New SCORE PRO Advance X-Ray Image Processing Unit

Medical Systems Division, Shimadzu Corporation
Kazuhiro Mori

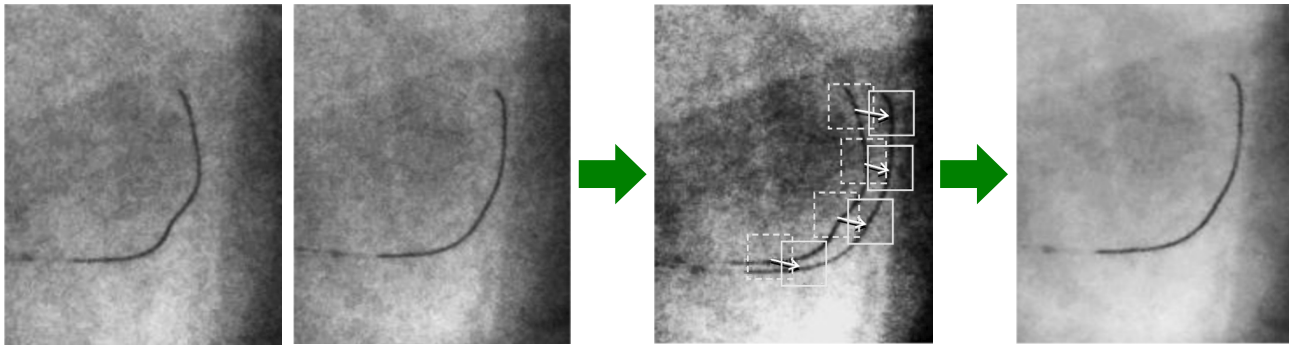
1. Introduction

A new SCORE PRO Advance image processing unit was developed to offer lower exposure levels and higher image quality in response to requirements for increasingly sophisticated intervention procedures. Interventional radiography involves inserting endovascular devices into the target area, where endovascular treatments are performed with the state of the device and area of interest being monitored. X-ray images are created by irradiating the body with X-rays and rendering an image based on the X-rays that pass through the body. However, overlapping organs or their motion can reduce the visibility of treatment devices. Furthermore, due to the principle used to generate the X-rays, X-rays exhibit a certain amount of fluctuation as they irradiate the body. This fluctuation appears as noise in images, which also reduces the visibility of target treatment devices and treatment areas. Reducing the amount of X-rays irradiating the body in an effort to reduce the exposure dose level increases the noise level as a proportion of the total signal obtained from the X-ray transmittance through the body. Consequently, keeping noise as low as possible is a key issue for achieving both low exposure levels and high image quality. Therefore, we tried using the SCORE PRO Advance, a new image processing unit, to find a sophisticated solution to this issue. The article describes using a Trinias series angiography system that includes the SCORE PRO Advance image processing unit, along with clinical images obtained with that system.

2. Principle of Image Processing

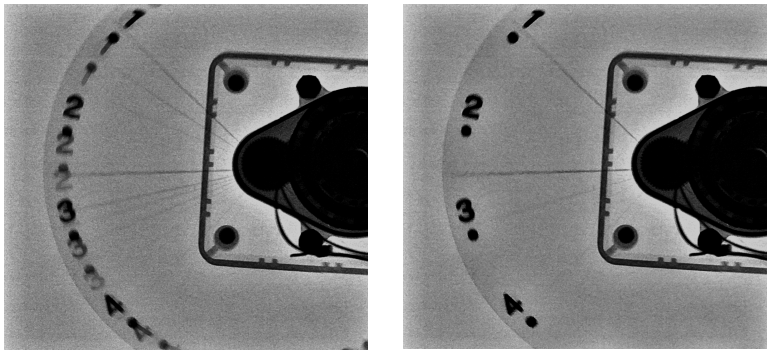
Conventional X-ray image noise reduction measures are based on the fact that noise is emitted randomly, such as by using recursive filters to smooth the noise components by integrating it over time or by isolating and removing noise components from each image. Edge enhancement is also used to display the tiny treatment devices more clearly. Current edge enhancement mainly involves methods that selectively enhance certain frequencies, from high frequency components that indicate detailed variations in brightness to low frequency components that indicate more gradual variations in brightness (image parametric equalization). By selectively enhancing only the components that compose the object of interest, the object stands out. However, with the method using recursive filters to integrate signals over time, image information from previous frames remains in the subsequent frame and causes residual images if the object moves, resulting in reduced visibility of the target object. In noise reduction and edge enhancement using image parametric equalization, it can be difficult to separate the noise from the object of interest, if the noise components and the target object have extremely close frequencies. In such cases, noise reduction processing can reduce the sharpness of target objects because it affects frequency components in the target object that are similar to noise components. Similarly, edge enhancement can enhance noise at the same time as it enhances the target object. Consequently, it was very difficult to both reduce noise and enhance the target object at the same time. However, SCORE PRO Advance resolves these conflicting problems by accurately identifying the object (by extracting certain patterns) in different frames and using pattern matching technology to reduce noise by integrating signals over time without residual images from object motion **(Fig. 1)**. It also allows enhancing target objects independently from the noise by selectively enhancing only identified objects.

