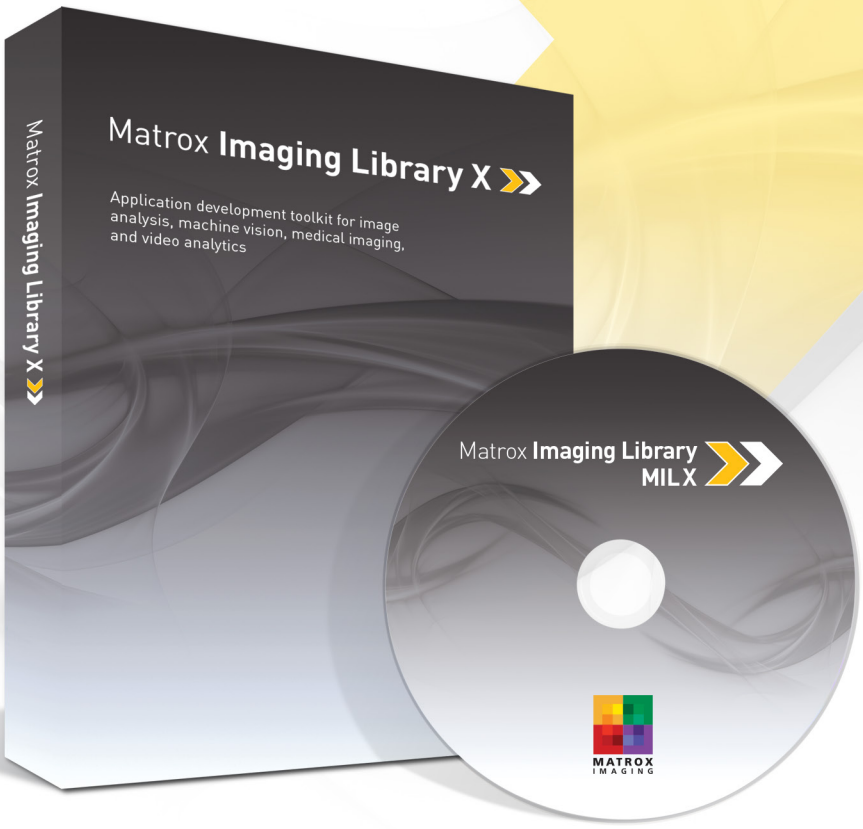


Matrox **Imaging Library X**

Machine vision, image analysis, and medical imaging software development kit

MATROX IMAGING

Overview

Industrial imaging tools

Matrox® Imaging Library (MIL)[1] is a comprehensive collection of software tools for developing machine vision, image analysis, and medical imaging applications. MIL includes tools for every step in the process, from application feasibility to prototyping, through to development and ultimately deployment.

The software development kit (SDK) features interactive software and programming functions for image capture, processing, analysis, annotation, display, and archiving. These tools are designed to enhance productivity, thereby reducing the time and effort required to bring solutions to market.

Image capture, processing, and analysis operations have the accuracy and robustness needed to tackle the most demanding applications. These operations are also carefully optimized for speed to address the severe time constraints encountered in many applications.

MIL development

First released in 1993, MIL has evolved to keep pace with and foresee emerging industry requirements. It was conceived with an easy-to-use, coherent API that has stood the test of time. MIL pioneered the concept of hardware independence with the same API for different image acquisition and processing platforms. A team of dedicated, highly skilled computer scientists, mathematicians, software engineers, and physicists continue to maintain and enhance MIL.

MIL is maintained and developed using industry recognized best practices, including peer review, user involvement, and daily builds. Users are asked to evaluate and report on new tools and enhancements, which strengthens and validates releases. Ongoing MIL development is integrated and tested as a whole on a daily basis.

Manual testing performed prior to each release

MIL X at a glance

Solve applications rather than develop underlying tools by leveraging a toolkit with a more than 25-year history of reliable performance

Tackle applications with utmost confidence using field-proven tools for analyzing, classifying, locating, measuring, reading, and verifying

Base analysis on monochrome and color 2D images as well as 3D profiles, depth maps, and point clouds

Harness the full power of today's hardware through optimizations exploiting SIMD, multi-core CPU, and multi-CPU technologies

Support platforms ranging from smart cameras to high-performance computing (HPC) clusters via a single consistent and intuitive application programming interface (API)

Obtain live data in different ways, with support for analog, Camera Link®, CoaXPress®, DisplayPort, GenTL, GigE Vision®, HDMI, SDI, and USB3 Vision®[2] interfaces

Maintain flexibility and choice by way of support for 32-/64-bit Windows® and 64-bit Linux®

Leverage available programming know-how with support for C, C++, C#, CPython, and Visual Basic® languages

Experiment, prototype, and generate program code using MIL CoPilot interactive environment

Increase productivity and reduce development costs with Matrox Vision Academy online and on-premises training

Overview (cont.)

MIL SQA

In addition to the thorough manual testing performed prior to each release, MIL continuously undergoes automated testing during the course of its development. The automated validation suite—consisting of both systematic and random tests—verifies the accuracy, precision, robustness, and speed of image processing and analysis operations. Results, where applicable, are compared against those of previous releases to ensure that performance remains consistent. The automated validation suite runs continuously on hundreds of systems simultaneously, rapidly providing wide-ranging test coverage. The systematic tests are performed on a large database of images representing a broad sample of real-world applications.

Setup for continuous automated testing

Latest key additions and enhancements[3]
Deep neural network training for image-oriented classification[4]
Coarse segmentation from image-oriented classification using deep learning[4]
Feature-oriented classification using tree ensemble[4]
High-Dynamic-Range (HDR) imaging[4]
Container object type for multi-component data (e.g., 3D)[4]
Revamped 3D processing and analysis[4]
Integrated 3D display[4]
Speed optimization using Intel® Advanced Vector Extensions 512 (AVX-512)[4]
Support for Arm processor architecture

Field-Proven Vision Tools

Image analysis and processing tools

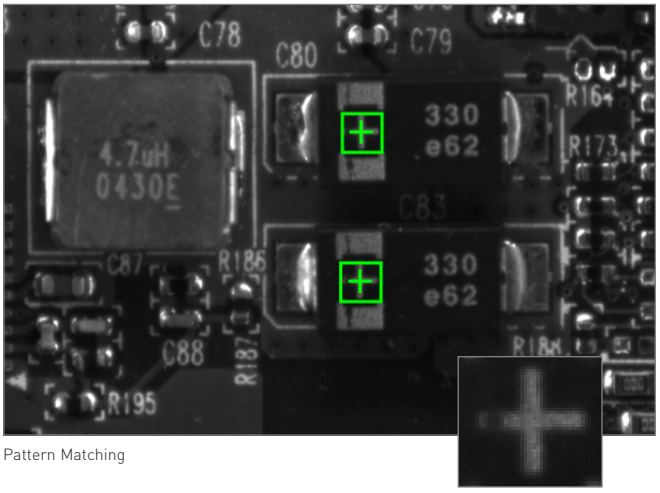
Central to MIL are tools for calibrating; classifying, enhancing, and transforming images; locating objects; extracting and measuring features; reading character strings; and decoding and verifying identification marks. These tools are carefully developed to provide outstanding performance and reliability, and can be used within a single computer system or distributed across several computer systems.

Pattern recognition tools

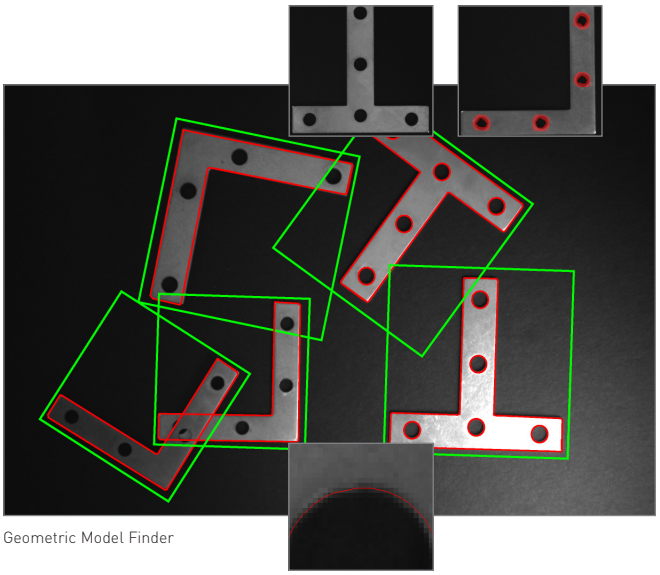
MIL includes two tools for performing pattern recognition: Pattern Matching and Geometric Model Finder (GMF). These tools are primarily used to locate complex objects for guiding a gantry, stage, or robot, or for directing subsequent measurement operations.

The Pattern Matching tool is based on normalized grayscale correlation (NGC), a classical technique that finds a pattern by looking for a similar spatial distribution of intensity. A hierarchical search strategy lets this tool very quickly and reliably locate a pattern, including multiple occurrences, which are translated and slightly rotated, with sub-pixel accuracy. The tool performs well when scene lighting changes uniformly, which is useful for dealing with attenuating illumination. A pattern can be trained manually or determined automatically for alignment. Search parameters can be manually adjusted and patterns can be manually edited to tailor performance.

The GMF tool uses geometric features (e.g., contours) to find an object. The tool quickly and reliably finds multiple models—including multiple occurrences—that are translated, rotated, and/or scaled with sub-pixel accuracy. GMF locates an object that is partially missing and continues to perform when a scene is subject to uneven changes in illumination, thus relaxing lighting requirements. A model can be trained manually from an image, obtained from a CAD file, or determined automatically for alignment. A model can also be obtained from the Edge Finder tool, where the geometric features are defined by color boundaries and crests or ridges in addition to contours. Physical setup requirements are eased when GMF is used in conjunction with the Calibration tool as models become independent of camera position. GMF parameters can be manually adjusted and models can be manually edited to tailor performance.



Pattern Matching

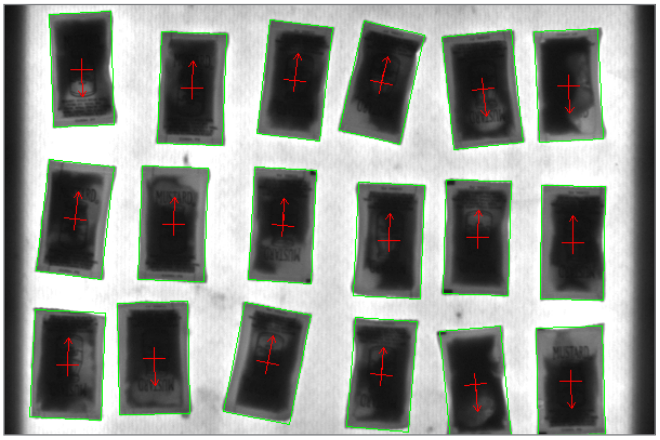

Geometric Model Finder

Field-Proven Vision Tools (cont.)

