An Analysis of Image Request Arrival Patterns from Image Display Terminals of PACS in a Large Scale Hospital

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Key words : PACS, Digital Imaging, Simulation, Modeling

Abstract

The development of a Picture Archiving and Communication System (PACS) is a complex process. To build a high performance PACS especially for large-scale hospitals, the cost for its introduction tends to be high. However, estimation of the performance of a PACS by employing simulation during relatively early design phase can result in an efficient PACS introduction because alternative configurations and designs can be investigated easily. However, to accurately build a PACS simulation model, accurate request pattern should be obtained from image display terminals so that the request patterns of the simulation model would be equivalent to those of a real PACS. In this article, we describe a method for obtaining request patterns from terminals and describe the approximated functions of request patterns as a form of probability density function. PACS logs with the recorded image requests from all terminals in a large-scale hospital were collected for 16 months. The interval time between image requests and a histogram of this were calculated from the logs. Using the nonlinear optimization method, an exponential curve that can be approximated for the model of a terminal in a PACS simulation model was derived. Our results showed that the probability density functions derived from terminals in wards and outpatient departments differed. These results suggested that the request patterns in wards and outpatient departments should be modeled separately in a PACS simulation model.

Introduction

The Picture Archiving and Communication System (PACS) was first developed to improve image accessibility and to reduce the costs for image handling. However, due to the vast amount of image data, a major problem of the PACS is a relatively long response time at an image display terminal caused by limited storage capacity and network bandwidth. To reduce response time, several methods involving the use of a high speed network and/or a high performance disk system in the PACS server are employed. Generally, however, it is quite expensive to introduce the PACS into a large scale hospital. In addition, since a short response time might not be needed in all the terminals in a hospital, a trade-off between response time and the cost for introducing PACS is important. Therefore, to achieve maximal effectiveness with a PACS, it is necessary to estimate how much the response time at each image display terminal must be reduced.

PACS modeling and its simulation using a discrete event simulator is often used to predict PACS performance at an early design phase. Since queue models are employed in a client/server model such as PACS, an accurate arrival rate and its type of probability density function reflecting a real PACS are required for the simulation model. Although studies have been made on PACS simulation, little attention has been given to the request patterns

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from the image display terminals of a PACS[1,2].

In this study, to construct a model, we investigated the arrival pattern of image requests from image display terminals in a large-scale PACS. Our results revealed data useful for estimating the performance of a PACS in the early design phase.

Materials and Methods

A large scale PACS was constructed in Osaka University Hospital to distribute radiographic images to image display terminals in all clinics and wards. Five PACS servers, 550 image display terminals and 22 intermediate servers were connected to a local area network (LAN). Eleven computed radiography systems (CR), three computed tomography (CT) scanners, three magnetic resonance imaging (MRI) systems and other image modalities were also connected to this LAN. The total capacity of the central image server was 1 TB (tera-byte), and the digital versatile disk (DVD-RAM) library systems had 7.6 TB capacity.

The image terminals were grouped and connected to intermediate servers which were introduced to reduce the load of the central PACS server. Images that were to be requested from terminals in the outpatient departments the next day had been transmitted from central PACS server to intermediate servers the previous night from a list of patients who were scheduled to visit the hospital the next day[3].

All the records of requests from image display terminals were recorded as a log file in the intermediate servers. Log files were collected from August 7, 2001 to December 12, 2002. Field names of the collected data are shown in Table. 1.

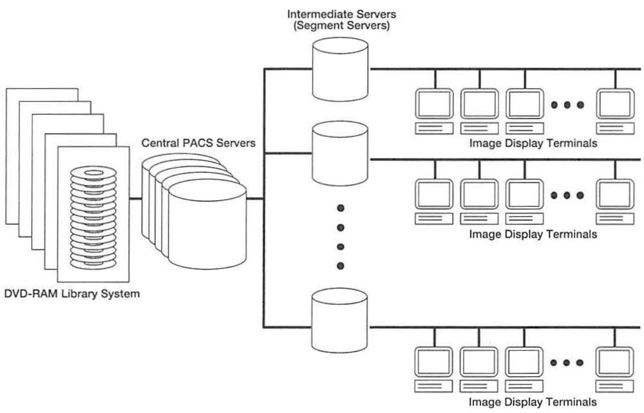

Fig. 1 A schematic design of PACS in Osaka University Hospital

All the records in the log files were entered into a database using Postgre SQL version 7.2.2 on RedHat Linux version 9. A total of PACS 323,993 log records were entered into the database. We derived the interval times of the image requests from the PACS log records using a program written in Perl version 5.

To compare the image request patterns from the terminals installed in the wards and outpatient departments, the histograms were recalculated using interval data distributed to each department, ward and outpatient department.

