EVP Plus Software delivers state-of-the-art image processing for CR and DR systems

Introduction

Radiographic technologists expect a high degree of automation and efficiency in the technology they use in their daily workflow, which means they expect minimal interaction with the technology's modality software. At the same time, radiologists also need the flexibility to specify their site's individualized diagnostic viewing preferences.

For image-processing technology, this means that the ultimate challenge is to attain a high degree of automation while simultaneously delivering flexibility and ease of use. This is a sizable challenge when it comes to digital-projection radiography, where X-ray images of patients using flat-panel digital radiography (DR) or photostimulable-storage phosphor-computed radiography (CR) systems require a processing step to transform the captured images into a form suitable for diagnostic interpretation.

The CARESTREAM DirectView EVP Plus Software successfully overcomes this challenge for digital-projection radiography. EVP Plus automatically processes and delivers diagnostic-quality DR and CR images to PACS, based on look preferences that can be uniquely specified by each site.

EVP Plus image processing

Figure 1 is a flow diagram comprising the six major automatic processing stages of the EVP Plus algorithm.

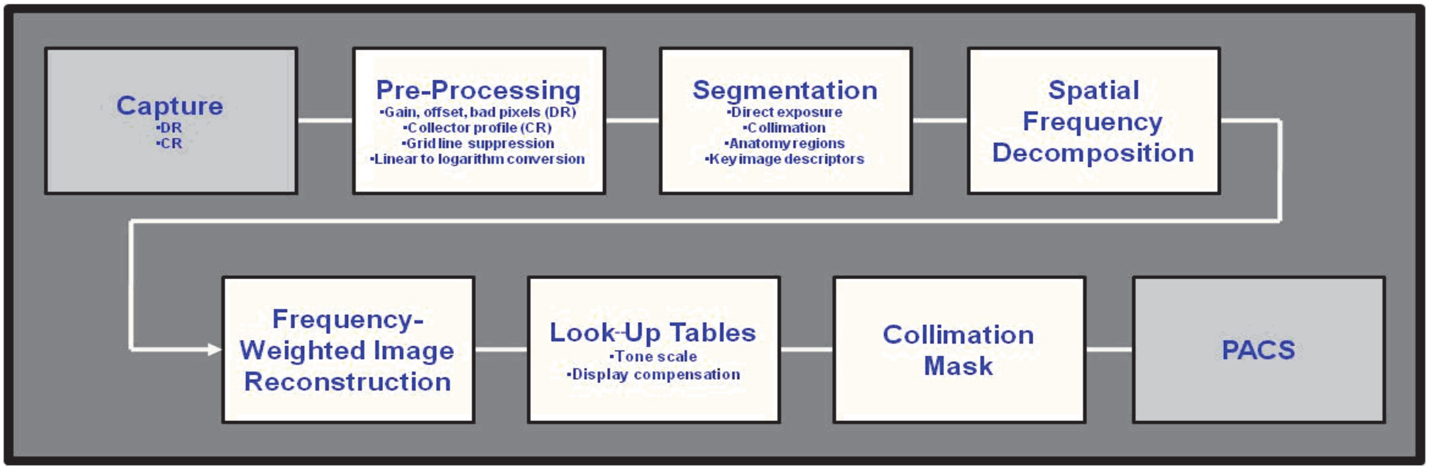


Figure 1 – EVP Plus processing flow diagram

During the pre-processing stage, various corrections such as detector gain and offset adjustments are performed on the raw pixel data. These corrections calibrate the imaging receptor so that it has a consistent response to X-ray exposures across the field of view. The pre-processing stage also incorporates linear-to-logarithmic conversion of the pixel values. Logarithmic conversion ensures that the shape of the image code value histogram doesn't vary with exposure level, which facilitates robust and consistent processing. If a stationary grid is used during image acquisition and a grid-line pattern is present in the image, the pre-processing software will detect the pattern, and the amplitude of the signal variations will be damped. Grid-line suppression prevents aliasing artifacts, such as Moire effects, from occurring when images are resized for display on PACS monitors.

