Carestream's companion-view processing for improved visualization of tubes, lines, and pneumothoraces in digital, portable chest radiography

Introduction

Carestream has implemented companion views in its digital radiography systems. A companion view is designed to complement the standard processed radiographic image delivered from the digital radiography capture modality to PACS, to provide an additional rendering tailored for the visual interpretation needed for a specific diagnostic or clinical purpose. Two companion views are available in Carestream products for chest radiography: one for the optimal visualization of tubes and lines in chest radiographs (CARESTREAM Tube & Line Visualization Software), and the other for enhancing the conspicuity of a pneumothorax (CARESTREAM Pneumothorax Visualization Software).

Companion Views

Carestream's digital radiography image processing software is designed to automatically render images with an appearance suitable for a radiologist to assess a patient's condition with respect to the spectrum of potential abnormalities. A single chest image typically comprises a wide range of exposure (gray) levels that exceed the number of brightness levels available on a PACS workstation monitor. Therefore, an appropriate overall rendering may not necessarily display the full grayscale fidelity for any particular indication. In other words, there are simply more gray levels in the raw, captured image than what the PACS monitor can display in a single, static presentation. This effect exists for radiologists who typically read images on high-resolution displays in rooms with reduced ambient lighting—but the effect is exacerbated for ICU clinicians who may need to interpret portable chest radiographs at the point of care, on lower-resolution monitors under bright light, which is common in the ICU setting.

For instance, a portable chest radiograph may be properly rendered and displayed with excellent overall diagnostic quality, yet it may still be challenging to localize tube and line tips in underpenetrated regions, such as in the mediastinum and subdiaphragm. In order to preserve global contrast and brightness for the overall image, gray levels may be quantized in the underpenetrated regions, which will cause some degree of detail contrast loss in the mediastinum (Figure 1 – image on left).

To address this issue, Carestream has developed a unique and robust image-processing algorithm that specifically highlights tube and catheter features [1] (CARESTREAM Tube & Line Visualization Software). To generate the companion view, the image is first decomposed into eight spatial frequency bands. These bands are individually manipulated using non-linear functions designed to achieve an equalized contrast enhancement of image details, while at the same time minimizing noise. The manipulated frequency bands are then reconstructed and the output image is passed through a grayscale look-up table for display. This method boosts the spatial frequencies required to enhance the conspicuity of tubes and lines while it suppresses the spatial frequencies containing noise. By enhancing the tube and line features while simultaneously suppressing noise, this method also works robustly for images captured at low exposure levels and for images of large patients containing excessive X-ray scatter. While the companion view presentation may not be suitable for general diagnostic interpretation, the image features necessary for interpretation of the tube and line structures are significantly enhanced (Figure 1 – image on right).
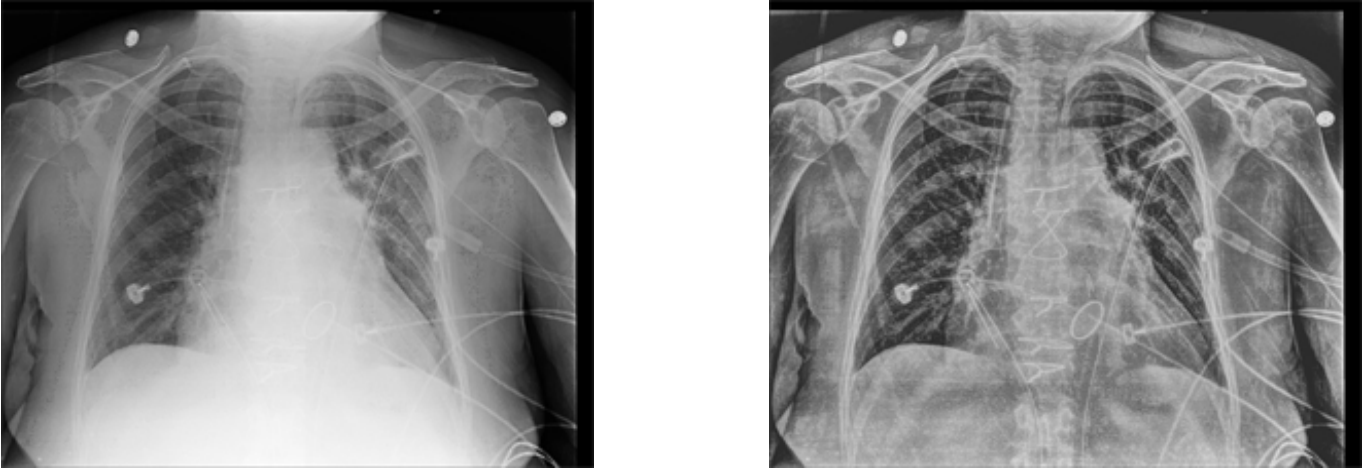
Figure 1 – Left: a portable chest X-ray image processed using default automatic processing. Right: the same image processed using the Tube & Line Visualization Software. The two images are delivered together to PACS.

