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Proposal of Relevant Information Visualization for a Universal Viewer in Oncology

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Abstract

Medical information, such as physicians' descriptions, nursing records, and various examination reports, is stored separately in the subsystems of an electronic medical record (EMR). To provide efficient treatment, health professionals require a universal viewer that collectively organizes and visualizes this distributed information at each clinical phase (i.e., first outpatient visit, treatment, follow-up observation, etc.). This research investigates a method to enable physicians to easily browse relevant information at each clinical phase, and to reflect and verify information in a universal viewer. We analyzed the patterns of picture archiving and communication system (PACS) reference logs and EMR performed orders to identify relevant information. We found that by considering the locations of display terminals in addition to disease types (clinical departments) and clinical phases, more relevant information could be identified, and the contents displayed on a universal viewer were improved accordingly.

Keywords:

Computer-Assisted Therapy, Information Technology, Neoplasms

Introduction

Our institution is a specialized hospital for treatment of malignant tumors with 597 beds, approximately 2,500 outpatients per day, and 10,000 new patients per year. Physicians specialize by organ, such as head and neck, lung, gastrointestinal, urinary, breast, and so on, in addition to the divisions of internal medicine, surgery, psychiatry, and palliative care. Our hospital information system (HIS) consists of an electronic medical record (EMR) system and approximately 60 departmental systems, such as radiation, biochemical testing, physiological testing, medicine, surgery information systems, and so on.

To fully understand a patient's situation, physicians must display a plurality of screens, such as the EMR description, a record of the first visit, biochemical test results, images from a picture archiving and communication system (PACS), and a pathology report. Information must be manually organized and displayed before each instance of medical care for patients. This complicated task takes significant time away from the medical care that should be prioritized.

Therefore, we have been investigating methods to enable physicians to browse the relevant information (i.e., medical records, nursing records, examination reports, etc.) necessary for clinical practice [1-4]. Morgan showed that integrated information visualization can improve radiologists' use of clinical decision support tools [5]. Jorritsma investigated the usability of PACS by analyzing logs based on pattern mining [6]. De-Arteaga and Zeng showed the possibility of improving retrieved information by analyzing image queries [7,8]. Vest showed a difference in access frequency of radiology reports between outpatient and inpatient users [9]. Our previous research identified that clinical departments (disease types) and clinical phases (i.e., first visit, treatment, follow-up observation, etc.) are important parameters distinguishing the relevant information that should be displayed in a universal viewer [10]. This research investigates whether the information on location of display terminals (i.e., inpatient ward and outpatient clinic) from PACS logs can aid in identifying relevant content for physicians.

It was determined by the ethics committee (institutional review board: IRB) of our institution that a formal review by the IRB was not required for this research.

Methods

Data Set

PACS reference logs from April 1-30, 2018, in respiratory medicine, colorectal surgery, and breast surgery departments were analyzed. The PACS reference logs included the operating physicians' information and referred image information. The operating physicians' information included physician ID, reference date and time, physician department, and terminal IP address and location. Referred image information included patient ID, imaging date and time, modality, and region of images. Modalities included computed radiography (CR), computed tomography (CT), endoscopy (ES), mammography (MG), magnetic resonance (MR), nuclear medicine (NM), positron emission tomography (PT), radio fluoroscopy (RF), x-ray angiography (XA), and others (OT). Image regions included the chest, pelvis, abdomen, head, and breast.

Pattern Analysis of Image References

The number of image references were counted for each clinical department, clinical phase, location of image references, imaging modality, and region of images.

Clinical Phase of Image References

The clinical phases of each image reference were determined by the time of the references. Major clinical events (e.g., first visit, hospitalization, surgery, discharge) and their time were extracted from EMR performed order information. The interval between two consecutive clinical events was defined as a clinical phase (e.g., hospitalization – surgery) [10]. The clinical phase of each image reference was determined by comparing

the time of the image reference and the time of the patient's clinical phases. This research focused on the clinical phases of first visit, before hospitalization, during hospitalization, and after discharge.

Location of Image References

The location of each image reference was determined by the IP address of the display terminal. Locations were categorized into three types: outpatient clinic, inpatient ward, and others. This research compared image reference patterns in outpatient clinics and inpatient wards.

Frequency of Image References

To quantify the frequency patterns of image references by physicians, we counted the frequency of references to each image or combination of images referred to at the same time. A sequence of image references for the same patient within 30 minutes by a single physician on a single terminal was defined as *one reference*. The number of image references was then counted based on this definition.