Once pre-processing is complete, the image is segmented and each pixel is classified as belonging to one of three regions: 1) diagnostically relevant anatomy, which generally corresponds to the region inside the skin line; 2) collimation; and 3) direct exposure. Figure 2 identifies the three main regions that are segmented.

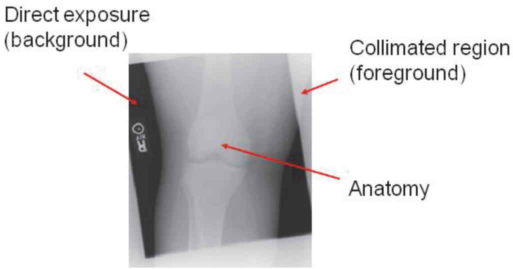


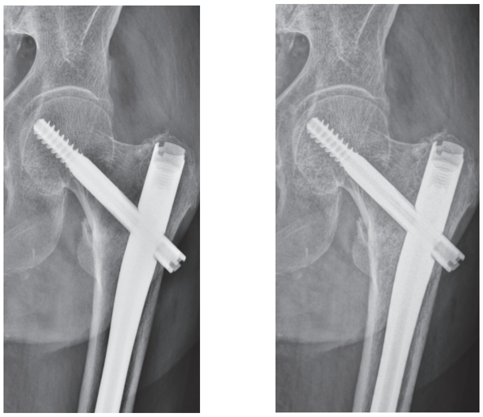
Figure 2 – Three image regions that are segmented

Within the anatomy, algorithms are used to refine the estimation of the diagnostically important regions such as bone, soft tissue and free air. The segmentation stage further identifies relatively smaller radio-opaque regions inside the skin line, including lead markers and pacemakers.

The EVP Plus Software ignores pixel values corresponding to the radio-opaque regions when deriving parameters that drive spatial-frequency enhancement, and it generates look-up tables for the image-grayscale rendition. In the case of CR, there may be occasions where multiple exposure fields are present on a single plate. For these cases, the software automatically identifies each region and then treats each exposure field as an individual image. The output from the segmentation stage is a set of key image descriptors, or in the case of a multiple-exposure CR exam, sets of descriptors. These key image descriptors are used to drive signal-dependent image rendering.

The first step in rendering the images is multi-frequency band decomposition. This is a powerful approach that allows the contrast of different-sized features in the anatomy to be independently manipulated. The relative contrast of these features can be adjusted to produce a preferred visualization for diagnostic interpretation for each exam type. Frequency band decomposition involves a process that successively blurs the image by increasing degrees to create a series of low-pass filtered images. The resulting images are used to create a series of images representing different spatial-frequency bands. Each frequency band represents a particular range of anatomical feature sizes. For example, low-frequency bands represent large anatomy-contrast variations, such as between the mediastinum and lung fields, whereas high-frequency bands represent small contrast variations, such as bony trabelculae. The high-frequency bands also generally contain the "salt and pepper" variations associated with quantum noise.

Once the image is decomposed into frequency bands, the pixel values in each band are multiplied by a gain term that essentially increases or decreases (if the gain term is < 1.0) the contrast of the image attributes that are represented by that band. The degree of enhancement or suppression for each spatial-frequency band is not a fixed value within EVP Plus. Instead, the frequency band gains are a function of exposure level and edge magnitude. Specifically, EVP Plus incorporates an edge-magnitude-dependent function that modulates the gain to mitigate halo (ringing) artifacts that can occur around high-contrast edges. This approach enhances subtle details without overly emphasizing the high-contrast edges susceptible to halo artifacts (Figure 3).



3a – Halo Artifact **3b – EVP Plus processing**

At diagnostic-exposure levels, the predominant source of noise in a radiographic image is quantum noise. As X-ray exposure levels decrease within the diagnostic range, the signal-to-noise ratio (SNR) also decreases, which has the effect of increasing the appearance of noise. Because noise appearance varies spatially as it corresponds to the relatively higher- and lower-exposure regions, EVP Plus applies greater suppression to regions of lower exposure.

After the frequency bands are manipulated, the bands are recombined to reconstruct the frequency-enhanced image (Figure 4).

