National Instruments

VISIÓN ARTIFICIAL

Yon Asensio – Responsable Zona Norte

Agenda

- INTRODUCCIÓN NATIONAL INSTRUMENTS
- PLATAFORMA DE VISION
- CONFIGURACION DE UN SISTEMA DE VISIÓN
- ADQUISICIÓN y VISUALIZACIÓN
- PROCESAMIENTO DE IMAGEN
- REFERENCIAS

What we do…

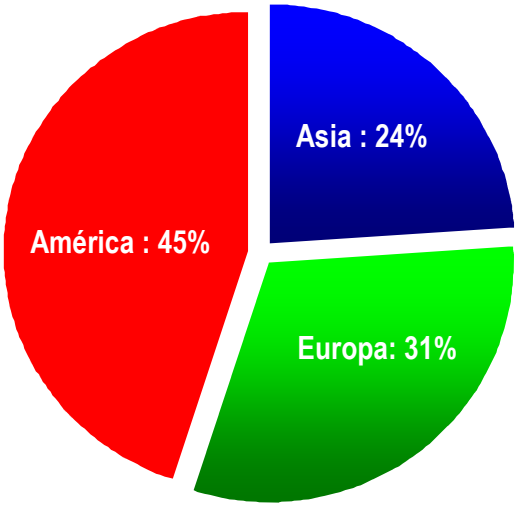
- Revolutionize measurement and automation
- Bringing Automation to Measurement, and Measurement to Automation

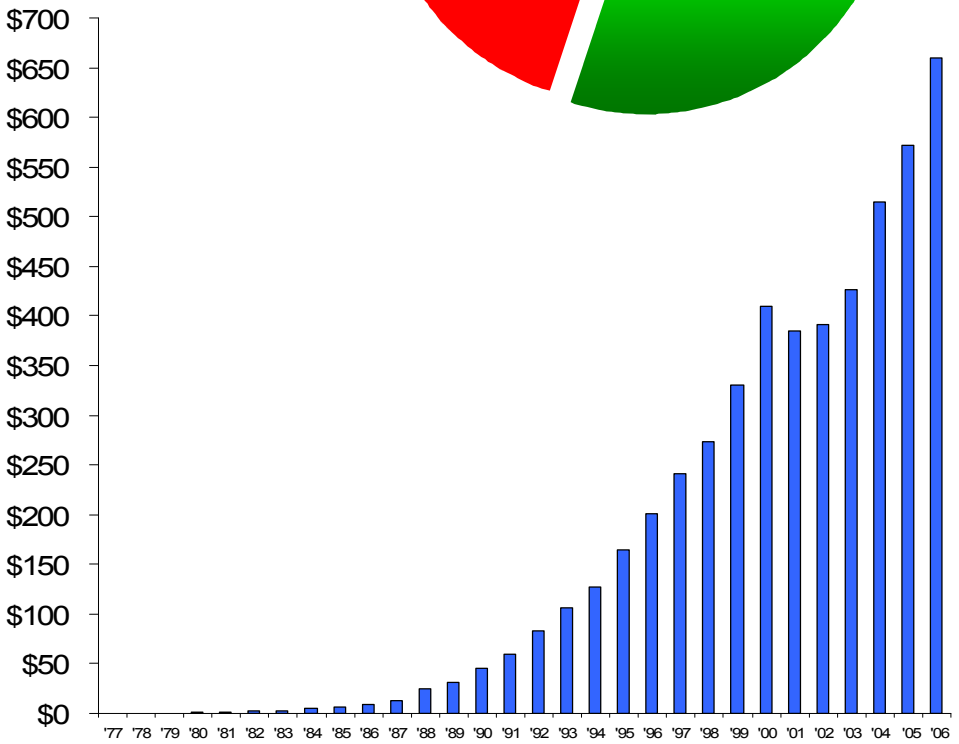
How we do it…

- Leverage mainstream PC, network, semiconductor technologies
  - ✚ User-friendly software
  - ✚ Cost-effective, modular hardware
  - ✚ Highly integrated driver software
  - = **Virtual instrumentation & PC-based Automation (PAC)**

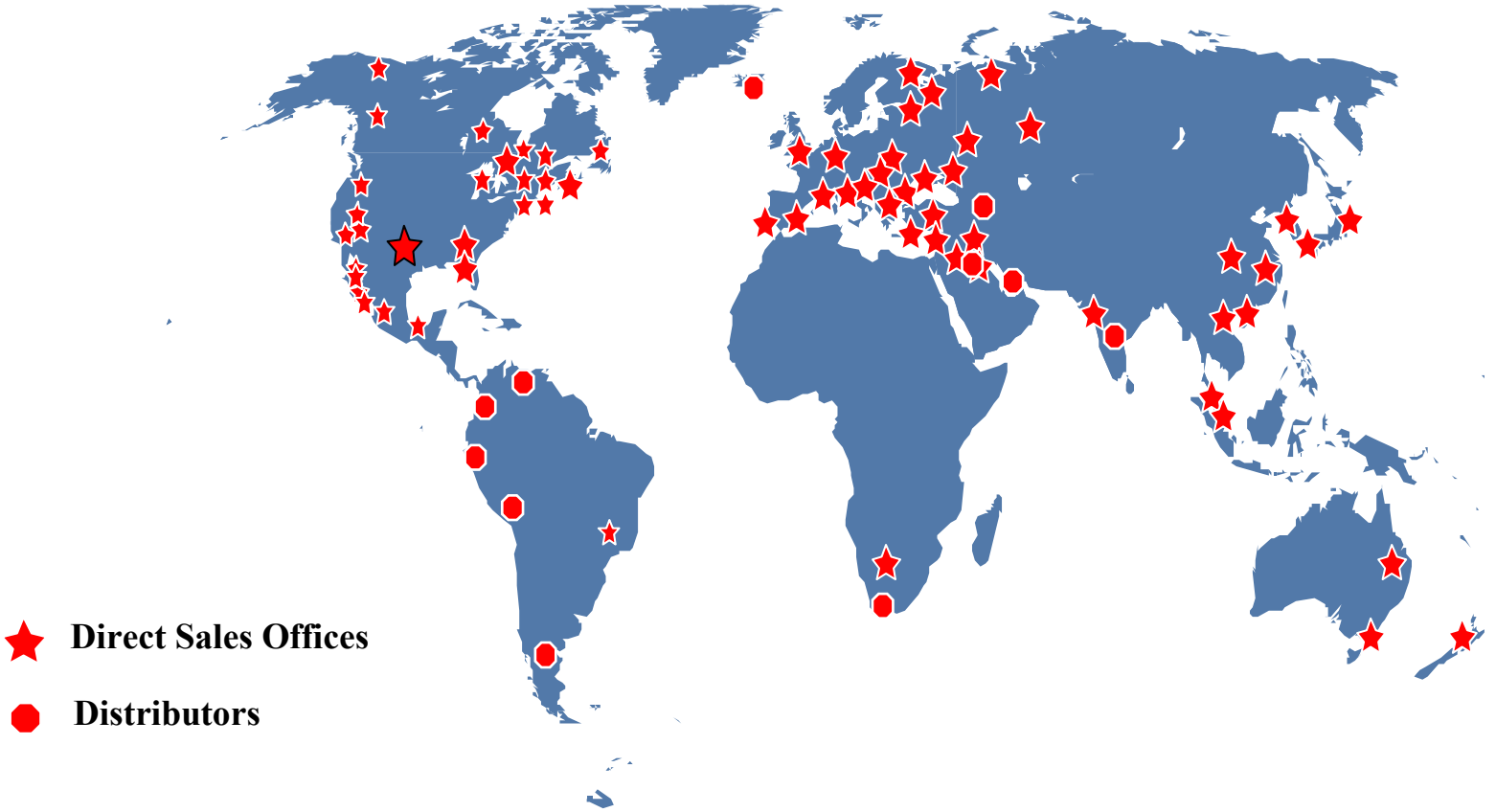
National Instruments

- 660 millones de $ de volumen de negocios en 2006: +15,5%
- Crecimiento y rentabilidad desde hace muchos años
- 16% invertido en I+D
- Más de 4.200 empleados
- NI nombrado por la revista *FORTUNE* entre las "100 mejores empresas para trabajar" por 8º año consecutivo
- La plataforma de adquisición USB NI CompactDAQ, nombrada "Best in Test" por la revista *Test & Measurement World*





Worldwide Presence



Diversity of Applications

No Industry > 10% of Revenue

Telecom

Automotive

Semiconductors

Electronics

Computers

ATE

Military/Aerospace

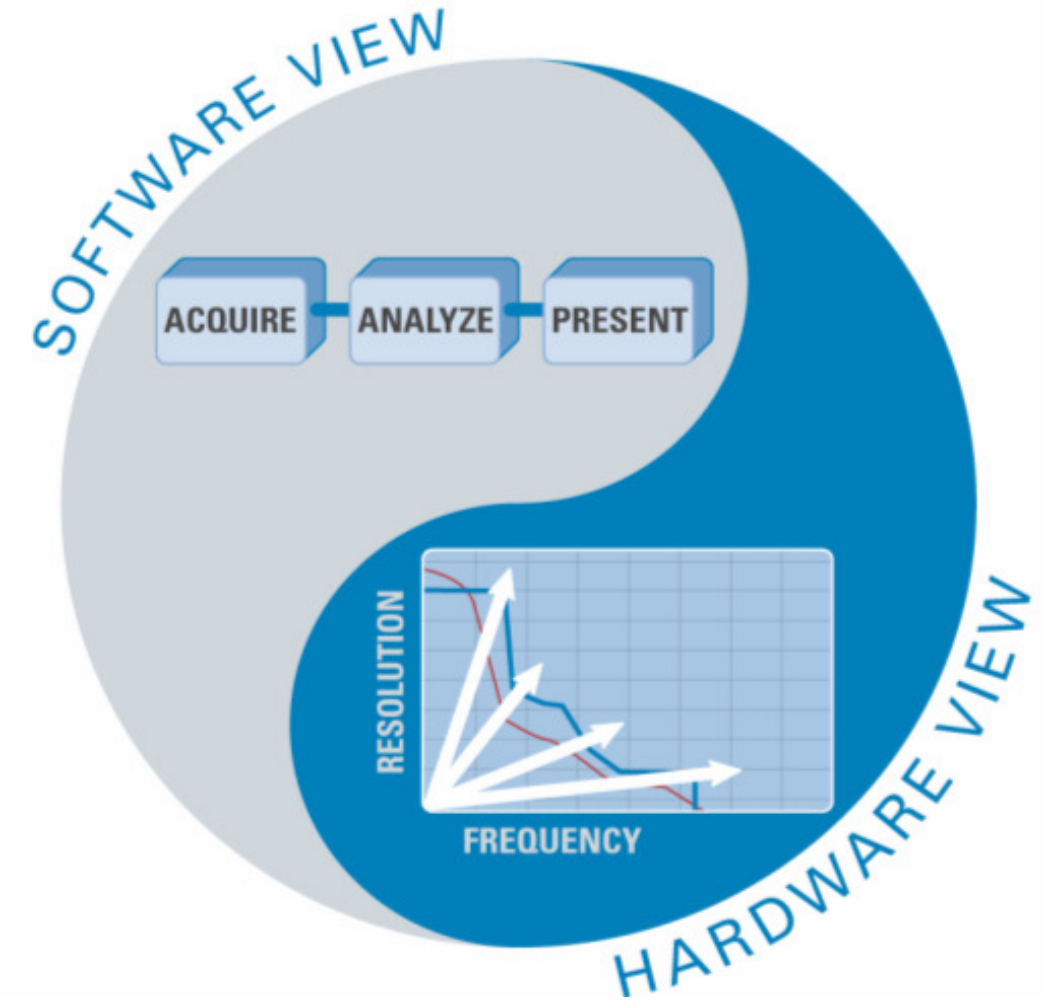
Consumer Goods

Petrochemical

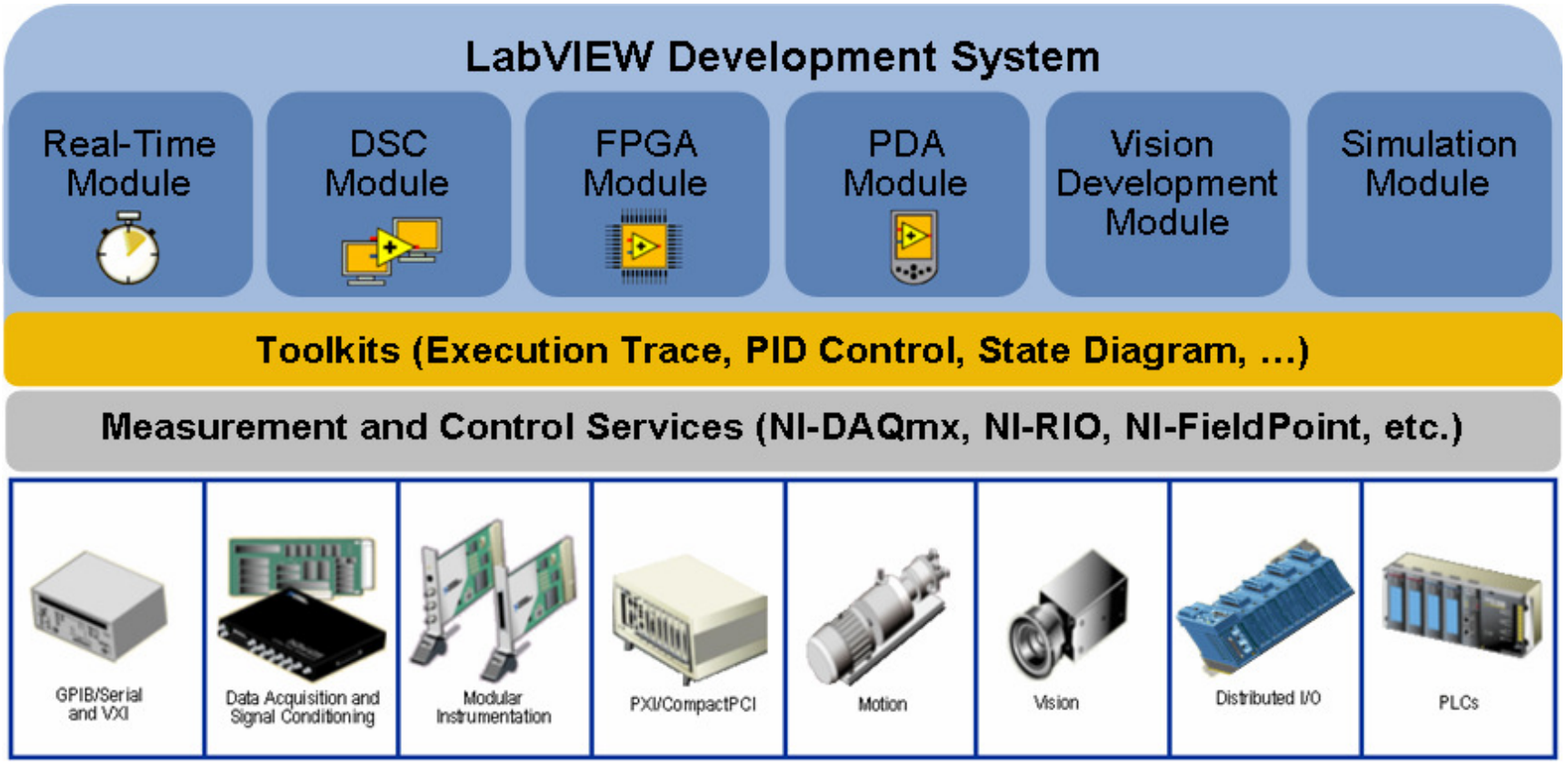
Food Processing

Textiles

Virtual Instrumentation



LabVIEW Platform



Windows Macintosh Linux

English | French | German | Japanese | Korean | Chinese

Introduction to NI Vision

Image acquisition (IMAQ) products

Vision software products

Camera configuration using MAX

The NI Vision Product Family

Vision Development Module

Programming tools for LabVIEW, C/C++, Visual Basic, and .NET

Vision Assistant

Prototype and generate scripts

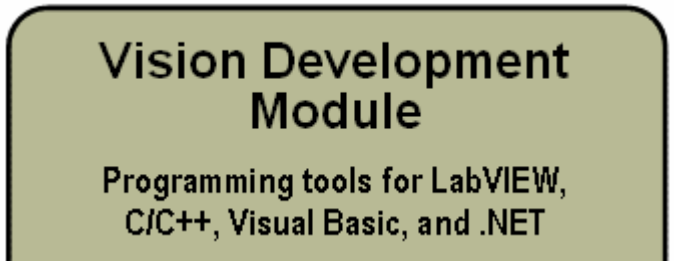
Vision Builder for Automated Inspection

Configure, benchmark, and deploy without programming

Vision Acquisition Software

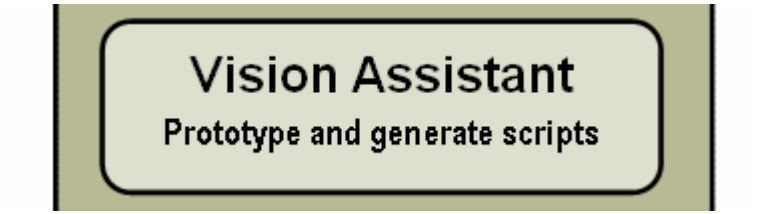
Acquire, save, and display images from 1000s of cameras

The NI Vision Product Family



- **Vision Development Module** features:
  - Hundreds of image processing functions including pattern and geometric matching, OCR, barcode readers, object classification, and particle analysis
  - Tools to enhance images, check for presence, locate features, identify objects, and gauge parts
  - Fast application prototyping and code generation with Vision Assistant

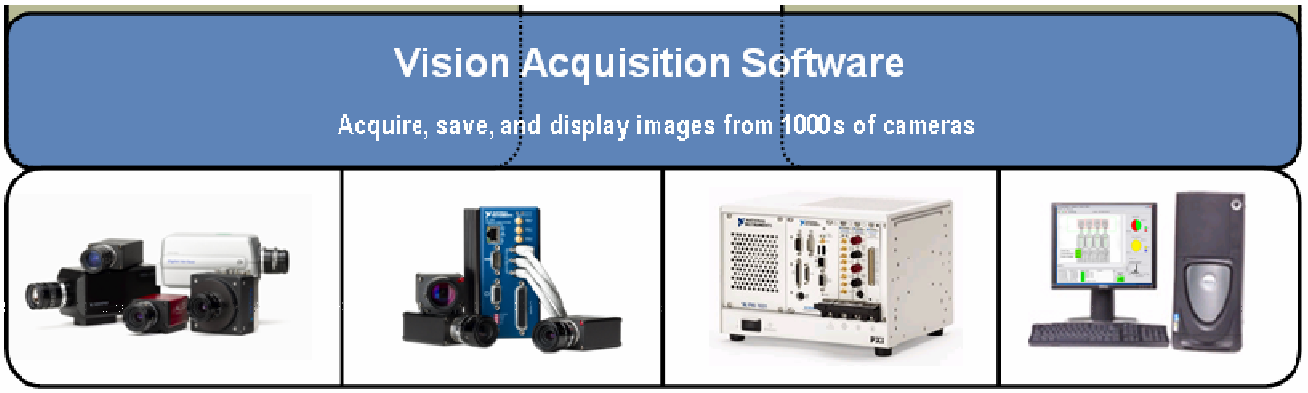
The NI Vision Product Family



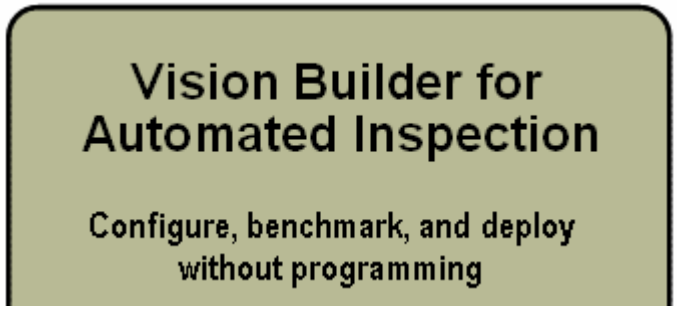
- **Vision Assistant** gives you the ability to:
  - Create complex custom algorithms
  - Generate a LabVIEW VI or C/VB program from your image processing script
  - Prototype vision systems and experiment with different image processing functions
  - Maintain your original image in the reference window while storing several images for processing in the image browser

