Improving Visual Inspection Quality with AI

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Introduction

Visual inspection is the oldest method for quality control. The human eye has proved to be excellent at detecting cracks, deformities, scratches, missing components, and other errors and issues that can impact quality.

However, when we get tired, distracted, or bored we make mistakes. Studies have found that manual inspection tasks can exhibit error rates of up to 30%. Often, these “errors” are actually false positives where an inspector had started to question their decision-making.

Considering these error rates, and the resulting product quality concerns and higher costs due to waste, additional screenings, and manufacturing downtime, there is increasing demand for AI-based technologies to provide decision-support for manual tasks. In particular, these technologies are well-suited for lower volume, higher value, and customized products where fully automated inspection isn’t cost-effective or practical.

This whitepaper discusses how AI can provide decision-support for visual and manual tasks throughout incoming, in-process, and outgoing (final) inspection steps of manufacturing. The paper also presents two uses cases where the technology is used in the food & beverage and electronics manufacturing markets.

Humans versus Machines

Every few days, there’s a new headline warning that artificial intelligence (AI) is poised to take away jobs from humans. Undoubtedly, there are tasks where machines are more cost-effective and efficient than humans. Buttons replaced the elevator operator, and machine vision-powered robotics has significantly changed large scale manufacturing by taking on many dull, dirty, and dangerous tasks.

For quality inspection, it’s not quite that simple. We excel at sensing differences through sight, touch, and even taste and smell depending on the product. We can distinguish subtle flaws, variations or differences
and can adjust when faced with unpredictability. Humans are also easily trained. We learn by example and can adapt for new products or requirements.

Depending on the product and end-market, human involvement can also be critical. For high-value consumer products, the “human craftsmanship” may be an important part of their brand. Human adaptability can also be more cost-effective for lower volume, customized, or regional products and assembly tasks where full automation is complex and costly.

Despite these human advantages, we also suffer from a number of limitations. Our eyes can be easily tricked, making us unreliable. Try and count the black dots in Figure 1. A machine vision system makes decisions faster, thanks to higher processing speeds and ever-expanding memory capacity. Automation can be programmed to be unbiased and consistently accurate.

**Figure 1:** Humans are very good at inspection. We can use our senses and are quick to learn and adapt. But we can also be easily fooled. Try and count the black dots in this image.

Considering the cost and brand risk posed by human error rates, there's an obvious opportunity to leverage advances in AI technology to help ensure quality for manual inspection and assembly tasks.

**AI-Powered Decision Support**

Adding automated decision-support to visual inspection helps speed inspection rates, improves end-to-end product quality, and provides more qualitative product evaluation to ensure manufacturing processes are repeatable and traceable. As consumers increasingly demand more customized products, human inspection can sometimes be more cost-effective and adaptive than automated processes for on-demand and low volume manufacturing.
New visual inspection systems leveraging advances in no-code algorithm development and edge processing platforms make it easier and more cost-effective for manufacturers to add AI decision-support for in-progress and finished goods. These systems provide pre-packaged inspection skills that can be easily customized and retrained for specific requirements, including verifying components, inspecting labelling, checking assembly, and digitizing work instructions.

As a fully integrated tabletop system, the operator can use the camera, edge processing, and display to acquire images and create an AI model. They don’t need to switch between cameras, PCs or cloud-based systems; making the system easy-to-use, highly cost-effective, and all in a smaller footprint.

Figure 2: A fully integrated visual inspection system includes a camera, display, edge processing, and pre-packaged common inspection skills, while no code development platforms enable easy customization for unique requirements.
No Code Advantages and Simple Training

One of the most significant hurdles for manufacturers considering AI-based inspection is algorithm development. There is a perception that it requires specialized skills, or expensive consulting, to deploy the technology for manufacturing applications.

For visual inspection systems, pre-packaged skills for common requirements such as image compare and image save can be quickly trained and deployed, without requiring programming language expertise.

Image compare is a visual application that makes errors obvious to a human inspector. The plug-in is easily trained, all you need is a single image of a known good product (a “golden reference”). All future products are then compared against this golden reference.

A manufacturer can have multiple golden masters for different product lines, or for regional requirements within those product lines. The plug-in can also be trained to verify product quality throughout different manufacturing steps.

Throughout various stages of manufacturing, an operator can use image save to capture a record of the product for traceability, batch tracking, or inventory management. This data can then be used to help pinpoint a root cause for errors. If an in-field issue is reported, images can be used to help speed resolution and avoid unnecessary claim costs.

The visual inspection plug-ins can also be customized for specific requirements using no-code software tools.
Visual Inspection and Brand Management

Dairy Distillery, a Canadian spirits manufacturer that has pioneered a unique process to produce vodka from a dairy byproduct, uses AI visual inspection to add decision-support for manual labelling and quality control (QC) checks.

