



Transformer-Based Super-Resolution Scanning Acoustic Imaging for Industrial Inspection

Trong Nhan Nguyen†, Vu Hoang Minh Doan†, Tan Hung Vo, Jaeyeop Choi and Junghwan Oh

Industry 4.0 Convergence Bionics Engineering, Department of Biomedical Engineering,

Pukyong National University, Busan 48513, Republic of Korea

Presenter: Trong Nhan Nguyen

† These two authors contribute equally to the work.

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Content

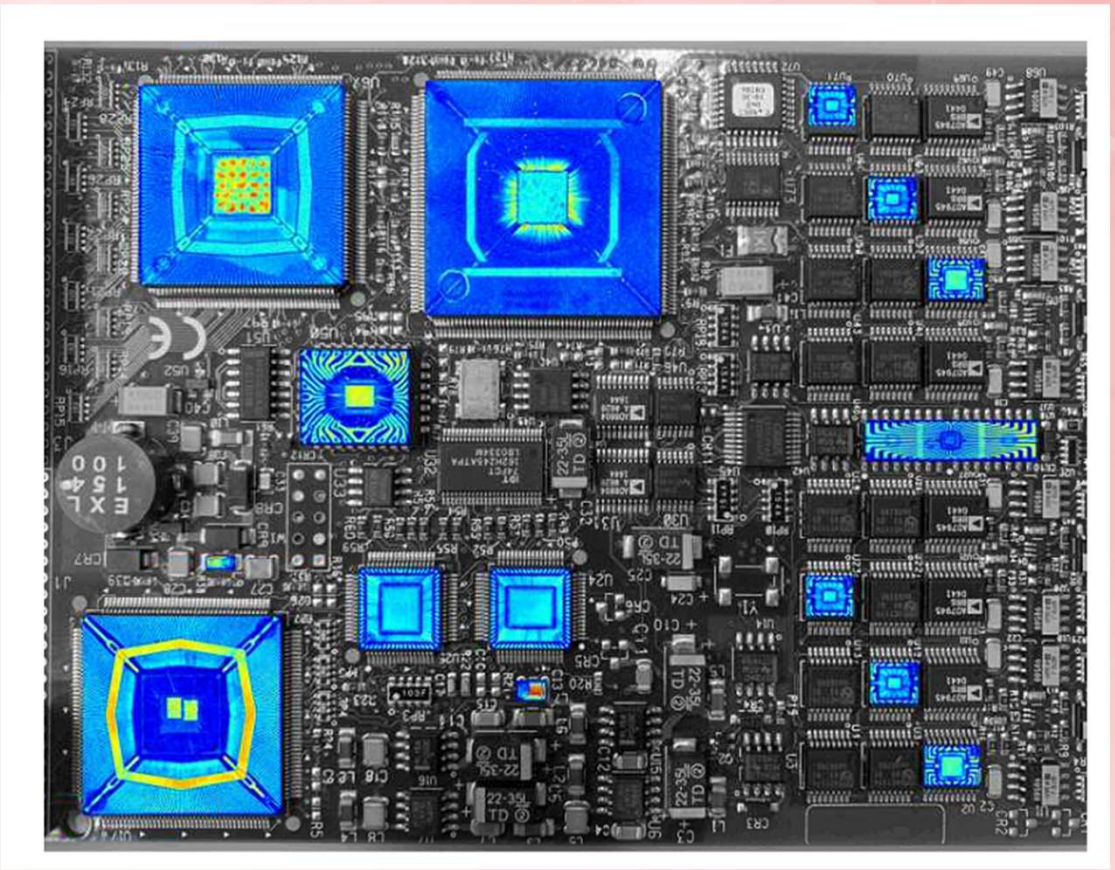
I. Introduction

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I. Introduction *Scanning Acoustic Microscopy (SAM) system*



Video 1.
Introduce Scanning Acoustic Microscopy system (Ohlabs Company)

SAM is a Non detructive Testing technique.

