Advanced Vision System Integration

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Advanced Vision System Integration

INTRODUCTION AND REVIEW

- What is Machine Vision
- Integration and Prerequisites

Introduction and Overview

- What is Machine Vision
  - Machine vision is the substitution of the human visual sense and judgment capabilities with a video camera and computer to perform an inspection task. It is the automatic acquisition and analysis of images to obtain desired data for controlling or evaluating a specific part or activity.
  - Key Points:
    - Automated/Non-Contact
    - Acquisition
    - Analysis
    - Data

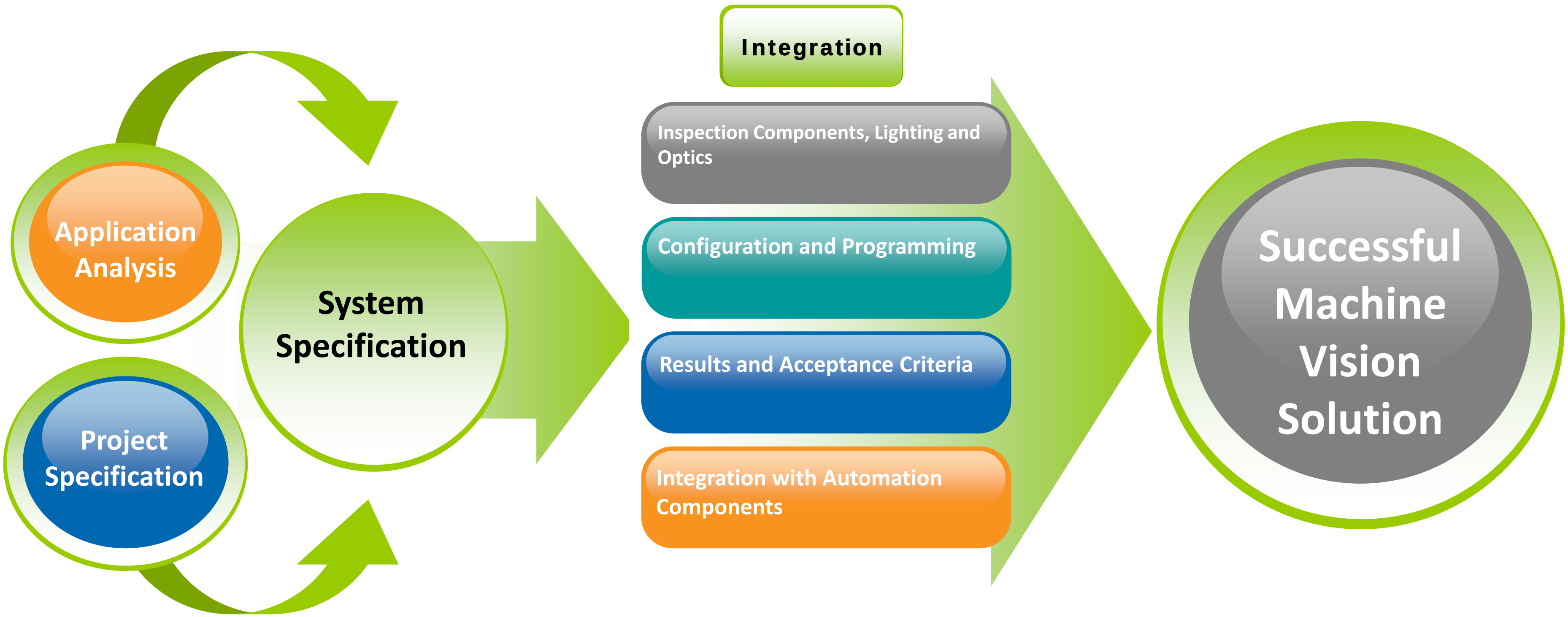
Introduction and Overview

- Integration and Prerequisites
  - Machine vision integration
    - Machine vision systems integration is the process where significant value is added to a machine vision component by the incorporation of software, peripheral hardware, mechanical devices, materials and engineering.
  - The machine vision marketplace contains
    - General purpose systems
    - Application Specific Machine Vision (ASMV) solutions
    - Specialty inspection devices
  - Tutorial focus: primarily general purpose systems

Introduction and Overview

- Integration and Prerequisites
  - Prerequisite integration expertise:
    - Application-based lighting and optics
    - Understanding of imaging and input devices
    - Electrical and mechanical engineering
    - Industrial automation systems and components
    - Machine vision algorithms
    - Programming and/or system configuration
    - Project management and customer support

Introduction and Overview



Advanced Vision System Integration

SYSTEM SPECIFICATION

- Application Analysis
- Project Specification

System Specification

- Application Analysis
  - Quality
    - Quality can not be “inspected into” a part
    - Quality can be evaluated at various steps in the process and used to improve the process
  - The purpose for thoroughly evaluating an application is to arrive at the solution that best improves the customer’s process results

System Specification

- Application Analysis
  - Why? Success is mandatory
    - Performance failure of a system is a significant monetary loss
    - Companies who have experienced a failed machine vision project tend not to use the technology again or not for a long time.
  - Key to a successful system is a competent application analysis
  - The application analysis must extract all of the important things about the target inspection

System Specification

- Application Analysis Document

System Specification

- Application Analysis
  - General overview
    - Define the target application and inspection criteria
    - Describe the part
    - Analyze and state the production process considerations
    - Identify business issues

System Specification

- Application Analysis
  - Define the target application and inspection criteria
    - Describe the desired inspection
      - Avoid discussion of machine vision technique and components
    - Clearly define good part criteria and bad part criteria
    - What is the reason for the inspection
    - What will happen to a bad part – can it be recovered

System Specification

- Application Analysis
  - Define the part(s) to be inspected
    - Include physical detail about geometric structure, features
    - Identify all possible part variations; color, size, structure
    - Describe the materials and surface finish of the part
    - Will the part change over time
    - Get photos, samples

System Specification

- Application Analysis
  - Production process analysis
    - Background information about how the part is manufactured and moved
    - Production rates, number of shifts
    - What factors in the process cause the bad parts
    - Benefits of implementing inspection
      - What happens if a bad part gets through
      - Will costs, yield, quality be improved
    - What is the cost of a falsely reject part
      - Can rejects be recovered/repaired

System Specification

- Application Analysis
  - Business issues
    - Scope of supply/deliverables; who is responsible for what
      - Engineering: design, integration, shipping, installation
      - Hardware components
      - Warranties
      - Documentation and training
    - Contractual items
      - Performance guarantees
      - Terms
      - IP ownership

System Specification

- Project Specification
  - The task is to define and communicate system inspection methods and performance; it is the PRELIMINARY DESIGN
  - Requires an understanding of machine vision technology, industrial automation, and the nature of the application based upon the application analysis
  - The ultimate proposed scope of inspection may be a sub-set of the original desired inspection tasks due to imaging, processing, or mechanical constraints.

System Specification

- Project Specification
  - Understand the technology – let technological capability drive the application
  - Define the resolution that will produce the required results
  - Define software, processing, and interfacing requirements
  - Design systems that are flexible, but focus on critical application requirements.
  - Standardize on machine vision, but not on components.

System Specification

- Project Specification
  - Once the constraints of the application are fully identified, system performance can be quantified.
  - The performance criteria of the system should include
    - Actual inspection capability (measurement tolerance, feature detection, etc.) with respect to the target application
    - Throughput and speed of inspection
    - Anticipated lighting and imaging methodology
    - General overview of the operation of the inspection system
    - Description of the automation and appropriate performance related a specific process if applicable

System Specification

- Project Specification
  - Exceptions and limitations
    - The project specification must identify all non-obvious exceptions and limitation to the performance of the system
    - Include all possible unknowns

System Specification

- Project Specification
  - Acceptance criteria
    - Proving that the inspection is functioning properly
    - How to resolve differences in opinion regarding machine function
    - Clearly state acceptance criteria AND methodology in quantifiable terms
    - Acceptance will be based on stated performance criteria

System Specification

- Project Specification
  - Analysis of system performance must be done using a verifiable sample or challenge set of parts
    - Verifiable: All parties agree that each specific challenge part meets the stated criteria, either reject criteria or feature size if a gauging application
  - Static testing is done with challenge parts
  - A gauge R&R is appropriate for gauging applications
  - Production testing can be done with parallel visual inspection
    - Rejected parts will be judged against the set of challenge parts
  - The acceptance criteria will list false accept and false reject rates

Advanced Vision System Integration

INTEGRATION

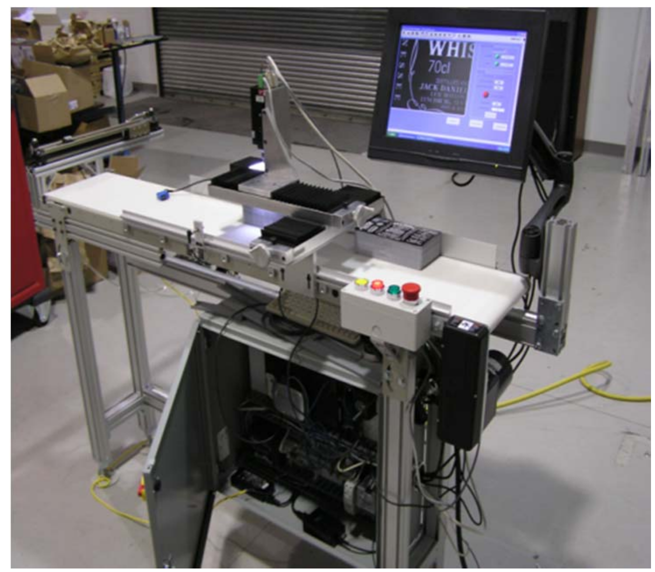
- Keys to Successful Integration
- Use and application of basic machine vision tools
- Advanced Application Notes
- Selecting and Working with Systems Integrators

