The User Experience: More Intuitive X-Ray Inspection Software

Overview

Consumer electronics like smartphones and laptops are designed to be user-friendly. The early days of the personal computer, when early adopters needed to understand software programming to use the machines, are long behind us. Now, consumers expect a touchscreen and an intuitive user interface (UI).

They expect menus with options that are easy to understand and icons that make sense. Files are stored in folders. Unwanted files go into the trash. A single click selects an item, and a double click opens it. Easily accessible help menus clarify any unfamiliar features.

Why not use the same familiar interface for the industrial equipment that inspects the circuit boards inside those smartphones, tablets, and laptops? Just because the equipment is in an industrial setting, the software shouldn't require extensive training to understand. There has been more attention on the design of human-machine interfaces (HMI) in recent years and efforts in multiple industries to create an HMI that is easy to understand and reduces the cognitive load on operators[1].

We propose that industrial software for semiconductor industry equipment need not be complicated. It does so with a concrete example. Manual X-ray equipment for inspection of surface mount technology (SMT) components is ready for a software upgrade.

Manual X-ray Inspection for SMT

SMT has advanced in the past twenty-five years. Component pitches have dropped, and board density has increased to accommodate higher-performing chips and greater memory storage. Ball grid arrays (BGAs) are often preferred over quad flat no-lead (QFN) for high lead count designs where reliability is critical. BGAs, originally designed with a pitch of 1.27 mm, now feature pitches below 1.0 mm and as low as 0.2 mm. Some BGAs include multiple pitches within a single component.

Inspection is a critical aspect of quality control for identifying problems in SMT manufacturing processes or components. X-ray inspection allows for non-destructive imaging with far greater magnification and level of detail than is possible with optical inspection. More importantly, X-rays can see features that optical inspection cannot (Figure 1). It is a necessary technique for identifying defects in BGA components, including missing, misplaced, or misshapen balls that cause opens or shorts.

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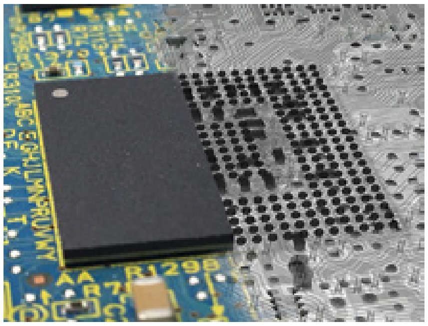

Figure 1: Optical (left) vs. X-ray (right) inspection of a BGA on a printed circuit board.

Automated X-ray inspection is often the most efficient solution for quickly evaluating production runs of the same product. Software is continually improving. Developments in computer vision technology are making inspection more accurate and reliable.[2] Still, the algorithms are not always accurate enough to meet quality control (QC) requirements for sensitive or high-reliability applications, and often mis-identify solder defects.[3] PCB houses often need to supplement automated processes with manual inspection. Manual inspection is necessary in R&D environments and for high-mix, lower-volume production lines where it is not cost-effective or efficient to run automated equipment.

Manual X-ray inspection can identify solder voids, cracks, bridging, or opens. It is useful for examining solder ball alignment and size variation for flip chips and ball grid arrays (BGAs). X-ray images show cracking and warpage of components for all sorts of packages. The technology is even able to identify counterfeit components, especially when combined with optical inspection.[4]

Inspection technology has advanced as well, especially resolution capabilities. High-end imaging can resolve features down to 100 nanometers (nm). Systems reliably inspect defects in fine-pitch solder balls ranging from 30 to 100 µm in diameter. The addition of high dynamic range (HDR) improves local contrast. It also allows operators to see all components on a board or all the layers of a package in one image instead of needing to refocus the system to image features at different heights above the PCB surface.

While these systems produce excellent images, they are not always the easiest to use.

The problem is that the software interfaces in X-ray inspection systems have not kept up with advances in other parts of the equipment nor with advances in software for consumer applications. Because of this, the inspection takes longer than necessary. Rethinking the UI and user experience (UX) can make inspection much faster and easier.

The Standard Interface

Most X-ray inspection equipment relies on old-fashioned joystick control that has been around since the advent of X-ray inspection. Operators type in specifications to instruct the software, which hasn't changed much in decades. Especially for younger employees who grew up in the smartphone and touchscreen era, this is far from intuitive.