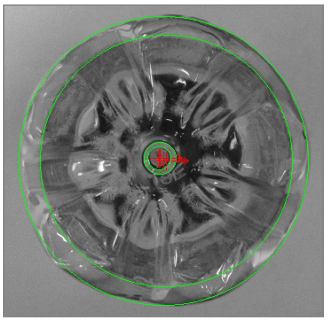
Shape finding tools

The GMF tool includes dedicated modes for finding circles, ellipses, rectangles, and line segments. These modes use the same advanced edge-based technique to locate one or more occurrences of any size—including ones within another for circles, ellipses, and rectangles. Circle finding is defined by the anticipated radius, the possible scale range, and the number of expected occurrences. Ellipse and rectangle finding are defined by the anticipated width and height, the possible scale and aspect ratio ranges, and the number of expected occurrences. Line segment finding is defined by the anticipated length and the number of expected occurrences. Continuous and broken edges lying within an adjustable variation tolerance produce the requested shape.

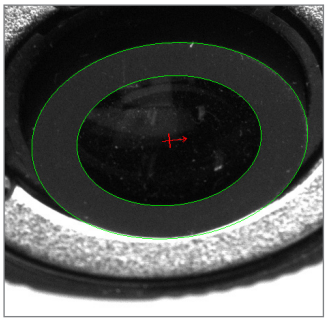
The shape-finding tool returns the total number of found occurrences; for each occurrence, the tool provides the center position and score relative to the reference. It also gives the radius and scale for circles; the angle, aspect ratio, width, and scale for ellipses and rectangles; and the start and end positions as well as the length for line segments. These specialized modes are generally faster and more robust at finding the specific shapes than generic pattern recognition.



Rectangle Finder



Circle Finder



Ellipse Finder

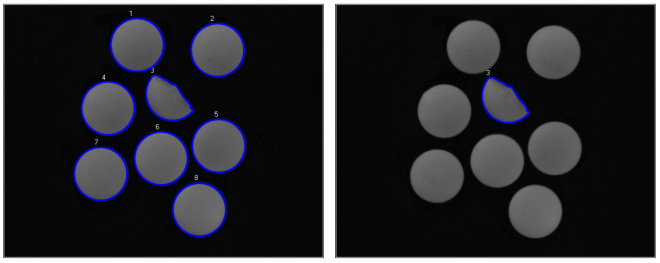
Field-Proven Vision Tools (cont.)

Feature extraction and analysis tools

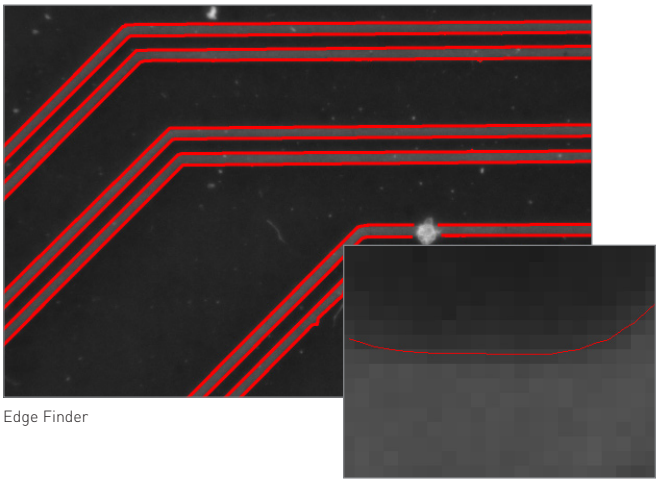
MIL provides a choice of tools for image analysis: Blob Analysis and Edge Finder. These tools are used to identify and measure basic features for determining object presence and location, and to further examine objects.

The Blob Analysis tool works on segmented binary images, where objects are previously separated from the background and one another. The tool—using run-length encoding—quickly identifies blobs and can measure over 50 binary and grayscale characteristics. Measurements can be used to sort and select blobs. The tool also reconstructs and merges blobs, which is useful when working with blobs that straddle successive images.

The Edge Finder tool is well suited for scenes with changing, uneven illumination. The tool—using gradient-based and Hessian-based approaches—quickly identifies contours, as well as crests or ridges, in monochrome or color images and can measure over 50 characteristics with sub-pixel accuracy. Measurements can be used to sort and select edges. The edge extraction method can be adjusted to tailor performance.



Blob Analysis



Edge Finder

Field-Proven Vision Tools (cont.)

Classification tools

MIL includes Classification tools for automatically categorizing image content or previously extracted features using machine learning.

Image-oriented classification makes use of deep learning—specifically convolutional neural network (CNN)—technology in two distinct approaches. The global approach assigns images or image regions to pre-established classes. Results for each image or image region consist of the most likely class and a score for each class. The coarse segmentation[4] approach generates maps indicating the pre-established class and score for all image neighborhoods. Image-oriented classification is particularly well-suited for analyzing images of highly textured, naturally varying, and acceptably deformed goods.

Users can opt to train a CNN on their own[4] or commission Matrox Imaging to do so using previously collected images; these images must be both adequate in number and representative of the expected application conditions. Different types of training are supported, such as transfer learning and fine-tuning, all starting from one of the supplied pre-defined CNN architectures. MIL provides the necessary infrastructure and interactive environment to build the required training dataset—including the labeling of images and augmenting the dataset with synthesized images—as well as monitoring and analyzing the training process. Training is accomplished using a NVIDIA GPU or x64-based CPU while inference is performed on a CPU, avoiding the need for specialized GPU hardware.

Feature-oriented classification[4] uses a tree ensemble technique to categorize objects of interest from their features, expressed in numerical form, obtained from prior analysis using tools like Blob Analysis. The categorization is made by majority voting of the individual-feature decision trees. As with image-oriented classification, users can train a tree ensemble on their own using the facilities provided in MIL or employ Matrox Imaging for the task.

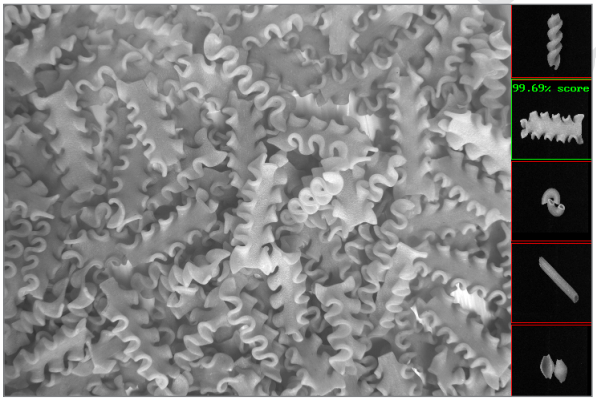


Image-oriented classification (global approach)

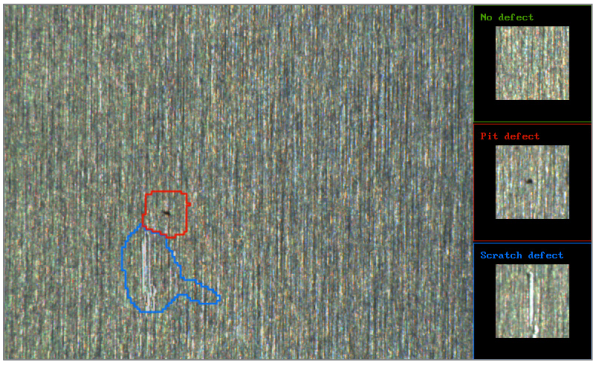


Image-oriented classification (coarse segmentation approach)

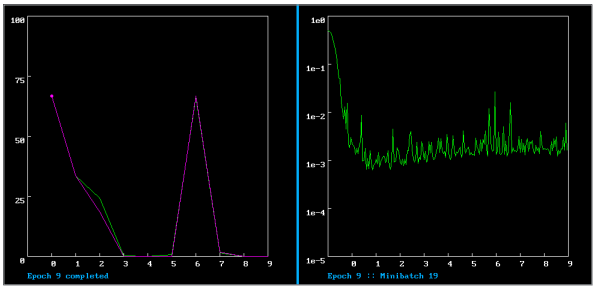


Image-oriented classification (training graphs)

Field-Proven Vision Tools (cont.)

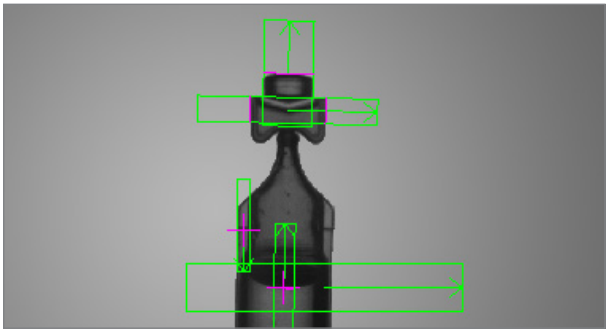
1D and 2D measurement tools

MIL offers three tools for measuring: Measurement, Bead inspection, and Metrology. These tools are predominantly used to assess manufacturing quality.

The Measurement tool uses the projection of image intensity to very quickly locate and measure straight edges or stripes, or circles within a carefully defined rectangular region. The tool can make several 1D measurements on edges, stripes, and circles, as well as between edges, stripes, and circles.

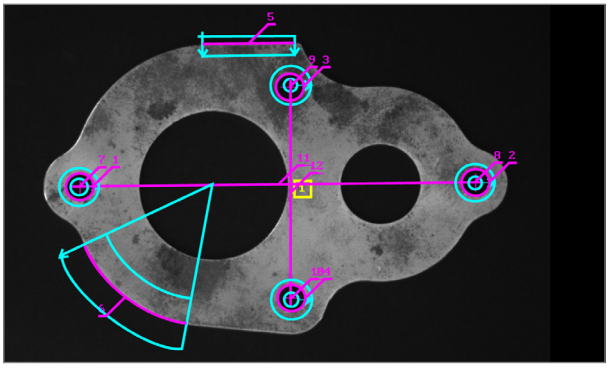
The Bead inspection tool is for inspecting material that is applied as a continuous sinuous bead, such as adhesives and sealants, or the channel where the bead will be applied. The tool identifies discrepancies in length, placement, and width, as well as discontinuities. The Bead inspection tool works by accepting a user-defined coarse path as a list of points on a reference bead and then automatically and optimally placing search boxes to form a template. The size and spacing of these search boxes can be modified to change the sampling resolution. The allowable bead width, offset, gap, and overall acceptance measure can be adjusted to meet specific inspection criteria.

The Metrology tool is intended for 2D Geometric Dimensioning and Tolerancing (GD&T) applications. The tool quickly extracts edges within defined regions to best fit geometric features. It also supports the construction of geometric features derived from measured ones or defined mathematically. Geometric features include arcs, circles, points, and segments. The tool validates tolerances based on the dimensions, positions, and shapes of geometric features. The tool's effectiveness is maintained when subject to uneven changes in scene illumination, which relaxes lighting requirements. The expected measured and constructed geometric features, along with the tolerances, are kept together in a template, which is easily repositioned using the results of other locating tools. The Metrology tool— along with the use of the Calibration tool—enables templates to be independent of camera position; it can also work on a 3D profile or cross-section image.