Integration

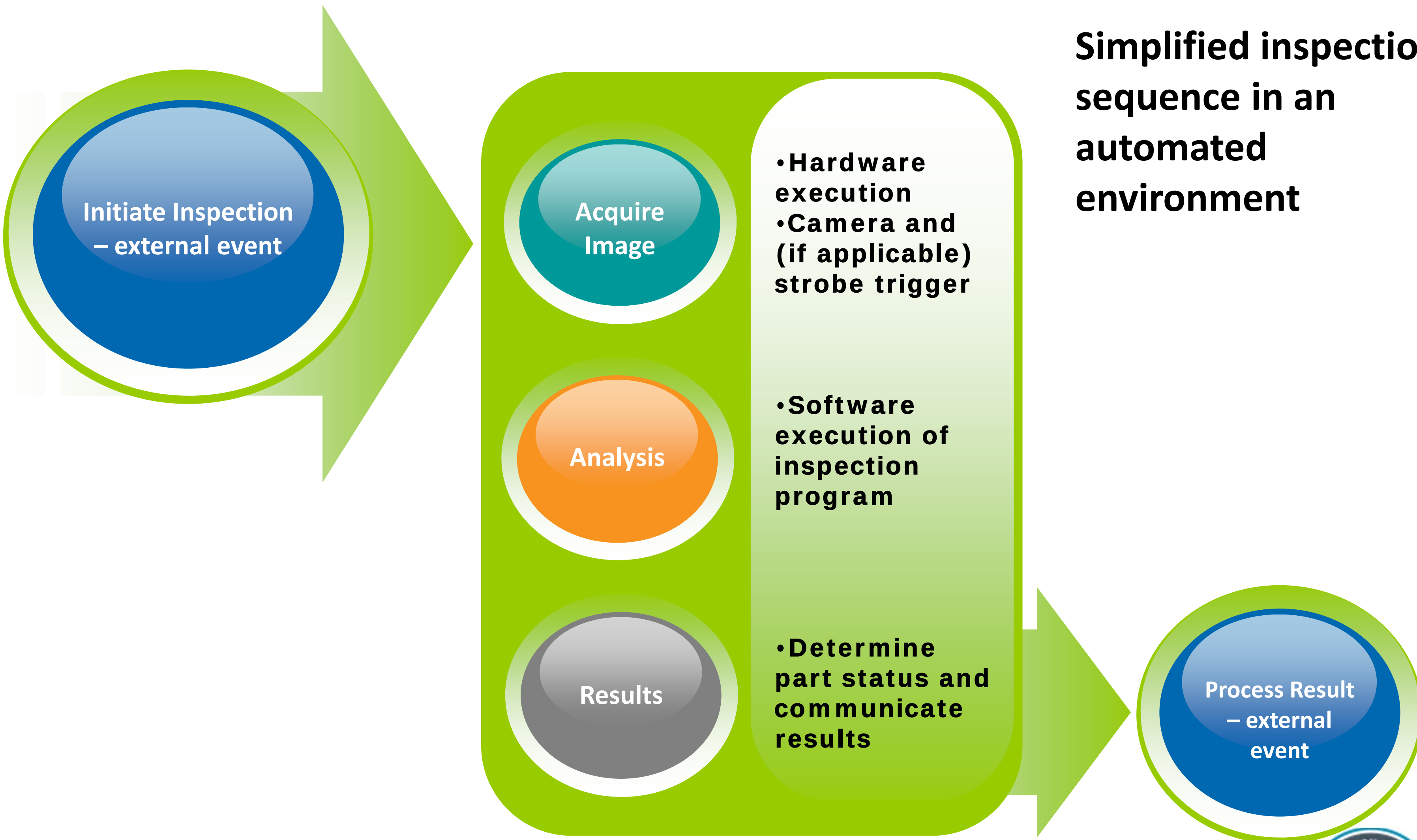
- Keys to Successful Integration
  - Integration is the part of the project where someone has to make the system work.
  - If the application has been well analyzed and specified, the integration task is easier.

Integration

- Keys to Successful Integration
  - Process steps
    - System design
      - Mechanical, electrical, software
      - Includes design for component interconnect and communications
    - Fabrication/build
    - Programming/configuration of devices
    - Testing/debug of the system
    - Installation/start-up
    - Run-off and acceptance
    - Training



Integration



Simplified inspection sequence in an automated environment

Integration

Initiate Inspection – external event

-Recipe changeovers
-Multiple images/lights
-Part tracking

Acquire Image

- Hardware execution
- Camera and (if applicable) strobe trigger

Analysis

- Software execution of inspection program

Results

- Determine part status and communicate results

Other considerations

-Part Tracking
-Multiple results
-Other data

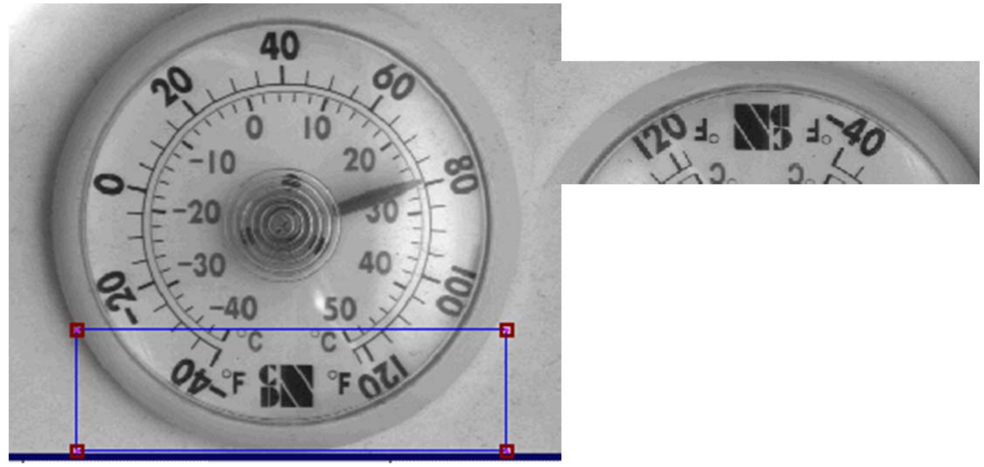
Process Result – external event

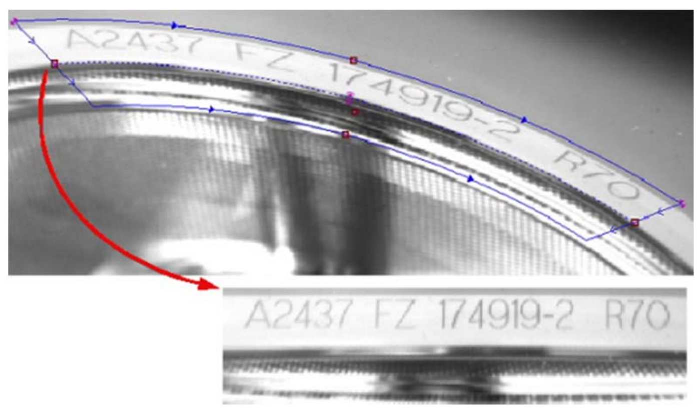
Integration

- Use and Application of Basic Machine Vision Tools
  - Image transformations
  - Calibration
  - Statistics
  - Image enhancement
  - Connectivity
  - Edge Detection
  - Correlation
  - Geometric Search
  - Compound Algorithms
    - OCR/OCV

Integration

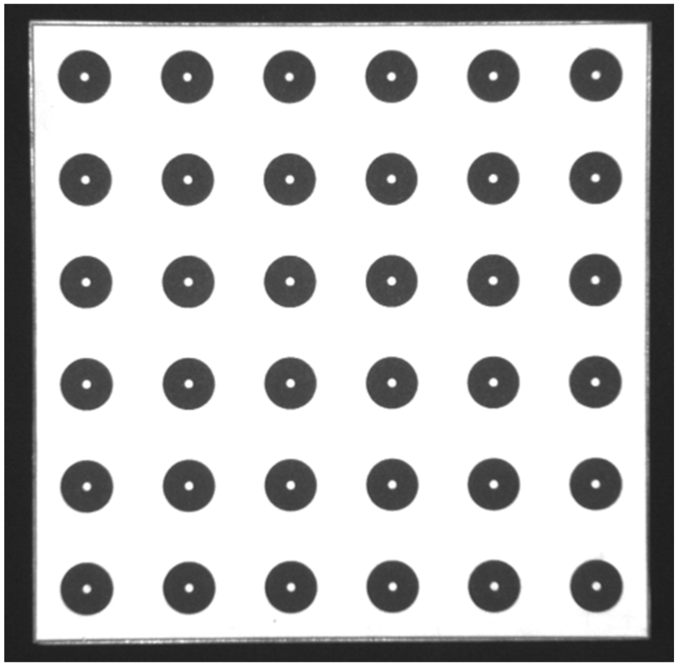
- Image Transformation
  - Geometric manipulation of the image
    - Shifting
    - Rotating
    - Mirroring
    - Inverting
    - Unwrapping





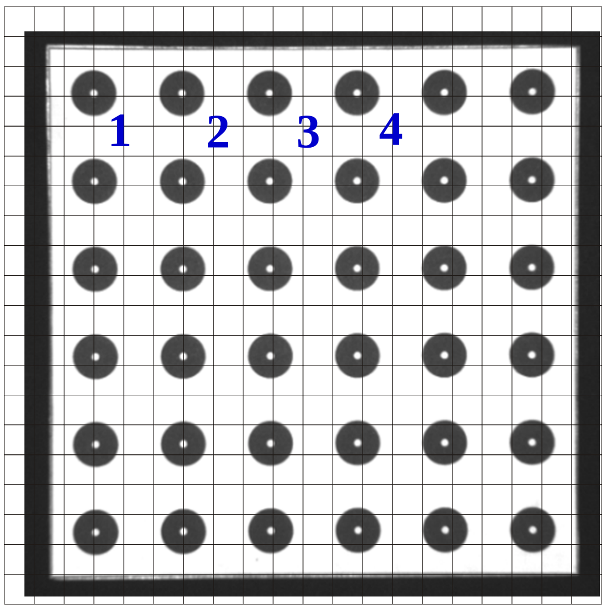
Integration

- Calibration
  - Maps image positions to real world coordinates
  - May correct for optical distortion and camera perspective
  - Typically involves a physical grid of points with known world coordinates



Integration

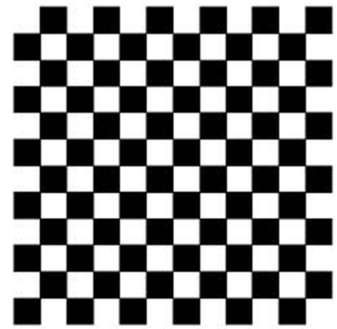
- Camera Calibration



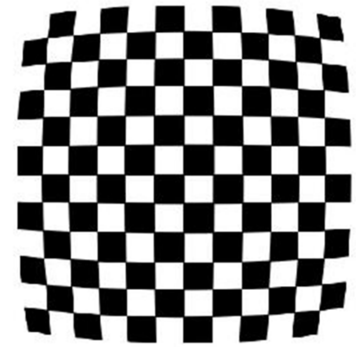
Object	Actual position on grid (mm)	Observed Pixel position (pixels)
1	(0,0)	(22,24)
2	(10,0)	(145,26)
3	(20,0)	(264,29)
4	(30,0)	(387, 31)
…		

Calibration

- Camera Calibration
  - May be simple linear relationship, or complex polynomial structure
- Multiple Cameras
- Robot Frame Calibration
  - 2-D, 3-D transformations
  - Mapping robot or cell frame to camera frame



