DynamicStentView: Cardiovascular Intervention Support Software

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1. Introduction

Percutaneous coronary intervention (PCI) using angiography systems has become more widespread in recent years, while the associated technologies have become increasingly sophisticated. There has been a corresponding demand for angiography system functions to support advanced medical treatments. In response to this demand, Shimadzu developed the DynamicStentView cardiovascular intervention support software according to an entirely new concept. The aims, operating principles, and applications of the newly developed DynamicStentView software are described below.

2. Background

In many cases of patients with advanced arteriosclerosis, the spread of the angiostenosis often requires placement of a new stent alongside a previously placed stent. In such cases, it is important for the new stent to slightly overlap the existing stent. Since stents have an extremely thin construction and poor visibility in X-ray images, clear confirmation of their position is often difficult. The position of a stent being placed is confirmed using markers placed at either end of the balloon on which the stent is mounted before expansion. The balloon is retrieved after placement of the stent. Since there are no markers present on a previously placed stent, it can be difficult to confirm its position in X-ray images. DynamicStentView was developed to simplify the positioning of new stents by improving the visibility of previously placed stents **(Fig. 1)**.

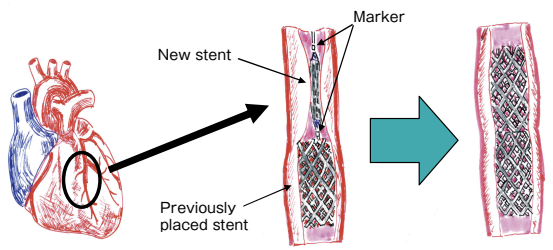
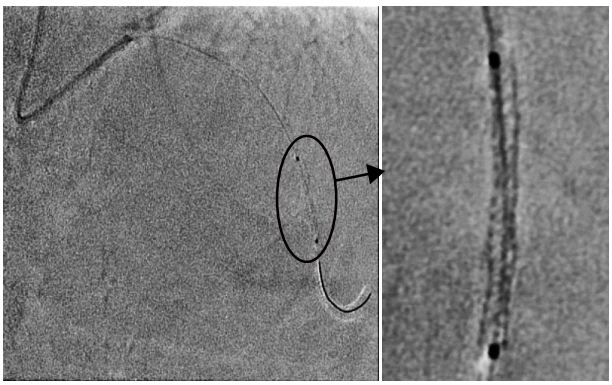


Fig. 1 Stent Placement

3. Operating Principle

To improve the visibility of a previously placed stent, it is necessary to enhance the weak image signals of the stent through addition/averaging processing. However, since the blood vessel in which the stent is placed moves significantly due to cardiac motion, simply adding and averaging the stent image signals is unable to enhance the image of the stent but instead results in diffusion and blurring of the stent image. Therefore, enhancing the stent in the image requires extraction of the stent and markers in each frame of the video image and adding and averaging on each frame while correcting for image deformation due to cardiac motion. This permits the display of an enhanced image of the stent.

By performing this processing on a single frame at up to 30 frames per second (within 33 ms), DynamicStentView displays an enhanced image of the stent in realtime during stent placement, with no delay due to post-processing. DynamicStentView also offers a clear display of the relative positions of the previously placed stent and the markers of the stent to be newly placed. **Fig. 2** shows an actual example during application, and **Fig. 3** shows the operating principle of DynamicStentView in an actual case.



Raw image Stent enhanced image

Fig. 2 Example Application of DynamicStentView
(Images provided by Heisei Shisenkai Foundation Kokura Memorial Hospital)

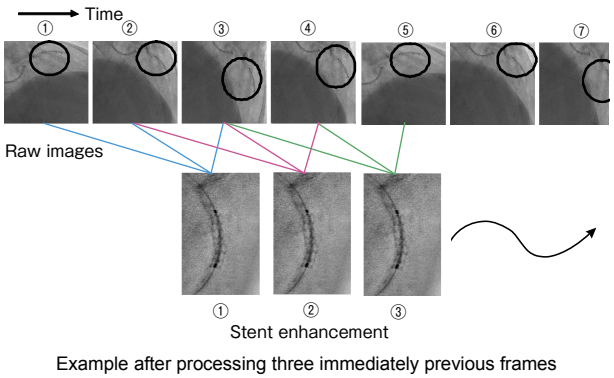


Fig. 3 Operating Principle of DynamicStentView

4. The Principle Behind Extracting Markers from an Image

The most important function for DynamicStentView is extracting the markers to use as the reference for correcting image deformation. This function uses a combination of image processing and pattern recognition processing. **Fig. 4** shows the principle and process of this function.