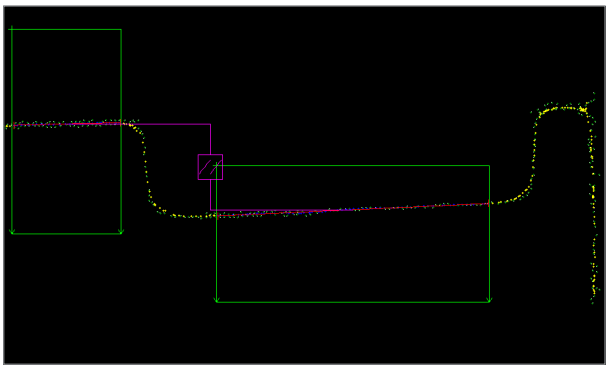


Measurement

Bead inspection



Metrology (2D image)

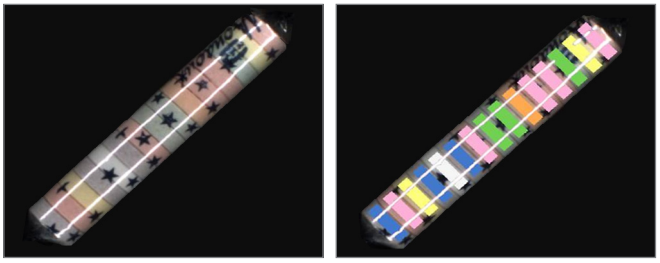


Metrology (3D cross section)

Field-Proven Vision Tools (cont.)

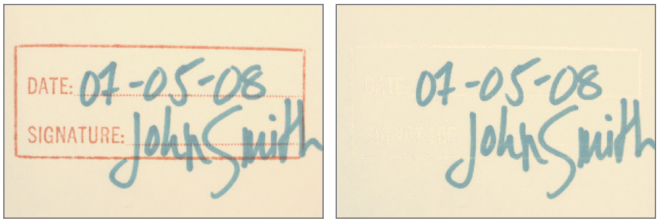
Color analysis tools

MIL includes tools to help identify parts, products, and items using color, assessing quality from color as well as isolating features using color. The Color Distance tool reveals the extent of color differences within and between images. The Color Projection tool separates features from an image based on their colors and can also be used to enhance color to grayscale conversion for subsequent analysis using other grayscale tools. The Color Matching tool determines the best matching color from a collection of samples for each region of interest within an image.



Color Matching

A color sample can be specified either interactively from an image—with the ability to mask out undesired colors—or using numerical values. A color sample can be a single color or a distribution of colors (i.e., histogram). The color-matching method and the interpretation of color differences can be manually adjusted to suit particular application requirements. The Color Matching tool can also match each image pixel to color samples to segment the image into appropriate elements for further analysis using other tools.



Color Projection

MIL includes color-relative calibration to correct color appearance due to differences in lighting and image sensing, thus enabling consistent performance over time and across systems. Three methods are provided: Histogram-based, sample-to-sample, and global mean variance. The first method is unsupervised, only requiring that the reference and training images have similar contents. The second method is semi-supervised, requiring the correspondence between color samples on reference and training images, typically of a color chart. The third method is best suited for dealing with color drift and relies on global color distribution.

Color-relative calibration (histogram-based):
Reference, target and corrected target

Field-Proven Vision Tools (cont.)

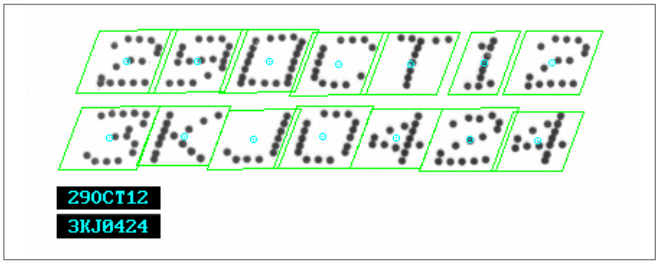
Character recognition tools

MIL provides three tools for character recognition: SureDotOCR, String Reader, and OCR. These tools combine to read text that is engraved, etched, marked, printed, punched, or stamped on surfaces.

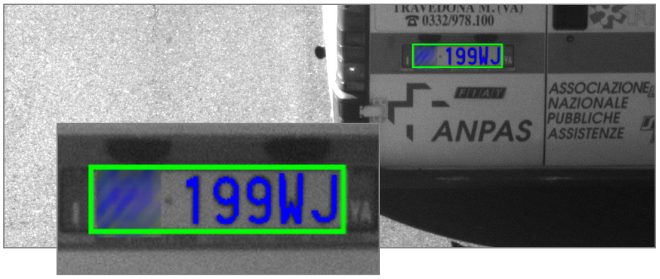
The SureDotOCR tool is uniquely designed for the specific challenge of reading dot-matrix text produced by inkjet printers. Its use is straightforward—users simply need to specify the dot size, the number of expected characters in a text string, and the dimension, but not the location, of the text region. The tool reads text at any angle, with varying contrast, and/or on an uneven background. It interprets distorted and touching characters as well as characters of varying scale. The tool recognizes punctuation marks and blank spaces. It supports the creation and editing of character fonts while including predefined fonts. The tool automatically handles multiple lines of text where each line can utilize a different font. The ability to set user-defined constraints, overall and at specific character positions, further enhances recognition rates. The SureDotOCR tool provides greater robustness and flexibility than case-specific techniques that convert dot-matrix characters into solid ones for reading with traditional character recognition tools.

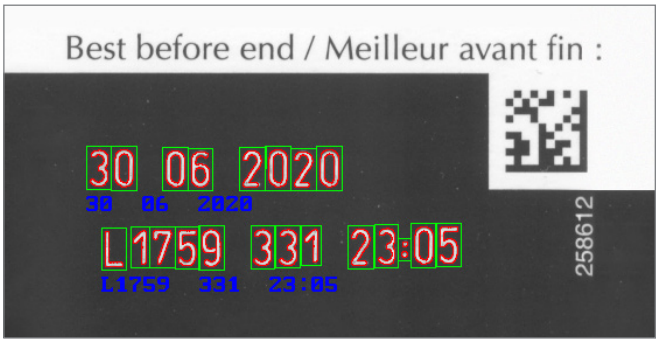
The String Reader tool is based on a sophisticated technique that uses geometric features to quickly locate and read text made up of solid characters in images where these characters are well separated from the background and from one another. The tool handles text strings with a known or unknown number of evenly or proportionally spaced characters. It accommodates changes in character angle with respect to the string, aspect ratio, scale, and skew, as well as contrast reversal. Strings can be located across multiple lines and at a slight angle. The tool reads from multiple pre-defined (TrueType™ and Postscript™) or user-defined Latin-based fonts. Also included are ready-made Latin-based unified contexts for automatic number plate recognition (ANPR) and machine print. In addition, strings can be subject to user-defined constraints, overall and at specific character positions, to further increase recognition rates. The tool is designed for ease-of-use and includes String Expert, a utility to help fine-tune settings and troubleshoot poor results.

The OCR tool utilizes a template matching method to very quickly read text with a known number of evenly spaced characters. Once calibrated, the tool reliably reads text strings with a consistent character size even if the strings themselves are at an angle. Characters can come from one of the provided OCR-A, OCR-B, MICR CMC-7, MICR E-13B, SEMI M12-92, and SEMI M13-88 fonts or a user-defined font. Strings can be subject to user-defined constraints, overall and at specific character positions, to further increase recognition rates.

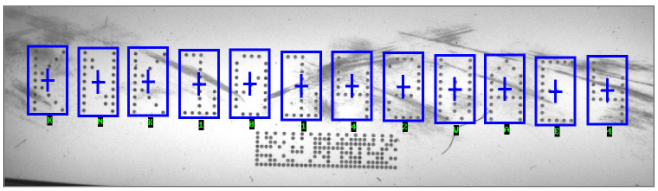


SureDotOCR





String Reader


OCR

Field-Proven Vision Tools (cont.)

1D and 2D code reading and verification tool

MIL offers Code Reader, a fast and dependable tool for locating and reading 1D, 2D, and composite identification marks. The tool handles rotated, scaled, and degraded codes in tough lighting conditions. It simultaneously reads multiple 1D or DataMatrix codes as well as small codes found in complex scenes. It can automatically determine a 1D code type and the optimal settings from a training set. The tool can return the orientation, position, and size of a code. In addition to reading, the tool can also be used to verify the quality of a code based on the ANSI/AIM and ISO/IEC grading standards[5].

Code Reader

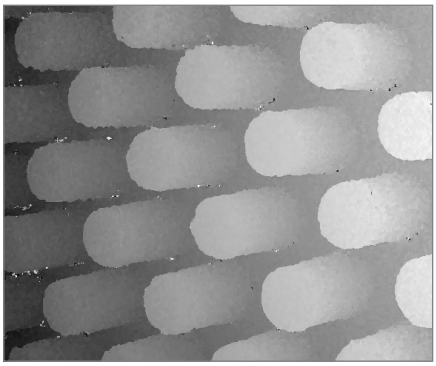
Field-Proven Vision Tools (cont.)

Registration tools

MIL has a tool set for handling the registration or fusion of images for various objectives. A Stitching tool is available for transforming images taken from different vantage points into a unified scene, which would be impractical or impossible to achieve using a single camera. It can also align an image to a reference for subsequent inspection. The tool contends with not only translation, but also with perspective, including scale. Alignment to a reference image or to neighboring images is performed with sub-pixel accuracy and is robust to local changes in contrast and intensity. In addition, the tool can be used for super-resolution where a sharper image is created from a series of images taken from roughly the same vantage point, which is useful for dealing with movement such as mechanical vibration.

Registration (Stitching)

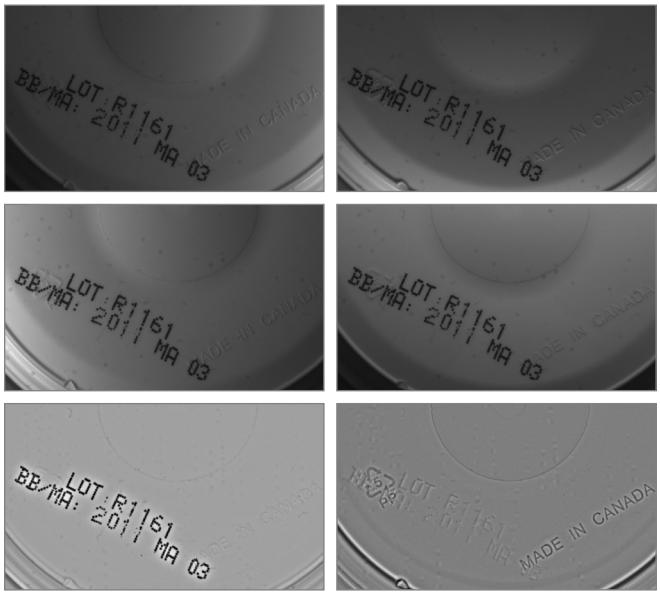
Separate extended Depth-of-field and Depth-from-focus tools are on hand to produce, respectively, a single all-in-focus image and an index image from a series of images of a motionless scene taken at different focus points. The index image can subsequently be used to infer depth.



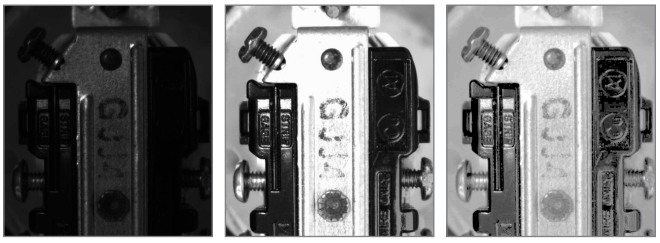
Registration (Depth-from-focus)

A Photometric Stereo tool is offered to produce an image that emphasizes surface irregularities—such as embossed or engraved features, scratches, or indentations. The image is produced from a series of images of the same scene taken with directional illumination as driven by a Quad (X2) Controller from Advanced Illumination (Ai), Light Sequence Switch (LSS) from CCS, a LED Light Manager (LLM) from Smart Vision Lights, or similar light controller.