Calibration Plate



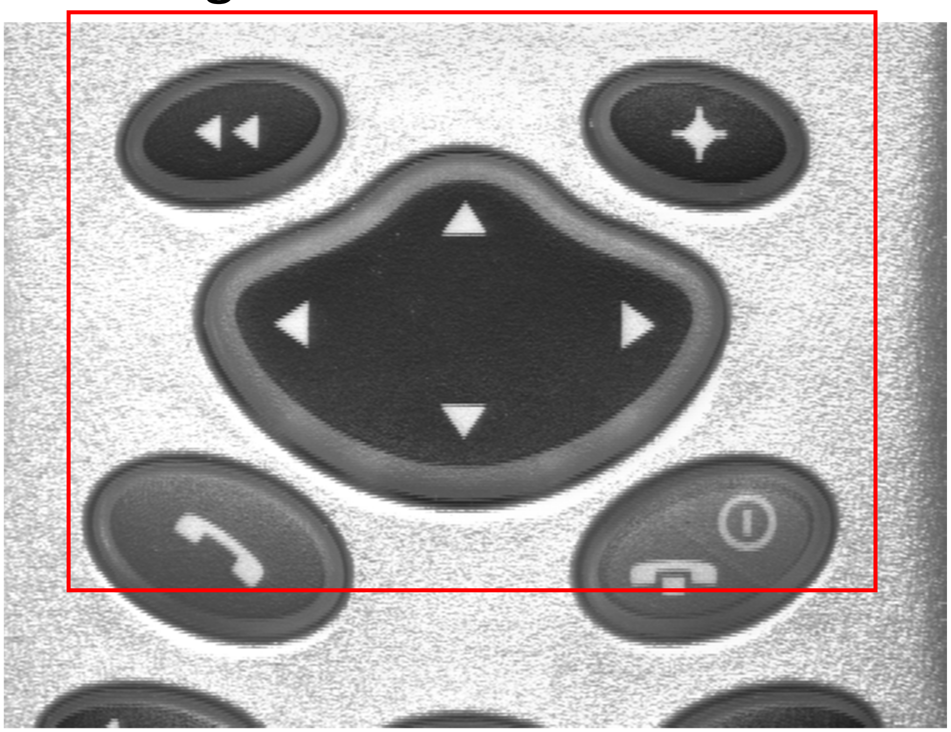
Acquired Image of Calibration Plate

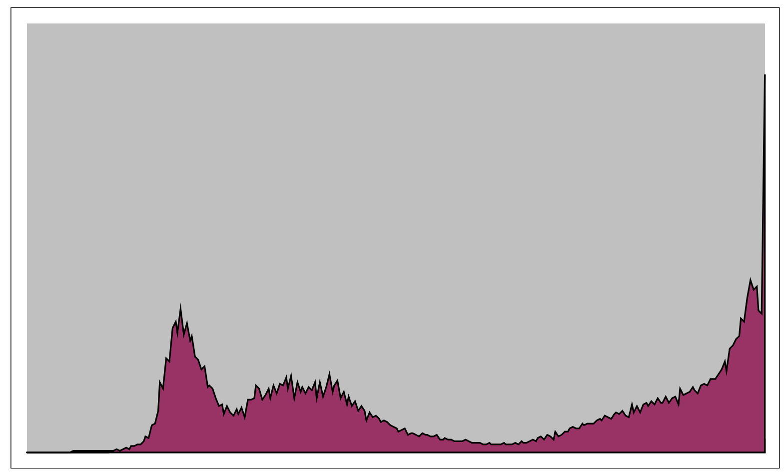
Acquired Image of Part

Warped (Corrected) Image of Part

Integration

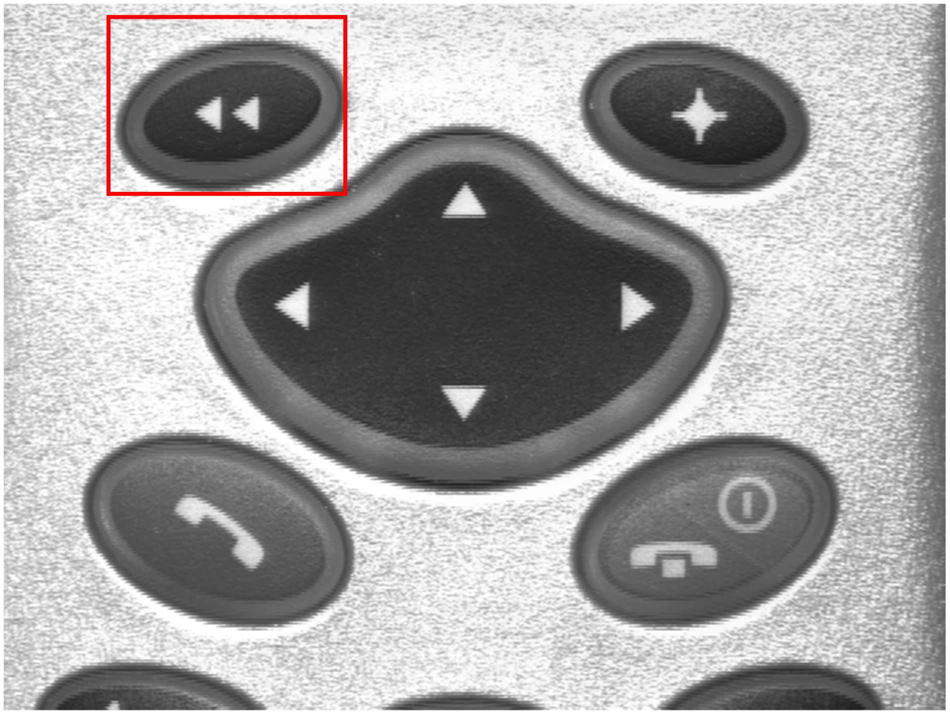
- Histogram Analysis
  - An image histogram shows the count of pixels at each gray-scale within either the image or a specified region.
  - The list can yield a variety of statistical information about the image or ROI.





Integration

- Histogram Analysis



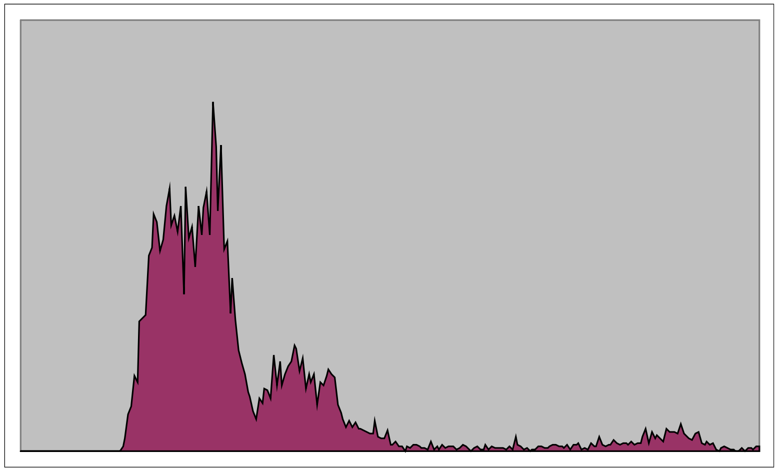
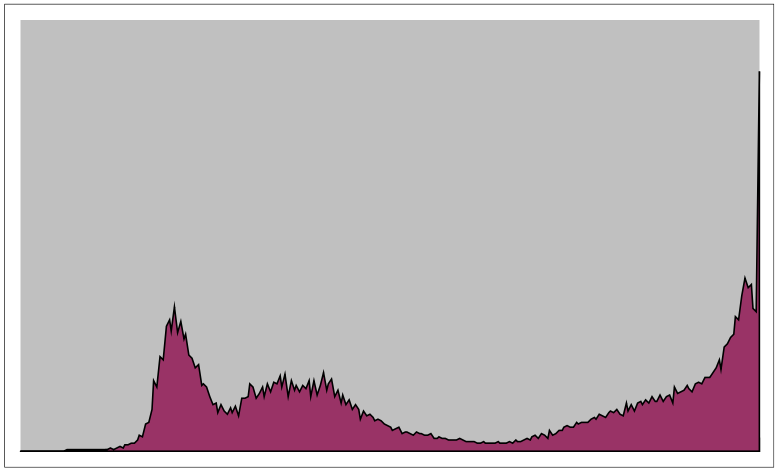
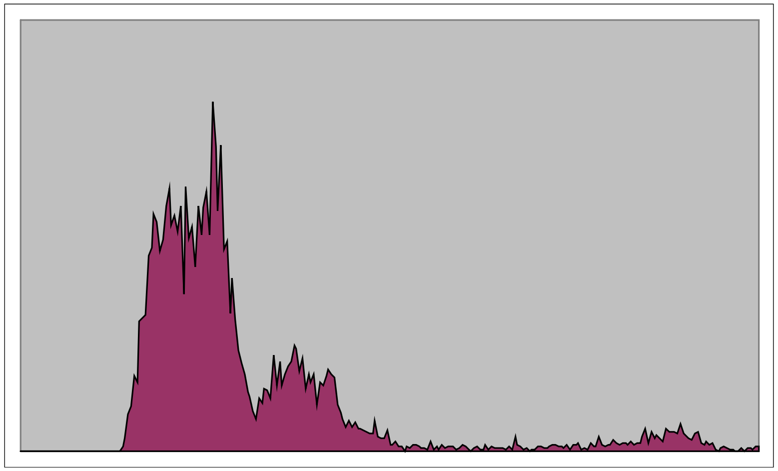


Image Statistics



Mean	51.89
SDev	76.79
Median	141.5
Mode	255
Count	228
Min	28
Max	255
Skew	0.05
Kurtosis	-1.66



Mean	78.43
SDev	40.42
Median	142.5
Mode	67
Count	214
Min	35
Max	255
Skew	2.38
Kurtosis	5.79

Integration

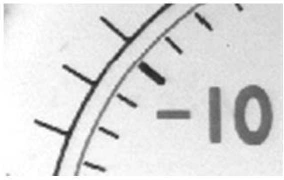
- Other Histogram Measures
  - Bi-modality
  - Relative contrast level
  - Relative brightness (white) level
- Applications of Histogram Statistics
  - Thresholding
  - Image equalization
  - Feature presence/absence
  - Surface analysis
  - Color/grayscale analysis
  - Lighting/camera status

Integration

- Image Processing and Enhancement
  - Algorithms that change the image by physically replacing pixel values
    - Morphology
    - Filtering/convolutions
    - Image Averaging
    - Pixel operations
  - Typical use
    - Eliminate noise
    - Create better contrast
    - Extract edge features
    - Otherwise manipulate the image