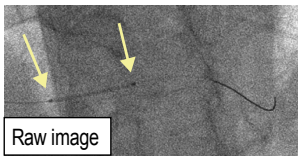
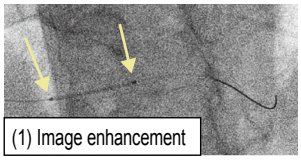
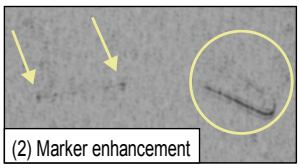
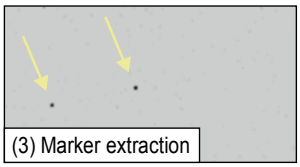
 Raw image	Raw image containing the wire and markers. Markers are indicated by the arrows.
 (1) Image enhancement	Image processing is performed to enhance the image contrast. Spherical patterns are extracted based on the signal differences between each pixel and the pixels surrounding it in the image.
 (2) Marker enhancement	The spherical areas with strong signals are recognized as the markers, and further enhanced. Apart from the markers indicated by the arrows, the end of the wire (circled) is also enhanced, since it is recognized as a series of spherical objects.
 (3) Marker extraction	Further processing removes linear structures from the enhancement target. As a result, only the marker areas (indicated by arrows) are extracted from the image.

Fig. 4 The Principle and Process of Marker Extraction

5. Experiment to Test DynamicStentView

DynamicStentView operation was confirmed by testing with a phantom. Video images were taken using Liberté™ stents made by Boston Scientific (3.0 mm diameter, 96.5 μm thick) and a chest phantom manufactured by Kyoto Kagaku that represents a chest thickness of 20 cm. The results of using DynamicStentView were then verified. The experimental set up is shown in **Fig. 5**. The experiment confirmed enhancement and improved visibility of the stent image.

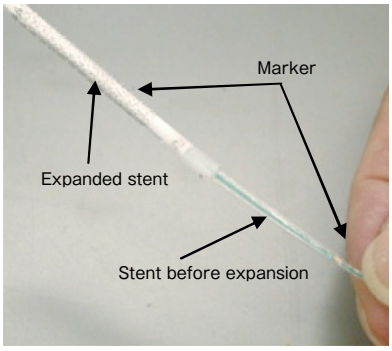
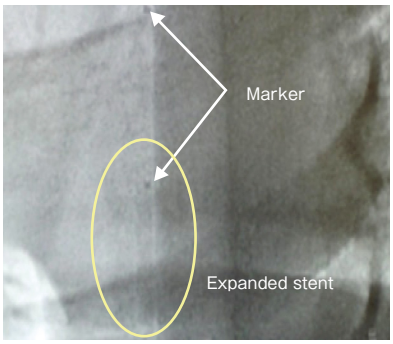
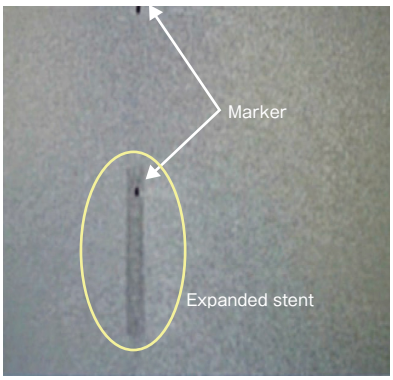
 **(a)** Stent used in experiment  **(b)** Movement over the chest phantom	To imitate cardiac motion, operation of DynamicStentView was confirmed while moving the stent in the area above the phantom. It was confirmed that no false images occurred.
 **(c)** Raw image  **(d)** Stent enhancement	The stent and markers are extracted from the acquired images and enhancement is performed. The relative positions of the stent and markers are clearly displayed.

Fig. 5

6. Operability (screen description)

This section describes DynamicStentView by focusing on its operation. DynamicStentView is useful for confirming positioning when using a balloon to re-expand a stent, or when placing overlapping stents. **Fig. 6** shows examples of the clinical applications of DynamicStentView.

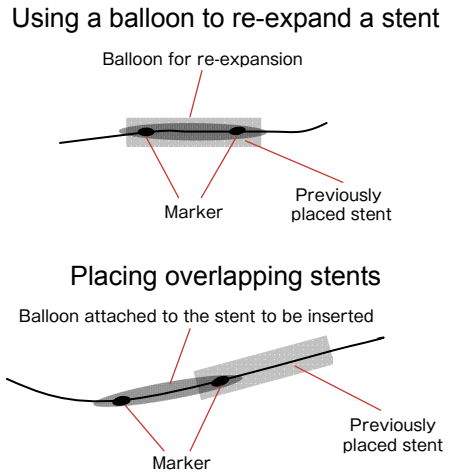


Fig. 6 Clinical Applications of DynamicStentView

Operation is simple. Press a button on the bedside console to select DynamicStentView. Subsequently, realtime images are displayed by pressing a foot pedal in the same way as performing radiography. This simplicity ensures smooth interventional procedures without interruption of the procedure workflow. Also, DynamicStentView offers a stationary display of stents that are moving due to cardiac motion in a fixed position on the screen. This makes the stents clearly visible with few effects from cardiac motion. **Fig. 7** describes the operation of DynamicStentView during a interventional procedure. Also, **Fig. 8** shows a live monitor display of DynamicStentView in operation.

