A Practical Approach to Store DICOM-conform Presentations of Radiological Images

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ABSTRACT

Engrane is a system which is used to prepare and show presentations of radiological images as well as the reports which belong to these images. The presentations with Engrane will be performed by displaying DICOM (digital imaging and communication in medicine)[1] images and an interpretation of the images presented as text. A database is used to manage DICOM-objects like images and reports. Images are transferred using the DICOM protocol enhanced by TLS (transport layer security)[2] protocol. Correlating images and reports is necessary as well as a log mechanism which is used to reconstruct a presentation. The correlation and the log mechanism lead to SR (structured reporting). An order is needed for sequences of elements. A new supplement called "hanging protocol"[3] define arrangements of elements. It has to be examined if SR or "hanging protocol" is sufficient in order to store presentation files of radiological images. Neither SR nor "hanging protocols" fulfil all requirements.

Engrane was developed in order to improve the presentation and the communication of radiological images. An appropriate standard to store those presentations has to be defined. Therefore, we suppose a combination of hanging protocols and SR in order to meet technical and organizational requirements.

Keywords: DICOM, presentation, image management, hanging protocols, security.

1. INTRODUCTION

Currently, we are developing a system called Engrane. Engrane is a system which can be used to prepare and show presentations of radiological images, as well as reports which belong to these images. The presentations of Engrane consist of DICOM images and interpretations of the images represented as text. The Engrane system itself consists of three modules: a primary module to prepare the presentation, a module for actual presentation and a third module to organize the presentations. Additionally, a database is used to manage patient information data which is part of the DICOM images being presented. Several operations can be performed on the images during preparation and presentation, such as windowing and annotation. It is also possible to realize slideshows of series of images. Java is used to develop the user interface of Engrane in order to obtain a system independent interface. Methods for processing image data are written in programming language C in order to increase processing large amounts of data. Engrane retrieves images via using the DICOM protocol. To increase the performance of the image management, an algorithm of adaptive compression may be used. The system needs a practical approach in order to store DICOM conform presentations of radiological images.

1.1 PRESENTATION OF THE SYSTEM

The Engrane system integrates a DICOM-server and a user interface of different programming languages. Engrane displays patient data in accordance to DICOM Patient, Study, Series, Image object hierarchy. Important values of attributes for each level are listed. At the series level it is possible to choose two series and compare them. This feature is important to compare series of patient images that are made at different times. Image operations integrated at series level and image level are rotation, zooming, flipping, annotation, adjustment of brightness, and contrast, and windowing. The second module is developed in order to manage presentations and to arrange them into a calendar via drag and drop as shown in Fig.1. Every presentation is presented as an icon containing the patient's name and date of birth. The third module contains the presentation service. The presentation can be started simply by a click on the corresponding icon. Afterwards, a walk through the presentation can be realized simply by pressing a button.