Integration

- Morphology
  - Simple, fast, binary or gray-scale processing
  - Changes the value of a target pixel based upon the value of neighboring pixels
  - Morphology changes an object’s geometric shape
  - Terminology
    - Erosion
      - Shrinks light areas/expands dark areas
    - Dilation
      - Shrinks dark areas/expands light areas
    - Opening
      - Erosion then dilation
    - Closing
      - Dilation then erosion
    - Structured morphology
      - Non-symmetrical processing: skeleton, thinning, thickening, directional



Integration

- Morphology
  - Basic implementation is to replace each pixel with the Minimum (erosion) or Maximum (dilation) value of a group of neighboring pixels
  - May be performed using a “structuring element”: see “Minkowski” set theory
  - May be performed on a gray-scale or binary image

Original Image

24	48	69
45	57	84
81	79	98

Result after one dilation step on a single pixel

24	48	69
45	98	84
81	79	98

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	1	1	1	0	0
0	0	1	1	1	0	0
0	0	1	1	1	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

1	1	1
1	1	1
1	1	1

0	0	0	0	0	0	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	0	0	0	0	0	0

Integration

- Common Parameters
  - Size, shape of structuring element
  - Number of processing iterations
- Morphology – Uses
  - Reduce image noise
  - Eliminate undesired features
  - Cursory size verification

Integration

- Spatial Filters
  - Also called gradient filters, convolutions
  - Goal is to reduce noise, enhance features
  - Convolutions change pixel values by applying matrix arithmetic operations using a filter with the original image

Integration

- Spatial Filters – example-step 1

Original Image		0	1	2	3	2	1	0	
Filter or Template	1	3	1						
Result Image		**1**							

A * B Operation

(0*1) + (0*3) + (1*1)

Integration

- Spatial Filters – example-step 2

Original Image		0	1	2	3	2	1	0	
Filter or Template		1	3	1					
Result Image		**1**	**5**						

A * B Operation

(0*1) + (1*3) + (2*1)

Integration

- Spatial Filters – example-step 3

Original Image		0	1	2	3	2	1	0	
Filter or Template			1	3	1				
Result Image		**1**	**5**	**10**					

A * B Operation

$(1*1) + (2*3) + (3*1)$

Integration

- Spatial Filters – example-step 4

Original Image		0	1	2	3	2	1	0	
Filter or Template				1	3	1			
Result Image		**1**	**5**	**10**	**13**				

A * B Operation

(2*1) + (3*3) + (2*1)

Integration

- Spatial Filters – example-step 5

Original Image		0	1	2	3	2	1	0	
Filter or Template					1	3	1		
Result Image		**1**	**5**	**10**	**13**	**10**			

A * B Operation

(3*1) + (2*3) + (1*1)

Integration

- Spatial Filters – example-step 6

Original Image		0	1	2	3	2	1	0	
Filter or Template						1	3	1	
Result Image		**1**	**5**	**10**	**13**	**10**	**5**		

A * B Operation

(2*1) + (1*3) + (0*1)

Integration

- Spatial Filters – example-step 7

Original Image		0	1	2	3	2	1	0	
Filter or Template							1	3	1
Result Image		**1**	**5**	**10**	**13**	**10**	**5**	**1**	

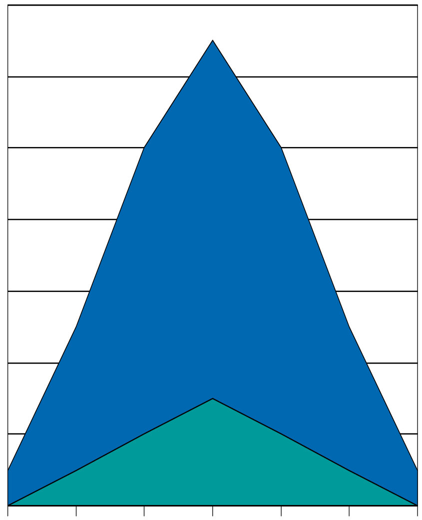
A * B Operation

(1*1) + (0*3) + (0*1)

Integration

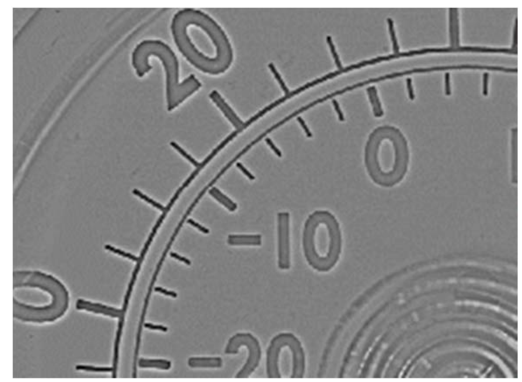
- Spatial Filters – result

Original Image		0	1	2	3	2	1	0	
Result Image		**1**	**5**	**10**	**13**	**10**	**5**	**1**	



Integration

- Common Filters
  - Edge extraction
    - Sobel
    - Laplacian
    - Roberts
  - Noise reduction, enhancement
    - High-pass
    - Sharpening
    - Low-pass
- Typical Parameters
  - Number of iterations
  - Size of filter kernel, custom kernel

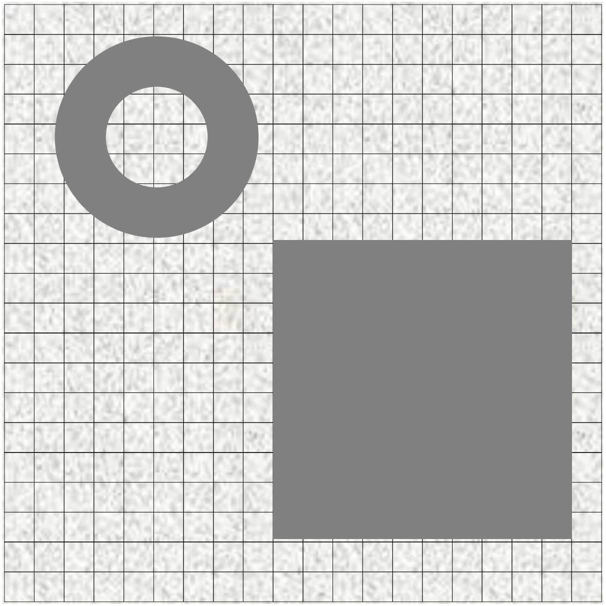


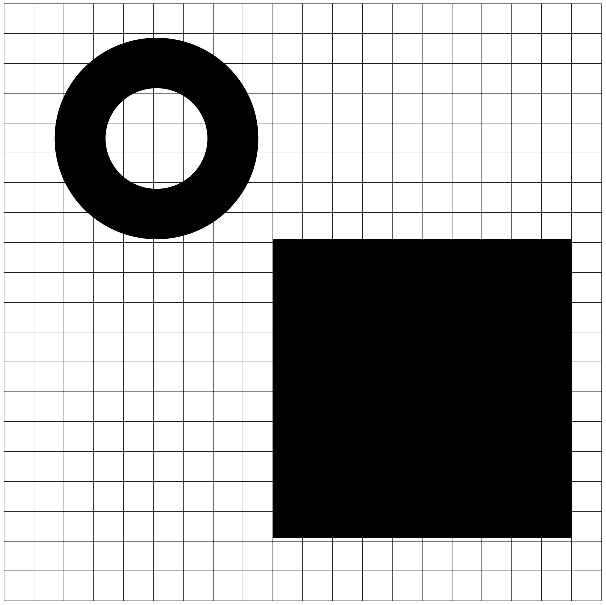
Integration

- Connectivity (particle analysis)
  - Extraction and analysis of 2-dimensional connected shapes (blobs)
  - Connectivity can be a very useful and powerful tool
  - Success often depends upon the image and the level of pre-processing
    - Suited for images with high contrast and consistent color levels
- Steps in Processing Blobs
  - Convert image or ROI to binary representation
  - Scan area for pixels with neighbors of the same value
  - Label and combine connected regions into blobs
  - Perform geometric and statistical analysis on the blobs

Integration

- Image Segmentation/Thresholding
  - Convert gray-scale image to binary



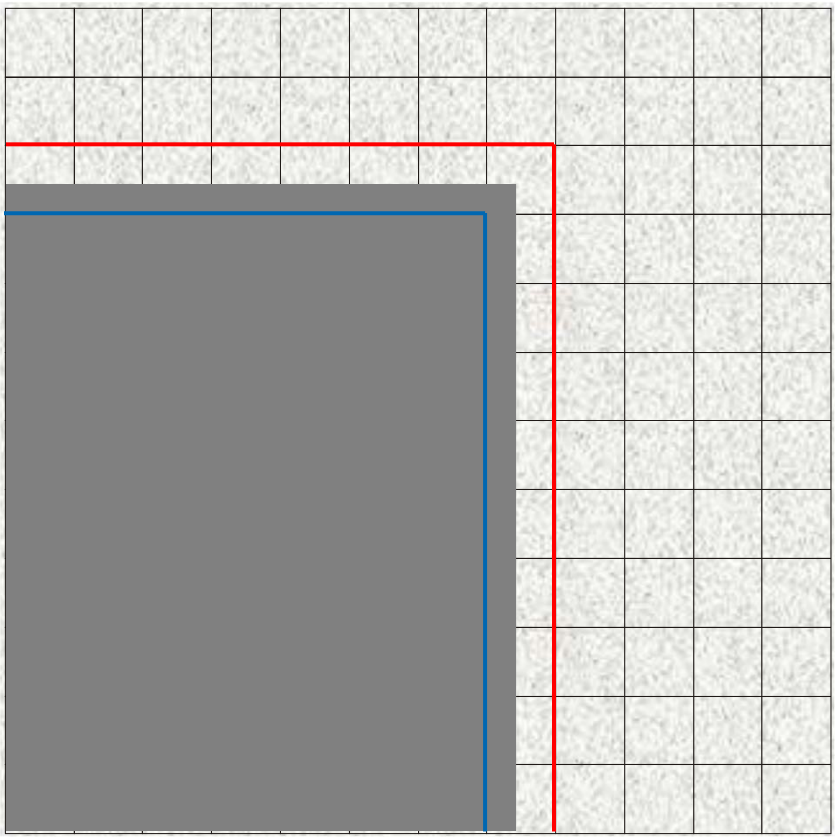


Integration

- Image Segmentation/Thresholding
  - Spatial errors in binarization

Object size at threshold 120

Object size at threshold 80

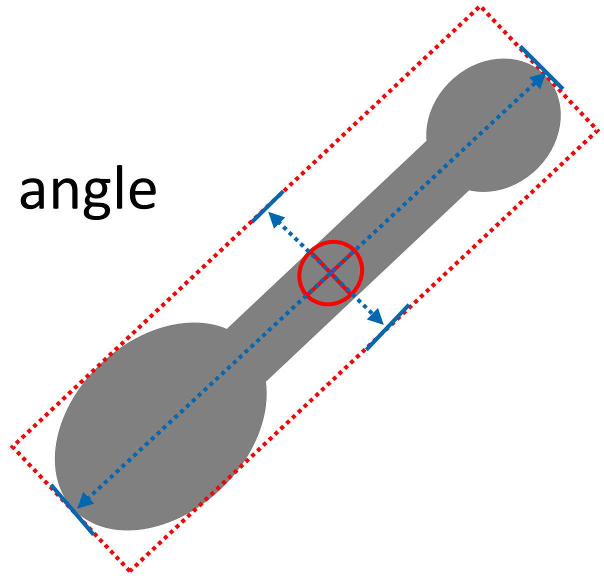


Integration

- Blob Statistics
  - Used to filter and categorize target shapes
  - Area
    - Total number of object pixels
    - May take into account pixel weighting to accommodate for spatial error
    - May or may not include “holes”
  - Perimeter
    - Size of the blob boundary
    - Usually corrected for spatial error

