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(54) **PHYSIOLOGY WORKSTATION WITH REAL-TIME FLUOROSCOPY AND ULTRASOUND IMAGING**

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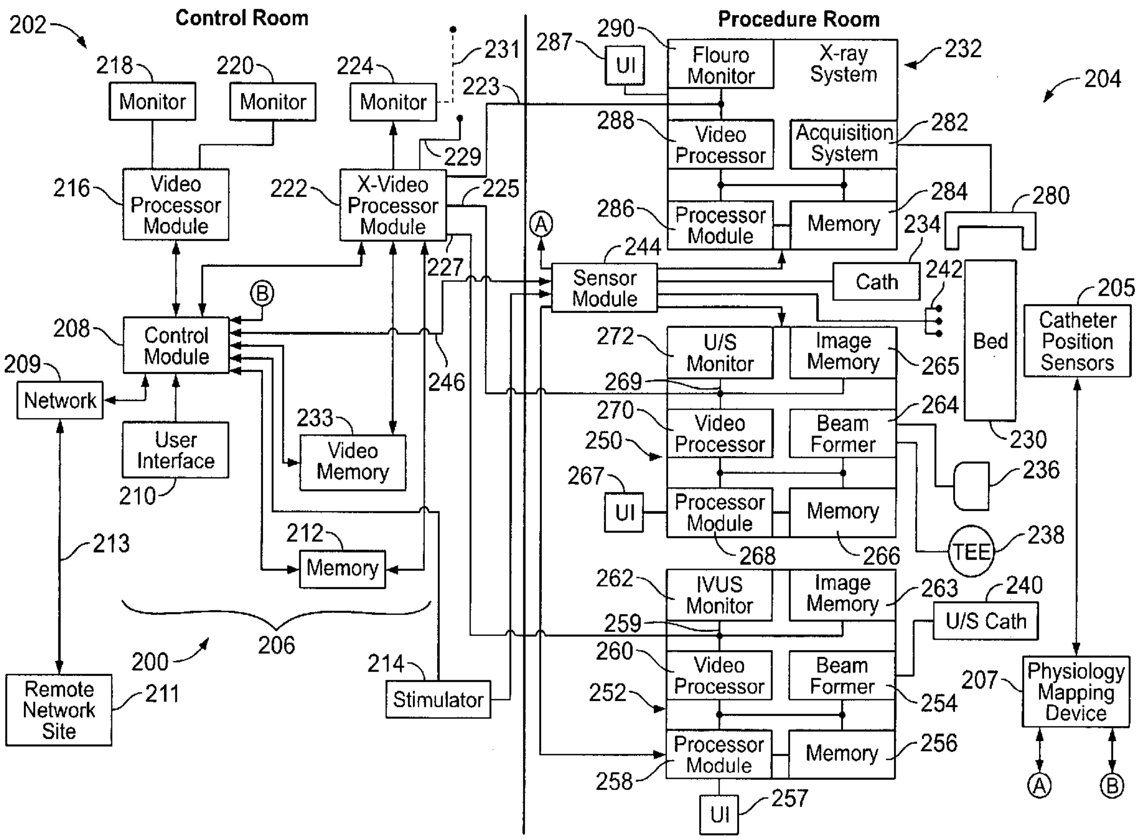
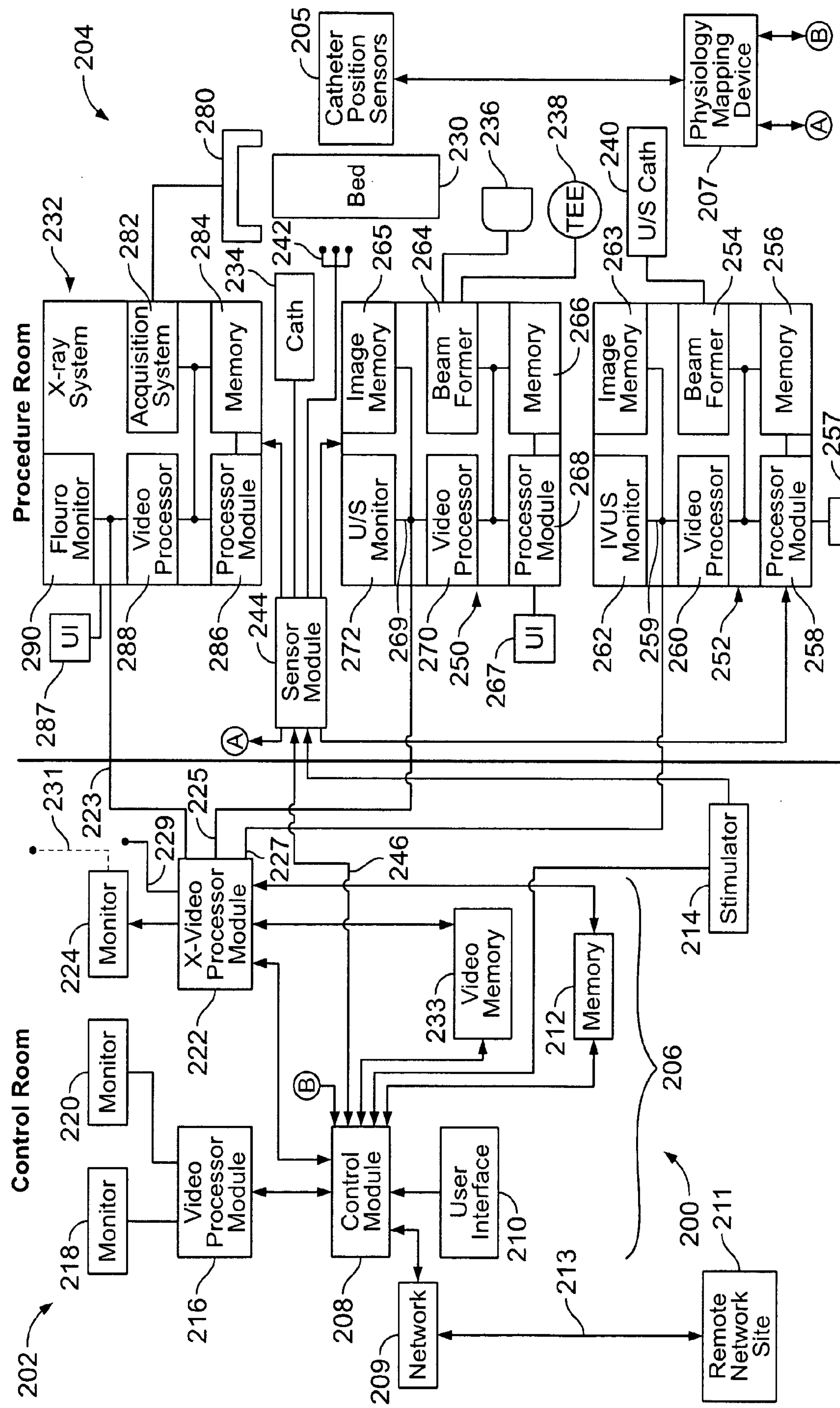
(57) **ABSTRACT**

A physiology workstation is provided that comprises an physiology input configured to receive physiology signals from at least one of an intracardiac (IC) catheter inserted in a subject and surface ECG leads provided on the subject. The physiology signals are obtained during a procedure. A video input is configured to receive image frames, in real-time during the procedure. The image frames contain diagnostic information representative of data samples obtained from the subject during the procedure. A control module controls physiology operations based on user inputs. A display module is controlled by the physiology control module. The display module displays the physiology signals and the image frames simultaneously, in real-time, during the procedure. Optionally, the workstation may include a video processor module that formats the physiology signals into a display format. The video processor module may include an video processor and an external video processor that receive and control display of the physiology signals and image frames, respectively. The image frames may include at least one of ultrasound images obtained from a surface ultrasound probe, intravenous ultrasound images obtained from an ultrasound catheter and fluoroscopy images obtained from a fluoroscopy system.




Control Room
Procedure Room
Monitor
Video Processor Module
Control Module
User Interface
Network
Remote Network Site
X-Video Processor Module
Video Memory
Memory
Stimulator
Flouro Monitor
X-ray System
Video Processor
Acquisition System
Processor Module
Memory
UI
Sensor Module
Cath
Bed
U/S Monitor
Image Memory
Beam Former
TEE
U/S Cath
IVUS Monitor
Catheter Position Sensors
Physiology Mapping Device
A
B
200
202
204
205
206
207
208
209
210
211
212
213
214
216
218
220
222
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224
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FIG. 1