An HDR imaging tool is also available to combine images of an identical scene, taken at different camera exposure levels, into a single image that contains a greater range of luminance.



Registration (photometric stereo): Illumination (top, right, left, bottom), albedo and local shape

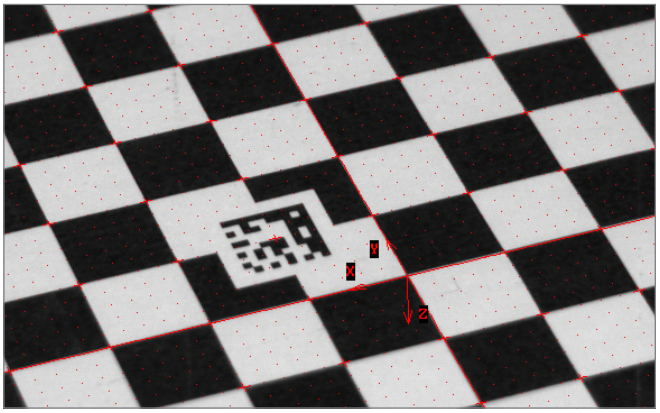


Registration (HDR): Short exposure, long exposure, result

Field-Proven Vision Tools (cont.)

2D calibration tool

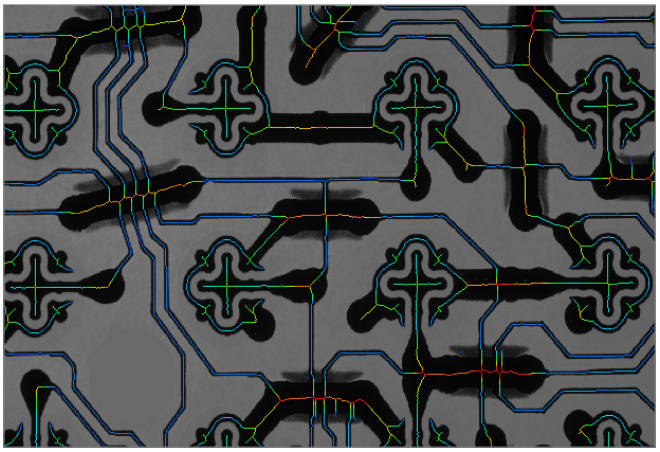
Calibration is a routine requirement for imaging. MIL includes a 2D Calibration tool to convert results (i.e., positions and measurements) from pixel to real-world units and vice-versa. The tool can compensate results, and even an image itself, for camera lens and perspective distortions. Calibration is achieved using an image of a grid or chessboard target, or just a list of known points. Calibration can be achieved from a partially-visible target. MIL also supports encoded targets that relay target characteristics—including coordinate system origin and axes—to further automate the calibration process.



2D Calibration

Image processing primitives tools

A professional imaging toolkit must include a complete set of operators for enhancing and transforming images, and for retrieving statistics in preparation for ensuing analysis. MIL includes an extensive list of Image Processing tools with fast operators for arithmetic, Bayer interpolation, color space conversion, de-interlacing, spatial and temporal filtering, geometric transformations, histogram, logic, lookup table (LUT) mapping, morphology, orientation, projection, segmentation, statistics, thresholding, and wavelets.



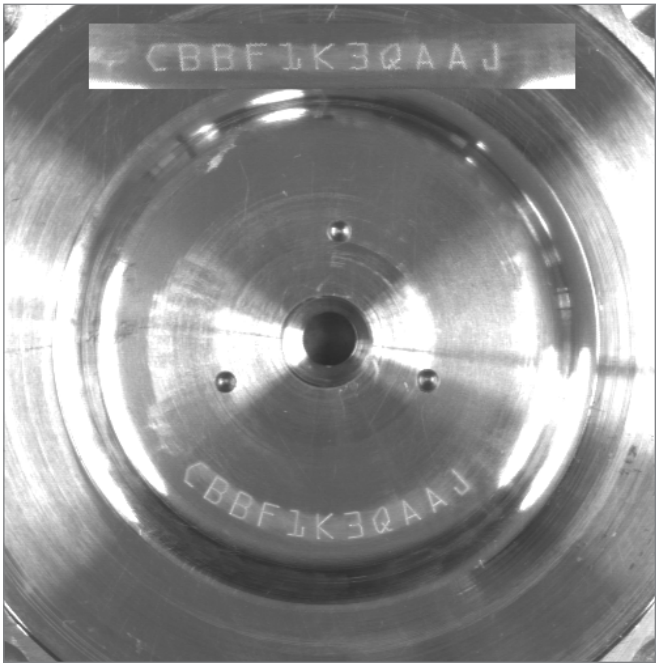


Image Processing

Field-Proven Vision Tools (cont.)

Image compression and video encoding tool

MIL provides Image Compression and Video Encoding tools for optimizing storage and transmission requirements. Lossy and lossless JPEG and JPEG2000 image compression and H.264 video encoding are supported. H.264 support can leverage Intel Quick Sync Video technology for encoding multiple high-definition video streams in real-time. MIL saves and loads compressed images individually using the JPG and JP2 file formats or as a sequence using the AVI file format. The H.264 elementary stream can be stored in and recovered from a MP4 format file. Compression and encoding settings can be adjusted for different size versus quality.

Tools fully optimized for speed

MIL image processing and analysis operations are optimized by Matrox Imaging to take full advantage of Intel SIMD instructions—including AVX2 and AVX-512[4]—as well as multi-core CPU and multi-CPU system architectures, to perform at top speed. MIL automatically dispatches operations across the number of processor cores needed to achieve maximum performance. Alternatively, it gives programmers control over the number of processor cores assigned to perform a given operation.

In addition, MIL is able to offload from the host CPU and even accelerate certain image processing operations when used with Matrox Imaging processing hardware with FPGA technology.

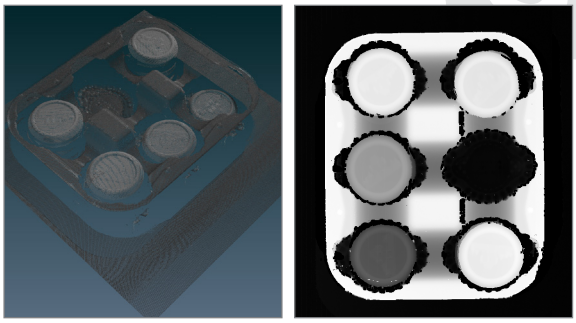
3D Vision Tools

Situations sometime arise where classical 2D vision techniques are unable to perform the required localization, recognition, inspection, or measurement tasks. These circumstances range from an inability to obtain the necessary consistent contrast from conventional illumination to needing the pose of an object with six degrees of freedom. This is where 3D vision tools step in—whether alone or in combination with 2D vision tools—to carry out the job.

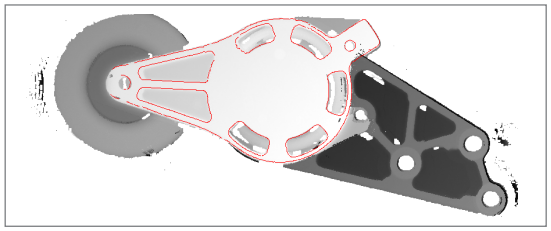
MIL has a rich set of tools for performing 3D processing and analysis. These tools work on the 3D data produced by profile and snapshot sensors as well as stereo and time-of-flight (ToF) cameras. Consult the Camera Interfacing section on the Matrox Imaging website for a list of qualified makes. The 3D data supported by MIL can also come from a Stanford Polygon Format (PLY) or stereolithography (STL) file.

The 3D processing tools in MIL operate on—and in between—point clouds, depth maps, and/or elementary objects. The latter can be a box, cylinder, line, plane, or sphere. Operations on a point cloud include rotation, scaling, translation, cropping/masking, re-sampling, and meshing into surfaces; computing normal vectors; projecting to a depth map; and extracting a cross-section. Operations on a depth map include addition, subtraction/distance, and minimum/maximum; filling gaps (i.e., caused by invalid or missing data); and extracting a profile. Additional operations on both a point cloud and depth map include establishing a bounding box, computing the centroid, counting the number of points, and calculating the distances to the nearest neighboring point.

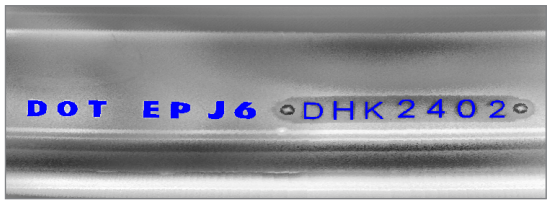
A depth map can subsequently be analyzed using MIL 2D vision tools like Pattern Recognition—without being affected by illumination variations or surface texture—and Character Recognition, when the alphanumeric code to read protrudes from, but has the same color as, the background. A profile or cross section can be analyzed using Metrology.



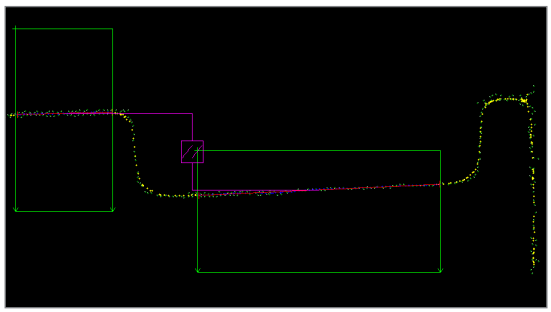
Point cloud to depth map projection



Pattern Recognition on depth map



Character Recognition on depth map

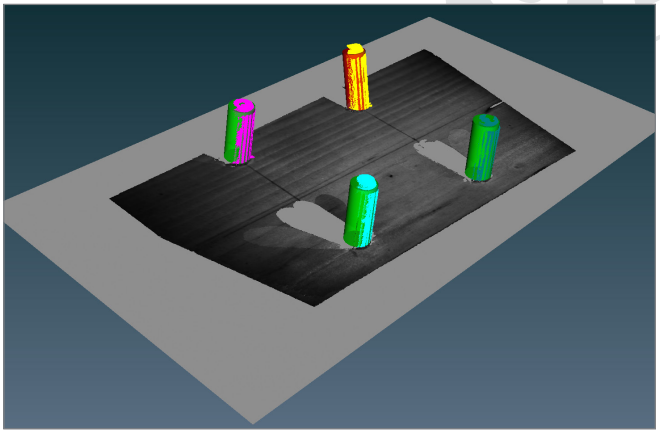


Metrology on cross section

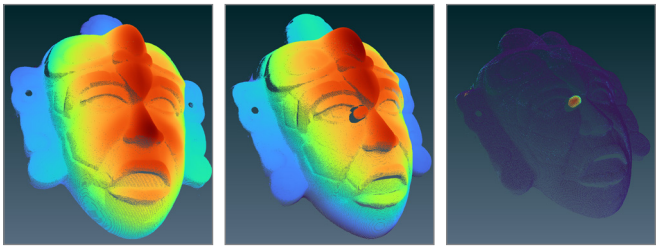
3D Vision Tools (cont.)

MIL includes a toolset for 3D Metrology. Within this toolset, one tool fits a point cloud or depth map to a cylinder, line, plane, or sphere. Additional tools compute various distances and statistics between point clouds, depth maps, and fitted or user-defined elementary objects. Another tool is available to determine volume in a variety of ways.