The NI Vision Product Family

- **Vision Acquisition Software** hardware drivers:
  - Are compatible with LabVIEW, C/C++, Visual Basic, and .NET
  - Acquire, save, and display images from thousands of different cameras
  - Work with any NI frame grabber and IIDC-compliant FireWire camera
  - Are included with the Vision Development Module and Vision Builder AI
  -



The NI Vision Product Family

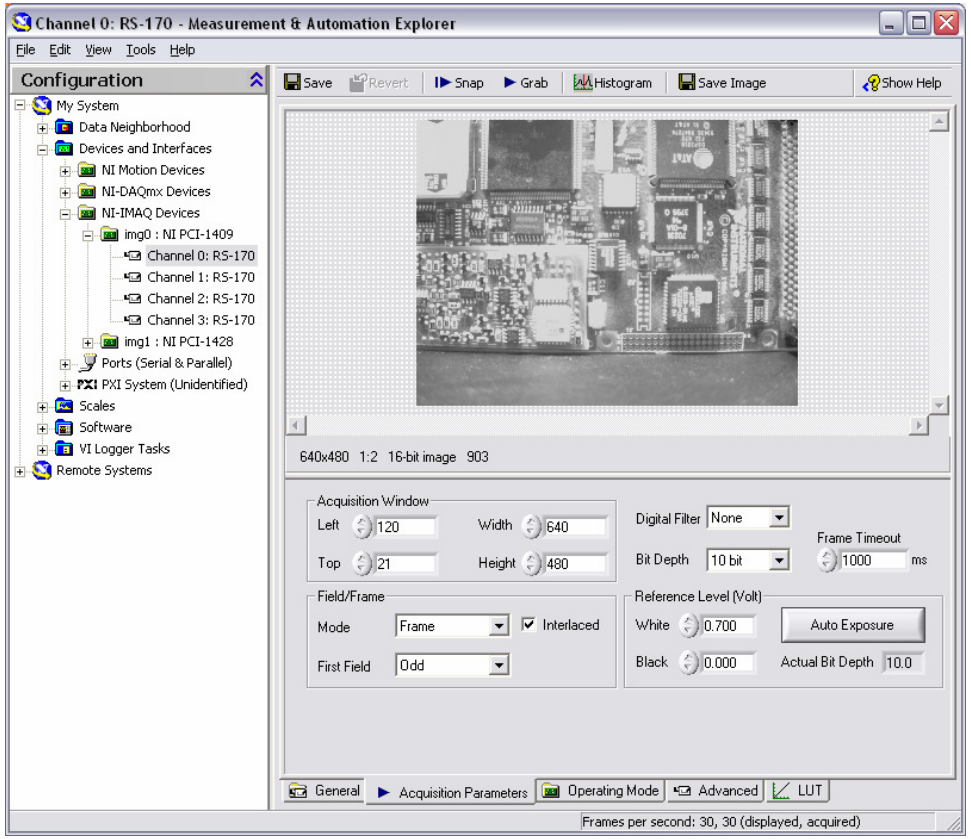


- **Vision Builder for Automated Inspection** lets you:
  - Acquire and process images with any NI frame grabber, more than 100 IEEE 1394 cameras, or the NI Compact Vision System
  - Build, benchmark, and deploy complete machine vision applications without programming
  - Configure more than 100 powerful machine vision tools including geometric matching, OCR, and particle analysis
  - Communicate triggering and inspection results directly to industrial devices over digital I/O, serial and Ethernet protocols

Measurement and Automation Explorer

One-stop configuration of all your NI hardware

- Set camera attributes
- Configure frame grabber features
- Test your acquisition
- Access remote devices on your network



NATIONAL INSTRUMENTS

Preparing Your Imaging Environment

How to choose a camera

Lighting considerations

How to choose an image acquisition device

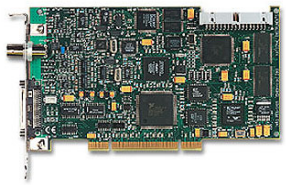
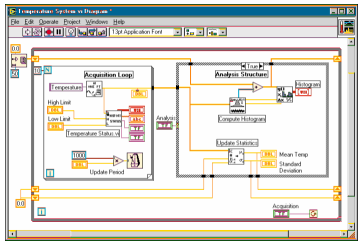
Compact Vision Systems, Smart Cameras

IEEE 1394, Camera Link, GigaEthernet

Scientific Imaging Approach

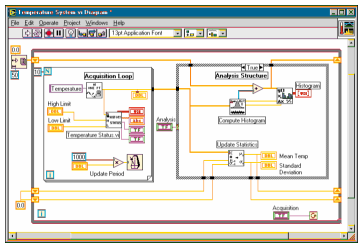
Lighting, Lens, Camera, HW, SW



Transducer, Signal Conditioning, A/D, SW





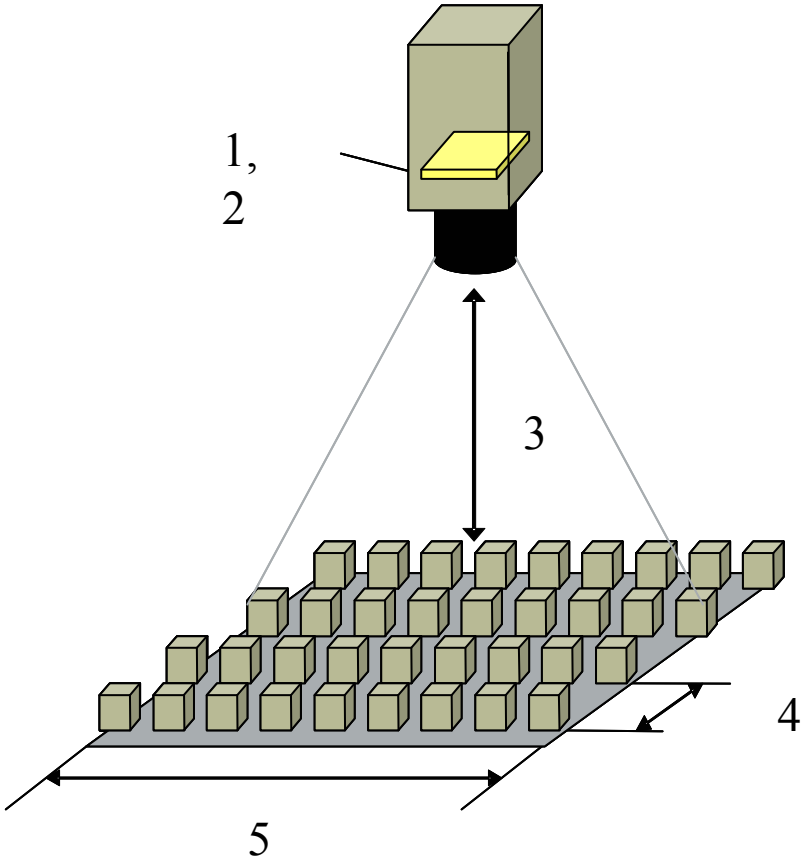
How to Choose a Camera

Deciding factors in camera choice:

- Physical dimensions of your imaging system
  - Maximize detail of features and size of projected image
- Scan type
  - Line/Area
- Format and standard of data
  - Analog/Digital, standard or nonstandard, needed bandwidth
- Budget

Imaging System Parameters

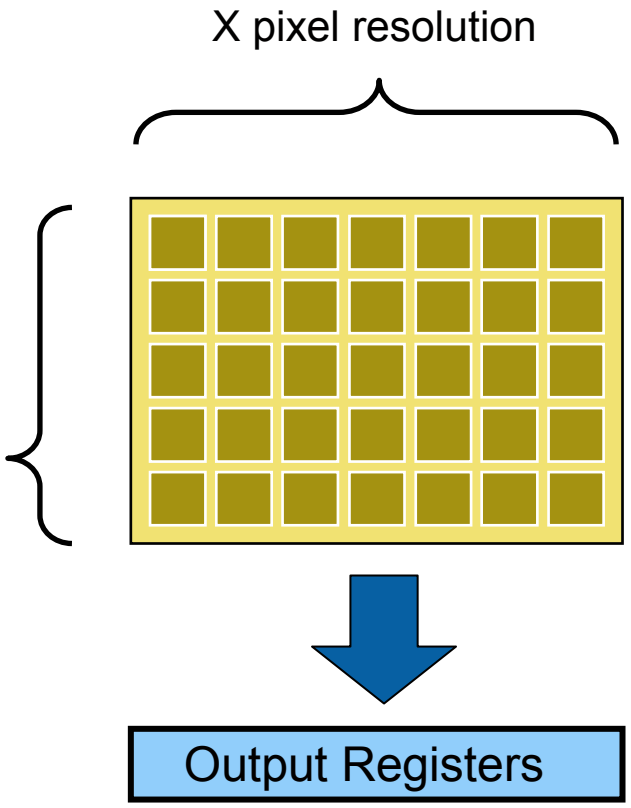
1. **Sensor resolution**: Number of columns and rows of pixels in camera sensor
2. **Sensor size:** Physical area of sensor array
3. **Working distance**: The distance from the front of the lens to the object under inspection
4. **Feature Resolution:** Smallest feature size on object that can be distinguished**.**
5. **Field of view**: Area under inspection that the camera can acquire



Sensor Resolution

Camera sensors contain an array of pixels.

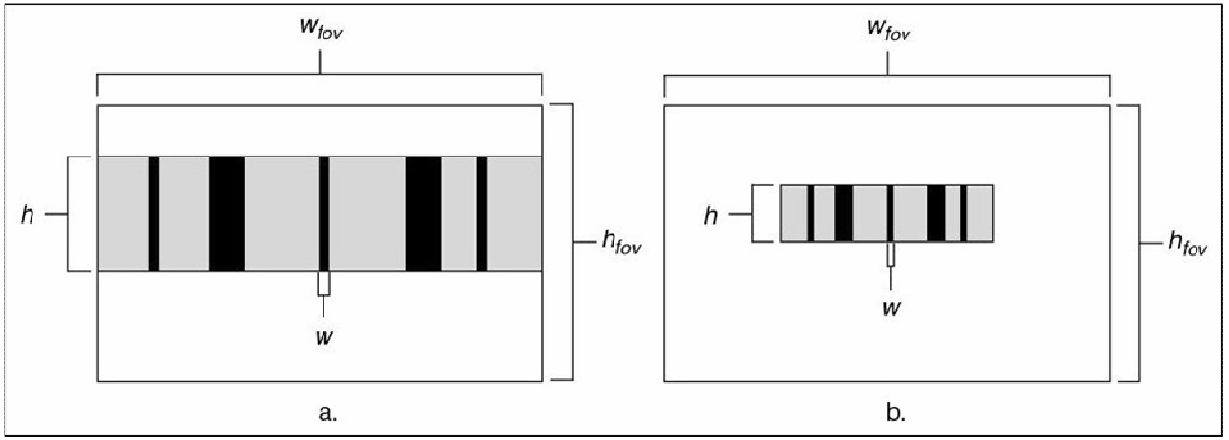
- Sense incident light intensity
- Output video data through registers



Determining Necessary Sensor Resolution

To be properly recognized by inspection algorithms, the smallest feature in the image must be represented by at least **two pixels**.

minimum sensor resolution = (FOV / feature resolution) x 2



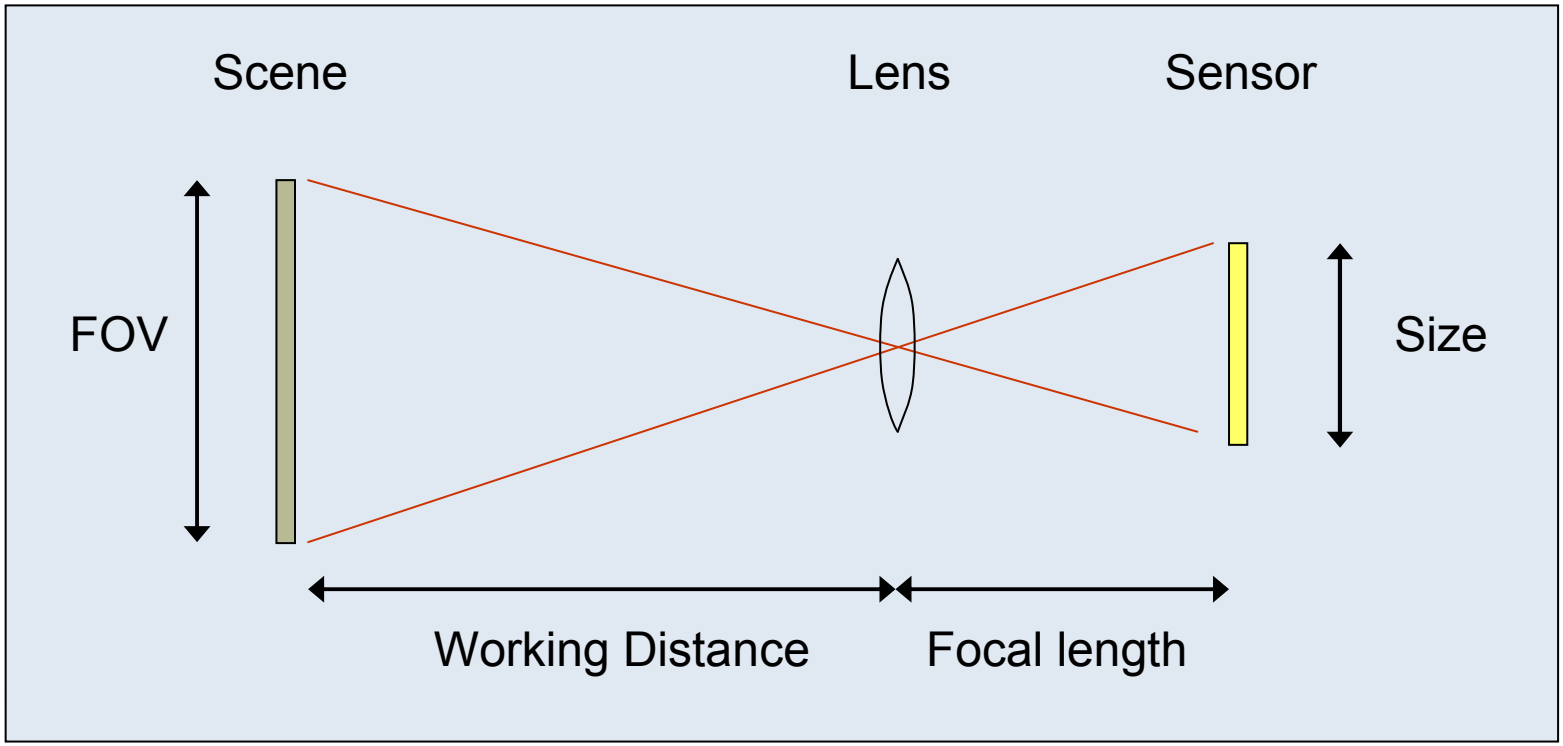
Common Sensors

Cameras are manufactured with a limited number of standard sensors

Number of CCD Pixels	FOV	Sensor Resolution
640 x 480	60 mm	0.185 mm
768 x 572	60 mm	0.156 mm
1281 x 1072	60 mm	0.093 mm
2048 x 2048	60 mm	0.058 mm
4000 x 2624	60 mm	0.030 mm

Determining Focal Length and Sensor Size

focal length = sensor size * working distance / FOV



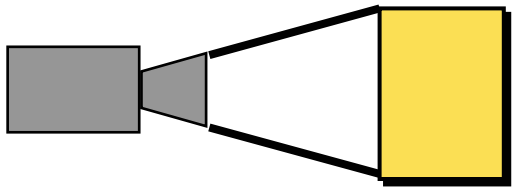
Example

- FOV H=30 mm
- FOV V=20 mm
- Requested resoltion: 0.1 mm
  - Safe: 3 pixel=0.1 mm -> 1 pixel=0.03 m…
  - 30 mm / 0.03 =1000
  - 20 mm / 0.03 = 667
  - Sensor Size 1000x1000
  - ANALOG not valid

Scan Type

Area Scan

Scans an area of pixels and acquires the entire rectangular image at once.



Advantages:

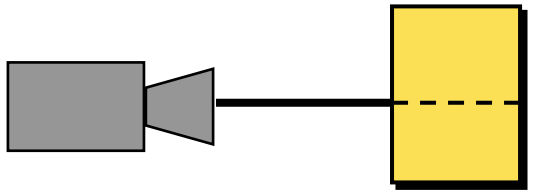
- Less processing needed
- Inexpensive

Disadvantage:

- Slower acquisition

Line Scan

Scans one line of pixels at a time, and image is pieced together afterward.



