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(71) Applicant: **FISCHER IMAGING CORPORATION**
[US/US]; 12300 North Grant Street, Denver, CO 80241 (US).

(72) Inventors: **MINYARD, Thomas, J.**; 500 Plateau Parkway, Golden, CO 80403 (US). **NIELDS, Morgan, W.**; #4 Sunrise Drive, Englewood, CO 80110 (US). **KREMER, Ted, V.**; 3159 6th Street, Boulder, CO 80304 (US). **BESSON, Guy, M.**; 1672 Emerald Street, Broomfield, CO 80020 (US).

(74) Agent: **MARSH FISCHMANN & BREYFOGLE LLP**;
MARSH, Thomas, R., 3151 South Vaughn Way, Suite 411,
Aurora, CO 80014 (US).

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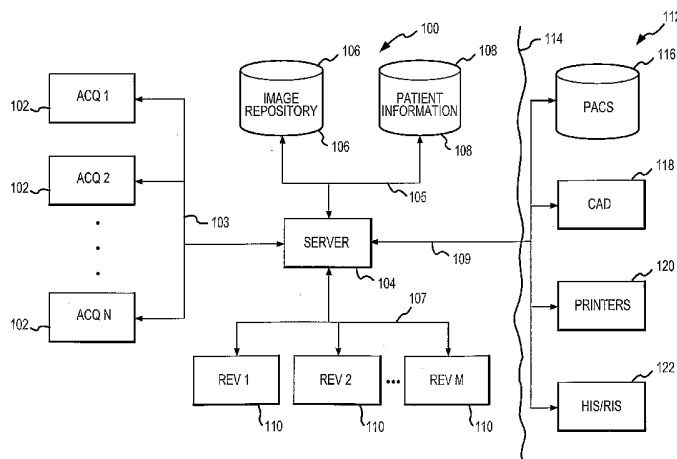
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(54) Title: DISTRIBUTED ARCHITECTURE FOR MAMMOGRAPHIC IMAGE ACQUISITION AND PROCESSING



(57) Abstract: A distributed architecture allows for decoupling of mammographic image acquisition and review, thereby enabling more efficient use of resources and enhanced processing. In one embodiment, the system (100) includes a number of image acquisition stations (102) and a number of image review stations (110) all associated with a central server (104). The server (104) is operative to access an image repository (106), a patient information data base (108) and a number of DICOM tools (112). The invention allows for more efficient and/or more convenient use of the image acquisition equipment and image processing stations. Moreover, the distributed architecture including the central image repository provides certain processing and analysis advantages. The invention also provides certain processing and workflow enhancements that allow for a more full realization of potential digital mammography advantages.

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DISTRIBUTED ARCHITECTURE FOR MAMMOGRAPHIC IMAGE ACQUISITION AND PROCESSING

FIELD OF THE INVENTION

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The present invention relates generally to medical imaging including mammography and, in particular, to a distributed architecture that allows for decoupling of mammographic image acquisition and review, thereby enabling more efficient use of resources and enhanced processing. The invention also involves a method and system for
10 use in processing mammographic images and in acquiring, displaying and/or organizing the display of medical images so as to enhanced workflow.

BACKGROUND OF THE INVENTION

Imaging techniques are utilized in a variety of common medical applications. For example, mammography, including x-ray imaging and other imaging modalities, is
15 widely used in detection and analysis of cysts, lesions, microcalcifications and other areas of interest within a patient's breast. Because of its proved effectiveness in early detection and analysis, including detection of nonpalpable lesions, mammography continues to be recommended for many women. As a result, mammography equipment is available in many locations and such equipment, as well as clinicians and physicians experienced in
20 using such equipment and analyzing the mammographic images, are typically kept busy meeting the demand.

Traditionally, mammography systems have been film-based. Film based mammography involves obtaining mammographic images on film which is typically loaded into a film tray positioned adjacent the patient's breast. The films can then be
25 reviewed using a light box. More recently, digital mammography has been gaining acceptance. In digital mammography, images are acquired digitally and can be displayed on an electronic monitor.

A number of advantages associated with digital imaging have been recognized. First, digital imaging provides substantially real-time images. In some cases, follow-up
30 views may be acquired based on real-time review of the digital images such that a return visit by the patient can be avoided. In addition, digital processing allows for image enhancement. In this regard, a physician may zoom in on an area of interest, adjust the image contrast or brightness or otherwise manipulate the image after acquisition.

Moreover, it is sometimes possible to obtain improved diagnostic information by digital processing. For example, a digital image that is identified as being suspicious or is otherwise of interest can be exported to certain CAD systems that perform digital analyses. For example, such CAD systems may perform a pixel-by-pixel analysis of the digital image to identify areas of reduced intensity that may be missed upon review of the images using the naked eye. Such areas may indicate microcalcifications or other conditions of interest that the physician may desire to review more closely, such as by zooming in on that region of the image or otherwise enhancing the image.

Despite these advantages, certain perceived disadvantages have slowed the process of full digital acceptance. Some of the perceived disadvantages are specific to particular digital imaging equipment. In this regard, some current digital imaging systems do not provide a full field of view for a patient's breast. As a result, multiple images may be required for a screening analysis or the digital imaging system may be relegated to follow-up imaging of an area identified by film. In addition, some current digital imaging systems provide a limited resolution that may be deemed insufficient for certain applications. However, full field, high-resolution digital imaging systems are now being marketed, including the SenoScan system of Fischer Imaging Corp. of Thornton, Colorado.

Other perceived disadvantages relate to operational restrictions of conventional digital mammography systems. Many conventional digital mammography systems are stand alone units that include the image acquisition equipment or gantry (e.g., the x-ray tube, compression paddles, detector and the like), a processor executing image processing logic and a display terminal that may include oversized high resolution monitors. In these cases, a physician may review images at the physical equipment site. This may tie up the equipment when needed, thereby reducing patient throughput or require that the physician plan around a schedule for accessing the equipment.

Moreover, the images available for review at the equipment may be limited. In this regard, physicians may desire to compare current images for a patient to images obtained for that patient at an earlier date, perhaps obtained using different equipment. Physicians may otherwise desire to review images obtained for multiple patients at different image acquisition sites, e.g., in connection with a large medical facility. In such cases, the images desired for a particular review session may not be readily available at the equipment site. Additionally, certain tools such as CAD processing or other diagnostic tools may not be available at each site where patient images reside.

Moreover, many physicians feel that using an electronic monitor to review images is slower than reviewing films. In the case of films, a physician may review a large quantity of films in one session. The films may be arranged in an order designated by the physician. When the films are thus properly prepared, an experienced physician may be able to adequately analyze certain images or sets of images in a matter of seconds, while devoting a larger time period to a subset of images requiring further analysis. In the digital context, significant time may be spent retrieving and arranging images. Even after an image is identified for review, significant time may be required to load and display the image due to the large amount of information contained in a high quality image. These operational difficulties have resulted in some degree of resistance to digital mammography in spite of the potential advantages as noted above.

SUMMARY

The present invention is directed to a mammography system and associated processes that involve a distributed system architecture. Such architecture allows for decoupling of the image acquisition and review processes. As a result, the invention allows for more efficient and/or more convenient use of the image acquisition equipment and image processing stations. The distributed architecture also facilitates development of a central image repository with certain processing and analysis advantages. In addition, the present invention provides certain processing and workflow enhancements that allow for more full realization of potential digital mammography advantages in relation to film-based mammography.

The present invention is further directed to tools and associated processing of mammographic images to enhance image acquisition and review workflow. In particular, the present invention enables rapid access to digital image information for improved workflow management and identification of images, upon initial review, for substantially instant recall at a later time. The invention also allows for background processing of image information for enhanced functionality substantially without workflow delay. The invention thus addresses certain perceived disadvantages of digital mammography while providing improved digital processing functionality, thereby providing additional digital advantages. In addition, it has been recognized that a medical imaging system may be equipped with one or more image acquisition and review protocols that generally enable the user to acquire images more efficiently and to view medical images in a desired arrangement and/or sequence. In this regard, a medical imaging system in accordance

with the present invention enables such a protocol to be utilized for a viewing medical images of a number of patients or multiple images of a single patient from a single or multiple imaging procedures.

According to one aspect of the present invention, a distributed architecture is employed to implement a mammographic image acquisition and review system. The system includes at least one image acquisition station associated with a digital image repository and at least one remotely located image review station where a physician can retrieve an image from the repository for review. The image acquisition station includes at least a detector for receiving an imaging signal from a patient's breast and providing digital imaging information based on the received signal. This station may further include a source for transmitting the imaging signal (such as an x-ray, ultrasound or other medical imaging source), an assembly for immobilizing the patient's breast as may be desired, a user interface such as a keyboard for entering patient information and managing acquisition workflow, a processor for performing various processing functions and one or more monitors for displaying near real-time images to assist the user.

Among other things, the processor may assist in transmitting the imaging information to or storing the imaging information in the image repository. The image repository may be located at the image acquisition site, the remote image review site, or at another location. In one implementation, the image repository is associated with a server separate from the acquisition and review sites. Such a client-server architecture allows for more efficient and/or convenient utilization of the acquisition and review equipment and certain processing advantages as discussed below.

The remote image review station includes a user interface such as a keyboard and/or mouse for receiving user inputs, a processor for assisting in image review workflow management based on the user inputs and one or more displays for displaying selected mammographic images. This station is located separate from the image acquisition site and, preferably, can be operated independent of the image acquisition equipment. In one implementation, the image acquisition equipment and image review equipment can be operated concurrently such that images for one patient can be acquired while images for another patient are being reviewed. This distributed architecture thereby allows for more efficient use of imaging equipment, higher patient throughput and more convenient image review.

According to another aspect of the present invention, at least one image-processing tool is provided in connection with a mammographic image server. The

associated mammographic imaging system includes image acquisition equipment, image review equipment and the server that is located separate from the image acquisition equipment and image review equipment. The server may be located at a separate location on the medical facility premises or off-site. The image acquisition equipment and image review equipment may be at the same location or at separate locations. The server is interconnected to the image acquisition equipment and the image review equipment for communication of imaging information therebetween and provides access to at least one tool for processing imaging information. In this regard, the tool may run on the server hardware or on a separate platform in communication with the server. Some examples of tools that may be provided in connection with the server include image repository database management tools, CAD tools, other diagnostic aids or medical information privacy and security tools. Providing such tools in connection with a server allows for beneficial resource sharing, improved access to image information and improved access to updated versions of processing logic.

According to a further aspect of the invention, a mammographic imaging system includes multiple image acquisition stations and/or multiple image review stations associated with a central server subsystem (i.e., a single server subsystem associated with one or more machines for serving the multiple stations). The number of image acquisition stations may be the same as or different than the number of image review stations. In the context of a large medical facility, one on-site server or a smaller number of on-site servers may thus support a larger number of image acquisition stations and/or image review stations. Alternatively, one or more off-site servers with appropriate privacy/security protection, e.g., operated by a mammographic equipment provider, may service image acquisition and review stations at separate facilities, each of which may be associated with the server by a high bandwidth connection. In this manner, the most updated versions of processing logic can be made readily available at each image acquisition and review station and alternate business models are possible for reducing medical facility costs and/or enhancing equipment provider revenues.

