DICOM Correction Item

Correction Number	CP-467
Log Summary: Add VOI LUT Function Attribute	

Type of Modification	Name of Standard
Addition	PS 3.3, 3.17 2004

Rationale for Correction

Projection X-ray images typically have a very high dynamic range due to the digital detector's performance. In order to display these images, various Values Of Interest (VOI) transformations can be applied to the images to facilitate diagnostic interpretation. The original description of the DICOM grayscale pipeline assumed that either the parameters of a linear LUT (window center and width) are used, or a static non-linear LUT is applied (VOI LUT).

This proposal describes an alternative for interpreting the window center and width parameters, which involves specifying a non-linear function, and conveying with a code string value sigmoid the curve used. The new attribute is being added to the Frame VOI LUT Functional Group Macro, the VOI LUT module and the Softcopy VOI LUT module, and hence is applicable to all image types and grayscale presentation states.

To ensure maximum compatibility with existing compliant applications, the new attributes are optional and existing devices are not required to support it.

If a receiving display application does not support the sigmoid function, then it can successfully apply the same window center and window width parameters to a linear ramp and achieve acceptable results, specifically a similar perceived contrast but without the roll-off at the shoulder and toe.

Sections of documents affected:

PS 3.3: A.1.2.10, C.7.6.16.2.10, C.8.11.3.1.5, C.11.2, C.11.8

PS 3.4: N.2.3

PS 3.6: 6

PS. 3.17

Modify PS3.3, A.1.2.10

A.1.2.10   VOI LUT IE

The VOI LUT IE defines the Attributes that describe the transformation of the modality pixel values into pixel values that are meaningful for print, display, etc. This transformation is applied after any Modality LUT. The VOI LUT may be contained within an image, or a presentation state that references an image, or as a Standalone VOI LUT ~~which~~that references an image. When the transformation is linear, the VOI LUT is described by the Window Center (0028,1050) and Window Width (0028,1051). When the transformation is non-linear, the VOI LUT is described by VOI LUT Sequence (0028,3010). **A non-linear interpretation of Window Center (0028,1050) and Window Width (0028,1051) may be defined by VOI LUT Function (0028,1056).**

Modify PS3.3, C.7.6.16.2.10

C.7.6.16.2.10   Frame VOI LUT Macro

Table C.7.6.16-11 specifies the attributes of the Frame VOI LUT Functional Group macro.

Table C.7.6.16-11
FRAME VOI LUT MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
…	…	…	…
>VOI LUT Function	**(0028,1056)**	**3**	**Describes a VOI LUT function to apply to the values of Window Center (0028,1050) and Window Width (0028,1051).** **See C.11.2.1.3 for further explanation.** **Defined terms:** **LINEAR** **SIGMOID** **When this attribute is not present, the interpretation of the values of Window Center (0028,1050) and Window Width (0028,1051) is linear as in C.11.2.1.2.**

Modify PS3.3, C.8.11.3.1.5

C.8.11.3.1.5   VOI Attributes

The Attributes of the VOI LUT Module (C.11.2) are specialized in the DX Image Module.

Window Center (0028,1050) and Window Width (0028,1051) specify a linear conversion (**unless otherwise specified by the value of VOI LUT Function (0028,1056); see C.11.2.1.3**) from the output of the (conceptual) Modality LUT values to the input to the (conceptual) Presentation LUT. Window Center contains the value that is the center of the window. Window Width contains the width of the window.

The application of the Window Center (0028,1050) and Window Width (0028,1051) shall not produce a signed result.

> Note: If the Presentation LUT Shape (2050,0020) is IDENTITY, then the result of applying the Window Center (0028,1050) and Window Width (0028,1051) is P-Values.

Modify PS3.3, C.11.2

C.11.2 VOI LUT module

Table C.11-2 specified the Attributes that describe the VOI LUT.

Table C.11-2
VOI LUT MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
…			
VOI LUT Function	**(0028,1056)**	**3**	**Describes a VOI LUT function to apply to the values of Window Center (0028,1050) and Window Width (0028,1051).** **See C.11.2.1.3 for further explanation.** **Defined terms:** **LINEAR** **SIGMOID** **When this attribute is not present, the interpretation of the values of Window Center (0028,1050) and Window Width (0028,1051) is linear as in C.11.2.1.2.**

Add PS3.3, C.11.2.1.3

C.11.2.1.3   VOI LUT Function

The VOI LUT Function (0028,1056) specifies a potentially non-linear conversion for the output of the (conceptual) Modality LUT values to the input of the (conceptual) Presentation LUT.