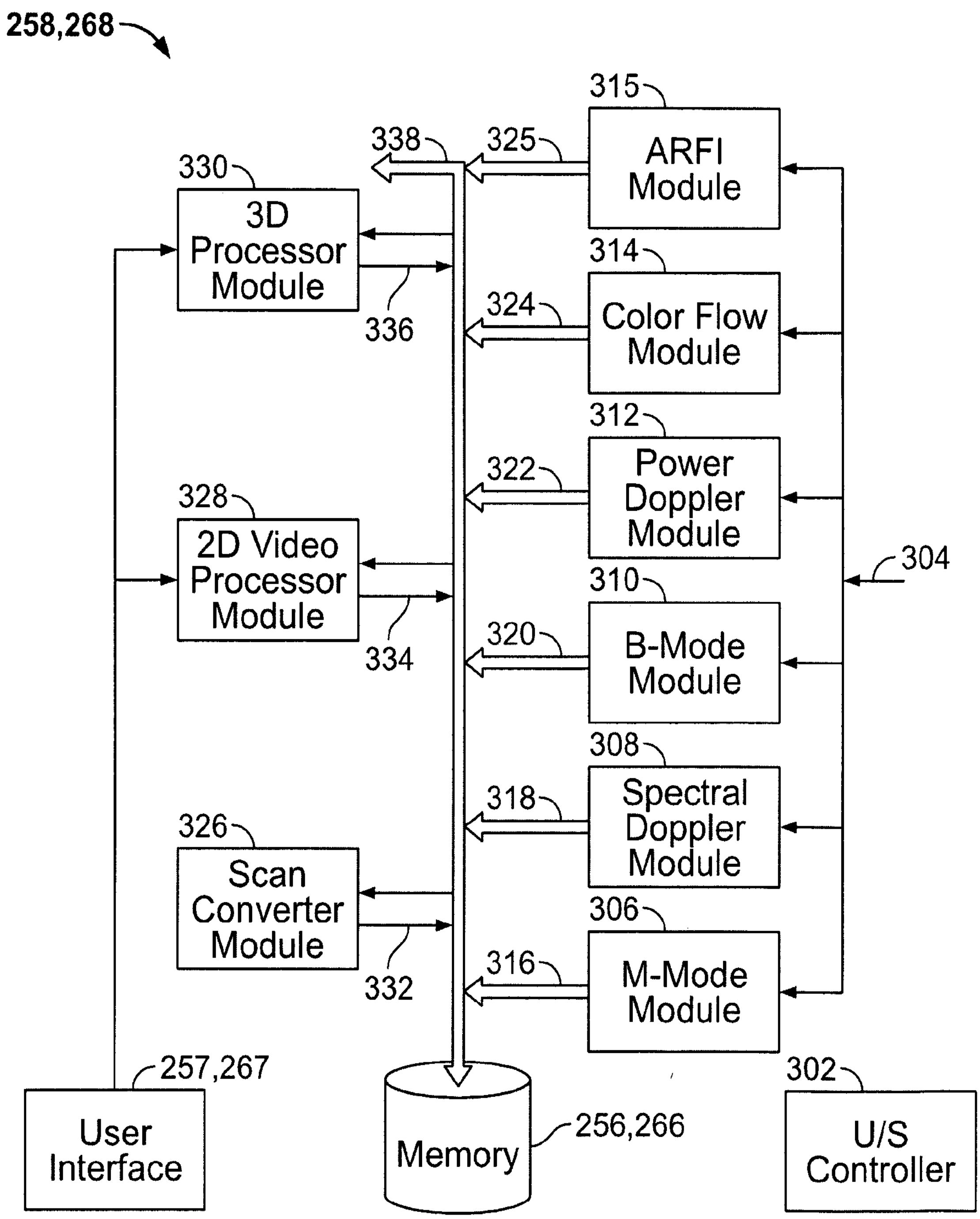

258,268
315
ARFI Module
338
325
330
3D Processor Module
336
314
Color Flow Module
324
312
Power Doppler Module
322
328
2D Video Processor Module
334
304
310
B-Mode Module
320
308
Spectral Doppler Module
318
326
Scan Converter Module
332
306
M-Mode Module
316
257,267
User Interface
Memory
256,266
302
U/S Controller

FIG. 2

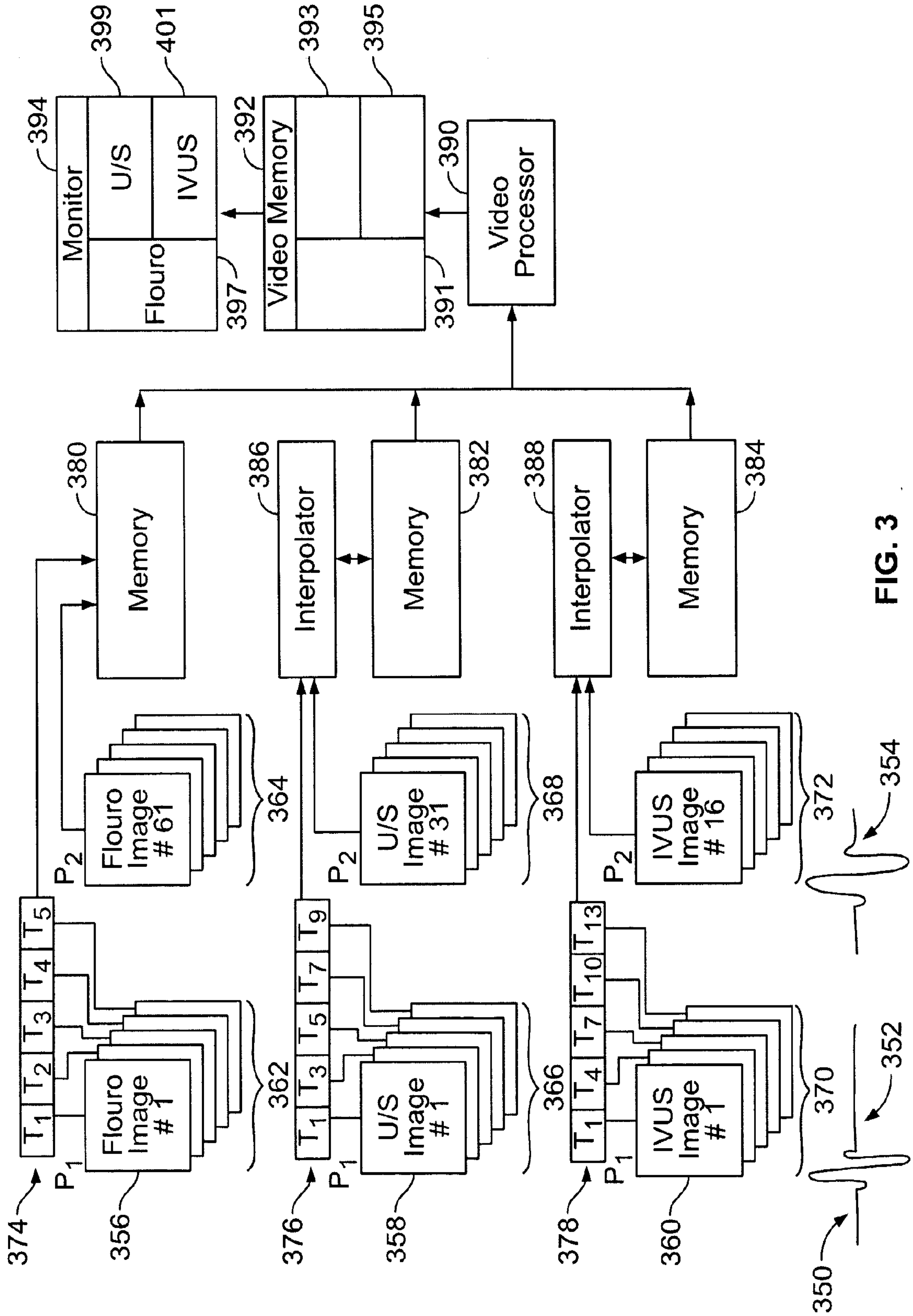
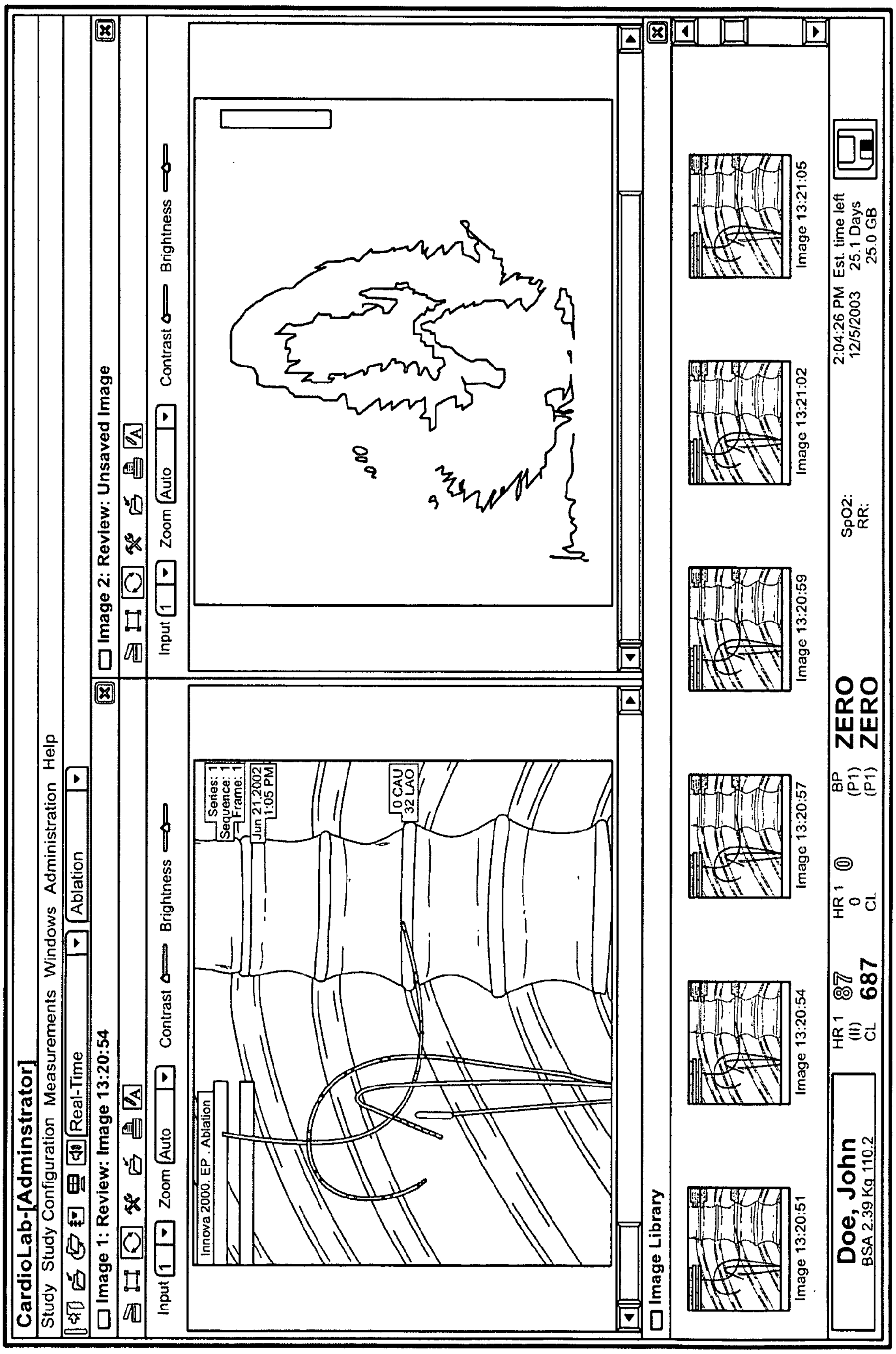