Advantages:

- Faster acquisition
- Accommodate moving objects

Disadvantages:

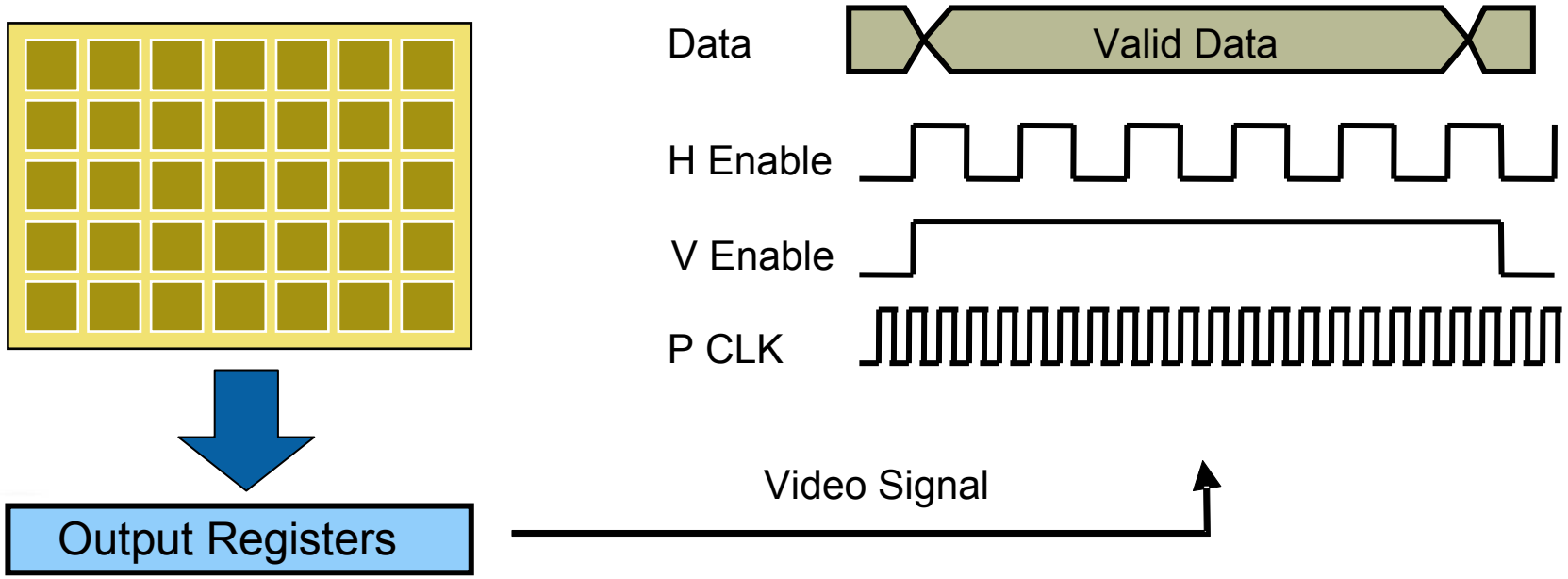
- Processing required to build image
- Expensive

Analog Cameras: Standard Formats

Standard	Location	Frames per second	Color	Image size
RS-170	USA, Japan	30	No	640 x 480
NTSC	USA, Japan	30	Yes	640 x 480
CCIR	Europe	25	No	768 x 576
PAL	Europe	25	Yes	768 x 576

Camera Formats: Digital

- Digitizer housed inside the camera
- High image quality and pixel depth
- Large image sizes and high frame rates



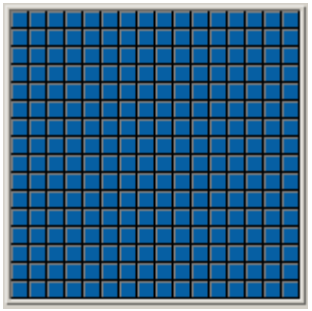
Digital Cameras: Standard and Nonstandard

Interface	Advantages	Disadvantages
Parallel	High speed Easy to configure	Complex cabling No interface standards
IEEE 1394 (FireWire)	Simple cabling Low cost	Slower data transfer rate
CAMERA Link®	High speed Uniform cables Standard interface	10m cable length limit

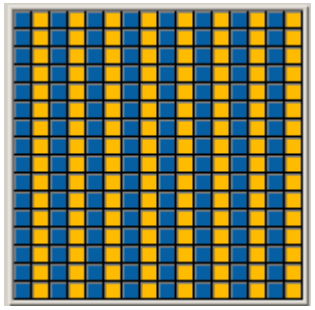
Digital Cameras: Taps

A tap, or channel, is a group of data lines that carry one pixel

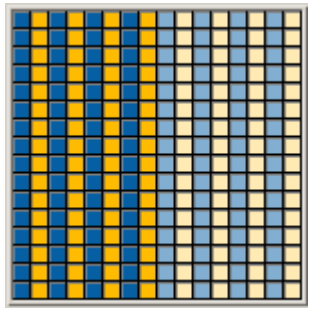
- Single-tap cameras latch only one pixel during the active edge of the pixel clock
- Multi-tap cameras can access multiple pixels during one active edge



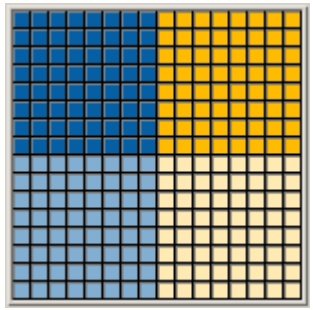
1 tap



2 taps interlaced vertically



4 taps split and interlaced vertically



4 taps in quadrants

Camera Formats: Summary

Analog

Digital

Advantages

- Established technology
- Simple cabling
- Low cost

Advantages

- High speed, high pixel depth, and large image sizes
- Programmable controls
- Less image noise

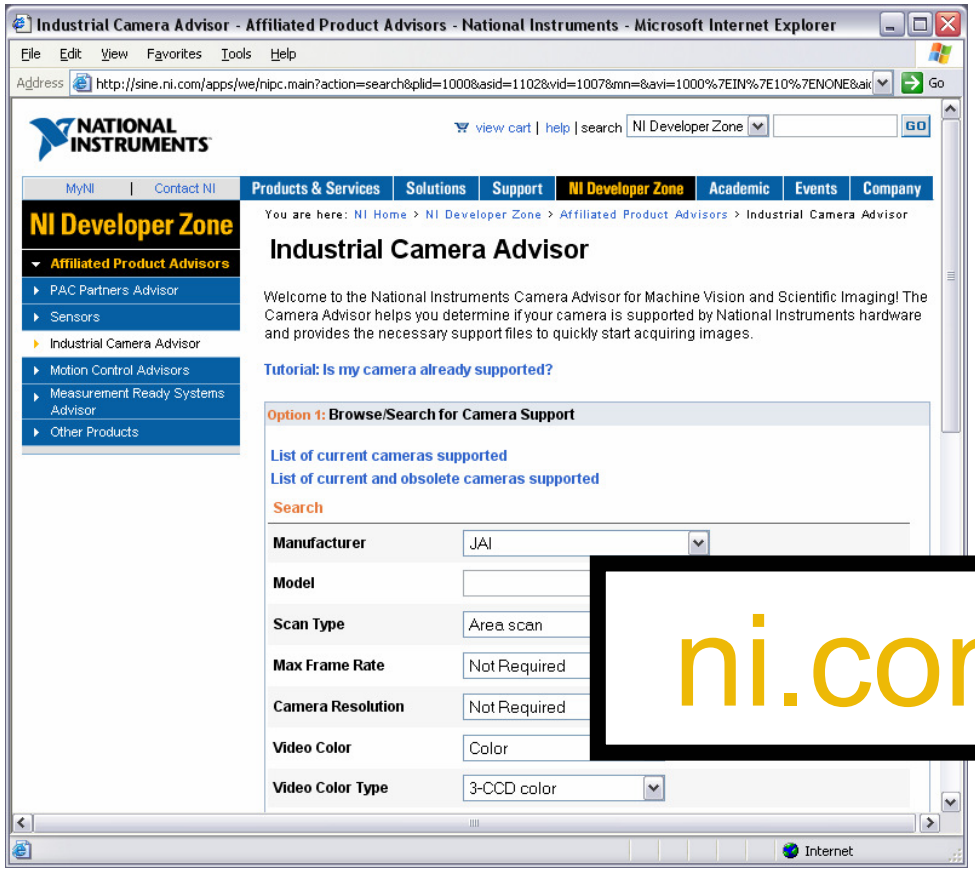
Disadvantages

- Little market variation
- Potentially poor image quality

Disadvantages

- Expensive
- May require custom cables
- May require **camera files** for custom configuration

Camera Advisor



- Helps you select the right camera
- Contains full camera specifications

ni.com/cameras

Lighting: A Critical Consideration

- Lighting is one of the most important aspects in setting up your imaging environment.
  - Separates the feature you want to inspect from the background of the image
  - Makes your image processing easier and faster
  - Reduces glare, shadows, and effects caused by changes in weather or time of day

Ring Lighting

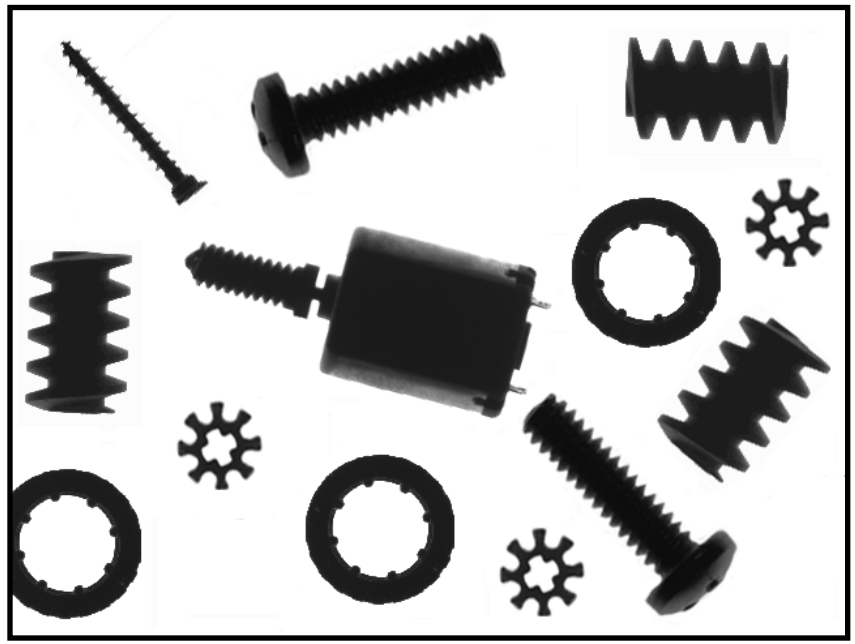
Light encircles the camera lens

Advantage: Even illumination without shadows along lens axis

Disadvantage: Can produce a circular glare

Backlighting

Object placed between camera and light source.



Advantage: creates a sharp contrast that makes finding edges and measuring distances easy

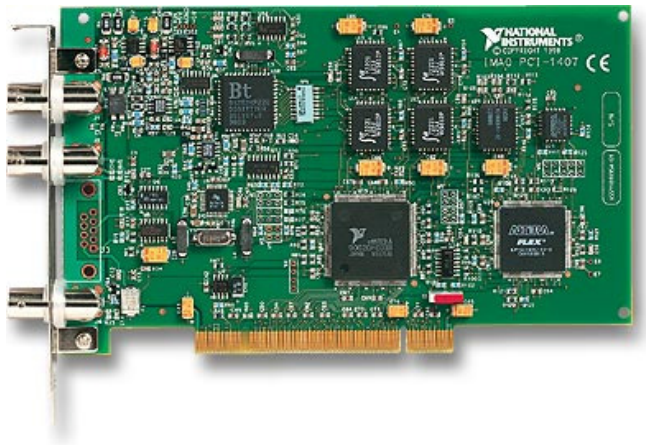
Disadvantage: curved objects can diffract light.

Diffused Lighting

- Some objects reflect light due to their surface texture or curvature
- You can use diffused lighting to eliminate glare

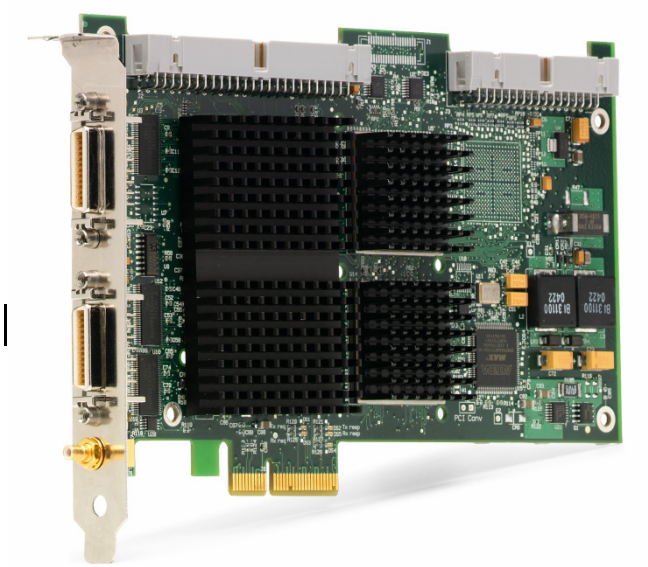
Analog IMAQ Hardware

- Support for color and monochrome cameras
  - Up to four monochrome channels
- Standard and nonstandard formats
  - All worldwide standards (RS-170, CCIR, NTSC, PAL)
  - S-video and progressive scan connections
- Plug into PCI and PXI form factors



Digital IMAQ Hardware

- Support for 32-bit color and 16-bit monochrome cameras
  - Multiple taps
  - Multiple cameras
  - Pixel clock up to 85 MHz
- Standard and nonstandard interfaces
  - IEEE-1394, CameraLink, parallel digital
- Plug into PCI, PXI, PCIe form factors



Compact Vision System

- Embedded high-performance processor for increased inspection speed
- 3 FireWire camera inputs
- Integrate with other devices through Ethernet, serial, and digital I/O
- Configure with NI Vision Builder

  for Automated Inspection, or prograr
  with NI LabVIEW and

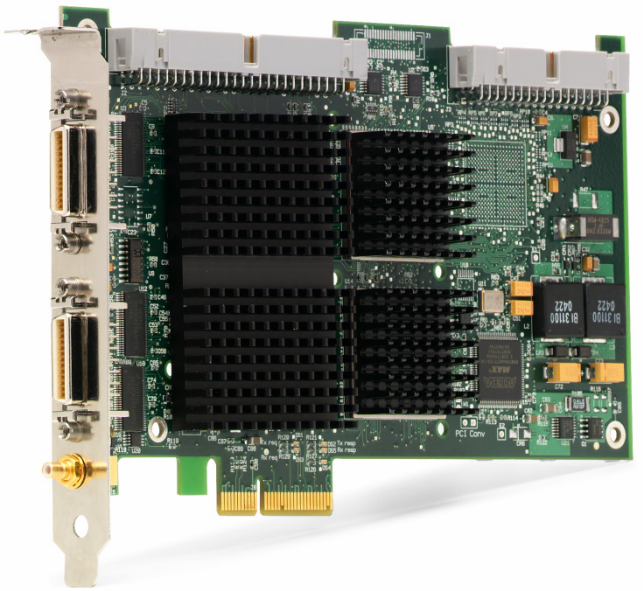
  Vision Development Module

NI Vision Hardware

- Frame grabber boards
  - PCI, PXI, PCIe
  - Standard and non-standard analog cameras
  - Digital cameras, including Camera Link
  - IEEE 1394 and GigE
- Compact Vision Systems

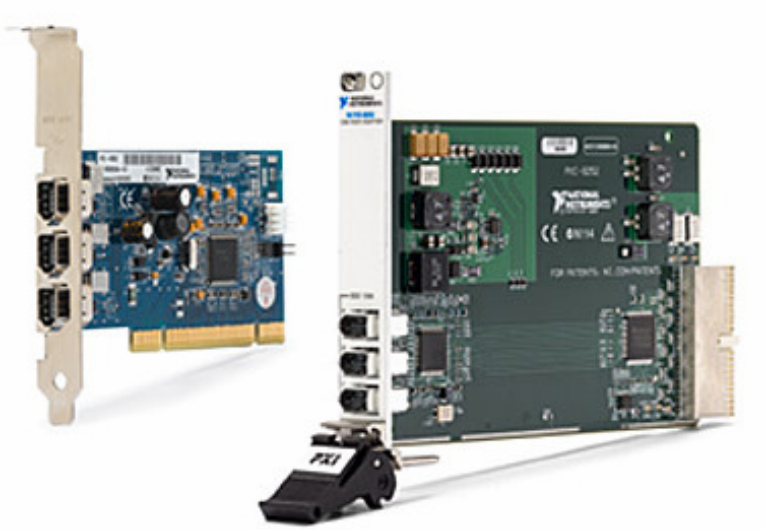
New PCIe 1429 – Industry's First

- **World's first PCIe Camera Link board**
- **Supports any Camera Link**
- **Specifications**
  - Full-configuration Camera Link
  - 680 MB/s
  - Extended I/O options
    - Isolated I/O, pulse train outputs, encoder inputs, stop triggers



NI IMAQ 1394

- PCI 8252/54
  - FireWire IEEE-1394
  - Standard
    - Electrical
    - Connectivity
    - Timing
  - Up to 800 Mb/sec



NI IMAQ GigE

PCIe 8231

GigaEthernet

Up to100 Mb/sec

NI Smart Camera Family

Multiple sensors, starting with
- Monochrome CCD, VGA 60fps
- Partial scan (½, ¼) and Binning

Lighting Control
- Pulse generation (5V TTL, 24V)
- DirectDrive – Current controller

Powerful processing
- Power PC 400/533 MHz
- DSP 720 MHz

LabVIEW Vision Builder
for Automated Inspection

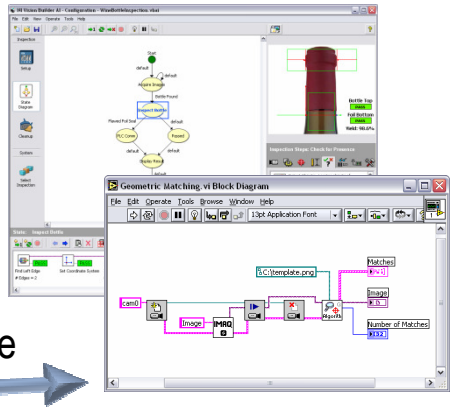
Dual Gigabit Ethernet
- I/O extension
- Debugging

Industrial I/O
- Opto isolated 2-in & 2-out
- RS232
- Encoder support

NI Smart Camera Eco-System

Lens

Lighting



Software

Camera Fixture

Operator Interface

Enclosure

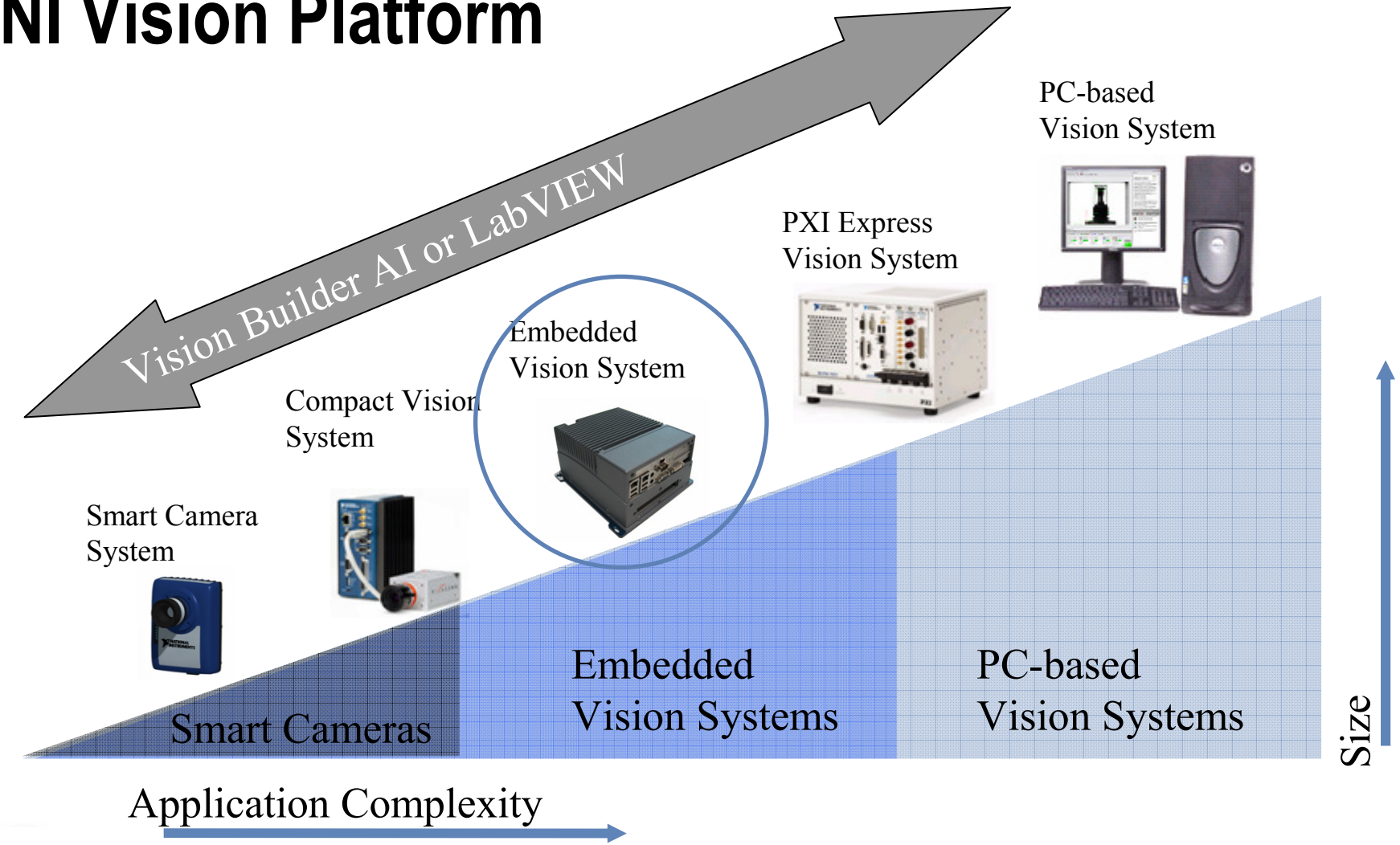
Direct I/O

Power Supply

Ethernet Expansion I/O

NATIONAL INSTRUMENTS

NI Vision Platform



NATIONAL INSTRUMENTS

Embedded Vision System

- High performance processor
- Rugged, embedded, passive cooling
- Operating system
  - LabVIEW RT
  - Windows
- Vision Acquisition
  - IEEE 1394a/b & GigE
  - Camera Link
- I/O tailored to Camera interface
- Price ~ $3500-$4000