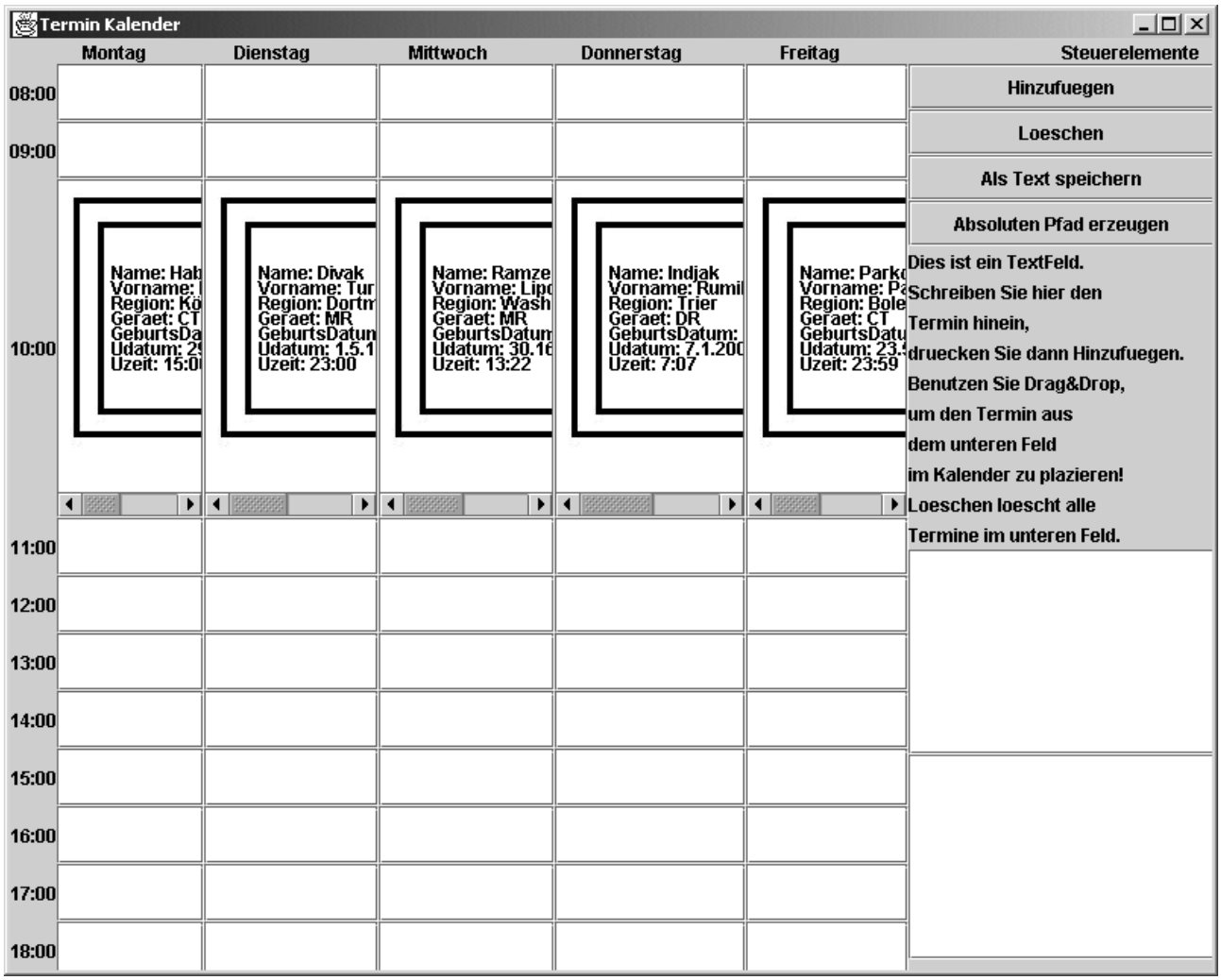

Fig.1: A calendar for managing presentations

1.2 INCREASING PERFORMANCE BY USING BEST FEATURES OF TWO PROGRAMMING LANGUAGES

The JNI (Java Native Interface) is included in the standard JDK (Java Development Kit), and allows interaction between native code and Java objects. The main advantage is the possibility to implement time-critical processes in a low-level programming-language, without renouncing the easy-to-do GUI-Development and the broad class library of Java. After setting up this development environment, the development of a Java application with JNI functionality (here, native language is C) takes several steps. First step is the implementation of a Java-Application with an interface to the desired dynamic library and the second step is the JNI-method invocation. Accomplishing these steps, you will have to consider, that the JNI maps data types to special JNI-data types when interacting between the VM (Virtual Machine) and the native method. While this procedure is not critical using primitive data types, the usage of arrays might lead into problems. Returning an array from C to Java, requires a duplication of the whole array, which might result in a lack of performance for your application. But there is a much more effective way of returning C-arrays to Java. First you need to hand a JNI-array of identical size and type to the C-routine. Within the C-routine, you copy the head of this array, which contains lengths and structure information, to a new C-array. Casting the pointer to the C-Array to a JNI-Array-pointer and returning this pointer to the invoking Java object before termination of the JNI-

method, completes the process. This approach is applied in order to transfer image data between Java and C within Engrane.

