SESSION 2B: Evaluation of System Components

Relevant Priors Prefetching Algorithm Performance for a Picture Archiving and Communication System

Katherine P. Andriole, David E. Avrin, Lloyd Yin, Robert G. Gould, David M. Luth,
and Ronald L. Arenson

Proper prefetching of relevant prior examinations from a picture archiving and communication system (PACS) archive, when a patient is scheduled for a new imaging study, and sending the historic images to the display station where the new examination is expected to be routed and subsequently read out, can greatly facilitate interpretation and review, as well as enhance radiology departmental workflow and PACS performance. In practice, it has proven extremely difficult to implement an automatic prefetch as successful as the experienced fileroom clerk. An algorithm based on defined metagroup categories for examination type mnemonics has been designed and implemented as one possible solution to the prefetch problem. The metagroups such as gastrointestinal (GI) tract, abdomen, chest, etc, can represent, in a small number of categories, the several hundreds of examination types performed by a typical radiology department. These metagroups can be defined in a table of examination mnemonics that maps a particular mnemonic to a metagroup or groups, and vice versa. This table is used to effect the prefetch rules of relevance. A given examination may relate to several prefetch categories, and preferences are easily configurable for a particular site. The prefetch algorithm metatable was implemented in database structured query language (SQL) using a many-to-many fetch category strategy. Algorithm performance was measured by analyzing the appropriateness of the priors fetched based on the examination type of the current study. Fetched relevant priors, missed relevant priors, fetched priors that were not relevant to the current examination, and priors not fetched that were not relevant were used to calculate sensitivity and specificity for the prefetch method. The time required for real-time requesting of priors not previously prefetched was also measured. The sensitivity of the prefetch algorithm was determined to be 98.3% and the specificity 100%. Time required for on-demand requesting of priors was 9.5 minutes on average, although this time varied based on age of the prior examination and on the time of day and database traffic. A prefetch algorithm based on metatable examination mnemonic categories can pull the most appropriate relevant priors, reduce the number of missed relevant priors, and therefore reduce the time involved for the manual task of on-demand requests of priors. Network and database traffic can be reduced as well by decreasing the number of priors selected from the archive and subsequently transmitted to the display

stations, through elimination of transactions on examinations not relevant to the current study.

Copyright © 2000 by W.B. Saunders Company

EARLIER REPORTS by Arenson et al.¹⁻³ stressed the importance of folder manager concepts such as autorouting and prefetching, which add software intelligence to a picture archiving and communication system (PACS). Autorouting is the PACS' ability to send an examination to the correct workstation(s) for interpretation and review, while prefetching is the more complex ability to retrieve relevant prior examinations from the archive on a patient scheduled for a new examination.⁴ Proper prefetching of relevant prior examinations for a patient from a PACS archive, when they are scheduled for a new imaging study, and sending the priors to the display station where the new examination is expected to be routed and subsequently read out, can greatly facilitate interpretation and review, enhancing radiology departmental workflow and overall PACS performance. In practice, it has proven extremely difficult to implement an automatic prefetch as successful as the experienced fileroom clerk or radiologist who could easily verbalize the types of examinations considered to be relevant priors for any given new examination.

A brute force method for searching a PACS database for relevant priors might be to examine a large two-dimensional matrix of examination types or examination mnemonics for a given department with the new or current examination along one axis and the priors along the other. This matrix can be large (hundreds of columns by hundreds of rows)

From the Department of Radiology, Laboratory for Radiological Informatics, University of California, San Francisco.

Address reprint requests to Katherine P. Andriole, PhD, UCSF Department of Radiology, 530 Parnassus Box 0628, San Francisco, CA 94143-0628. E-mail: Kathy.Andriole@Radiology.ucsf.edu.

Copyright © 2000 by W.B. Saunders Company

0897-1889/00/1302-1016\$10.00/0

doi:10.1053/jdim.2000.6831

and searching it for prior examination matches can be computationally intensive, inefficient and slow. A relatively recent analysis examined successful database hits for relevant priors based on two separate strategies: retrieval of a set number of historic examinations for a given patient, of any type pulled in chronological order, and retrieval of priors falling within a defined time interval.⁵ Retrieval of the previous two studies of any type resulted in an 83% likelihood of obtaining a relevant examination, while retrieval of the previous four studies of any type showed a 91% success rate for one matching examination.⁵ Retrieval of all studies performed on a given patient during the past month resulted in the prior matching study being available 80% of the time, with the last two relevant priors available in only 74% of cases.⁵

We have implemented one possible solution to the prefetch problem, designing an algorithm based on defined metagroup categories for examination type mnemonics. The metagroups such as gastrointestinal (GI) tract, abdomen, chest, etc, can represent in a small number of categories, the several hundreds of examination types performed by a typical radiology department. These metagroups can be defined in a table of examination mnemonics that maps a particular mnemonic to a metagroup or groups, and vice versa. This table is used to effect the prefetch rules of relevance. A given examination may relate to several prefetch categories, and preferences are easily configurable for a particular site.

An example prefetch metatable for the instance

of a computed tomography (CT) chest examination as the scheduled new study, with the reason for examination as "suspicion of esophageal carcinoma," would fall under the "Chest" prefetch category. Through the prefetch metatable, examination mnemonic, prefetch category, and study table links, the relevant prior examinations to be pulled, if they exist for this patient, include other CT chest examinations, chest x-ray examinations, and esophagrams.

METHODS

Our prefetch algorithm, described elsewhere,⁴ is based on defined metagroup prefetch categories for examination type mnemonics, and was implemented in database structured query language (SQL) using a many-to-many fetch category strategy, which facilitates cross-referencing and searching. Trigger events passed from the radiology information system (RIS) to the PACS, which invoke the prefetch mechanism include "exam scheduled" and "exam completed." Prefetching can occur on-demand as needed, or at a specified prefetch time (ie, 2 AM) for future scheduled examinations.