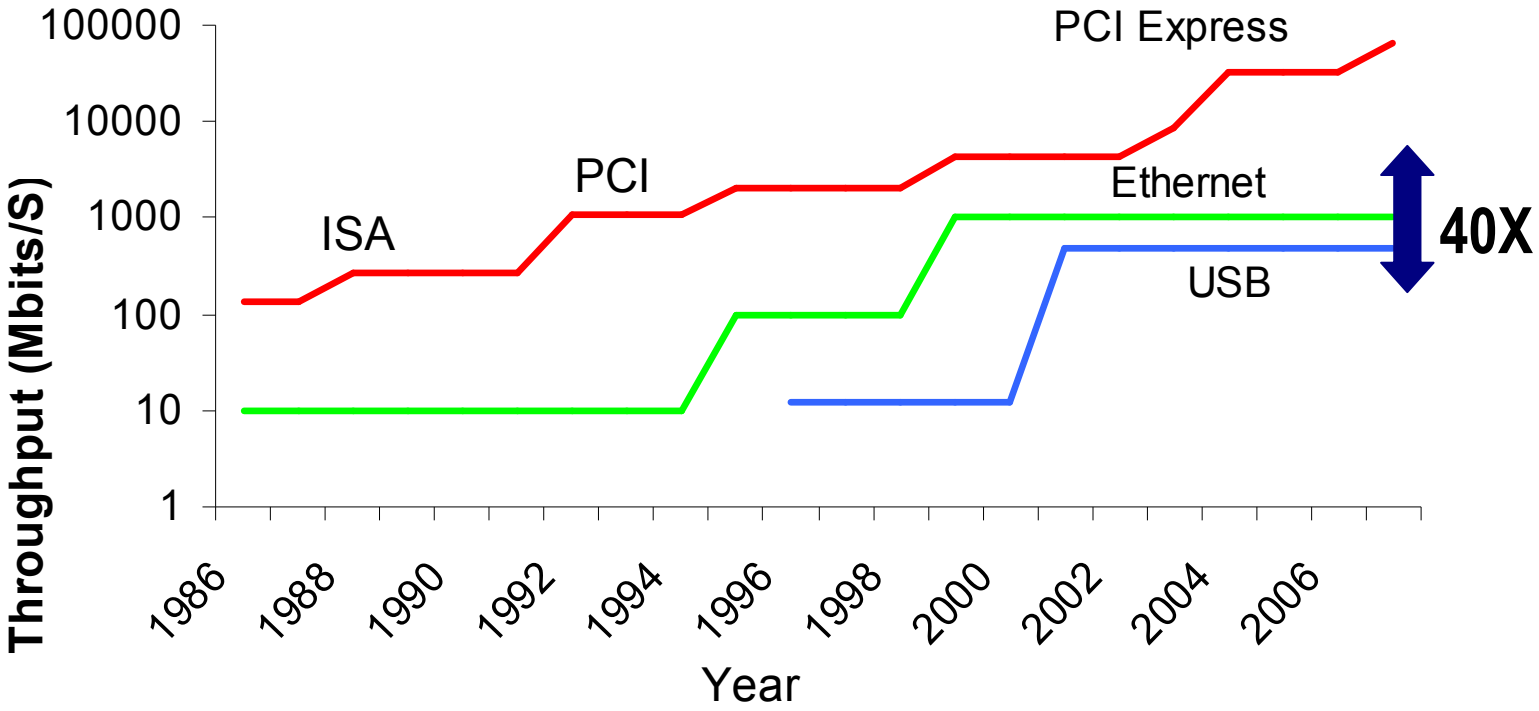
Dimensions 200W x 220L x 110H

EVS - Controller

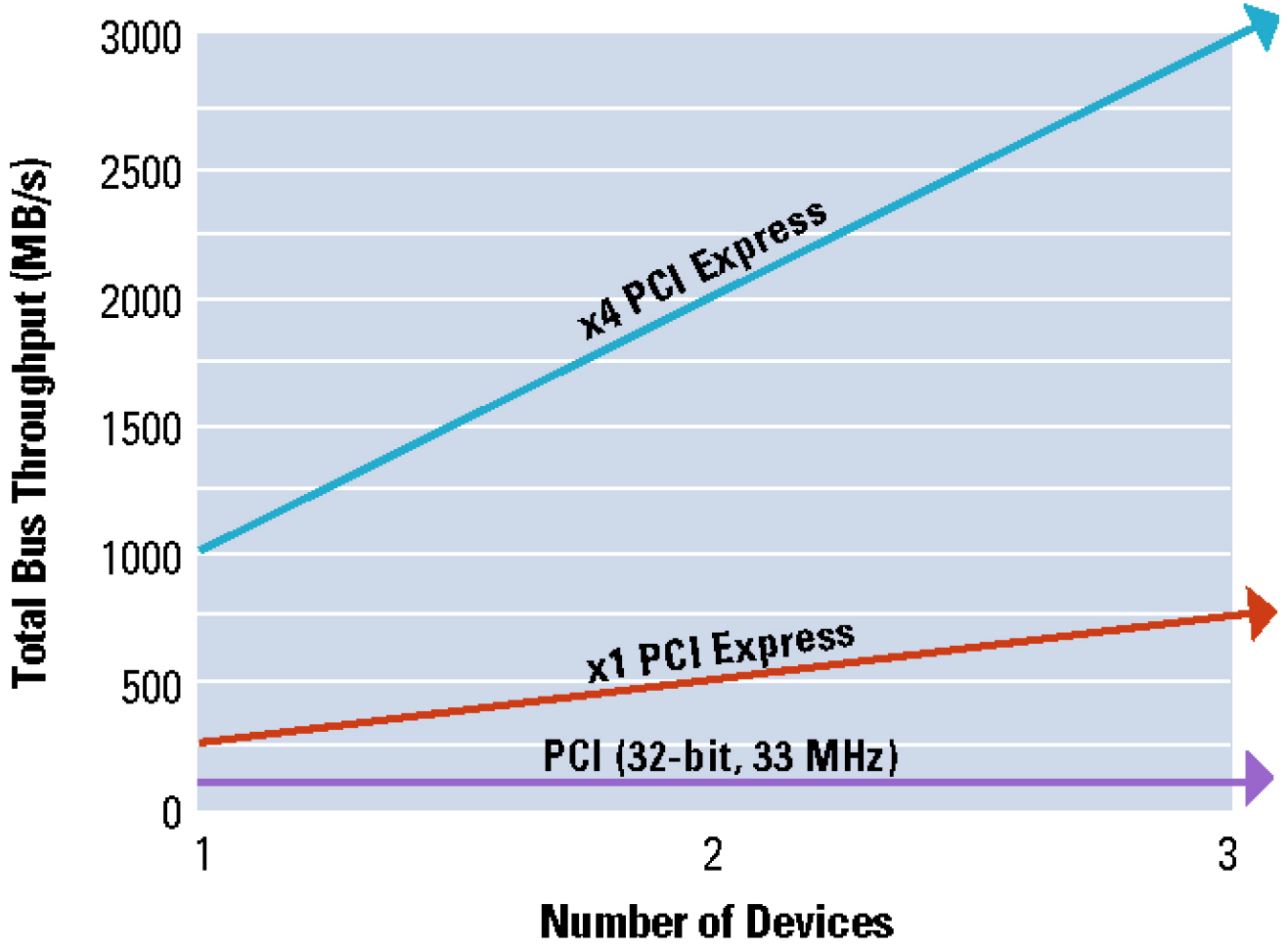
- Core Duo 1.66GHZ, 1 GB DDR2 memory
- Intel 945 Chipset
- 512 MB STHDD (RT) / 40GB HDD (Wir`
- Removable CF
- Cabled PCIe x1
- 4 x USB 2.0
- Dual Video (DVI-I) with external splitter
- Dual Gigabit Ethernet (Intel 82573)
- External DC PSU (12-30V input)

Dimensions 200W x 220L x 110H

La evolución de los buses de comunicación



Ancho de banda de los buses más comunes

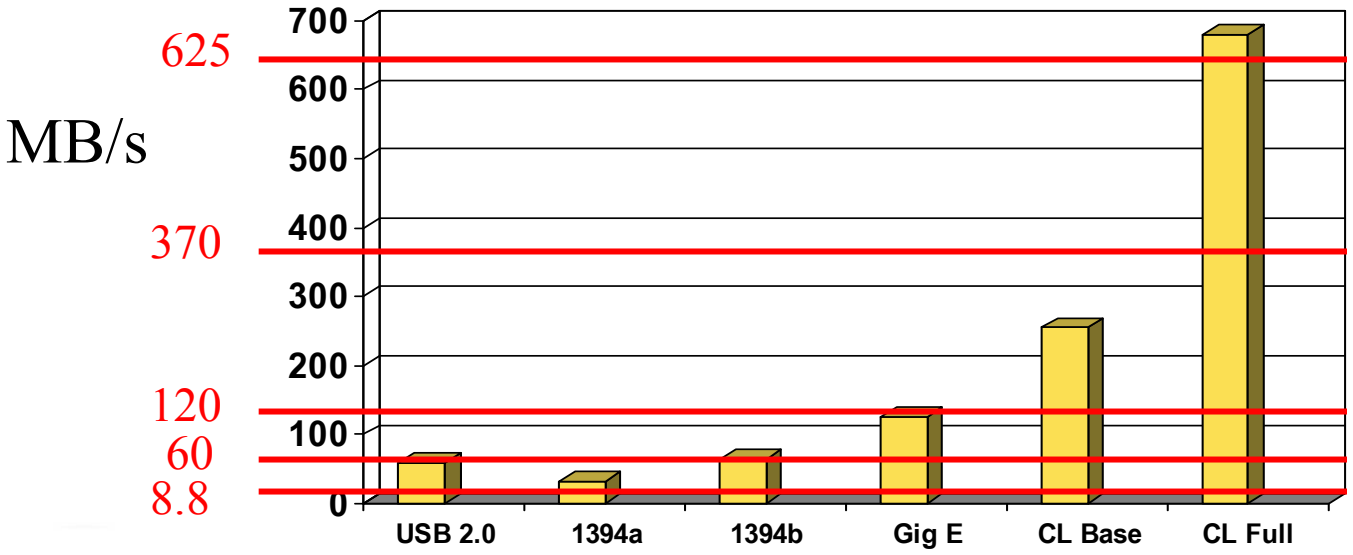


Relative Data Rate Comparisons

– Maximum data rate: ~125 MB/s

Resolution x Frame Rate x Bytes per pixel

(1360 x 1024) x 30 fps x 1 Bpp = 37.5 MB/s



Benefits of Gigabit Ethernet for Vision

- Cable
  - Length 100 m
  - Flexibility
  - Cost
- Maximum Throughput: ~125 MB/s
- Network Capable

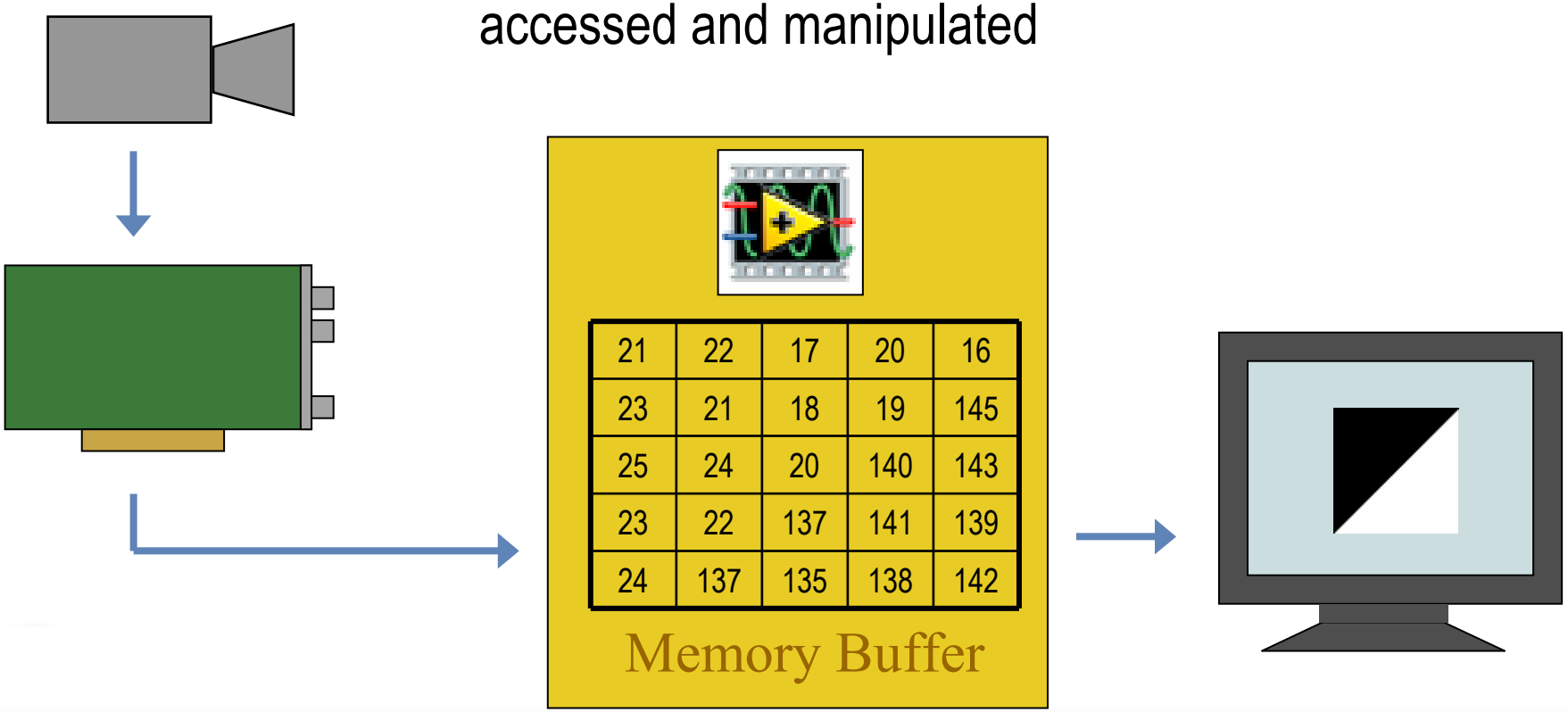
Acquiring and Displaying Images

NI-IMAQ utility functions
Single and multiple buffer acquisitions
Displaying images
Triggering features of NI-IMAQ

Images in Memory

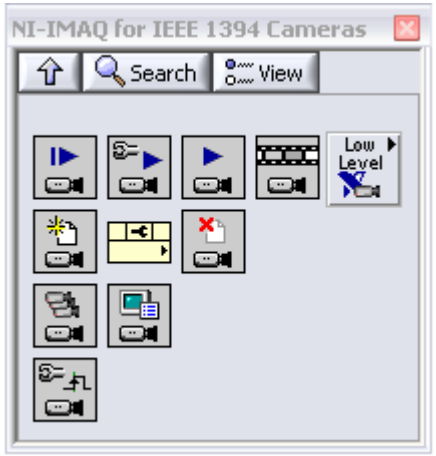
Images are not displayed directly when acquired.

- Stored in a memory buffer so they can be accessed and manipulated



Vision Acquisition Software

- **NI-IMAQ for IEEE 1394 Cameras** driver
- **NI-IMAQ** driver for NI frame grabber devices
- **NI-IMAQ I/O** personality for reconfigurable devices (FPGA)



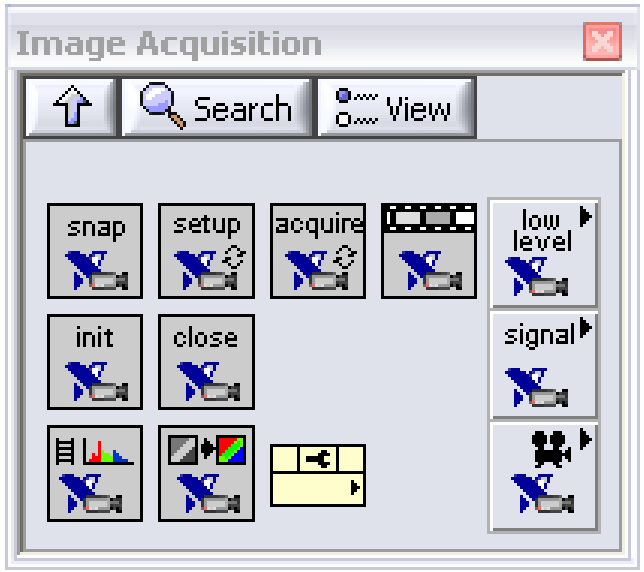


Image Acquisition Functions

- Acquisition management
  - Configure sessions and memory allocation
- Single buffer acquisition
  - Acquire images to one memory buffer
- Multiple buffer acquisition
  - Acquire images to multiple memory buffers
- Trigger
  - Synchronize acquisition with real-world events
- Display
  - Customize image display and user interface

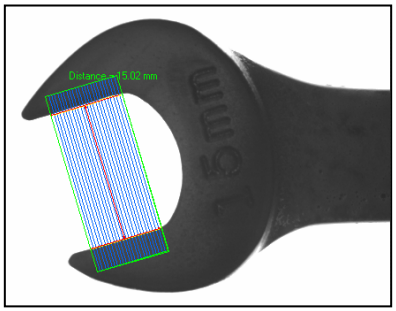
Processing Images

Selecting NI Vision functions to suit your application

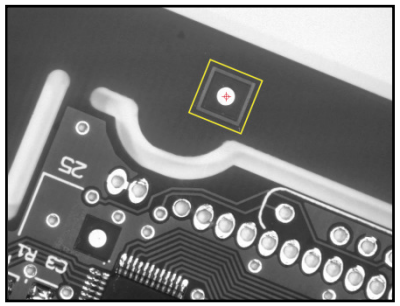
Using Vision Assistant to prototype your application

NI Vision Algorithms

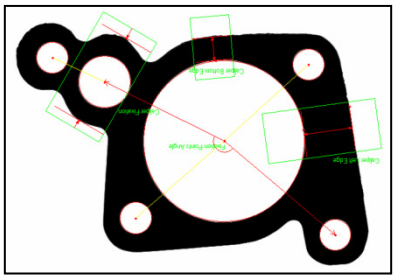
- **Enhance Image**
  - Calibrate Images
  - Filters



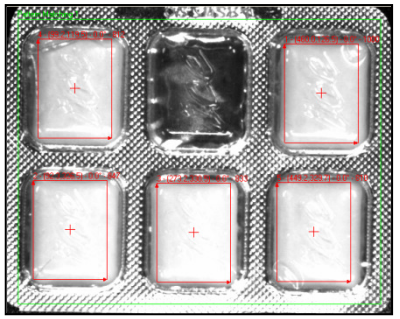
- **Locate Features**
  - Match Patterns
  - Detect Edges



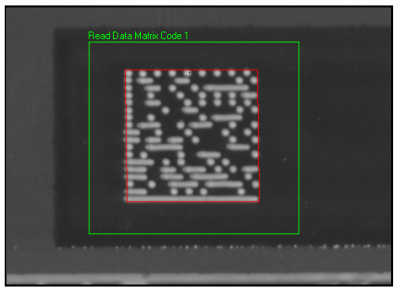
- **Measure Features**
  - Gauge
  - Geometry



- **Check for Presence**
  - Measure Intensity
  - Analyze Particles
  - Match Colors



- **Identify Parts**
  - Read characters (OCR)
  - Read 1D Barcodes
  - Read Data Matrix codes
  - Read PDF417 codes
  - Classification – NEW!