Days Elapsed from Imaging

To investigate the time distribution of the images referred to by physicians, we measured the number of days elapsed between the imaging date and the reference date. Elapsed days were categorized as shown in Table 1. The range for each category was determined so that reference counts for each category were distributed nearly equally, and so that categories would be weekly or monthly. Figure 1 shows the number of image references in each category.

Table 1 - Categorization of elapsed days

Category	Range of elapsed days	Note
0	0	Same date
1	1 – 3	1 to 3 days ago
2	4 – 7	3 days to 1 week ago
3	8 – 14	1 to 2 weeks ago
4	15 – 21	2 to 3 weeks ago
5	22 – 30	3 weeks to 1 month ago
6	31 – 40	1 month to 40 days ago
7	41 – 60	40 days to 2 months ago
8	61 – 150	2 to 5 months ago
9	151 +	More than 5 months ago

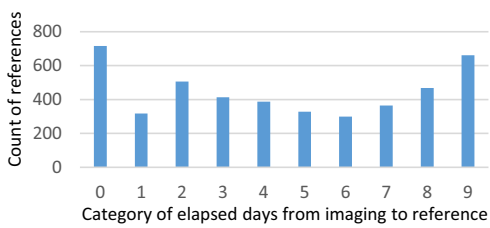

Figure 1 - Image reference counts in each category for days elapsed between imaging and reference

Combination Pattern of Referred Images

To analyze which images were referred to in combination, we analyzed combinations of images in one reference (defined above). The following three combination types were considered.

Type 1: Combination of elapsed days categories
Type 2: Combination of elapsed days categories and modalities
Type 3: Combination of elapsed days categories, modalities, and imaging regions

For example, when a physician referred to an abdomen MRI image from that same day (Category 0) and a chest CT image from more than 5 months ago (Category 9), Type 1 generated the combination (0,9), type 2 generated the combination (0_MRI, 9_CT), and type 3 generated the combination (0_MRI_ABDOMEN, 9_CT_CHEST). If only one image from the same day was referred to, Type 1 would generate (0), for example.

Comparison of Image Reference Patterns

The frequency of combination patterns of referred images was counted and compared among clinical departments, display terminal locations (outpatient clinic, inpatient ward), and clinical phases (first visit, before hospitalization, during hospitalization, after discharge). The relative frequency (ratio), as defined below, was compared.

Relative frequency (ratio) = number of image references for each combination / total number of image references

Analysis Environment

Python 3.7 was used on a computer running Windows 10 64-bit OS with 16 GB of memory.

Display of Relevant Information on a Universal Viewer

The combinations of frequently referred images were considered to be relevant information in each clinical phase and location. We developed a prototype universal viewer [11] that displays the frequent combinations of referred images at each clinical phase and location. The universal viewer displays modality images, reports, laboratory tests, image measurements, clinicians' descriptions, nursing records, and so on, switching the displayed contents to show those that are relevant at each clinical phase (Figure 2). The configuration of displayed content at each clinical phase and location was determined by the above method. The universal viewer runs on a web browser and can flexibly adjust to various sizes/resolutions of displays including multiple displays and tablet displays.

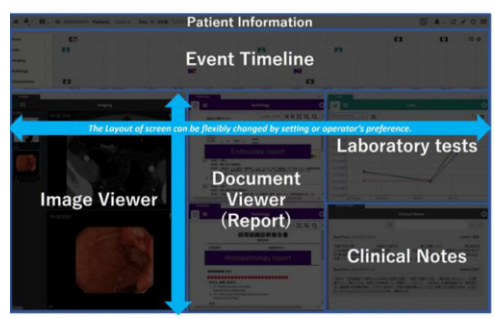

Figure 2 – Screen configuration of a universal viewer

Results

The total number of PACS image reference logs was 24,966. The total number of terminals with log records of usage was 234 (outpatient clinic 19, inpatient ward 121, others 94). Thirty-eight physicians used PACS (14 in respiratory medicine, 11 in colorectal surgery, 13 in breast surgery). The total number of

image references as defined in the Methods section was 3,331 (1,066 in respiratory medicine, 939 in colorectal surgery, 1,316 in breast surgery).

The results of pattern analysis of image references are illustrated in Figures 3-15.

At outpatient terminals, there were many cases of reference to an image from within one week alone, and to combinations of current and several months old images (Figure 3). At inpatient ward terminals, same-day images alone were most referred to (Figure 4).

