Consistency of Softcopy and Hardcopy: Preliminary Experiences with the new DICOM Extensions for Image Display

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ABSTRACT

The DICOM standard defines in detail how medical images can be transmitted and stored. However, there have been no precise rules on how to interpret the parameters contained in a DICOM image which deal with the image presentation. As a result, the same image frequently looks different when displayed on different workstations or printed on a film from various printers. Three new DICOM extensions attempt to close this gap by defining a comprehensive model for the display of images on softcopy and hardcopy devices: Grayscale Standard Display Function, Grayscale Softcopy Presentation State and Presentation Look Up Table.

A prototype implementation of these extensions has been shown at the 1999 annual tradeshow of the Radiological Society of North America (RSNA) as part of the scientific exhibit (infoRAD). This demonstrated a simulated radiological workflow in which images were created, interpreted at a diagnostic workstation and later reviewed on a clinical workstation. Images could also be printed using DICOM Print. The prototype shows a proof of concept, i. e. that image integrity and consistency over a variety of display and print devices can be achieved and in addition, that the new DICOM extensions can be implemented relatively easily, without a significant performance penalty. The extensions allow to store all parameters defining how an image is displayed or printed in a separate DICOM object that can be managed with the existing DICOM database services. In particular, this satisfies the users' need to view images at different locations in a consistent manner, and to document the image appearance on which a diagnosis is made in softcopy environments.

Keywords: DICOM, Softcopy, Hardcopy, Display Consistency

1. INTRODUCTION

The DICOM (Digital Imaging and Communications in Medicine) standard [1] has been quite successful in establishing a vendor independent platform that allows the creation of complex image management networks with different types of modalities, archives, printers and information systems. DICOM started in 1993 with basic services for image management such as transmission, archival and printing of medical images. Since then, the standard was supplemented with a multitude of enhancements defining new modalities (e. g. full-field digital X-ray) and new services (e. g. Basic Worklist Management, Modality Performed Procedure Step). One area that was never addressed by the DICOM standard in the past, however, is the problem of display consistency. Even though it might be possible to exchange a particular medical image between two display stations, there was no guarantee that both systems displayed the same image, even if all display settings (e. g. window level and width) were identical. Even worse, when the image is printed to a hardcopy printer, it is quite likely that the hardcopy looks different than the softcopy display. In installations with only a small number of different viewing station and printer types, this limitation might be acceptable because many systems can be adjusted with different kinds of correction curves to match the users' preferences on image appearance. However, this requires a separate adjustment for each combination of modality and display device and, therefore, becomes an increasingly complex and time consuming task with the growing number of DICOM compliant devices in a network. Recognizing this problem, the DICOM committee has developed three supplements to the standard which address issues of display consistency for both softcopy and hardcopy displays (e. g. viewing software and printers):

- Grayscale Standard Display Function [2],
- Grayscale Softcopy Presentation State Storage [3], and
- Presentation Look Up Table [4].

The supplements on the Grayscale Standard Display Function and Presentation LUT (Look-Up Table) have been part of the standard for a while (they are included in the 1998 edition of the standard), but have not been implemented widely in the past. The supplement on Presentation States has been finalized only recently (September 1999).

2. GRAYSCALE STANDARD DISPLAY FUNCTION

The human perceptual response to different levels of brightness is not linear – a fact that we have to deal with in the medical imaging area, where the luminance range typically varies around 1 - 2000 cd/m^2 (candela per square meter) for conventional film-screen systems. The eye is much more sensitive to brightness changes in the bright areas of an image than in the dark areas. The DICOM Grayscale Standard Display Function (GSDF) describes this property of human vision in mathematical terms, based on Barten's model of the human visual system [5]. The GSDF uses the notion of "Just Noticeable Differences" (JNDs), which are defined as *the luminance difference of a given target under given viewing conditions that the average human observer can just perceive*, and derives a set of 1023 discrete JNDs (for a standard target and well-defined viewing conditions) that fall into the luminance range from 0.05 to about 4000 cd/m^2 which is covered by the model. The JNDs allow to determine an upper boundary for the number of shades of gray that can be visualized on a display system with a given luminance for black and white. They also allow to describe the characteristic curve of a display system that matches the sensitivity of the human eye to changes in brightness, i. e. a perceptually linearized display system. Figure 1 shows the formula from [2] which defines the Grayscale Standard Display Function as an interpolation of the luminance curve over the complete JND range (with constants *a..h, k, m* as defined in [2]).

$$\log_{10} L(j) = \frac{a + c \cdot Ln(j) + e \cdot (Ln(j))^2 + g \cdot (Ln(j))^3 + m \cdot (Ln(j))^4}{1 + b \cdot Ln(j) + d \cdot (Ln(j))^2 + f \cdot (Ln(j))^3 + h \cdot (Ln(j))^4 + k \cdot (Ln(j))^5}$$