Monitor
U/S
IVUS
Flouro
394
399
401
397
Video Memory
392
393
395
391
Video Processor
390
Memory
380
Interpolator
386
Memory
382
Interpolator
388
Memory
384
Flouro Image # 61
U/S Image # 31
IVUS Image # 16
P2
364
368
372
354
T1 T2 T3 T4 T5
T1 T3 T5 T7 T9
T1 T4 T7 T10 T13
Flouro Image # 1
U/S Image # 1
IVUS Image # 1
P1
362
366
370
352
374
356
376
358
378
360
350

FIG. 3



CardioLab-[Adminstrator]
Study Study Configuration Measurements Windows Administration Help
Real-Time
Ablation
Image 1: Review: Image 13:20:54
Image 2: Review: Unsaved Image
Input 1
Zoom Auto
Contrast
Brightness
Innova 2000 EP Ablation
Series: 1
Sequence: 1
Frame: 1
Jun 21,2002
1:05 PM
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32 LAO
Image Library
Image 13:20:51
Image 13:20:54
Image 13:20:57
Image 13:20:59
Image 13:21:02
Image 13:21:05
Doe, John
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HR 1 87
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25.0 GB

FIG. 4

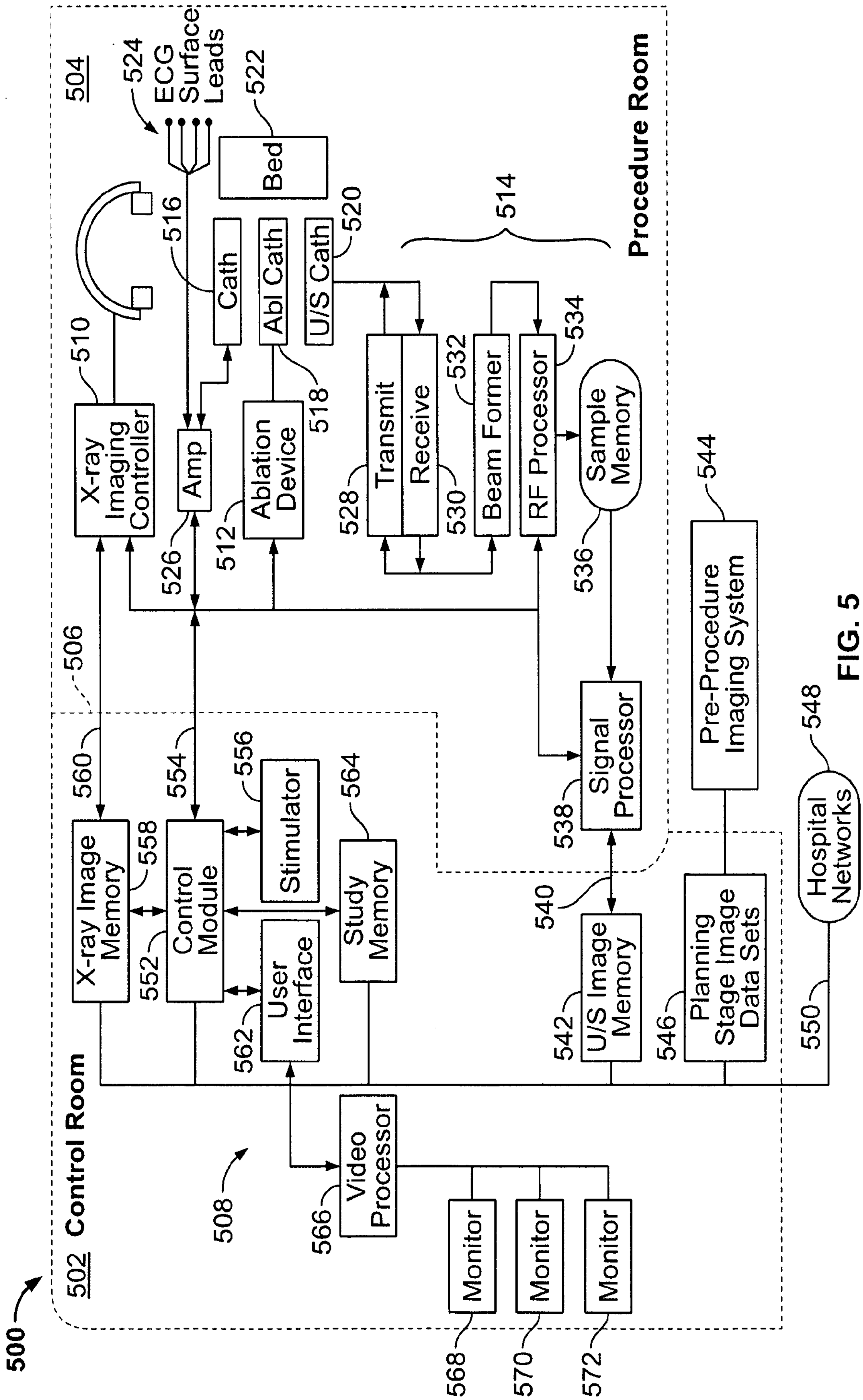
500
502 Control Room
504
506
508
Procedure Room
X-ray Imaging Controller
510
Amp
526
Cath
516
ECG Surface Leads
524
Bed
522
Abl Cath
518
Ablation Device
512
U/S Cath
520
514
Transmit
528
Receive
530
Beam Former
532
RF Processor
534
Sample Memory
536
Signal Processor
538
540
U/S Image Memory
542
Pre-Procedure Imaging System
544
Planning Stage Image Data Sets
546
Hospital Networks
548
550
X-ray Image Memory
558
560
Control Module
552
554
Stimulator
556
Study Memory
564
User Interface
562
Video Processor
566
Monitor
568
Monitor
570
Monitor
572

FIG. 5

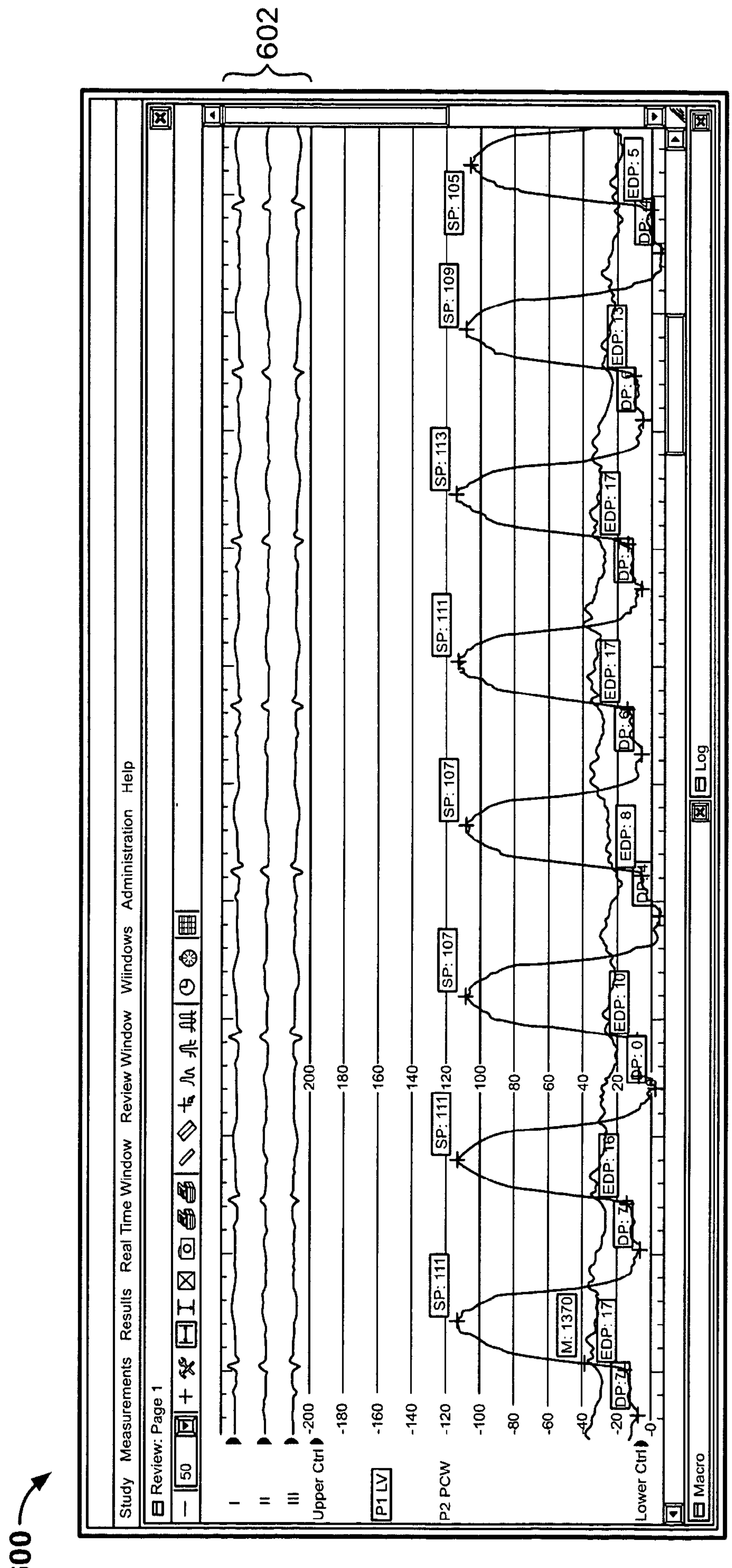
600
602
Study Measurements Results Real Time Window Review Window Windows Administration Help
Review: Page 1
50
I
II
III
Upper Ctrl
P1 LV
P2 PCW
Lower Ctrl
SP: 111
SP: 111
SP: 107
SP: 107
SP: 111
SP: 113
SP: 109
SP: 105
M: 1370
EDP: 17
EDP: 16
EDP: 10
EDP: 8
EDP: 17
EDP: 17
EDP: 13
EDP: 5
DP: 0
Macro
Log