It takes a long time to get new employees up to speed so they can use the software efficiently. As operators with decades of experience head toward retirement, up-to-date software will smooth the path for those who follow.

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Next-generation Interface

The ideal UI for any industrial inspection equipment. is easy to use and troubleshoot. Graphics and icons are familiar and easy to find. Startup is rapid and doesn't require frequent resetting. The software is responsive to user input and adjusts automatically depending on the device under test (DUT). It is flexible enough to work with many use cases and applications. Users can save data and export it in various formats depending on how they want to use it. The software is also ungradable as customers' needs change.

Nordson has developed a new UI for its latest manual X-ray inspection systems that fulfills the above wish list. It features an ultrawide touchscreen monitor (Figure 2) plus point-and-click interaction. This allows the X-ray equipment to leverage the advantages of consumer electronics. Optional joystick control still exists, so users can interact with the software however it works best for them.

Figure 2: X-ray inspection system with touchscreen interface.

The setup is intuitive. Operators can quickly adjust specifications like viewing angle or position with a simple click or touch. They can move control windows around the screen and save settings to their user profile, The system is then set to their preferences every time they log in.

Some adjustments happen automatically as the software detects component pitch and orientation. For more advanced settings, the system has a search feature that will feel familiar to anyone who works on a Windows laptop or desktop computer.

The software includes many helpful features, including drag and drop application of image filters. Technicians can change the viewing angle with software rather than physically rotating the board or component. They can adjust brightness and contrast to their preference, as not everyone's eyes are identical.

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Example:

BGA Inspection

X-ray inspection is an essential quality control step for BGAs, especially for those with complex designs. More accurate automatic detection methods are being developed, including some specifically designed to inspect BGAs.[5] Manual inspection is still often necessary, especially for in-depth evaluation of individual solder balls at high magnification.

BGAs come in many different ball configurations and pitches, including, as noted earlier, mixed pitches within one component. This variety is challenging for both automated and manual X-ray inspection equipment. There is a trade-off between speed and accuracy. If operators don't customize the setup for the part, they risk letting errors like variation in ball size or missing balls go undetected. However, the setup is time-consuming and can be frustrating.

Software that simplifies the setup process reduces frustration and improves results. The operator can see the entire field that the detector sees and a close-up of a specific component or feature at the same time (Figure 3).

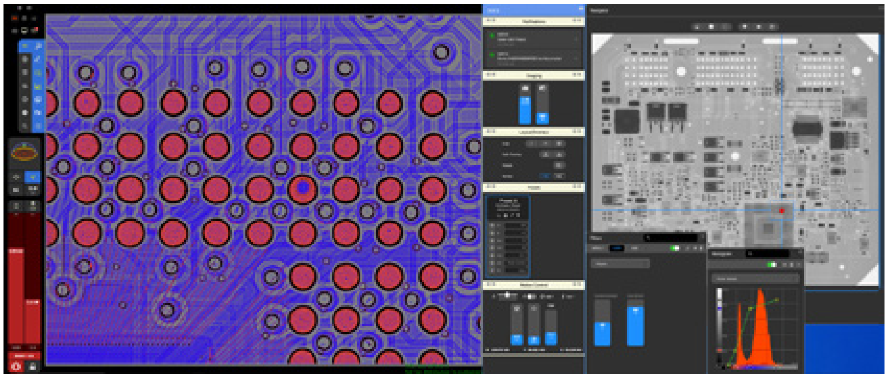

Figure 3: X-ray image of a PCB along with a close-up of one corner of a BGA (location marked with a red dot on the PCB) and a menu to adjust settings.

When inspecting a BGA, image filters can help identify problems. Figure 4 shows greyscale and color images of a BGA with two ball sizes. While defects are visible in the standard greyscale image, colored image filters make the deformed and missing balls much more obvious. A technician can quickly see where to investigate further.