Figure 1: DICOM Grayscale Standard Display Function L(j): Luminance as a function of the JND index

The GSDF is intended as a standard curve against which different types of display devices can be calibrated, such that the calibrated image display uses the available contrast of the display device in a perceptually linear way (i. e. the difference between black and 5% gray is perceived equal to the difference between white and 95% gray). A calibration of different types of display devices (e. g. screen/film and grayscale monitor) according to the GSDF cannot yield an *identical* image display if the physical properties of the display devices in terms of spatial and contrast resolution differ. However, the calibration can yield a *consistent* image display which means that the appearance of the image to the human observer is as similar as possible given the differing properties of the display devices.

The DICOM GSDF model can be applied to a wide range of display devices, including CRT (cathode ray tube) and flat-panel monitors (which are considered as a display system together with the graphics adapter to which they are attached), reflective hardcopy printers and transmissive hardcopy printers. All of these systems have in common that they allow a discrete number of shades of gray to be addressed (typically 256 for monitors and 256 – 4096 for transmissive hardcopy printers). The index number used to address the shades of gray is called Digital Driving Level (DDL) in DICOM. The calibration of a display system requires that the characteristic curve of the display system is measured, taking the reflection caused by ambient light into account. For softcopy displays, the luminance for each DDL is measured. For hardcopy printers the optical density *D* for each DDL is measured instead. A luminance can be computed from the optical density using the formula from [2] shown in Figure 2, where L_a is the luminance contribution due to reflection of ambient light (defined to be 0 for reflective hardcopy) and L_0 is the luminance of the light box (for transmissive hardcopy) or the maximum luminance obtainable from diffuse reflection of the illumination (for reflective hardcopy).

$$L = L_a + L_0 \cdot 10^{-D}$$

Figure 2: Relationship between Optical Density and Luminance

Figure 3 shows the measured characteristic curve of a particular display device (the PC on the author's desk) together with the part of the DICOM GSDF which falls into the same luminance range. A correction function can be derived from the two curves in a straightforward way: For each pixel value that may occur in the image to be displayed, the corresponding luminance according to the GSDF (i. e. the luminance of a perceptually linearized display using the same luminance range as the real display system) is determined. Then a DDL of the real display system is selected such that it matches the GSDF luminance as close as possible. The resulting transformation can be implemented efficiently as a simple look-up table.

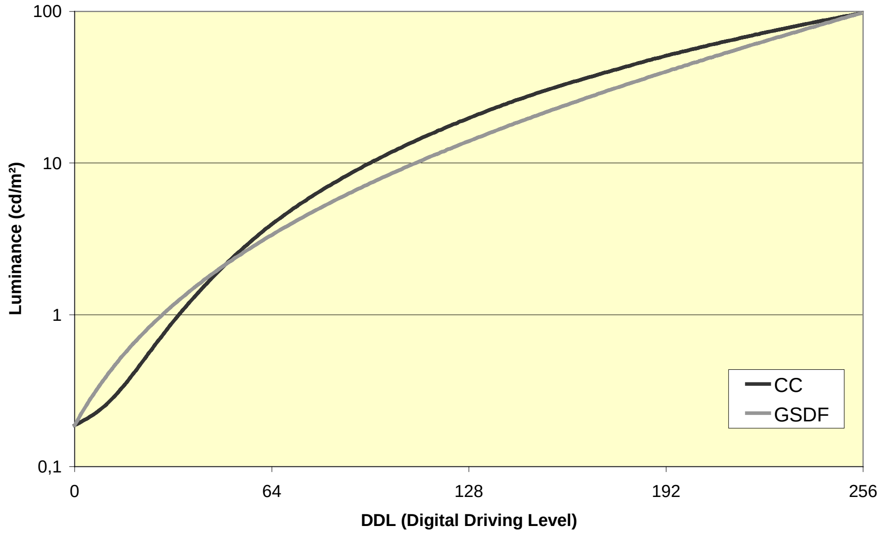

Figure 3: DICOM Grayscale Standard Display Function (GSDF) versus measured Characteristic Curve (CC)

DICOM does not mandate a particular implementation of the correction function, and in fact, different approaches are possible. Most graphics adapters used with high resolution / high brightness grayscale monitors for softcopy reading of digital radiography implement the correction look-up table as part of the adapter hardware. Systems using conventional color monitors and graphics boards can implement the image correction as part of the display software. It should be noted that the image correction can be implemented such that the source image data (which typically contains a contrast range of more than 8 bits for modalities like CT or CR) is directly mapped to DDLs. This eliminates a prior reduction of the source image data contrast range which could lead to the loss of shades of gray (and, thus, a loss of information caused by the software based display calibration).

