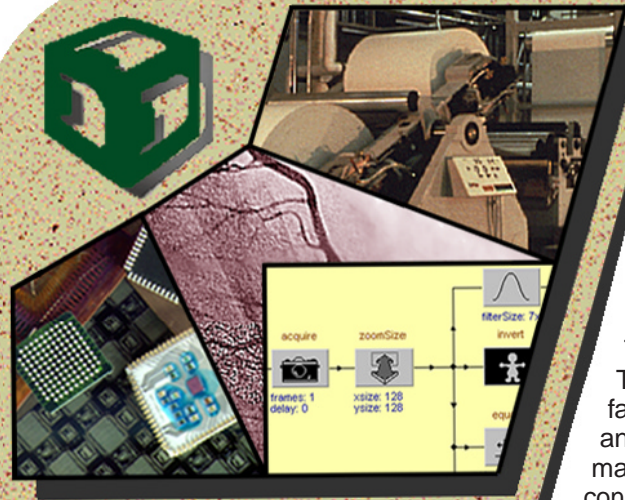## Fast, Accurate Software for Machine Vision

- **Highly accurate metrology and finder tools**

- **2D calibration corrects perspective distortion**

- **Works with any resolution camera or data source**

- **Available as a set of add-on icons for DatacubeWiT**

- **Finder tool is rotation and perspective independent**

- **Supported by MaxPCI, MaxLC, and mvPower**

Machine Vision Solutions

The MaxVision Toolkit is a package of fast, highly accurate, and easy-to-use machine vision tools. It consists of machine vision C routines for image acquisition, preprocessing, object finding, metrology, inspection functions, and camera calibration in a package specifically designed to minimize programming time for machine vision applications.

MaxVision applications operate with Datacube's MaxPCI and *mvPower* pipeline image processors and with MaxLC framegrabbers. The toolkit runs on Windows NT with MaxPCI and MaxLC and on the VxWorks real-time operating system with *mvPower*. It is also available as a set of add-on icons to DatacubeWiT.

The Toolkit's finder and metrology routines include fast normalized correlation, connectivity, line fitting, arc fitting, and edge locators. These functions are used with golden template and pixel counting inspection tools to verify the correctness of part position and dimensions, the presence of features, and the detection of surface flaws.

Normalized correlation searches for matches to a pre-defined gray-scale template. For each instance found, a match score and location (sub-pixel accurate) are recorded.

Connectivity or blob analysis involves processing a binary image and extracting blobs from the background. Holes of blobs are also extracted with parent-child-sibling relationships formed.

Connectivity is used to locate randomly oriented objects.

The line fitter finds linear edges in an image with high precision by searching rectangular ROIs (in any orientation) for sub-pixel edge points, then fitting a line to them using a least-squares algorithm. The arc fitter tool fits circular arcs in the image with high precision to find circular fiducials, measure hole diameters, or verify roundness.

The edge locator determines edges with sub-pixel accuracy along a linear path to detect the presence of features in an image, and to measure the distance between them.

A complete camera calibration procedure is included to provide pixel-to-millimeter scaling and correction for perspective distortion. Acquisition device support is provided for various cameras, strobe lights, and external part-presence triggers.

A remote procedure call (RPC) option allows Toolkit users to both develop and control MaxVision applications for *mvPower* embedded vision systems from a remote host. The RPC interface uses the same API for easy portability.

With power, speed, and accuracy in an open, extensible, easy-to-use and cost-effective system, the MaxVision Toolkit and Datacube hardware combine to provide the ideal solution for a wide variety of machine vision applications.
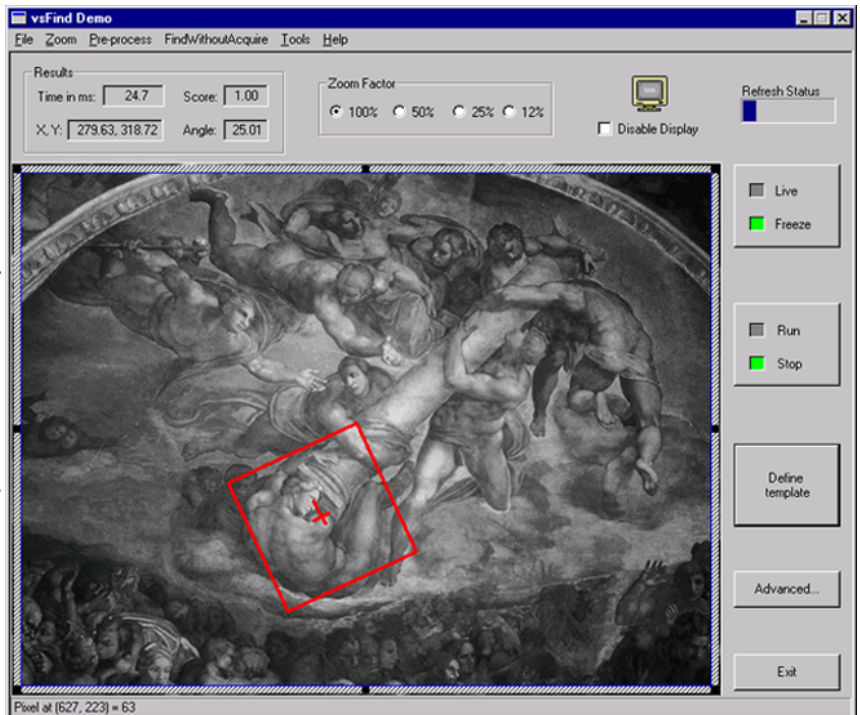
Finder tool showing recognition, in under 25ms, of rotated template (red) within 640x480 search region (blue)