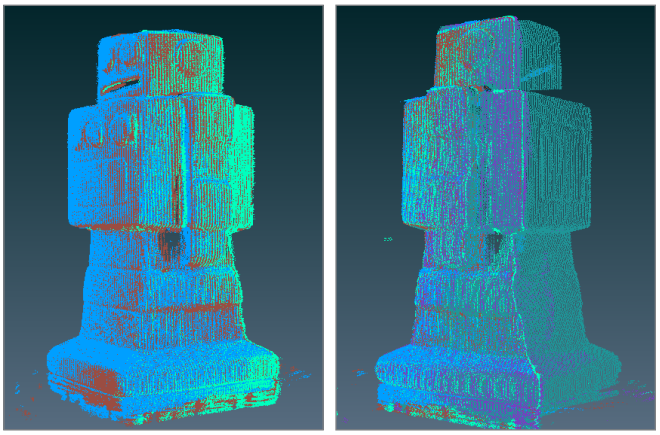
An additional 3D Registration tool in MIL establishes the fine alignment of two or more point clouds and merges them together if required. This tool provides the means to perform high-accuracy comparative analysis between a 3D model and target, as well as full object reconstruction from multiple neighboring 3D scans.



3D Metrology



3D alignment for comparative analysis: Model, target, and difference

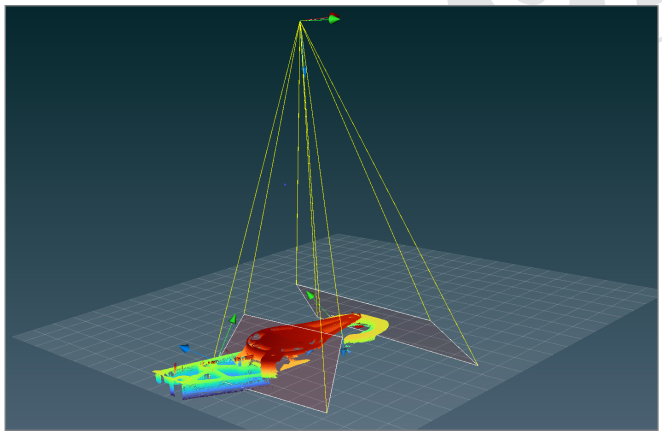


3D alignment for full reconstruction

3D Vision Tools (cont.)

MIL also contains tools to perform 3D profiling using a discrete sheet-of-light source (i.e., laser) and a conventional 2D camera. A calculator is included to establish the camera, lens, and alignment needed to achieve the desired measurement resolution and range. MIL provides straightforward calibration methods and associated tools to produce a point cloud or depth map. The calibration carried out in MIL is able to combine multiple sheet-of-light sources and 2D camera pairs to work as one, thus avoiding the need for post alignment and merger. Such configurations are useful to limit occlusion, increase scan density, and image the whole volume of an object. Moreover, MIL makes use of a unique derivative-based algorithm for beam extraction or peak detection, which is both more accurate and robust than traditional ones based on the center of gravity.

In addition, MIL provides the necessary calibration services to position and orient a camera and robot (base) with respect to the absolute coordinate system. It then enables an application to locate a point of interest and even establish an objects' 3D pose with respect to the absolute coordinate system using multiple views. This is achieved by using other MIL tools for pattern recognition—to find the one identical feature across views, or a minimum of three identical features in case of pose estimation—and then relying on MIL to triangulate the 3D position(s). The pose is established by the application using the geometric relationship of these features, which can come from an object model. Pose estimation can also be performed using a single view by locating a minimum of four object features whose geometric relationship is known beforehand by way of an object model.



3D profiling

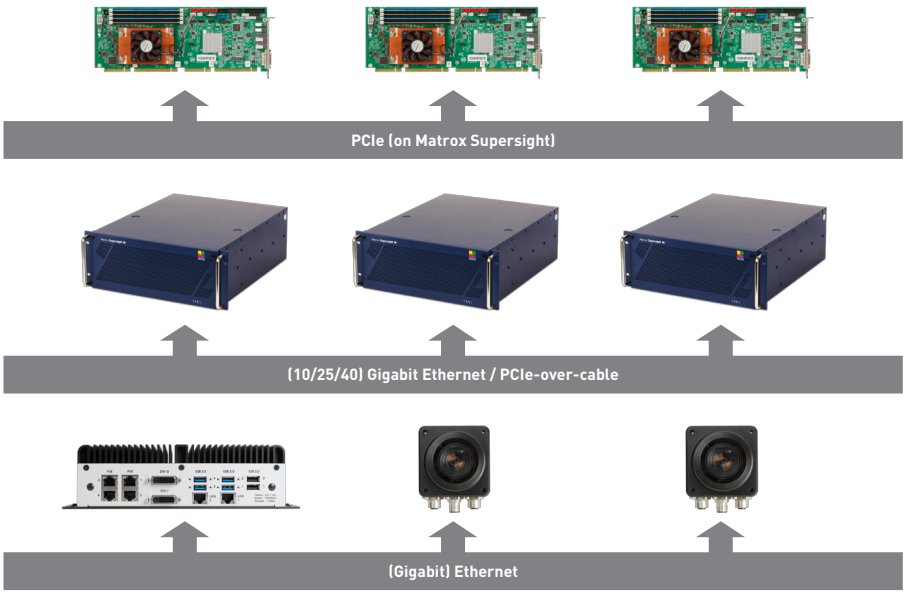
Distributed MIL Interface

Coordinate and scale performance outside the box

MIL has the ability to remotely access and control image capture, processing, analysis, display, and archiving. Distributed MIL functionality provides the means to scale an application beyond a single computer and make the most of modern-day HPC clusters for machine vision applications. The technology can also be used to control and monitor several PCs and smart cameras deployed on a factory floor. Distributed MIL simplifies distributed application development by providing a seamless method to dispatch MIL (and custom) commands; transfer data; send and receive event notifications (including errors); mirror threads; and perform function callback across systems. It offers low overheads and efficient bandwidth usage, even allowing agent nodes to interact with one another without involving the director node. Distributed MIL also gives developers the means to implement load balancing and failure recovery. It includes a monitoring mode for supporting the connection to an already-running MIL application.

32-bit application on 64-bit Windows

MIL supports the installation and running of a 32-bit application on 64-bit Windows, which is required for third-party legacy software components not natively available in 64-bit. Distributed MIL further enables the 32-bit application to capture video using 64-bit MIL. The 32-bit and 64-bit versions of MIL interact with each other through shared memory. This gives the 32-bit application access to the additional buffering available in the 64-bit address space.



MIL can easily and efficiently be distributed across HPC clusters and multiple PC / smart camera installations

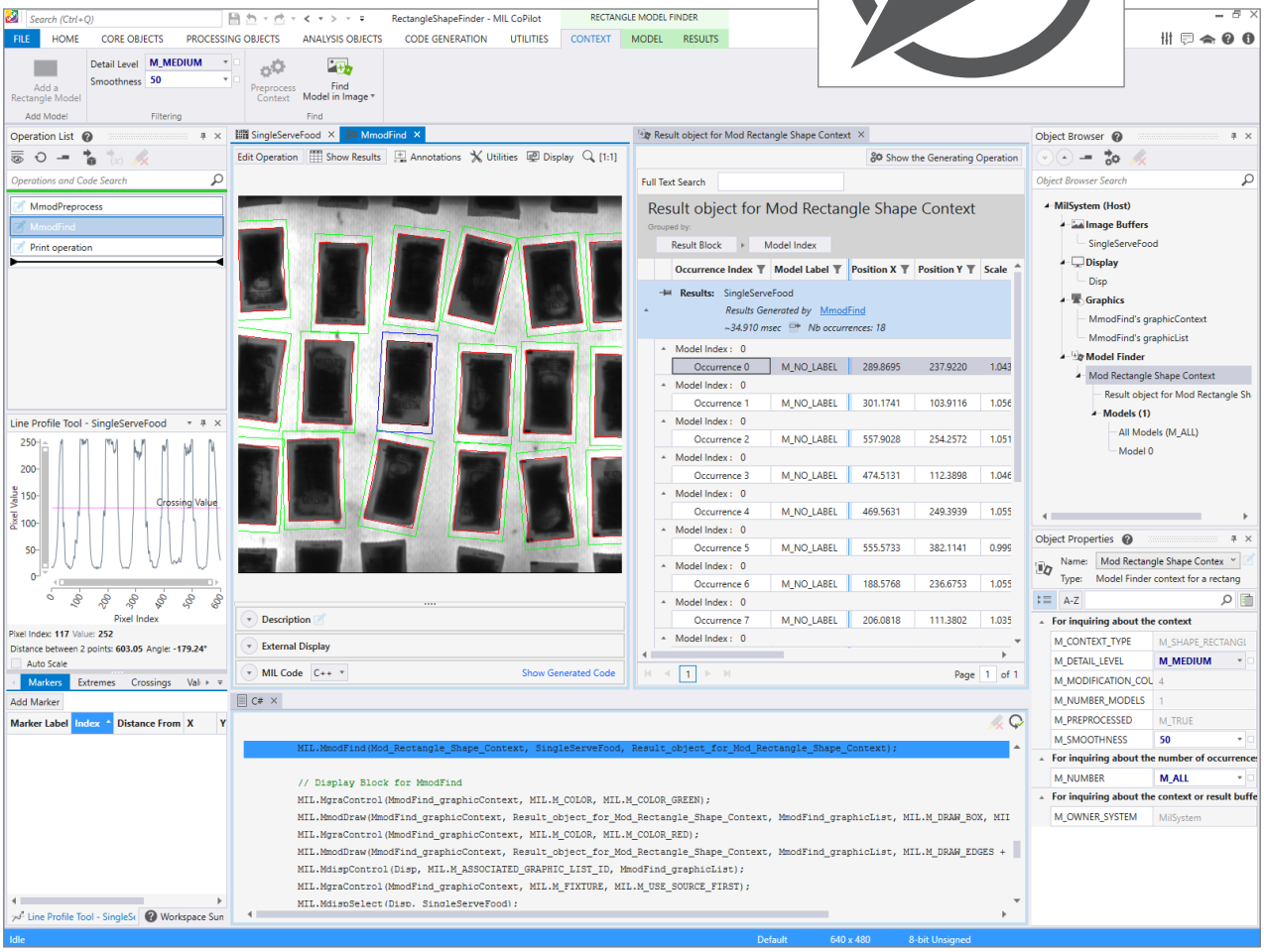
Utilities

MIL CoPilot interactive environment

Accessible to MIL users is an interactive environment to facilitate and accelerate the evaluation and prototyping of an application. This includes creating the contexts or configurations for applicable MIL tools like Classification. The same environment can also initiate—and therefore shorten—the application development process through the generation of MIL program code.

Running on 64-bit Windows, MIL CoPilot provides interactive access to MIL processing and analysis operations via a familiar contextual ribbon menu design. It includes various utilities to study images and help determine the best analysis tools and settings for a given project. Applied operations are recorded in an Operation List, which can be edited at any time. An Object Browser keeps track of MIL objects created during a session and gives convenient access to these at any moment. Non-image results are presented in tabular form and a table entry can be identified directly on the image. The annotation of results onto an image is also configurable.

