Disease Specific Intelligent Pre-fetch and Hanging Protocol for Diagnostic Neuroradiology Workstations

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Clinical data sets for neuroradiological cases can be quite large. A typical brain tumor patient at UCLA will undergo 8-10 separate studies over a 2 year period, each study will produce 60-100 magnetic resonance (MR) images. Gathering and sorting through a patient’s imaging events during the course of treatment can be both overwhelming and time consuming. The purpose of this research is to develop an intelligent pre-fetch and hanging protocol that automatically gathers the relevant prior examinations from a picture archiving, and communication systems (PACS) archive and sends the pertinent historical images to the diagnostic display station where the new examination is subsequently read out. The intelligent hanging protocol describes the type of layout and sequence for image display. We have developed a classification scheme to organize the pertinent patient information to selectively pre-fetch and intelligently present the images to review brain tumor cases for a diagnostic neuroradiology workstation.

Introduction
Previous research by Arenson et al. stressed the importance of data management concepts such as autorouting and pre-fetching, which add intelligence to PACS [1-2]. Autorouting sends patient’s examinations to the correct workstation for interpretation and review. Pre-fetching is the ability to retrieve relevant prior examinations from the archive on a patient scheduled for a new examination. The function of a diagnostic workstation is to access, organize and manipulate large volumes of clinical data. Typically, PACS workstations have not lived up to radiologist’s expectations due to poorly defined interfaces, a lack of data integration and insufficient understanding by the designers of the goals and process by which a radiologist work [3]. Once the image data has been retrieved from the PACS archive, the viewing layout and order by which the radiologist reviews multiple image series on the workstation is critical to efficient and accurate read-out. Valentino et al recognized the complexity in pre-fetching previous exams and developed a methodology for designing and implementing intelligent hanging protocols for neuroradiology [3-5].

Materials and Methods
The underlying data model for the intelligent pre-fetch and hanging protocol was based on DICOM version 3.0 from National Electrical Manufacturers Association (NEMA) [6]. The DICOM standard was chosen because medical imaging modality and PACS vendors have adopted the standard as a path toward integration of data between their respective systems. The DICOM standard is divided into a communications component and a data structure component. The classification scheme that we use is based on the data structure component, which defines a hierarchy for the collection of patient information (see figure 1). The hierarchy classifies the patient information into sub-modules that compartmentalize the patient’s information. Figure 1 describes the relationship between the various modules. An individual patient can have 1..n, number of studies or examinations. Each study can be further subdivided into 1..n, number of series that define the frame of reference for the location of the imaging procedure. Finally within each series, there are 1..n, number of images. Each module contains fields that describe pertinent information concerning the patient and the conditions under which the examination takes place. Table 1. displays our definition of each individual module that was subsequently used to define the individual database tables for our PACS image database. The relational database we used was Postgres version 7.0.3. In addition to the DICOM information, data from the hospital information system (HIS) and radiology
information system (RIS) was used to identify particular studies. From HIS, we obtained the physicians’ current procedural terminology (CPT) codes that were used to schedule a particular imaging procedure [7]. A MR brain scan is classified by one of four unique CPT codes shown in Table 2. The CPT code for a particular study is stored in the study module.

![Diagram](image)

Figure 1. Dicom Data Model

From the RIS report the radiologist determines the status of the disease by a numeric code. The numeric coding scheme is based on the International Classification of Diseases, 9th Revision (ICD-9) code indicating the disease state [8]. The respective ICD-9 codes are then stored in the database within the study module.

The final component in our classification scheme is the magnetic resonance (MR) imaging module from the DICOM standard (see Table 3). The MR module provides the details necessary to determine the pertinent image parameters that allow comparison with images from previous studies.

Based on the information in the MR module, the identification of key classification parameters is possible. MR acquisition type determines if the scan was a 2D or 3D acquisition. Scanning sequence provides information on the type of pulse sequences used during the scan. Typical pulse sequences include: Spin Echo (SE),

![Table 1](image)

Table 1. Module field definitions.

![Table 2](image)

Table 2. CPT code for MR Brain Imaging.

Inversion Recovery (IR), and Echo Planar (EP). The acquisition parameters describing echo time (TE), repetition time (TR), and flip angle

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(6), diffusion gradients, and magnetization transfer pulses determine the type of contrast characteristics within the image (T1, T2, diffusion contrast or magnetization transfer). The series description field within the series module provides information about the orientation of the image acquisition. Typical values found in the series description field include: axial, coronal, sagittal, and oblique.

