

Development of a Digital Imaging and Communications in Medicine Viewer with an Input Device for Paging in Multislice Computed Tomography

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ABSTRACT— *The number of images generated in a single scan has considerably increased with the introduction of multislice computed tomography (CT). However, this high number of images cannot be handled by standard film interpretation. Therefore, conventional thick-slice images and three-dimensional (3D) workstations are employed to enable diagnoses from such data. To address this problem, we developed a multislice CT Digital Imaging and Communications in Medicine (DICOM) viewer with a dedicated desktop console comprising input devices designed for various functions. The functions normally provided on 3D workstations were omitted from this viewer. Rather, the dedicated desktop console includes a three-step variable-speed encoder. This study aimed to compare our viewer with an existing multipurpose image observation system. Here, we describe the development of our multislice CT DICOM viewer, characterized by its intuitive operability mediated through the combination of a dedicated desktop console and software for stress-free image interpretation. We compared the operabilities of the different slide lever encoder-operated control programs on our multislice CT DICOM viewer and dedicated desktop console. We also compared the ease of use and operability during the mouse-mediated paging of the dedicated desktop console associated with our multislice CT DICOM viewer and a commercially available multipurpose image observation system. Our system was found to be superior to the commercially available system with regards to the paging speed and the ease of use. To avoid image skipping and to prevent mouse-induced problems such as tendonitis during paging, it will be necessary to provide alternative input devices that are suitable for paging and compatible with the associated driver software. In conclusion, tools other than a mouse can be useful for multipurpose image observation systems.*

Keywords—Digital Imaging and Communications in Medicine (DICOM), picture archiving and communications system, paging, multislice computed tomography, input device

1. INTRODUCTION

In recent years, there have been many advances in computed tomography (CT) technology, including the development of multislice CT, area-detector CT [1], and dual-source CT [2, 3]. However, these advances have considerably increased the number of images generated, producing up to 20 times the number of images as single-slice CT. For example, multislice CT produces multiple thin-slice images (e.g., 0.5–1 mm). Applications that permit the full usage of these imaging data, including multiplanar reconstruction (MPR) displays and interpretations and diagnoses of coronal and sagittal sections suited to various clinical purposes [4], are being introduced into clinical use. However, these applications render conventional film image interpretation impractical in terms of space, cost, conservation, and storage [5–7]. A digital imaging and communications in medicine (DICOM) viewer has been developed to address these problems [8, 9].

A multislice CT system manufactured by Toshiba Medical Systems (Tokyo, Japan) was introduced in our hospital in 1999, and we expected that this multislice CT technology would be widely adopted. In 2002, in conjunction with Nemoto

Kyorindo Co., Ltd. (Tokyo, Japan), we developed a multislice CT DICOM viewer capable of observing a large number of images for use on a dedicated desktop console [10, 11]. We tested four types of paging device prototypes during development to identify an appropriate console for the paging and selection of large numbers of slices.

Our hospital began filmless operations following the introduction of a Toshiba Medical Systems picture archiving and communication system (PACS) in May 2012. The efficient use of PACS is required to resolve the abovementioned problems associated with monitor-based image interpretation. However, conventional multipurpose image observation systems, CT consoles, and three-dimensional (3D) workstations are expensive and feature complex operations. In addition, the multipurpose image observation systems and 3D workstations currently in common use incorporate a keyboard and a mouse for standard operation. However, the use of a mouse or a keyboard during image interpretation with these systems introduces the potential risk of tendonitis [12] or other device-induced problems.

A DICOM viewer that uses open-source software and incorporates a video-editing jog-wheel device was developed [13]. Devices other than a standard mouse are preferred when interpreting 3D images [14]. Commonly available alternative mouse types manufactured by other companies are frequently used to prevent tendonitis and other problems. The use of a 3D mouse or similar device could decrease operator strain.

With this in mind, we attempted to use a programmable jog-wheel, a device commonly used in video editing, to appropriately adjust the paging speed during image interpretation, while maintaining a fixed paging speed on a multipurpose image observation device. However, these devices are not generally used in Japan because modifications to multipurpose image observation systems are not permitted under the Pharmaceutical Affairs Act [15]. For example, the terminals at our hospital, on which a jog-wheel operational driver software has been installed, are not covered under the warranty from the manufacturer because of the modification to the multipurpose image observation system.

This study aimed to compare our viewer with an existing system to evaluate the operability of the multislice CT DICOM viewer and multipurpose image observation system and thus to examine whether tools other than a mouse would be useful for such systems. We also included a mouse with the dedicated console developed for paging to enable comparison of the ease of image observation.