Once an operation sequence is established, it can be converted into functional program code in any language supported by MIL. The program code can take the form of a command-line executable or dynamic link library (DLL); this can be packaged as a Visual Studio project, which in turn can be built without leaving MIL CoPilot. All work carried out in a session is saved as a workspace for future reference and sharing with colleagues.

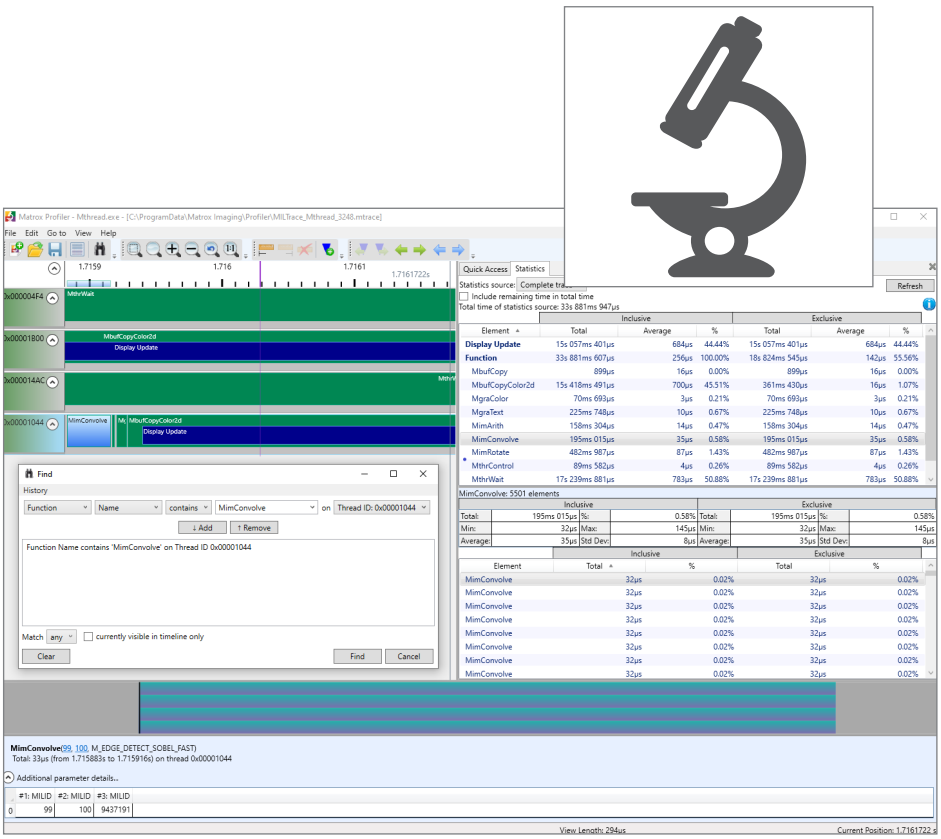


MIL CoPilot interactive environment

Utilities (cont.)

Matrox Profiler

Matrox Profiler is a Windows-based utility to post-analyze the execution of a multi-threaded application for performance bottlenecks and synchronization issues. It presents the function calls made over time per application thread on a navigable timeline. Matrox Profiler allows the searching for, and selecting of, specific function calls to see their parameters and execution times. It computes statistics on execution times and presents these on a per function basis. Matrox Profiler tracks not only MIL functions but also suitably tagged user functions. Function tracing can be disabled altogether to safeguard the inner working of a deployed application.



Matrox Profiler application analysis performance tool

Development Features

Complete application development environment

In addition to image processing, analysis, and archiving tools, MIL includes image capture, annotation, and display functions, which form a cohesive API. The API and accompanying utilities are recognized by the large installed base of users for facilitating and accelerating application development.

Portable API

The MIL C/C++ API is not only intuitive and straightforward to use but it is also portable. It allows applications to be easily moved from one supported video interface or operating system to another, providing platform flexibility and protecting the original development investment.

.NET development

Included in MIL is a low-overhead API layer for developing Windows applications within the .NET Framework using managed Visual Basic and Visual C# code.

JIT compilation and scripting[4]

MIL supports C# and Visual Basic JIT compilation and CPython scripting, facilitating experimentation and prototyping. Such code can even be executed from within a MIL-based application, providing a simpler way to tailor an already-deployed application.

Simplified platform management

With MIL, a developer does not require in-depth knowledge of the underlying platform. MIL is designed to deal with the specifics of each platform and provide simplified management (e.g., hardware detection, initialization, and buffer copy). MIL gives developers direct access to certain platform resources such as the physical address of a buffer. The software also includes debugging services (e.g., function parameter checking, tracing, and error reporting), as well as configuration and diagnostic tools.

Designed for multi-tasking

MIL supports multi-processing and multi-tasking programming models, namely, multiple MIL applications not sharing MIL data or a single MIL application with multiple threads sharing MIL data. It provides mechanisms to access shared MIL data and ensure that multiple threads using the same MIL resources do not interfere with each other. MIL also offers platform-independent thread management for enhancing application portability.

Buffers and containers

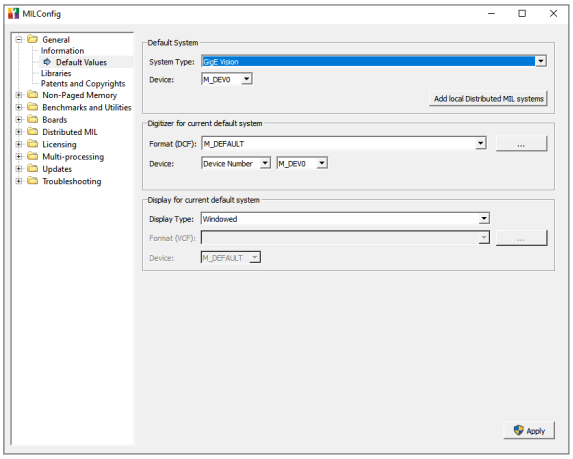
MIL manipulates data stored in buffers, such as monochrome images arranged in 1-, 8-, 16-, and 32-bit integer formats, as well as 32-bit floating point formats. It also handles color images laid out in packed or planar RGB/YUV formats. Commands for efficiently converting between buffer types are included. MIL additionally operates on containers[4], which combine related buffers into a cohesive whole. Containers simplify working with multi-component data such as point clouds for 3D processing and analysis as well as display.

Saving and loading images

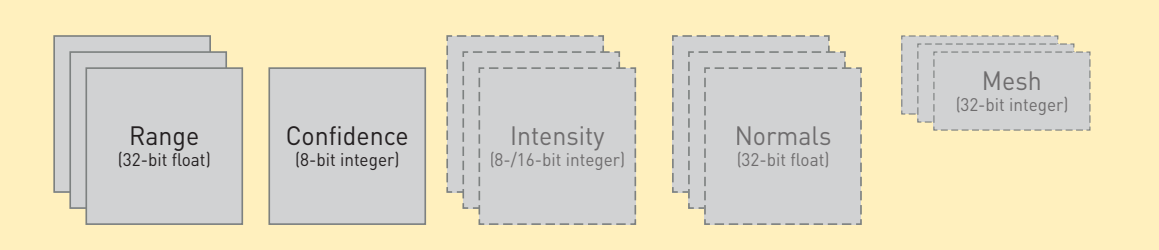
MIL supports the saving and loading of individual images, image sequences, and containers to and from disks. Supported file formats are AVI (Audio Video Interleave), BMP (bitmap), JPG (JPEG), JP2 (JPEG2000), MP4 (MPEG-4 Part 14), PLY, MIM (native), PNG, STL, and TIF (TIFF), as well as a raw format.

Industrial and robot communication

MIL lets applications interact directly with automation controllers using the CC-Link IE Field Basic[4], EtherNet/IP™, Modbus®, and PROFINET®[6] industrial communication protocols. It also supports native communication with robot controllers from ABB, DENSO, EPSON, FANUC, KUKA, and Stäubli.



MIL configuration and diagnostic tool



MIL 3D (point cloud) data container

Development Features (cont.)

WebSocket access

MIL allows an application to publish MIL object data for access from a browser or another standalone application using the HTML-5 WebSocket communication protocol. It uses a client-server architecture where the server is the MIL-based application and the client is a JavaScript program running in a browser or a standalone application.

The functionality can be used locally on the same device running the MIL-based application or remotely on another device that does not have MIL installed on it. The API extension supports client-side programming in JavaScript or C/C++. The MIL objects supported are the buffer and display ones. The functionality serves to view and interact with a MIL display (i.e., pan, scroll, zoom, etc.).

Flexible and dependable image capture

There are many ways for an imaging system to capture video: Analog, Camera Link, CoaXPress, DisplayPort, GenTL, GigE Vision, HDMI, SDI, and USB3 Vision. MIL supports all these interfaces either directly or through Matrox Imaging or third-party hardware. MIL works with images captured from virtually any type of color or monochrome source including standard, high-resolution, high-rate, frame-on-demand cameras, line scanners, slow scan, and custom-designed devices.

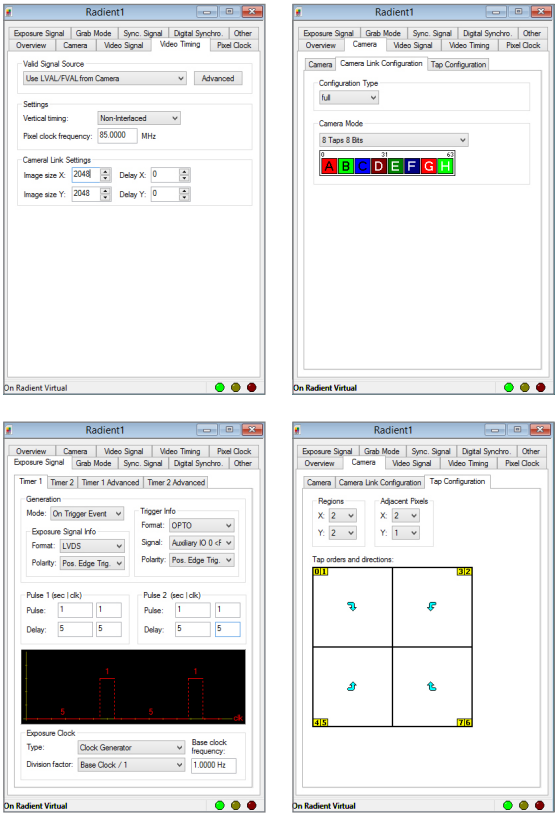
For greater determinism and the fastest response, MIL provides multi-buffered image capture control performed in the operating system's kernel mode. Image capture is secured for frame rates measured in the thousands per second even when the host CPU is heavily loaded with tasks such as HMI management, networking, and archiving to disk. The multi-buffered mechanism supports callback functions for simultaneous capture and processing even when the processing time occasionally exceeds the capture time.

