Why Inspection is Critical to Automation

Bhaskar Ramakrishnan
Technical Sales Engineer
DWFritz Automation, Inc.
Acknowledgements

John Sklarz
Regional Product Sales Director – West Region
Machine Vision Technology Group
Keyence Corp. of America
Agenda

• Definition of inspection
• Why is inspection in Automation critical?
• Sampling vs. 100% Inspection
• Automotive, Medical and Consumer Electronics market needs
• Inspection technology selection process
• Inspection Technology Overview
• Case Study
Definition Of Inspection

• Wiki definition:
  • An inspection is, most generally, an organized examination or formal evaluation exercise.
  • The results are usually compared to specified requirements and standards

• Bhaskar’s definition:
  • Comparison to a desired baseline
  • You get what you measure!

Source: https://en.wikipedia.org/wiki/Inspection
Why Is Inspection In Automation Critical?

• Product Quality
  • Reduce yield loss
    • Provide feedback to improve the process
  • Prevent field failures and product recalls
    • Warranty cost
    • Lawsuits
  • Intangible Value – Brand Name
Samsung Note 7: Billion Dollar Battery

Source: https://www.youtube.com/watch?v=YxFaHldaptE
Sampling Versus 100% Inspection

• Sampling:
  • Not measuring the quality of the lot (only Go/No-Go)
  • Risk of rejecting good parts and accepting bad parts
    • Producer risk vs Consumer risk
    • What happens when accepted bad sample gets assembled with high value item?

• 100% inspection:
  • Very expensive (inspectors and time)
  • Can’t use when product must be destroyed to test (weapons testing)
  • Handling for inspection can induce defects (cosmetic, contamination, stent)
## Industry Needs

<table>
<thead>
<tr>
<th>Medical</th>
<th>Auto</th>
<th>Consumer Electronics</th>
</tr>
</thead>
</table>
| 100% metrology driven by | • Patient health  
• Product recall  
• Cost of inspection  
• FDA regulations | • Safety  
• Fuel efficiency (CAFE regulation)  
  • Warranty cost  
• Autonomous driving/EV  
• Aesthetics (customer) | • Continuous improvement and Yield maximization  
• Miniaturization  
• Cosmetics |
| Applications/Examples | • Class 3 medical device  
• Unique Device Identification (UDI)  
• Particulate contamination in vials  
• Package seal breach  
• Surgical instrument miniaturization  
• 3D printing or Additive Manufacturing | • Fasteners  
• Crankshafts, Camshafts and Drive shafts  
  • Flexibility within the component family  
• Body parts, Large scale plastic components such as instrument panel, and soft materials | • Final Assembly and Test Packing (FATP)  
  • Packaging more than 100 parts within a 3 inch square  
  • Missing components  
  • ≤ 50 microns placement accuracy |
| Challenging environment | • Cleanroom compatible | • Dirty and Oily parts | • Overseas installation |
Inspection Technology Selection and Evaluation

1. Understand the application
2. Obtain the specifications e.g. Drawing, Cost, Constraints, Environment etc.
3. Review the material type and surface treatments
4. Part fixture review
5. Estimate error contribution from imaging and assign remaining error to mechanical system
6. Determine the hardware e.g. lighting type based on material, optics, FOV, Depth of Field, motion accuracy and constraints
7. Determine suitable technology
8. Calculate desired resolution based on desired gage repeatability OR smallest defect size
9. Conduct empirical test and analysis to validate
10. Confirm mechanical system variation for part location is within the error allocation (retrofits becomes tricky)
Recap of Process

1. Requirements
2. Test object
3. Vision system
4. Mechanical fixture
## 100% Inspection Technologies Overview

<table>
<thead>
<tr>
<th>Technology</th>
<th>Continuous Scan</th>
<th>3D</th>
<th>Auto</th>
<th>Medical</th>
<th>Consumer Electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D Area Camera</td>
<td>Yes</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Laser Triangulation</td>
<td>Yes</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Structured light</td>
<td>No</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Stereo color line scan triangulation</td>
<td>Yes</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
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<tr>
<td>2D Chromatic Confocal</td>
<td>Yes</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>White Light Interferometer</td>
<td>No</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>1D Conoscopic Holography</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>2D Micrometer</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
2D Area Scan With Directional Lighting

Camera

Synchronized light

For Challenging Machine Vision Inspections

Embossed Characters on Packaging

Source: Keyence
Laser Triangulation

\[ h = \frac{d}{\tan(\Theta)} \]

Source: Keyence
Laser Triangulation Applications

- Coplanarity of components on circuit board

- Width, Length, and Volume of Sealant

- Flatness/Warpage of Clutch plate

Source: Keyence
Structured Lighting - Operating Principle

The laser interference method works with two wide planar laser beam fronts. Resulting interference forms regular, equidistant line patterns on workpiece which is then used to understand features in 3D space.