The behavior for the value LINEAR is defined in C.11.2.1.2. For all other values, the VOI LUT Function (0028,1056) shall include a unique descriptor of the LUT function to be used. Each descriptor is associated with a bivariate function of Window Center (0028,1050) and Window Width (0028,1051).

If the VOI LUT Function (0028,1056) is present with a value other than LINEAR, the values provided in Window Center (0028,1050) and Window Width (0028,1051) shall not be interpreted as a linear conversion of the (conceptual) Modality LUT values to the input to the (conceptual) Presentation LUT – but as parameters for the function defined by the VOI LUT Function descriptor in (0028,1056).

When defined, each descriptor must provide the functional relationship between the output of the (conceptual) Modality LUT values to the input of the (conceptual) Presentation LUT.

C.11.2.1.3.1.   SIGMOID descriptor

If the value of VOI LUT Function (0028,1056) is SIGMOID, the function to be used to convert the output of the (conceptual) Modality LUT values to the input of the (conceptual) Presentation LUT is given by

$$OUT = \frac{Output\_range}{1 + \exp\left(-4\dfrac{IN - WC}{WW}\right)} \quad\quad (1)$$

where

> *IN* is the input value of the LUT (i.e., the output of the (conceptual) Modality LUT).
>
> *WC* (resp. *WW*) is the Window Center (resp. Window Width) defined interactively by the user or by using the values provided in (0028,1050) (resp. 0028,1051).
>
> *Output_range* is the maximum output value (see Note below on encoding depth)
>
> Note: The encoding depth of the input values for the VOI LUT function is given by the number of bits specified in Bits Stored (0028,0101). The output values of the VOI LUT function must be encoded with an appropriate depth to be then used as input for the Presentation LUT (typically this value is 8 bits) and the *Output_range* parameter allows this scaling. Moreover, Eq. 1 is given assuming float values for clarity but the actual implementation must include rounding to output integer values.

Modify PS3.3 C.11.8

C.11.8   Softcopy VOI LUT module

Table C.11.8-1 specifies the Attributes that describe the Softcopy VOI LUT. These Attributes have the same meaning and behavior as defined in the VOI LUT Module Section C.11.2.

Table C.11.8-1
SOFTCOPY VOI LUT MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
…			
>VOI LUT Function	**(0028,1056)**	**3**	**Describes a VOI LUT function to apply to the values of Window Center (0028,1050) and Window Width (0028,1051).** **See C.11.2.1.3 for further explanation.** **Defined terms:** **LINEAR** **SIGMOID** **When this attribute is not present, the interpretation of the values of Window Center (0028,1050) and Window Width (0028,1051) is linear as in C.11.2.1.2.**

Modify PS3.4 N.2.3

N.2.3   VOI LUT

The value of interest (VOI) LUT transformation transforms the modality pixel values into pixel values ~~which~~that are meaningful for the user or the application.

> Note: Photometric Interpretation (0028,0004) is ignored, since its effect is defined by the application of the grayscale transformations.

The Softcopy VOI LUT Module in the Presentation State is analogous to the VOI LUT Module in an Image.

In the case of a linear transformation, the VOI LUT is described by the Window Center (0028,1050) and Window Width (0028,1051). In the case of a non-linear transformation, the VOI LUT is described by the VOI LUT Sequence. **A VOI LUT Function (0028,1056) may be present to define a potentially non-linear interpretation (e.g., SIGMOID) of the values of Window Center (0028,1050) and Window Width (0028,1051).** The rules for application of the VOI LUT are defined in PS 3.3 Softcopy VOI LUT Module.

The VOI LUT may have sections with negative slope.

   Note: In the Basic Print Service Class a VOI LUT may not have negative slope.

If a VOI LUT is part of both the Image and the Presentation State then the Presentation State VOI LUT shall be used instead of the Image VOI LUT. If a VOI LUT (that applies to the Image) is not present in the Presentation State, it shall be assumed to be an identity transformation. Any VOI LUT or equivalent values in the Image shall not be used.