According to another aspect of the present invention, a mammographic image system includes an image repository associated with a database search engine. The image system includes multiple image acquisition stations for acquiring images and providing image information to the image repository and multiple image review stations (at the same location as or different locations than the image acquisition stations) for accessing image information from the repository. The search engine is operative for searching the

image repository based on certain search fields to access responsive image information. In this regard, the image repository may be structured as a relational database where cross-indexed information corresponding to a single image is stored in multiple tables. Such indexing may be used to facilitate field-based searching. Examples of fields that may be searched include patient name, image record number, date (study), equipment operator/clinician, reviewing physician, medical facility, diagnosis/condition, etc. In this manner, various records can be readily accessed to facilitate image review, research and staff performance. Moreover, searches may be performed based on physical features or medical condition, e.g., microcalcifications, mass, mass location, to access similar images or image portions, for improved diagnosis.

According to a still further aspect of the present invention, a mammographic image system includes an image repository associated with a processing platform for enabling concurrent access to particular imaging information by multiple users. The processing platform may make instances of the imaging information available to each user for independent or collaborative processing. In this regard, individual users may wish to annotate information corresponding to a particular digital image, for example, to denote the image as having been reviewed, to tag the image for further review at a later time or to identify and/or characterize areas of interest. An annotated copy of the image may then be stored in the repository. The processing platform may further provide a collaboration utility whereby multiple users, e.g., physicians at different locations, can access and manipulate a single image record. Such concurrent access to image information thus enhances access to the information for more efficient or convenient review by individual users and enables collaborative processing with attendant advantages.

According to another aspect of the present invention, digital images are processed in the background, i.e., they are automatically processed, free from specific task-orientated direction by a user, using resources that are not otherwise occupied addressing user-directed tasks. The associated system includes image acquisition equipment for acquiring mammographic images from a patient, image review equipment for displaying images of the patient, and a processor for receiving imaging information from the acquisition equipment, processing the image information and making processed image information available to the image review equipment. The processor runs logic for identifying background tasks for particular images and executing the tasks in the background. The logic identifies at least one task and executes the task free from

concurrent user prompts. In this manner, certain processing can be accomplished without requiring significant waiting time associated with processing from the perspective of the user.

Two important types of background processing that may be supported by the present invention are preprocessing and interim processing. Preprocessing refers to processing of an image that occurs prior to initial review of that image by a physician. As discussed below, such preprocessing may facilitate optimization of the displayed image or review workflow, i.e., the sequencing and timing of image display. Interim processing refers to background processing that occurs during a review session, e.g., in a time period between initial review and a subsequent review of an image. Such preprocessing may be based on monitoring of the review process.

Thus, in accordance with another aspect of the present invention, digital mammographic images are automatically preprocessed prior to initial review by a physician. An associated process involves operating image acquisition equipment to acquire digital image information regarding a patient's breast and store the image information in an image repository, operating a processor to process the image information in background to provide processed image information, and making the processed image information available for subsequent initial review by a physician. The background processing of the image information involves executing at least one task for processing the image information free from any concurrent prompts from a user. A variety of different types of tasks may be performed in this regard including, for example, performing a diagnostic analysis of the image information, associating diagnostic information with the imaging information, optimizing certain display parameters of the imaging information and preparing images for display in accordance with a desired review workflow. In this manner, certain enhancement tasks can be performed prior to initial review by a physician for improved efficiency.

In accordance with a further aspect of the present invention, a mammographic image system is operated to prepare images for more rapid display during a review process. An associated method involves determining an anticipated sequence for an image review session by a physician; accessing an image repository to obtain image information corresponding to the anticipated sequence, and transferring the identified image information to a memory location for rapid display at a selected review station. The anticipated sequence may be determined based on an image review protocol for a particular physician, based on the type of medical process (e.g., mammographic screening

or diagnosis), based on an initial analysis of the images to identify areas of possible interest to a physician, or based on other potentially predictive criteria. The logic for determining the sequence may be resident on an image review platform, a separate server or other location. The identified image information may be transferred to storage associated with the image review platform such as, for example, cache storage or may be retrieved from archive storage and stored in an active image repository. The images thus transferred are available for rapid display on the display terminal or terminals of the review equipment so as to reduce loading delay times otherwise associated with large image files.

According to another aspect of the present invention, mammographic image information is automatically preprocessed for optimized display. An associated process involves accessing image information from an image repository, identifying a display parameter relative to an image review process and optimizing the image information for display in connection with image review equipment based on the identified display parameter. Examples of optimization processes that may be performed in this regard include selecting and optimal monitor setting relative to a luminous range of a display device, optimally filling the viewing area of a display device, filling the available viewing area with a selected portion of the image and displaying the image in a known reference position or orientation to assist the physician in getting oriented to the image perspective. Such optimization logic may be executed by a processor resident at the image review site, at a central server, or at another location. Preprocessing of mammographic image information for optimal display increases the efficiency of the reviewing physician and reduces, eliminates or reverses a perceived disadvantage of digital imaging relative to film-based mammography.

In accordance with a still further aspect of the present invention, annotated instances of a digital mammographic image can be stored in an image repository. The associated mammographic image system includes an image repository; image review equipment for accessing images from the image repository; and logic for associating annotations with the image information to establish annotated image information and storing the annotated image information in the image repository. The annotations may be associated with the imaging information automatically or in response to user prompts. Thus, image information may be processed in background by a CAD utility to identify areas of interest and associate an annotation with those areas of interest. For example, the CAD system may perform a pixel-by-pixel or area-by-area analysis of an image to

identify a potential microcalcification or other area of interest and superimpose a symbol on the image to identify the area of interest and the nature of the potential diagnosis. Alternatively, a physician may tag an image for later review. Thus, for example, a physician may perform an initial review of a large number of images corresponding to all of the patients who were screened on a given day. A subset of these images may be tagged by the physician (e.g., by selecting an appropriate icon or providing another input) for later review. These images can be readily recalled by the physician based on a search for tagged images. It will thus be appreciated that the annotation does not necessarily affect the visual display of the image. Additionally, images may be marked as reviewed, as may be desired.

In another aspect, the present invention comprehends a medical imaging system including a user interface for use in medical imaging applications. The associated medical image may include any image capable of at least generally being utilized to diagnose, treat, and/or observe/manipulate a course of treatment of at least one patient. Examples of appropriate medical images may include, but are not limited to, x-ray images, MRI images, CAT scan images, and the like. In one embodiment, this user interface may be characterized as including an input device such as one or more of a keyboard, mouse, audible input device (e.g., microphone or the like), hand-held controller and/or other appropriate input device(s) capable of enabling a user to define or manage an image acquisition or review process. In another embodiment, the user interface may be characterized as including both an input device and a logic controller (e.g., a programmable logic circuit such as a programmable computer or a "server"). Preferably, this logic controller is capable of being programmed to include one or more image acquisition or review protocols. Such an image acquisition or review protocol generally includes a process utilized to designate/control various parameters of a workflow associated with the acquisition or viewing of the above-described medical images. Where a workflow generally refers to a progression, rate of progression, arrangement and/or sequencing of displaying the medical images. Still another embodiment may be characterized as including an above-described input device and an above-described logic controller, both being separate and distinct components yet, being electrically interconnected in an appropriate fashion.

Still referring to the inventive system of the present invention, the imaging system may also include an interface monitor that is associated with the user interface and/or logic controller. Preferably, this interface monitor is capable of displaying options

relating to the image viewing protocol. Such options may include one or more choices provided to the user to enable the same to select at least one particular workflow parameter for acquiring or reviewing the medical images. For example, the option(s) may include a view selection option that enables selection of at least one of a plurality of
5 viewing angles (e.g., craniocaudal, mediolateral oblique, sagittal, cross-sectional, orthogonal, and the like) of the medical image(s). Even further, the option(s) may include a study selection option that enables selection of at least one medical image corresponding to at least one image procurement date. And still further, the option(s) may include an area selection option that at least generally enables specification/selection
10 of a particular viewing area of at least one medical image. In other words, this area selection option may enable the user to view only one or more desired portions of the image(s). Moreover, this area selection option may also include a magnification feature in which the desired portion(s) of the image(s) to be viewed are magnified. The workflow protocol may also allow a physician to define a sequence for
15 acquiring/reviewing images and a format for displaying the images.

The inventive medical imaging system may also include an image display associated with the user interface. That is, the image display is capable of displaying images, for example, those designated/formatted by the user as a result of utilizing the above-described user interface. Preferably, this image display is capable of displaying at
20 least one digital image. In one implementation, the image display is divided into multiple display areas. One or more images (e.g., digital images) may thus be displayed on a single graphical display. So, for example, first and second graphical displays may be oriented in a side-by-side or bottom-top relationship as may be desired by a reviewer.

Numerous other refinements are also comprehended regarding this inventive
25 system. For instance, an image library may be electrically interconnected with one or both the user interface and the logic controller. The image library may include one or more databases that include medical images (e.g., digital medical images) indexed to patient information. As another possible refinement, the medical imaging system may be equipped with an appropriate image screening program capable of at least generally
30 recognizing and/or indicating image irregularities (e.g., cancerous and/or precancerous tissues/cells). Such image irregularities may include any abnormal tissular presence such as one or more cancerous or precancerous cells, enlarged or anomalous scar tissue formation, tissular fracture(s), tissular strain(s), tissular tear(s), tissular sprain(s) and the like. So, for example, in one embodiment, when the image screening program is utilized

for mammographic medical images, image irregularities such as stellate masses (e.g., with spiculated margins) and/or clusters of microcalcifications (with or without one or more stellate masses) may be one or both displayed and detected.

In another aspect, the present invention generally relates to an inventive method of using a medical imaging system. In one embodiment, the method may include providing an image display protocol independent of a content of images for any particular patient. In other words, the image display protocol may be transferred from patient to patient. This image display protocol generally defines at least one of a sequence and an image layout for a series of display screens, where, a sequence generally refers to the order in which images are arranged for image acquisition or viewing and image layout generally refers to the way in which at least one image is spatially arranged and/or oriented relative to another image or the display screen(s) at any given time. The method of this aspect also includes configuring the medical imaging system for acquiring medical images of patients. In this regard, the method preferably involves programming the medical imaging system to execute the image acquisition or display protocol. So, for instance, a user (e.g., a laboratory technician, nurse, physician, or other appropriate medical personnel or other program) may program the medical imaging system to include a selected protocol. In the case of an image acquisition protocol, an appropriate series of screens associated with a desired acquisition sequence may automatically appear as a user increment through a medical provider. Such screens may be automatically populated with certain information to facilitate acquisition workflow. In the case of image review, first and second images of a first patient can be displayed on at least one of first and second screens of the series of display screens in accordance with the image display protocol.

Various refinements exist of the features noted in relation to this aspect of the present invention. Further features may also be incorporated in the subject aspect of the present invention as well. These refinements and additional features may exist individually or in any combination. For example, inputs (e.g., data entered into the system) defining preferences of a first user may be stored (e.g., in an appropriate database). The image display protocol is preferably established based on these preferences. In one embodiment, the image display protocol may refer to or include a protocol for a specific type of analysis. This analysis may generally refer to a manner in which images are to be acquired, viewed, examined and/or compared. In another embodiment, the image display protocol may refer to or include a protocol for both a specific user and a specific type of analysis. In yet another embodiment, multiple

protocols may be established to define a workflow relative to image acquisition and/or review. These multiple protocols may be established for a single user or for multiple users.

5 With regard to the display of the images, the first and second images may both be displayed on the first screen, or they may each be displayed on separate screens. Moreover, in one embodiment, more than two images may be displayed on at least one of (and preferably both of) the first and second screens. As an example of such an embodiment, each of the first and second screens may be capable of displaying as many as 9 or more images at one time. Accordingly, some embodiments may be characterized
10 as being capable of simultaneously display images on more than one display screen. For example, different images may be simultaneously displayed on the first and second screens. Additionally, multiple images of a given patient may be displayed in a sequential fashion (e.g., successively).