Analysis of the reference information at outpatient and ward terminals with consideration of clinical phase showed the following tendency. At outpatient terminals upon first visit, there were many cases of references to images from within one week or from several months previous alone (Figure 5). At outpatient terminals after discharge, combinations of same-day images and images from 2 to 5 months ago were referred to (Figure 6). At ward terminals, the number of references was greater before hospitalization than during hospitalization. The reference pattern included images from various periods, particularly images from immediately before hospitalization (Figure 7). At ward terminals during hospitalization, same-day images alone were most referred to (Figure 8).

Adding clinical department as a parameter showed the following tendency. At outpatient terminals in respiratory medicine, same-day images alone or combinations of same-day images and images from 2 to 5 months ago were referred to most, regardless of clinical phase (Figure 9). However, images from a relatively long period were referred to equally at ward terminals (Figure 10). In colorectal surgery, recent images were referred to at outpatient terminals (Figure 11). At ward terminals, references differed before hospitalization (Figure 12) and during hospitalization (Figure 13). During hospitalization, same-day images were referred to. In breast surgery, images (mammography) from one or two weeks previous were primarily referred to at outpatient terminals upon first visit (Figure 14). Same-day images (nuclear medicine) were referred to during hospitalization (Figure 15).

Considering these results, the information display on a universal viewer was configured for each terminal location and clinical phase. Figure 16 shows a display for breast surgery at outpatient terminals upon first visit (left) and a display forward terminal before hospitalization (right). Figure 17 shows the difference in screen configuration between breast surgery (left) and colorectal surgery (right) during treatment.

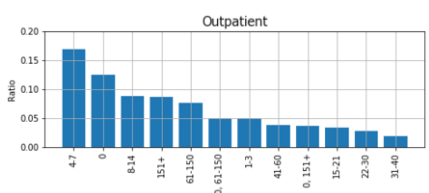

Figure 3 – Image references at outpatient terminals

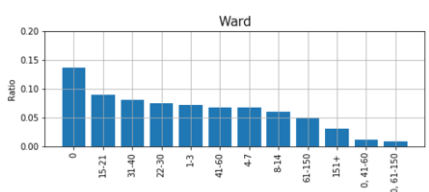

Figure 4 – Image references at ward terminals

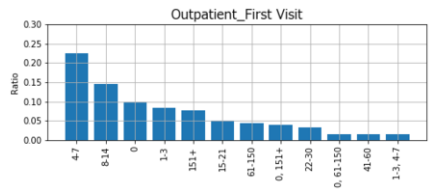

Figure 5 – References at outpatient terminals upon first visit

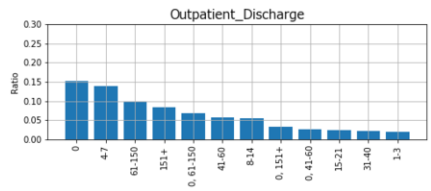

Figure 6 –References at outpatient terminals after discharge

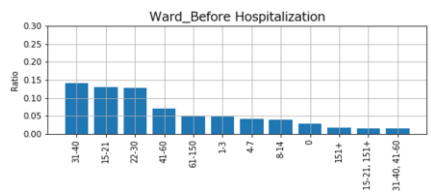

Figure 7 – References at ward terminals before hospitalization

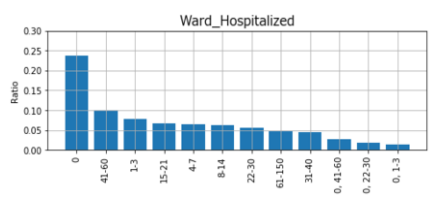

Figure 8 – References at ward terminals during hospitalization

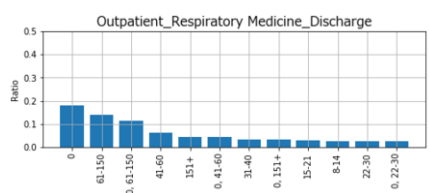

Figure 9 – References at outpatient terminals in respiratory medicine

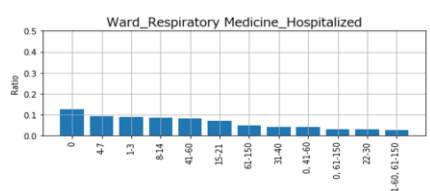

Figure 10 – References at ward terminals in respiratory medicine

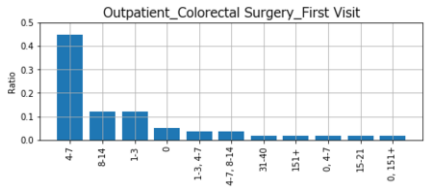

Figure 11 – References at outpatient terminals in colorectal surgery

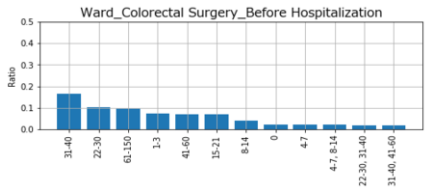

Figure 12 – References at ward terminals in colorectal surgery before hospitalization

