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Restoring low resolution response in phosphor-coupled X-ray detectors via diffusion deblurring network

Phosphor-coupled or indirect-conversion X ray detectors are widely used in both industrial non destructive testing (NDT) and medical imaging. However, there is an inherent tradeoff between spatial resolution and conversion efficiency: detectors with a thin phosphor offer higher spatial resolution but suffer from lower X ray conversion efficiency, leading to higher quantum noise, whereas those with a thick phosphor achieve better conversion efficiency at the expense of reduced spatial resolution. In industrial imaging applications, where factors such heat loading on the X ray source and inspection throughput are critical, the use of a thicker phosphor is desirable, even though it leads to degraded spatial resolution.

To address this limitation, we propose a deep learning-based image processing approach. The aim is not merely to convert low-resolution (LR) images to high-resolution (HR) ones, but to enhance the detector's response function itself. We have incorporated the diffusion model [1,2] into the network architecture and trained it to improve the detector's response function by restoring HR details in images acquired from a thick-phosphor detector. The HR ground truth images for printed-circuit board (PCB) samples were obtained using a detector with a thin phosphor. To simulate the response of a thick phosphor detector, we generated blurred HR (BHR) images by convolving each HR image with a point spread function derived from the ratio of the modulation-transfer functions measured for both thin and thick phosphor detectors. A series of intermediate degraded images, I_j, required for training the diffusion model, was generated by blending the HR and BHR images:$I_j = (1 - w_j)\, I_{\mathrm{HR}} + w_j I_{\mathrm{BHR}}$, where the blending weight w_j at the jth stage increases linearly over a predefined number of stages, thereby emulating the gradual degradation from HR to LR. These I_j images were then used as inputs to a modified U-Net deblurring network [3], trained to recover HR details from progressively degraded inputs. Fig. 1 shows the preliminary results of the diffusion deblurring network, which effectively restores HR images. Fig. 1(a) shows the input, output, and target images. Fig. 1(b) presents the structural similarity index measure (SSIM) maps for the corresponding target images. The average SSIM values for the BHR images and the network outputs were 0.75 and 0.96, respectively.

The proposed network enables the restoration of high-resolution images obtained from thick-phosphor detectors under low-dose X-ray conditions. This capability has the potential to significantly enhance inspection capacity, improving sensitivity in defect detection for PCB inspections and other industrial NDT applications.

Reference

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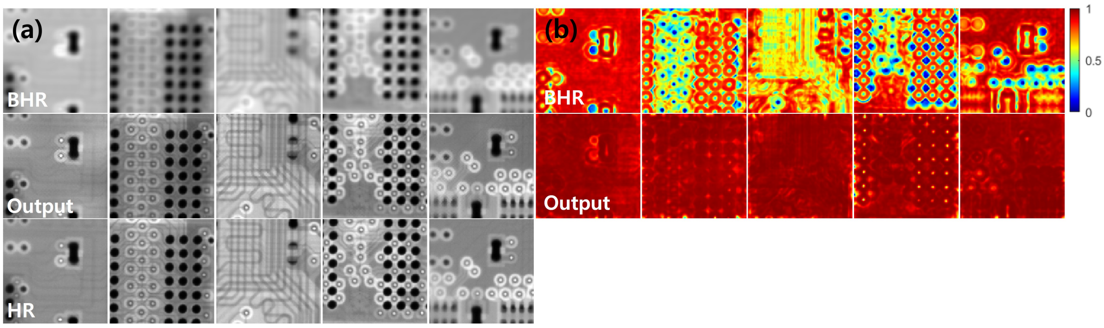

Figure 1: (a) Input (BHR) and output images of the diffusion deblurring network, compared with the corresponding HR ground truths. (b) SSIM maps of the input and output images against the corresponding HR ground truths.

Workshop topics

Applications

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