NI Vision

NI Vision functions are divided into three categories:

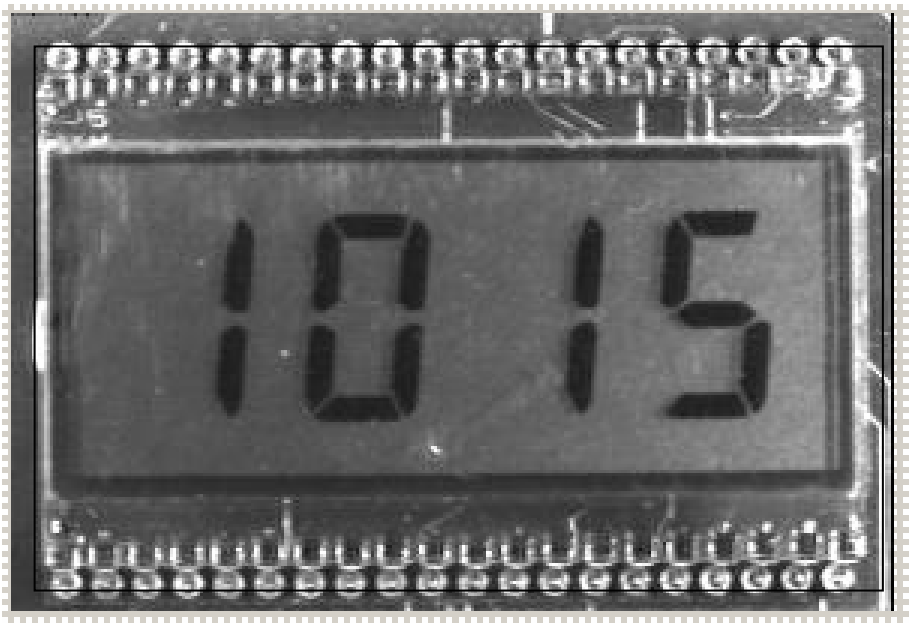
- **Vision Utility** VIs allow you to create and manipulate images to fit your application
- **Image Processing** VIs analyze, filter, and process images
- **Machine Vision** VIs perform common machine vision inspection tasks

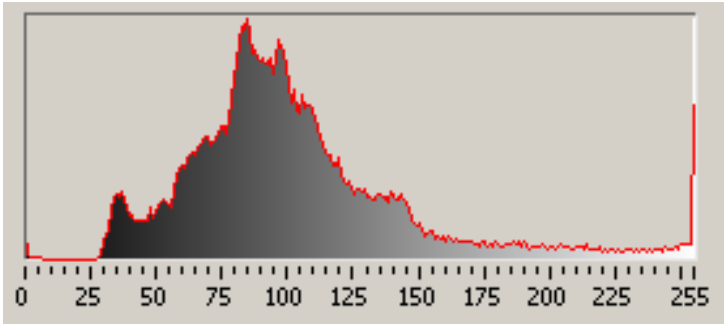
NI Vision

- Most of the fall into these function categories:
  - Statistics
  - Particle analysis
  - Pattern matching
  - Edge detection
  - Gauging

Statistics

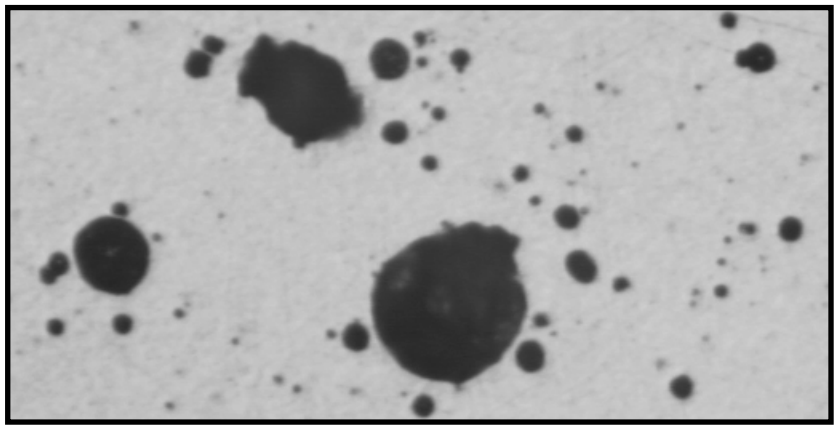
- Detect objects in an image with histograms
- Evaluate lighting and focus using standard deviation

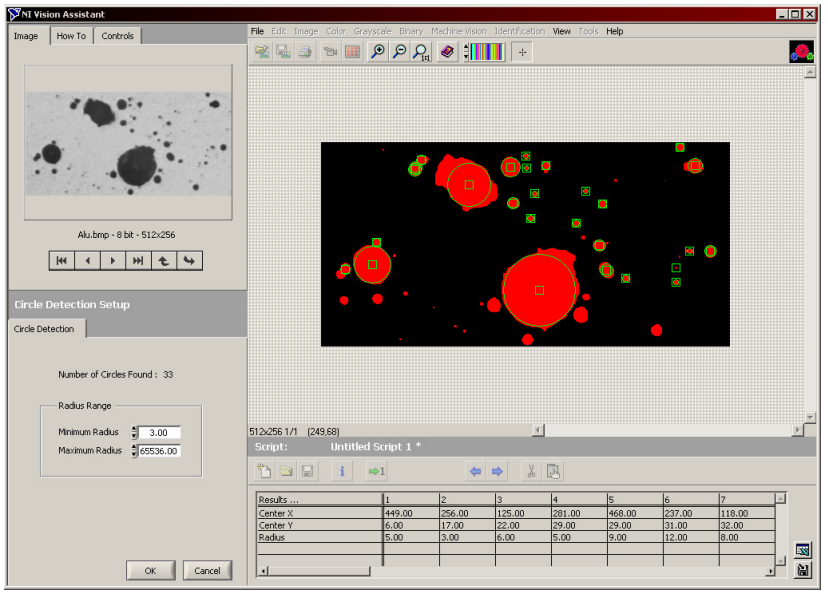




Particle Analysis

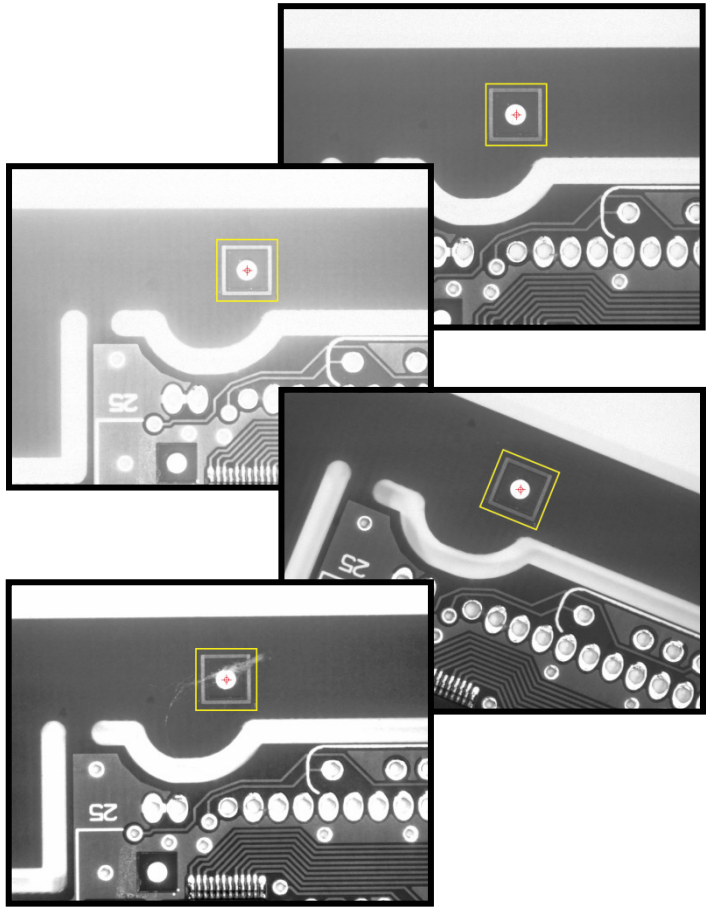
- Calculate particle area, perimeter, location, and more than 50 other parameters
- Count, label, and filter particles





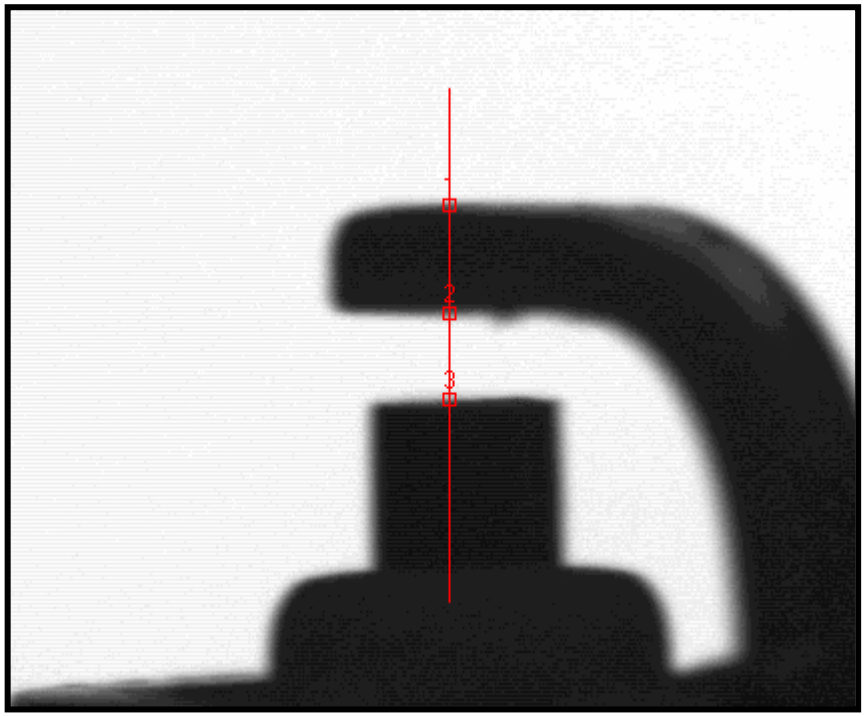
Pattern Matching

- Locates patterns very quickly
- Resistant to changes in
  - Lighting
  - Rotation
  - Focus
  - Shape
- Supports partial occlusion



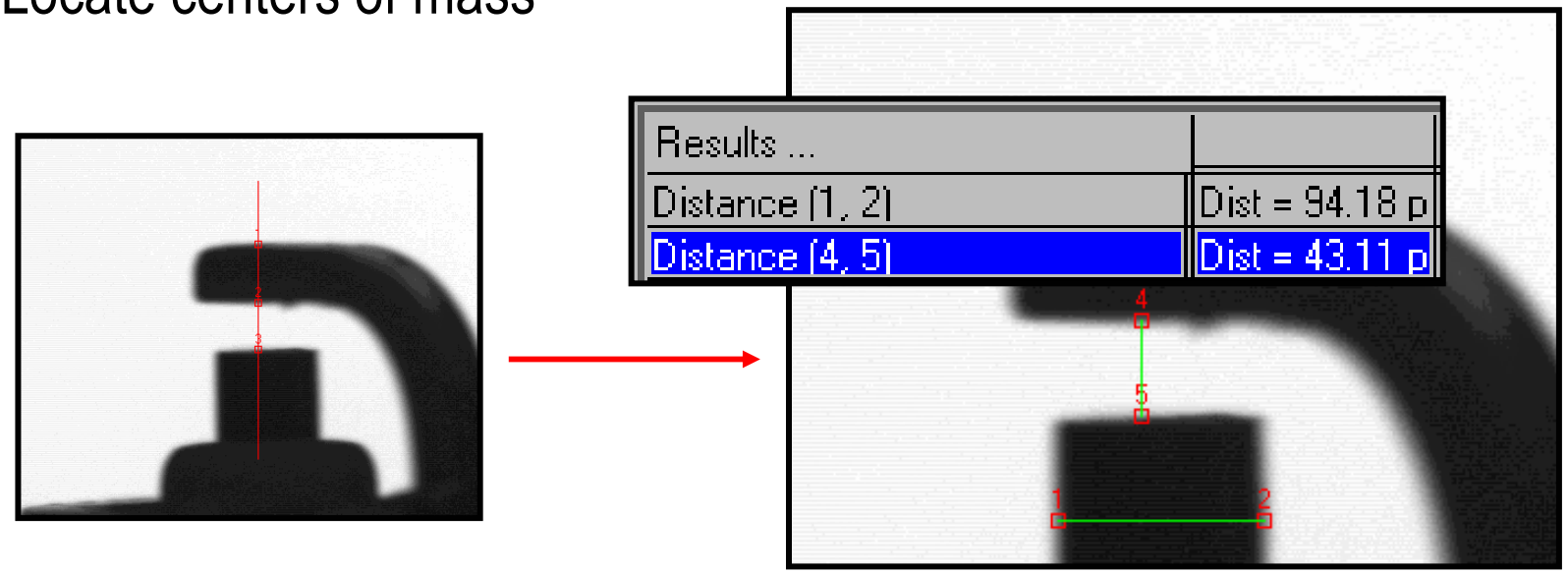
Edge Detection

- Find the edges of objects along any line in an image
- Test for sharpness
- Use edge positions for alignment and gauging
- Sub-pixel accuracy



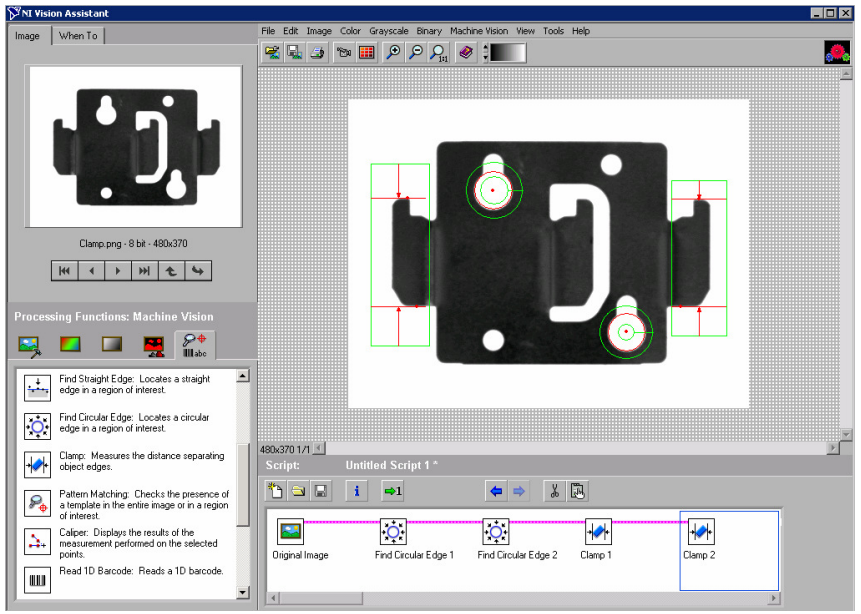
Gauging

- Measure angles and distances
- Identify linear midpoints
- Locate centers of mass



Many More NI Vision Functions

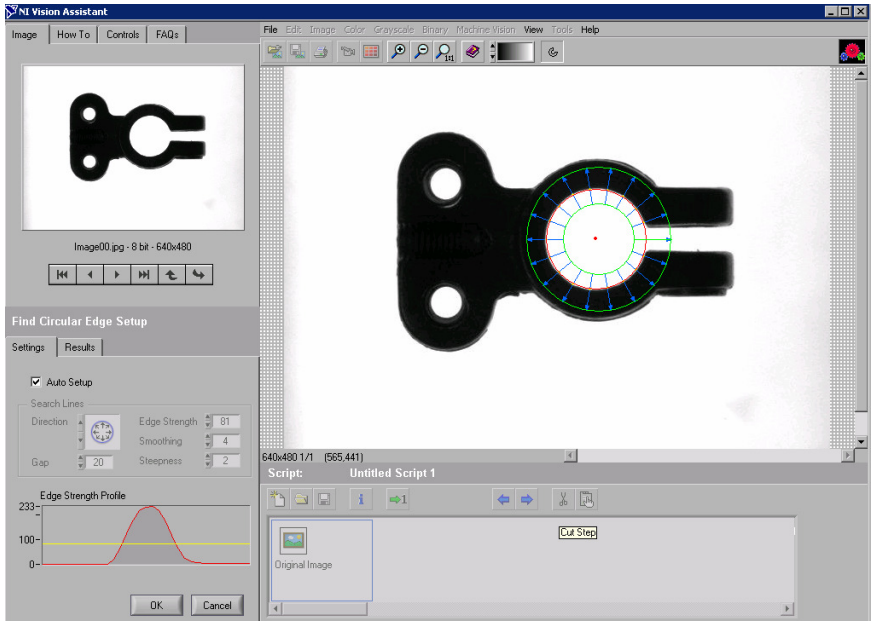
- Calibration
- Color matching
- Color pattern matching
- Line profiles
- FFTs and correlation
- Geometric transformations
- Resampling and equalization
- Arithmetic and logic operators



NATIONAL INSTRUMENTS

Vision Assistant

- Introduce the Vision Assistant scripting program



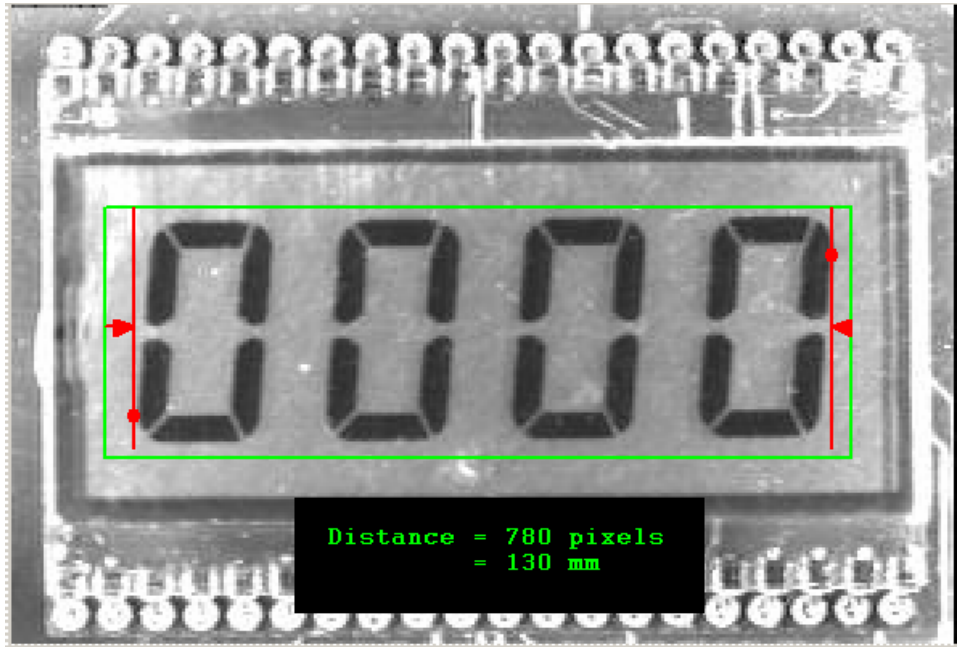
Enhancing Acquired Images

Spatial Calibration and Perspective Correction

Spatial Filtering

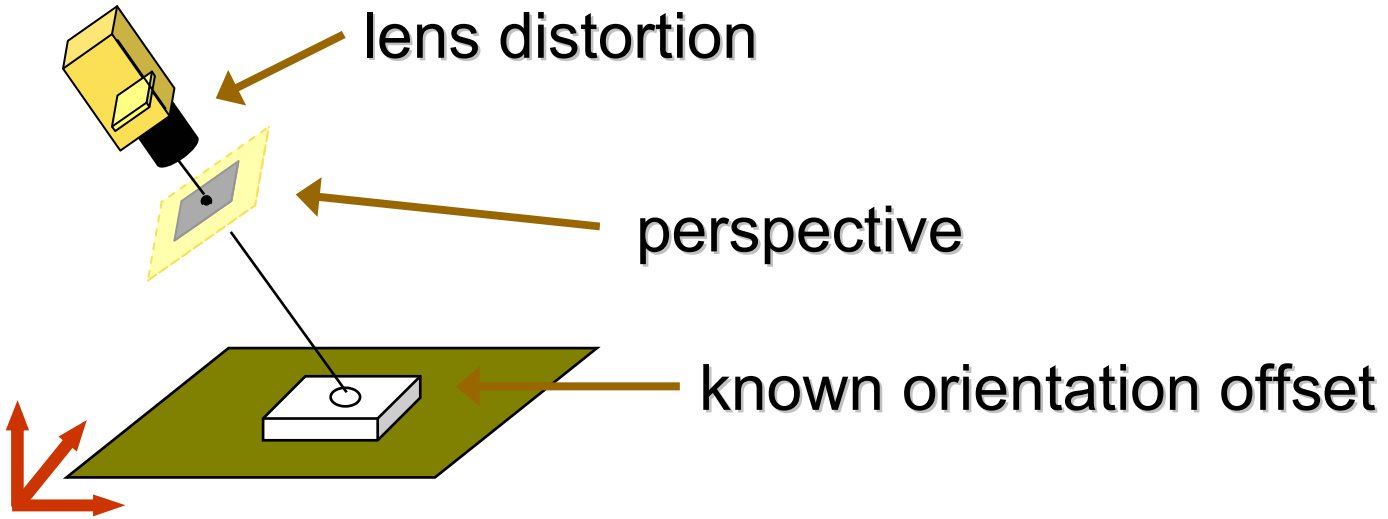
Spatial Calibration

Allows the designer to take real-world measurements from image based on pixel locations.