SAM to see the inside of some object.

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I. Introduction *Scanning Acoustic Microscopy (SAM) system*

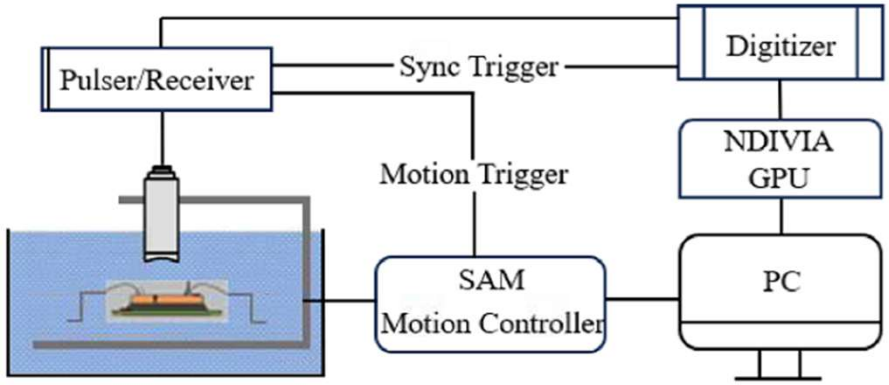


Figure 1.
The scanning acoustic microscopy schematic diagram

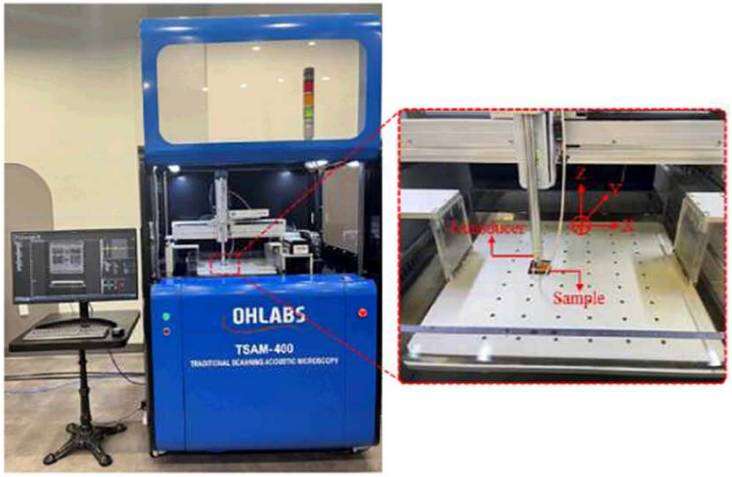


Figure 2.
Scanning Acoustic Microscopy system in reality



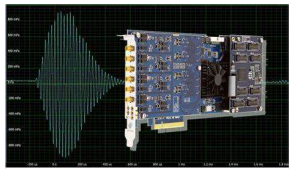
Tranducer:
Generated HF ultrasound wave



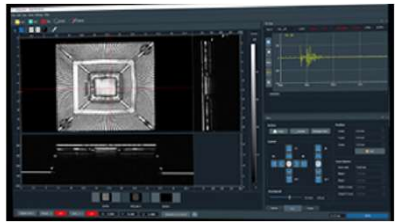
Pulser/Receiver
Excited waves and receive
the echoed signal



Scanning Mechanism
Move the transducer over the objects



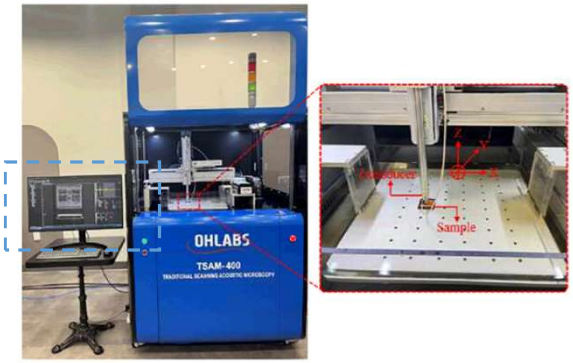
Digitizer
Capture the signal from receiver and convert Analog to Digital.