FIG. 6

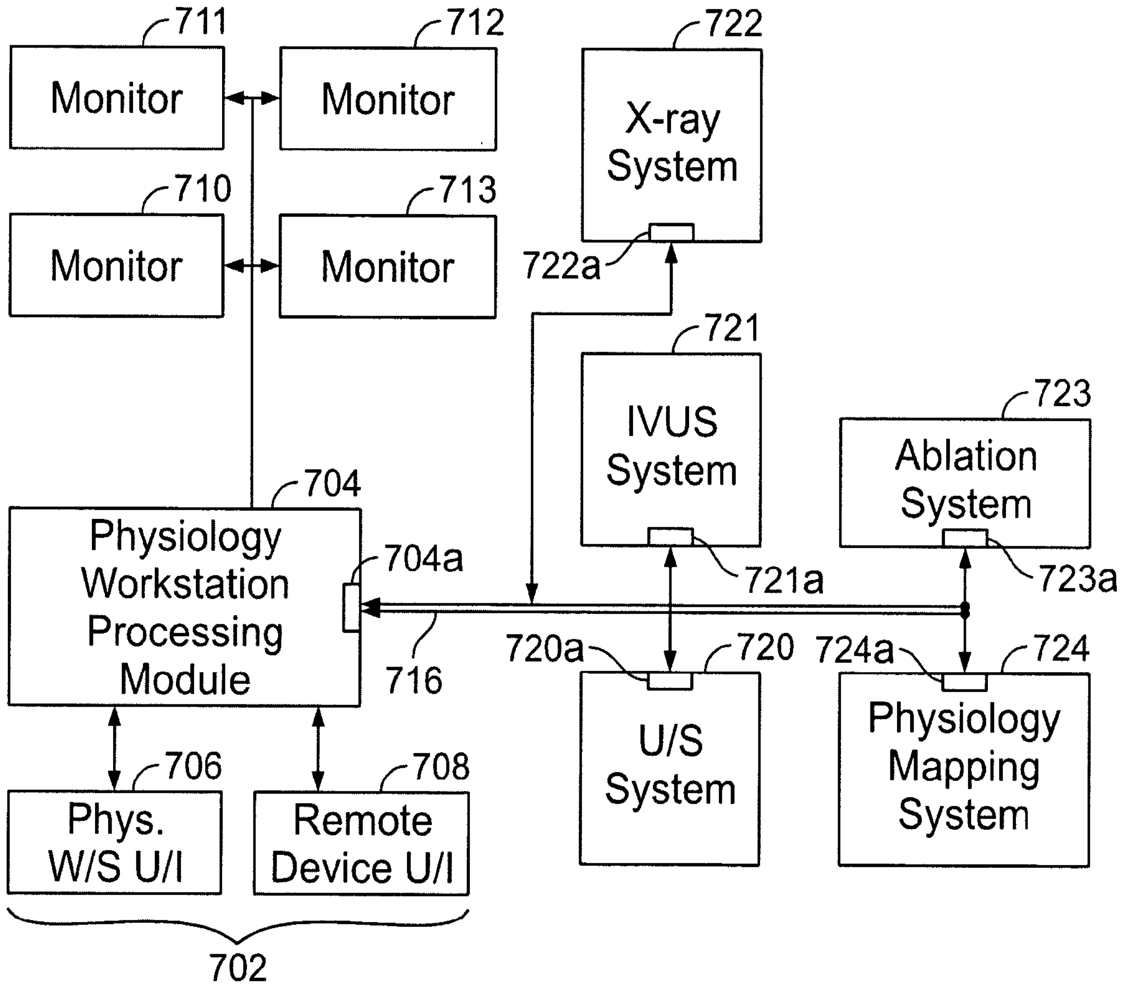
711
Monitor
712
Monitor
722
X-ray System
722a
710
Monitor
713
Monitor
721
IVUS System
723
Ablation System
704
Physiology Workstation Processing Module
704a
721a
723a
716
720a
720
724a
724
U/S System
Physiology Mapping System
706
708
Phys. W/S U/I
Remote Device U/I
702