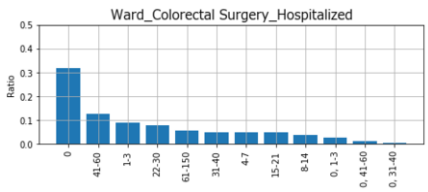

Figure 13 – References at ward terminals in colorectal surgery during hospitalization

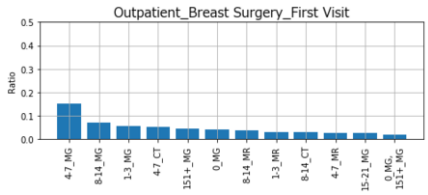

Figure 14 – References at outpatient terminals in breast surgery upon first visit

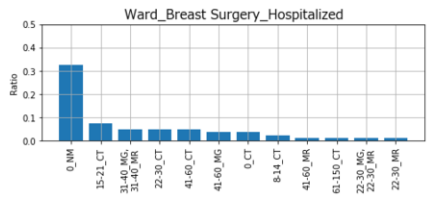

Figure 15 – References at ward terminals in breast surgery during hospitalization

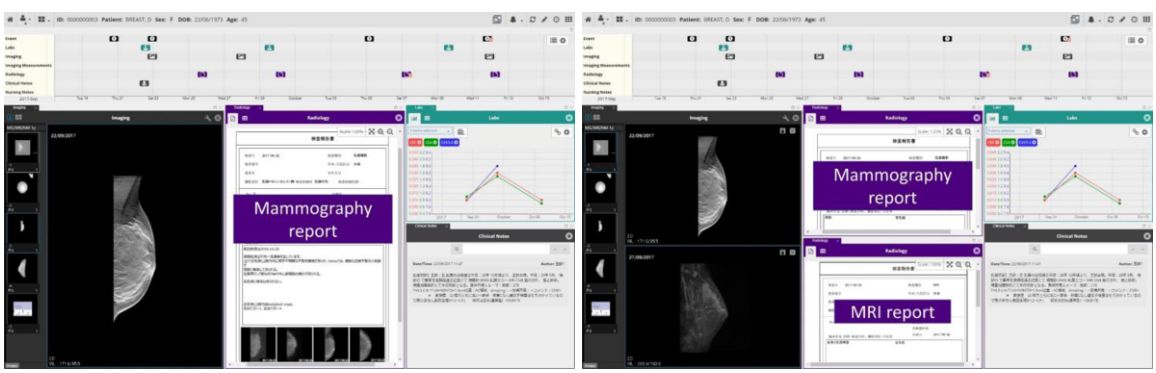

Figure 16 – Example of display configuration for a universal viewer in breast surgery (Left: outpatient clinic upon first visit. Right: inpatient ward before hospitalization)

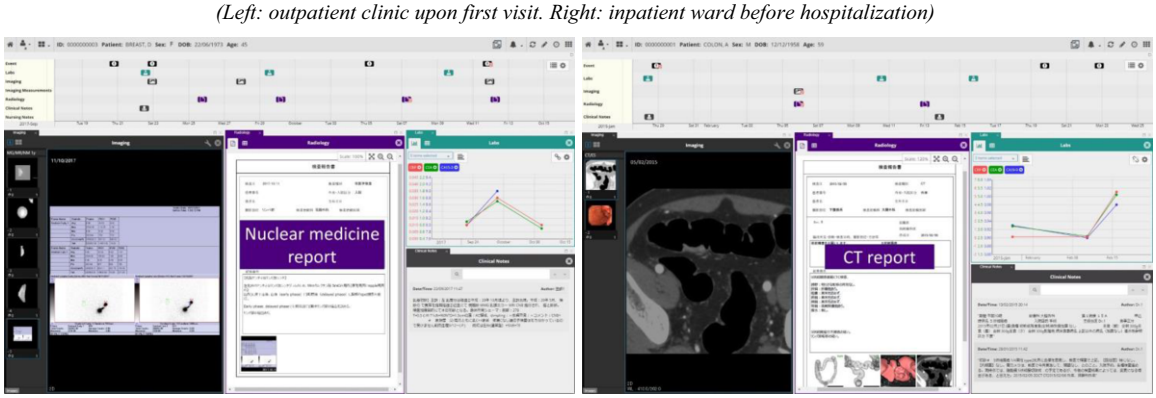

Figure 17 – Example of display configuration for a universal viewer (Left: breast surgery during treatment. Right: colorectal surgery during treatment