2. METHODS

2.1 Device construction

2.1.1 Multislice CT DICOM viewer

In 2002, we developed a multislice CT DICOM viewer to view single multislice CT images from among a large number of thin slices without the need for a keyboard or mouse. We constructed this multislice CT DICOM viewer using an ordinary DOS/V personal computer (PC), a dedicated desktop console, and a commercially available 18.1-inch high-resolution liquid crystal display (LCD) color monitor (FlexScan L685; EIZO, Hakusan, Japan).

The PC contained a Pentium IV 1.7-GHz central processing unit (CPU), an 80-GB hard drive for system and image memory, 1 GB of random access memory (Rambus Dynamic), and a video board (Gladiac 920; ELSA AG, Aachen, Germany). The PC used the Windows 2000 Professional operating system (Microsoft Corporation, Redmond, WA, USA).

Our multislice CT DICOM viewer was connected to the network in the Department of Radiology at Fujita Health University from 2002 to 2004, prior to the introduction of a Web DICOM Archive Server (WebDAS) [16, 17, 18].

Unlike conventional image observation systems, this viewer was not operated by a mouse or a keyboard but rather by a dedicated desktop console capable of operation using hardware keys.

The dedicated desktop console was fitted with multiple input devices, including patient search, series search, image display, MPR display, and multiscreen display keys, as well as window width/level variation dial encoders (jog-wheels), window preset keys, and an image paging device (Figure 1a–f).

Several image paging device prototypes were produced for our multislice CT DICOM viewer. These prototypes incorporated a sliding lever encoder with two different control programs [relative coordinate format (Figure 2a), variable-speed format (Figure 2b)], and two types of three-step variable-speed encoders, each of which was capable of bi-directional three-step encoding [bi-directional switch-type (Figure 2c) and stick-type (Figure 2d)].

Using the slide lever encoders, the slide lever movement range on the relative coordinate format encoder was assigned to the display coordinates of the entire image. A variable-speed encoder format was also incorporated to increase or decrease the paging speed in the cranial or caudal direction in accordance with the distance moved by the slide lever from the central point.

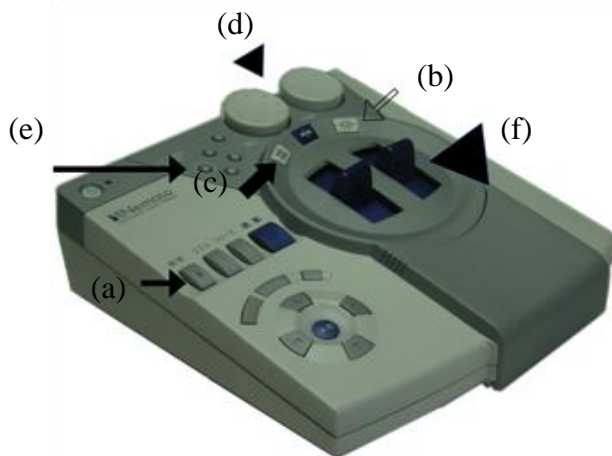


Figure 1: Desktop console with visible operation keys

- (a) Patient search key, image display keys, and series search key (short thin arrow)
- (b) MPR display key (unshaded arrow)
- (c) Multiscreen display key (short thick arrow)
- (d) WW/WL selector jog dials (small arrowhead)
- (e) Window condition preset keys (long arrow)
- (f) Image paging devices (three-step variable-speed switch; large arrowhead)



Figure 2: Four types of image paging devices

- (a) Relative coordinate-type console
- (b) Variable speed-type console
- (c) Bi-directional switch-type console
- (d) Stick-type console (final specification)

The three-step variable-speed switches incorporated three sub-switches each for the cranial and caudal directions. This enabled the stepwise selection of input data via a top-down individual and sequential selection (Figure 3). Specific paging speeds were set for the individual sub-switches, which were programmed such that ceasing the operation and the input to a sub-switch would stop the paging. The three-step paging speeds could be varied as desired during the initial setup, thereby enabling the selection of optimum paging speeds for individuals or cases.

Jog-wheels and button switches with preset window conditions (preset button) were installed as input devices for varying the window conditions. The preset button included settings for the lung field, soft tissue, bone, and other conditions. An additional button function allowed temporary recording of the window conditions in the displayed image.

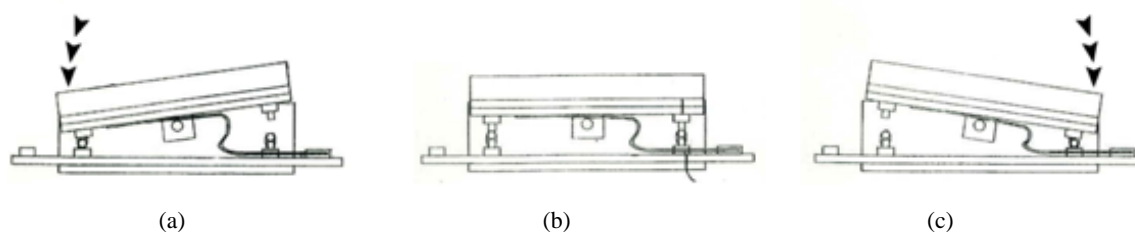


Figure 3: Inner structure of the three-step variable-speed switch

- (a) Cranial view
- (b) Neutral view
- (c) Caudal view

Each sub-switch has three input positions. Each of the three positions is turned on by a single action.