In yet another aspect, the present invention relates to a method of using a medical
15 imaging system such as that described herein. In this aspect a patient selection option for enabling a user to select a database of digital images associated with the patient is displayed. Subsequently, a desired patient is selected from the patient selection option of the imaging system. Moreover, the method of this aspect generally includes displaying an image selection option for enabling a user to select at least one image (e.g., digital
20 image) from the database, as well as actually selecting at least one of the images therefrom. Further, the method of this aspect includes determining at least one of a sequence and a layout of how the image(s) is to be displayed. Still further, the image(s) are generally displayed in a manner that exhibits the determined sequence and/or the determined layout of the images.

25 Various refinements exist of the features noted in relation to this aspect of the present invention. Further features may also be incorporated in the subject aspect of the present invention as well. These refinements and additional features may exist individually or in any combination. For example, the selection of the digital image(s) to be viewed and/or the determination the sequence/layout of the images may be user-specific. That is, each user may be able to dictate/control the sequence/layout of the
30 images as well as which image(s) are chosen for viewing. So, with regard to determining the sequence/layout of the images, a plurality of images may be displayed simultaneously and/or sequentially (e.g., successively). Further, with regard to selecting particular images to be displayed, the images may be craniocaudal views and/or mediolateral oblique views

of the patient. Moreover, the images selected may include first and second images taken at respective first and second times, wherein the second time occurred after the first time.

Various features discussed above in relation to one or more of the aspects of the present invention may be incorporated into any of the other aspects of the present invention as well, and in the manner noted above.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and further advantages thereof, reference is now made to the following Detailed Description, taken in conjunction with the drawings, in which:

Figure 1 is a schematic diagram of a mammographic image acquisition and review system in accordance with the present invention;

Figure 2 is an image acquisition station of the system of Fig. 1;

Figure 3 is an image review station of the system of Fig. 1;

Figures 4A – 4B are front and side views respectively of a monitor of the review station of Fig. 2; and

Figures 5 – 7 are user interface screens used in the system of Fig. 1.

DETAILED DESCRIPTION

In the following description, the invention is set forth in the context of a mammographic image system employing a distributed architecture based on a client server model. In particular, the invention is described below in connection with an implementation at a large medical facility that includes multiple mammographic image acquisition sites and multiple image review sites all associated with a central server and central image repository. While this implementation effectively illustrates the operation and advantages of the present invention, it will be appreciated that the invention is not limited to this implementation or similar contexts. For example, various aspects of the present invention are applicable to environments having a single image acquisition site and/or a single image review site. Additionally, it is not necessary that the acquisition equipment, review equipment and server be located at one site. In this regard, particular elements of the system or combinations of elements may be located at different sites that are interconnected by a wide area network or the like. Also, certain elements of the image processing discussed below may be conducted at an image acquisition site, an image review site, a server site or at another location or may be distributed across

multiple platforms. Accordingly, the description that follows should be understood as exemplary and not as limiting the scope of the invention.

Referring first to Fig. 1, a mammographic image system 100 employing a distributed architecture is schematically illustrated. The system 100 generally includes a number (n) of image acquisition stations 102 and a number (m) of image review stations 110 all of which are associated with a central server 104. It will be appreciated that the number of image acquisition stations 102 and the number of image review stations 110 that may be supported within the mammographic image system 100 is substantially unlimited and the number of image acquisition stations 102 may not be equal to the number of image review stations 110. Indeed, it is anticipated that the numbers of these stations 102 and 110 often will not be equal but will be determined and occasionally changed based on work volume and other needs. Additionally, although a single central server 104 is illustrated, it will be appreciated that the server functionality discussed below may be distributed over multiple machines or platforms.

The image acquisition stations 102 are preferably interconnected to the server 104 by a wide bandwidth connection 103. This connection 103 may be provided as part of a Local Area Network or a Wide Area Network, e.g., a TCP/IP network. In addition, the image review stations 110 are also preferably interconnected to the server 104 by a wide bandwidth connection 107. This connection 107 may also be provided as part of a Local Area Network or Wide Area Network. In the latter regard, the illustrated system architecture allows a physician to review images from a remote location, such as a reviewing station 110 at a physician's office separate from the medical facility that includes the acquisition stations 102, or to review images from multiple acquisition stations 102 located at different medical facilities from one another.

The illustrated server 104 is operative to access an image repository 106 and patient information database 108, as will be discussed in more detail below. It is also operative to access a number of DICOM tools 112 via a standard DICOM interface 109. These tools 112 are schematically illustrated as residing behind a DICOM boundary 114 associated with the interface 109, but may physically reside at a local or remote location. A variety of such DICOM tools are available. The illustrated tools 112 include a picture archiving and communication system (PACS) database 116, a computer aided design (CAD) diagnostic tool 118, printers 120 and a hospital information system (HIS)/radiology information system (RIS) 122.

The stations 102 and 110 will be described in more detail below. The image repository 106 stores image information from the image acquisition stations 102 and the patient information database 108 stores associated patient information. The illustrated repository 106 and database 108, though schematically illustrated as separate components, are configured to form a composite searchable database structure such as a relational database system and may physically be embodied in any of various high-capacity data storage systems, such as a RAID system. That is, the images of the repository 106 are indexed to the patient information of database 108 and the patient information is organized in tables of cross-indexed data fields. Such fields may include information identifying the patient, the x-ray technique involved including dose estimates and compressed breast thickness, the available images, including images from ultrasound, MRI, PET or images of pathology relating to prior or current breast biopsies, the dates of images (study), the facility where the images were acquired, the x-ray technicians involved in the image acquisition, whether the images have been reviewed, any annotations or annotated image versions, the reviewing physician, and any other information that may be of interest.

This database structure may be searched by field(s) using a database management tool associated with server 104. Such tools are well known. For instance, by using such a tool a reviewer at an image review station 110 can query the database structure to obtain all images for a given patient or all such images acquired within a given date range. Alternatively, a physician may obtain all images acquired on a given date, all images for all patients acquired on a given date and associated with a particular acquisition station or stations 102, all images associated with a specific mammographic finding such as microcalcifications, or all images for all patients acquired on a given date and associated with an identified physician. Moreover, the search tool can be used to improve diagnosis or prognosis. In this regard, the database may be searched based in image features such as microcalcifications, mass, mass location etc. such a search may be conducted based on physician annotations, CAD annotations or other indications of the feature of interest. In this manner, similar images or image portions, or files that re otherwise of interest may be readily accessed by using the search tool.

The database structure may be used for purposes other than patient analysis. For example, the database structure may be queried by technician or acquisition site to obtain information regarding work performance or efficiency or to correct any recurring image acquisition or processing errors. The illustrated connection 105 between the server 104

and the repository 106 and database 108 may be, for example, an internal server connection (e.g., a data bus), a LAN connection or a WAN connection.

The illustrated DICOM tools 112 include a picture archiving and communication system (PACS) database 116. This database 116 is used to archive images that do not
5 need to be kept in the repository for immediate access, but which may be desired for review. For example, a physician reviewing images for a patient may wish to review current images together with old images from a prior screening or screenings to identify any changes or signs of advancement of a condition. Such older images may be recalled from the PACS database 116 via the DICOM interface 109. Alternatively, such images
10 may be stored, for example, on a storage device accessible at a review station 110 such as a magneto-optical (MO) drive. In either case, such archiving frees repository resources while providing flexibility for physicians to construct desired review workflows as discussed below. Moreover, the physician workflow protocols and other predictive logic of the system 100 allow the server 104 to predictively retrieve images from the repository
15 106 and database 116 as a background task for prompt display during a review session.

CAD tool 118 may be any of various commercially available, computer-based medical image analysis and diagnostic tools. These tools typically analyze a single image or multiple images, such as on a pixel-by-pixel basis to identify any features that may have diagnostic significance and apply diagnostic algorithms or heuristic engines to
20 determine a possible diagnosis. In the context of mammography, such tools may identify a suspicious mass, e.g., based on a locally reduced detected signal intensity, and may further identify the possible nature of the mass (e.g., microcalcifications) based on features of the mass. Corresponding information may be annotated on the image. For example, a graphic such as a particular geometric shape (e.g., a cone or triangle) may
25 indicate a particular potential condition and the location of the graphic on the image may indicate the location of the condition. A physician may use the graphic to zoom in on or otherwise further review the area of interest. Such an enlarged image may be automatically retrieved or otherwise prepared for display at station 110, e.g., stored in cache at the station 110. Thus, when the physician selects the associated graphic (which
30 may comprise a graphical user interface element superimposed on the image), an associated image may appear instantaneously. This image may be optimized based on the nature of the associated condition of interest, e.g., enlarged, contrast/brightness enhanced, edge detection enhanced, etc.

In accordance with the present invention, the CAD tool 118 can be used for preprocessing images or otherwise automatically processing images, e.g. in the background during a review session. In this regard, the server 104 may be programmed to automatically, upon receiving an acquired image from any of the acquisition stations 5 102, store one instance of the image (e.g., the raw image information) in the image repository and forward another instance or copy of the image to the CAD tool 118. This latter instance of the image may be formatted in accordance with standards of the DICOM interface 109. The image is then processed by the CAD tool 118 as discussed above and the processed image, including CAD annotations, is stored by the server 104 in the image repository 106 and indexed to the original image and corresponding patient information. 10

All of the noted CAD processing can occur automatically prior to the initiation of a review session by a physician. Accordingly, if desired, when the physician enters a query to gather images for a review session, the CAD-processed images may be provided from the image repository. The physician may alternatively or additionally access the 15 raw (unprocessed) image, e.g., for comparison/confirmation purposes.

Similar CAD processing may occur during or after a review session. For example, upon an initial screening of an image, a physician may note a suspicious mass in the patient's breast. The physician may then tag the image or a location on the image for CAD processing so as to obtain the benefit of the CAD diagnostic tool. The user 20 interface of the review station 110 may have defined keystrokes or graphical interface elements to facilitate such tagging. In response to these inputs, the processor of the review station 110 transmits the image or image portion to the server 104 which reformats the image information as necessary and forwards the information to the CAD tool 118 for analysis.

25 The server 104 or a processor of the review stations 110 may execute predictive algorithms, in connection with the noted CAD processing or otherwise, to anticipate the needs of the reviewing physician and improve workflow. In connection with CAD processing, the server 104 may monitor CAD processed images to anticipate such needs and automatically, as a background task, prepare enhanced images for display. For 30 example, where a CAD annotation is included in the processed image indicating and characterizing a potential condition of interest, an enlarged view of the relevant image section with display parameters (e.g., contrast, brighteners, and enhanced edge definition) appropriate for the characterized condition may be prepared for automatic display on a monitor of the station 110 or may be stored for display upon receiving a prompt from the

user. As discussed below, images may be prepared for display in a similar fashion based on protocols defined for a user, user type, review type or the like. Such protocols may also be developed or supplemental for a particular physician or on a user independent basis, using logic to monitor acquisition and review processes to empirically or
5 heuristically learn patterns that may be used to predict physician needs.

The DICOM tools 112 also include printers 120 in the illustrated embodiment. These printers 120 receive image information via the DICOM interface 109 and provide hard copies of the images, e.g., on paper or transparencies for review on a light box or the like. This allows physicians the option of reviewing hard copy images and facilitates
10 patient discussions in an office environment.

The HIS/RIS tool 122 provides access to HIS/RIS systems. The HIS/RIS systems include databases of patient information such as appointment dates and times and other information that may be imported into the patient information database 108 and used for populating fields of the image acquisition and image review protocols as discussed below,
15 as well as in fashioning queries for image information. This information is readily handled by the processor 104 based on the DICOM standard. As will be appreciated by those skilled in the art, DICOM (Digital Imaging and Communications in Medicine) provides an industry standard for the exchange of digital imaging related information.