The algorithm activity log for several days was examined for 350 cases that invoked prefetching. Figure 1 shows a snapshot sample of this log. The appropriateness of the priors fetched based on examination type and the number of missed relevant priors were analyzed. Algorithm activities fell into one of the following four categories: priors fetched that are relevant or true-positives (TP), priors fetched that are not relevant or false-positives (FP), relevant priors that are not fetched or false-negatives (FN), and irrelevant priors that are not fetched or true-negatives (TN). Sensitivity (S_e) is calculated as the true positive rate where $S_e = 100\% \times TP / (TP + FN)$, and specificity (S_p) is calculated as the true negative rate where $S_p = 100\% \times TN / (TN + FP)$. In addition, the average time it takes to search at readout for a patient's relevant prior examination not appropriately prefetched, including the time required to retrieve that

```

2000:00:07:07:51:24:00000760::mrn:32128807 acc:3155322 age:0 pt_loc:ZCT

CCHES - Jan 7 2000 1:30:00:000PM
-Any MR CT CR
-Any CHEST

Exam History:
  Edt:19981013      acc:MUEXJ exm:2797494 offlin:2
  Edt:19980706      acc:CNECE exm:2717174 offlin:2
  Edt:19980706      acc:CTHAPE exm:2717170 offlin:2
  Edt:19980302      acc:CTHAPE exm:2637611 offlin:2
  Edt:19980302      acc:CNECE exm:2637610 offlin:2
  Edt:19980114      acc:MCHES exm:2558876 offlin:2
  Edt:19970926      acc:MNECK exm:2523522 offlin:2

Prefetch Candidates:
  acc:2717170 exm:CTHAPE
  -vg:vg47/32128807->local
  ->ASOS1->RS7UCSF->RS8UCSF->WEB1000->remove cache->done
  acc:2637611 exm:CTHAPE
  -vg:j2vg32->local
  ->ASOS1->RS7UCSF->RS8UCSF->WEB1000->remove cache->done
  acc:2558876 exm:MCHES
  -vg:vg47/32128807->local
  ->ASOS1->RS7UCSF->RS8UCSF->WEB1000->remove cache->done

```

Fig 1. Snapshot of the prefetch algorithm activity log.

Table 1. Prefetch Algorithm Performance Measures

Relevant priors prefetched (TP)	417		
Relevant priors not fetched (FN)	7	Sensitivity	98.3%
Irrelevant priors prefetched (FP)	0		
Irrelevant priors not fetched (TN)	834	Specificity	100%

study from the PACS archive was measured and averaged over 25 instances over several days, at different times of the day.

RESULTS AND DISCUSSION

Performance measures for our prefetch algorithm are summarized in Table 1. The sensitivity of the prefetch algorithm was determined to be 98.3% and the specificity 100%, and multiple relevant priors can be fetched. In practice, the maximum number of relevant priors prefetched in the event that multiple exist is three, with the most relevant chosen first. Time required for on-demand requesting of priors was 9.5 minutes on average, although this time varied based on age of the prior examination (with older studies taking longer to retrieve) and on time of day and database traffic, with busy times corresponding with morning and afternoon readout.

Problems encountered included handling of instances in which it is difficult to assign a prefetch category because of the limited information known about the current examination. For example, the only information that may be passed from the RIS to the prefetch algorithm could be "CT Angio" for

computed tomography angiogram, but no body part or specialty region is included. In this case, there may be existing relevant priors other than simply other CT angiograms. These examinations would most likely be missed. It is important to note that the prior studies prefetched electronically can only be those existing in the PACS, and that it is often difficult to reconcile which relevant priors on a given patient need to be pulled manually from the film fileroom. It is anticipated that this dilemma will lessen as departments transition over to fully filmless archives.

Future algorithm enhancements include adding the capability of tagging priors with pertinent positive findings or key studies (such as baseline or admission examinations) that would be included in the prior examinations to be pulled particularly when there are multiple relevant prior candidate examinations, configurability of how far back in a patient's imaging history examinations should be pulled, and refinement of the prefetch metatable.

This highly sensitive prefetch algorithm based on metatable examination mnemonic categories can pull the most appropriate relevant priors, reduce the number of missed relevant priors, and therefore reduce the time involved for the manual task of on-demand requests of priors. The high algorithm specificity suggests that network and database traffic can be reduced as well by decreasing the number of priors selected from the archive and subsequently transmitted to the display stations, through elimination of transactions on examinations not relevant to the current study.

REFERENCES

1. Arenson RL, Seshadri SB, Stevens FJ, et al: The overlapping domains and interface between radiology information systems and medical image management systems (PACS), in Lemke HU, Rhodes ML, Jaffee CC (eds): *Proceedings of Computer Assisted Radiology*. Berlin, Germany, Springer-Verlag, 1987, pp 855-865
2. Seshadri SB, Kishore S, Arenson RL: Software suite for image archiving and retrieval. *Radiographics* 12:357-363, 1992
3. Feingold, Seshadri SB, Arenson RL: Folder management on a multimodality PACS display station. *SPIE Med Imaging V: PACS Design and Evaluation*, 1991, pp 1446-1431
4. Andriole KP, Avrin DE, Yin L, et al: PACS databases and enrichment of the folder manager concept. *J Digit Imaging* 13:3-12, 2000
5. Seigel E, Reiner B: Recommendations for image prefetch or film digitization strategy based on an analysis of an historic radiology image database. *J Digit Imaging* 11:130, 1998 (suppl 1)