1.3 EASE THE USER INTERFACE

For managing presentation files Engrane uses drag and drop (Fig. 1). The package Swing from Java 1.3 gives the opportunity to implement this feature as a part of Java programs. The Idea was to implement a date book. The user should be able to fill in dates, to move them and to delete them. For the integration of drag and drop into Engrane were used some ready-made classes that have been expanded. Displayed objects were constructed by using predefined elements and patient related information which is retrieved from DICOM image documents.

2. REQUEST FOR A PRESENTATION SYSTEM

One major task in every day's work is the transfer of knowledge into text, pictures or alternative types of communication. The method knowledge is presented must be comprehensible for an audience who are not familiar with this kind of specific knowledge. However they need this knowledge as a part of the work they have to perform. The easiest way to communicate and transfer knowledge can realized by using images, gestures and words. The communication of knowledge is therefore usually performed as a presentation containing text and/or images in order to explain a solution or a result. In order to explain the images, the presenter uses his or her hands, a laser pointer or a stick to focus attention on special features of the image. Meanwhile, the image is explained using 'spoken word'. If the audience has questions relating to the presentation, there might be the possibility to ask questions. For other kinds of presentations it is very important to understand the presentation's tenor immediately. Additionally, there is less time to pose questions. Such a type of presentation, which can be used in meetings between radiologists and other members of medical staff in a hospital or other medical institution will be discussed below.

Regarding the procedure of knowledge transfer between the scope of radiology and other fields of application in healthcare, results in the problem how to represent the interpretation of radiological images. The way of representation must be clear and plain.

In cases of emergency, there is no spare time to discuss results of the interpretations of radiological images. Reports are written in a hurry. In many cases, images are added to a report but without a little knowledge in radiology it is hard, i.e. time consuming, to relate the reports to the images. Therefore, these presentations are performed in order to avoid difficulties resulting from report-image-association. The presentations are performed in a special room. An alternator serves as a helping tool to show the images in a convenient order. The radiologist explains the findings of an image and after finishing the comment he proceeds further on to the next case. Nowadays, this traditional form of presentation can be replaced by computers, used to facilitate the interpretation of radiological images. The computer is connected to a beamer in order to display the image on a silver screen. The management and transfer of images are done by using the standard of DICOM.

The internet offers a wide choice of free-, share- and commercial software of DICOM applications. Most of the applications are DICOM viewers to display and manage images. A simple way to develop a presentation system is to get such a DICOM viewer, install it on a computer (e.g. notebook) and copy the images for presentation on the computer's hard disc. However, after careful consideration of all features of the offered viewers it is quite obvious, that these viewers are not suitable for every kind of presentation. A further problem is the way of organizing and preparing presentations.

3. TAKE CARE WITH COMPLEXITY OF DICOM

The use of computers in medical imaging and the development of applications that process images, which have been produced by imaging devices, creates the problem of how to exchange images with related patient data between devices of different manufacturers. A common interface has to be specified for the devices and applications. This interface, called DICOM, makes it possible to connect devices, PACS and databases that contain diagnostic data. The DICOM-standard is accepted and used by many manufacturers.

The status of the standard is represented by the core. This core consists of parts which specify the required elements needed to develop and to understand a DICOM-conform application. The required elements are: the definitions of attributes, the representation of these attributes, the transfer of a set of attributes and the storing of these attributes in a file. A statement declaring which attributes defined in the DICOM-standard have been used and how they are being represented, as well as additionally defined attributes that do not occur in the DICOM-standard, has to be written. The statement is important for a user who wants to buy a DICOM application or hardware with a DICOM interface. The statement may serves as information about the interoperability of two DICOM interfaces. Interoperability may not be guaranteed if the statement is vague, incomplete, not precise or incorrect. Developers of DICOM-conform applications, as well as manufacturers of DICOM-conform devices, must be sure to describe the features of their products thoroughly in order to increase the interoperability and acceptance of products that conform to the DICOM-standard.

The core of the DICOM-standard may be extended by correction-proposals or supplements. The evolution of DICOM is achieved by the integration of accepted supplements that have reached a final status and by the acceptance of correction proposals.

An SOP is a combination of a set of modules representing a DICOM document, called 'Information Object Definition' (IOD) and a service that allows to work on the attributes of the modules and therefore, on the IOD. Operations that move data from one point to another are an example of such a service.