The server 104 or processors of the image review stations 110 may also execute
20 logic for image display optimization. Such optimization may relate to optimally using the available display area for displaying the selected images (e.g. selecting a landscape, portrait, or other orientation, sizing the images, selecting zoom settings and image portions, and establishing a reference position or orientation for images to assist the physician), optimally setting display parameters (brightness, contrast, edge enhancement,
25 etc.) or optimizing any other display-related characteristics. It will be appreciated that patient images may include imaging such as ultrasound, MRI, PET, or other molecular techniques relating to the specific patient undergoing radiologic review. Such functionality may be executed based on defined workflow protocols, CAD, or other annotations or other information available to the relevant processor(s). In this regard,
30 optimization of a luminescence setting may be performed relative to a specific image or image portion. This may depend on a number of factors. For example, a human's ability to distinguish shades is dependent on the location of such shades within a gray scale range. That is, the ability to discern shades is not a linear function with respect to gray scale such that a given shade increment may be more readily distinguished by a viewer at

a given point on the gray scale than the same increment at a different point on the gray scale. Presenting the image at an optimized luminescence may therefore enhance the viewer's ability to distinguish features of interest. So, the luminescence setting may be selected based on CAD or physician annotations indicating a condition of interest and
5 may also take into account tissue density, source settings, exposure and other factors affecting optimal display parameters. Such display optimization may also take into consideration the size and resolution of the display as well as the display's aspect ratio including, in the case of rotatable displays as discussed below, whether the display is currently in a landscape or portrait orientation.

10 Additionally, special filtering may be used to optimize display parameters relative to specific areas of an image. For example, specific zoom or enlarged views of particular image areas may be provided, for example, based on a CAD annotation indicating a condition of potential interest. Moreover, the image resolution may be varied based on a feature of interest associated with a specific image area. Thus, a 25mm resolution (as is
15 available in the noted SenoScan system of Fischer Imaging) may be provided for an image area where microcalcifications are indicated and a lesser resolution may be provided for areas where a mass is indicated or where no annotation is indicated. This allows for reducing the size of the image file to be loaded so as to improve processing speed while providing high resolution where it may be desired. Relatedly, a high resolution mode or
20 lower resolution mode may be determined by the processing logic for an overall image, or may be selected by a user as part of a protocol definition.

As noted above, the server 104 may store multiple instances of an image in the repository 106. Such instances may include CAD-processed images and user annotated instances. A user may annotate an image to mark the image as reviewed, identify areas of
25 interest on the image, or include other information. The annotations or markings are specifically tagged to the physician or technologist creating a record including all other relevant parameters such as date, time, location, etc. Additionally, a user may utilize the server 104 to store a user-processed image or image portion that is enlarged, edge-enhanced, or otherwise modified based on user inputs. Alternatively, image modification
30 information may be stored and indexed to an image so that modified images can be constructed as needed. Relatedly, high resolution and lower resolution versions of an image may be used for different purposes. For example, a high resolution version may be provided to a CAD system for enhanced analysis and a lower resolution version may be provided to a review station for display so as to reduce the file size and loading times.

The server 104 may also make a single image or copies of the same image available to multiple review stations 110. This may be desired for concurrent independent work or collaborative work. In the latter regard, the server 104 may include conventional collaboration logic for allowing multiple users to work on a common document and see changes entered by the other collaborator(s). Such collaboration may improve diagnosis.

An example of an acquisition station 200 is illustrated in Fig. 2. The station 200 generally includes an imaging device 202 and a control module 204. The illustrated imaging device 202 is an x-ray-based mammography system such as the SenoScan system marketed by Fischer Imaging Corp. of Thornton, Colorado. Such imaging systems generally include an imaging source 206 such as an x-ray tube, an imaging detector 210 such as a direct x-ray detector or a phosphorescent element associated with a light detector. The illustrated device 202 further includes a compression paddle 208 that is vertically movable to immobilize and flatten, to an extent, the patient's breast for improved imaging. The paddle 208 is preferably substantially transparent to the imaging signal. In the case of the noted SenoScan system, the source 206 can be rotated to scan a fan beam of x-rays across the patient's breast. The detected x-rays are then electronically combined to form a substantially full field composite image of the patient's breast. The illustrated processing module 204 includes a user interface 214 such as a keyboard and mouse for receiving user inputs, a local monitor 212 for displaying near real-time images acquired by the device 202 and a processor 216.

During a screening procedure, a physician or clinician may direct the process via inputs using the user interface 214. The inputs may identify the patient, the image projection view, the examination date, certain imaging parameters and any other information of interest. The interface 214 can also be used to initiate exposures and otherwise manage the image acquisition workflow. These inputs are received by the processor 216 which operates the imaging device 202, directly or in response to inputs from a server. The processor 216 also receives digital image information from the detector 210 and executes logic for forming a composite image for display on the monitor 212 and transmits the image information together with associated patient data and any other desired information to the server 104 (Fig. 1).

Fig. 3 schematically illustrates an image review station 300. The illustrated image review station 300 includes a workstation 302, a processor 308 and display monitors 310. More specifically, the workstation 302 includes a user interface 304 such as a keyboard

and mouse for allowing a user to manage workflow during an image review session. The workstation 302 also includes a display 306 for displaying certain information and managing review session workflow as will be discussed in more detail below. Based on input from the workstation 302 the processor 308 causes images 312 to be displayed in the display area of the monitors 310. The illustrated monitors are high-resolution large format monitors. The monitor display area may be divided into multiple regions for displaying multiple images as may be desired by a physician.

As noted above, the mammographic image system may include at least one monitor, e.g., at an acquisition station or review station, that is rotatable. A physician may desire to rotate a monitor so as to obtain a different viewing area aspect ratio for viewing images arranged in a particular pattern or format. Such a rotatable monitor 400 is generally illustrated in Figs. 4A and 4B, the illustrated monitor 400 includes a flat panel display 402 mounted on a rotatable mount 404 that communicates with a processor 406 of a review station via a communications link 408. The mount 404 allows the display 402 to rotate between at least landscape (shown in phantom in Fig. 4A) and portrait orientations. In this regard, the mount 404 preferably includes recesses, detents or the like for registering and locking into each of the orientations in lazy-Susan fashion.

The orientation of the illustrated display 402 is reported to the processor 406 via link 408. For example, where the mount 404 includes a detent associated with each of the orientations, the orientation of the screen may be detected based on deployment of the detent associated with position registration (which may be converted to an electric signal via a contact switch). More sophisticated feedback mechanisms such as involving encoders may be employed to provide detection of a range of orientations. In any event, this orientation information can be used by the processor 406 or the server to appropriately orient displayed images, e.g., to orient images so that annotations or markings are right-side-up or to otherwise provide the desired image orientation with due regard for the current display orientation. Moreover, the display orientation may be automatically taken into consideration in sizing or orienting images so as to optimally utilize the display area. The display orientation may also be defined by a physician as part of an image review protocol. A motor 410 may be provided to automatically rotate the monitor 402 to the desired orientation. Moreover, the orientation of the monitor may be selected by the user as part of a protocol definition or selected by processing logic, e.g., to optimize monitor space utilization for a given layout of multiple images.

In connection with the monitors of the image acquisition stations and the image review stations, a number of screens may be provided to enable the user to define patient studies, and define workflows. Figs. 5 - 7 illustrate exemplary user interface screens in this regard. It will be appreciated that alternate user interface implementation may be used to provide corresponding functionality. The logic for defining the screens, receiving and processing inputs from the screens and implementing associated functionality may be performed at an image acquisition/review station or at a server(s) or may be distributed as between the station and server(s).

Referring to Fig. 5, a projection screen 500 is illustrated. This screen is used to set the image projection preferences by type and sequence, for example, for each individual user, station, or type of user or procedure. It should be noted that images may include ultrasound, MRI, PET or other image data associated with the patient under review. In the case of user-specific protocols, the preferences set on this screen are automatically associated with the specific user when that particular user accesses the acquisition screen. This causes the exam to automatically increment to the next projection in sequence as each projection is selected.

The users drop down menu 502 shows the users and types of users that have been authorized to operate the image acquisition equipment. Users listed in this menu have been previously stored in the database.

To establish a projection listing for a particular user, the name of the user can be selected from the drop down menu to cause the selected name to appear in the header field at the top of the menu. The user may then construct the sequence listing for the selected user by using several of the illustrated screen features.

The user's sequence listing 504 shows the types of projections selected for association with the indicated user. The selections are added to the user sequence listing by selecting the projection attributes from the laterality 506, view 508, and modifier's 510 drop down menus and then clicking on the add button 512. Projections can be revised, added, removed, or reordered in this listing until the screen entries are saved into the system database by means of the save button 514. As the listing is being added to, the order in which a particular projection appears in the sequence can be changed by first selecting the projection in the listing, then clicking on the move up or move down button 516 as required.

The laterality drop down menu 506 allows the user to select the laterality of the projection. Selections include left, right, and both.

The view drop down menu 508 allows the user to select the view that is to be combined with the laterality as selected from the laterality drop down menu 506. The views that may be selected include medio-lateral, medio-lateral oblique, latero-medial, latero-medial oblique, cranial-caudal, cranial-caudal from below, superolateral to inferomedial oblique, CC exaggerated, CC exaggerated laterally, and CC exaggerated medially.

The modifiers drop down menu 510 allows the user to further modify the laterality and view selected. The modifiers that may be selected include magnification, cleavage, axillary tail, rolled lateral, rolled medial, rolled superior, rolled inferior, implant displaced, spot compression, and tangential.

The add button 512 allows the user to add the projection, as thus defined, to the user's sequence listing.

The move up and move down buttons 516 allow the user to change the order in which the selected projections appear in the user's sequence listing 504. The remove button 518 allows the user to remove a projection from the user's sequence listing 504. Finally, the save button 514 saves the projection list for the indicated user to the system database.

Fig. 6 illustrates a screen 600 that can be used to program one or more preferred workflow sequences into the system for each user, type of user, or type of examination/study. These sequences can be used during image acquisition to automatically select the patient lists and ordering of patients at the appropriate acquisition workstation for each exam. During exam review, the workflow sequence automates the display of selected exam images on the review station monitors. It will be appreciated that these workflows may be used by the server to retrieve images from the image repository and download the appropriate images to the review workstation. The review workstation processor may load these images in sequence in cache so that the images can be quickly displayed, thereby reducing review timeframes. Workflows may also be constructed during image acquisition or image review by a user while in the patient information screen at either the acquisition or the review workstation.

The process for defining workflows may be understood by reference to the workflows screen 600 as shown in Fig. 6. Generally a workflow includes a filter of patients (e.g., all patients who had exams on a given day), a filter of the studies for a particular patient (e.g., the current study plus the study from the previous year), and a sequence of display protocol. Construction of a new workflow begins with the selection

of the user associated with the workflow. This selection is made from the users select menu 602. The selected user may be an individual registered to use the system, or a type of user, such as administrator, technologist, or physician.

5 The new workflow button 604 is used to enter a descriptive name for the new workflow configuration. From the patient progression area of the screen, the patients, studies, and viewed criteria that is to be used to select images for the new workflow can be selected. These selections determine the category of patients, the number of studies per patient, and which of the previous studies are to be selected.