Intelligent Calibration

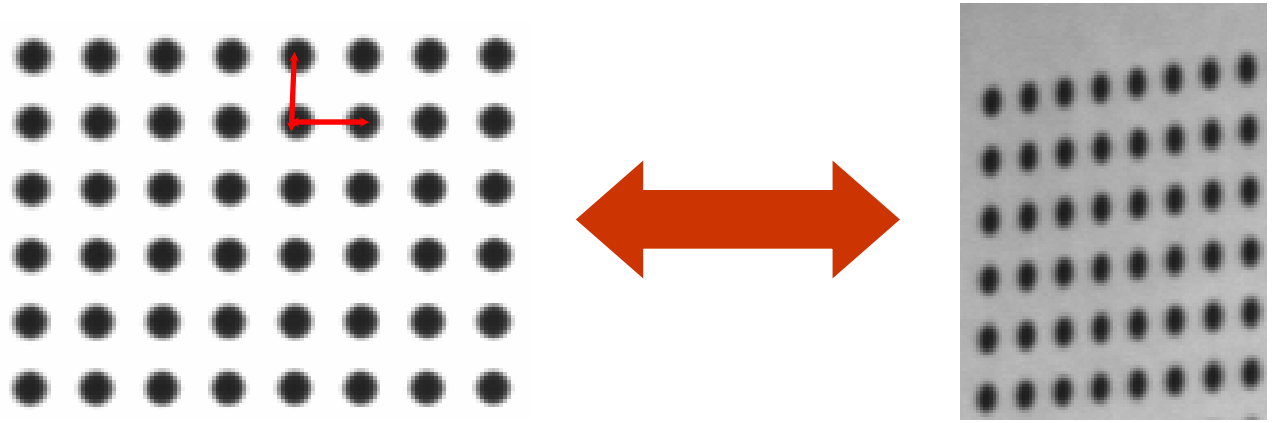
- Also accounts for errors due to:



Calibration Grid

- Snap a calibration template with known real-world distances between the dots

- Learn the calibration (mapping information) from its perspective and distortion

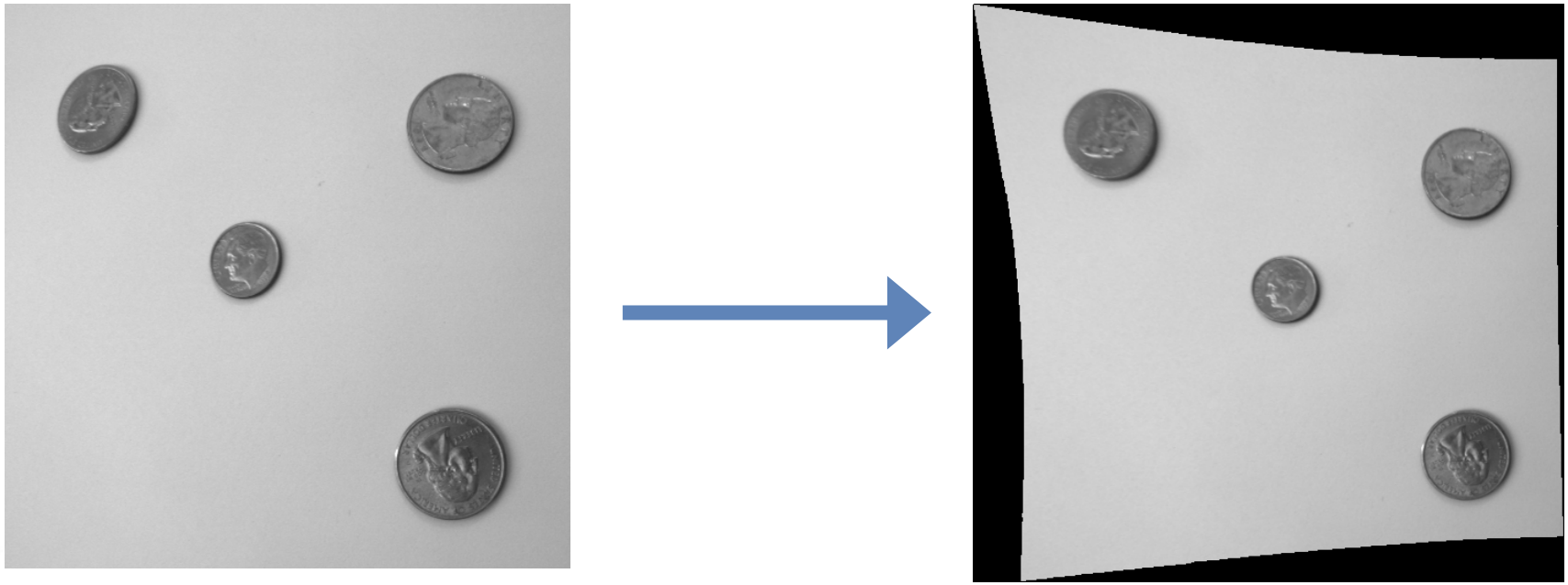


Original Template

Image of the Template

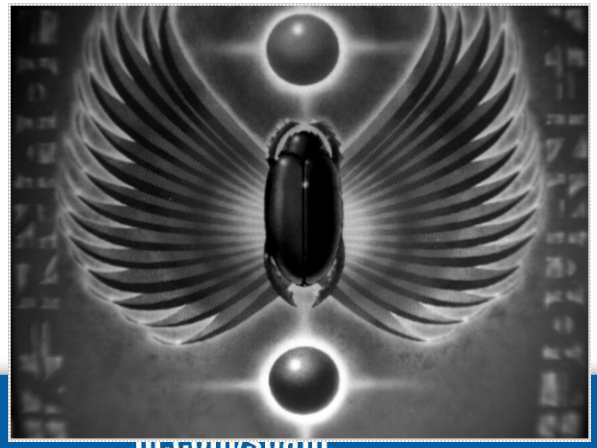
Perspective Correction

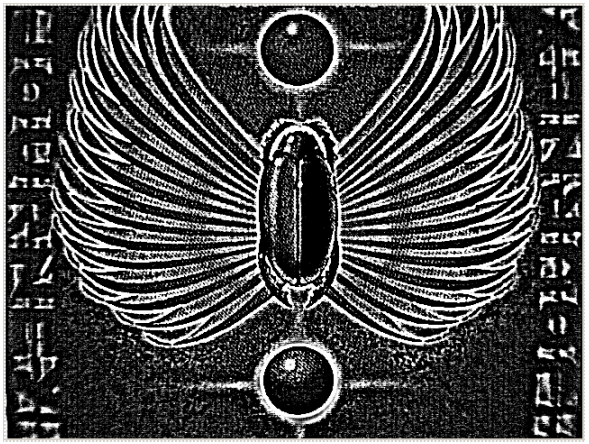
- NI Vision can use a calibration to adjust image geometry so the features are represented properly

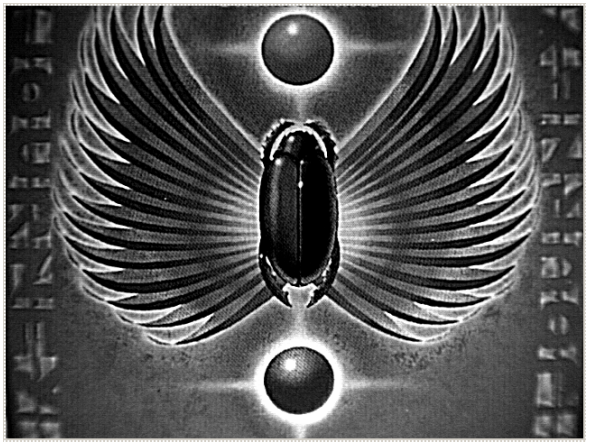


Spatial Filtering

Filtering adjusts pixel values based on the values of their neighbors. It is useful for highlighting features of an image, removing noise, and locating transitions in an image.

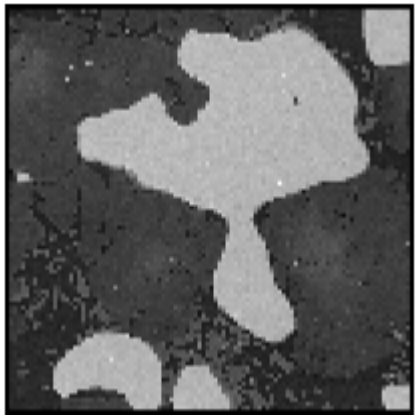






Define Your Own Filter

- You can define any linear filter using NI Vision
- Kernel can be adjusted to yield different results



-1	-1	-1
-1	**8**	-1
-1	-1	-1

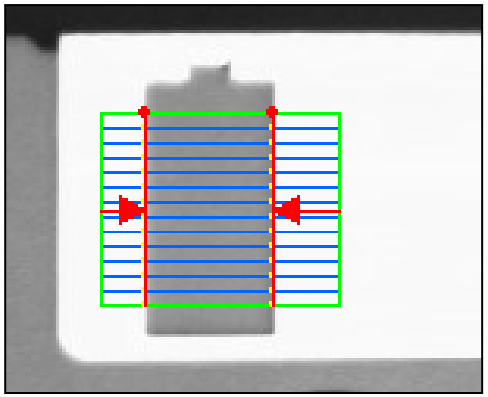
-1	-1	-1
-1	**9**	-1
-1	-1	-1

Measuring Features

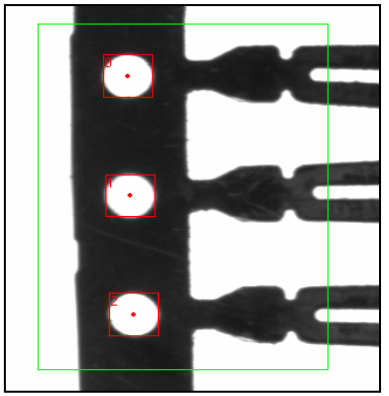
Machine Vision VIs
Regions of Interest
Edge detection

Common Machine Vision Applications

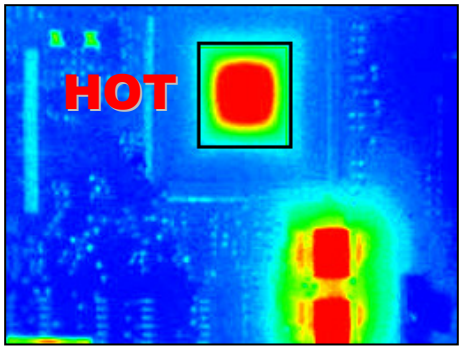
Gauge



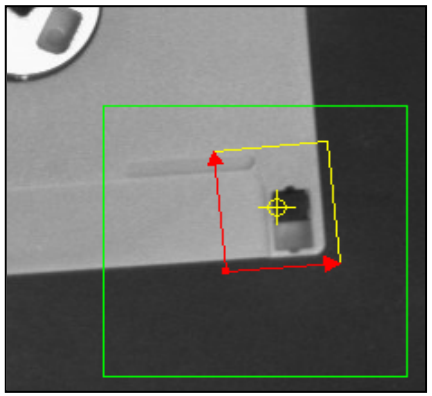
Count



Detect

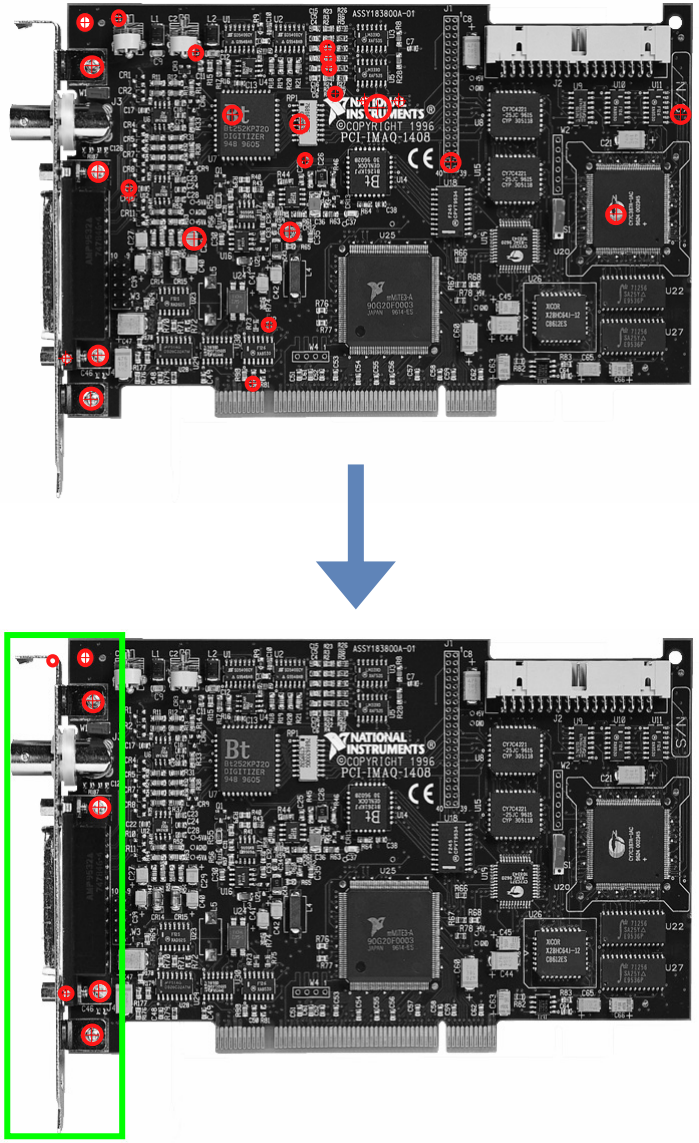


Locate



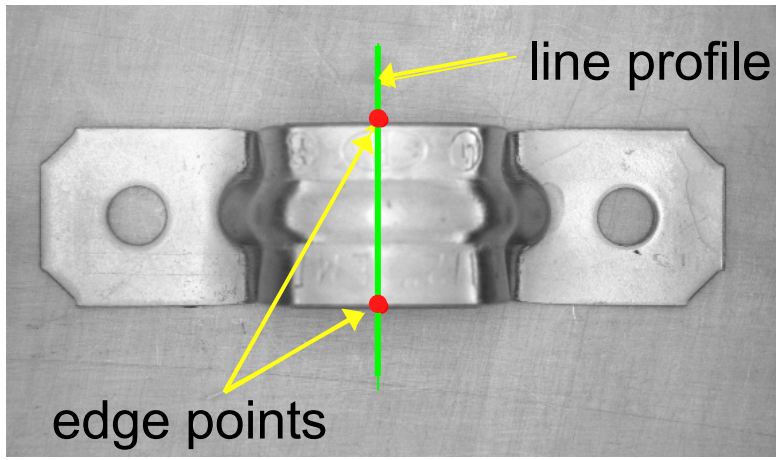
Region of Interest

- An area of an image in which you want to focus your image analysis
- Define your ROI interactively or using one of the following methods:
  - Construct an ROI in an image window
  - Erase the current ROI from an image window
  - Transform an image mask into an ROI
- You can define a complex ROI that includes multiple regions.



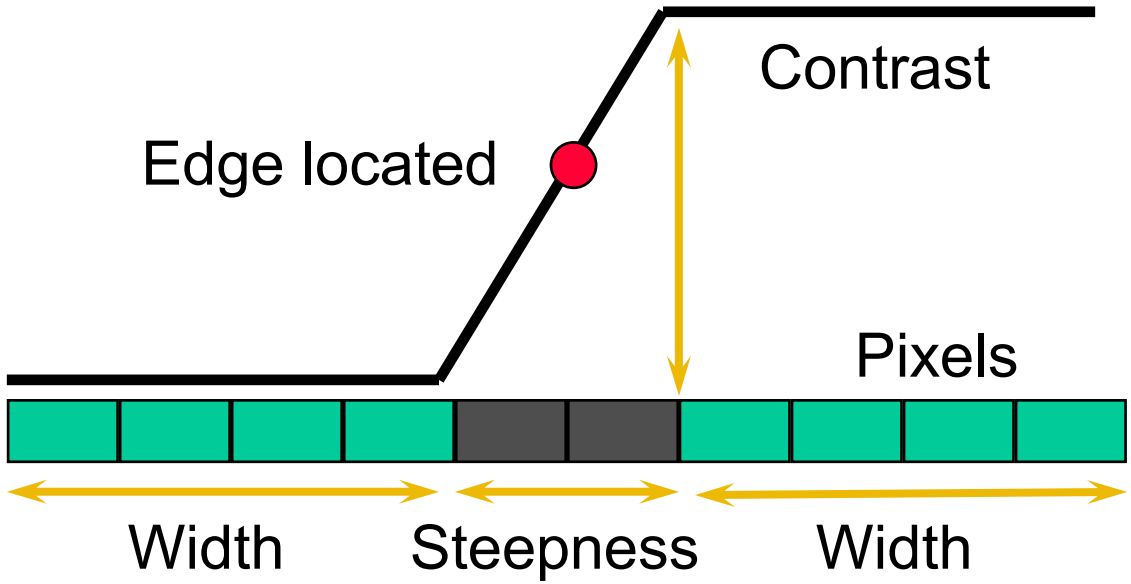
Edge Detection

- Finds locations of significant intensity changes within an image
- Algorithm is performed on a line profile
- Detects boundaries of objects



What Is an Edge?