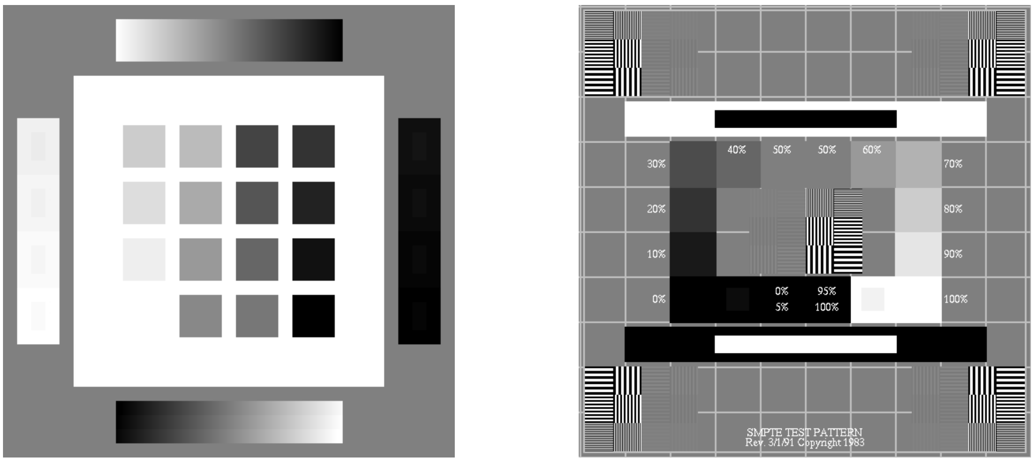

Figure 4: Grayscale Test Patterns (Philips DSI Pattern, SMPTE Pattern)

The result of the calibration can be visualized with test patterns such as the DSI pattern from Philips Medical Systems or the SMPTE pattern from the Society of Motion Picture and Television Engineers, as shown in Figure 4. The low contrast fields (i. e. the 5% and 95% fields on the SMPTE pattern and the 2% contrast fields on the left and right of the DSI pattern) should be visible. The steps from black to white should appear equidistant and, when measured, should match the GSDF for the available contrast range of the display device.

3. GRAYSCALE SOFTCOPY PRESENTATION STATE

Unlike conventional images which can be viewed without any additional tool (except a lightbox in an environment with appropriate lighting), digital medical images consist of binary data which must be processed and presented to the human eye on a display device such as a printer or monitor. In particular, the mapping of the raw binary image data to the display usually requires the application of image processing algorithms in order to produce a meaningful image. A well-known example is the adjustment of window level and width, but there are others, for example the mapping of vendor specific data to a standardized domain (e. g. Hounsfield units for CT) or the mapping of data acquired in optical density linear space (e. g. scanned film) to image data meaningful for softcopy display. Therefore, DICOM allows to store a number of image processing parameters in the header of each DICOM image, together with other medically relevant information about the acquisition (patient demographic data, radiation dose, contrast media, date and time of acquisition etc.) However, practice has shown that this approach has its limitations:

- In many PACS configurations, all modalities send their images to the archive after acquisition. The archive permanently stores the images and forwards them to the workstation scheduled for the reading of the images. Since the study is already archived, adjustments performed on the images during diagnosis (e. g. window level and width) cannot be stored unless the complete study is duplicated in the archive.
- Although DICOM defines fields in which parameters like Window Center (level) and Window Width can be stored, the corresponding algorithms were never precisely defined (i. e. DICOM never really defined how a Window Center and Window Width should be interpreted). Not surprisingly, this ambiguity has lead to differing implementations. It is possible today to have two different display stations which are perfectly DICOM compatible but still display the images in a different manner, even when the same image is shown with the same processing parameters.

The Grayscale Softcopy Presentation State Storage Supplement [3] addresses these two problems. First of all, it precisely defines the different grayscale transformations that must be applied to the raw DICOM image data in order to yield a consistent image display. The upper part of Figure 5 shows these grayscale transformations.