Matrox Intellicam

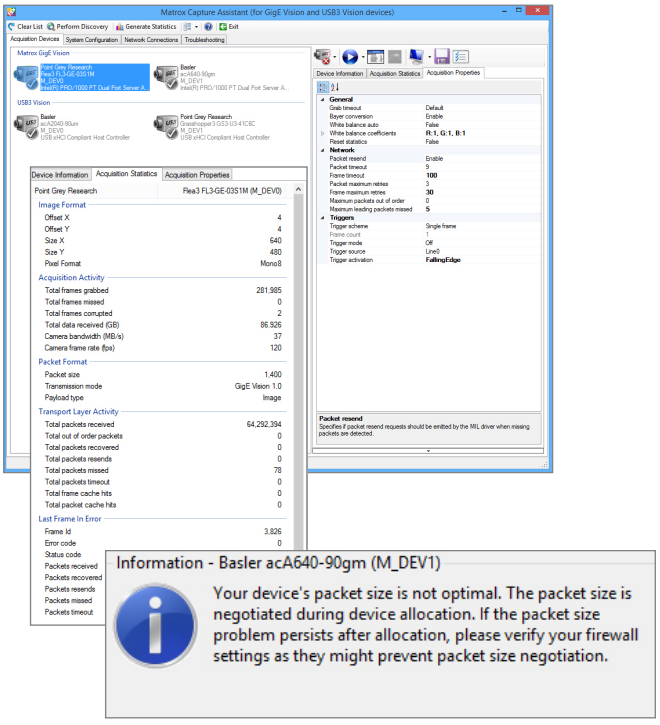
MIL features the Matrox Intellicam image capture and frame grabber configuration utility. This Windows-based program lets users interactively configure Matrox image capture hardware for a variety of image sources or simply try one of the numerous ready-made interfaces available from Matrox Imaging.

Matrox Capture Assistant

MIL includes Matrox Capture Assistant, a Windows-based utility for verifying the connection to one or more GigE Vision or USB3 Vision cameras and testing video acquisition. It can obtain GigE Vision and USB3 Vision device information, collect and present acquisition statistics, and provide access to acquisition (GenICam™) properties. The gathering and display of statistics can be performed when acquiring within or outside of Matrox Capture Assistant. Matrox Capture Assistant also allows the adjustment of GigE Vision driver settings and provides the means to troubleshoot connectivity issues.



Matrox Intellicam frame grabber and camera configuration tool



Matrox Capture Assistant GigE Vision and USB Vision configuration and test tool

Development Features (cont.)

Simplified 2D image display

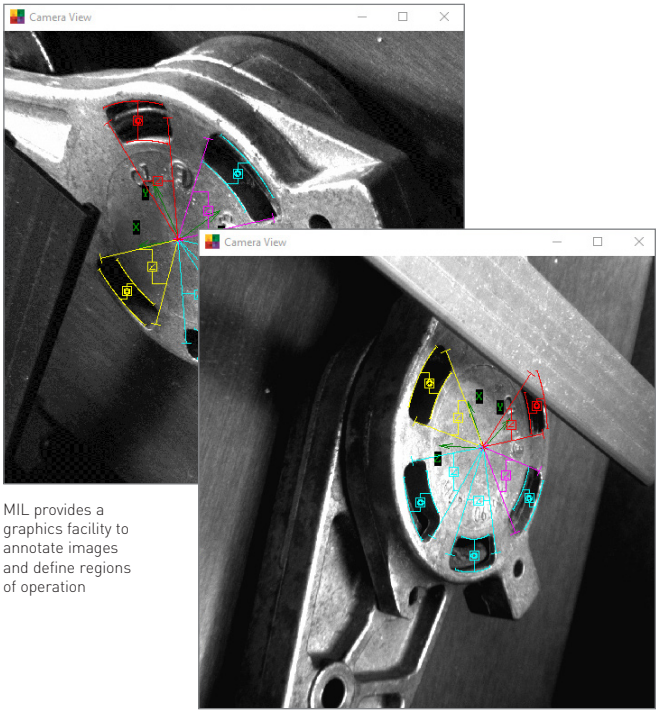
MIL provides transparent 2D image display management with automatic tracking and updating of image display windows at live video rates. MIL also allows for live image display in a user-specified window. Display of multiple video streams using multiple independent windows or a single mosaic window is also supported. Moreover, MIL provides non-destructive graphics overlay, suppression of tearing artifacts, and filling the display area at live video rates. All of these features are performed with little or no host CPU intervention when using appropriate graphics hardware.

MIL also supports multi-screen display configurations that are in an extended desktop mode (i.e., desktop across multiple monitors), exclusive mode (i.e., monitor not showing desktop but dedicated to MIL display), or a combination.

MIL can manage image display across multiple monitors

Graphics, regions, and fixtures

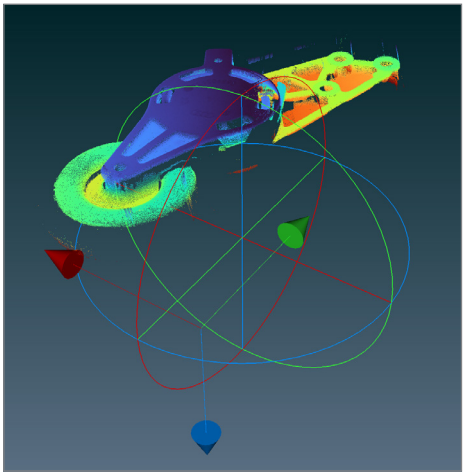
MIL provides a feature-rich graphics facility to annotate images and define regions of operation. This capability is used by the MIL analysis tools to draw settings and results onto an image. It is also available to the programmer for creating application-specific image annotations. The graphics facility supports different shapes—dot, line, polyline, polygon, arc, and rectangle—and text with selectable font. It takes image calibration into account, specifically the unit, reference coordinate system, and applicable transformations. The graphics scale smoothly when zooming to sub-pixel. An interactive mode is available to easily allow developers to provide user editing of graphics, and the ability to add, move, resize, and rotate graphic elements. Moreover, the application can hook to interactivity-related events to automatically initiate underlying actions. The graphics facility can further be used to define regions to guide or confine subsequent MIL analysis operations. Regions can also be repositioned automatically by tying their reference coordinate system to the positional results of a MIL analysis operation.



MIL provides a graphics facility to annotate images and define regions of operation

Native 3D display

MIL can natively display point clouds. A 3D display can be panned, titled, and zoomed in all directions. Visual guides appear to help orient the view. In addition to showing individual points, a 3D display can be supplemented with geometric shapes (i.e., arc, cylinder, line, plane sphere, and textured polygon), text, coordinate system axes, grid (on reference plane), and orientation box. MIL allows control over appearance (solid or wireframe), opacity, color (including point cloud colorization using jet or turbo lookup tables), visibility, and thickness.



MIL 3D display

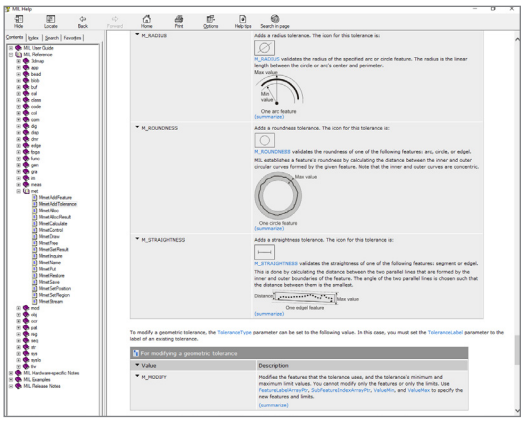
Application deployment

MIL offers a flexible licensing model for application deployment. Only the components required to run the application need to be licensed. License fulfillment is achieved using a pre-programmed dongle or an activation code tied to Matrox Imaging hardware (i.e., smart camera, vision controller, I/O card, frame grabber, or dongle). Some components are pre-licensed with certain Matrox Imaging hardware; please consult the individual Matrox Imaging hardware datasheets for details. The use of Distributed MIL within the same physical system does not require the additional specific license. The installation of MIL for redistribution can even be hidden from the end user.

Development Features (cont.)

Documentation, IDE integration, and examples

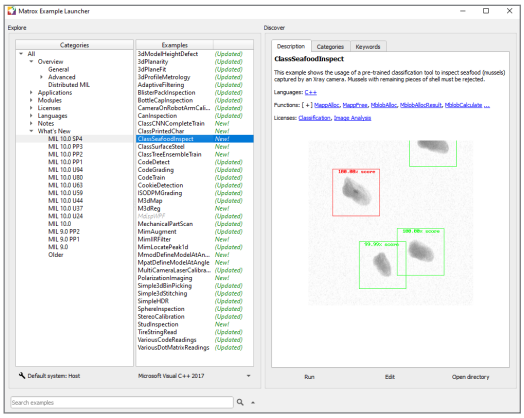
MIL's online help provides developers with comprehensive and easy-to-find documentation, and online help can even be tailored to match the environment in use. The online help can be called up from within Visual Studio to provide contextual information on the MIL API. Also supported is Visual Studio's intelligent code-completion facility, giving a programmer on-the-spot access to relevant aspects of the MIL API. An extensive set of categorized and searchable example programs allow developers to quickly get up to speed with MIL.



MIL includes comprehensive and easy-to-find documentation

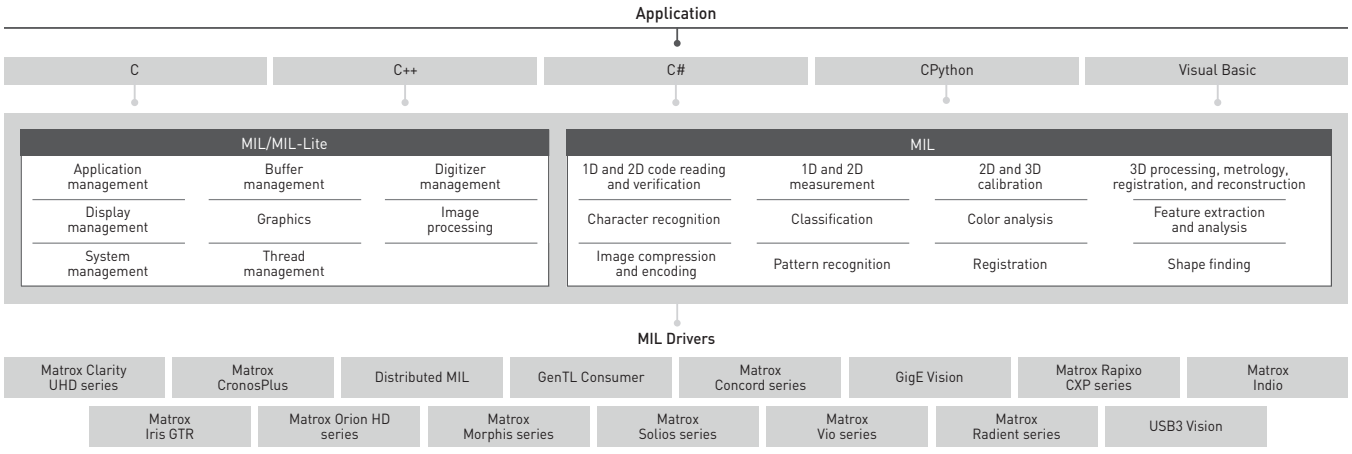
MIL-Lite

MIL-Lite is a subset of MIL, featuring programming functions for performing image capture, annotation, display, and archiving. It also includes fast operators for arithmetic, Bayer interpolation, color space conversion, de-interlacing, temporal filtering, basic geometric transformations, histogram, logic, LUT mapping, and thresholding. MIL-Lite is licensed for both application development and deployment in the presence of Matrox Imaging hardware or a supplemental license tied to a dongle.