FIG. 7

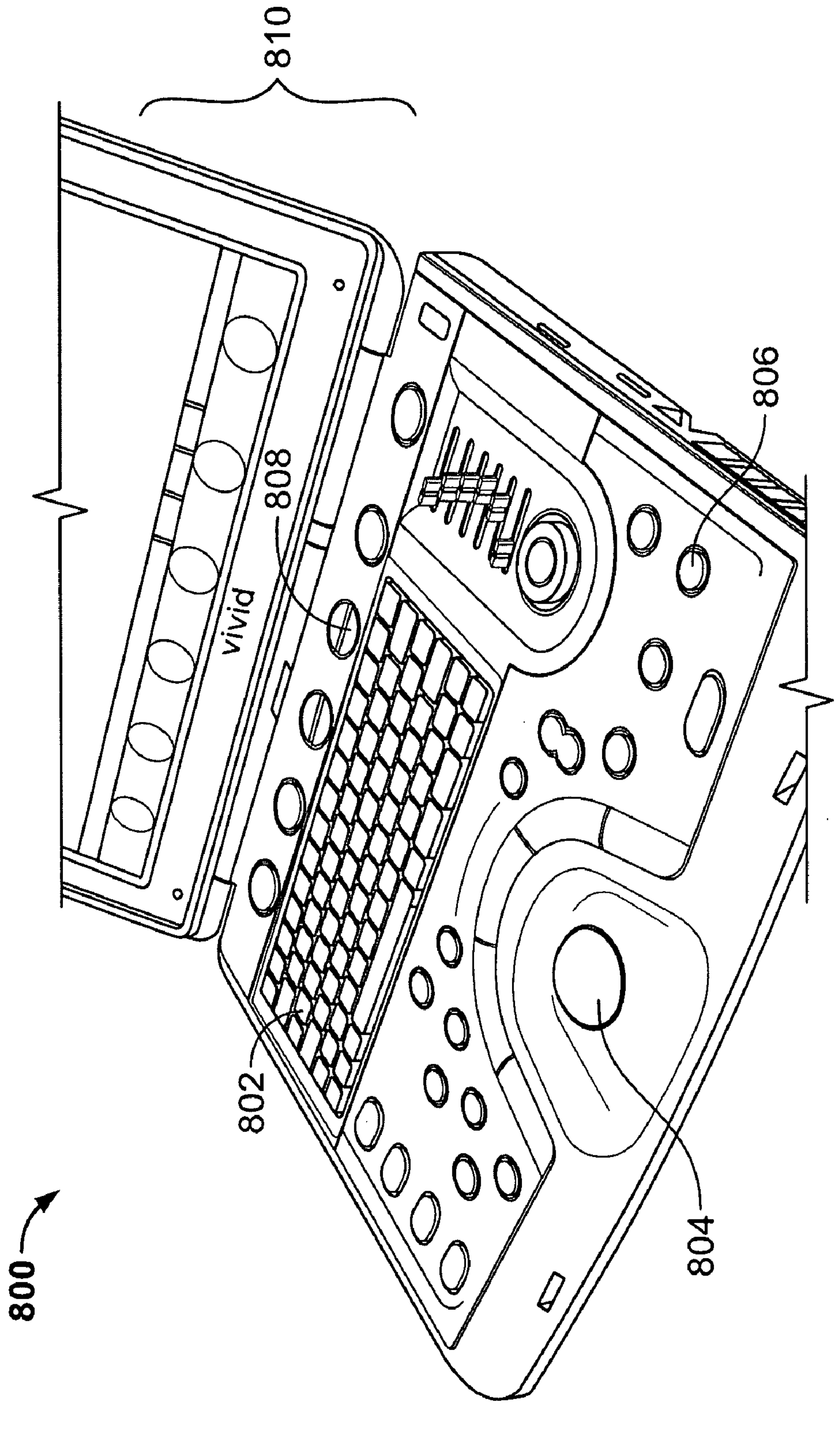

FIG. 8

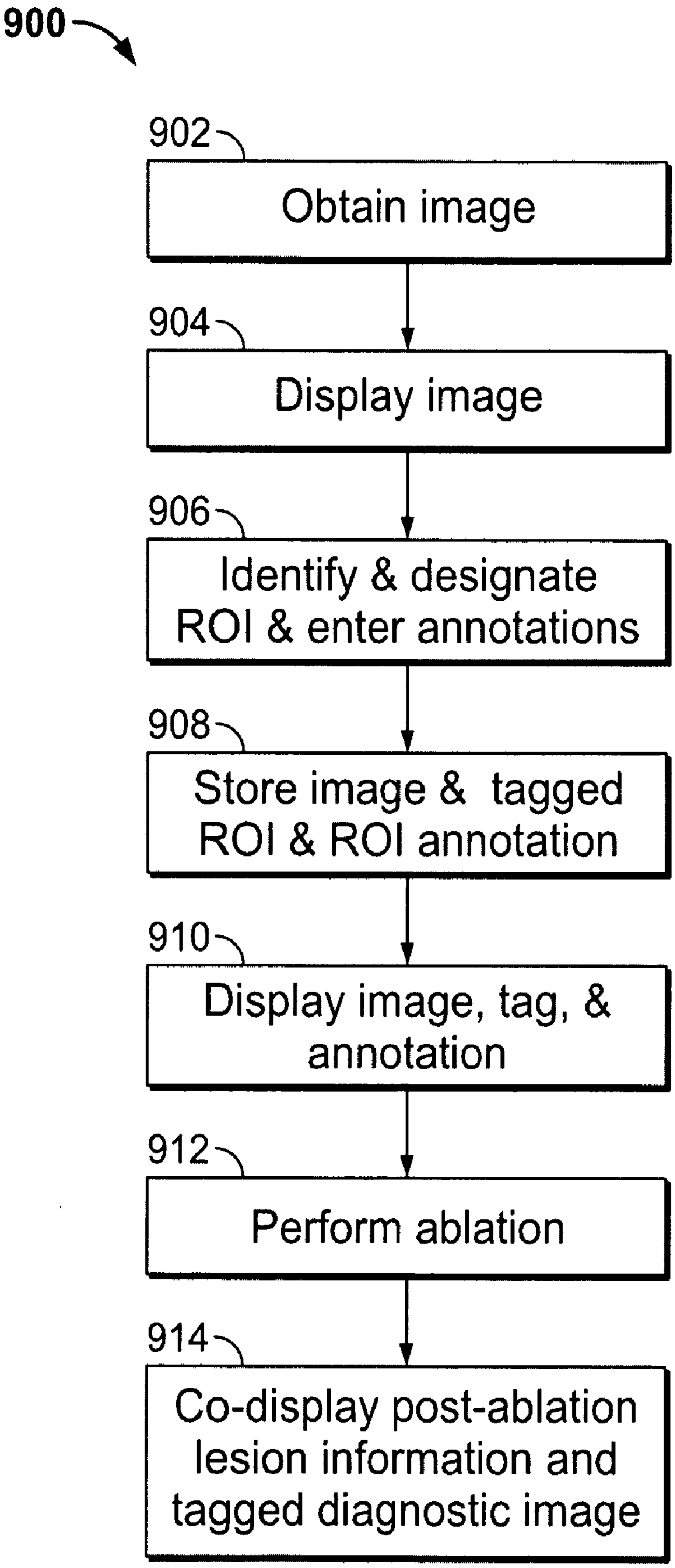
900
902
Obtain image
904
Display image
906
Identify & designate ROI & enter annotations
908
Store image & tagged ROI & ROI annotation
910
Display image, tag, & annotation
912
Perform ablation
914
Co-display post-ablation lesion information and tagged diagnostic image

FIG. 9

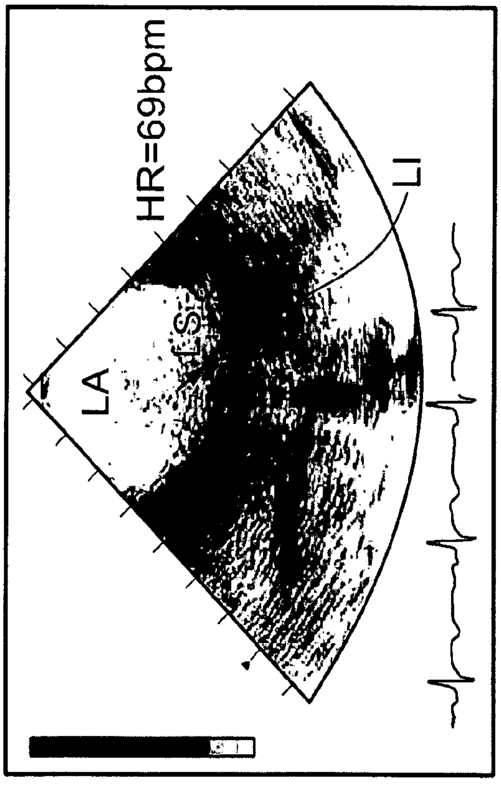

FIG. 10

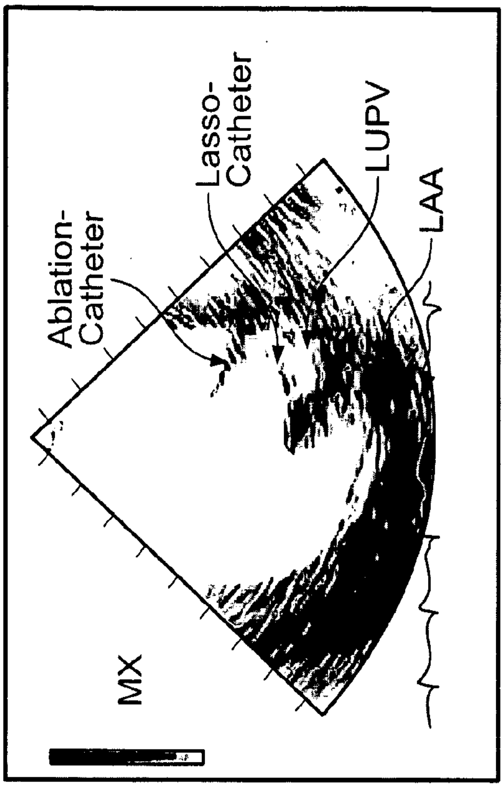

FIG. 11A

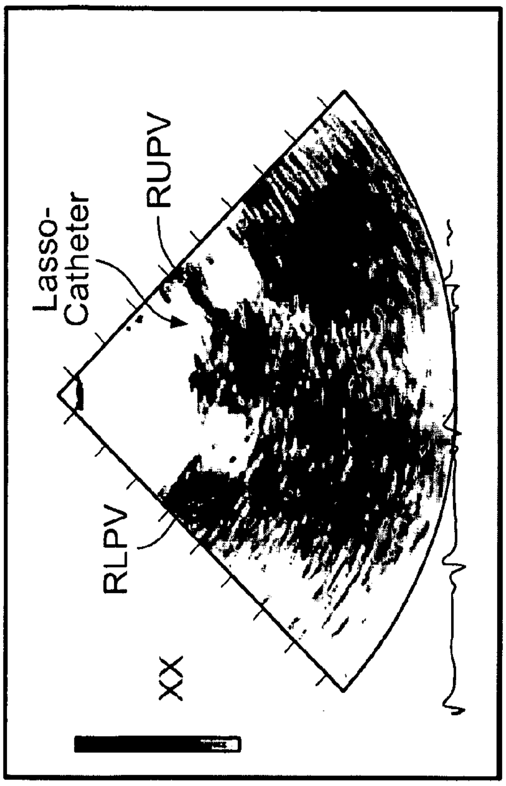

FIG. 11B

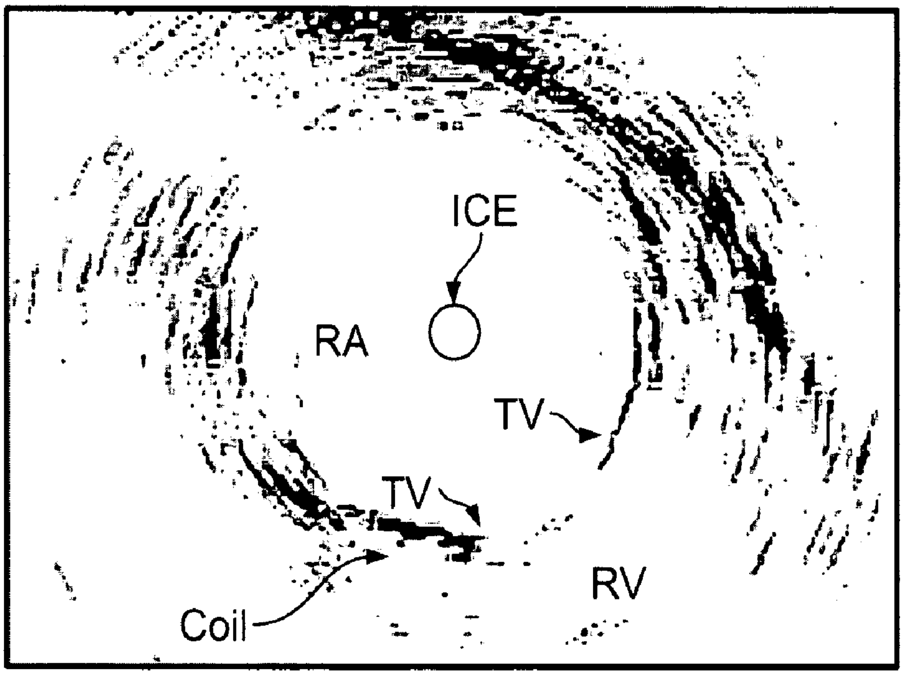

FIG. 12A

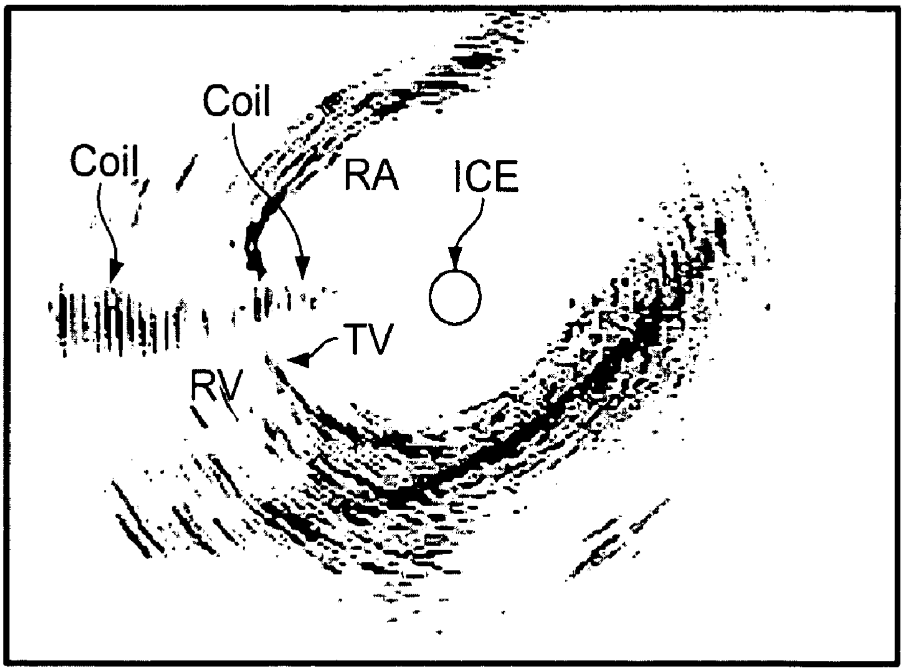

FIG. 12B

PHYSIOLOGY WORKSTATION WITH REAL-TIME FLUOROSCOPY AND ULTRASOUND IMAGING

BACKGROUND OF THE INVENTION

[0001] Embodiments of the present invention generally relate to electrophysiology (EP) workstations, hemo-dynamic (HD) workstations, fluoroscopy workstations and ultrasound imaging workstations. More particularly, embodiments of the present invention relate to providing a physiology workstation (e.g., EP or HD workstation) with real-time fluoroscopy imaging, ultrasound imaging and other diagnostic imaging modality.