Software (GUI)
Visualize data and control

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I. Introduction *Scanning Acoustic Microscopy (SAM) system*



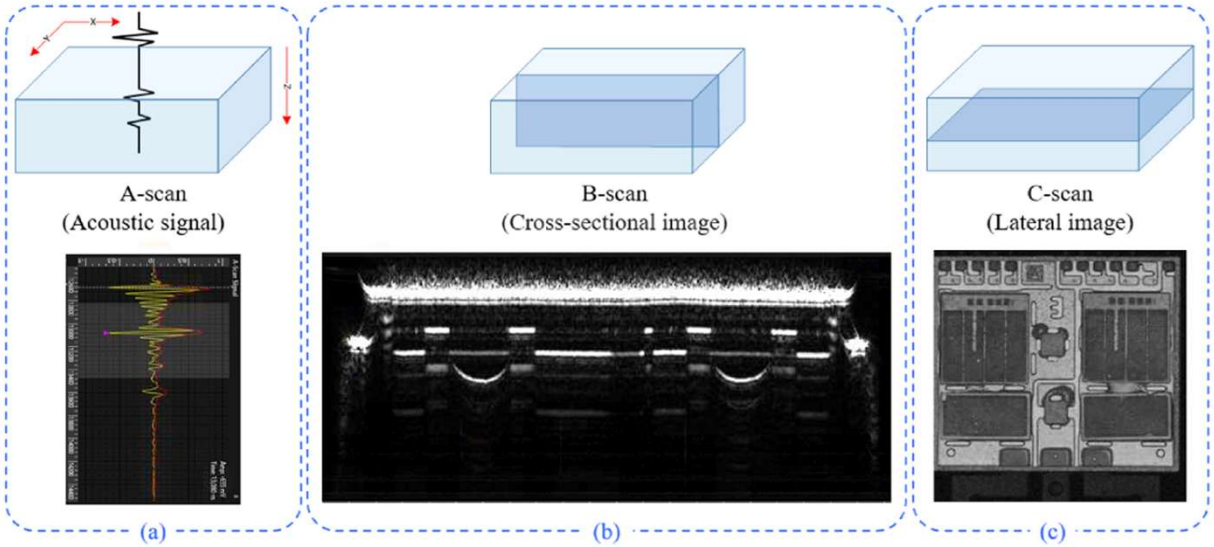


Figure 3.

Figure about A-Scan, B-Scan and C-Scan on system

A-scan mode: A-Scan shows acoustic signals over time to detect internal structures and defects. (mVotage)