Fig. 2 shows the difference between results in fluoroscopy images obtained using the conventional and new image processing methods with a rotating phantom. Compared to the image obtained using



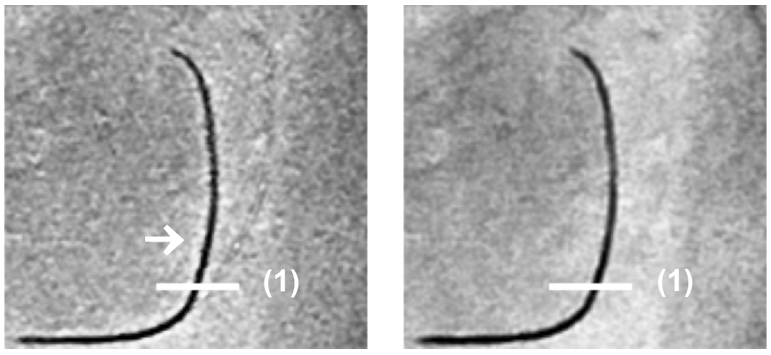
(a) Input Image Frame N (b) Input Image Frame N+1 (c) Pattern Extraction and Matching (d) SCORE PRO Advance Processing Results

Fig. 1 Overview of Noise Reduction



(a) Recursive Filter (b) SCORE PRO Advance

Fig. 2 Example of Noise Reduction in Fluoroscopy Images of Rotating Phantom



(a) Image Parametric Equalization (b) SCORE PRO Advance

Fig. 3 Example of Edge Enhancement

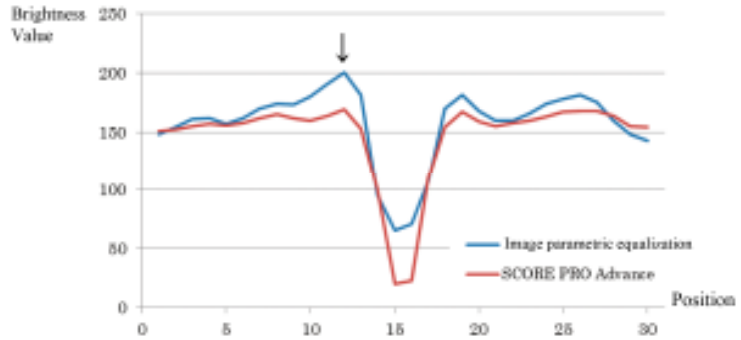


Fig. 4 Brightness Profile on Line (1) in **Fig. 3**

recursive filter processing (a), the image obtained using SCORE PRO Advance (b) shows equivalent noise reduction, but almost no residual images.

Fig. 3 shows a comparison of guidewire fluoroscopy images edge enhanced with image parametric equalization and SCORE PRO Advance. **Fig. 4** shows the brightness profile at guidewire position (1) indicated in **Fig. 3**. Image parametric equalization not only enhances noise components, but also causes white artifacts, referred to as overshooting, in edge enhanced areas (indicated by an arrow in

Fig. 3 (a) and 4). However, because SCORE PRO Advance identifies target objects before enhancing, it minimizes any artifacts that normally occur with multiple image parametric equalization, which allows more natural and intensive edge enhancement (Fig. 3 (b) and red line in Fig. 4).

3. Clinical Example

Fig. 5 is a contrast image of the right coronary artery. In addition to showing clearly rendered vascular walls of the main portion of the right coronary artery, which move more rapidly, it also shows clearly rendered peripheral arteries. The fluoroscopy image in Fig. 6 was processed with adequate noise reduction. It shows no residual images caused by the operator moving the guidewire. These images demonstrate how the SCORE PRO Advance processor is able to sufficiently track even rapid motion and identify even low-contrast objects, such as peripheral arteries and guidewire shafts. Consequently, it achieves the opposing goals of reducing noise and clearly enhancing target objects, which was difficult to accomplish using previous processing methods. Furthermore, without residual images, the image processing method also allows accurately determining the position and orientation of guidewires even when time resolution is low during low frame rate fluoroscopy. That means it can help reduce exposure levels by effectively using fluoroscopy at lower frame rates. Chest images that include the heart involve a mixture of low-density areas prone to halation, such as the lung field, and areas with high X-ray absorption that are prone to underexposure, such as the vertebral body. Such areas can interfere with the visibility of treatment devices when they overlap with these areas. SCORE PRO Advance selectively enhances target objects while also suppressing brightness differentials in the background by using dynamic range compression based on grayscale processing and image parametric equalization. Therefore, it clearly renders targeted treatment devices even when they overlap with a variety of organs.

Fig. 7 shows a DSA image of the hepatic artery in the abdomen. Because DSA images involve enhancing the contrast of a small amount of contrast media, DSA images require a high level of noise reduction. For abdominal areas where motion is minimal, conventional methods also involved using recursive filters. However, for blood vessels near the heart, such as the upper left hepatic artery, the larger heart beat effects could cause residual images of the blood vessels that sometimes resulted in unclear contrast images. However, even in such cases, SCORE PRO Advance provides clear images that are unaffected by motion, while also maintaining high noise reduction levels, as indicated by the arrow in Fig. 7.