[0002] EP, HD and ablation procedures are complex and sensitive procedures, and as such, utilize numerous diagnostic and therapeutic systems. Generally, EP, HD and ablation procedures are carried out in a procedure room including, among other things, EP catheters, HD catheters and patient sensors joined to an EP or HD workstation. The procedure room also includes a fluoroscopy system, a diagnostic ultrasound system, a patient monitoring device and an ablation system. A monitoring room and a control room may be located adjacent to the procedure room. The EP or HD workstation and a stimulator may be located in the control room. Alternatively, when remote monitoring rooms are not used, the EP or HD workstation and stimulator are provided in the procedure room in a corner or monitoring area. An example of a conventional HD workstation is the Mac-Lab® Hemodynamic Monitoring system offered by G.E. Healthcare. An example of a conventional EP workstation Is the Cardio Lab® EP Lab Monitoring system offered by G.E. Healthcare.

[0003] Conventional EP and HD workstations include monitors that present information related directly to the EP or HD study, such as EP or HD signals, case logs, patient information and the like. The diagnostic imaging systems (fluoroscopy, ultrasound and the like) are provided in the procedure room and are operated as stand-alone systems. For example, conventional fluoroscopy systems utilize one or two monitors provided on the fluoroscopy device located in the procedure room. The fluoro-monitors present fluoroscopy images to the procedure team to facilitate and monitor catheter placement and operation. Similarly, conventional ultrasound systems are constructed as stand-alone, independent units having a monitor and user interfaces on the system. The ultrasound system is positioned in the procedure room and operated by the procedure team. Images obtained by the ultrasound system are provided on the monitor mounted to the ultrasound system. The imaging capabilities of these various systems are independent and physically remote from one another.

[0004] Conventional EP and HD workstations and diagnostic systems suffer from various disadvantages, that are addressed by various embodiments of the present invention.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In accordance with one embodiment, a physiology workstation is provided that comprises a physiology input configured to receive physiology signals from at least one of an intracardiac (IC) catheter inserted in a subject, a hemodynamic catheter inserted in a subject, and surface ECG leads provided on the subject. The physiology signals are obtained during a procedure. A video input is configured to receive image frames, in real-time during the procedure. The image frames contain diagnostic information representative of data samples obtained from the subject during the procedure. A control module controls workstation operations based on user inputs. A display module is controlled by the EP control module. The display module displays the physiology signals and the image frames simultaneously, in real-time, during the procedure.

[0006] Optionally, the physiology workstation may include a video processor module that formats the physiology signals into a display format. The video processor module may include a physiology signal video processor and an external video processor that receive and control display of the physiology signals and image frames, respectively. The image frames may include at least one of ultrasound images obtained from a surface ultrasound probe, or intravenous, intraarterial or transesophageal ultrasound images obtained from an ultrasound probe and fluoroscopy images obtained from a fluoroscopy system.

[0007] In accordance with another embodiment, a method is provided for managing a physiology workstation. The method comprises receiving, at a physiology workstation, physiology signals from at least one of an intracardiac (IC) catheter inserted in a subject, a hemodynamic (HD) catheter inserted in a subject and surface ECG leads provided on the subject, the physiology signals being obtained during a procedure. The method also includes receiving, at the workstation, image frames, in real-time during the procedure, the image frames containing diagnostic information representative of data samples obtained from the subject during the procedure. Physiology operations are controlled based on user inputs and the physiology signals and the image frames are displayed simultaneously, in real-time, during the procedure at the workstation.

[0008] Optionally, the method may include synchronizing the physiology signals and image frames and displaying the physiology signals and image frames in a synchronized manner based on a cardiac cycle of the subject. Alternatively, the physiology signals and image frames may be displayed in a non-synchronized manner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 illustrates a block diagram of an image management system formed in accordance with an embodiment of the present invention.

[0010] FIG. 2 illustrates a block diagram of an image management system formed in accordance with an alternative embodiment of the present invention.

[0011] FIG. 3 illustrates a pictorial representation of an image management flow carried out in accordance with an embodiment of the present invention.

[0012] FIG. 4 illustrates a screen shot of an exemplary monitor layout presented in accordance with an embodiment of the present invention.

[0013] FIG. 5 illustrates a block diagram of an image management system formed in accordance with an alternative embodiment of the present invention.

[0014] FIG. 6 illustrates a screen shot of an exemplary window on an HD workstation monitor presented in accordance with the an embodiment of the present invention.

[0015] FIG. **7** illustrates a block diagram of an alternative embodiment in which remote control is provided for various systems and devices presented in accordance with the an embodiment of the present invention.

[0016] FIG. **8** illustrates an exemplary remote device user interface **708** constructed one to substantially resemble the keyboard of an ultrasound system presented in accordance with the an embodiment of the present invention.

[0017] FIG. **9** illustrates a processing sequence that may be carried out by the physiology workstation **206** presented in accordance with the an embodiment of the present invention.

[0018] FIG. **10** illustrate an image acquired by an echocardiography (ICE) catheter presented in accordance with the an embodiment of the present invention.

[0019] FIGS. **11**A and **11**B illustrates an ultrasound image obtained by an ICE catheter located on the right side of the inter-atrial septum positioned to image the left pulmonary veins presented in accordance with the an embodiment of the present invention.

[0020] FIGS. **12**A and **12**B represent ultrasound images obtained by an ICE catheter presented in accordance with the an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0021] FIG. **1** illustrates an image management system **200** formed in accordance with an embodiment of the present invention. The image management system **200** may be distributed between a control room **202** and procedure room **204** or, alternatively, may be all located in the procedure room **204**. Thus the image management system **200** may be located entirely in the procedure room **204**. A physiology workstation **206** (e.g., EP or HD workstation) is provided to control and coordinate EP or HD procedures, ablation procedures and the like. The physiology workstation **206** includes a control module **208** that is controlled by an operator through user interface **210**. Memory **212** stores various information as will be explained below in more detail. A stimulator **214** is provided to generate stimulus signals delivered to the patient in the procedure room **204**. A physiology video processor module **216** communicates with the control module **208** and controls monitors **218** and **220**. An external video processor module **222** is also provided within the workstation **206**. The external video processor module **222** communicates with control module **208** and controls a real-time imaging monitor **224**. Optionally, the physiology and external video processor modules may be combined as a single module and/or may implemented utilizing a single or parallel processors.

[0022] A physiology mapping device **207** is provided in the procedure room **204** and is joined to the workstation **206** over link B and to the sensor module **244** over link A. The physiology mapping device **207** communicates with catheter position sensors **205** to monitor the position of EP, HD and/or mapping catheters, while being positioned within the heart. Examples of a conventional EP mapping device **207** are the LocaLisa® intra-cardiac navigation system offered by Medtronic, Minneapolis, Minn., and the CARTO® system by Biosense Webster.

[0023] The workstation **206** integrates, among other things, real-time EP and HD information, real-time intracardiac (IC) echography, transesophageal ultrasound, transthoracic ultrasound, fluoroscopic images, EP mapping data and pre-surgery planning CT & MR images. The workstation **206** offers integrated monitoring and review of EP, HD, patient, and mapping information as well as stored and real-time diagnostic images, ECG signals and IC signals.

[0024] The procedure room **204** includes a patient bed **214** to hold the patient during pre-procedure intracardiac mapping and during EP, HD and ablation procedures. A fluoroscopy system **232** is provided proximate patient bed **214** to obtain fluoroscopic images of the region of interest while the doctor is conducting mapping or a procedure. EP or HD catheters **234**, ultrasound probes **236**, **238** and an ultrasound probe **240** are provided for use throughout the procedure. EP or HD catheter **234** performs sensing and stimulating functions. An ablation catheter (not shown) may represent an RF ablation catheter, a laser ablation catheter or a cryogenic ablation catheter. HD catheters may represent open lumen catheters that measure pressure.

[0025] The ultrasound catheter **240** and ultrasound probes **236**, **238** are configured to obtain ultrasound images of the region of interest, as well as images that indicate directly the position and placement of other instruments, devices and catheters, such as a defibrillator or pacemaker lead, catheter **234**, an ablation catheter and the like relative to the region of interest. Surface ECG leads **212** are provided and attached to the patient to obtain surface ECG information. The surface ECG leads **212** and the catheters **234** are joined to the sensor module **244** which amplifies and/or pre-conditions signals sensed by the surface ECG leads **212** and catheters **234** prior to transmitting the sensed signals over communications link **246**. When stimulus pulses are to be delivered to the patient, the stimulus signals are passed either around or through the sensor module **244** to the corresponding catheters **234**. An ablation source and controller (not shown) controls operation of the ablation catheter and provides ablation-related data to the workstation **206**. The ablation technique may be cryosurgical, radio frequency, high intensity focused ultrasound, microwave, laser and the like.