10 The user may then define the protocol that is to be used for the first image projection and the new workflow. This protocol defines the overall configuration and progression of image formats that will be automatically displayed in sequence as the user increments through the review session. To define this protocol, the user selects the type for the first image display. The types that may be selected include blank, selected, or custom. If the user selects custom, the user may then specify the number of images that
15 are to be displayed on the screen, by the number of rows and columns in which the exam images will be displayed. For example, the user can specify a screen display that can accommodate any desired format including ranges from, for example, one row by one column for a total of one image, up to three rows by three columns for a total of nine images in one implementation. It will be appreciated that images selected in this manner
20 for display may include ultrasound, MRI and PET images relating to the patient undergoing review. The user may also select other image modifications that impact the workflow display format, such as view, tools, and zoom.

The user may then select the study number from which the images are to be selected for inclusion in the workflow. The display select menu 606 can then be used to
25 select the display on which this image and the workflow is to be displayed. Once all the selections and image modifications have been made, the add button 608 can be used to add the current image configuration to the workflow. A box will appear in the display field selected from the display select menu 606. Each time the above process is repeated a new box will be displayed in the selected display field. If a specific projection is to be
30 displayed at a particular step in the workflow sequence and on a particular display, it may be selected from the projection field and dragged to the desired location.

The screen illustrated in Fig. 6 includes a number of features for assisting in the workflow definition. The users select menu 602 shows the users and types of users that have been authorized to operate the system. These are the same users that have been

stored in the system database as discussed above. The workflow listing 610 displays the default screening and diagnostic workflows and any custom workflows that have been created for specific users or types of users. The new workflow button 604 is used to initiate the construction of a new workflow. The description field 612 allows the user to enter a name for the new workflow that is being created.

The patients select menu 614 allows the user to select a category of patients to be filtered by the workflow algorithm. Available selections include all today's work, all pending work, all today's unread, all pending unread, user's today's work, and user's pending work. The studies select menu 616 provides a listing of studies from which images may be selected. The viewed select menu 618 allows the user to select images from specific exam histories that are to be included in the workflow. In this regard, it will be appreciated that particular users may wish to review current images against images from prior exams. The study number menu 620 allows the user to specify the exam study histories from which the images are to be obtained. These selections correspond to the number of exams for which images are available. The projection field 622 displays the projections that exist for each patient exam included in the studies selected for inclusion in the workflow.

The protocol may be defined in relation to any number of monitors that may be provided at an image review station. In this regard, the illustrated display 1 and display 2 fields 624 and 626 display the constructive workflow for a two monitor station. The workflow is presented as a series of blocks, each block representing a single screen display. The actual format or configuration of each block in the workflow is determined by the type, view, tools, zoom, and display selections selected by the user prior to adding the block to the workflow.

The display select menu 606 allows the user to select the display field into which the next workflow element will be added. This determines which monitor will display the image currently being added to the workflow sequence.

The type select menu 626 allows the user to specify the type of display to be added to the workflow sequence. Selections include blank, selected, and custom. If blank is selected, the specified monitor will display a blank screen for this step in the workflow. If selected is chosen, the specified monitor displays the image format that is the next image in the selected study for this step in the workflow or the image selected by the current button press to provide the desired enhancement, e.g., full resolution display. If custom is chosen, the specified monitor will display the image display format that

meets the criteria established by this workflow. When custom is selected, the rows 628 and columns 630 buttons are active. The rows button 628 determines the number of rows of images that will be displayed on the monitor and the column button 630 determines the number of columns.

5 The view select menu 632 allows the user to specify how the image is fitted to the display. Selections include full resolution, fit window (“auto size”). In this manner, the available monitor space can be effectively utilized, with due regard for monitor orientation in the case of rotatable monitors.

10 The tools select menu 636 allows the user to select tool features that are to be applied to the image when it is displayed. The tools that may be selected include zoom, processed, annotation, CAD, patient information, invert, flip horizontal, flip vertical.

 The zoom select menu 636 is used when the zoom tool is active to select a zoom multiplier. For example, zooms of 2X thru 6X may be selected.

15 When a user has made all the desired selections and modifications for the next element to be added to the workflow, the add button 608 may be used to save the element definition. The remove button 638 may be used to delete an element from the workflow. Finally, once the user is satisfied with the formatting and sequencing of the workflow, the save workflow button 640 can be used to save the workflow into the system database. It will be appreciated that this workflow information may be used for retrieving and caching
20 images for improved image review efficiency. The remove workflow button 642 is used to remove an entire workflow from the system database. A start button (not shown) can be used to start a newly selected workflow sequence.

 Fig. 7 illustrates a user interface screen 700 that allows the user to define the search criteria used to create the work list of patient examinations from appointment
25 information that has been entered into the facility’s HIS/RIS system. To create a work list, the user enters the date and time of the first and last scheduled appointments to appear on the work list and selects import. All scheduled appointments that fall within the date/times entered into the start date and end date fields will be imported into the system database from the HIS/RIS system. This screen 700 can be used to set work list
30 criteria for acquisition station and review station operations. In this regard, the server may be utilized to access the HIS/RIS system and thereby define such operations.

 Fig. 7 illustrates a number of screen features for the work list screen. The start date field 702 is used to enter the date and time for the first scheduled patient exam to appear on the work list. The end date field 704 is used to enter the last scheduled exam

that is to appear on the work list. The patient reference number field 706 allows for searching the HIS/RIS database for the patient exam identified by the reference number entered into the field. This allows a user to access a specific patient record. The patient reference number check box 708 is used to enable a search for the patient record associated with the reference number entered in the patient reference number field. The station HIS/RIS identification name drop down menu 710 allows the user to select the workstation where the extracted work list will be used. The HIS/RIS provider drop down menu 712 allows the user to select the HIS/RIS database from which the patient appointment work list will be extracted. The user to assign selected work items pop up menu 714 allows the user to select the user to which the work list is assigned. All users authorized to use the system are included in the pop up menu selections. Finally, after all field entries have been made, an import button (not shown) is used to import the results of the work list search into the system database.

Those skilled in the art will now see that certain modifications can be made to the apparatus and methods herein disclosed with respect to the illustrated embodiments, without departing from the spirit of the instant invention. While the invention has been described above with respect to the preferred embodiments, it will be understood that the invention is adapted to numerous rearrangements, modifications, and alterations, and all such arrangements, modifications, and alterations are intended to be within the scope of the appended claims.

What is claimed:

1. A mammographic imaging system, comprising:
 - a) a first mammographic image acquisition station including:
 - 1) an imaging source for transmitting an imaging signal relative to a patient's breast;
 - 2) a digital detector for detecting said transmitted signal from said patient's breast and providing a digital signal based on said received signal, wherein said digital signal defines a first digital image of at least a portion of said patient's breast;
 - 3) an image acquisition station user interface for receiving image acquisition inputs from a first user of said mammographic image acquisition station to control a process for acquiring said first digital image of said patient's breast;
 - 4) at least one image acquisition station monitor for displaying a first displayed image corresponding to said first digital image; and
 - 5) an image acquisition station controller for receiving said image acquisition inputs and operating said imaging source and digital detector at least partially in response thereto, said image acquisition controller further being operative for providing said first digital image to an image repository for storing digital images;
 - b) a remote mammographic image review station disposed at a location separate from said mammographic image acquisition station, including:
 - 1) a first image review station user interface for receiving image review inputs from a second user of said mammographic image review station, the same or different than the first user, to control a process for reviewing digital mammographic images;
 - 2) an image review station controller for receiving said image review inputs, said image review controller being operative to access said image repository in response to said image review inputs to obtain first information corresponding to said first digital image; and
 - 3) at least one image acquisition station monitor, operatively associated with said image review controller for displaying a second displayed image corresponding to said first digital image based on said first obtained information.

2. A mammographic imaging system as set forth in Claim 1, further comprising a second image acquisition station separate from said first image acquisition station, for use in obtaining a second digital image of a second patient's breast and providing said second digital image to said image repository.

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3. A mammographic imaging system as set forth in Claim 2, wherein said first image review station is operative for accessing said image repository to obtain said second digital image acquired at said second image acquisition station.

10 4. A mammographic imaging system as set forth in Claim 1, further comprising a second image review station separate from said first image review station, for use in accessing said image repository to obtain second information, the same or different than said first information, corresponding to said first digital image and displaying a third displayed image corresponding to said first digital image based on said second obtained
15 information.

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5. A mammographic imaging system as set forth in Claim 4, wherein said first and second image review stations are operative to concurrently display said second and third images corresponding to said first digital image.

6. A mammographic imaging system as set forth in Claim 1, wherein said image repository is associated with a processing platform separate from each of said first image acquisition station and said first image review station.

25 7. A mammographic imaging system as set forth in Claim 6, wherein said processing platform is operative for accessing at least one tool, executed in a processor separate from all of said processing platform, said image acquisition station and said image review station, wherein said tool is useful for one of image acquisition, image processing and image review.

30

8. A mammographic imaging system as set forth in Claim 7, wherein said tool comprises a database tool for accessing a database of patient information.

9. A mammographic imaging system as set forth in Claim 7, wherein said tool comprises a diagnostic tool for processing digital imaging information for diagnostic purposes.
- 5 10. A mammographic imaging system as set forth in Claim 1, wherein said image repository is associated with image information indexed to image information fields and said system further comprises a database tool associated with said image repository for searching said image information based on said information fields.
- 10 11. A mammographic imaging system as set forth in Claim 1, further comprising a diagnostic tool for preprocessing said first digital image for diagnostic purposes independent of any associated user command, such that preprocessed image information is automatically available for use by said second user.
- 15 12. A mammographic imaging system as set forth in Claim 1, further comprising a collaboration tool associated with said image repository for enabling collaborative review of said first digital image by multiple users at multiple review stations.
13. A mammographic imaging system, comprising:
- 20 an input port for receiving digital mammographic images from multiple mammographic image acquisition stations;
- a processor for use in storing said mammographic images in an image repository and providing access to said image repository; and
- an output port for use in outputting one or more of said mammographic images to
- 25 multiple mammographic image review stations.
14. A mammographic imaging system as set forth in Claim 13, wherein said mammographic image information includes first information defining first digital image and second information associated with said first digital image and said processor is
- 30 operative for separately storing said first and second information in a database where said second information is indexed to said first information such that said second information can be used by a search tool to access said first information.

15. A mammographic imaging system as set forth in Claim 13, wherein said processor is operative for accessing at least one tool, executed on a platform separate from said processor, wherein said tool is useful for one of image acquisition, image processing and image review.

5

16. A mammographic imaging system as set forth in Claim 13, wherein said processor is operative for accessing a diagnostic tool for preprocessing a first digital image for diagnostic purposes independent of any associated user command, such that preprocessed image information is automatically available for use by a second user the same or
10 different than the first user.

17. A mammographic imaging system, comprising:
a number, n , of mammographic image acquisition stations, each said image acquisition station including an imaging source for transmitting an imaging signal relative
15 to a patient's breast, a digital detector for detecting said transmitted signal from said patient's breast and providing a digital signal based on said received signal, wherein said digital signal defines a first digital image of at least a portion of said patient's breast; and
a number, m , of mammographic image review stations, wherein each said mammographic image review station includes a monitor for displaying mammographic
20 images acquired at one or more of said mammographic image acquisition stations and a controller for controlling the display of mammographic images on said monitor;
wherein m is different from n .

18. A mammographic imaging system, comprising:
25 an image repository for storing mammographic images obtained at multiple mammographic image acquisition stations and associated imaging information, said imaging information identifying at least a patient, a study and a mammographic view associated with each of said mammographic images, wherein said image information is indexed to a number of predefined image information fields; and
30 a database tool associated with said image repository for searching said image information based on said information fields;
wherein said image repository can be searched based on said predefined fields so as to access corresponding digital images.