By combining the parameters defined previously, we can then classify the image series and update the appropriate series description within the series module. Figure 2 is a depiction of the DICOM classification scheme [3].

From our discussions and observations of the radiologists, we have determined a workflow for the basic tasks that a radiologist performs when reading out a case [4,5]:

1. Browse the patient worklist for unread cases.
2. Select current patient exams for review.
3. Review pertinent medical records: lab reports (HIS), pathology reports (HIS), medical history (HIS), previous radiology reports (RIS).
4. Select within current patient previous exams for review based on information from medical records. (pre-fetch)
5. Read current and pertinent previous images (hanging protocol)
6. Dictate radiology report with findings
7. Consult with referring physician concerning the status of the patient.

HIS – Hospital Information System
RIS – Radiology Information System

Table 3. MR module Data Elements

The process of performing the pre-fetch reduces the time that neuroradiologists spend in obtaining the images for readout. Presently, the only information available to a neuroradiologist when performing a primary readout is the CPT code that was used to classify the scheduled examination and the image data after completion of the examination. Based on some simple rules, we pre-fetch previous images by querying the PACS database for previous exams with similar CPT codes. The CPT codes are very general and do not allow the pre-fetch to be very selective.

The referring physician will generate an ICD-9 code(s) for the patient symptom(s) (i.e. headache – ICD-9 code 784.0). Since the radiologist does not know the ICD-9 code(s) for the current images without finishing the read out, RIS reports from previous exams along with a patient history can provide some information in order to deduce the previous ICD-9 code. Based on the ICD-9 code(s) images can be selectively filtered out.

The third component in the pre-fetch scheme allows the user to further filter the data set by pre-fetching the study based on DICOM attribute information. For instance, the DICOM header contains descriptive fields: modality, study description, body part examined, and series description.

We have developed an intelligent hanging protocol to aid the radiologist in making an accurate diagnosis of the patient. We allow side-by-side comparisons of images from different studies or within the same study for the same modality. The user has full control over each individual image for basic image processing functions such as: rotation, scale, pan, window and level, and cine mode. The individual images involved in the comparison can be linked so that the image processing operations can be simultaneously applied to both images.

Our image classification scheme forms the basis for specifying the hanging protocols. Hanging protocols are defined by domain experts (radiologists) for each study and are disease specific. Some default hanging protocols are also defined based on the acquisition parameters and are applicable to all disease categories. Listed below are examples of these display protocols for within study comparisons [3]:

1. Comparison scans of pre- and post-contrast T1 images.
2. Comparison scans of images with and without magnetization transfer.
3. Comparison scans of T2-weighted images and diffusion maps.

The intelligent hanging protocols are also defined for comparing current and prior studies. In this format, the intelligent pre-fetch tries to match an imaging sequence from a current study with the same (or similar) sequence from a prior study. Alternate sequence options are listed with the preferred sequence. For example, given the current image series that has been classified as "2D Axial T1 SE" (current exam), these images would be shown within the right image frame and the comparison image series "2D Axial T1 SE" (previous related exam) would be shown in the left image frame (see figure 3). In the example shown, the brain tumor in the left hemisphere has grown in size. The user could then select the next image series to compare with the most current image series "3D Axial T1 GE", or "2D Axial T1 GE", or finally "2D Axial T2 FSE".

Figure 2. Example of DICOM classification scheme.

Figure 3. Display of the most current image on the right and previous exam on the left after DICOM classification and application of hanging protocol.

Image series (current study on the right)
- 2D Axial T1 SE

Image series (comparison study on the left - descending order of selection)
1. 2D Axial, T1, SE (primary)
2. 3D Axial, T1, GE (secondary)
3. 2D Axial, T1, GE (tertiary)
4. 2D Axial, T2, FSE (quartic)

Conclusion
We have developed a new classification scheme based on HIS (CPT codes), RIS (ICD-9 classification) and DICOM information. This classification scheme provides the intelligence for the PACS system to pre-fetch images based on the procedure, disease type and DICOM attributes. The intelligent hanging protocol is tailored to view the data set allowing the neuroradiologist to access the tumor condition of the patient based on the DICOM attributes and expert rules tailored for viewing the image series.

We are in early development in finishing the classification module to perform more
sophisticated comparisons and have developed a questionnaire to determine the effectiveness of our pre-fetch and intelligent hanging protocol compared to a conventional PACS workstation. Our classification scheme lays the foundation for future outcome studies on a particular type of patient procedure, specific type of disease and/or imaging parameters.

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References