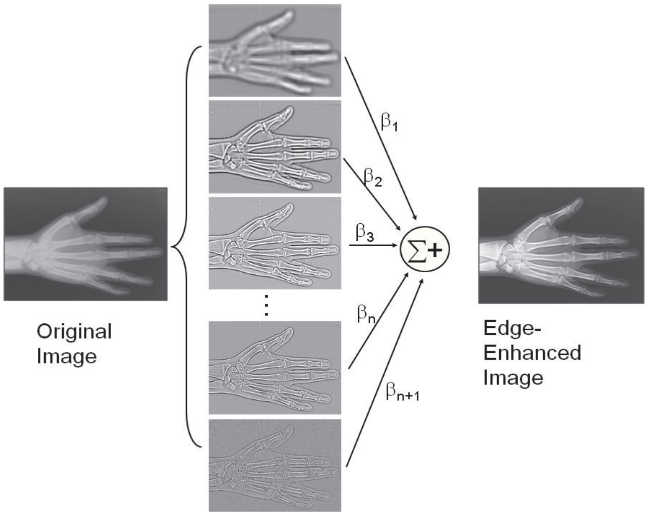


Figure 4 – EVP Plus multi-frequency decomposition and frequency-enhanced reconstruction

The key image descriptors are used to generate a tone scale derived from the segmentation stage. The tone scale is applied to the frequency-enhanced image and used to control image brightness (average density or luminance) and the latitude (the range of exposures that are rendered for display).

In addition, the tone-scale look-up table is mapped through a standard gray-scale display function (DICOM GSDF) for image presentation on a calibrated PACS monitor. A collimation mask may also be applied to the display-ready image.

Figure 5 shows two examples illustrating the progression of image appearance through various stages of EVP Plus image processing. Shown from left to right are: the unprocessed raw image, the image after tone-scale application, the frequency-enhanced image, and the display-ready image after the application of the collimation mask.