19. A mammographic imaging system, comprising:

mammographic image acquisition equipment including a patient support for supporting a patient's breast in an imaging position, an imaging source for transmitting an imaging signal relative to said patient's breast, and a digital detector for detecting said transmitted signal from said patient's breast and providing a digital signal based on said received signal, wherein said digital signal defines a first digital image of at least a portion of said patient's breast;

an image acquisition station user interface for receiving user inputs from a first user of said mammographic image acquisition station to control a process for acquiring said first digital image of said patient's breast; and

an image acquisition station controller, said controller being operative for:

receiving said user inputs from said image acquisition station user interface;

transmitting a controller output based on said user inputs to a remote processing platform, wherein said remote processing platform executes logic for use in operating said mammographic image acquisition equipment;

receiving a controller input from said remote processing platform; and

operating said mammographic image acquisition equipment based on said controller input from said remote processing platform.

20. A mammographic imaging system, comprising:

mammographic image review equipment including a user interface for receiving user inputs from a user to control a process for reviewing digital mammographic images and at least one monitor for displaying mammographic images; and

a mammographic image review station controller operative for:

receiving the user inputs from the image review equipment;

transmitting a controller output based on said image review inputs to a remote processing platform, wherein said remote processing platform is operative to execute logic for controlling said image review equipment;

receiving a controller input from said remote processing platform; and

operating said mammographic image review equipment based on said controller input from said remote processing platform.

21. A method for use in managing digital mammographic image information, comprising the steps of:

receiving, at a processing platform, digital images from multiple mammographic image acquisition stations;

5 storing the received mammographic images in an image repository associated with the processing platform;

receiving, at the processing platform, queries from the multiple mammographic image review stations;

10 processing, at the processing platform, the queries to obtain responsive mammographic image information; and

transmitting the responsive mammographic image information from the processing platform to the mammographic image review stations.

22. A method of using a medical imaging system, comprising:

15 first displaying a patient selection option for enabling a user to select a data base of images associated with said patient;

first selecting a desired patient from said patient selection option of said imaging system;

20 after said first selecting step, second displaying an image selection option for enabling a user to select at least one image from said database;

second selecting said at least one image;

determining at least one of a sequence and a layout of how said at least one image is to be displayed; and

25 third displaying said at least one image in accordance with said determining step.

23. A medical imaging system, comprising:

a user interface programmed to comprise a user-specific image viewing protocol;

30 an interface monitor electrically interconnected with said user interface, wherein said interface monitor is at least capable of displaying options relating to said image viewing protocol;

an image display operatively associated with said user interface, wherein said image display is capable of displaying at least one digital image.

24. A medical imaging system, as claimed in Claim 23, wherein:
said image display is divided into first and second graphical displays, wherein said first graphical display is separate and distinct from said second graphical display.
- 5 25. A medical imaging system, as claimed in Claim 23, wherein:
said options relating to said image viewing protocol comprise a patient selection option, wherein said patient selection option enables selection of digital images corresponding to at least one of a plurality of patients.
- 10 26. A medical imaging system, as claimed in Claim 23, wherein:
said options relating to said image viewing protocol comprise a view selection option, wherein said view selection option enables selection of at least one of craniocaudal and mediolateral oblique digital images.
- 15 27. A medical imaging system, as claimed in Claim 23, wherein:
said options relating to said image viewing protocol comprise a time selection option, wherein said time selection option enables selection of at least one digital image corresponding to at least one image procurement date.
- 20 28. A medical imaging system, as claimed in Claim 23, further comprising:
a digital image library electrically interconnected with said user interface, wherein said digital image library comprises a plurality of digital images.
- 25 29. A method of using a medical imaging system, comprising:
providing a patient-independent image protocol defined independent of a content of images for any particular patient, said protocol defining at least one of a sequence and an image layout for a series of images of a medical image procedure;
programming said medical imaging system to comprise said image display protocol; and
- 30 operating said medical imaging system to control a particular medical imaging procedure for a particular imaging study in accordance with said protocol.
30. A method as set forth in Claim 29, further comprising the step of storing multiple image protocols for multiple users of said medical imaging system.

31. A method as set forth in Claim 29, further comprising the step of storing multiple image protocols for a single user of said medical imaging system.

32. A method as set forth in Claim 29, further comprising the step of storing multiple
5 image protocols corresponding to multiple types of medical imaging procedures.

33. A method as set forth in Claim 29, wherein said medical image procedure involves acquiring a number of different images for a patient and said protocol defines a sequence for acquiring said images.

10

34. A method as set forth in Claim 29, wherein said medical image procedure involves reviewing a number of images and said protocol defines a sequence for displaying said images on at least one display device.

15 35. A method as set forth in Claim 29, wherein said medical image procedure involves reviewing a number of images and said protocol defines a layout for concurrently displaying multiple ones of said images on a first display device.

36. A method as set forth in Claim 29, wherein said medical image procedure
20 involves reviewing a number of images and said protocol defines an orientation for each of said images on a display area of a display device, wherein an orientation of a first one of said images is different than a second one of said images.

37. A method as set forth in Claim 29, wherein said medical imaging system
25 comprises a first display device having a first display area and a second display device having a second display area.

38. A method as set forth in Claim 37, wherein said protocol defines a layout of images in each of said first and second display areas.

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39. A method as set forth in Claim 37, wherein said protocol defines a sequence of images in each of said first and second display areas.

40. A method as set forth in Claim 37, wherein said protocol defines images for concurrent display in said first and second display areas.

41. A method as set forth in Claim 29, wherein said protocol defines a content of one
5 or more of said images.

42. A method as set forth in Claim 41, wherein said content is defined based on a preference relating to available image enhancement options.

10 43. A method as set forth in Claim 42, wherein said image enhancement options relate to presentation of an image with diagnostic information.

44. A method as set forth in Claim 42, wherein said image enhancement options relate to presentation of an image with optimized display parameters.

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45. A mammographic imaging system, comprising:

mammographic image acquisition equipment, including an imaging source for transmitting an imaging signal to a patient's breast, a detector for receiving said transmitted signal from the patient's breast and providing a digital signal based thereon,
20 said digital signal defining a first digital image of at least a portion of said patient's breast;

at least one processor for obtaining first image information including information corresponding to said first digital image, automatically processing said first image information to provide first processed image information different from said first image
25 information and making said first processed information available for review by a user;

said at least one processor running logic, in connection with said automatic processing, for identifying at least one task to be executed in connection with said first image information for controlling a display of said first image information, and executing said task to provide said first processed information, said task being automatically
30 identified and executed by said at least one processor free from any concurrent user prompts related to said task; and

mammographic image review equipment including at least one monitor for displaying a mammographic image based on said first processed image information.

46. A mammographic imaging system as set forth in Claim 45, wherein said at least one processor is operative for performing said automatic processing prior to initiation of an image review session by a user.

5 47. A mammographic imaging system as set forth in Claim 46, wherein said at least one processor is operative for performing said automatic processing during an image review session by a user.

48. A mammographic imaging system as set forth in Claim 45, wherein said at least
10 one processor is operative for performing said automatic processing by employing a diagnostic tool for processing said first digital image for diagnostic purposes.

49. A mammographic imaging system as set forth in Claim 45, wherein said at least
15 one processor is operative for performing said automatic processing by associating diagnostic information with said first image information to provide said first processed image information.

50. A mammographic imaging system as set forth in Claim 45, wherein said at least
20 one processor is operative for performing said automatic processing so as to optimize a display of said first image information by said mammographic image review equipment.

51. A mammographic imaging system, comprising:

mammographic image acquisition equipment, including an imaging source for
transmitting an imaging signal to a patient's breast, a detector for receiving said
25 transmitted signal from the patient's breast and providing a digital signal based thereon,
said digital signal defining a first digital image of at least a portion of said patient's breast;

at least one processor for obtaining first image information including information
corresponding to said first digital image, automatically preprocessing said first image
30 information to provide first preprocessed image information different than said first
image information, and making said first preprocessed information available for review
by a user;

said mammographic image review equipment being operative by a user for
supporting a review session by the user involving the review of one or more images, said

review sessions being initiated by said user by entering a command to access said system and being terminated by said user by entering a command to exit said system, and said processor is operative for performing said automatic preprocessing prior to initiation of said image review session by said user;

5 said at least one processor running logic, in connection with the automatic preprocessing, for identifying at least one task to be executed in connection with said first image information for controlling a display of said first image information and executing said task to provide said first preprocessed information, said task being automatically identified and executed by said at least one processor free from any concurrent user
10 prompts related to such task; and

 mammographic image review equipment including at least one monitor for displaying a mammographic image based on said first processed image information.

52. A mammographic imaging system, comprising:
15 an input port for receiving a request from a mammographic image review station;
 a processor for receiving said request and managing a workflow of a review session associated with said request, said processor being operative to identify an image based on said desired workflow independent of any concurrent user input identifying said image and move said image from a first storage location to a second storage location,
20 prior to a time for displaying said image according to said workflow, so as to facilitate rapid display of said image.

53. A mammographic imaging system as set forth in Claim 52, wherein said processor is operative to move said image from an image repository associated with a server to an
25 image review station.

54. A mammographic imaging system as set forth in Claim 52, wherein said processor is operative to move said image from an image archive to an image review station.

30 55. A mammographic imaging system as set forth in Claim 52, wherein said request identifies a protocol for presentation of multiple images and said processor is operative for sequentially moving said multiple images from said first storage location to said second storage location in accordance with said protocol.

56. A mammographic imaging system, comprising:
storage for storing at least a first digital mammographic image;
a monitor for viewing mammographic images, said monitor being rotatable
between a first angular orientation and a second angular orientation different than said
5 first angular orientation;
a processor operative for retrieving said at least first digital mammographic image
from said memory and controlling operation of said monitor to display said first digital
mammographic image, said controller further being operative for receiving an input
indicating a current angular orientation of said monitor and controlling the display of said
10 at least first digital mammographic image based on said input.
57. A mammographic imaging system as set forth in Claim 56, wherein said monitor
has an available display area for displaying said at least one image and said processor is
operative for fitting said at least one image to said available display area such that
15 substantially an entirety of said at least one image is displayed in a desired image
orientation.
58. A mammographic imaging system as set forth in Claim 56, further comprising a
sensor for sensing an angular orientation and providing a signal to said processor
20 indicative thereof.
59. A mammographic imaging system as set forth in Claim 56, wherein said monitor
has a display area that has a generally rectangular configuration including a minor
dimension and a major dimension greater than said minor dimension, and said monitor is
25 moveable between a portrait orientation, wherein said major dimension has a substantially
vertical orientation and a landscape orientation, wherein said major dimension has a
substantially horizontal orientation.
60. A method for use in processing mammographic imaging information, comprising:
30 receiving at least a first digital mammographic image from a mammographic
image acquisition station;
automatically processing said digital mammographic image free from any
concurrent user prompts by identifying at least one task to be executed in connection with
said at least first digital mammographic image relating to a display of said at least first

mammographic digital image and executing said task to provide at least a first processed mammographic image; and

outputting said at least first processed mammographic image to a mammographic image review station.