4. DICOM CONFORMS RADIOLOGICAL REPORTS

The DICOM-standard was enhanced by a supplement called Structured Reporting (SR). This supplement is now part of the core. The SR defines a way to produce medical reports of radiological image interpretations. In practice, the production of a report is achieved by using a dictaphone. The report recorded on tape is transcribed by a secretary. The secretary shows the transcribed report to the physician who recorded the tape. The physician verifies the report and signs it. To reduce the amount of text, the physician uses a medical code. The code is often a standard-code like logical observation identifier names and codes (LOINC) or systemized nomenclature of human medicine (SNOMED). Additionally, private codes of physicians who want their code to be understood only by themselves or by a group of people they trust is also used. The supplement SR uses the supplements for coding medical data which are integrated in the core now in a pre-defined scheme. In the definition of SR, there are three pre-defined kinds of reports. The basic-text, the enhanced, and the comprehensive Information Object Definition (IOD).

The structure of a SR report is complex [4, 5]. This structure is represented in DICOM as an IOD. In [1], there are three definitions for a report IOD. These three definitions will be described in the following. The simplest definition is the SR-Basic-Text-IOD. This definition possesses the features of reference images and other reports. The structure of a report in this definition consists of the following elements: a document content that contains information about the examiner, as well as information pertaining to the time the report was created and why the report was created. Medical Codes may be integrated. An observation context may be integrated by using relationships between predefined classes defined for the creation of a report.

The SR-enhanced-IOD provides additional classes like coordinates to reference an area in an image. The coding scheme defined for these three IOD is the SNOMED DICOM micro glossary (SDM). This coding scheme is a medical coding scheme that assigns medical code words to their descriptions.

The comprehensive IOD allows the specification of relationships by reference instead of using values like in the other two IODs.

There are some implementations of SR which use SR to relate text to images. Currently, SR is regarded as very complex. The complexity can let applications run into difficulties when interpreting SRs because too many variations of ways to construct a report exist.

Nevertheless, we decided to use SR because it provides the best way to relate images and reports. In order to reduce the complexity and resulting problems and due to our aim of constructing a presentation, we chose not to use medical coding schemes.

5. DICOM DEFINES HANGING PROTOCOLS

The “Hanging Protocol” contains information about physician viewing preferences, related to display capabilities. The goal is for physicians to be able to conveniently define their preferred methods of presentation and interaction for different types of viewing circumstances once, and then to have image sets automatically hung according to the user’s preferences on display systems of similar capability. The main expectation is to facilitate the automatic and consistent hanging of images according to definitions provided by the physicians, sites or vendors of the display systems.

Specifically,

- save defined hanging protocols, and search for them by id (username, site, manufacturer), exam type, and display characteristics.

- allow automatic hanging of primary and comparison image sets to occur for all exams on defined displays, or similar displays by matching against user or site defined hanging protocols. This includes supporting automatic hanging when the user reads from different locations, or on different but similar display types. Allow shared use of hanging protocols to facilitate consulting on shared tele-reads (i.e., two physicians reviewing the same case from remote locations).

Further, it is anticipated that vendors will make it easy for users to point to a graphical representation of what they want (like 4x1 versus 12x1 format with a horizontal alternator scroll mechanism) and select what they want. Obtaining the images for comparison image sets is outside the scope of the Hanging Protocol IOD, and left up to vendor specific implementation. The following services are considered to be beyond the scope of the Hanging Protocol IOD and SOP Classes:

- the services required to retrieve the information (e.g., image sets) that is to be presented by an instance of a Hanging Protocol IOD.

6. HANGING PROTOCOLS USES PRESENTATION STATES

Softcopy Presentation states are used to store viewing preferences. A workstation that supports this service memorizes how the image was viewed initially, stores this in a "Softcopy Presentation State" object and is able to send image with this information to other devices that support the interpretation of this DICOM object. The receiving device interprets the Presentation State and knows exactly how to recreate the initial image appearance. Presentation States makes use of the Grayscale Standard Display Function, which defines how displays can present images in a consistent manner. This consistency is achieved by defining how the input values to the display should be converted into the luminance values, measured at the screen surface. If the two displays at the earlier scenario both support this Grayscale Function, their presentation in luminance would be defined, and identical. According to hanging protocols presentation states are either referenced or inserted values.