Integration

- Other Blob Statistics
  - Center of Gravity, median
  - Bounding Box, Length, width, angle



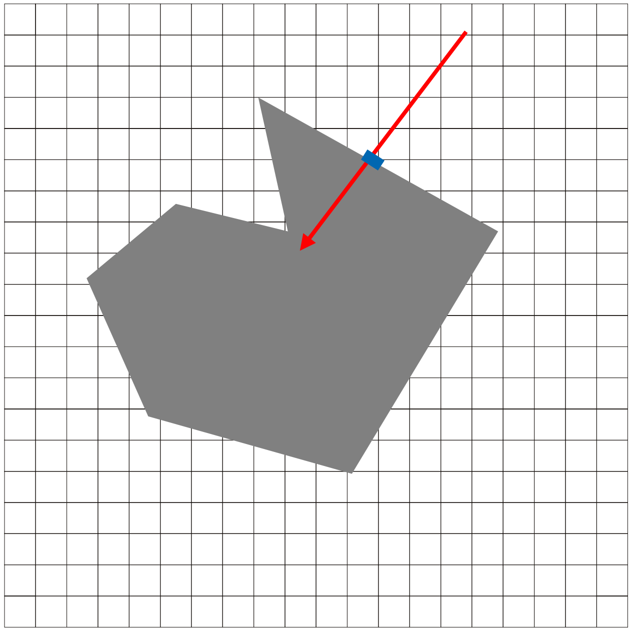
  - Circularity, elongation, aspect ratio

Integration

- Typical Connectivity Parameters
  - Threshold value or method for auto-thresholding
  - Size filters – limit detected objects based upon min and max area
  - Number of blobs to detect, sorting typically done by area
- Uses for Connectivity
  - Object location, identification
  - Cursory gauging
  - Presence/absence

Integration

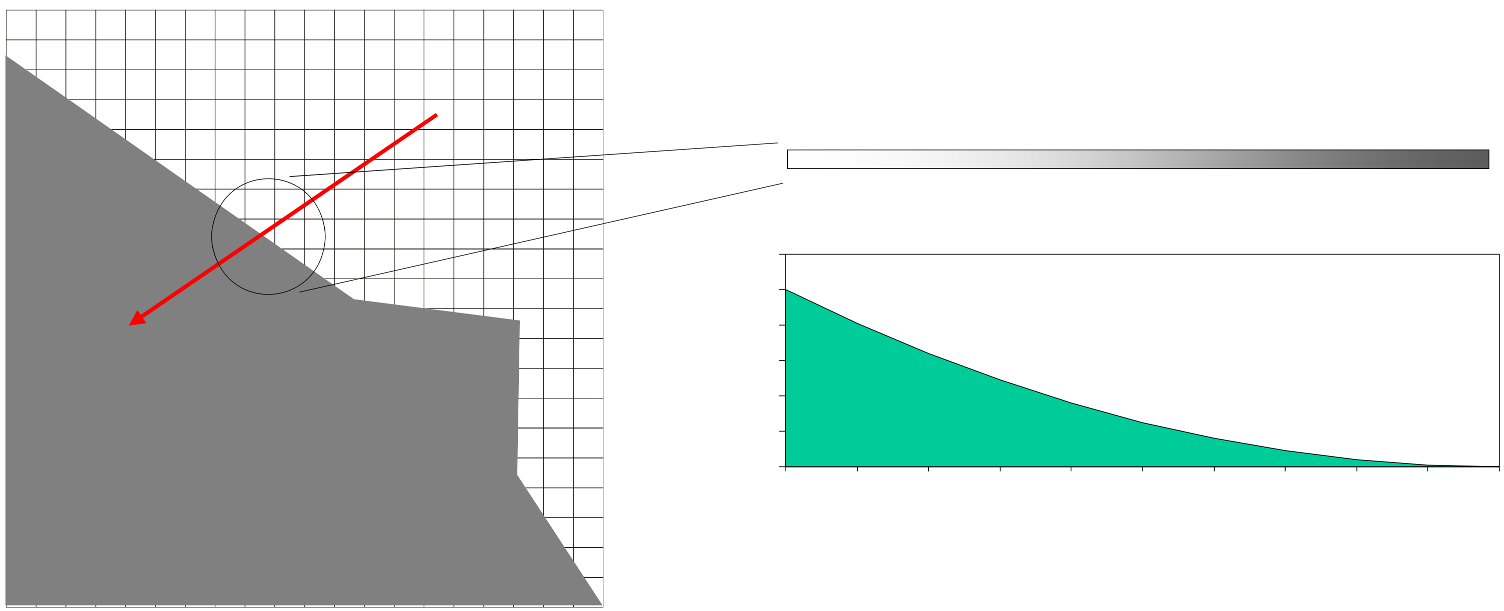
- Edge Detection/Analysis
  - Edge detection is the process of isolation of significant local changes in contrast within the image
  - Edge tools locate whole or sub-pixel edge points



(231.651, 172.295)

Integration

- Edge Detection/Analysis
  - Basic operation happens on a line of image pixels

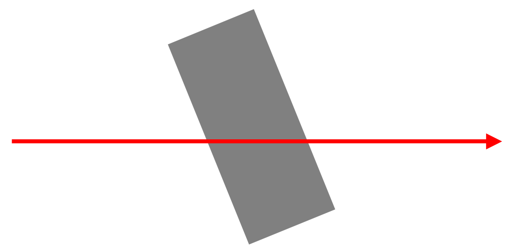


Integration

- Edge Detection/Analysis
  - First step is to extract the edges
  - Edges are the first derivative of the gray-scale image data
  - Spatial filtering is used to extract the edge information

Integration

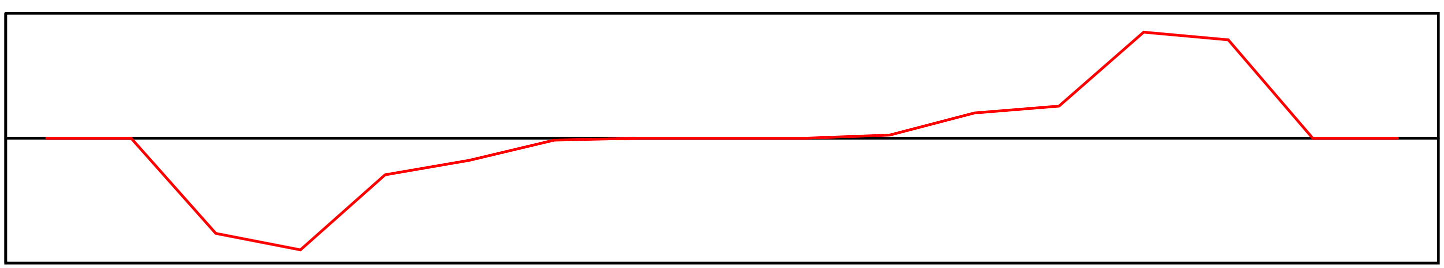
- Edge Extraction on a Gray-scale Line of Pixels



255	255	102	76	43	41	40	41	40	41	45	81	97	251	255

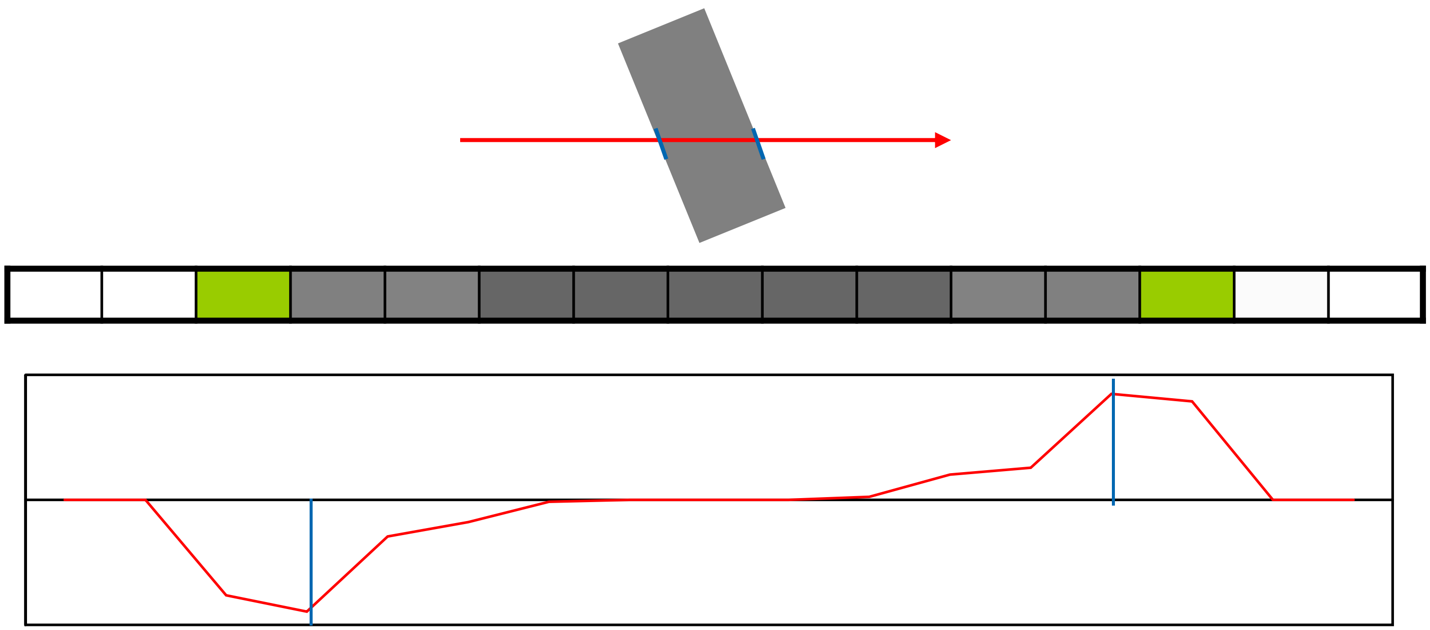
-1	0	1

	-153	-179	-59	-35	-3	0	0	0	5	40	52	170	158	



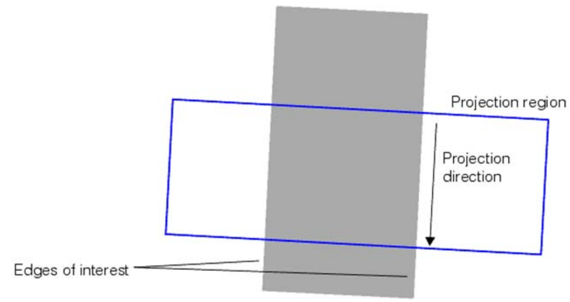
Integration

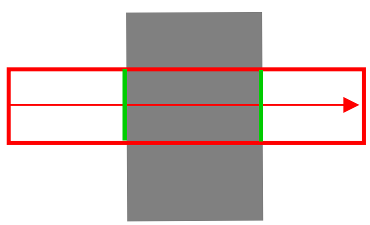
- Localized Peaks are the Edge Positions
  - Further processing is done to provide sub-pixel position estimation