The Wilcoxon rank test was used to investigate whether there were statistically significant differences in the request patterns between wards and outpatient departments. $P < 0.05$ was considered to indicate a significant difference. Statistical analysis was carried out using "R" version 1.7.1 on RedHat Linux version 9. The histograms were also constructed by "R". From the histograms, we selected a similar function to the histogram and fitted the function using nonlinear least square optimization method by minimizing the sum of the squared errors or residuals ("nlm" function equipped in "R" was used).

Results

The average image request interval time is 115.4 sec, and the median was 23.0 sec. The result of curve fitting to the exponential function is shown in Fig. 2. From the results of nonlinear optimization, we obtained $\lambda = 0.0345$.

Table 1 Field names of parameters recorded on log files in an intermediate server of PACS

Requested Date
Requested Time
Requested Terminal ID
Modality Type
Image Recorded Date
Segment Server ID

The fitted curves achieved for both terminals by nonlinear optimization method are also shown in Fig. 3. For terminals in wards and outpatient departments, we obtained $\lambda = 0.0293$ and $\lambda = 0.0209$ respectively. There were significant difference between the wards and outpatient departments ($p = 5.12 \times 10^{-5}$).

Discussion

Many discrete event simulators such as GPSS, Ultra-SAN[4] and Möbius[5] can be used to estimate PACS performance, including the response time at image display terminals. Since the client/server models in such simulators can be assumed to be queue models, an arrival distribution function is required to make calculate. Empirically, Sanders et al assumed exponential function to be probability density function of requests from terminals. Generally, this is reasonable because random events in nature often occur according to the Poisson distribution. Our results, which indicated that histograms of request interval time from terminals could be fitted to exponential function, appeared to prove that their assumption is sufficiently accurate.

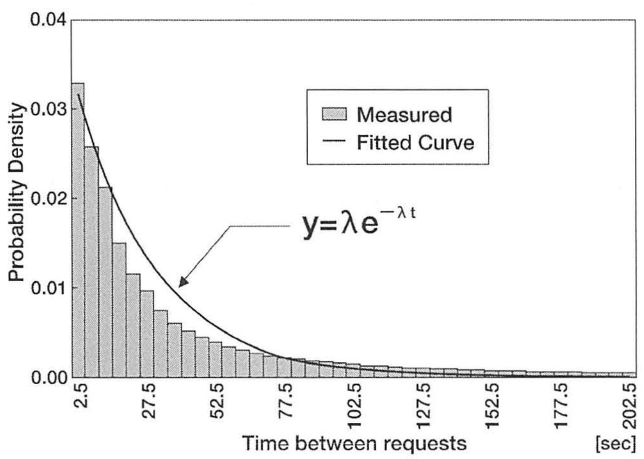

Fig. 2 Probability density functions fitted to the histogram from all image display terminals.

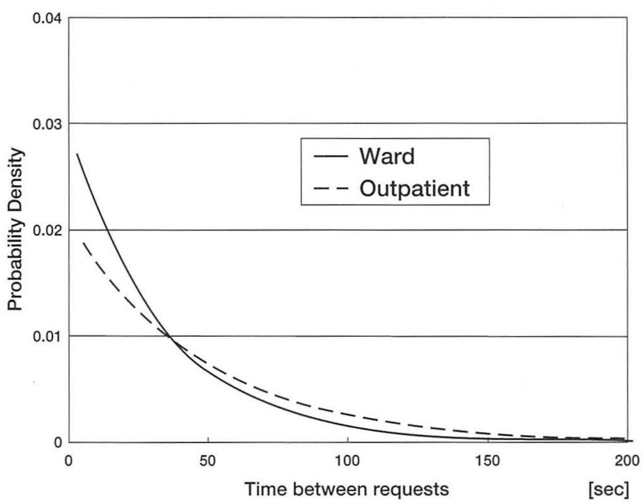

Fig. 3 Probability density functions derived from the image request logs of terminals installed in the outpatient department and the ward.

It is noteworthy that the probability density functions of requests from the terminals in wards and outpatient departments differed. The results of Wilcoxon rank test showed both probability density functions to be significantly different ($P < 0.01$). This fact shows that terminals in these areas should be modeled separately in PACS model.

Our results may also have shown another factor to be considered in building PACS models. If all of components in the PACS model could be assumed to be included in the Markov process, it might be possible to solve problems with the model mathematically. If this is the case, more accurate predictions of the response time at terminals could be achieved. In addition, this would also us to increase the size of simulation model easily.

Request patterns are influenced by several conditions, including the size of the PACS and the type of hospital. Since our results were derived from "one" large-scale hospital, different results might be obtained when derived from multiple hospitals. More studies, including ones of small scale hospitals, should be carried out to build a more general PACS model.

In this study, we reported that exponential function can be used as a probability density function of the request interval from the image display terminals of a PACS for PACS performance simulation. Accurate simulation result will resulted in efficient method for designing the configuration of PACS in hospitals.

Acknowledgements

We would like to thank Kiyonari Inamura, Takeshi Washiashi and Shinichi Okada for their detailed comments and support.

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