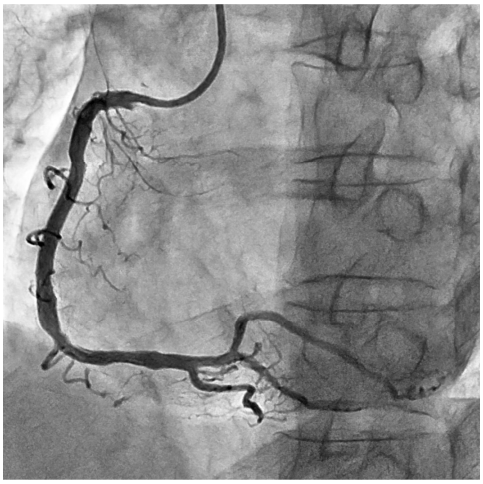


Fig. 5 Contrast Image of Right Coronary Artery

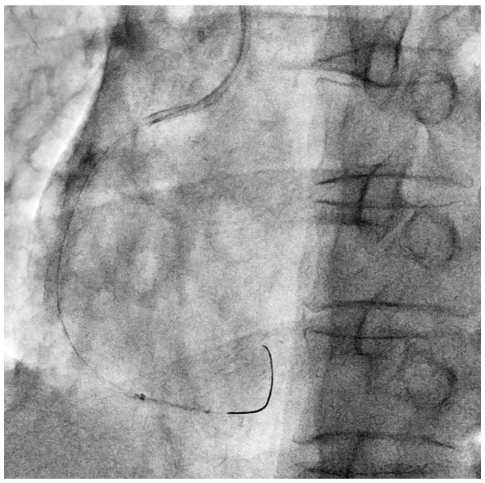


Fig. 6 Fluoroscopy Image

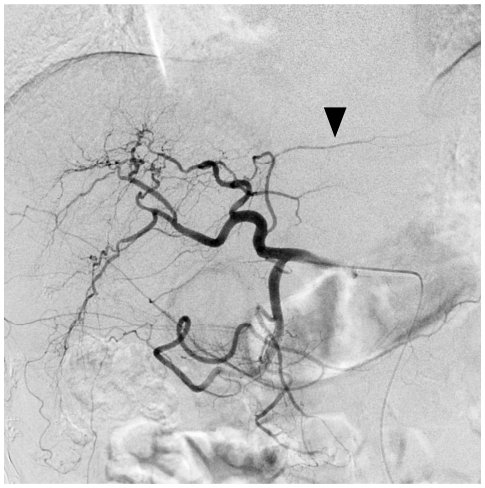


Fig. 7 DSA Image of Hepatic Artery

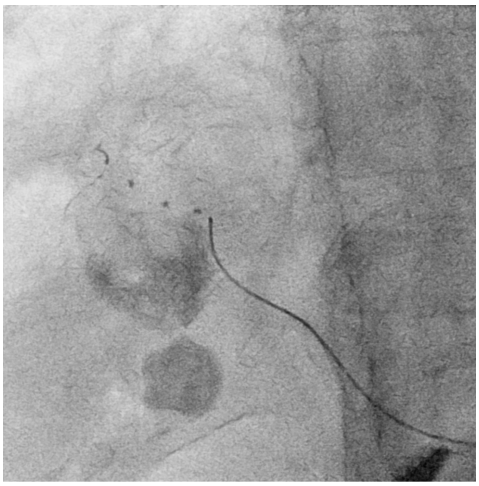


Fig. 8 Fluoroscopy Image of Hepatic Artery

Fig. 8 shows a fluoroscopy image of a hepatic artery injected with an oil-based contrast medium. Carried by the fast blood flow through the artery, the oil-based contrast medium splits at bifurcations in the blood vessels, flowing into narrower blood vessels. As the oil-based contrast medium moves further into the peripheral arteries, the narrower diameter results in lower contrast levels. However, SCORE PRO Advance renders the oil-based contrast medium until it is even narrower, while also reducing noise adequately without residual images.

4. Summary

The new SCORE PRO Advance image processing unit was developed to provide higher image quality for fluoroscopy and radiography while reducing exposure levels. This image processing system allows reducing both noise and residual images and increasing edge enhancement of target objects, which previously required a trade-off. Consequently, it now enables clearly rendering objects of interest, such as inserted medical treatment devices, that are moving within the body, which contains various organs with differing X-ray absorption levels. In addition to providing outstanding noise reduction, it also increases the usefulness of low frame rate fluoroscopy by eliminating residual images, which further contributes to reducing radiation exposure levels. Therefore, in conclusion, we hope this state-of-the-art technology will be of service to customers everywhere. Lastly, we would like to thank all those at the Mimihara General Hospital for their invaluable help in evaluating results and providing advice during development of the image processing system.