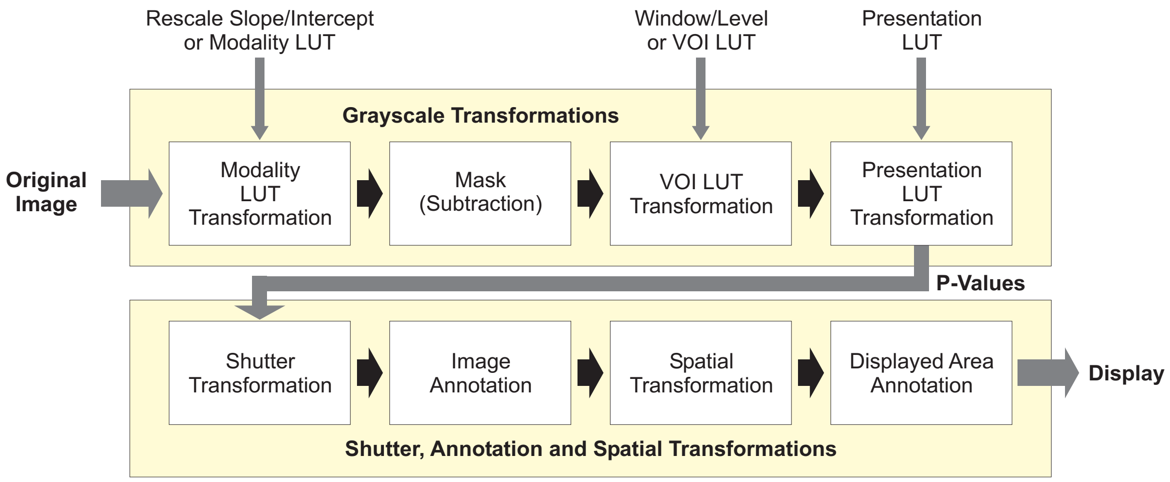

Figure 5: DICOM Grayscale Image Transformation Model

The first step in the display chain is the Modality LUT Transformation, which maps device or vendor dependent data into a vendor-independent space. This can either be a linear mapping of the form $f(x) = m*x+b$ where m is called “rescale slope” and b is called “rescale intercept”, or it can be a look-up table (e. g. mapping optical densities from a scanned film into a space linear to perceived intensity). The second step, mask subtraction, is used in angiographic studies, where images might be subtracted from a reference image functioning as a mask. The third step, the Value of Interest (VOI) LUT Transformation, is DICOM’s notion of the window level and width adjustment. Figure 6 shows the precise (and surprisingly complex) definition of the formula which maps an arbitrary image pixel value x into the output interval $[f_{min}, f_{max}]$, depending on the Window Center c and the Window Width w, which must be ≥ 1. As an alternative to window level and width, a look-up table can also be used to specify a Value of Interest transformation.

$$f(x,c,w) = \begin{cases} f_{min}, & x \leq c - \frac{1}{2} - \frac{w-1}{2} \\ f_{max}, & x > c - \frac{1}{2} + \frac{w-1}{2} \\ \left(\frac{x-c+\frac{1}{2}}{w-1} + \frac{1}{2}\right)(f_{max} - f_{min}) + f_{min} & \text{otherwise} \end{cases}$$

Figure 6: DICOM Formula for Window Level/Width Calculation

The last DICOM grayscale transformation is called Presentation LUT Transformation. This is a rather new addition which was introduced with the 1998 edition of the standard. A Presentation LUT allows to encode non-linear image transformations for specific applications or user preferences, for example a gamma correction. A good example might be the display of orthopedic images which might need more contrast to clearly show potential fractures. The output space of the Presentation LUT is called "Presentation Values" (P-Values) and by definition approximately related to human perceptual response. P-Values do not depend on the characteristics of a particular display device and are used as the input for a standardized (calibrated) display device such as a workstation or printer conforming to the DICOM Grayscale Standard Display Function.

In addition to a precise definition of DICOM's grayscale image transformation model, the Grayscale Softcopy Presentation State Storage Supplement creates a new DICOM Information Object Definition (IOD) called "Presentation State". This object contains an extensive set of parameters defining how a particular image or set of images is to be presented (displayed) to the user. A Presentation State only contains references to the images it applies to and, therefore, does not duplicate the image data. Presentation State objects are relatively small (typically only few Kbytes) and can be stored and transmitted with a minimal resource increase. Presentation State objects fit well into the established DICOM information model (they are just a separate DICOM series within the study containing the images) and can be transmitted, stored and retrieved with the existing DICOM storage and query/retrieve services, requiring few changes in existing systems. It is possible to have a single Presentation State for a complete series of images or to have different Presentation States ("views") of the same image (see Figure 7).