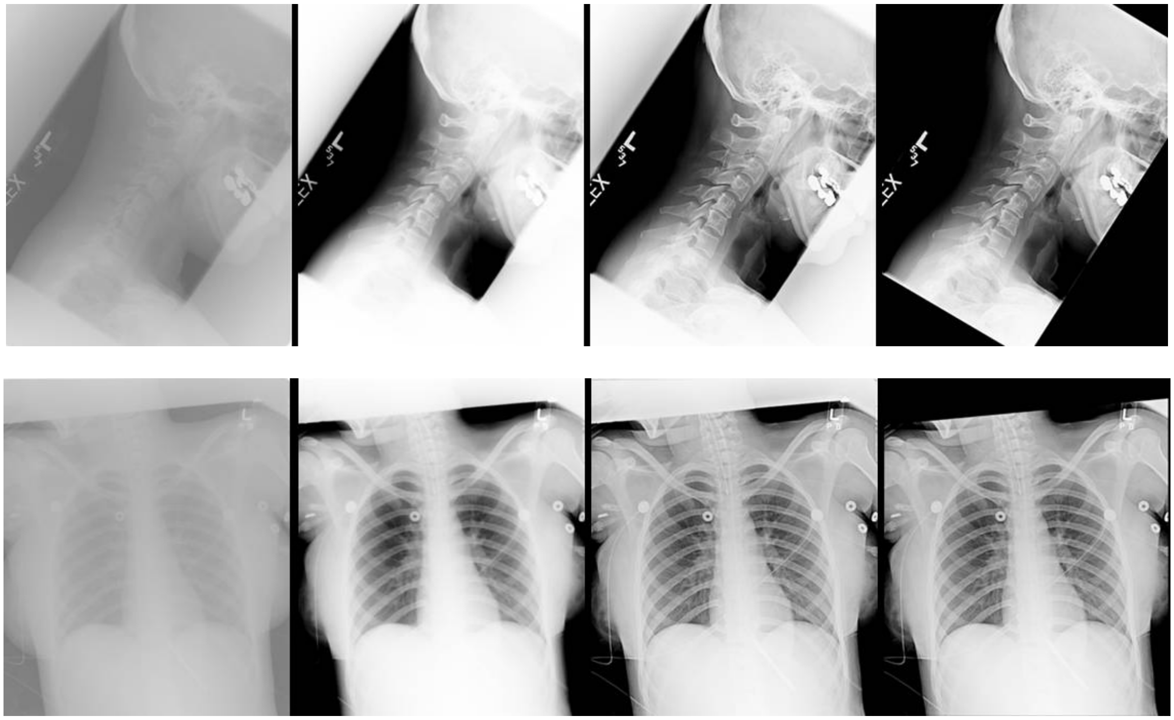


Figure 5 – From left to right, the progression of image: unprocessed image, tone scale, frequency enhancement, collimation mask applied

Establishing image-visualization preferences

Carestream's CR and DR systems have implemented an intuitive user interface (Figure 6) that provides independent controls for five fundamental attributes of image quality: brightness, latitude, detail contrast, sharpness and noise.

The user interface as it's described below (Figure 6) can be used for initial setup in setting the unique "look" preferences for a clinical site. Once the preferences are established, EVP Plus automatically processes images to the specified "look."

Portable Chest - AP - Upright
Poole, Gene

Brightness 0
Latitude 0
Detail Contrast 0
Sharpness 0
Noise 0

Category 1: Portable
Category 2: Portable Chest
View Name: Portable Chest - AP - Upright
Look: CR Premium Processing with noise suppression

Category 1: Portable
Category 2: Portable Chest
View Name: Portable Chest - AP - Upright
Exposure Index: 2298
Patient Name: Poole, Gene
Patient ID:

Figure 6 – User interface with independent controls of image-quality attributes

Each image-quality attribute is controlled via sliders in the preference editor. The brightness slider controls the average density (or luminance) of the image. Simply sliding this brightness control up or down lightens or darkens the brightness level, respectively.

The latitude slider controls the range of exposures that are mapped to the display range without affecting the local detail. Move this slider up to increase the visible shades of gray; move it down to decrease the visible shades of gray.

The detail-contrast slider controls the local contrast of medium-sized structures in an image, such as joint spaces, spacing of vertebral bodies, and ribs, without affecting the latitude of the image. Increasing the slider value causes the medium-sized structures in the image to be more pronounced, while decreasing the value makes these structures less pronounced. Figure 7 illustrates differences between interdependent and independent control of latitude and detail contrast.