B-Scan mode

I. Introduction

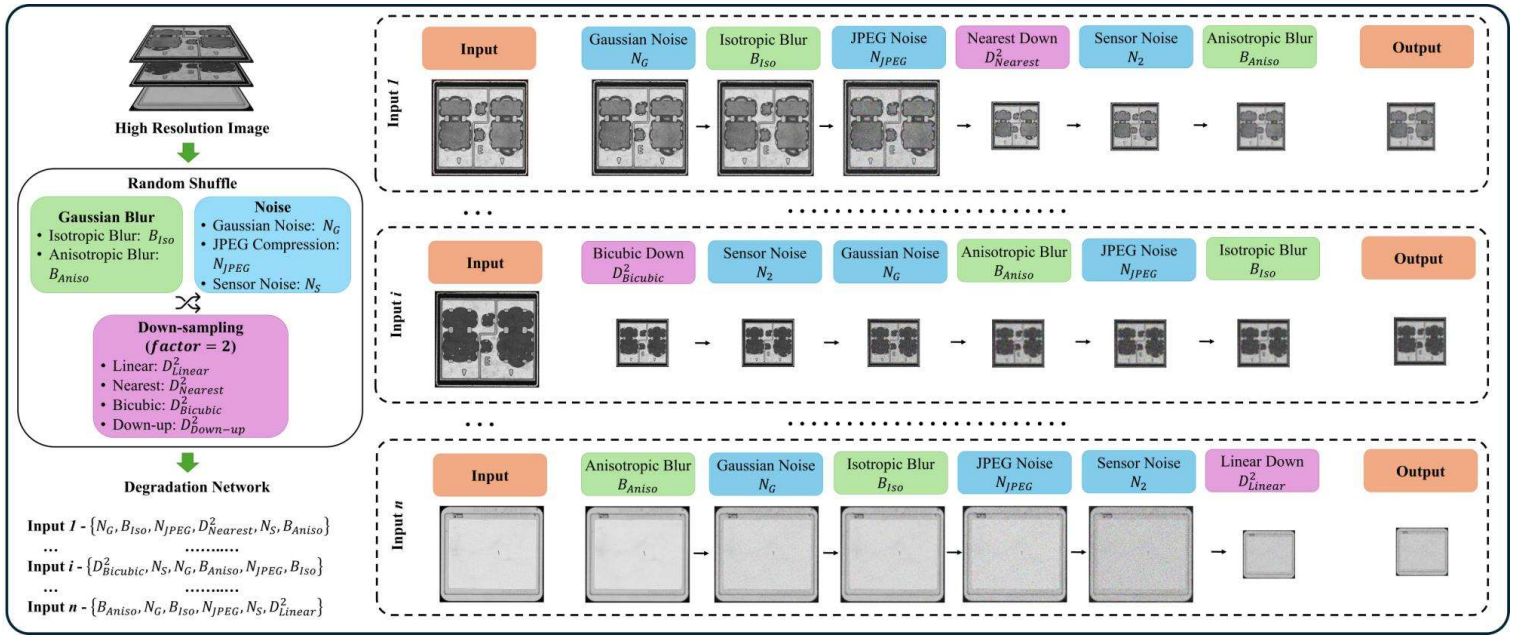
Super Resolution method

- SR is an advanced image processing technique widely used in various fields such as biomedical.
- But its application in the industrial Non-destructive testing ultrasound field are still limited.
- In this study, we proposed an approach that integrates a transformer-based generator with a GAN architecture to advance SR imaging for SAM - **SAMTransGAN** .
- Our solution significantly enhances image quality by improving both structural accuracy and perceptual fidelity, accelerating the resolution of SAM images to meet industrial standards for electronic component inspection.