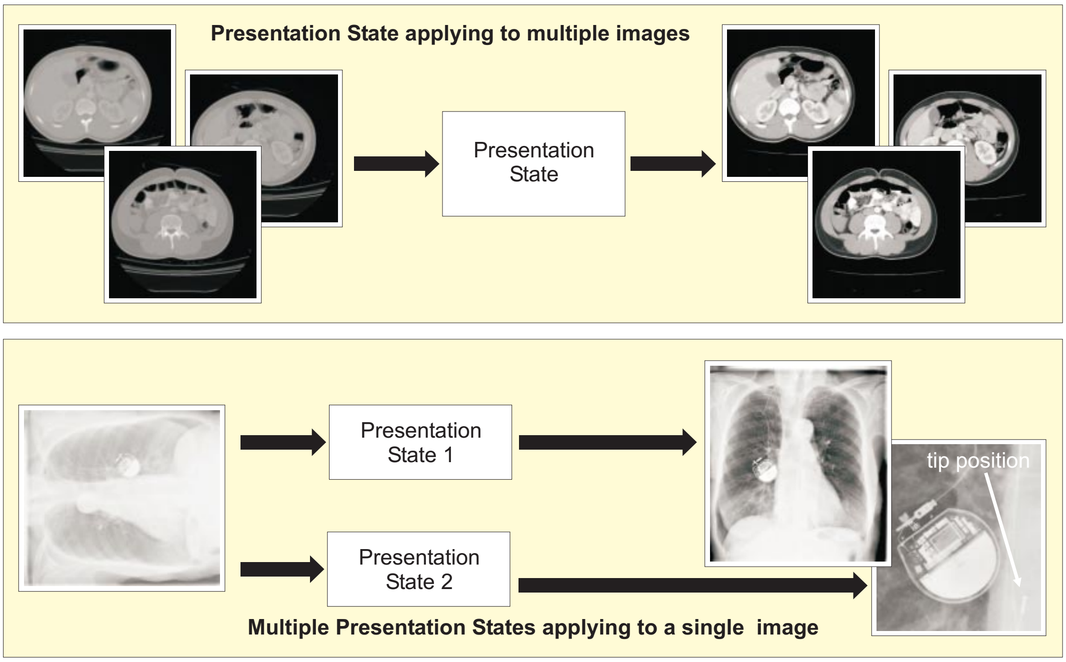

Figure 7: Different Mappings between Presentation States and Images

A Presentation State contains all the grayscale transformations described before (all of these transformations are optional, though, and can be replaced by an "identity" transform). In addition, a Presentation State can contain graphical annotation and a number of spatial transformations (see lower part of Figure 5):

- *Shutter Transformation:* Display shutters allow to mask unwanted parts of the image, e. g. unexposed parts of an X-ray which are displayed very brightly because of collimation and affect the visibility of relevant parts of the image.
- *Image Annotation:* Images can be annotated with graphical and textual comments displayed as overlays on the image, e. g. in order to highlight regions of interest (ROI) or document measurements on the image. Unlike overlays that are "burned" into the image, annotations in a Presentation State could be displayed and switched off at the user's discretion.
- *Spatial Transformations:* Images can be rotated and flipped (often required for Computed Radiography images). Images can be zoomed to a defined "displayed area" (rectangle) or to a specified zoom factor. It is also possible to request the display of an image at its true physical size if this size is known.
- *Displayed Area Annotation:* This annotation is not "attached" to the image but to the display (view port). This allows for example to display the patient demographic data (name, birth date, sex) or patient comments in the edges of the screen independent from the zoom factor or rotation applied to the image.

Most DICOM image viewing applications already support similar annotation features, mostly preserved in a proprietary manner. However, DICOM Presentation States allow to archive this information in a PACS and to have it available for the full lifetime of the images, even if devices change over time. Presentation States can also be exchanged between viewing stations of different vendors supporting this DICOM service.

4. PRESENTATION LOOK UP TABLE

The concept of the DICOM Grayscale Standard Display Function and the notion of P-Values as the input to a standardized display system are not limited to the softcopy domain but can also be applied to hardcopy. The DICOM Presentation LUT Supplement [4], which is already integrated into the main standard text since the 1998 edition, makes these concepts available for printing as an extension of the DICOM Print Management Service Class. This service class consists of a number of print services and optional extensions and has been available as part of the DICOM standard since its initial release in 1993. "Basic Grayscale Print Management" is the service that is most often used for printing grayscale images. It differs from softcopy display by the fact that the image sent to the printer is always pre-formatted. This means that most steps of the DICOM grayscale transformation model (Figure 5) must be rendered by the print client before sending the image to the printer.

Although a pre-formatted image does not leave much room for ambiguity, the fact that DICOM never defined the precise relationship between image pixel values and luminance or optical density turned out to be a major problem since different vendors interpreted pixel values differently (e. g. linear to optical density or linear to human perceptual response). Most print vendors addressed this problem by implementing a large number of correction curves and configuration options that allow to adapt a printer to the characteristics of the modality from which images are printed. The correction curves also serve as a non-standard replacement for the Presentation LUT, i. e. they allow to change the image appearance in accordance with the user's preferences. The obvious disadvantage of this approach is that it requires an adaptation of the printer settings for each modality which is to be connected to the printer (and, at least in theory, even for each user with different preferences about image appearance). While this may be acceptable for installations with a limited number of modalities and printers, it becomes a significant problem in complex, heterogeneous PACS where printers need to be able to serve requests from a large number of modalities and workstations.