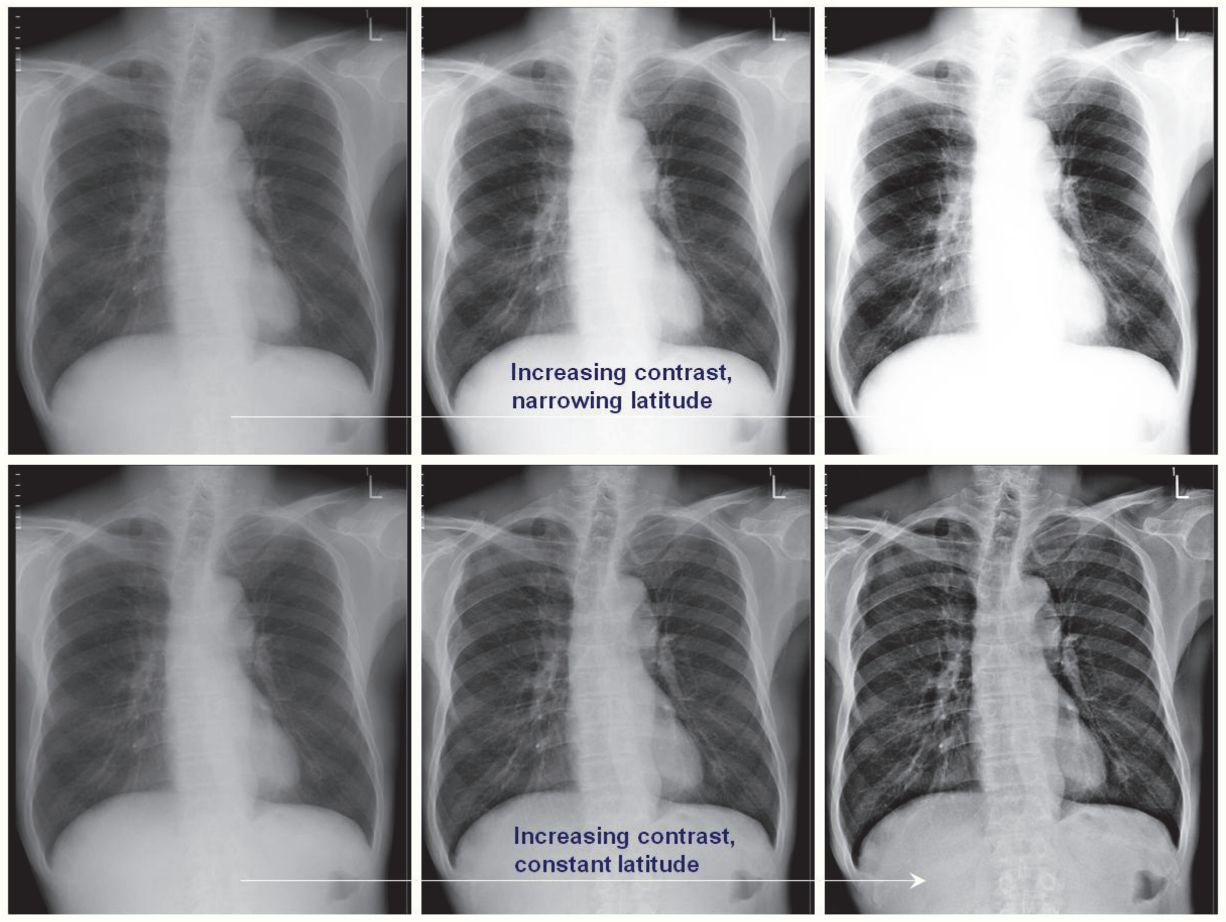
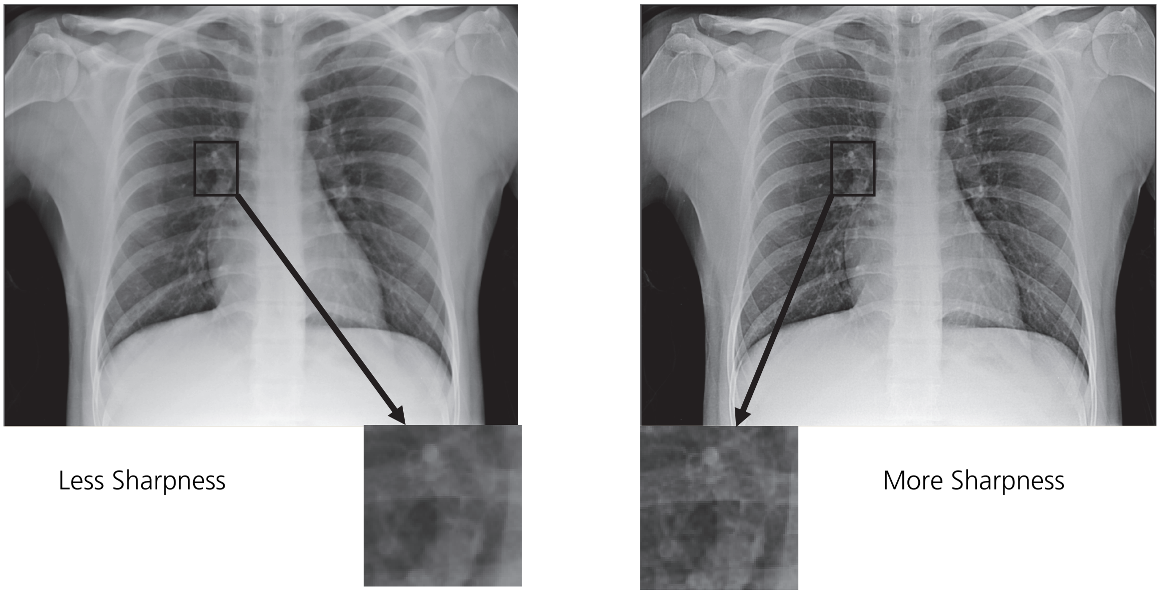


Figure 7 – Top row: traditional tone-scale operation illustrates that increasing contrast decreases the range of exposures that are visualized (this is the classic interdependent contrast / latitude tradeoff). Bottom row: EVP Plus processing achieves the same degree of increasing contrast, while it maintains the same range of exposures that can be visualized. EVP Plus provides independent control of latitude and contrast.