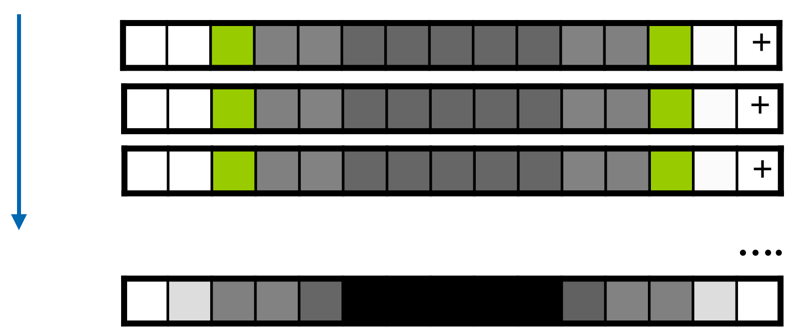
Integration

- Edge Tool ROIs often have the Ability to Combine Lines of Data
- Image Data is Combined into a Single Line as a "Projection" of the Area of the ROI



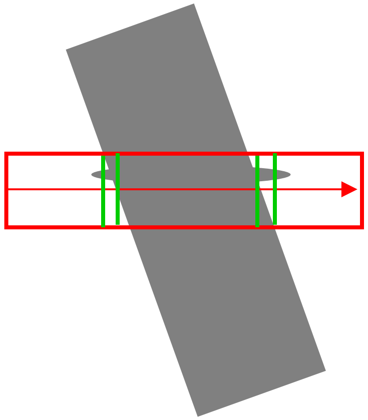


Projection



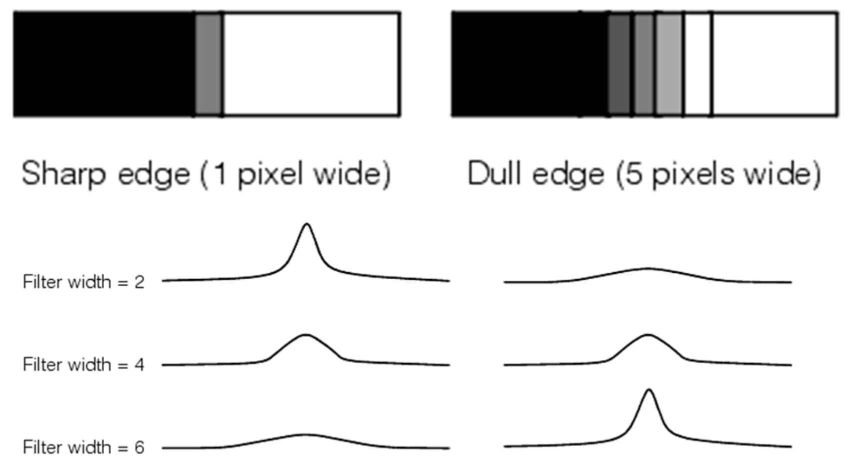
Integration

- Projection can create interesting results if the tool is not perpendicular to edge surface or if there exist small features



Integration

- Calipers – pairs of edges
- Typical Edge Tool Parameters
  - Filter
    - Size, steepness
  - Edge direction
  - Contrast
    - Min level, edge strength
  - Feature matching
    - Edge pair distance, position, strength
- Uses for Edge Tools
  - Gauging
  - Feature presence, verification
- Other Edge Tools
  - Line, curve or object approximation
    - Regressions
    - Hough transformation



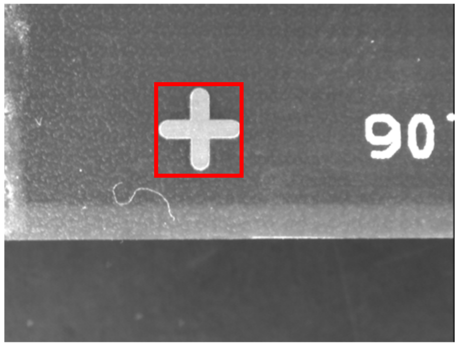
Integration

- Image Correlation
  - Finds pre-trained features
  - Other names
    - Normalized correlation
    - Template matching
    - Search
    - Pattern matching

Integration

- Implementation
  - A “model” or “template” is trained from an existing image
    - Models may be, but rarely are, synthesized
  - The model is stored as a complete gray-scale image
  - Implementation may allow for scaled and rotated search

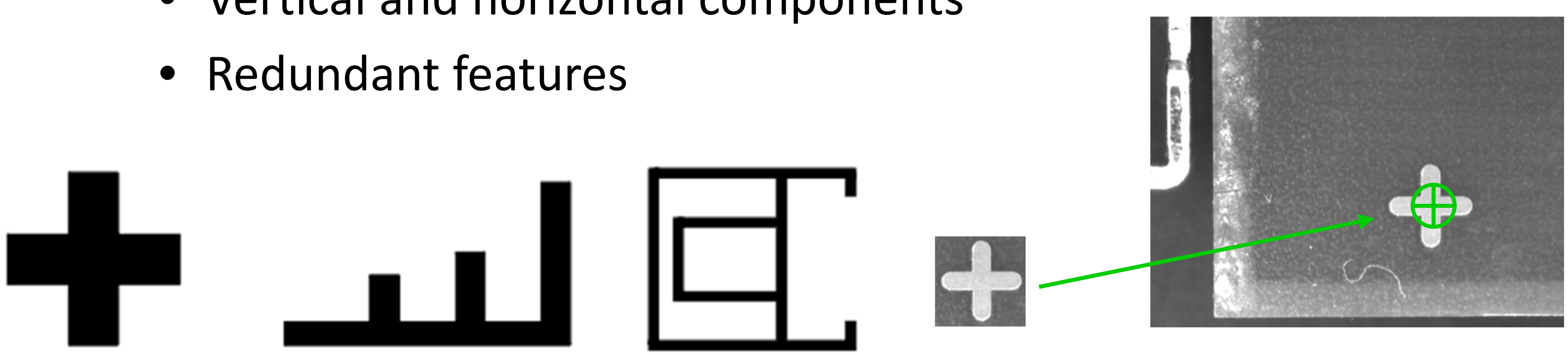
Target Image



Trained and Stored Model Template

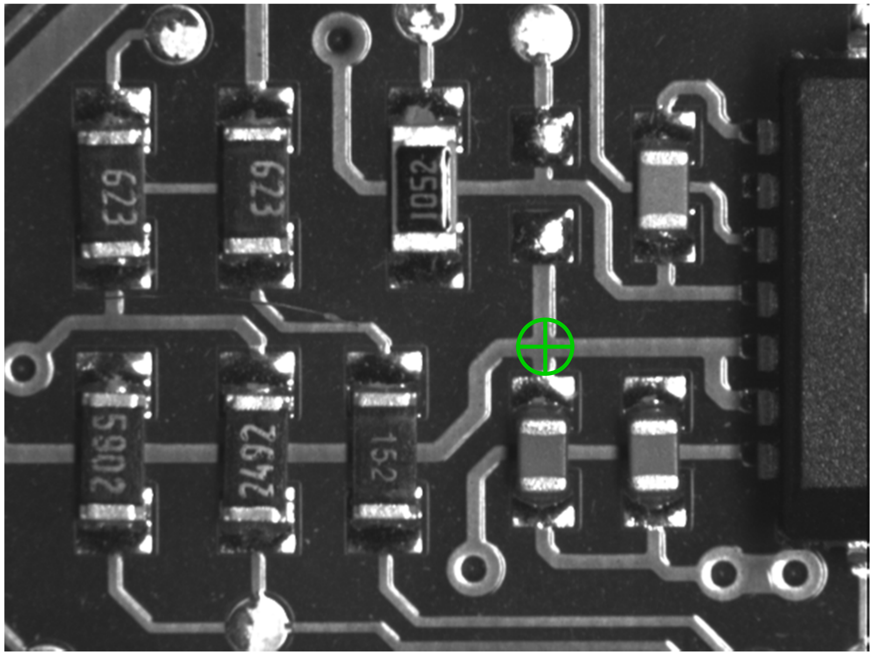
Integration

- Implementation
  - The target image or ROI is searched by mathematically comparing the model template at all points
  - Similar to a convolution, sometimes called a large kernel convolution
  - Search process is “normalized” with respect to the gray-scale image to make the search tolerant of brightness or contrast changes
  - Pattern selection should be done to optimize the result
    - Vertical and horizontal components
    - Redundant features



Integration

- Common Challenges
  - Model selection
  - Confusing scenes

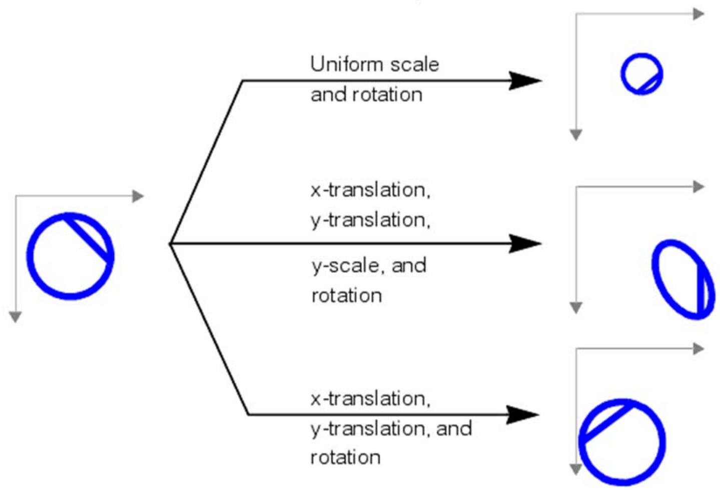


Integration

- Common Parameters
  - Minimum match
  - Number to find
  - Angle and scale variation
- Typical Uses
  - Feature presence/absence
  - Position verification
  - Guidance