6.1 EXAMPLE SCENARIO ADAPTED TO ENGRANE

A Physician sits down at workstation and brings up a chest CT study. He reads his first case. The workstation queries the DICOM server. It finds nothing for this specific user, but matches a site default, which was setup when the workstation was installed at the site. It uses the site default, and the physician reads the case. He decides to customize and configure the application. He tells the application to save this hanging protocol for him, which causes the DICOM HP IOD defining his preferences to be stored to the DICOM server. He has chosen to define a 2 columns by 1 rows tiled presentation (Fig. 2) with a “vertical alternator” interaction, and a default scroll amount of one row of images. In this case the best match returned is with the userid matching his userid, the study type matched to the study type of the image set he is bringing up for viewing, and the display type matching the display system he’s using now. A list of matches is produced, with the defined HP IOD the user defined yesterday for chest CT matching the best, and the study is automatically brought up on the monitor with that hanging protocol. Alternative next best matches are available to him via the application interface’s pull-down menu list of all closely matching hanging protocols. Also, because this hanging protocol defines a comparison image set, the year prior chest CT for the same patient is automatically displayed next to the current image set on the right monitor. The next week, the same radiologist reads chest CT at the Ambulatory Care Center one mile away on a similar type workstation, workstation Y, from a different vendor.

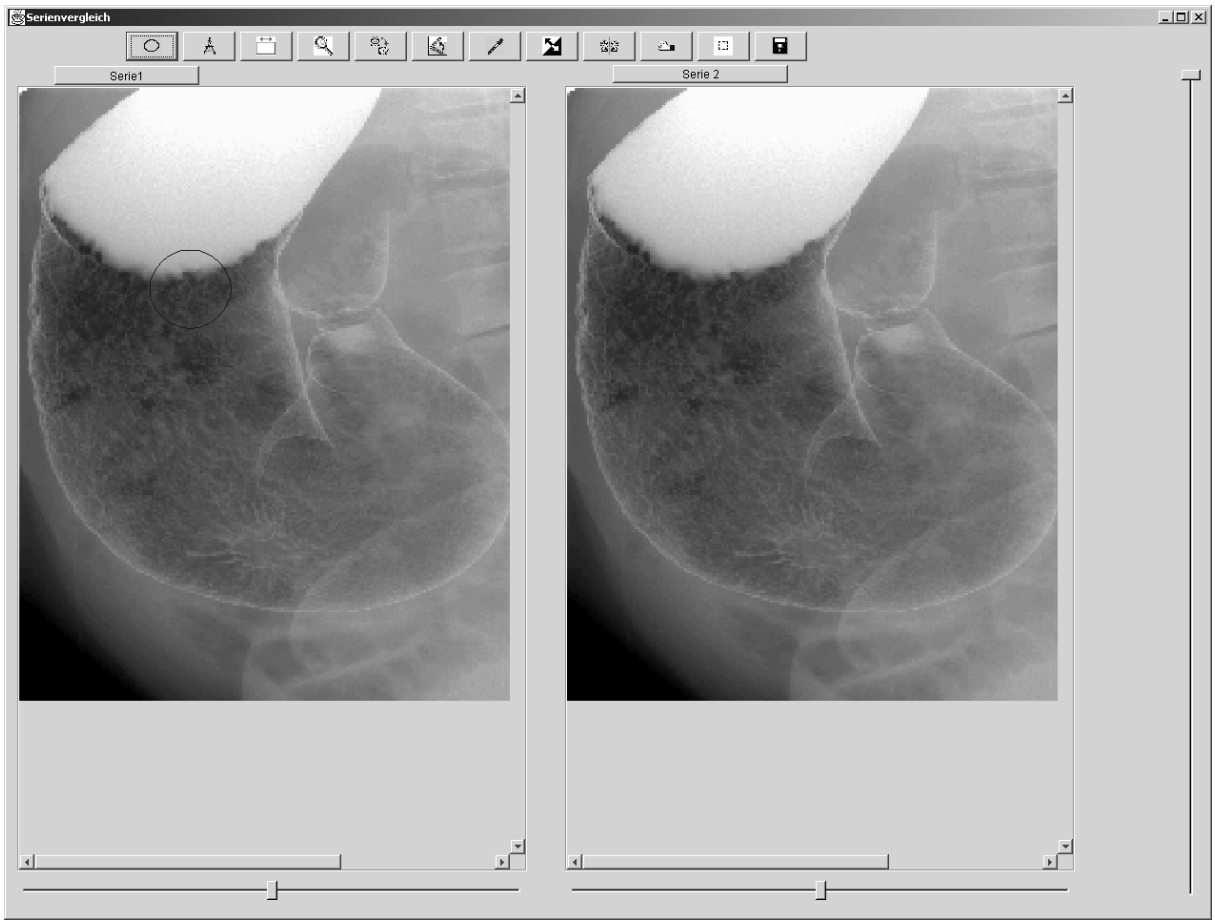

Fig. 2: Example for comparing two series of images by indicating areas of interest

7. EXAMINATION OF SR AND HP

We examined if the usage of DICOM SR (structured reporting) or a new supplement called “hanging protocol” are useful storage tools in the discussion of radiological images. SR defines a way to generate medical reports like radiological image interpretations. To produce a slide show of radiological images a SR log mechanism can be used. This SR log mechanism can be practically used for the presentation of radiological images and image series. But there is no definition in SR to ensure the order how images are selected during their loading and displaying. SR is a perfect solution for storage and exact retrieval of stored reports. Additionally, SR saves space on storage devices by referencing images and other objects, thus data redundancy can be avoided.