[0026] An ultrasound system **250** and an intravascular ultrasound (IVUS) system **252** are joined to, and control, the ultrasound probes **236**, **238** and catheter **240**. The ultrasound catheter **240** may generally represent an intravascular ultrasound (IVUS) catheter, in that the catheter **240** and IVUS system **252** may be used to perform diagnostic ultrasound examination of any and all portions of a subjects vascular structure, including but not limited to, the cardiac structure, peripheral veins, peripheral arteries and the like. One exemplary application of an IVUS system **252** is to perform intracardiac echocardiography (ICE), in which the catheter **240** is utilized in an intra-cardiac examination. An user interface **257** permits an operator to control operation of the IVUS system **252**, and to enter modes, parameters and settings for the IVUS system **252**. The IVUS system **252** includes a beamformer **254** that is responsible for transmit and receive beamforming operations. The link between the beamformer **254** and ultrasound catheter **240** may comprise individual channels associated with each transducer element within the transducer head of the ultrasound catheter **240**. The beamformer **254** controls the phase and amplitude of each transmit signal delivered over the link to induce a transmit or firing operation by the ultrasound catheter **240**. Reflected echoes are received at the ultrasound catheter **240** and delivered to the beamformer **254** as analog or digital signals representative of the detected echo information at each individual transducer element.

[0027] The beamformer **254** may include a demodulator and filters (or a processor programmed) to demodulate and filter the received echo signals. The beamformer **254** generates RF signals from echo signals and performs RF processing to produce digital base-band I and Q data pairs formed from the RF signals associated with acquired data samples. The I, Q data pairs are derived from the reflected ultrasound signals from respective focal zones of the transmitted beams. The I and Q data pairs are filtered, such as in FIR filters that are programmed with filter co-effecients to pass a band of frequencies centered at a desired fundamental frequency of the transmit waveform or at harmonic or sub-harmonic frequencies of the transmit signal's fundamental frequency. An I, Q data pair corresponds to each data sample within the region of interest. The beamformer **254** may pass the I, Q data pairs to memory **256**, or directly to processor module **258**.

[0028] The I, Q data pairs are processed by mode-related modules (e.g., B-mode, color Doppler, power Doppler, M-mode, spectral Doppler anatomical M-mode, strain, strain rate, and the like) of the processor module **258** to form 2D or 3D data sets of image frames, volumetric data sets and the like. For example, the processor module **258** may generate B-mode, color Doppler, power Doppler, M-mode, anatomical M-mode, strain, strain rate, spectral Doppler image frames and combinations thereof, and the like. The image frames are stored in memory **256**. The processor module **258** may record, with each image frame, timing information indicating a time at which the image frame was acquired. The processor module **258** may also include a scan conversion module to perform scan conversion operations to convert the image frames from Polar to Cartesian coordinates. A video processor module **260** reads the image frames from memory **256** and displays the image frames on the IVUS monitor **262** in real time during the procedure is being carried out on the patient. Optionally, the video processor module **260** may store the image frames in an image memory **263**, from which the images are read and displayed on IVUS monitor **262**.

[0029] A video link **259** is maintained between the video processor **260**, image memory **263** and IVUS monitor **262**. The IVUS system **252** includes a video output (e.g., a VGA output) that is connected to a video link **227** (e.g., a VGA cable). The video link **227** conveys to the physiology workstation **206** the identical video signals as presented to the IVUS monitor **262**.

[0030] The ultrasound system **250** includes a transmitter (within beamformer **264**) which drives ultrasound probes **236**, **238**. An user interface **267** permits an operator to control the operation of, and enter modes, parameters and settings for, the ultrasound (U/S) system **250**. The ultrasound probes **236**, **238** include transducer arrays that emit pulsed ultrasonic signals into a region of interest. The probes **236**, **238** may be moved over the region of interest 2D or 3D volumetrically in order to acquire image information in scan planes of the region of interest. The probes **236**, **238** may conform to one of many geometries, as examples, transesophageal, a 1D, 1.5D, 1.75D, or 2D probe. Structures in the region of interest (e.g., a heart, blood cells, muscular tissue, and the like) back-scatter the ultrasonic signals. The resultant echoes return to the transducers. In response, the transducers generate electrical signals that the receiver receives and forwards to the beamformer **264**.

[0031] The beamformer **264** processes the signals for steering, focusing, amplification, and the like. The beamformer **264** generates RF signals based on the received echoes. The beamformer **264** also filters and demodulates the RF signals to form in-phase and quadrature (I/Q) data pairs representative of the echo signals from data samples. The RF or I/Q signal data may then be routed to the memory **266** for storage or directly to the processor module **268**.

[0032] The processor module **268** acquires ultrasound information (i.e., the RF signal data or IQ data pairs) from memory **266** and prepares frames of ultrasound information (e.g., graphical images) for storage or display. The processor module **268** may record, with each image frame or volume, timing information indicating a time at which the image frame was acquired The processor module **268** provides the ultrasound information to the video processor **270**. The video processor **270** stores image frame data in the image memory **265** and outputs the video signals that drive the monitor **272**. The monitor **272** may be, as examples, a CRT or LCD monitor, hardcopy device, or the like.

[0033] The processor module **268** executes instructions out of the program memory **266**. The memory **266** stores, for example, an operating system for the ultrasound system **250**, image processing programs, and the like. In general, the processor module **268** performs any selected processing operation available on the acquired ultrasound information chosen from the configured ultrasound modalities present in the ultrasound imaging system **250**. The processor module **268** may process in real-time acquired ultrasound information during a scanning session as the echo signals are received. Additionally or alternatively, the ultrasound information may be stored temporarily in the memory **266** during a scanning session and processed in less than real-time in a live or off-line operation.

[0034] The ultrasound system **250** may acquire ultrasound information at a selected frame rate (e.g., 12.5, 15, 25, 30, 50 or 60 frames per second) and display those frames at the same or different frame rate on the monitor **272**. The memory **266** shown in FIG. **1** may store processed frames that are not scheduled for immediate display. For example, the memory **266** may be sized to store several seconds or more of image frames. In one embodiment, the ultrasound system **250** stores the image frames with triggering information (e.g., ECG signal or respiratory signal) so that the ultrasound system **250** can present looping image sequences on the monitor **272**, synchronized to selected events in the region of interest (e.g., heart cycle or breathing cycle).

[0035] In addition or alternatively, the ultrasound system **250** may scan a volume from the region of interest. To that end, the probes **236**, **238** may be used in conjunction with techniques including 3D scanning, real-time 3D imaging, volume scanning, 2D scanning with transducers having positioning sensors, freehand scanning using a Voxel correlation technique, 2D or matrix array transducers and the like.

[0036] When the probes **236**, **238** move, as examples, along a linear or arcuate path, it scans the region of interest.

At each linear or arcuate position, the probes **236**, **238** obtain scan planes from the region of interest. The scan planes are collected to cover a selected thickness, for example, by collecting adjacent scan planes. The scan planes are stored in the memory **266**, and then passed to a volume scan converter in the processor module **268**. In some embodiments, the probes **236**, **238** may obtain lines instead of the scan planes, and the memory may store lines obtained by the probe rather than the scan planes.

[0037] A volume scan converter module in the processor module **268** receives a slice thickness setting from a control input at user interface **267**, that an operator adjusts to choose the thickness of a slice to be created from the scan planes. The volume scan converter module in the processor module **268** creates a data slice from multiple adjacent scan planes. The number of adjacent scan planes that form each data slice is dependent upon the thickness selected by the slice thickness control input. The data slice is stored in memory **266** for access by the volume rendering processor in the processor module **268**. The volume rendering processor module in the processor module **268**, in conjunction with image display programs in the memory **266**, performs volume rendering upon the data slice. The output of the volume rendering processor module passes to the video processor **270** and monitor **272**.

[0038] A video link **269** is maintained between video processor module **270**, image memory **265** and U/S monitor **272**. the U/S system **250** includes a video output (e.g., VGA output) that is connected to a video link **225** (e.g., a VGA cable). The video link **225** conveys to the physiology workstation **206** the identical video signals as presented to the U/S monitor **272**.

[0039] The processor module **258** in the IVUS system **252** and the processor module **268** in the ultrasound system **250** may also receive hemodynamic, inter-cardiac and/or surface ECG signals from the sensor module **244**, surface leads **242** and catheter **234**. Optionally, the processor modules **258** and **268** may receive respiratory signals corresponding to the breathing cycle of the patient. The processor modules **258** and **268** utilize the IC signals, HD signals, ECG signals and/or respiratory signals to derive timing information that is tagged to each ultrasound image frame generated by the scanned converter **326** (FIG. **2**). In one mode of operation, the ultrasound system **250** displays sequences of images captured by the probes **236**, **238**. One or more of the images may be displayed in synchronism with an event trigger determined by in the processor module **268**.

[0040] Optionally, the IVUS system **252** and/or the ultrasound system **250** may be operated in an acoustic radiation force imaging (ARFI) mode. ARFI allows examination of the functionality of tissue subsets, such as in the heart, organs, tissue, vasculature and the like. ARFI is a phenomenon associated with the propagation of acoustic waves through a dissipative medium. It is caused by a transfer of momentum from the wave to the medium, arising either from absorption or reflection of the wave. This momentum transfer results in the application of a force in the direction of wave propagation. The magnitude of this force is dependent upon both the tissue properties and the acoustic beam parameters. The duration of the force application is determined by the temporal profile of the acoustic wave. ARFI images the response of tissue to acoustic radiation force for the purpose of characterizing the mechanical properties of the tissue. When the duration of the radiation force is short (less than 1 millisecond), the tissue mechanical impulse response can be observed. ARFI imaging has many potential clinical applications, including: detecting and characterizing a wide variety of soft tissue lesions, and identifying and characterizing atherosclerosis, plaque, and thromboses.