MIL provides a rich set of categorized and searchable programming examples

Software architecture



MIL provides a comprehensive set of application programming interfaces, imaging tools, and hardware support

Supported Environments

For Windows

- 32-/64-bit Windows 7 with SP1 and Windows 10 (versions 1607 to 1909)
- Visual Studio 2012, 2013, 2015, 2017, and 2019 (unmanaged C++, C#, and Basic)
- CPython 2.7 and 3.5 (3.7 with MIL X Service Pack 4)

For Linux

- 64-bit Ubuntu 18.04 LTS
- 64-bit Red Hat Enterprise Linux 8(.1) and CentOS 8 (build 1905)
- 64-bit SUSE Linux Enterprise 15 SP1
- GNU Compiler Collection and Python (from particular Linux distribution)

MIL for Arm®

The majority of processing, analysis, annotation, display, and archiving functionality in MIL is also available to run on Arm Cortex®-A family processors, specifically those employing the Armv8-A 64-bit architecture. The processing and analysis functions are optimized for speed using the Neon™ SIMD architecture extension. MIL for Arm is supported on appropriate 64-bit Linux distributions, like the one from Ubuntu. MIL for Arm is available to select users as a separate package upon qualification. For more information, contact Matrox Imaging sales.

Training and Support

Matrox Vision Academy

Matrox Vision Academy provides all the expertise of live classroom training, with the convenience of on-demand instructional videos outlining how to get the most out of MIL vision software. Available to customers with valid MIL maintenance subscriptions, as well as those evaluating the software, users can seek out training on specific topics of interest, where and when needed. Regularly scheduled live classroom training is also offered at Matrox Imaging Headquarters.

Matrox Vision Academy aims to help users increase productivity, reduce development costs, and bring applications to market sooner. For more information, contact Matrox Vision Academy.

Matrox Professional Services

Matrox Professional Services delivers deep technical assistance and customized trainings to help customers develop their particular applications. These professional services comprise personalized training; assessing application or project feasibility (e.g., illumination, image acquisition, and vision algorithms); demo and prototype applications and projects; troubleshooting, including remote debugging; and video / camera interfacing.

Backed by the Matrox Vision Squad—a team of high-level vision professionals—Matrox Professional Services offer more in-depth support, recommending best methods with the aim of helping customers save valuable development time and deploy solutions more quickly. For more information on pricing and scheduling, contact Matrox Sales.

MIL maintenance program

MIL users have access to a Maintenance Program, renewable on a yearly basis. This maintenance program entitles registered users to free software updates and entry-level technical support from Matrox Imaging, as well as access to Matrox Vision Academy.

For more information, please refer to the Matrox Imaging Software Maintenance Programs.

Ordering Information

Part number	Description
MIL X Development Toolkits	
MILXWINPU	MIL X development toolkit for Windows. Contains installation media (DVD), a single-user USB hardware license key, and MIL Maintenance registration number. Note: 75% discount for MILXWINPU if purchased with a Matrox Design Assistant development package (i.e., DAXWINPU) for the same user with their name as proof or for a Matrox Design Assistant user with valid maintenance with the registration number as proof. 50% educational discount for MILXWINPU with proof of affiliation with an academic institution. Discounts cannot be combined.
MILXLNX	MIL X development toolkit for Linux. Contains installation media (DVD). Also requires MILXWINPU.
MIL-Lite X Development Toolkits	
MILLITEXWIN	MIL-Lite X development toolkit for Windows. Contains installation media (DVD) and MIL-Lite Maintenance registration number. Note: 50% educational discount for MILLITEXWIN with proof of affiliation with an academic institution.
MILLITEXLNX	MIL-Lite X development toolkit for Linux. Contains installation media (DVD). Also requires MILLITEXWIN.
MIL/MIL-Lite X Maintenance Program	
MILMAINTENANCE	One-year extension to the MIL maintenance program per developer. Note: 50% educational discount for MILMAINTENANCE with proof of affiliation with an academic institution. Included in the original purchase price of the MIL X development toolkit, registered users are entitled to one year of technical support, access to updates, and Matrox Vision Academy online training website.
LTEMAINTENANCE	One-year extension to the MIL-Lite maintenance program. Note: 50% educational discount for LTEMAINTENANCE with proof of affiliation with an academic institution. Included in the original purchase price of the MIL-Lite X development toolkit, registered users are entitled to one year of technical support, access to updates, and Matrox Vision Academy online training website.
Matrox Vision Academy Online Training	
Included with MIL/ MIL-Lite Maintenance Program	Matrox Vision Academy Online provides a range of categorized instructional videos on how to use the software to create applications. Matrox Vision Academy Online is available to customers with current MIL/MIL-Lite X maintenance subscriptions, as well as those evaluating the software. Visit www.matrox.com/imaging/en/vision_academy/ for more information.
Matrox Vision Academy On-Premises Training	
MILLITETRAIN Ask for availability.	Introduction to the *MIL/MIL-Lite Environment*: Three-day instructor-led training, hands-on labs, and Q&A periods with support and development staff. An optional fourth day is available for one-on-one application-specific discussions with experienced Matrox Imaging technical staff. *Key topics*: General overview of MIL/MIL-Lite; setting up a development environment; managing image buffers, image capture, and display. Visit www.matrox.com/imaging/en/vision_academy/on_premises/ for more information.

Ordering Information (cont.)

Part number	Description
MIL/MIL-Lite Run-Time/Supplemental License Software Keys	
MXRTxxxxxxxx00	MIL X run-time software license key. The user must supply a lock code generated using the appropriate MIL utility/page. This unique lock code identifies the target computer system and MIL package(s) to license. Note: Combine packages by substituting 0 at the appropriate position x with the appropriate letter or other digit.
MXRTA000000000	MIL X Image Analysis package. Includes Image Processing, Blob Analysis, Bead inspection, Measurement, and Calibration modules. Note: Starting with Service Pack 4, 3D Processing functionality also requires 3D Calibration and Supplemental package (MXRT0000030000 or MXRT0000020000).
MXRTM000000000	MIL X Machine Vision package. Includes Image Processing, Blob Analysis, Bead inspection, Pattern Matching (NGC-based), Measurement, and Calibration modules. Note: Starting with Service Pack 4, 3D Processing functionality also requires 3D Calibration and Supplemental package (MXRT0000030000 or MXRT0000020000).
MXRT0I00000000	MIL X Identification package. Includes OCR and Code Reader modules.
MXRT0C00000000	MIL X SureDotOCR and String Reader package.
MXRT0200000000	Both MXRT0I00000000 and MXRT0C00000000.
MXRT00J0000000	MIL/MIL-Lite X Image Compression package. Includes JPEG, JPEG2000, and H.264 codecs.
MXRT000G000000	MIL X Geometric Model Finder package. Includes Shape Finding.
MXRT000E000000	MIL X Edge Finder package.
MXRT0002000000	Both MXRT000G000000 and MXRT000E000000.
MXRT0000S00000	MIL/MIL-Lite X interface (GenTL, GigE Vision, and USB3 Vision) package. Note: Required if using a third-party NIC or a USB 3.0 port on a third-party PC.
MXRT0000D00000	Distributed MIL/MIL-Lite X package for director or agent node. Note: Not needed if used within the same physical system.
MXRT00000R0000	MIL X Registration package. Note: Starting with Service Pack 4, 3D Registration functionality also requires 3D Calibration and Supplemental package (MXRT0000030000 or MXRT0000020000).
MXRT0000030000	MIL X 3D Calibration and Supplemental package. Note: Starting with Service Pack 4, 3D Processing functionality also requires Image Analysis or Machine Vision package (MXRTA000000000 or MXRTM000000000), 3D Registration functionality also requires Registration package (MXRT00000R0000 or MXRT0000020000) and 3D Metrology functionality also requires Metrology package (MXRT000000Y000 or MXRT000000B000).
MXRT0000020000	Both MXRT00000R0000 and MXRT0000030000.
MXRT000000Y000	MIL X Metrology package. Note: Starting with Service Pack 4, 3D Metrology functionality also requires 3D Calibration and Supplemental package (MXRT0000030000 or MXRT0000020000).

Ordering Information (cont.)

Part number	Description
MIL/MIL-Lite Run-Time/Supplemental License Software Keys	
MXRT000000Q000	MIL X Color Analysis package.
MXRT000000B000	Both MXRT000000Y000 and MXRT000000Q000.
MXRT0000000Z00	MIL X Industrial and Robot Communication package.
MXRT0000000N00	MIL X Classification package. Includes inference and training.
MXRT0000000200	Both MXRT0000000N00 and MXRT0000000Z00.
MXRTM2B2B2B200	All MIL X packages.
MIL/MIL-Lite Run-Time/Supplemental License Hardware ID Key	
MILRTIDCMC	MIL/MIL-Lite run-time/supplemental license USB hardware fingerprint and storage. Note: Replaces Matrox Imaging hardware as the fingerprint used to generate the unique system code. MXRT...00 still required.
MIL/MIL-Lite Run-Time/Supplemental License Hardware Key	
MXRTxxxxxxxx00U	Pre-programmed MIL/MIL-Lite X run-time USB hardware license key that enables appropriate package(s). Note: See *MIL/MIL-Lite Run-Time/Supplemental License Software Keys* for available selections. Alternative to MXRT...00.

Endnotes:
1. The software may be protected by one or more patents; see www.matrox.com/patents for more information.
2. Only under Windows.
3. Since previous re-release and processing/service pack.
4. Through an update.
5. In conjunction with the proper hardware setup.
6. With appropriate Matrox Imaging I/O card, smart camera, or vision controller.

The Matrox Imaging advantage

Assured quality & longevity
We adhere to industry best practices in all hardware manufacturing and software development; product designs pay careful attention to component selection to secure consistent long-term availability. Matrox Imaging is able to meet Copy Exact and Revision Change Control procurement requirements in particular circumstances, backed by our dedicated team of QA specialists.

Trusted industry standards
Matrox Imaging champions industry standards in our design and production. We leverage these standards to deliver quality compatible products, protecting our customers' best interests by ensuring our hardware and software components work with as many third-party products as possible.

Comprehensive customer support
Our devoted front-line support and applications teams are on call to offer timely product installation, usage, and integration assistance. Matrox Professional Services delivers deep technical assistance to help customers develop their particular applications in a timely fashion. Services include personalized training and device interfacing as well as application feasibility, prototyping, troubleshooting, and debugging.

Tailored customer training
Matrox Vision Academy comprises online and on-premises training for Matrox Imaging vision software tools. On-premises intensive training courses are regularly held at Matrox headquarters, and can also be customized for onsite delivery. Matrox Vision Academy online training platform hosts a comprehensive set of on-demand videos available when and where needed.

Long-standing global network
Matrox Imaging customers benefit from a global network of distributors who offer complementary products and support, and integrators who build customized vision systems. These relationships are built on years of mutual trust and span the globe, ensuring customer access to only the best assistance in the industry.

About Matrox Imaging

Founded in 1976, Matrox is a privately held company based in Montreal, Canada. Imaging, Graphics, and Video divisions provide leading component-level solutions, leveraging the others' expertise and industry relations to provide innovative, timely products.

Matrox Imaging is an established and trusted supplier to top OEMs and integrators involved in machine vision, image analysis, and medical imaging industries. The components consist of smart cameras, vision controllers, I/O cards, and frame grabbers, all designed to provide optimum price-performance within a common software environment.

Industries served

MIL tools are used to put together solutions for the aerospace, agricultural, automotive, beverage, cosmetic, construction material, consumer, electronic, energy, flat panel display, food, freight, machining, medical diagnostic, medical device, packaging, paper, pharmaceutical, printing, resource, robotics, semiconductor, shipping, textile, and transportation industries.

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