The SR log mechanism is practical to be used for a presentation of radiological images. But, there is no definition in SR to ensure that the order in which the images are selected is regarded during loading and displaying of images. In contrast, the hanging protocol contains information about physician viewing preferences, related to display capabilities. The goal for physicians is to be able to conveniently define their preferred methods of presentation and interaction for different types of viewing circumstances. Image sets automatically hung according to the user’s preferences on display systems of similar capability. Therefore the hanging protocol definition suppose to use the definition of “softcopy presentation state” and “grayscale standard display function” to realize the configuration. In case of presenting results SR is a better choice, because it defines the relationship between several multimedia elements, e. g. text and image whereas the hanging protocol defines the order of these elements. Presentation states also allow those specifications but the elements specified in presentation states are integrated into an presentation object and therefore there is a lost of flexibility. SR does not specify that an element has to be a DICOM-object. Elements can be somewhere in the internet.

Engrane is intended for creating presentations. Presentations are multimedia documents which have ordered elements. All elements referenced by a document needn’t to be a DICOM object. Therefore, the module “UIDREF” of SR is important for DICOM-document files of Engrane. SR-Concepts has to be defined in order to retrieve such files, containing the information about the location of the files.

8. INTEGRATION OF DERIVED SPECIFICATION INTO THE APPLICATION

We want to derive a definition that fulfils the requirements for the Engrane application. Important features for the specification are:

- the order of images, the series of images and objects which will be linked to the images, i. e.:
    - links between images
    - links between images and text or audio files
    - links between images, series, and annotations
- measurements
- image orientation
- image colour is inverted or not
- security:
    - text is encrypted or not
    - image is encrypted or not
    - encryption algorithm to be used

    - user access

- compression is used for images or not.

Engrane uses SR in combination with the hanging protocol in order to store the presentations in files. The SR and hanging protocols are stored separately to ensure compatibility to systems that are not capable to process hanging protocols.

9. CONCLUSION

Engrane was developed in order to improve the presentation of radiological images and the communication of these images. A convenient standard to store those presentations has to be defined. We suppose a combination of hanging protocols and SR in order to meet technical and organizational requirements. The implementation of Engrane will currently be provided with a subset of hanging protocols. In order to conform to the definition of hanging protocols we exclude presentation states and store these HP instances separately from structured report instances.

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