The DICOM Presentation LUT Supplement [4] provides a solution to this problem by precisely defining how the pre-formatted image relates to the P-Value space and by making the parameters which are required to control hardcopy image appearance an explicit part of the communication protocol. Figure 8 shows a number of parameters which are required by a DICOM printer to control the image appearance on the hardcopy. The black arrows show extensions of the DICOM print communication protocol from [4]. The basic idea of the Presentation LUT Supplement is that a print client (modality or workstation) and a print server (printer) which are both aware of this DICOM extension can negotiate support for it during establishment of a connection (i. e. print session). The print client then either transmits a pre-formatted image in P-Values, or it sends a pre-formatted bitmap that is accompanied by a Presentation LUT which allows the print server to convert the bitmap into P-Values. The latter option is useful for modalities which only support the transmission of 8-bit image data. The print client also sends information about the lighting conditions (illumination and reflection caused by ambient light) under which the resulting hardcopy will be viewed. DICOM recommends default values of 2000 cd/m^2 for illumination and 10 cd/m^2 for reflected ambient light for transmissive hardcopies, which are typical viewing conditions for hardcopy reading. Knowing its own internal characteristic curve, which is a result of the printer's calibration procedure, and the desired maximum and minimum density for the print, which can also be transmitted as part of the DICOM print protocol, the print server can compute a correction curve which calibrates the hardcopy to the DICOM Grayscale Standard Display Function for the defined viewing conditions.

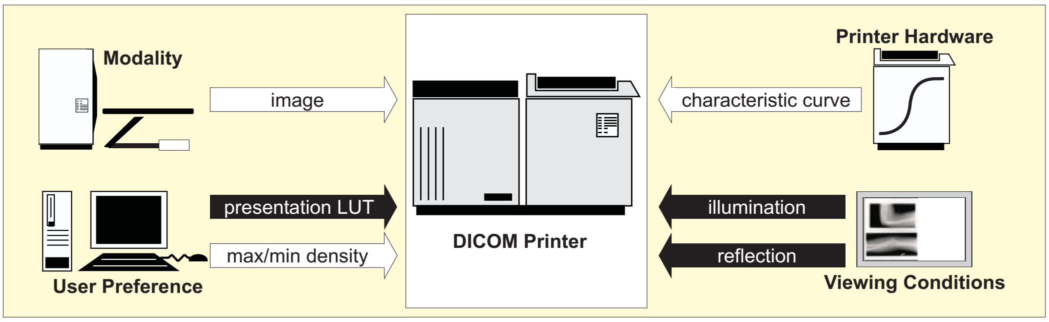

Figure 8: Parameters affecting the Rendering of an Image in a DICOM Printer

This approach combines the advantages of a standard display function with the flexibility required to adapt hardcopy image appearance to user preferences. Since modalities and printers supporting the Presentation LUT Supplement use a well-defined interface for image transmission, P-Values, there is no need to adapt each printer to each modality any more. A calibration of the printers against the GSDF makes sure that hardcopies from different printers become directly comparable (consistent), of course within the physical limitations of the printer. Since DICOM proposes that both softcopy and hardcopy devices should be calibrated against the GSDF, this even allows to make softcopy display and hardcopy image appearance directly comparable. On the other hand, the possibility to use Presentation look-up tables gives the flexibility needed to adapt image appearance to user (or vendor) preferences, independent from the printer. Finally, Presentation States allow to carry the concept of user preference over to the "softcopy world".

5. EXPERIENCES

In order to validate the feasibility of the new services described above and to demonstrate its potential to the radiological society, the NEMA Committee for the Advancement of DICOM commissioned a prototype implementation of a DICOM image viewer supporting Presentation States, GSDF calibration and DICOM printing with Presentation LUT support. This prototype has been shown at RSNA infoRAD 1999, together with a number of prototype implementations of DICOM printers supporting Presentation LUT, as the "DICOM Softcopy and Hardcopy Consistency Demonstration". Figure 9 shows the concept of the demonstration.