Brand appearance plays a significant role in consumer choice, and the manufacturer competes against larger players with much deeper marketing budgets. In addition, operating in the food and beverage market brings another set of risks. Approximately 60% of companies in the market experience a recall. While recalls related to food quality generate media headlines, and can significantly damage a brand's reputation, typically one-third of recalls from the US Food and Safety Inspection are related to packaging and labelling errors. These misbranded or incorrectly labelled products may not impact consumer safety, but they can result in costly shipment delays and rework for a manufacturer.
For the distillery, their main concern is maintaining a consistent, eye-catching appearance so they can earn a premium spot on a store shelf. The distillery uses a bottle fashioned after an old fashioned milk bottle, with distinctive and eye-catching labelling. The main label and a cap label are applied by machine. A human has to accurately place an emblem logo that visually aligns with brand elements on the other labels to ensure a consistent and appealing shelf display. With multiple products and short manufacturing runs, it’s uneconomical for the distillery to fully automate its labelling process.

Over a long shift, the emblem placement would begin to shift as the operator got tired. Mistakes were often not noticed until the final packaging stage, when staff was then tasked with manually removing and replacing labels. This resulted in downtime, production delays, and additional costs. Worse, there was always the risk a poorly labelled product could reach the store shelves.

AI-based visual inspection provides decision-support for the operator to help eliminate labelling errors. Without requiring any programming skills, the distillery quality manager trained the image compare plug-in to add decision-support for its labelling process. With just one
image of a known good product — a “golden reference” — the system automatically identifies the key brand elements on the bottle. In this example, the plug-in identifies the position of the main label and cap label, and adds a graphic overlay on the visual display to guide the correct placement of the medallion label for the operator.

AI-based visual inspection ensures brand consistency and accuracy for the distillery, as well as cost-savings as labelling does not have to removed and replaced due to human error. The technology is also being used by the manufacturer as a training tool for new operators, so they can quickly understand the proper positioning of brand elements on the bottle and the difference between “good and bad” products.

With expanding production, the quality manager or operator can easily update the visual inspection system with additional “golden references” to provide labelling guidance for new bottles, labelling, and packaging. The operator simply chooses the correct plug-in for the product to be inspected. An additional image save plug-in could also be used to capture images of products at various stages of production for batch tracking. This will also provide the manufacturer with key data related to their manual assembly and inspection processes for root cause analysis and productivity management.

As the distillery adds more automation to its production, the visual inspection system can provide a valuable QC check for in-process or finished goods to ensure all machines and humans are operating in sync.

For this application, the distillery is developing a custom plug-in based on image compare that provides a quick pass/fail assessment on the placement of all bottle labelling. This helps remove stressful subjective decision-making for operators, and will increase production as errors can be identified well before final packaging.

The plug-in could be further trained to assess things like fill levels, cap seal integrity, and verifying the correct labels are being used for custom or regional products.
Figure 6: The visual inspection system requires just one “good image” of the bottle to help the operator align labelling.

For the distillery, the visual inspection system offers many valuable benefits:

• Reduces subjective decision-making for the human operator, especially over a long shift, where the system is consistent and accurate.

• Cost-savings, as labeling does not have to be removed and reapplied if an error is detected during the final phase of production.

• The system is quickly trained with images of “good product” for multiple product lines. An operator or quality manager can train the system, with no programming skills required.

• It’s faster to train new employees on understanding the relationship of key elements of the brand.

In addition, the manufacturer use the system to capture and save an image of every printed circuit board. This data is shared with traceability systems for inventory and shipment management and batch tracking, as well as other business processes including root cause analysis for defects.
Visual Inspection and Electronics Manufacturing

Manual visual inspection is an important part of electronics assembly, from the initial verification of quality and count for incoming components through to final packaging and shipping for outgoing products.

Manual visual inspection is still often included in key parts of the manufacturing process, even where there are more sophisticated automated optical inspection (AOI) methods, for issues related to missing or misaligned components, incorrect orientation, and insufficient or excess solder. Throughout these stages of manufacturing, AI technology can help highlight differences and deviations between products. (Figure 7)

For electronics assembly tasks, visual inspection technology is used to verify that the right type, quality, and quantity of components have been received and are being used. For example, the system can be trained to verify that 8 mm screws should be used during one specific step in the assembly process. (Figure 8)
## Visual Inspection and Electronics Inspection

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<tr>
<th>Process</th>
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<th>How Pleora Helps</th>
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| **Incoming Inspection QC**    | Verify and visually check that the correct components for the assembly have all been received from suppliers. | • PCB defects (scratched)  
• Incorrect, defective or wrong quantity of components received  
Add automated decision-support for the visual inspection process, including verifying quality and quantity of components received, during the incoming inspection QC. |
| **First Article Inspection (FAI)** | Visually check and test first-run units before full production. | • Incorrect component placement due to programming error  
• False positives due to operator error  
Add automated decision-support to the manual first article inspection phase. First-run units are compared against a golden reference image, with differences and deviations visually highlighted for the inspector on a display monitor. |
| **Automated Production**      | Automated assembly of the boards, including SMT pick-and-place of components and AOI (Automated Optical Inspection) to check for defects. Manual sampling inspection may also be used throughout the process. | • Automated processes are not suitable, or may be too expensive, for short-run or customized products  
• AOI misses through-hole errors  
Add decision-support and automation for sampling processes, including detecting defects commonly missed by AOI. |
| **Manual Component Soldering** | Manual assembly processes, including soldering of through-hole components based on work instructions | • Wrong components placed due to operator error  
• Components accidently damaged  
• Incorrect polarity  
• DNP (Do Not Populate) instructions  
Automate work instruction processes to ensure the right components and quantities are used. Decision-support for visual inspection makes missing components and errors obvious to operator. |
| **Final Inspection / QC**     | Final visual inspection quality control check before boards are packed and shipped, including gold finger visual inspection to ensure contact edges are smooth and clean. | • Connector defects, such as pinholes, copper exposure, and surface issues  
Label placement  
Solder defects  
Missing, broken components  
False positives due to operator error  
Add decision-support and automation to detect differences and deviations, making missing or broken components visually obvious to the human inspector. |
| **Packaging & Shipping**      | Final boards are packaged and shipped to customer. | • In-field quality issues  
Operator saves image of final product. Images can be used for traceability systems, including inventory, shipment management and batch tracking. If an in-field issue is reported, system can be used in root cause analysis to help speed resolution and avoid unnecessary claim costs. |