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II. Method

Degradation Network

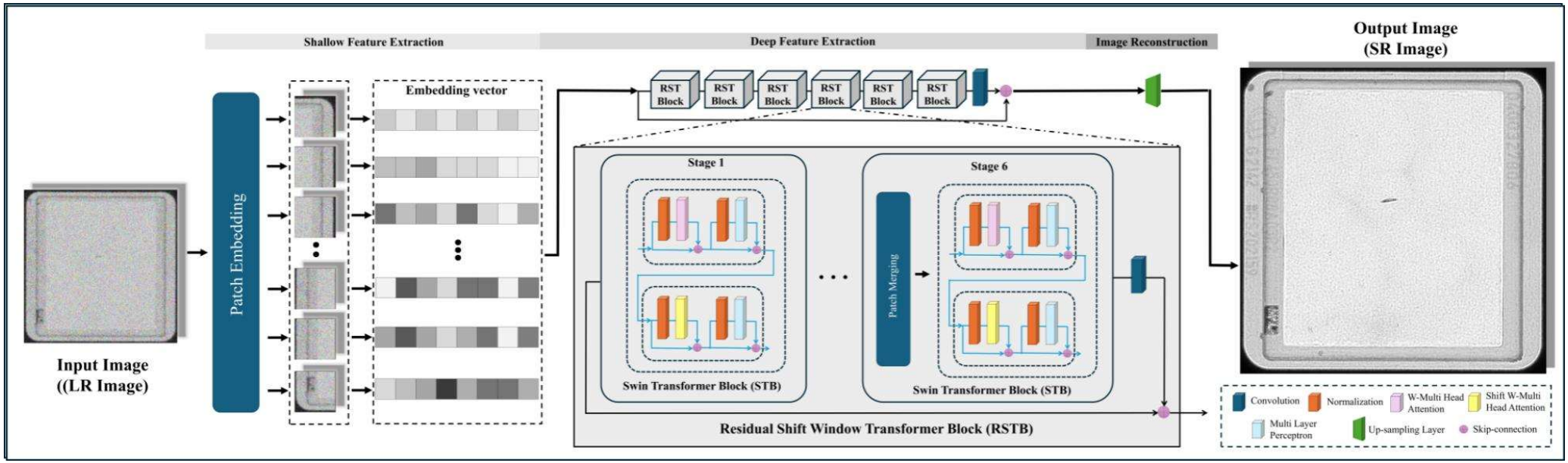


- The SAMTransGAN model was trained using synthetic low-resolution (LR) images, generated from HR images through a degradation process.
- This process follows the classical degradation model, which incorporates three main components: blur, noise, and downsampling.
- To introduce variability, the degradation pipeline utilizes a randomized sequence of operations across these components

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II. Method

Generator Network

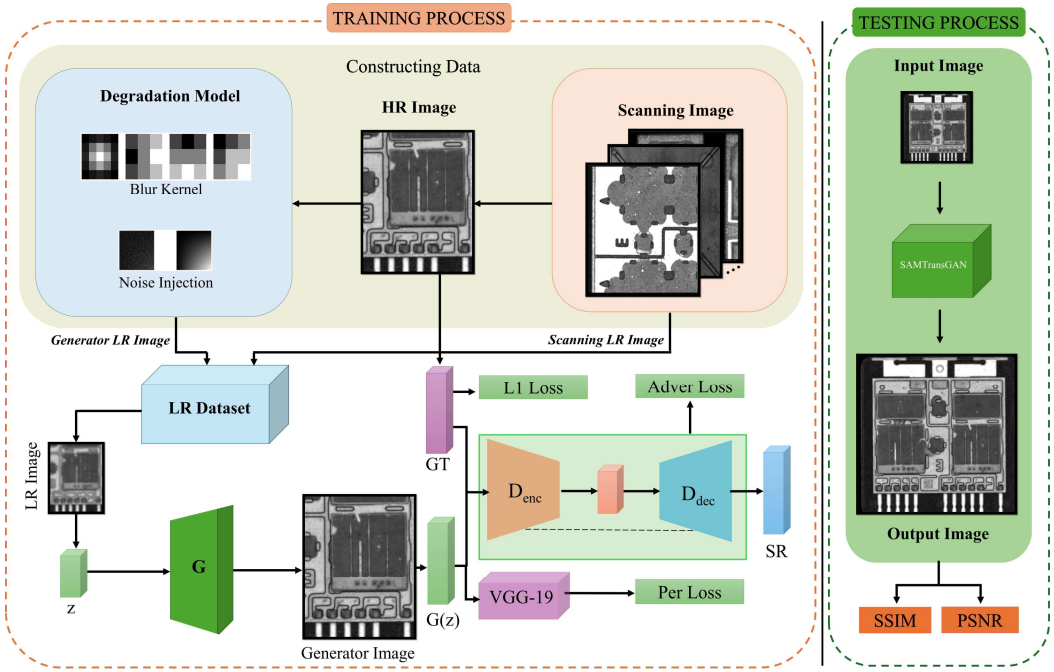


- The generator network architecture is composed of three main modules: shallow feature extraction, deep feature extraction, and image reconstruction.
- The integration of these modules allows the network to transform an LR input image into an HR output image by doubling the dimensions while preserving fine details and structural features for high-quality image reconstruction.