For some abnormalities, the visual characteristics of the key diagnostic features may be masked by, or confounded with, normal anatomical structures. This is a very different effect from the insufficient grayscale resolution issue described above. This effect can be more readily thought of as visual interference between the features corresponding to the abnormality and the normal anatomical structures.

For instance, consider a pneumothorax, defined as the presence of air in the pleural space. A pneumothorax is visualized by a delineation of the lung edge, which is displaced from the chest wall by the air contained between the visceral and parietal pleura. Depending on positioning, there will be no visible lung markings in this region. The delineation of the lung edge, and the absence of lung markings, may be difficult to perceive and be potentially masked by the radiographic presentation of the scapula or ribs. The conspicuity of the pneumothorax features may be further dampened by insufficient grayscale resolution of the PACS display.

In an approach analogous to that used in tube- and line-enhanced visualization, Carestream has developed a companion view for pneumothorax that is specifically designed to enhance the appearance of the associated features (CARESTREAM Pneumothorax Visualization Software). The algorithm differs from the tube- and line-enhancement technique. Instead of focusing on boosting the spatial frequencies associated with the diagnostic features of interest, the pneumothorax algorithm uses a texture filter that enhances the appearance differences between the characteristic markings for the regions inside and outside the lung. On page 3, Figure 2 (image on left) shows an example of a large pneumothorax (the lung edge is indicated by arrows). The image on the right in Figure 2 shows an insert that illustrates the effect of the enhancement resulting from the application of the texture filter.
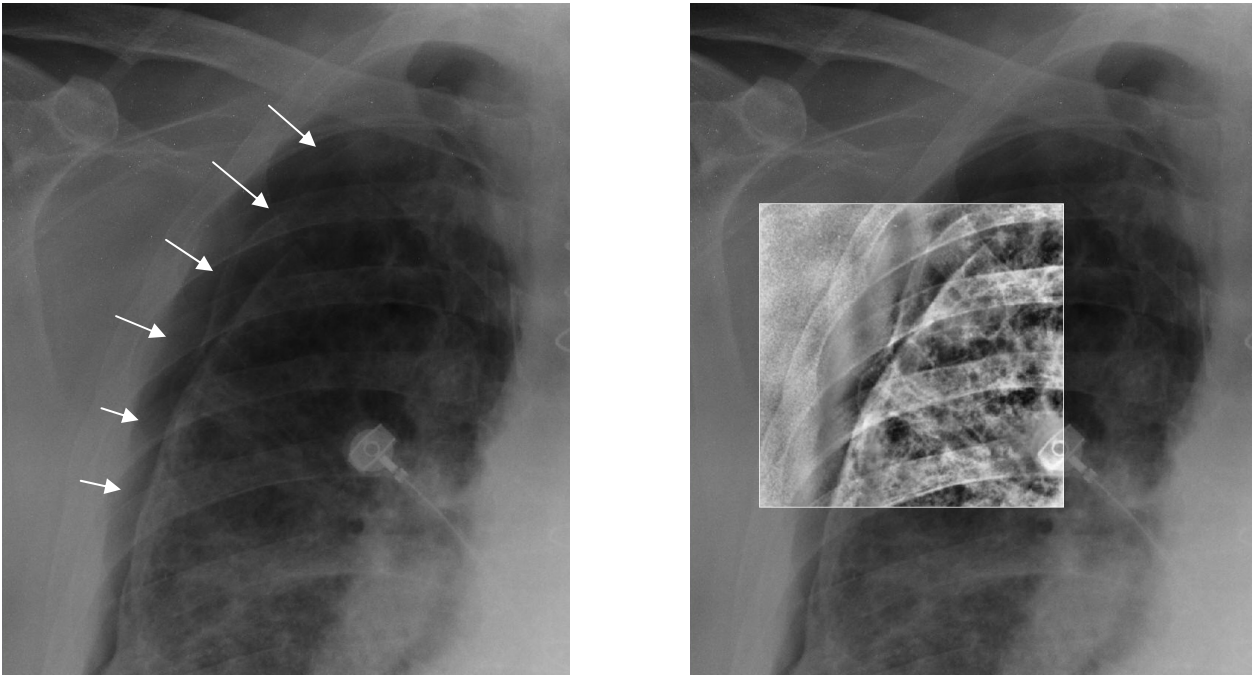
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Figure 2 – Left: a portable chest X-ray image illustrating a large pneumothorax. Right: an insert showing the texture differences resulting from processing the image using the pneumothorax-enhancement filter.