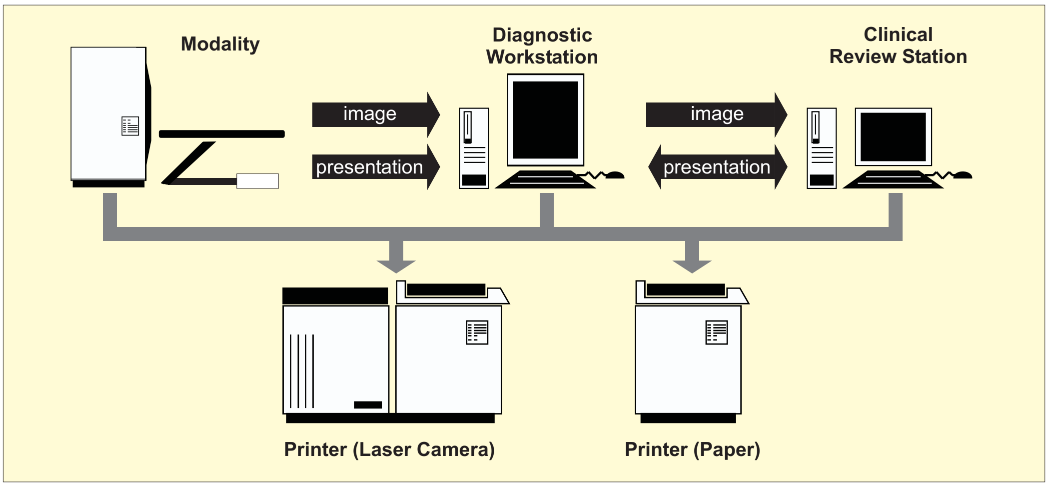

Figure 9: Concept of RSNA infoRAD 1999 Demonstration

The exhibit demonstrated a simulated radiological workflow in which images were created by a modality and transmitted to a diagnostic workstation (with 2×2.5k high resolution grayscale monitor) where a Presentation State was created for the image. Both image and Presentation State were then sent to a review workstation (PC with conventional color monitor) and displayed. Finally, images could be printed on a laser camera or a paper printer. A number of printers from different vendors and softcopy displays using different technologies (monochrome CRTs with hardware support for display calibration, conventional color CRTs, flat-panel color LCD) allowed to compare the display consistency between display devices with very different characteristics. The prototype DICOM viewer which was installed on the "simulated modalities" as well as on the diagnostic and review workstations is an extension of the software shown for the first time at the European Congress of Radiology 1999 [6]. It is implemented in a combination of Java and C++ (which allows easy porting of the software to different operating systems such as Microsoft Windows, Sun Solaris or Linux) and freely available as Open Source software on the Internet [7,8]. Figure 10 shows a screenshot of the demonstration software.

Figure 10: DICOM Softcopy Presentation State Demonstration Software

Altogether the demonstration included seven independent implementations of a DICOM GSDF calibration (four printers and three softcopy display systems including the demonstration software mentioned before) which can be regarded as a true proof of concept for the applicability of the GSDF to different types of display devices. An image displayed on different types of monitors and printed with different printers does not really look "the same" because the physical properties of these devices (resolution, brightness, color temperature) are quite different, however, the visual impression confirms that the image appearance is consistent. Most healthcare professionals visiting the demonstration acknowledged that the possibility to calibrate both hardcopy and softcopy displays to a common standard solves a problem which is a major issue in many institutions. Many of them were also not aware that the concept of calibration is not bound to specialized hardware and can be implemented with rather moderate expenditure like a portable photometer and a software-based correction. This fact might be of importance wherever images are viewed on standard consumer devices (e. g. a radiologist reading an emergency case at home on a standard PC).

6. DISCUSSION

Since human visual perception depends on the lighting conditions under which images are viewed, measuring and controlling these conditions is important if one wants to guarantee a consistent image appearance. In particular the reflection caused by ambient light on a monitor or screen film must be measured and taken into account for the calibration – the conventional "suction cup" type of photometer do not allow to measure this factor. Changing lighting conditions require an adjustment of the image correction tables implementing the display calibration. Whereas this can be automated with dedicated hardware (an ambient light sensor permanently tracking changing lighting conditions and adjusting the correction tables), it is an open question how this could be handled in a way which does not become a burden to the user on systems where such hardware is not available. It is also debatable whether it can be guaranteed that printed films are always viewed under the same lighting conditions, in particular if films are moved from the radiology department to the operating theatre or the clinical ward. However, even if a hardcopy is "only" calibrated for average viewing conditions, this is still a significant step forward from the current state where no consistency at all is the normal case and not the exception.

The calibration of softcopy displays requires that the monitors are carefully adjusted first and measured under stable conditions (e. g. full operating temperature). One particular problem with standard "consumer quality" monitors is the fact that the brightness and contrast settings, which affect the calibration, can be easily changed because the control is usually located on the front side of the monitor and cannot be locked. There is also a number of other factors which affect image display quality on softcopy displays that are outside the scope of the DICOM GSDF, such as spatial resolution, image geometry, image stability, artifacts and color temperature. However, there are other standards such as the German DIN standard on acceptance testing of image display devices [9] which address these issues.