Discussion

In previous research, physicians' behavior was analyzed by PACS operation logs or retrieval queries mainly to improve usability of PACS or image retrieval systems [5-9]. However, this research analyzed the PACS operation logs to investigate the method to display relevant information at each clinical phase. Specifically, this research showed that identification of the clinical scene (clinical department, clinical phase and the location of display terminals) and pattern analysis of physicians' image references (imaging date and time, modality, and regions of the images) at the clinical scene allow the universal viewer to display relevant information, which is effective for clinical decision support for diagnosis and treatment.

In our hospital, almost all patients are referrals from other hospitals. Cases in which a physician refers to an image from several months before the first outpatient visit are presumed to be references to the initial examinations at the patient's original hospital to verify the patient's status at the time of the initial diagnosis.

Images from before hospitalization are referred to at inpatient wards for conferencing and consideration of treatment policy. Images are referred to during hospitalization to confirm the treatment situation and conduct necessary immediate examinations. The results of this study's analysis reflect the clinical workflow in practice.

The finding that reference tendencies differ among clinical departments also reflects differences in the requirements of each department. The treatment period is longer in respiratory medicine, and confirmation of status during the course of treatment is important. Colorectal surgery and breast surgery require examinations for recurrence and confirmation of metastasis.

References to mammography images before hospitalization and to nuclear medicine images during hospitalization in breast surgery also reflect clinical practice, considering the burden of mammography on patients and the necessity of metastasis examination.

The limitation of this research is that PACS reference logs are available at the study level, but not the series level. Display of axial images of specific series, sagittal images, and fusion images according to disease condition and reference purpose warrants further investigation

Conclusions

This research showed that the location of display terminals (outpatient clinic, inpatient ward) in combination with clinical phase and disease type (hospital department) can potentially identify relevant contents for display on a universal viewer. The results warrant further investigation for the application of the proposed method to other clinical departments, clinical scenes, and diseases, given that a universal viewer is expected to improve the efficiency of medical treatment for various diseases, not only for specific diseases such as cancer.

Acknowledgements

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References

[1] Mihara N, et.al; Collaborative development of universal viewer in medicine using VNA (Vendor Neutral Archive) technology to accelerate integrated management of clinical data, Monthly report 'Shin-Iryou' (Japanese magazine), 8-13, July, 2018.
[2] Mihara N, et.al; What is the best method of saving image for medicine ~ Report of analyzing for operational PACS log, both short term and long-term storage ~ 2nd report, 73rd annu meeting of Japan Radiol Soc, 2016.
[3] Mihara N, et.al; How should we do to realize saving and viewing image efficiently? Primitive report of analyzing log data of PACS, Annu meeting of Japan Radiol Soc, 2013.
[4] Mihara N, et.al; The prototype of the self-leaning system of the chest X-ray images, Japan J Med Inform, 31:576-79, Nov., 2011
[5] Morgan MB, et.al; Just-in-time radiologist decision support: the importance of PACS-integrated workflow. J Am Coll Radiol, 8(7):497-500, 2011.
[6] Jorritsma W, et.al; Pattern mining of user interaction logs for a post-deployment usability evaluation of a radiology PACS client. Int J Med Inform, 85(1):36-42, 2016.
[7] De-Arteaga M, et.al; Analyzing medical image search behavior: semantics and prediction of query results. J Digit Imaging, 28(5):537-46, 2015.
[8] Zeng QT, et.al; Assisting consumer health information retrieval with query recommendations. J Am Med Inform Assoc, 13(1):80-90, 2006.
[9] Vest JR, et.al; Using a health information exchange system for imaging information: patterns and predictors. AMIA Annu Symp Proc, 1402-11, 2013.
[10] Mukai, et.al; What is required for Universal Viewer - in case of Oncologist - ?, JCMI2018.
[11] Hirashima V; Development of Abierto™ Cockpit that integrates and visualizes clinical information, JIRA technical report, 28(1):28-9, 2018.

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