2.1.2 Toshiba Medical Systems multipurpose image observation system

In this study, the device used for comparison was a Toshiba Medical Systems multipurpose image observation system that comprised a PC (Dell, Austin, Texas, USA) equipped with the Windows 7 operating system (Microsoft) and three color monitors (RadiFoce RX240/FlexScan S1721; EIZO).

The PC contained a core i7-2600 3.4-GHz CPU, an 80-GB solid-state drive (SSD) for system and image memory, 4 GB of Double-Data-Rate3 synchronous dynamic random access memory (DDR3 SDRAM), and a video board (Matrox Xenia; Matrox, Dorval, Quebec, Canada). This device used a wheel mouse for paging, and necessary keyboard shortcuts were set for various operations along with preset values for conditions such as the window level and paging. The screen display method enabled the image series designated by the interpreting physician to be selected from thumbnails and to be displayed at the desired size.

The Toshiba Medical Systems multipurpose image observation system was connected to a 1-GB server via the Fujita Health University Hospital network.

2.2 Evaluation parameters

2.2.1 Operability during paging

We investigated the operabilities of the following four types of image paging devices used by the multislice CT DICOM viewer: the slide lever-type relative coordinate (Figure 2a) and variable-speed formats (Figure 2b); and the bi-directional switch (Figure 2c) and stick-types (Figure 2d) of the three-step variable-speed encoder format. We also investigated several formats for dedicated input devices that could efficiently display large images for image paging as well as the associated control programs.

First, we compared the operabilities of the different control programs when used with the slide lever-type devices. The viewer either could or could not display all images and stop paging at the desired page. We also compared the operabilities of the bi-directional switch and stick-types of the three-step variable-speed encoders. We further compared the slide lever and the three-step variable-speed encoder types.

Finally, we compared the operability of the multislice CT DICOM viewer with that of the Toshiba Medical Systems multipurpose image observation system during paging.

2.2.2 Imaging speed

We compared the paging speed of the multislice CT DICOM viewer using the stick-type dedicated desktop console with that of the Toshiba Medical Systems multipurpose image observation system using wheel mouse-mediated paging. The paging speed was measured using a single series of 1000 CT images. The single-image series paging display was evaluated by measuring the time taken to perform 10 successive paging actions and the mean time was then calculated. We used imaging data of a phantom to measure the paging speeds in this study.

2.3 Limitations

This study has some limitations. We were unable to measure the times required for paging on the developed systems because these consoles no longer exist. Computer technology has progressed considerably since 2002. Therefore, a comparison of the paging speeds with PACSs and an older computer is not appropriate. In addition, the system architecture, including the operating system, other simple specifications, and network performance, has changed. The older system delivered image data in advance, whereas the current system is a large-scale system that analyzes both past and present data.

3. RESULTS

3.1 Operability during paging

3.1.1 Image paging devices in the multislice CT DICOM viewer

When using the relative coordinate format, the resolution of the coordinate positional information from the slide lever was inadequate for a series comprising several hundred images. Therefore, some images could not be displayed. When using the variable-speed format, it was difficult to stop paging, as this continued when the lever was sliding as well as when it was held at its final position. The three-step variable-speed encoder could display all images at variable speeds. In addition, because paging stopped when the operation stopped, it was possible to stop paging at the desired position, thereby providing the easiest target image display method. A comparison of the bi-directional switch-type and stick-type three-step variable-speed encoders revealed that a shorter hand motion distance was required to operate the stick-type encoder, thereby decreasing the operating time. A constant paging speed was easily maintained during paging with the three-step variable-speed encoder.

3.1.2 Toshiba Medical Systems multipurpose image observation device

Wheel mouse-mediated paging was achieved by rotating the mouse wheel or dragging the mouse. Occasionally, it was not possible to stop paging at the desired slice if the mouse wheel was rotated at a high speed. Keyboard-mediated paging could be performed by typing the key assigned to the appropriate short cut.

3.2 Imaging speed

3.2.1 Image paging devices in the multislice CT DICOM viewer using stick-type dedicated desktop console

A single series of 1000 axial-view CT images could be paged at the maximum speed setting in a 25-s period (40 images/s). Because paging cannot be performed at a speed greater than the monitor refresh rate, there were no occasions during which an image was not displayed during paging. No delays occurred during paging.