The images shown in Figure 3 compare a portable chest X-ray image presented using the default processing (on the left) against the same image processed with the pneumothorax-enhancement filter (on the right).
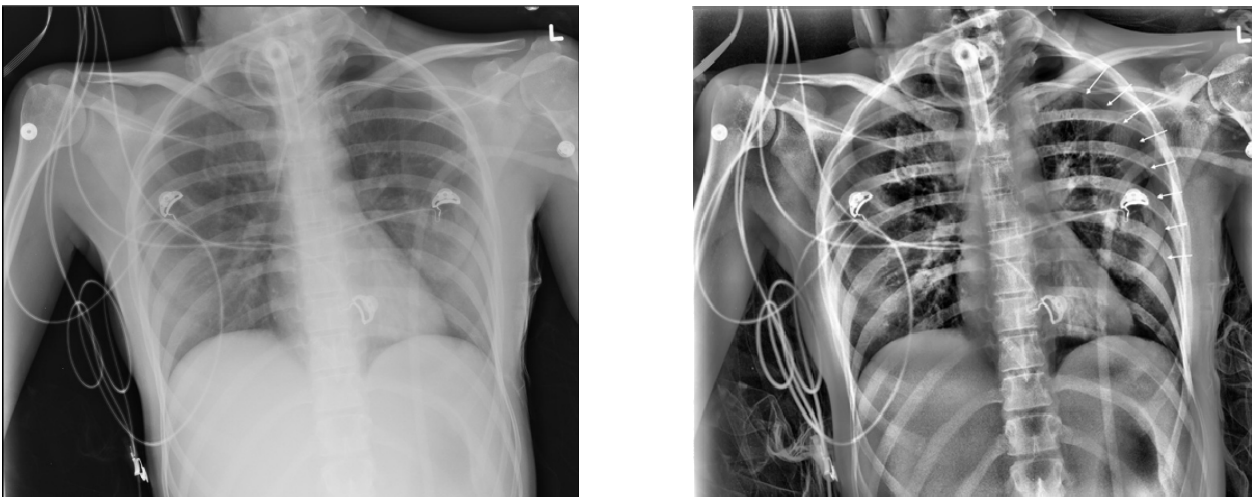

Figure 3 – Left: a portable chest X-ray image of a patient with a pneumothorax. Right: the companion view processed using the pneumothorax texture-enhancement filter. The lung edge is indicated by arrows.

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Companion views improve interpretation confidence and radiologist reading efficiency

PACS workstations provide window/level adjustment capabilities to help address the generic shortcomings of insufficient luminance dynamic range on PACS monitors, and for enhancing the contrast of subtle features. However, interactive window and leveling is time-consuming and degrades radiologist reading efficiency. The enhanced visualization delivered to PACS as a companion view, together with the default processed image, makes it possible for radiologists and clinicians to rapidly toggle between the standard visualization optimized for general interpretation, and the customized visualization that is optimized for a specific diagnostic task. Because the companion view can be toggled with the default processed image, radiologists can more easily make their interpretations with minimal workstation interaction.

A study was conducted with both radiologists and pulmonary ICU physicians to assess the utility of the tube and line companion view in terms of interpretation and reading efficiency [2]. The companion view method was evaluated by two reader groups, radiologists and pulmonary ICU physicians. Each reader group evaluated the images under viewing conditions consistent with their typical respective reading environment. The companion view method was shown to provide improved interpretation confidence and improved diagnostic efficiency for radiologists (30% less reading time), and more confident interpretation for pulmonary ICU physicians in the same amount of time, when used in lieu of window and level adjustments at the PACS workstation.

Summary

Carestream now offers companion-view processing that is designed to enhance the visualization of tubes, lines, and pneumothoraces in chest images captured using Carestream CR and DR modalities. These companion views complement the standard default rendering delivered from the capture modality to PACS with a second image that is processed to enhance the features for a particular diagnostic or clinical indication. The Tube & Line Visualization Software has been shown to improve interpretation confidence for radiologists and pulmonary ICU physicians, and improve reading efficiency for radiologists.

References

1. Couwenhoven ME, Senn RA, Foos DH. Enhancement method that provides direct and independent control of fundamental attributes of image quality for radiographic imagery. SPIE Medical Imaging Proceedings; 5367: 474-481, 2004.

2. Foos DH, Yankelevitz DF, Wang X, Berlin D, Zappetti D, Cham M, Sanders A, Novak Parker K, Henschke CI. Improved visualization of tubes and lines in portable intensive care unit radiographs: a study comparing a new approach to the standard approach. Clinical Imaging Volume 35, Issue 5, September–October 2011, Pages 346–352.

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