The sharpness slider controls the appearance of finer structures, such as bony trabeculae, lung markings, and calcifications. Figure 8 illustrates the effects of adjusting the sharpness slider. Increasing the slider value makes these finer structures more pronounced, while decreasing the slider de-emphasizes these structures.

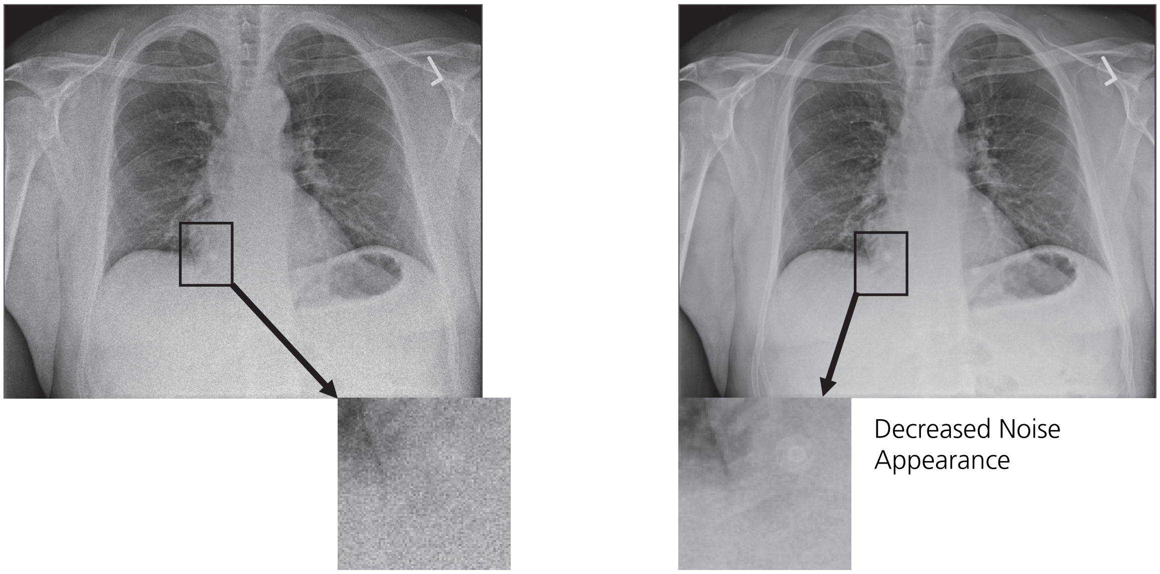


Less Sharpness

More Sharpness

Figure 8 – Effect of increasing the sharpness slider on the appearance of finer image structures

Finally, the noise slider controls the level of noise suppression applied to the image. The same ease of use applies here—decreasing the slider minimizes the appearance of noise, while increasing the slider applies less noise suppression, which can make noise more apparent in lower-exposure areas. Figure 9 illustrates the effect of decreasing the noise slider.



Decreased Noise Appearance

Figure 9 – Decreasing the noise slider reduces the appearance of noise

EVP Plus offers a set of predefined looks, each of which takes into consideration different degrees of brightness, latitude, detail contrast, sharpness and noise appearance. Imaging sites can select a starting look from these predefined settings and then customize exams to their own preferences, using simple and intuitive controls.

Summary

Carestream's EVP Plus Software provides highly automated, state-of-the art image processing for DR and CR, which is delivered together with an intuitive user interface. Following the software's installation, users can easily "dial in" individualized visualization preference settings for each type of radiographic exam at their site. Once the software is configured, the EVP Plus software automatically delivers radiographic images that meet the preferred image presentation for each exam.

References

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