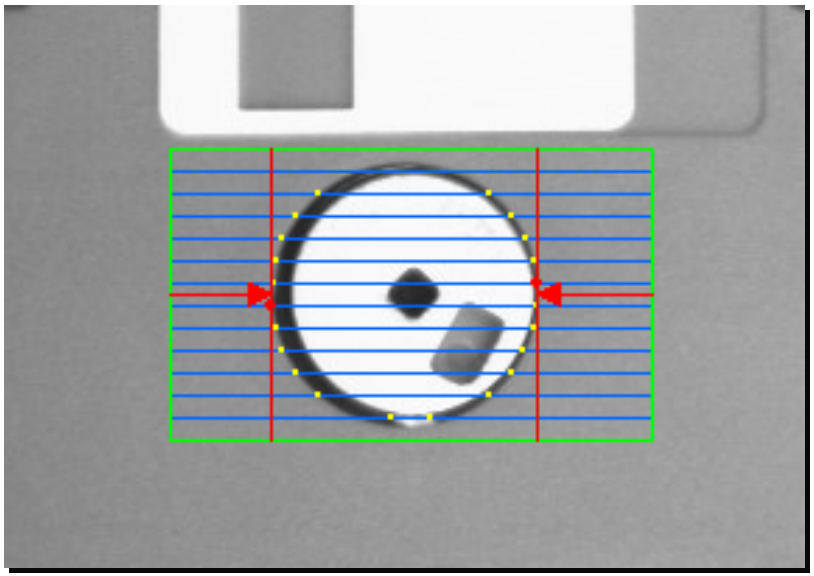
- **Contrast:** A change in pixel value
- **Width:** The mean pixel value near an edge
- **Steepness:** The slope of an edge



Clamping

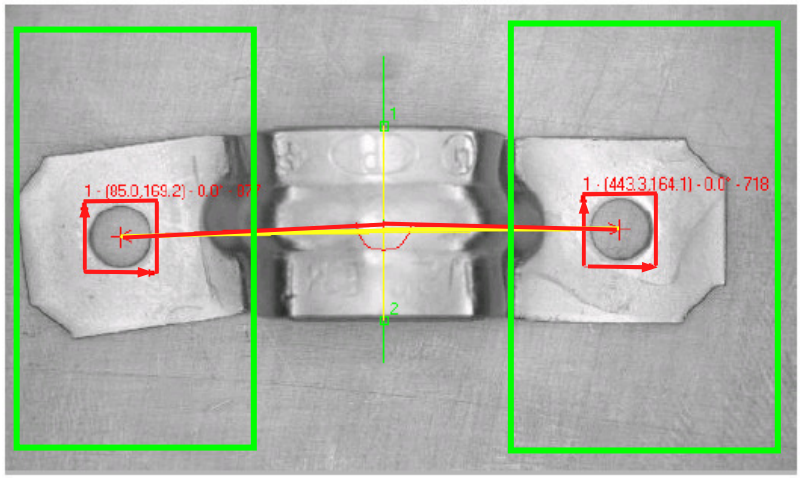
- Searches for the first and last edges along a rake and computes the distance between those edges

- Can clamp:
  - inside→out
  - outside→in



Gauging

- Dimensional measurements such as lengths, distance, and diameter
  - Inline gauging inspections are used to verify assembly and packaging routines
  - Offline gauging is used to judge product quality according to a sample

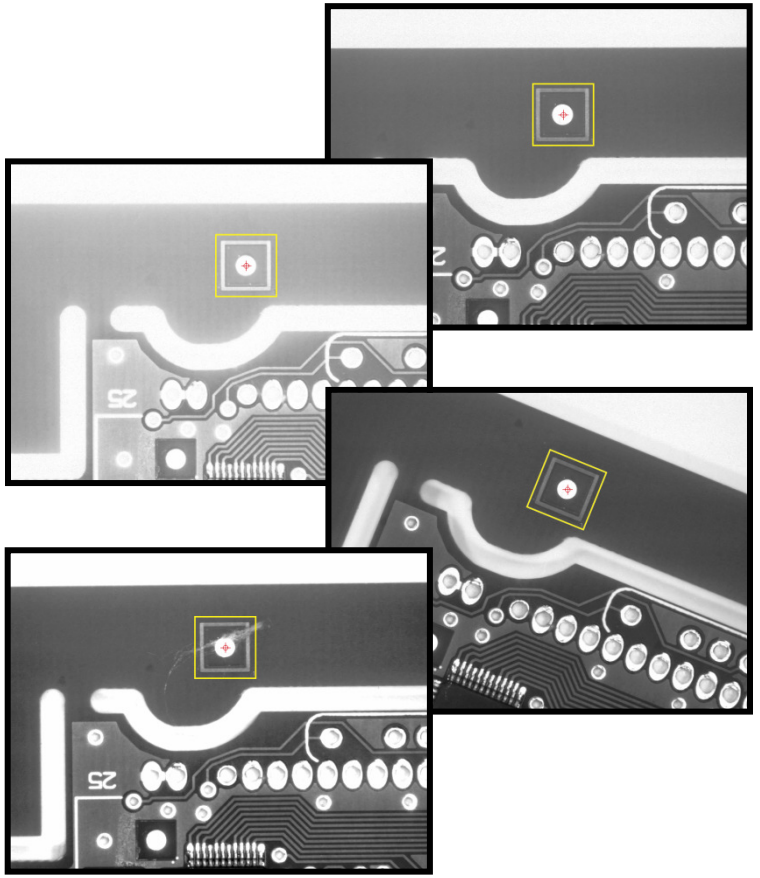


Machine Vision Techniques

Pattern Matching
Coordinate Systems
Histogram and Thresholding

Pattern Matching

- Locates regions of a grayscale image that match a predefined template
  - Calculates a score for each matching region to indicate quality of match
  - Insensitive to position, rotation or multiplicity of template.
- Helps you locate key components in a part quickly and reliably

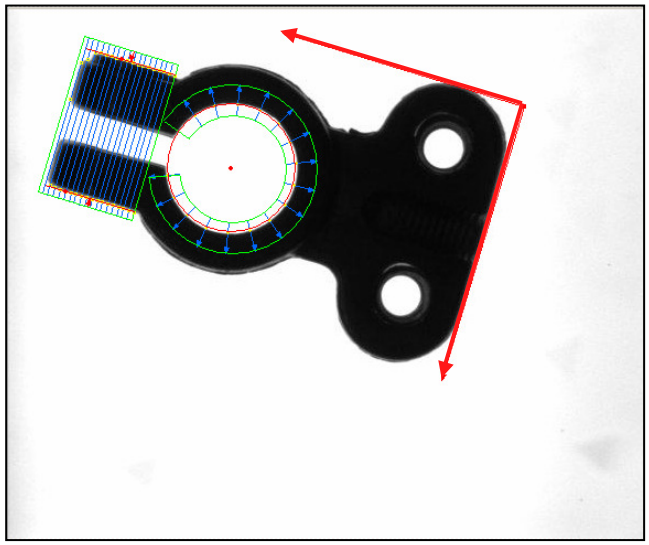


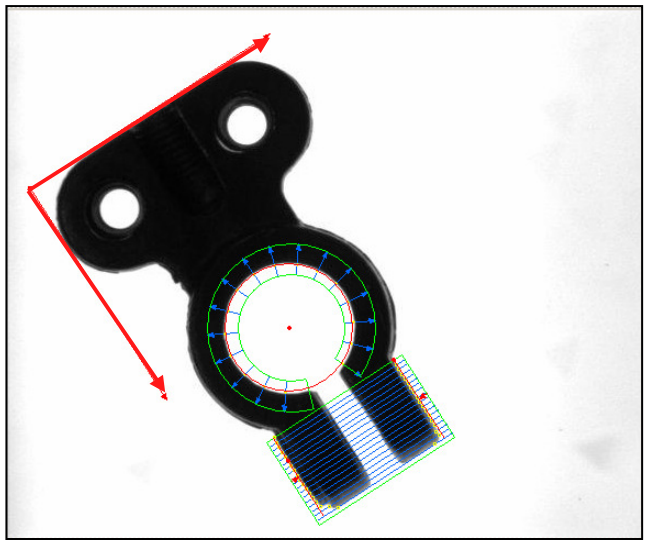
Pattern Matching Applications

- **Alignment:** Determines the position and orientation of a known object by locating features. The features are used as points of reference on the object.
- **Inspection:** Detects simple flaws, such as missing parts on illegible printing
- **Gauging:** Measures lengths, diameters, angles, and other critical dimensions to determine manufacturing quality

Coordinate Systems

- Allow you to define search areas that can move around the image with the object you are inspecting
- Defined by a **reference point** (origin) and **angle** within the image, or by the lines that make up its axes
- Usually based on a characteristic feature of the object under inspection

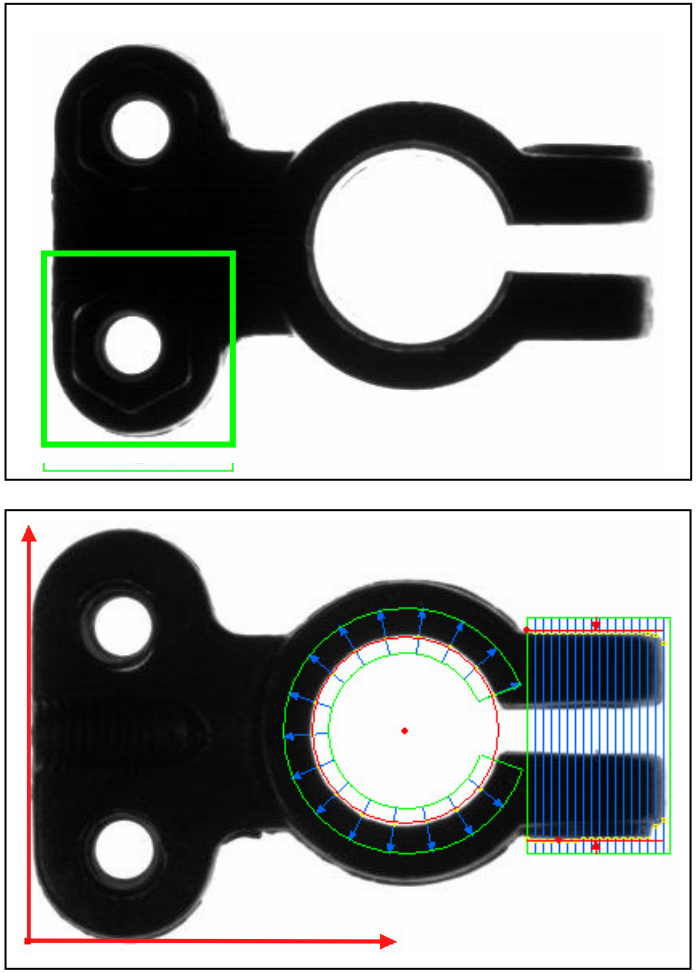




Defining a Coordinate System

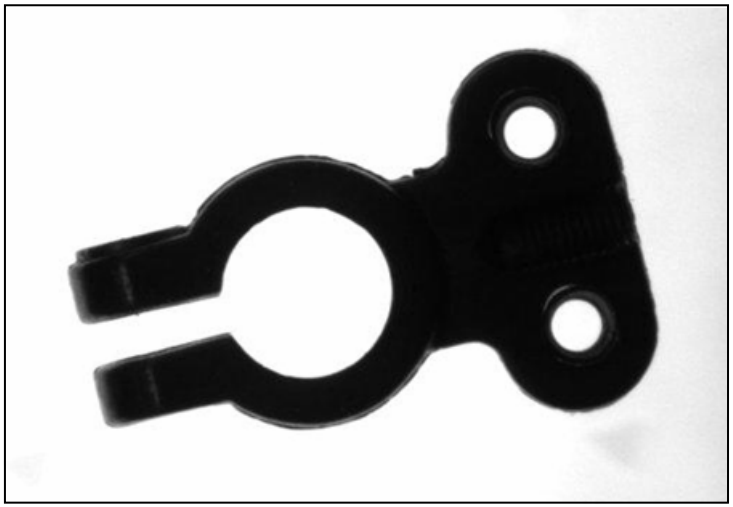
1. Define a reference coordinate system.
   - Locate an easy-to-find feature in your **reference image**
   - NI Vision builds a coordinate system based on its location and orientation.

2. Set up measurement ROIs in the reference image using this **reference coordinate system**.

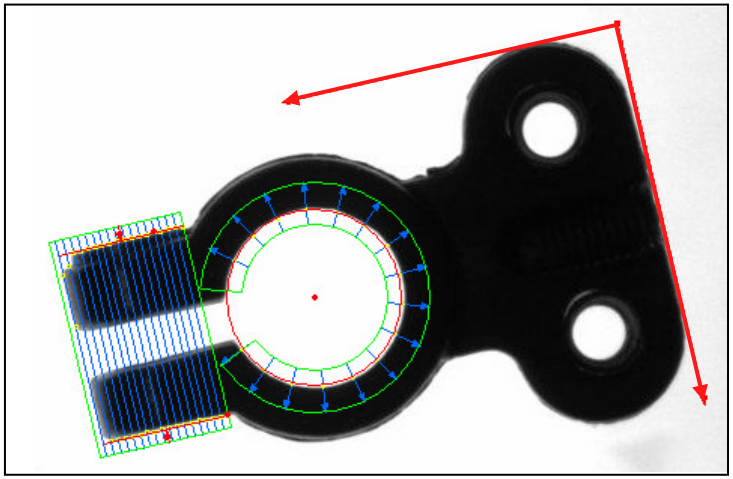


Defining a Coordinate System

3. Acquire an image of the real object under inspection.



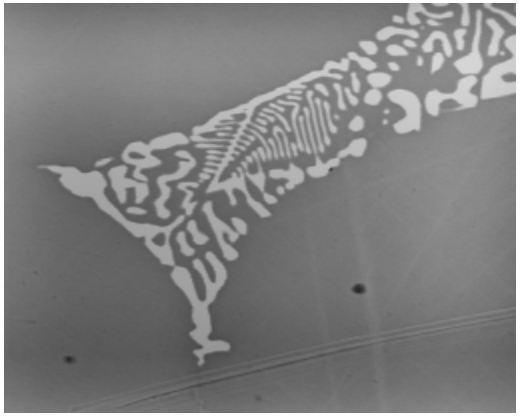
4. Find the reference feature in this image and **update** the coordinate system.
   – NI Vision moves the measurement ROIs with respect to the new coordinate system



Using Histograms and Thresholding

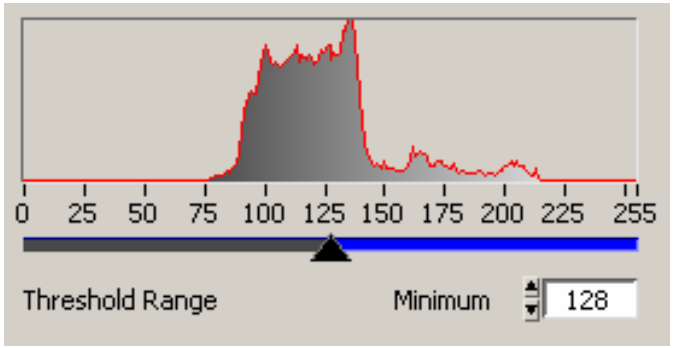
- Histograms
  - Provide a quantitative distribution of pixels in an image
  - Indicate the number of pixels at each gray level
- Thresholding
  - Converts each pixel value in an image to 0 or 1 according to the value of the original pixel
  - Help extract significant structures in an image

Histogram and Thresholding



Original Image

Histogram of Image



Binary Image

- Values in blue range are kept (1)
- Values in gray range are removed (0)

What Is a Binary Image?

- An image segmented into two regions during the thresholding process
  - Particle region (pixels equal to 1)
  - Background region (pixels equal to 0)

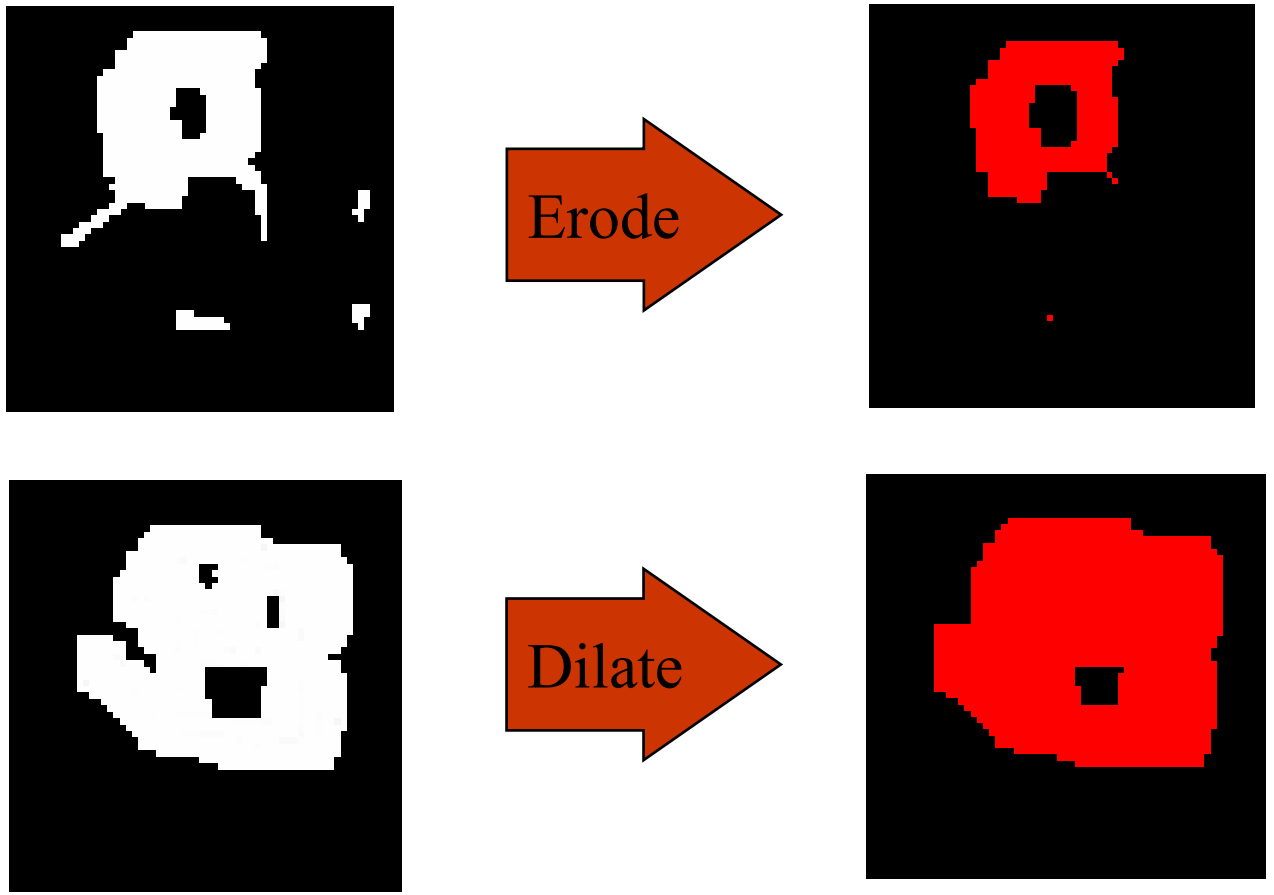
Morphology

- Morphological functions remove unwanted information caused by the thresholding process:
  - Noise particles
  - Particles touching the border of an image
  - Particles touching each other
  - Particles with uneven borders
- Binary morphological functions extract and alter the structure of particles in a binary image

Morphology Functions - Dilation

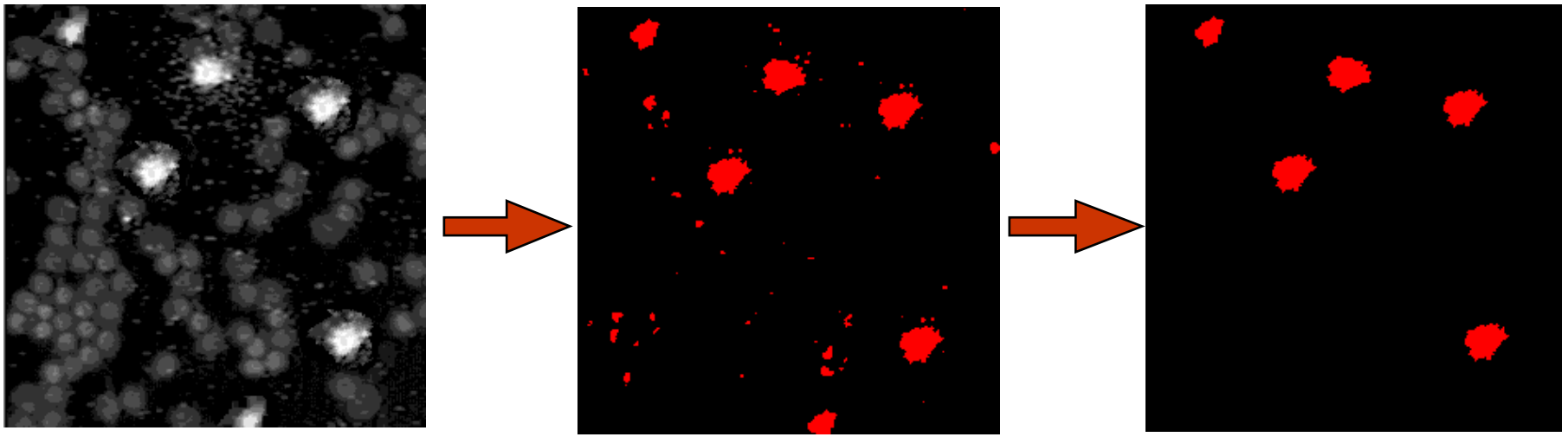
- Increases the size of objects in an image
  - Adds a layer of pixels around the boundary of an object (including the inside boundary for objects with holes)
  - Eliminates tiny holes in objects
  - Removes gaps or bays of insufficient width
- Use *Dilate* to:
  - Fill in small holes in a particle
  - Calculate the area by counting pixels in a neighborhood

Erosion vs. Dilation



Particle Filtering

- Alters the structure of particles
- Typically used on binary images
- Cleans up noisy images



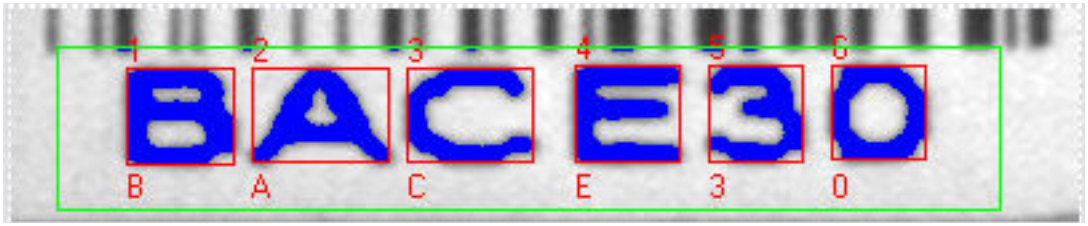
The Golden Template

- Comparison of an object against its ideal model
  - Commonly used in label and stamping inspections
- Can use **defect map** to analyze object's proper placement.