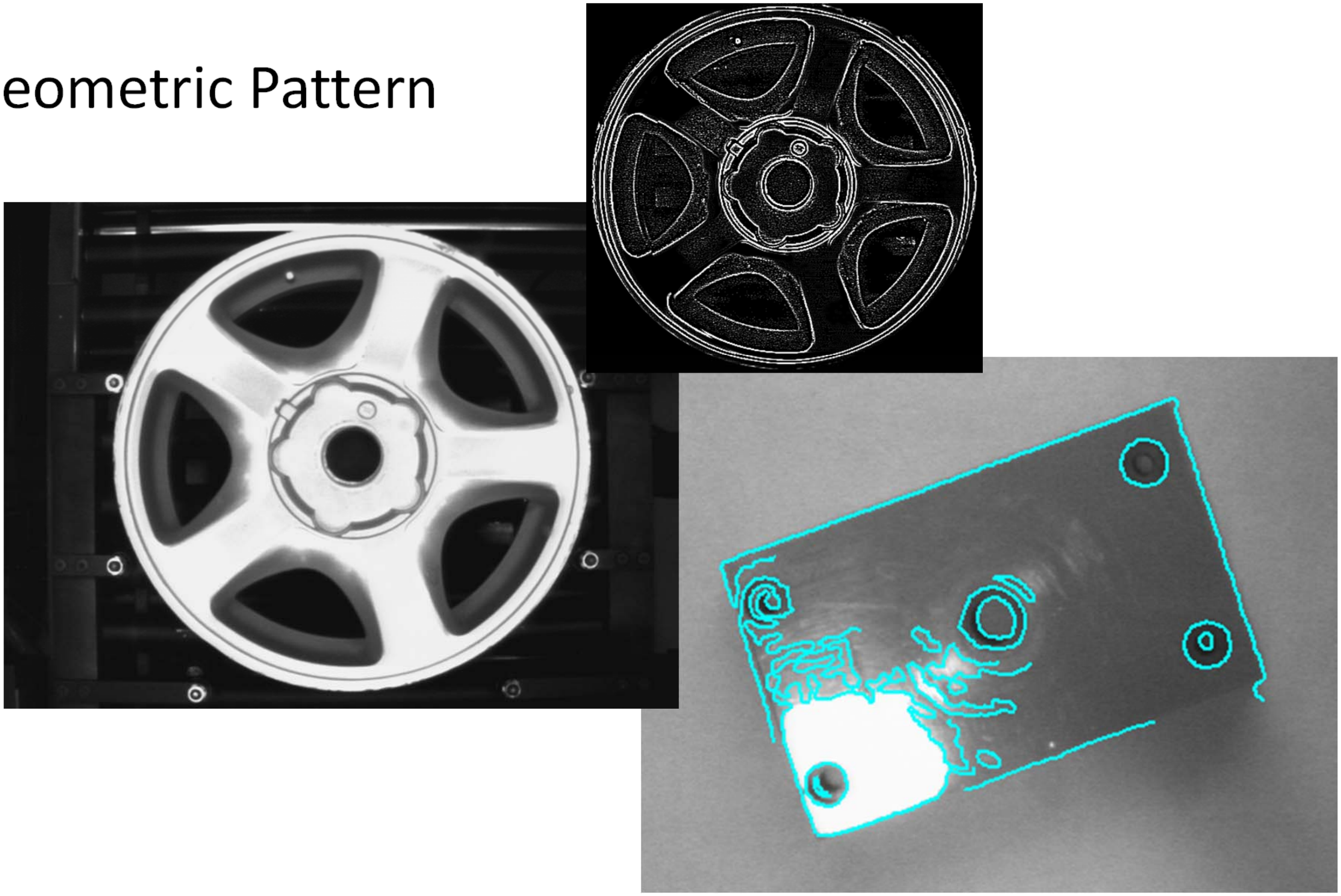
Integration

- Geometric Search
  - Locates features within an image
  - Based upon geometric structure, feature relationships
  - Also called pattern matching
    - Known by a variety of product names: PatMax©, Smart©.
  - The search pattern is trained from an image or may be synthesized.
  - Geometric search pattern is a mathematical representation of the target object, not an actual image
  - Training and search process both use contour (e.g. edge) image
  - Process allows for fast, reliable search with full transformation and rotation.



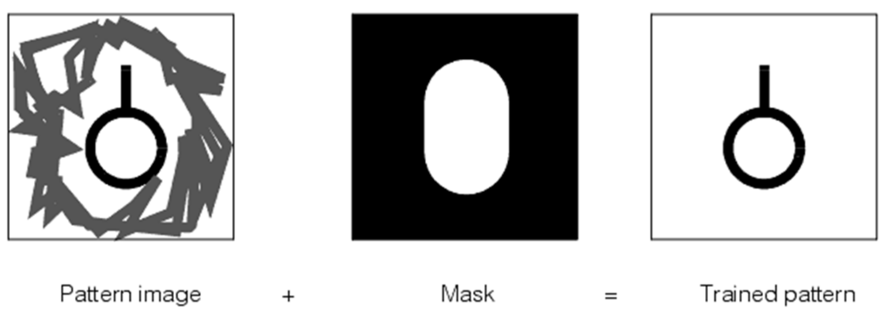
Integration

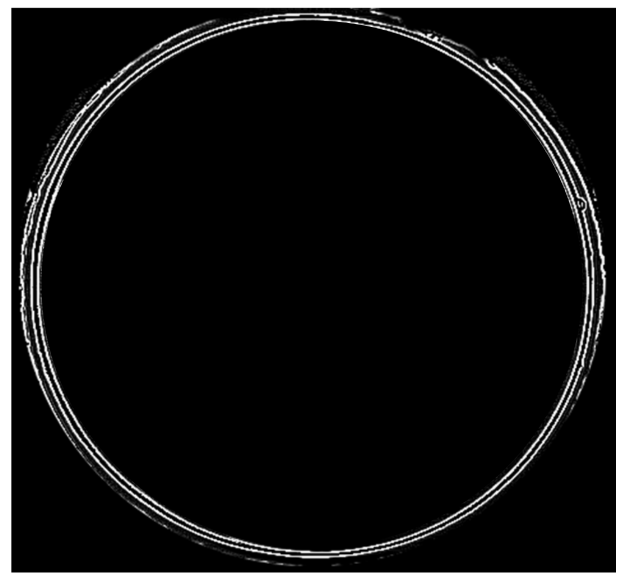
- Geometric Pattern



Integration

- Pattern may be editable, or otherwise masked or manipulated to optimize performance





Integration

- Common Search Parameters
  - Search minimum match
  - Various training parameters
- Typical Uses
  - Guidance
  - Feature location
  - Part verification

Integration

- Combination of Multiple Functions to Perform a Single Task
  - OCR/OCV
  - Golden template matching

Integration

- Inspection Concepts and Techniques by Application
  - General type of inspection
    - Assembly Verification/Recognition
      - Blob (grayscale consistency)
      - Search (confusing images?)
      - Edge detection
    - Flaw Detection
      - Blob
      - Image statistics/processing
      - Edge analysis
    - Gauging/Metrology
      - Blob
      - Search
      - Edge detection
    - Location/Guidance
      - Blob
      - search
    - Character verification
      - OCR/OCV
      - Template Matching
      - Blob

Integration

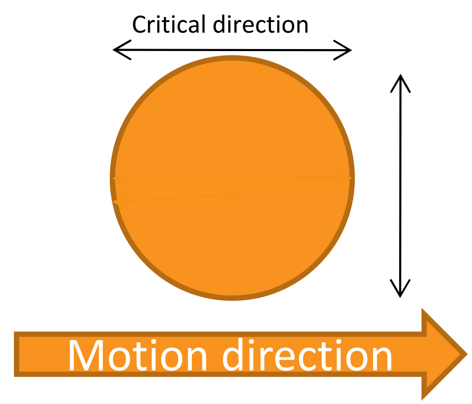
- Advanced Application Notes – High-speed Applications
  - Key issues
    - Triggering
      - Higher speed applications must be aware of triggering inconsistency
      - Trigger latency must be repeatable not random
    - Stopping the motion
    - Acquisition rates

Integration

- Advanced Application Notes – High-speed Applications
  - Imaging
    - Stopping part motion
      - An issue for any moving part – enhanced when speeds are higher
      - Electronic shutters
        - » Useful from about 30 microseconds up
        - » Main challenges are light intensity and related depth of field problems
      - Strobe lighting
        - » Useful from about 2 microseconds up
        - » Always overdrive the strobe light
          - How? Why?
          - LED duty cycles
      - Pixel blur
        - » All moving parts cause a pixel blur at any speeds
        - » How much blur is acceptable
        - » Calculating shutter or strobe timing

Shutter or strobe time calculation example: part in motion at 1 meter per second, desired field of view 50mm with 1024x1024 camera. For this application desired pixel uncertainty ½ pixel.

Speed: 1mm/msec, pix size 0.04882mm. ½ pixel size 0.02441mm. Part will move 0.02441mm in 0.24ms.



