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Enhancing Object Detection Performance in Non-Visible Environment Images Using Artificial Intelligence

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1. Introduction

Deep learning of artificial intelligence is also used as an image feature extraction technology to detect objects in various fields, and among them, it is used as a technology to detect mechanical defects in the machinery industry, especially in the safety field. This is because object detection using deep learning enables efficient problem solving with various defect detection and quick response.[1]

Among the next-generation nuclear power plants, particularly those using Sodium-cooled Fast Reactor(SFR), are conducting research on visualization techniques using ultrasonics to comply with In-Service Inspection(ISI) regulations (ASME Sec XI, Div.3) in environments with poor visibility where internal structures are difficult to visually inspect.[2] The system that converts ultrasound into image format in environments with poor visibility offers the advantage of creating a visualization environment. However, since the quality of the image is represented by the converted data from acquired ultrasound signals, there is a high possibility of reduced image resolution when various forms of noise are present. This noise makes it difficult to distinguish information in the data and becomes a primary cause of performance degradation when performing object detection through artificial intelligence.[3]

The present study, we aimed to enhance the object detection performance of artificial intelligence by effectively improving data quality. We applied two methodologies, Deep Learning Super-Resolution and Filtering algorithm in Image data, to achieve this goal. Additionally, algorithms were designed for each methodology, and object detection was conducted using the artificial intelligence deep learning model (Yolov7).

2. Experiment

2.1 Deep Learning Super-Resolution

Deep Learning Super-Resolution is a deep learning technique that utilizes the SR-GAN(Super-Resolution Generative Adversarial Network) model to enhance the resolution of image data. This approach has been researched to improve the details of textures during the upscaling process and generate visually natural images. The operational mechanism of the SR-GAN model involves the iterative process of the Generator creating adversarial images and the Discriminator learning to distinguish these adversarial images, thereby enhancing its ability to discern adversarial images.

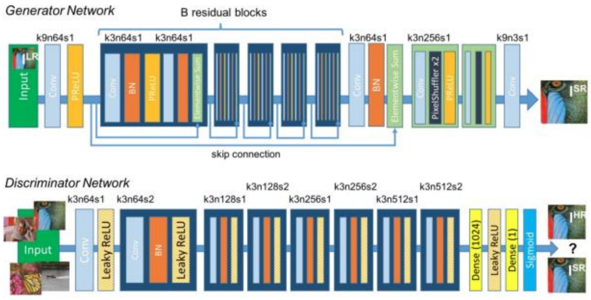


Fig1. Adversarial network architecture

The Generator Network of the SR-GAN model is characterized by the incorporation of Residual blocks in the middle section and the addition of Pixel Shuffle blocks to efficiently perform computational tasks, without upscaling at the input stage. The Discriminator Network primarily utilizes 3x3 filters and increases the Feature Map by doubling until reaching 512. The final section of the model incorporates Dense Layers and Sigmoid functions to distinguish the images created by the Generator and the Discriminator. As a result, the Super-Resolution images are visually enhanced in a natural manner.[3]

2.2 Filtering Algorithm in Image Data

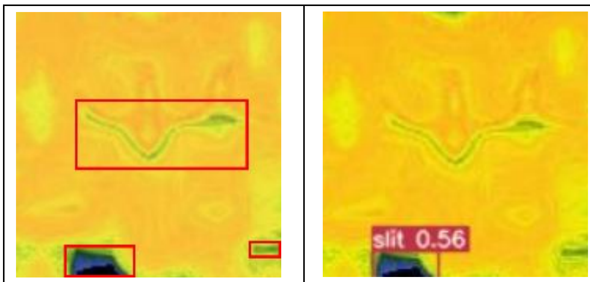
The Filtering Algorithm in Image Data is used to adjust pixel values or detect specific patterns in images by applying specific algorithms, among other purposes.

Table 1. Characteristics of Representative Filtering Algorithms

Watershed	Converting pixel intensities into a topographical representation of elevation.
Laplacian	Object edge detection and image sharpening.
Sobel	Efficient computation of intensity variations in the edges of an image and its surrounding pixels.

2.3. Apply Algorithms & Object Detection Test

Fig 2. (a) shows the image obtained using ultrasound C-SCAN for object detection in the data (Raw Data), and Fig 2. (b) represents the result of object detection performed using the Yolov7 artificial intelligence model [4-5] after training.



(a) RAW DATA (b) Yolov7

Fig 2. Results of object detection using the Yolov7 model

Object detection in the data was categorized into three classes. While objects at the bottom, where information differentiation is clear, were correctly indicated by bounding boxes, objects at the center were relatively blurry and went undetected. To improve this, a new methodology was designed by combining the SR-GAN deep learning model and Filtering Algorithms to enhance data quality, and it was applied. The training of Yolov7 was conducted using 43 data samples for each category, and the training was carried out for 200 epochs.

Table 2. Image enhancement and confidence score results.

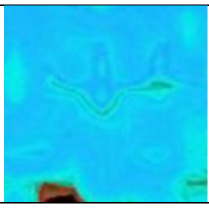
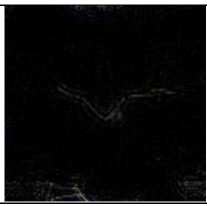
Object Detection Image / Confidence Score	
	
Watershed / 0.32	Laplacian / 0.11
	
Sobel & Adaptive / 0.35	SR-GAN + Sobel & Adaptive / 0.66

Table 2 presents the results of object detection performed by applying the algorithms introduced in Table 1. The object detection results were compared by obtaining the Mean Confidence Score of the Object Detection results through equations (1) and (2).

$$IOU = \frac{Area\ of\ Overlab}{Area\ of\ Union} \tag{1}$$

$$\begin{aligned} &ClassSpecificConfidenceScore \\ &= ConditionalClassProbability * ConfidenceScore \\ &= Pr(Classi|Object) * Pr(Object) * IOU_{pred}^{truth} \\ &= Pr(Classi) * IOU_{pred}^{truth} \end{aligned} \tag{2}$$

Comparing the Object Confidence scores, it can be observed that Laplacian showed lower performance in Object Detection, whereas in the case of 'SR-GAN + Sobel & Adaptive', there was an increase. Figure 3 illustrates the results of Object Detection performed using the Yolov7 model after preprocessing with the 'SR-GAN + Sobel & Adaptive' algorithm. Despite limited data and training volume, it can be observed that the Deep learning model(Yolov7) detects objects effectively.

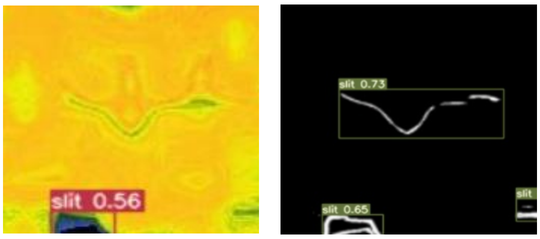


Fig 3. AI Object Detection Before vs. After

3. Conclusions

We conducted a study aimed at enhancing object detection performance through image quality improvement. As a result, we have found that applying the 'SR-GAN + Sobel & Adaptive' algorithm among various algorithmic techniques for image quality enhancement leads to an improvement in object detection performance. Through this study, it is determined that the level of refinement of input data is crucial for enhancing the performance of object detection. If this study is applied in the future, it could provide assistance in determining the presence of defects in the ISI (In-service Inspection) of SFR (Sodium-Cooled Fast Reactor).

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