Finally, image consistency by means of calibration requires organizational measures. Responsibilities for the calibration procedure need to be assigned and the intervals for the calibration must be defined (the vendors' recommendations on how often a calibration should be performed vary significantly). Test patterns allowing to easily check whether the display "looks right" (e. g. whether the 5% and 95% steps in the SMPTE pattern are visible) should be available to the medical users, for example as a screen saver or as part of the login dialog. This also implies that users need to be trained what to look for (on the test patterns) and what to avoid (changing the monitor's contrast and brightness).

The software developed for the RSNA infoRAD 1999 demonstration shows that DICOM Presentation States can be integrated with an image viewer application in a way that does not require the user to know the details about the underlying concepts. For the user, Presentation States only manifest themselves as the possibility to store, retrieve and select not only images but also "snapshots" of the viewer settings defining how the image is displayed. Implementing this "added value" for the user, however, is everything but easy because the Presentation State definition contains many details that need to be addressed. In order to prevent partial implementations of the standard from defeating the concept of exchanging the visual presentation of an image between different viewers, DICOM requires that all mandatory parts of a Presentation State (which means most parts) must be supported by a "Presentation State aware" viewer if it chooses to accept a Presentation State at all:

> *A display device acting as an SCP of this SOP Class shall make all mandatory presentation attributes available for application to the referenced images at the discretion of the display device user, for all Image Storage SOP Classes defined in the Conformance Statement for which the Grayscale Softcopy Presentation State Storage SOP Class is supported.* [3]

Another complication is caused by the fact that the linkage between image and Presentation State is only contained in the Presentation State object and not in the image. This means that, in order to find out which Presentation States are available for a particular image, a viewer must search and download all Presentation States that are part of the same study. Finally, there are a number of limitations in the current Presentation State object which need to be addressed by further extensions of the standard: Presentation States do not provide information about how to display cine-based multi-frame images (e. g. angiography) and they do not support color images. There is also no support yet for hanging protocols (i. e. screen layouts). These features might be defined in a future "Advanced Presentation State" object, but are not yet available. Finally, Presentation States, or the graphical annotations contained in them, are not associated with any semantics. This means that it is possible to draw the graphical representation of a scale into a Presentation State as the result of a on-screen measurement, but it is not possible to store the information that the lines and characters comprising this graphical element define a measurement. It is also not possible to mark a number of frames from a series as "key frames". Such features will be available with the advent of DICOM Structured Reporting (SR), and a tight integration of SR with Presentation States is, therefore, more than desirable.

7. CONCLUSION

The DICOM Grayscale Standard Display Function defines a standard for the calibration of softcopy and hardcopy display devices. It allows to implement a consistent image display over a wide variety of display devices with different characteristics. The GSDF can be implemented in hardware or – also rather efficiently – in software. It only requires the use of a photometer (for monitors) or densitometer (for printers) to measure the characteristic curve of the display device during calibration. Calibrating a display device cannot improve its physical properties but makes sure that the available contrast range is used in an optimal manner. Moreover, the continuous control over the device's life-time allows to detect and potentially compensate for failures or degradation of the display quality early in time. A regular check of all output devices is a critical part of the quality control in clinical environments. It should be noted, however, that the DICOM GSDF is only applicable to the display of monochrome images and cannot be used for a color calibration as it might be required in pathology or dermatology. At the time being the DICOM standard does not include or recommend a procedure for color calibration.

The possibility to store and distribute the presentation of an image including annotations between softcopy devices from different vendors in a standard manner is new to the PACS world. The same applies to the possibility to offer multiple alternative views of the same image (by means of multiple Presentation States). The well-defined image processing pipeline paves the way for a consistent image display on calibrated monitors in conjunction with the DICOM Grayscale Standard Display Function. Several application fields for Presentation States come to mind, for example:

- Documentation of softcopy reading: When images are read from plain film, the film itself precisely documents on which information the radiologist based the diagnosis. However, digital images can be viewed in different ways, e. g. with different window level and width, magnification factor, etc. Presentation States allow to accurately document the diagnostic process in a softcopy environment.
- Image transfer to clinical departments: Presentation States permit to make sure that images are sent out to the clinical departments with reasonable viewing defaults (window level and width adjusted, image orientation corrected etc.) Annotations allow to point out important details on an image.
- Teleradiology: Since Presentation States are very small, they are well suited for teleradiology applications in which images are transferred in advance and only Presentation States (e. g. together with reports) are exchanged online.

The current definition of Presentation States is still relatively basic. Nevertheless, based on our feedback during the RSNA, Presentation States seem to be a useful extension of the set of DICOM services. It will be interesting to see at which time frame they will start to be supported in commercial products.

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