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III. Method

Implementation detail

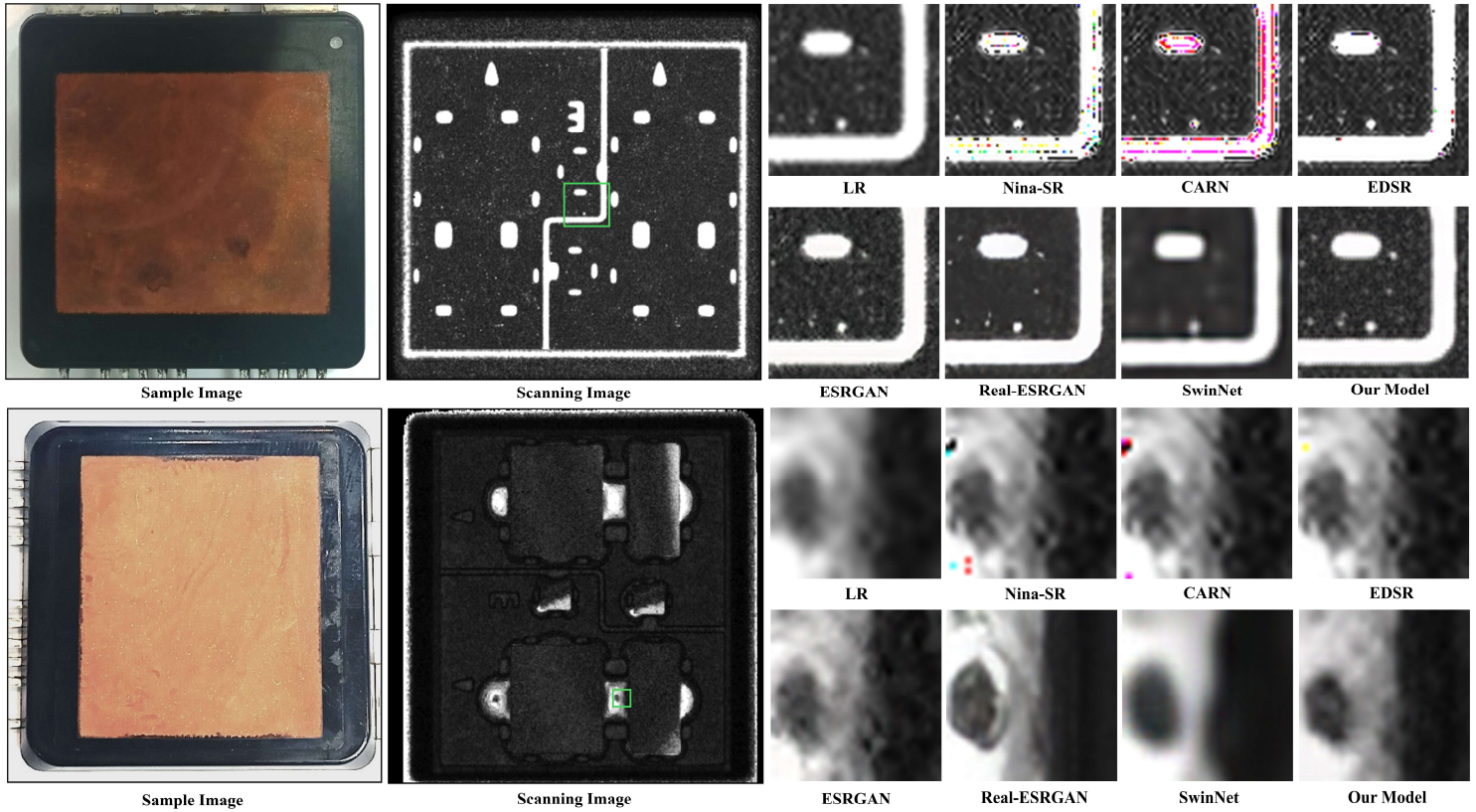


Overview of the SAMTransGAN framework, including both the training and testing processes. During training, the degradation model generates synthetic LR images, which are combined with existing LR images to form the LR dataset for the generator model. The generator enhances the resolution of the input images, while the discriminator evaluates the outputs. The training process optimizes a total loss function, ultimately producing SR images. In the testing process, LR images at a step size of 100 um are used as inputs to SAMTransGAN, which enhances their resolution. Image quality is evaluated using PSNR and SSIM metrics.