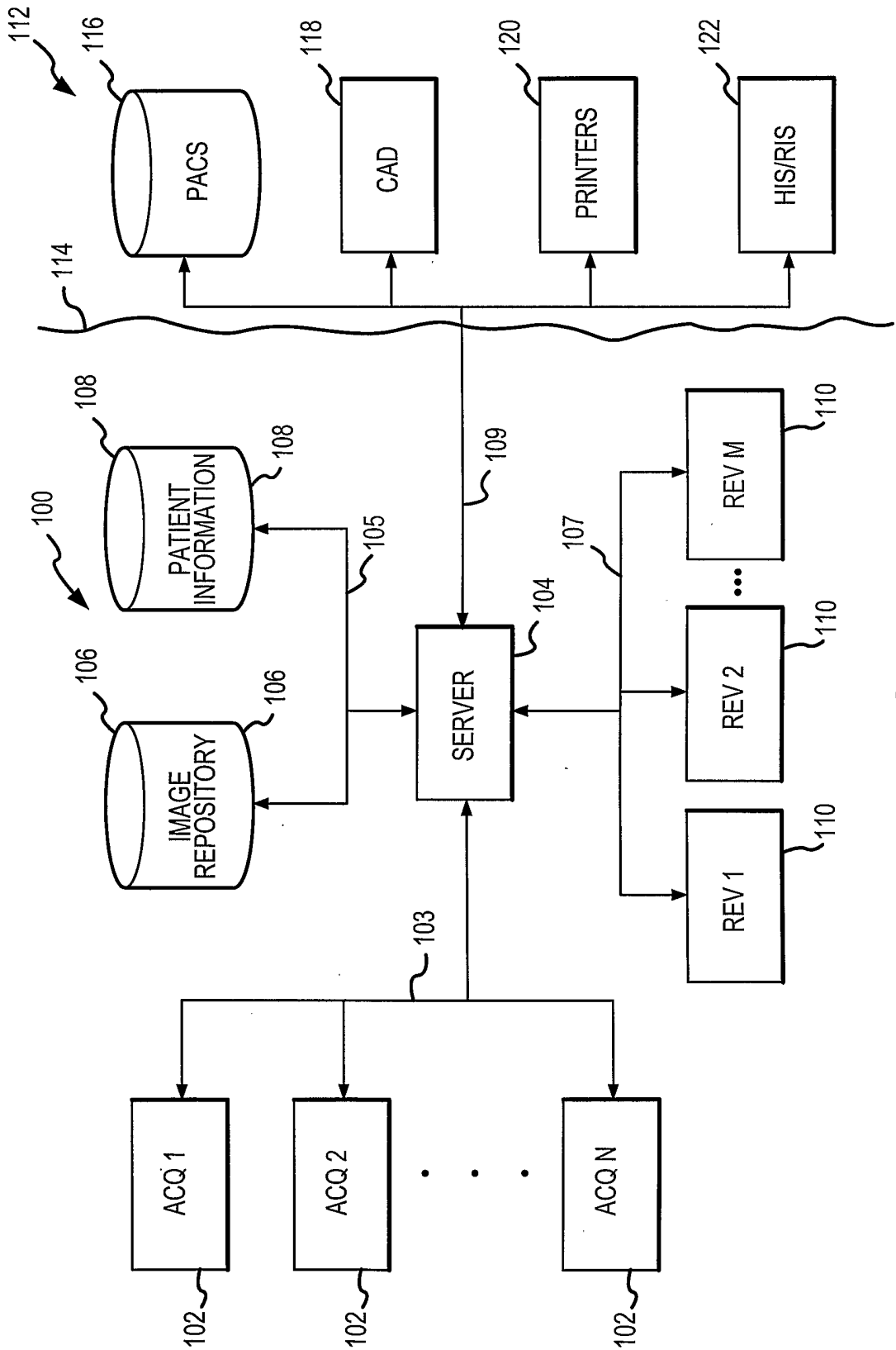


FIG.1

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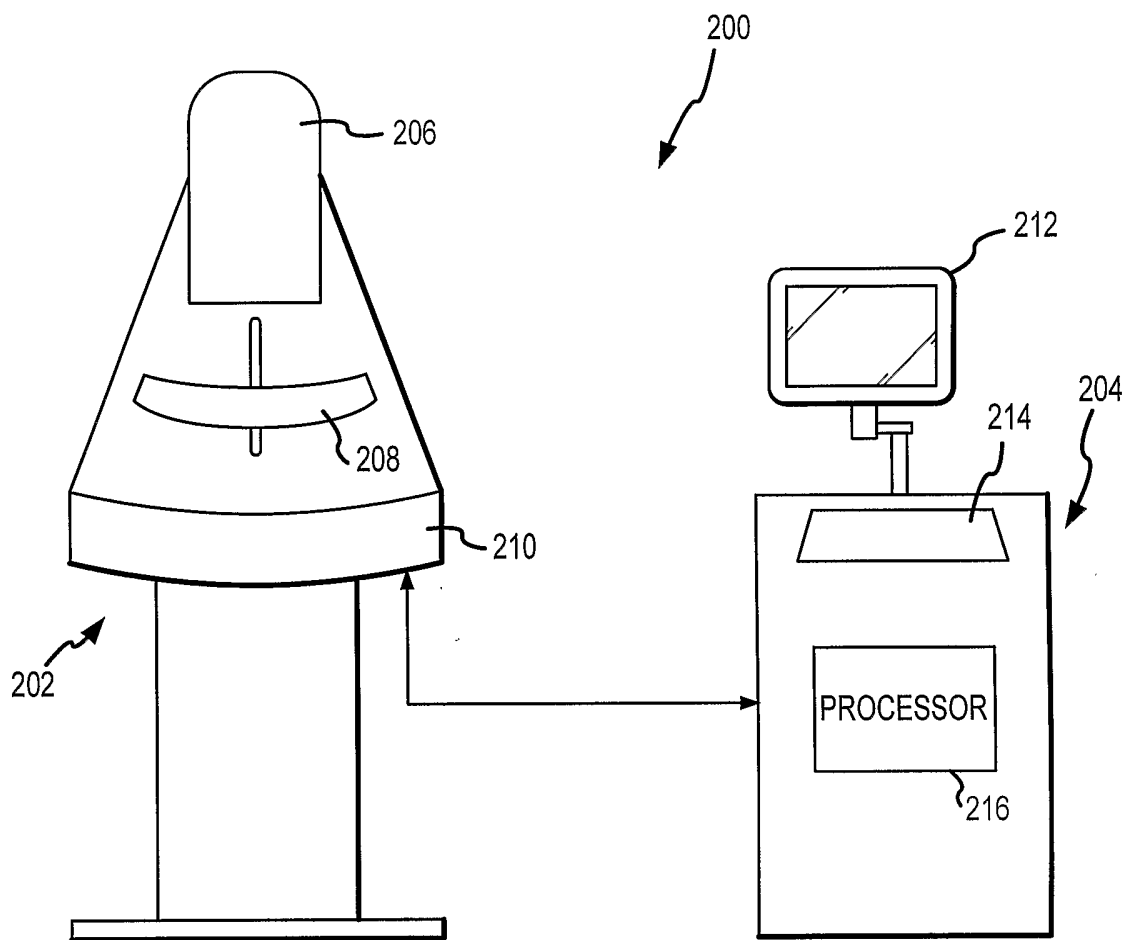