3.2.2 Toshiba Medical Systems multipurpose image observation device using wheel mouse-mediated paging

A 41-s period was required to page a single series of 1000 CT images using wheel mouse-mediated paging. Rotational mouse operation was not consistent between operators, and paging continued even when the wheel was no longer being rotated. Paging using mouse dragging was faster than wheel-based paging, but some images were not displayed because the operator speed limit was not set. Keyboard-mediated paging could be performed at a constant speed, but it was impossible to switch to the desired paging speed when using this method. In some cases, more input than required was transmitted from the keyboard to the viewer, resulting in paging past the desired section.

4. DISCUSSION

Conventional CT interpretation is primarily performed using film images. However, multislice CT, which has become widely used in recent years, incorporates wide-area scans and involves the reconstruction of thin-slice images.

In addition, it is not uncommon for a single series to include several hundred images or more, rendering the interpretation of all film images impractical. As such, there is a growing demand for methods to easily view large numbers of images on a monitor [5–7, 19]. The multipurpose image observation systems that are currently in common use incorporate a mouse and a keyboard. However, these devices are not necessarily suited to page through large numbers of images on an image interpretation terminal.

To resolve these issues, we developed a multislice CT DICOM viewer intended for the specific interpretation and viewing of large numbers of multislice CT images. Because this viewer was designed for use in busy clinical settings, we avoided using a keyboard and a mouse as the operative instruments. Rather, we produced a dedicated desktop console fitted with hardware switches to perform several different functions.

The continuous paging of continuous sections allows efficient observation of large numbers of images [20–23], and most multipurpose image observation systems use either a Next Page button or mouse input for this purpose. Input from a Next Page button, which occurs one page at a time, reduces the paging speed and increases the time needed to reach the target section. In addition, operators may overshoot the target section by excessively repeating the input. Mouse-mediated paging is difficult to maintain at a constant speed, and if the mouse is operated at a speed faster than the system's imaging speed, the image display tends to become intermittent. The smooth display of continuous sections requires an input device that can continuously encode the coordinates of the sections to be displayed. To meet this requirement, we produced slide lever-type and three-step variable-speed encoder input devices. Good paging was achieved with three of these devices, the variable-speed format slide lever-type and both three-step variable-speed encoders (bi-directional switch-type and stick-type). However, with the variable-speed format slide lever-type, paging continued even when the slide lever was held at the desired stopping point. Anticipation of this movement was therefore necessary when operating the device, thus decreasing its operability. The three-step variable-speed encoder input devices could efficiently page through all images with little movement and could easily select the desired sections. The stick-type required less hand movement compared with the bi-directional switch-type, with no associated loss of operability.

During image interpretation, the interpreter must be able to focus on the displayed images. Our dedicated desktop console incorporated a small number of switches, a three-step variable-speed encoder, and a jog-wheel to facilitate intuitive operation, all of which improved both the operability and imaging efficiency.

Our multislice CT DICOM viewer has the following limitations. Although this viewer can display up to two series, scans for the investigation of disorders such as liver tumors often include five time phases. For the viewer to handle multiphase displays of three or more time phases, the series selection method and display format would need to be changed, and at least two monitors would be required. In addition, the operating system memory management function automatically utilized the virtual memory when more than 1500 images were opened. Hard disc access via this virtual memory reduced the paging speed or resulted in temporary freezes. In the future, a 64-bit operating system will be required for memory management to enable the smooth display of more than 1500 images. Finally, to avoid image skipping and to prevent mouse-induced problems such as tendonitis during paging, it will be necessary to create an environment in which radiologists can use appropriate input devices and associated driver software that are currently beyond the regulatory scope of the Pharmaceutical Affairs Act.

5. CONCLUSIONS

We have developed a dedicated and simple-to-operate multislice CT DICOM viewer to resolve the problems associated with the advent of multislice CT and the consequent generation of large volumes of imaging data. We have successfully achieved simple and intuitive operability by incorporating hardware such as a three-step variable-speed encoder for paging and a jog-wheel to change the window conditions. However, to avoid image skipping and to prevent mouse-induced problems such as tendonitis during paging when the speed limit is not set, it will be necessary to provide alternative input devices that are suitable for paging, as well as the associated driver software.

6. CONFLICTS OF INTEREST

Our multislice CT DICOM viewer was developed in cooperation with Nemoto Kyorindo Co., Ltd. and Resource One Inc. (Kanagawa, Japan). However, this viewer is not currently available for sale, and none of the authors have any mutual profit relationships with these companies.

7. ACKNOWLEDGEMENTS

Figures 1–3 were modified from [11]. The usefulness of the DICOM viewer using the dedicated desktop console, *Eizo Joho Med.*, 35(8), pp. 1346–1154, 2003.

We thank the following doctors who provided us the opportunity to produce this article. Ryoichi Kato, MD**; Shigeru Nemoto, BSc***; Masashi Goto, BSc****; Kazuhiro Katada, MD*****; and Hiroshi Toyama, MD*

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