Source: Keyence
Structured Lighting Applications

Apply Count, Area, Aspect ratio and other Vision tools

- Solder Bridge detection

- Solder Presence

Source: Keyence
Stereo Color Line Scan Triangulation

- Stereo camera: Left and Right side image captured
- Two images are Pattern Matched around the ROI
- Triangulation for height

Source:
http://www.visionchinashow.net/upload/201510301650201519788548.pdf
Chromatic Confocal

- Chromatic: Optical probe spreads the focal length of the Polychromatic (white) light source over a discrete number of points creating a full spectrum of light.

- Confocal: Based on the wavelength and intensity of the reflected light collected via the special filter, a very precise distance measurement can be taken several times per second.

- Possible to measure on nearly all materials:
  - Glass, metal, leather, paper, liquid.

Laser Scan Micrometer

Traceable two dimensional inspections in line

Measurement principle
Uniform collimated lighting with a green LED. Two-dimensional CMOS array detects the light-dark edges in the received light, and measures the dimensions.

Dual telecentric optical system
Dual telecentric lenses ensure only collimated light is used for imaging. Even though the distance from the object to the lenses changes, the size of the image on the CMOS does not change. High precision measurement is possible.

Pinpoint sub-pixel processing
High speed and high precision are achieved by performing pinpoint extraction and sub-pixel processing on just the contour within the specified measurement area, from the silhouette imaged on the CMOS.

HUD unit + collimator lens
Collimated light is produced without any unevenness by spreading LED light uniformly across the common range.

High brightness InGaN green LED
A high brightness LED is used, combining three features:
- Even Brightness Distribution - Resistant to EMF
- Eye Safe

Principles of The Conventional Laser Scan Micrometer

Structure

Principle

A semiconductor laser beam is projected onto a polygon mirror which is rotated by a motor to scan the measuring range. The time in which the laser beam is interrupted by the target is measured to obtain the dimension of the target.

Source: Keyence
Case Study: Medical Packaging Seal Issues

- **Problem:**
  - Human inspection is unable to reliably identify defects

- **Need to detect:**
  - Foreign material
  - Seal width
  - Holes and punctures
    - ≥ 50 microns
# Medical Packaging Seal Breach Summary

<table>
<thead>
<tr>
<th>Technology</th>
<th>Resolution</th>
<th>100% inspection?</th>
<th>Material compatibility</th>
<th>Comments</th>
<th>Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Camera</td>
<td>50 microns</td>
<td>Yes</td>
<td>Translucent plastic on one side</td>
<td>Seal inspection, Transparent material dependent</td>
<td>Depth of field and lighting</td>
</tr>
<tr>
<td>Thermal</td>
<td>Low resolution</td>
<td>Yes</td>
<td>AU, PET, PE, Paper</td>
<td>Seal integrity</td>
<td>Low resolution</td>
</tr>
<tr>
<td>Opposing lasers</td>
<td>Micron level</td>
<td>Yes</td>
<td>Can accommodate opaque materials</td>
<td>Deterministic, material agnostic</td>
<td>Cost and Material handling</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>700 microns</td>
<td>Yes</td>
<td>Tyvek®, Paper, Foil. Film, Aluminum, Plastic</td>
<td>Seal integrity</td>
<td>Low resolution</td>
</tr>
</tbody>
</table>
### Packaging Seal - Area Camera

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% inspection</td>
<td>Yes</td>
</tr>
<tr>
<td>Resolution</td>
<td>50 microns</td>
</tr>
<tr>
<td>Speed</td>
<td>150 mm/sec</td>
</tr>
<tr>
<td>Material compatibility</td>
<td>One side/laminate needs to be transparent</td>
</tr>
<tr>
<td>Advantages</td>
<td>Deterministic</td>
</tr>
</tbody>
</table>

**Image:**
- Image of packaging seal with a transparent laminate.
- Zoomed-in view showing the seal area.
- High-resolution image of the laminate sheet.
Bhaskar Ramakrishnan
Technical Sales Engineer

DWFritz Automation Inc.
27200 SW Parkway Avenue
Wilsonville, OR 97070
USA

Telephone: 503.866.5705
Email: Bhaskar@DWFritz.com

www.DWFritz.com