Integration

- Advanced Application Notes – High-speed Applications
  - Imaging
    - Acquisition rates
      - Maximum inspection rate: frame rate
      - Background acquisition – “ping pong”
      - Increasing throughput – partial scanning
        - » How?
      - Note: camera shutter speed directly adds to image rate

Integration

- Advanced Application Notes – High-speed Applications
  - High speed image processing and analysis
    - Component processor/computer speed may be critical
      - Algorithm processing time is directly related to computing power
      - Tools that take little time
        - » Simple edge extraction and edge detection
        - » Binary processes
      - Tools that can take more time
        - » Blob analysis (non-deterministic)
        - » Any feature location – particularly with scaling and/or rotation
      - Tool timeouts

Integration

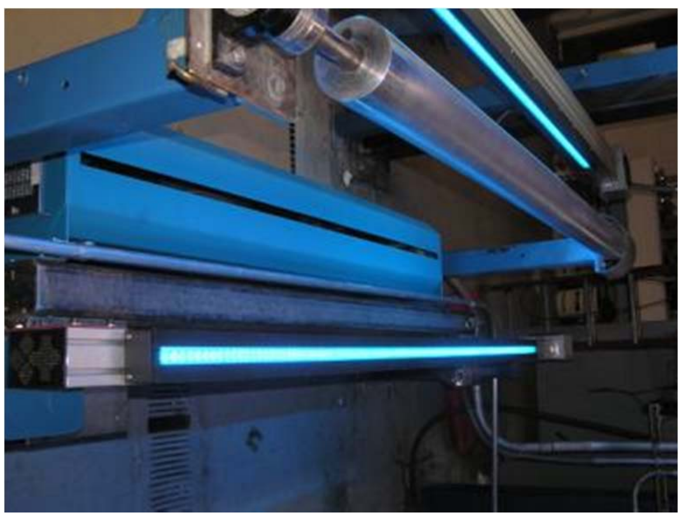
- Advanced Application Notes – Line-scan Imaging
  - Line-scan imaging overview
    - Highest possible image resolution - with added complexity and cost
    - The camera can create a single image by combining multiple separately acquired lines
    - Acquisition rates typically are from about 9kHz to 15kHz and up
      - Rate is per image line

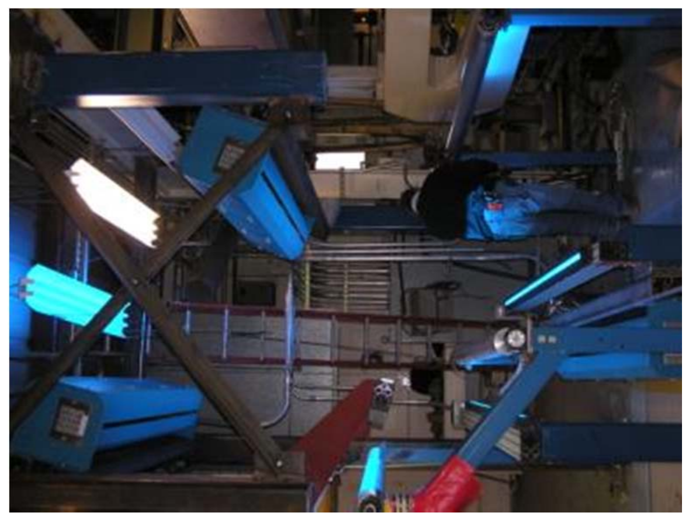
Integration

- Advanced Application Notes – Line-scan Imaging
- Line-scan cameras and optics
  - Sensor /camera size
    - Package usually is (much) physically larger than standard area camera
    - Sensor widths range from about 14mm to 90mm and more
  - Lens sizes and mounting
    - Lens primary optics must be much larger cover the large sensor size
    - Standard mounting formats are F-mount, M42, M72
    - Special considerations may be required to align lens with the sensor

Integration

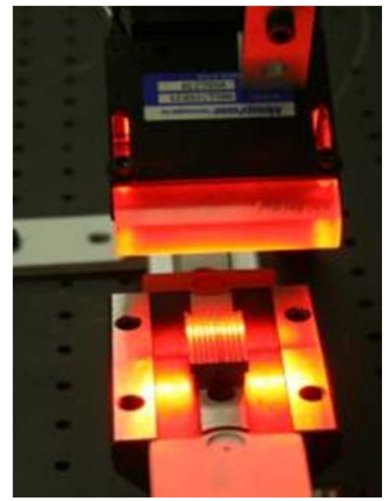
- Advanced Application Notes – Line-scan Imaging
  - Lighting issues
    - Light must cover the entire linear scan area, and be virtually uniform over that area
    - Aligning the light to the imager can be one of the challenges
    - Light intensity must be much greater than for standard area-scan applications due to the high image acquisition rate
    - Strobing is not practical due to line rate (but possible?)





Integration

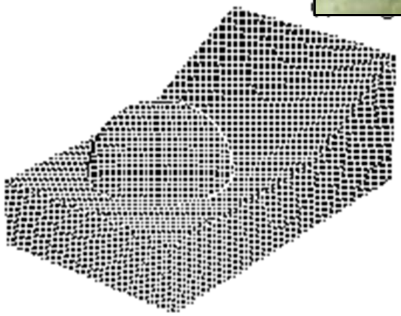
- Advanced Application Notes – Line-scan Imaging
  - Camera triggering and square pixel calculations
    - The image lines (usually) must be clocked with the motion to achieve a square pixel
    - Typical calculation:



Field of view: 2” Sensor resolution: 2K Pixel size: 0.0009765
Part speed: 3’ / second. Image must be triggered every 0.0009765”, or every 0.325ms (about 3kHz)

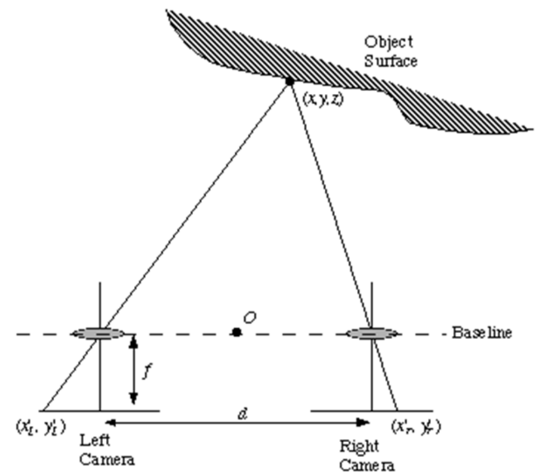
Integration

- Advanced Application Notes – 3D Imaging
- 3D Concepts
  - 3D point
  - Image reconstruction
  - Full point cloud



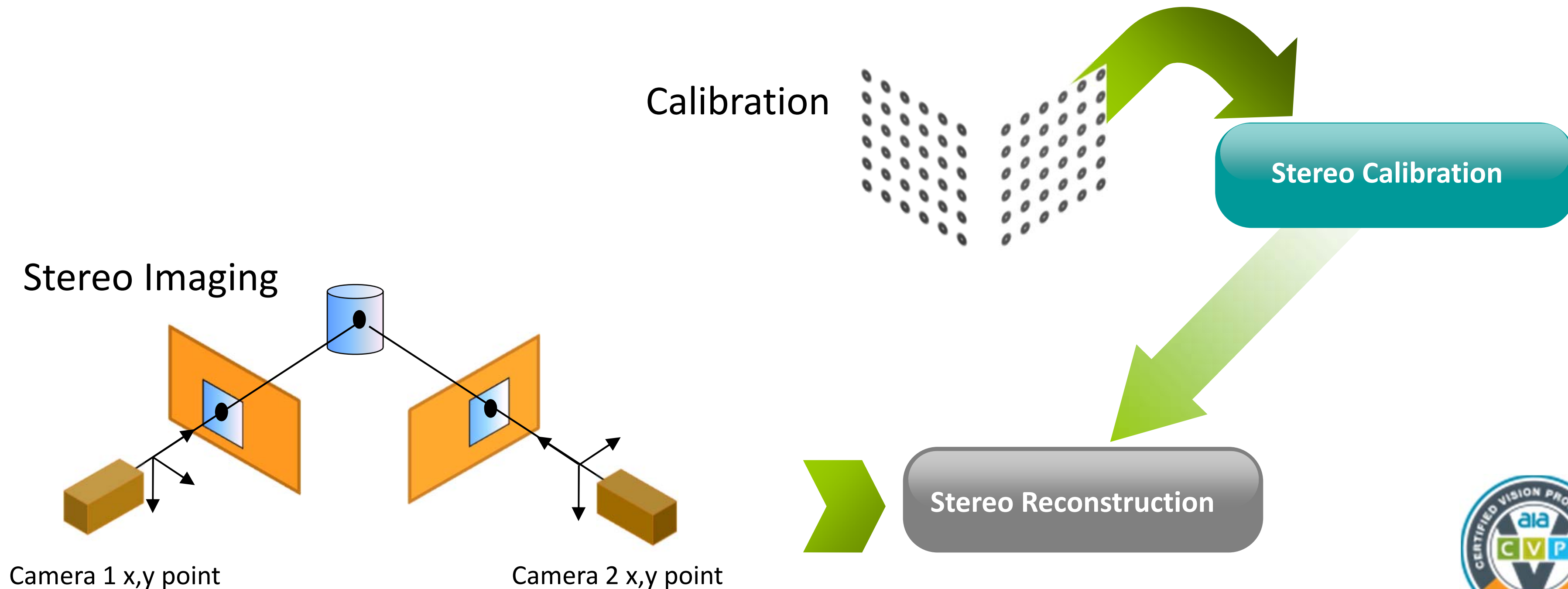
Integration

- Advanced Application Notes – 3D Imaging
  - Techniques
    - Stereo/multiple cameras
      - Point data or image reconstruction (typ.)
      - Binocular
      - Photogrammetric/photometric
    - Single camera
      - Point data only
      - Feature geometry
      - Range from focus
    - Structured/Laser lighting
      - Point cloud



Integration

- Advanced Application Notes – 3D Imaging
  - Calibration is the key component to 3D imaging
  - Machine vision techniques remain critical for feature identification
  - 3D imaging for machine vision <> computer graphics!



Integration

- Advanced Application Notes – Robotic Guidance
  - Robotic guidance is the act of communicating a world-calibrated point from a machine vision system to a robot controller
    - 2D or 3D guidance depending upon the application
    - Data available
      - X, Y, rotation about z (2D)
      - X, Y, Z, rotation about z (3D)
        - » Standard 2D image with height of feature included
      - X, Y, Z, yaw, pitch roll (3D)
        - » All degrees of motion (6-axes)
      - Dependent upon imaging methodology and application
    - Machine vision considerations still drive the application

Integration

- Advanced Application Notes – Robotic Guidance
  - Guidance applications
    - Discrete part pick – single or multiple generally known stable resting states
    - Bin picking – random orientation

Integration

- Selecting and Working with System Integrators
  - As an end user can the integration be done in-house?
  - Key questions when deciding to use in-house resources or outsourced integration services
    - Do we have or are we prepared to fully develop all of the technical skills this project requires?
    - Can we maintain the skills developed in-house and benefit from the experience of integrating a machine vision system?
    - Do we have sufficient time and resources available to see the project through to success?
    - If the project turns out to have unexpected challenges, how will we meet them?
    - Are we able and willing to retain ownership of the system for the long term with respect to maintenance, support, service, and upgrades or re-configuration?

Integration

- Selecting and Working with System Integrators
  - Selecting the right outside integrator
    - Purposes of outsourcing integration tasks: cost reduction and mitigation or transferal of project risk
    - Sources: publications, referrals
    - Types of capabilities
      - Consultation
      - Software, system configuration
      - Application specific integration
      - Fixturing, robots and vision integration
      - Complete machine integration

Integration

- Selecting and Working with System Integrators
  - Choosing an integrator
    - Develop subjective criteria
    - Evaluate technical capability relative to the project
    - Determine competence based upon response to specification.
    - Look for a system guarantee with turnkey installations.
    - Cost is not the defining factor

Conclusions

- Machine Vision can be Successful
- Prepare and Plan
  - Analyze the application and collect information about the required inspections and process
  - Prepare a viable specification for an inspection that will deliver the appropriate results
- Integrate
  - Execute the proposed specification
  - Don’t cut corners
  - Train appropriate support staff

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