FIG.2

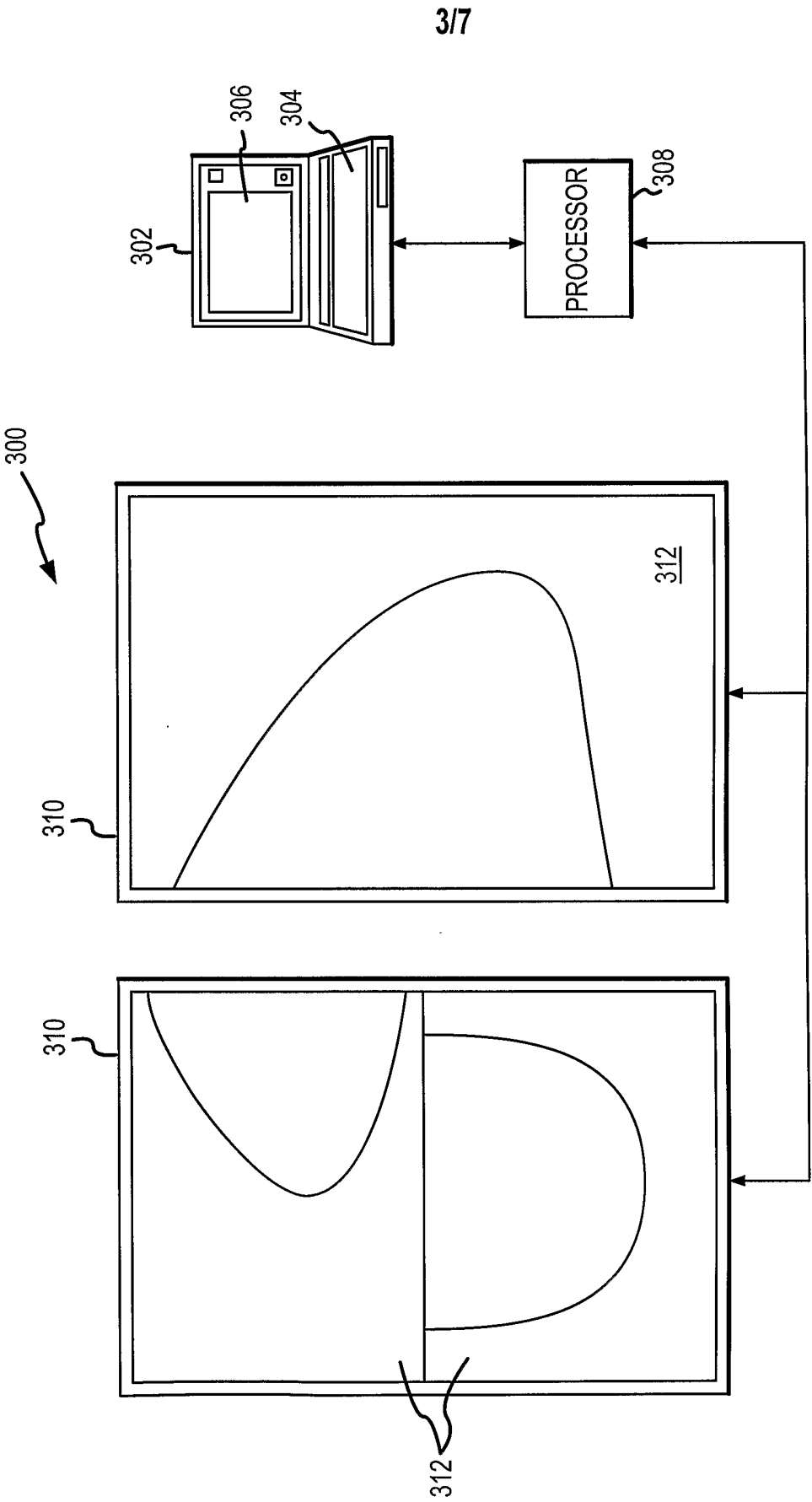


FIG.3

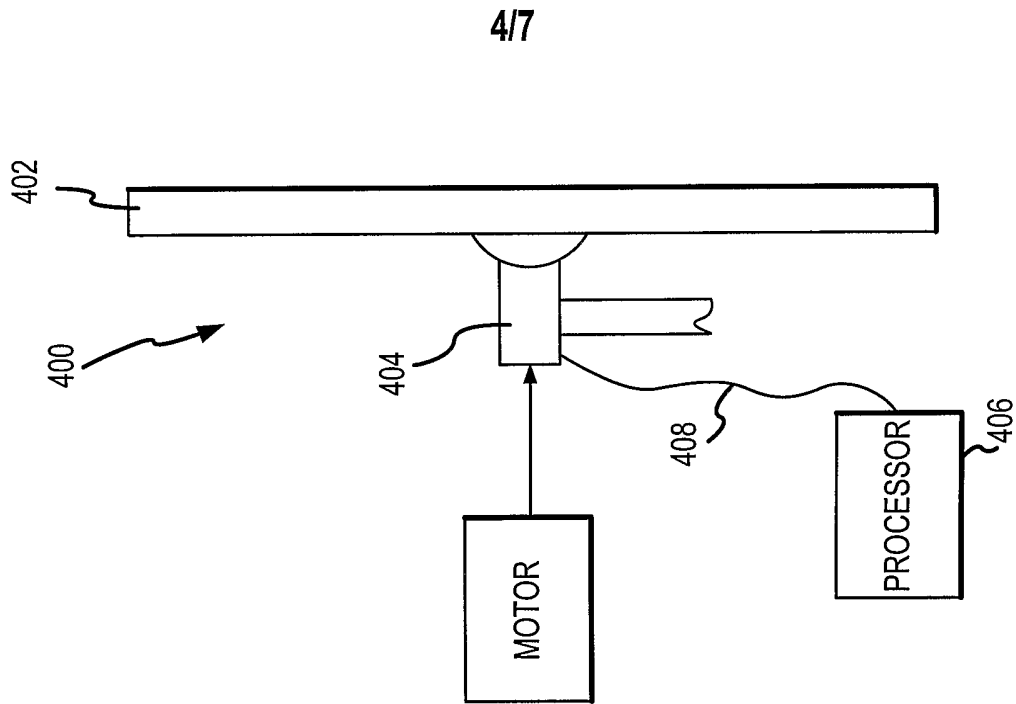


FIG. 4B

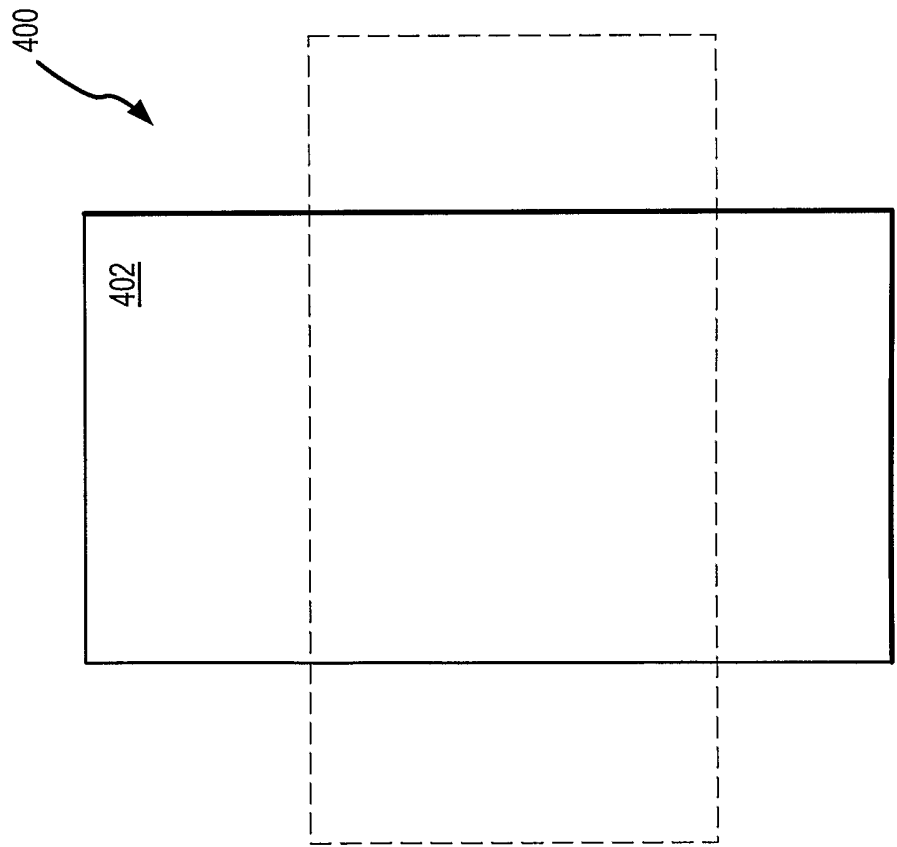


FIG. 4A

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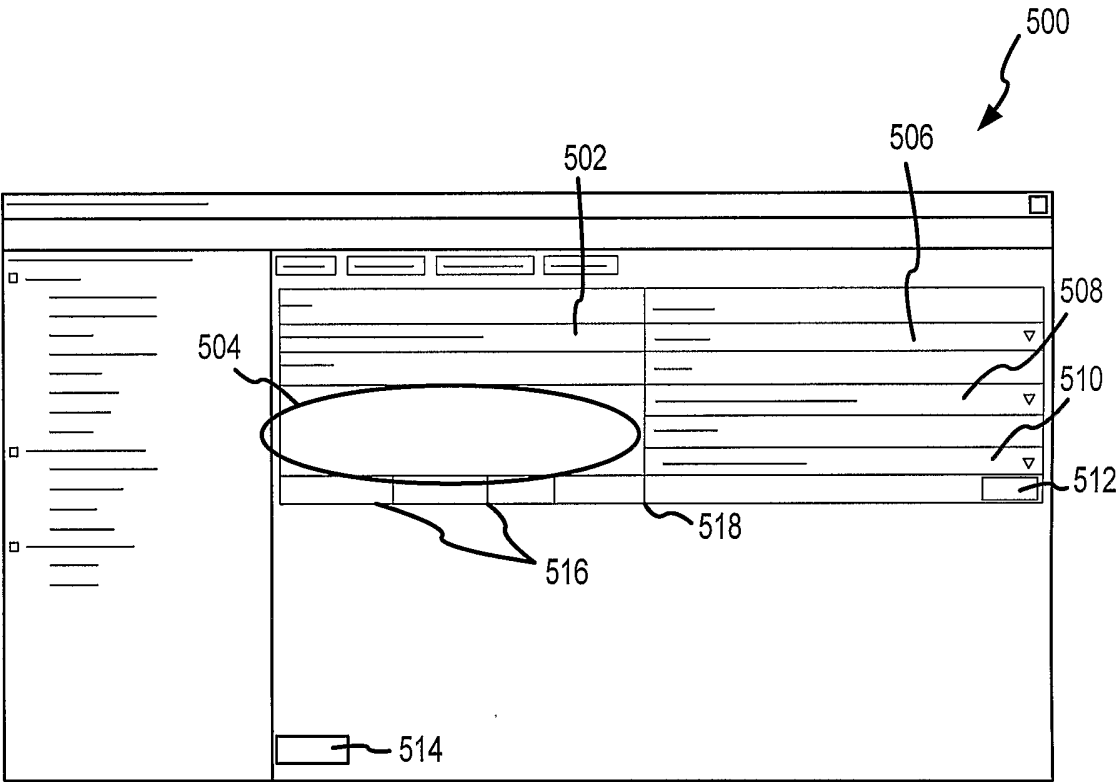


FIG.5

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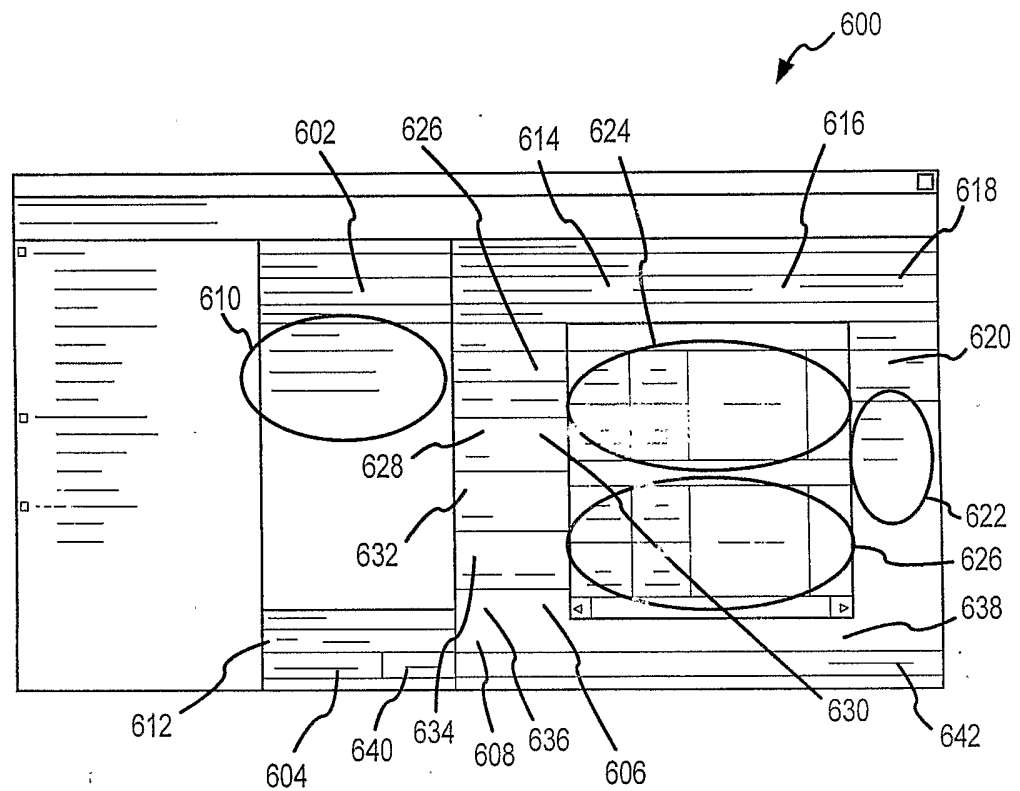


FIG. 6

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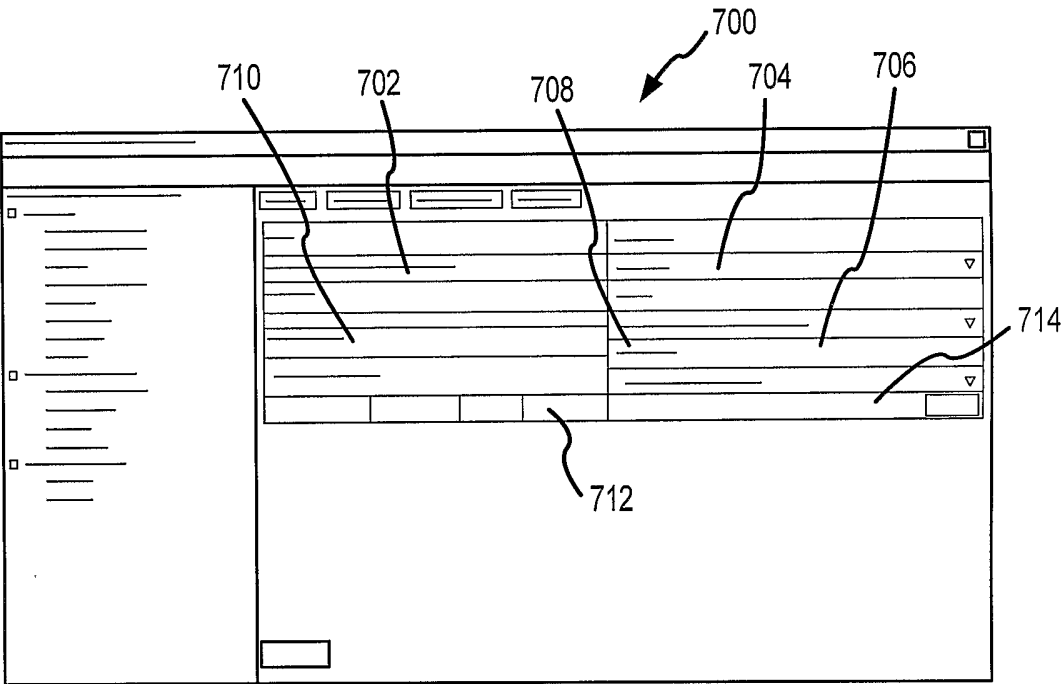


FIG.7