Add to PS3.6 6. Registry of DICOM data elements

Tag	Name	VR	VM
(0028,1056)	**VOI LUT Function**	**CS**	**1**

Add new Informative Annex to PS 3.17

Annex X – VOI LUT Functions (Informative)

Digital projection X-ray images typically have a very high dynamic range due to the digital detector's performance. In order to display these images, various Values Of Interest (VOI) transformations can be applied to the images to facilitate diagnostic interpretation. The original description of the DICOM grayscale pipeline assumed that either the parameters of a linear LUT (window center and width) are used, or a static non-linear LUT is applied (VOI LUT).

Normally, a display application interprets the window center and width as parameters of a function following a linear law (see figure X-1).
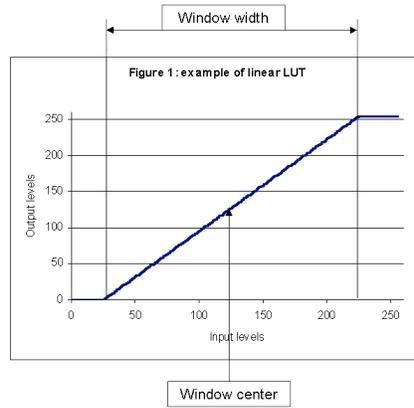
Figure X-1.

A VOI LUT sequence can be provided to describe a non-linear LUT as a table of values, with the limitation that the parameters of this LUT cannot be adjusted subsequently, unless the application provides the ability to scale the output of the LUT (and there is no way in DICOM to save such a change unless a new scaled LUT is built), or to fit a curve to the LUT data, which may then be difficult to parameterize or adjust, or be a poor fit.

Digital X-ray applications all have their counterpart in conventional film/screen X-ray and a critical requirement for such applications is to have an image "look" close to the film/screen applications. In the film/screen world the image dynamics are mainly driven by the H-D curve of the film that is the plot of the resulting optical density (OD) of the film with respect to the logarithm of the exposure. The typical appearance of an H-D curve is illustrated in figure X-2.
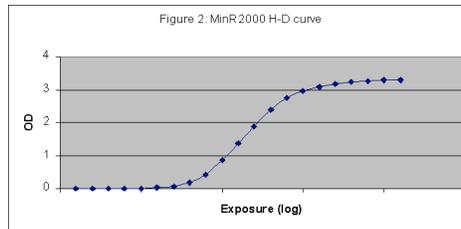

Figure X-2.

In digital applications, a straightforward way to mock up a film-like look would be to use a VOI LUT that has a similar shape to an H-D curve, namely a toe, a linear part and a shoulder instead of a linear ramp.

While such a curve could be encoded as data within a VOI LUT, DICOM defines an alternative for interpreting the existing window center and width parameters, as the parameters of a non-linear function.

Figure 3 illustrates the shape of a typical sigmoid as well as the graphical interpretation of the two LUT parameters window center and window width. This figure corresponds to the equation definition in PS 3.3 for the VOI LUT Function (0028,1056) is SIGMOID.
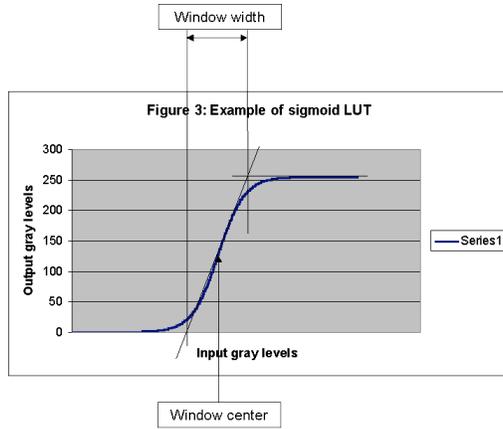
Figure X-3.

If a receiving display application does not support the SIGMOID VOI LUT Function, then it can successfully apply the same window center and window width parameters to a linear ramp and achieve acceptable results, specifically a similar perceived contrast but without the roll-off at the shoulder and toe.

A receiving display application that does support such a function is then able to allow the user to adjust the window center and window width with a more acceptable resulting appearance.