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III. Result and Analysis

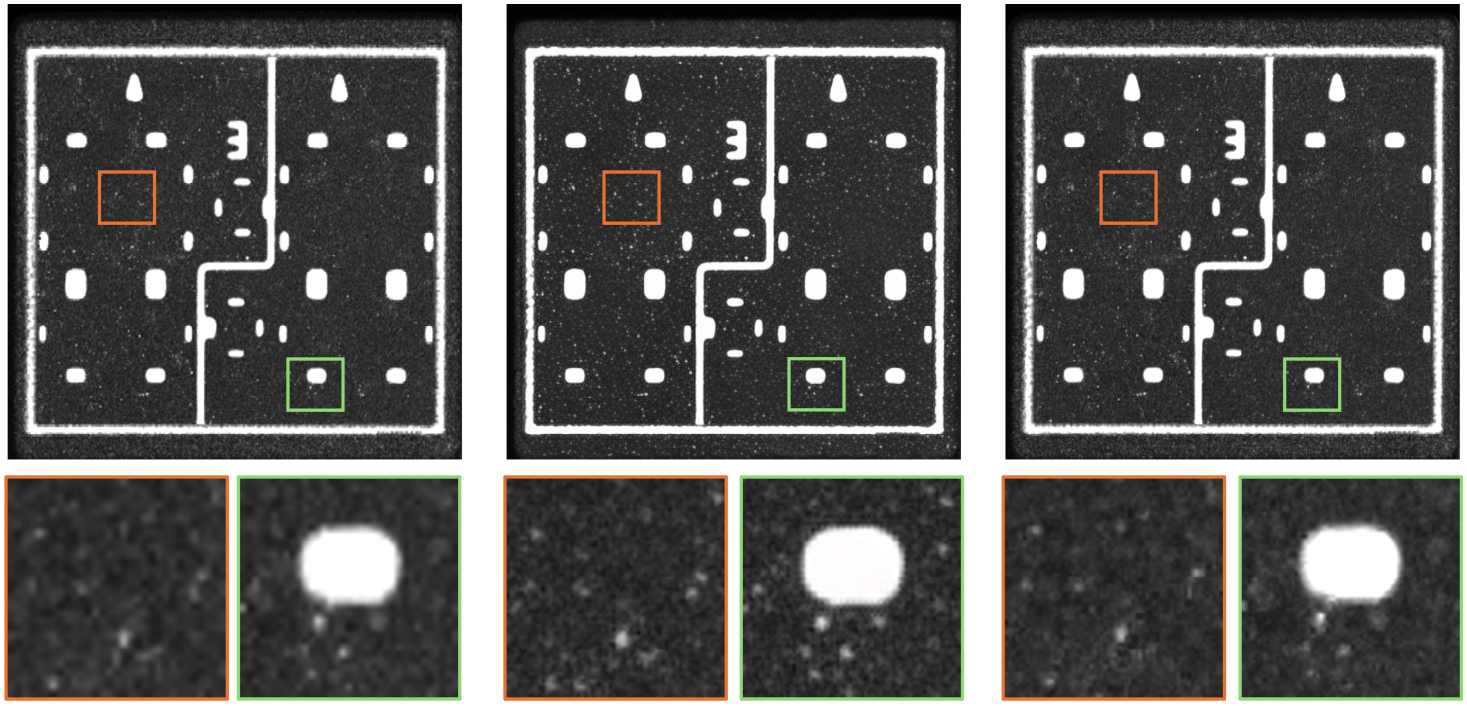
Result



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III. Result and Analysis

Result



Original LR Image | Our Model's SR Image | Original HR Image

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III. Result and Analysis

Result - PSNR

Image no.	Nina-SR	CARN	EDSR	ESRGAN	Real-ESRGAN	SwinNet	Our Model
1	21.269	26.223	31.526	36.780	37.060	35.588	38.324
2	21.113	31.754	32.099	35.697	28.425	33.924	32.630
3	26.357	29.292	29.058	29.280	24.180	27.560	29.443
4	17.149	17.260	17.549	24.913	26.185	26.616	26.817
5	16.590	17.897	18.405	25.028	25.236	24.847	26.417
6	15.386	16.006	16.693	24.801	25.940	25.450	26.081
7	15.769	17.337	16.967	24.388	25.540	24.992	25.989
8	15.842	16.920	16.993	24.166	25.167	24.710	25.677
9	14.726	14.248	14.462	22.938	24.483	24.813	25.212
10	16.908	17.823	19.272	25.319	25.025	25.567	24.988
Avg	**18.111**	**20.476**	**21.302**	**27.331**	**26.724**	**27.407**	**28.158**

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III. Result and Analysis

Result - SSIM

Image no.	Nina-SR	CARN	EDSR	ESRGAN	Real-ESRGAN	SwinNet	Our Model
1	0.896	0.922	0.921	0.902	0.936	0.919	0.933
2	0.912	0.940	0.941	0.916	0.897	0.910	0.932
3	0.803	0.825	0.820	0.819	0.848	0.811	0.864
4	0.755	0.770	0.766	0.798	0.811	0.735	0.840
5	0.813	0.816	0.823	0.824	0.845	0.812	0.838
6	0.786	0.800	0.810	0.814	0.843	0.802	0.834
7	0.699	0.708	0.703	0.686	0.536	0.618	0.783
8	0.711	0.731	0.715	0.727	0.778	0.738	0.782
9	0.702	0.727	0.704	0.723	0.774	0.733	0.780
10	0.697	0.708	0.729	0.738	0.751	0.748	0.767
Avg	**0.777**	**0.795**	**0.793**	**0.795**	**0.802**	**0.782**	**0.835**

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III. Result and Analysis

Analysis

- Our SAMTransGAN built on a GAN framework with an optimized Transformer-based generator significantly enhances image clarity and contrast, recovering high-frequency textures and background details.