*Figure 7: For electronics assembly, AI can provide valuable decision-support across incoming, in-process and outgoing stages of manufacturing.*
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<td><strong>Incoming Inspection QC</strong></td>
<td>Verify bill of material and visually check that the correct parts are received to build the box, including the assembled PCBs, mechanical enclosure, cables, screws, etc.</td>
<td>Add automation and decision support for component inspection, including verifying quality and quantity of components received.</td>
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<td><strong>Cable Assembly</strong></td>
<td>Operator follows work instructions to build the box, including wire cutting, checking the terminations of cables, verifying connections, assembly into a harness, and testing.</td>
<td>Automate the verification process for measured length of wires, correct components for harness, and the visual order of cables (for example, correct color coding).</td>
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<td><strong>Mechanical Assembly</strong></td>
<td>Components for the assembly are kitted for the operator, who follows work instructions to retrieve the correct parts and build the box. The operator may be assembling the full box or may be tasked with specific assembly steps.</td>
<td>Detect quality issues during error-prone steps in assembly by comparing in-process assembly to a golden reference image.</td>
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<td><strong>Testing</strong></td>
<td>Electrical testing of the product to ensure the fully assembled system works correctly.</td>
<td>Incorporate in-process inspection checkpoints to verify test results, comparing a sample under testing against a golden reference result.</td>
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<td><strong>Final Inspection / QC</strong></td>
<td>Visual inspection of the final assembly, including checking components, visual appearance, and labelling (verifying that proper regulatory labels are used and in the correct position).</td>
<td>Add visual inspection assistance for operator, including final check of externally visible components of the units such as connectors, labels, screws (whether they are present) and default configurations for the product (e.g. jumpers or switches).</td>
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<tr>
<td><strong>Packaging &amp; Shipping</strong></td>
<td>Packaging and kitting of the product, including required documentation, guides, accessories and shipping labels. Packaging may have country or variant specific requirements.</td>
<td>Add operator work instruction assistance to visually verify kit contents and shipping labels. Operator saves image of final product. Images can be used for traceability systems, including inventory, shipment management and batch tracking. If an in-field issue is reported, system can be used in root cause analysis to help speed resolution and avoid unnecessary claim costs.</td>
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*Figure 8: AI visual inspection provides assistance during complex assembly steps to help avoid missed steps and errors that result in added production and material costs.*
DICSA is an electronics contract manufacturer located just outside of Ottawa, Ontario that services an expansive list of healthcare, industrial controls, telecommunications, security, and digital imaging companies. The company specializes in high quality electronic assembly services for the small-to-medium volume market.

Serving a high-value, lower volume market can pose inspection challenges for the company, as not all products are well-suited to automated processes. As a result, a number of products are primarily inspected by human operators. The company prides itself on its exemplary record for product quality, and views the automated visual inspection system as a method to add decision-support for its inspectors.

Like the distillery, the electronics manufacturer has trained the image compare plug-in with a known, good image of a final product. Operators and quality control staff have trained multiple image compare plug-ins to inspect different products.

The AI capabilities are used to match the approved layout and final production for electronic assemblies. The system quickly compares the placement of components on the circuit board, and highlights differences and deviations for the human inspection before it moves to the next step in the manufacturing process or to final packaging.

The system is also used by the manufacturer for quality checks on incoming components from suppliers. In addition, the manufacturer uses the system to capture and save an image of every printed circuit board. This data is shared with traceability systems for inventory and shipment management and batch tracking, and helps reduce root time analysis time and costs if a potential error is detected in the field.
AI is Changing Visual Inspection

Adding decision support and automating processes for visual inspection helps ensure consistency. The technology can aid a tired operator at the end of a shift, a new employee who is unsure what makes a product “good” or “bad”, or simply speed the inspection process. It lets manufacturers take advantage of new technologies for processes where automation is cost prohibitive, including low volume production.

As part of a wider Industry 4.0 initiative, automation and decision-support tools for visual inspection can help provide real-time process visibility to drive data-based decisions.

To learn more about Pleora’s AI Solutions visit pleora.com/ai-for-quality-inspection/