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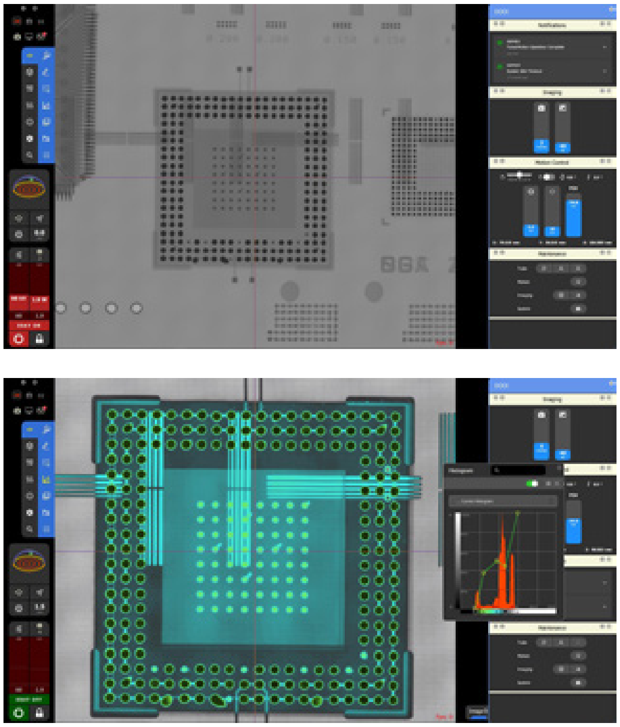

Figure 4: X-ray image of BGA component in greyscale (top) and with color filtering (bottom).

Hovering over an individual ball brings up detailed results for that ball (Figure 5). Details include diameter, circularity (shape), location, number of voids, and other user-specified information. Having this data at hand speeds up quality assurance (QA). It is also useful for identifying counterfeit components that do not match the expected pattern.

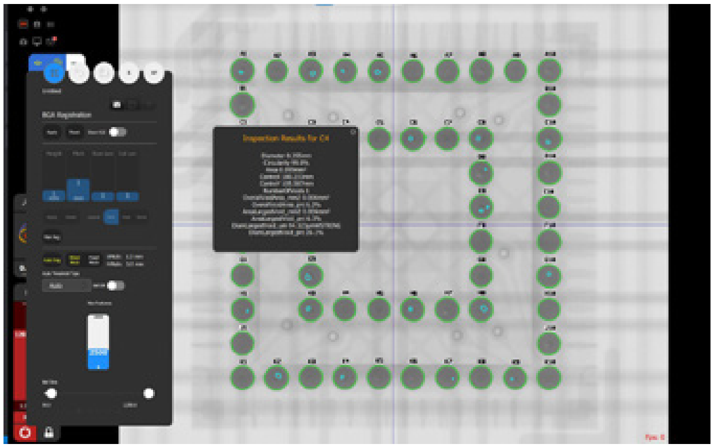

Figure 5: Detailed inspection results of individual BGA ball.

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Reducing X-ray Exposure

Faster, easier inspection improves throughput and reduces operator frustration. It also reduces total X-ray exposure for the board. This matters because excessive exposure to X-rays can cause bit errors that corrupt the data on flash memory chips.[6] The dose a particular component can take varies wildly with the device type, substrate material, and package design. In general, the closer the X-ray source is to the board, the higher the X-ray tube power, and the longer the exposure, the greater the risk.

Exposure is cumulative, so it is best to limit the need for repeated inspection. The software system mentioned above includes a dose calculation tool that tracks X-ray exposure.

With more efficient inspection processes, sensitive memory components are less likely to sustain damage from the inspection process. Automated, easy-to-use software helps reduce the risk of damage. Technicians can adjust the X-ray dose to be the minimum needed to achieve sufficient image contrast for each use case. They can finalize settings with a dummy board in place. While running functional boards through the tool, advanced software with a low dose mode can automatically switch off the X-ray power when it detects that the sample is not being imaged.

Summary

High resolution and excellent signal-to-noise ratio are critical for accurate X-ray inspection. Many tools can achieve the performance necessary to inspect complex PCBs with fine-pitch traces and components. However, legacy UIs often require extensive training for new employees to get up to speed. Even when they learn how to use it, employees spend a lot of time adjusting the setup for different PCB designs. If they don't do it correctly, they might not catch all the defects on the board.

It is possible to keep all the advantages of high-performance X-ray inspection while making the equipment easier to use. In high-mix, low-volume production environments, flexibility is the key to improving the user experience. Cumbersome software causes unnecessary delays and frustration. When we reimagine the UI by leveraging what works for consumer electronics, we save technicians time. That translates to higher throughput, better employee satisfaction, and more efficient QA and QC.

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