Image Subtraction

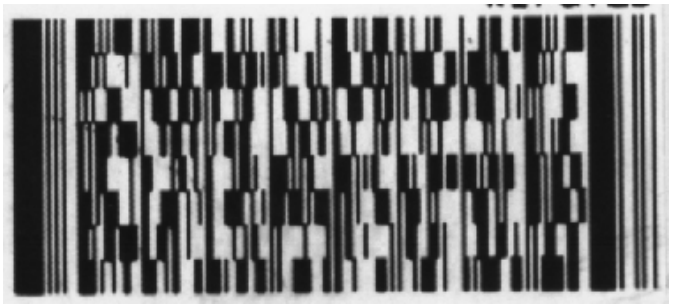
- Basis for Golden Template comparison
  - Result of pixel subtraction shows flaws in acquired image

Optical Character Recognition (OCR)



- Same idea as Classification
  - Apply threshold to ROI
  - Filter and separate particles
  - Identify particles by comparing them to template characters
- **OCR Training Utility** is similar to Classification utility
  - Specific settings for character recognition
- **Character Set File** is stored as .abc

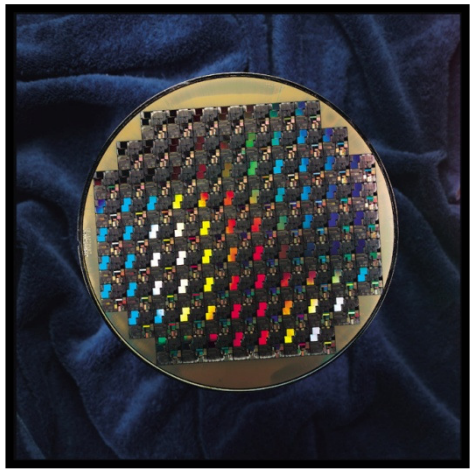
2D Barcodes

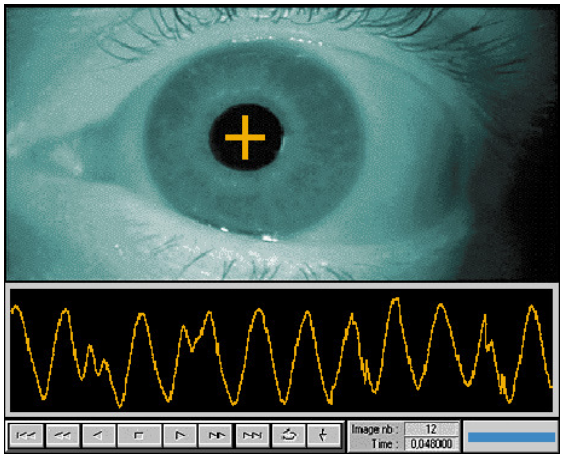


- Two types of 2D barcodes:
  - **Matrix:** based on position of particles in a matrix
  - **Multi-row:** stacked rows of data

- NI-Vision reads **Data Matrix** and **PDF-417** codes

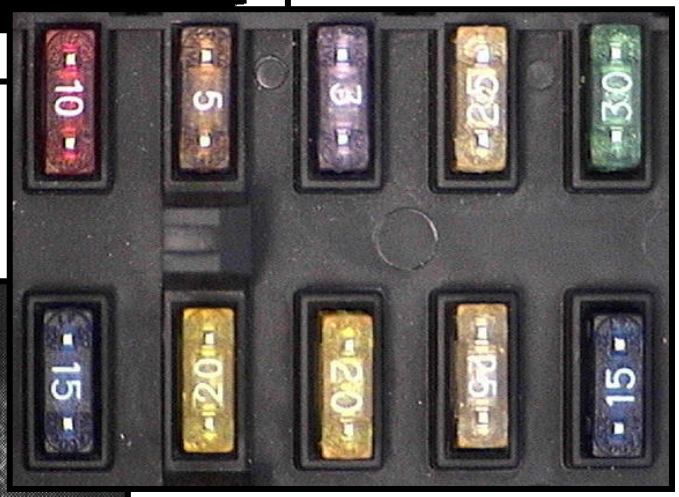
References of Machine Vision

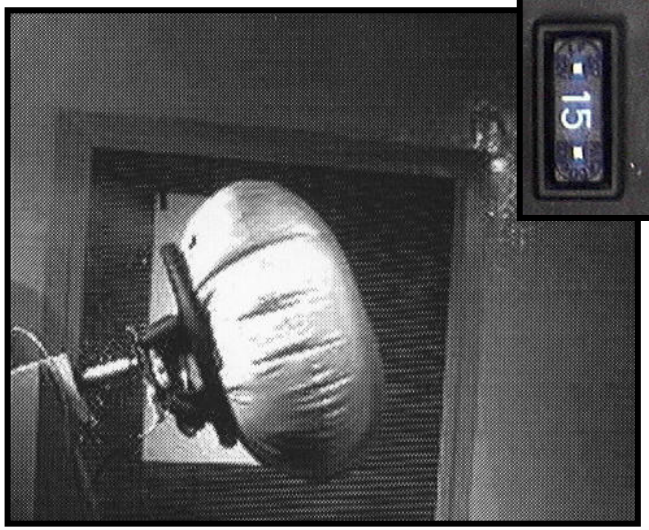




Automotive

- Meter calibration
- Fuse box inspection
- Airbag deployment tests

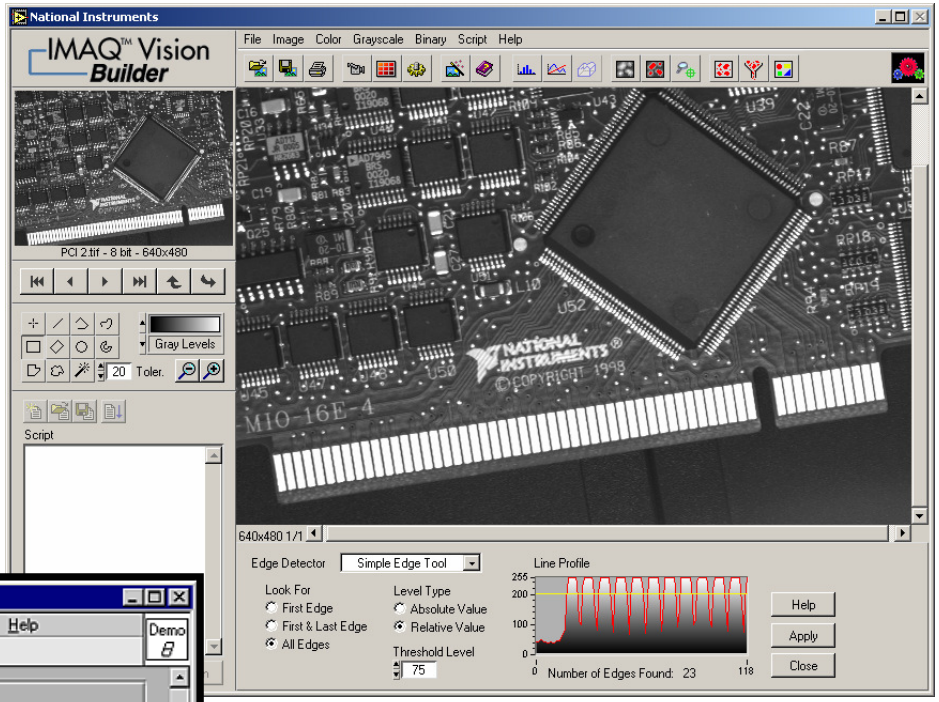


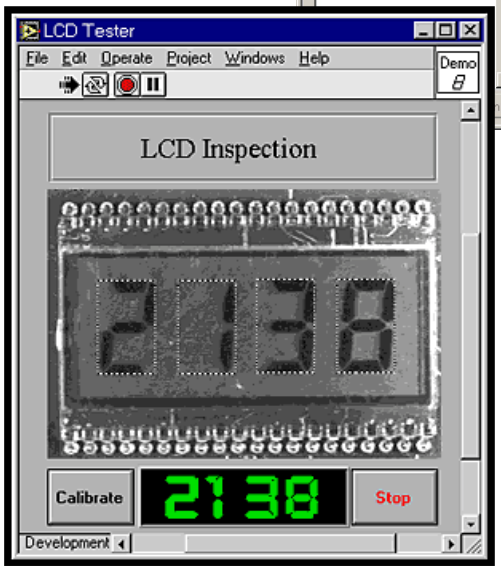


- MICHELIN
- Magneti Marelli
- Bosch

Electronics

- Resistor placement verification
- Inspection of liquid crystal displays
- EIIT
- Geyser Gastech

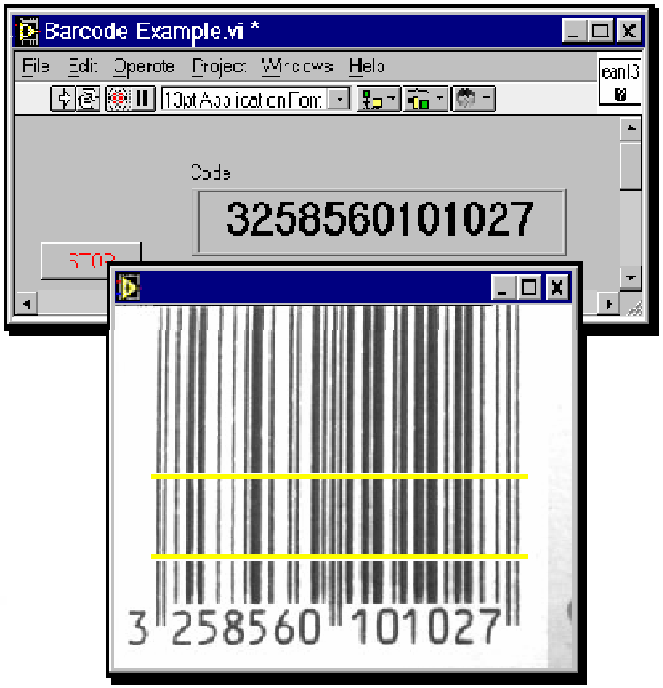


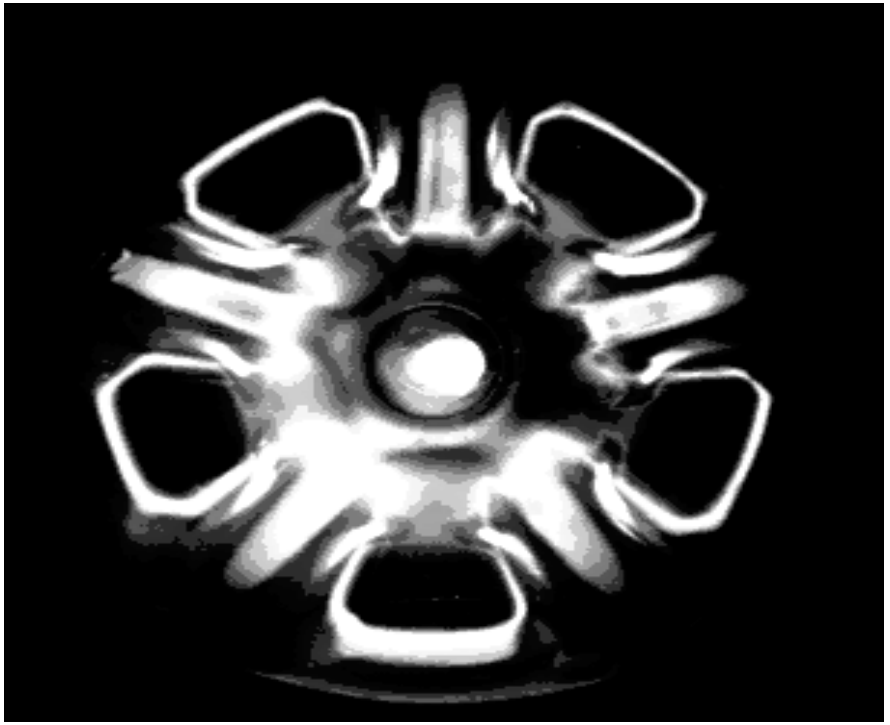


NATIONAL INSTRUMENTS

Industrial Automation

- Container inspection
- Barcode inspection

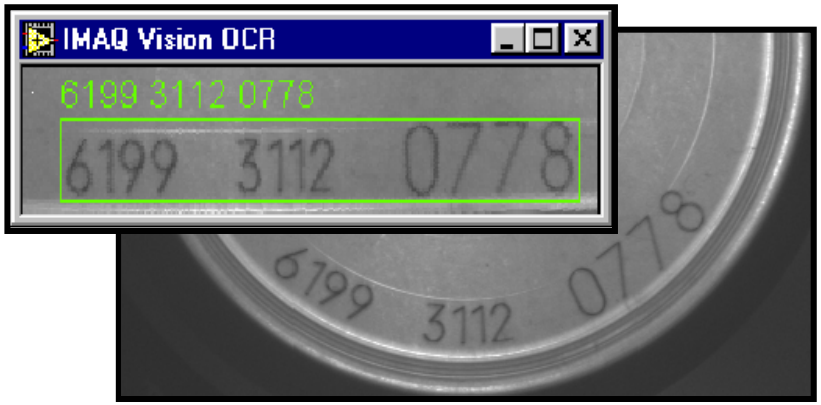


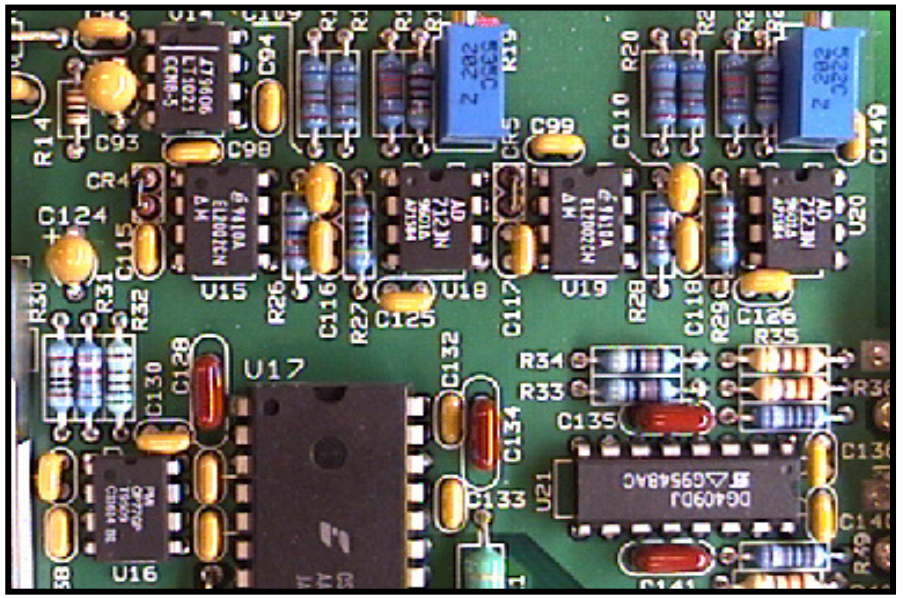


NATIONAL INSTRUMENTS

Manufacturing

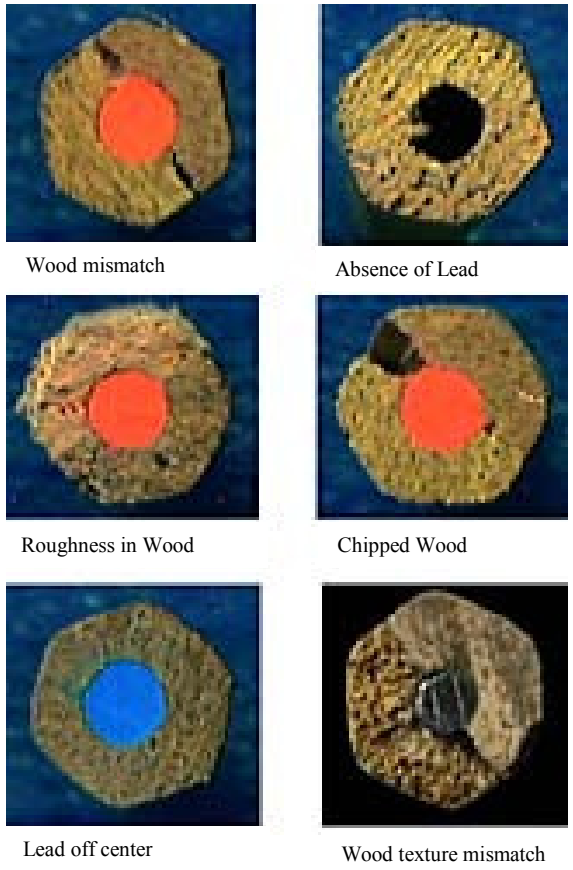
- Inspection of printed circuit boards
- Identification of supply canisters





High Throughput Pencil Sorting System

- Complete inspection and classification at 25 pencils/sec
- 300 um tolerance
- NI Tools leveraged:
  - PCI digital frame-grabber
  - NI LabVIEW
  - NI Vision Development Module




High Speed Pencil Sorting System

Other Industries

- Steel
- Food
- Games

MÁS INFORMACIÓN

- www.ni.com/vision
- www.ni.com/camera
- http://www.ni.com/solutions/

- **YON ASENSIO ROY** **yon.asensio@ni.com**

GRACIAS