Finder Tools
- **Normalized Correlation**:
  - Searches for a gray-scale template within the image at any orientation
  - User defines a template as a rectangular region-of-interest (ROI)
  - Sub-pixel accuracy for returned locations
  - Find multiple instances of one template or multiple templates in the same image
  - Selectable brightness variability (e.g., +/- 2 *f*-stops)
- **Rotation Invariance**
  - Selectable rotational range (e.g., +/-180 degrees)
  - Operates with non-square pixels and perspective distortion

Typical normalized correlation finder search times for various template sizes as a function of rotational range are given below. A complex, cluttered 640x480 image was searched using a 400MHz Pentium II.

	64x64	128x128	256x256
± 0°	6 ms	6 ms	5 ms
± 45°	17 ms	21 ms	8 ms
± 180°	46 ms	47 ms	10 ms

- **Connectivity**: standard blob statistics computed for area, centroid, bounding box, best-fit ellipse (2nd moments), perimeter, minimum and maximum radii

Metrology Tools
- **Line Fitter**:
  - Fits a straight line to edge points with high accuracy
  - Searches rectangular ROI in any orientation for sub-pixel edge points, then uses least-squares algorithm to fit line
- **Arc Fitter**:
  - Fits an arc to edge points with high accuracy
  - Finds the center given the radius, the radius given the center, or both the center and radius
- **Line Fitter** and **Arc Fitter**:
  - Can filter out edge points distant from the fit edge, then refit the line or arc to enhance accuracy and robustness in noisy images
  - Operates on binary as well as gray-scale images
- **Edge Locator**:
  - Locates edges with sub-pixel accuracy along a linear path
  - Detects the presence of features
  - Measures distances like a caliper or ruler

- Operates on binary and gray-scale images

Inspection
- **Golden Template**:
  - Parts are inspected through comparison to a predefined master or "golden template"
  - Includes compensation for jitter
- **Pixel Counting**: computes image statistics including mean, standard deviation, minimum, maximum, and both the centroid and area of a single blob
- **Histogramming**
- **Projection**: along X and Y axes

Image Processing
- **Convolutions**: numerous, parameterized, user-defined kernels including low pass, gaussian, and laplacian
- **Sobel Edge Filters**: absolute magnitude suitable for thresholding
- **Cross Gradient Edge Filters**
- **Threshold Operations**: for one or two thresholds
- **Morphology**: binary or gray-scale
- **Image Arithmetic**: addition, subtraction, maximum, minimum
- **Image Copy**: ranges of bits can be specified for source and destination with optional zoom; pyramid building option

Geometry Routines
- **Library of 2-D Geometry Routines**

Input/Output
- **Image Acquisition**:
  - Full frame or field, interlaced or non-interlaced, area or linescan
  - Shuttered cameras and strobe light controls
  - External binary I/O trigger
  - Gain and offset
  - Variable image size
  - Extended exposure control
  - Double buffering to overlap processing with acquisition
  - Simultaneous dual camera acquisition
- **Display Options**:
  - Live video: gray-scale or binary
  - Display captured images: gray-scale or binary
  - Graphics overlay
  - Zoom/shrink and show regions of interest
- **Binary I/O**:
  - Multiple inputs and outputs
  - Input can indicate part presence to trigger acquisition
  - Outputs can be analog, digital, programmable edge or pulse signals

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- **Disk I/O**: save and load images in various formats

Calibration
- Accurate 2-D calibration procedure provides pixel-to-millimeter scaling and corrects for perspective distortion
- All functions and tools automatically make use of calibration data by assuming that input parameters (coordinates and distances) are in millimeters, and by returning results in millimeters
- Origin can be upper-left or lower-left corner (user selectable)

Miscellaneous Features
- **Automatic Tool Positioning**: after locating an object (via connectivity or correlation), subsequently used tools can be automatically translated and rotated into alignment with the found part
- **Automatic Resource Management**:
  - Double buffering for parallelism of acquisition, display, and pipeline processing
  - Automatic temporary image management
- **Pixel Access by CPU**: read a pixel or ROI of pixels
- **Open System Standards**: C language-based, Windows NT, or VxWorks
- **Extensible Architecture**: Toolkit works with Datacube's broad product line of high-performance image processing hardware, digital image recorders, and storage systems

Hardware Requirements (choose one of the following):
- MaxPCI image processor *or*
- MaxLC framegrabber *or*
- mvTD compact machine vision system *or*
- *mvPower*

Additional Information
For more information about the products mentioned in this document, please refer to the following Datacube literature:

MaxPCI Data Sheets
MaxLC Data Sheets
***mvPower* Data Sheet**
mvTD Data Sheet
DatacubeWiT Data Sheet