DICOM Correction Proposal

STATUS	Final Text
Date of Last Update	2013/08/08
Person Assigned	Ulrich Busch (ulrich.busch@varian.com)
Submitter Name	Christof Schadt (christof.schadt@brainlab.com)
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Correction Number CP-1289
Log Summary: Note on transitivity of registrations
Name of Standard PS 3 2011
Rationale for Correction: Utilizing Spatial Registrations in combination with a Well-Known Frame of Reference that is not patient-centric, but device-centric, may lead to an error when transforming coordinates from one coordinate system to another via the Well-Known FOR. The proposal is to add a note to the section dealing with the use of transformation to inform the user that the transitivity that is mathematically possible may be questioned in case a Well-Known Frame of Reference is used that has a device-centric semantic, e.g. a head-frame, treatment device isocenter or a surgical registration clamp. Applications performing patient coordinate transformations via a Well-Known FOR shall handle this operation with great care.
Correction Wording: <include proposed change below, following guidelines for formatting of changes in supplements>

Add to PS3.3, Chapter C.20.2.1.1

C.20.2.1.1 Frame of Reference Transformation Matrix

The Frame of Reference Transformation Matrix (3006,00C6) ${}^{A}M_{B}$ describes how to transform a point $({}^{B}x, {}^{B}y, {}^{B}z)$ with respect to RCS_B into $({}^{A}x, {}^{A}y, {}^{A}z)$ with respect to RCS_A according to the equation below.

$$\begin{bmatrix} {}^{A}x \\ {}^{A}y \\ {}^{A}z \\ 1 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & T_x \\ M_{21} & M_{22} & M_{23} & T_y \\ M_{31} & M_{32} & M_{33} & T_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} {}^{B}x \\ {}^{B}y \\ {}^{B}z \\ 1 \end{bmatrix}$$

The Matrix Registration is expressible as multiple matrices, each in a separate item of the Matrix Sequence (0070,030A). The equation below specifies the order of the matrix multiplication where $\mathbf{M_1}$, $\mathbf{M_2}$ and $\mathbf{M_3}$ are the first, second and third items in the sequence.

$$\begin{bmatrix} x' & y' & z' & 1 \end{bmatrix}^T = \mathbf{M}_3\left(\mathbf{M}_2\left(\mathbf{M}_1\begin{bmatrix} x & y & z & 1 \end{bmatrix}^T\right)\right)$$

$$\text{where } \begin{bmatrix} x & y & z & 1 \end{bmatrix}^T = \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Registration often involves two or more RCS, each with a corresponding Frame of Reference Transformation Matrix. For example, another Frame of Reference Transformation Matrix ${}^{A}M_{C}$ can describe how to transform a point (${}^{C}x,{}^{C}y,{}^{C}z$) with respect to RCS_C into (${}^{A}x,{}^{A}y,{}^{A}z$) with respect to RCS_A. It is straightforward to find the Frame of Reference Transformation Matrix ${}^{B}M_{C}$ that describes how to transform the point (${}^{C}x,{}^{C}y,{}^{C}z$) with respect to RCS_C into the point (${}^{B}x,{}^{B}y,{}^{B}z$) with respect to RCS_B. The solution is to invert ${}^{A}M_{B}$ and multiply by ${}^{A}M_{C}$, as shown below:

$$\begin{bmatrix} {}^{B}x \\ {}^{B}y \\ {}^{B}z \\ 1 \end{bmatrix} = ({}^{A}\mathbf{M}_{B})^{-1} * {}^{A}\mathbf{M}_{C} \begin{bmatrix} {}^{C}x \\ {}^{C}y \\ {}^{C}z \\ 1 \end{bmatrix}$$

If two or more transformation matrices describe the relation between Patient coordinates and a device-centric Well-known Frame of Reference, any calculations assuming transitivity via the Well-known Frame of Reference must be performed with great care to assure that both registrations reflect the same positioning of the patient with respect to the common Well-known Frame of Reference.