- The integration of residual connections at each Transformer layer and the shifted window mechanism further strengthens long-range dependency modeling, ensuring more effective deep feature extraction. Based on this, our model can maintain both the foreground and background of defect areas without introducing artifacts, demonstrating exceptional robustness and practicality for high-precision NDT applications.

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IV. Deployment

- A web-based application was designed using HTML, CSS, and JavaScript, with a Flask API backend to manage model inference requests.

- For example, when scanning a power MOSFET sample with dimensions of 37 x 35 mm using the step size of 100 µm (resulting in an image resolution of 370 x 350 pixels), the scanning process takes approximately 2.42 minutes. Reducing the step size to 50 µm (which gives an image resolution of 740 x 700 pixels) would typically double the scanning time to about 4.84 minutes. **However, by applying our proposed SR method, the resolution enhancement is achieved in just 16.44 seconds, reducing the processing time by 44.26%, while maintaining image quality equivalent to the 50 µm step size scan.**

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IV. Conclusion

- In this study, we propose a GAN-based model with a transformer generator for SR in industrial ultrasound imaging, focused on enhancing image quality.
- Our future work will explore the development of a transformer-based version of the discriminator model, which will be tested and synchronized with the generator to evaluate its potential to improve model performance and accuracy.
- The training process will be designed to generate defect-oriented SR images, focusing on preserving the defect structure and morphology to further enhance industrial applicability.

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Q&A

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Thanks





Best regards,

Nguyen Trong Nhan
NBM Lab, Pukyong National University
(+82) 10 5836 2411
nguyennhan8521@gmail.com
202355504@pukyong.ac.kr
45 Yongso-ro, Nam-gu, Busan, Republic of Korea

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