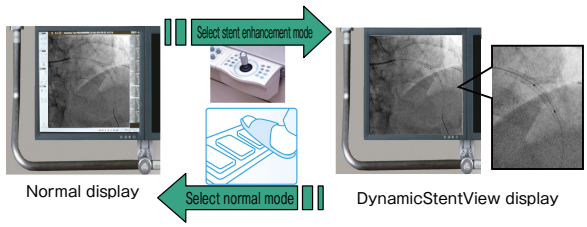


Fig. 7 DynamicStentView Operation During a Interventional Procedure

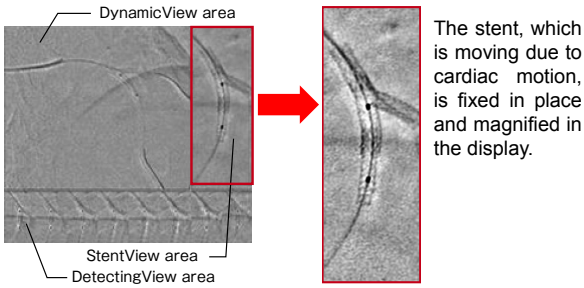


Fig. 8 Live Monitor Display Using DynamicStentView

(1) DynamicView area

The DynamicView area is intended to show an overview of the whole image and to avoid risks due to failure of marker detection during the realtime processing to display the enhanced image of the stent. However, the DynamicView area does not simply display the acquired images. It also uses image processing to reduce the effects of the background and to display the enhanced image data necessary for the medical procedure, such as catheters and guide wires. Shimadzu's systems employ an extremely original RSM-DSA technique, which is a type of DSA function that is not affected by movement. The RSM-DSA technique uses a mask image containing the moving components to remove the effects of movement by subtraction. DynamicView exploits the principle of this RSM-DSA technique. It extracts the areas where there is little movement in the time axis direction to produce the mask image. Subtraction then removes background interference from the original image to extract only the moving areas. This produces a clear display of the guide wires and stents that are always moving due to cardiac motion.

(2) StentView area

The StentView area displays an enhanced image of the stent centered on the markers. The principle behind it is to make the stent easy to see by improving the signal-to-noise (S/N) ratio in the image by addition/averaging processing using recursive time integration filters. Normally, S/N ratio improvement using recursive time integration filters is only effective when the subject is not moving, and it cannot be applied to subjects that are moving. As a result, this technique cannot usually be employed in the cardiac region where there is blood-vessel movement due to cardiac motion. DynamicStentView improves the S/N ratio by using addition/averaging processing with recursive time integration filters unique to Shimadzu that cancels out the effects of movement due to cardiac and other motions. Therefore, DynamicStentView significantly improves stent visibility.

Furthermore, the StentView area displays the stent that is moving due to cardiac motion in a single fixed position while eliminating the effects of cardiac motion to make the interventional procedure easier to perform. This is another original technology developed by Shimadzu to provide powerful support for stent treatments.

(3) DetectingView area

Appropriate marker detection is important for enhancement processing. The marker extracted from each frame of the video image is displayed in the DetectingView area to confirm whether markers are detected correctly. If something other than the marker is recognized by mistake, the mistakenly recognized object is then displayed. While viewing the DetectingView area display, the collimator can be used to remove the mistakenly recognized object from the field of view to ensure appropriate marker detection.

(4) Operability

Smooth operation during interventional procedures that does not interrupt the operator's workflow is extremely important. We envisage DynamicStentView to be used for the final confirmation of positioning when placing stents side by side. The normal operation for such an application would normally be as follows.

(1) Move the stent to the target position during fluoroscopy
(2) Select DynamicStentView
(3) Confirm positioning using DynamicStentView
(4) Expand stent under fluoroscopy

Steps (2) to (4) are the key to achieving a smooth workflow.

DynamicStentView allows step (2) to be performed with a single touch of a button on the bedside console. At step (3), the realtime image display permits instantaneous confirmation. Subsequently, it is not necessary to cancel the stent enhancement mode before starting step (4). The stent can be expanded immediately after confirming the position. Also, from the image management perspective, DynamicStentView processes images in realtime within the system without using a separate workstation. Therefore, images with enhanced stents are recorded and stored in the same manner as ordinary radiographic images within a single unified procedural workflow.

7. Conclusion

DynamicStentView introduced here was developed with emphasis placed on the opinions of doctors performing leading-edge cardiovascular intervention therapy in clinical settings, focusing on the objective of safe and accurate interventional procedures. The application of digital image processing technologies that continue to evolve in terms of speed now permits realtime pattern recognition, which was once thought to be impossible, and image processing using neural networking. The cardiovascular intervention support software DynamicStentView is configured from these leading-edge technologies.

Finally, we would like to offer our sincere gratitude to the staff of Kokura Memorial Hospital for their valuable advice and clinical evaluations we received in the development of this software.