[0041] The procedure room **204** may include various equipment and systems, such as an x-ray system **232** that controls a rotating support arm **280**. The modes, parameters and other settings of the x-ray system **232** are entered and controlled from the user interface **287**. The support arm **280** includes a x-ray source and a x-ray detector on opposite ends thereof. The x-ray detector may represent an image intensifier, a flat panel detector, a change coupled device and the like. The x-ray detector provides fluoroscopy data to a data acquisition system **282** which stores the x-ray data in memory **284**. A processor module **286** processes the x-ray data to generate x-ray images that may be stored in memory **284** or passed directly to video processor module **288**. The processor module **286** also receives HD, IC and/or ECG signals from the sensor module **244**. The processor module **286** enters timing information with each image frame representing the time at which the frame was acquired. The video processor **288** may include a frame grabber which obtains single x-ray images from the memory **284** and controls presentation of the x-ray images on the monitor **290**.

[0042] In each of the x-ray system **232**, IVUS system **252** and U/S system **250**, the timing information may be derived from the time of day, or from a reference clock. Alternatively, the various processors may have synchronized clocks which result in all the various systems being synchronized to the identical spot in the cardiac cycle. Alternatively, the timing information may be associated with the cardiac cycle of the patient which is determined by the EP signals provided from the sensor module **244**.

[0043] The workstation **206** includes a physiology control module **208** which is configured to receive and transmit a variety of signals and data that are conveyed to and from the patient over leads, cables, catheters and the like. Examples of signals that may be received by the control module **208** include intercardiac (IC) signals and/or hemodynamic signals from catheters **234**, patient monitoring signals (e.g., from a blood pressure cuff, SPO2 monitor, temperature monitor, CO2 levels and the like), ECG signals from surface ECG leads **212**.

[0044] When separate rooms are used, the link **246** extends from the workstation **206**, through the wall or other divider separating the control and procedure rooms **202** and **204**, into the procedure room. Alternatively, all equipment may be in the same room. The link **246** conveys, among other things, IC signals, hemodynamic signals, patient monitoring signals, surface ECG signals and pressure signals. The content and nature of the information conveyed over the link **246** is explained below in more detail. In one embodiment, the link **246** is comprised of physical connections (e.g. analog lines, digital lines, coaxial cables, Ethernet data cables and the like or any combination thereof). Optionally, the link **246** may be all or partially wireless (e.g., an RF link).

[0045] The workstation **206** is used in an EP or HD study, such as to provide a detailed evaluation of the heart's electrical system. During an EP or HD study, typically 3-5 catheters may be used. Each EP catheter **234** includes platinum electrodes spaced near the tip of the catheter, where such electrodes have the ability to record electrical signals from inside the heart as well as deliver stimulus pulses to the heart from different locations, such as to pace the heart. The workstation **206** evaluates normal and abnormal conductions and rhythms. The protocol used during the EP study may vary from site to site or procedure to procedure (e.g. corrected sinus node recovery time, AV Wenckebach and the like). Typically, HD catheters **234** have an open lumen to monitor pressure.

[0046] The control module **208** communicates directly with an external stimulator **214**, which may be part of or separate from the workstation **206**. The stimulator **214** delivers electrical signals (such as for pacing or defibrillating the heart) the catheters **234** positioned within the patient. The stimulator **214** is utilized to induce a pacing train of pulses in order to stabilize a refractory period. The pacing train is considered to have "entrained" the heart once it has captured the heart for a predetermined series of beats. Once the heart is entrained, extra stimuli are added to mimic certain capabilities of the heart. The stimulator **214** may drive ventricular protocols through pacing from a ventricular catheter. One reason for ventricular pacing may be to assess the conduction retrograde through the AV node or bypass tract. When assessing conduction retrograde through the AV node, a VAWBK will also be obtained. Another ventricular protocol is the ventricular effective refractory period (VERPS). The stimulator **214** may also be used to induce arrhythmias. For example, during ventricular protocols, ventricular tachycardia or ventricular fibrillation may be induce as an end point. A patient's level of consciousness is assessed while attempts are made at overdrive pacing (if appropriate).

[0047] The incoming signals from the patient are passed through sensor module **244** which may perform various signal processing operations upon the incoming signals and/or reroutes the EP signals to the X-ray system **232**, ultrasound system **250**, IVUS system **252** and workstation **206**. The control module **208** manages overall control and operation of the workstation **206**. The EP control module **208** receives user inputs through the user interface **210**. The EP control module **208** stores data, images and other information in the memory **212**. The EP video processor module **216** accesses memory **212** in order to obtain and store various data, signal traces, images and the like. The memory **212** may store diagnostic images, such as ultrasound CT and MR images acquired prior to the procedure. The stored images facilitate pre- and post-procedure analysis for image optimization, manipulation and analysis.

[0048] The control module **208** communicates uni-directionally or bi-directionally with video processor module **216** which controls monitors **218** and **220**. The monitors **218** and **220** may simply present displayed information as explained hereafter. Optionally, the monitors **218** and **220** may include input buttons for operation by the user to directly enter certain commands and instructions at the monitor **218** and **220**. Optionally, the monitors **218** and **220** may represent touch sensitive screens that enable the user to enter information directly by touching active areas of a corresponding monitor **218** and **220**.

[0049] In the example of FIG. **1**, monitors **218** and **220** have been assigned different categories of functions (e.g. real-time monitoring, operations monitoring, documentation monitoring and the like). Monitor **218** presents numerous windows, such as an ablation window, a real-time EP/HD monitoring window and a preprocessing planning window. The monitor **220** displays windows related to operation control, such as an EP/HD recording user interface window, a mapping user interface window and a catheter steering user interface window. The user interface windows allow the operator to enter and change parameters, modes, patient information, values and the like in connection with a particular EP study. Optionally, one of the monitors **218** and **220** may present windows associated with documentation of a particular patient case, such as a case review window, a case reporting window and a case log window. The case-related windows allow the user to review patient history information, as well as current patient information associated with the EP study.

[0050] The workstation **206** integrates the display of real-time ultrasound and fluoroscopy images with other EP/HD study information and/or ablation procedure information by utilizing one or more of monitors **218**, **220** and **224**. For example, the real-time image monitor **224** may present ultrasound images obtained from an ultrasound catheter, while the planning window presents previously acquired CT or MR images. Integrating the ultrasound images into the workstation affords, among other things, an improved standard of care, increased user confidence and shorter procedure time.

[0051] Optionally, the real-time image monitor **224** may present ultrasound images as a cine loop, in which a sequence of ultrasound frames is acquired and associated with one or more cardiac cycles. The cine loop of ultrasound images may be repeatedly displayed or frozen. While the real-time image monitor **224** presents the ultrasound images, the monitor **218** simultaneously displays real-time EP or HD signals corresponding to the ultrasound cine loop.

[0052] FIG. **2** illustrates an exemplary block diagram of processor module **258** or **268** of the IVUS or ultrasound systems **252** or **250**, respectively. The processor module **258**, **268** is illustrated conceptually as a collection of modules, but may be implemented utilizing any combination of dedicated hardware boards, DSPs and processors. Alternatively, the modules may be implemented utilizing an off-the-shelf PC with a single processor or multiple processors, with the functional operations distributed between the processors. As a further option, the modules may be implemented utilizing a hybrid configuration in which certain modular functions are performed utilizing dedicated hardware, while the remaining modular functions are performed utilizing an off-the shelf PC and the like. The operations of the modules may be controlled by a local ultrasound controller **302**. The modules **306-312** perform operations that may generally be characterized as mid-processor operations.

[0053] The processor module **258**, **268** receives ultrasound data **304** in one of several forms depending upon the type of probe or catheter. In the embodiment of FIG. **2**, the received ultrasound data **304** constitutes I, Q data pairs representing the real and imaginary components associated with each data sample. The I, Q data pairs are provided to a color-flow module **314**, a power Doppler module **312**, a B-mode module **310**, a spectral Doppler module **308** and M-mode module **306**. Optionally, other modules may be included such as a strain module, a strain rate module, ARFI module and the like. Each of modules **306-312** process the I, Q data pairs in a corresponding manner to generate color-flow data **324**, power Doppler data **322**, B-mode data **320**, spectral Doppler data **318**, M-mode data **316**, ARFI module **315**, strain data and strain rate data, all of which may be stored in memory **256**, **266**. The color-flow, power Doppler, B-mode, spectral Doppler, M-mode data, ARFI module **315**, strain data and strain rate data **316-325** may be stored as sets of vector data values, where each set defines an individual ultrasound image frame. The vector data values are generally organized based on the polar coordinate system.

[0054] The scan converter module **326** reads from memory **256**, **266** the vector data values associated with an image frame and converts the set of vector data values to Cartesian coordinates to generate an ultrasound image frame **332** formatted for display. Once the scan converter module **326** generates the ultrasound image frames **332** associated with B-mode data, color-flow data, power Doppler data, ARFI module **315**, strain data and strain rate data, and the like, the image frames may be restored in memory **256**, **266** or passed over bus **338** to the video processor **260** or **270**.

[0055] As an example, it may be desired to view a B-mode ultrasound image in real-time on monitor **262** or **272** associated with the ultrasound signals detected by an ultrasound catheter **240** or probe **236**, **238** (FIG. **1**). To do so, the scan converter module **326** obtains B-mode vector data sets for images stored in memory **256**, **266**. The B-mode vector data is interpolated where necessary and converted into the X, Y format for video display to produce ultrasound image frames. The scan converted ultrasound image frames are passed to the video processor **260**, **270** that maps the video to a grey-scale mapping for video display. The grey-scale map may represent a transfer function of the raw image data to displayed grey levels. Once the video data is mapped to the grey-scale values, the video processor **260**, **270** controls the monitor **262**, **272** to display the image frame in real-time during a procedure. The B-mode image displayed in real-time is produced from an image frame of data in which each datum indicates the intensity or brightness of a respective pixel in the display. The display image represents the tissue and/or blood flow in a plane through the region of interest being imaged.

[0056] The color-flow module **314** may be utilized to provide real-time two-dimensional images of blood velocity in the imaging plane. The frequency of sound waves reflected from the inside of the blood vessels, heart cavities, etc., is shifted in proportion to the velocity of the blood vessels; positively shifted for cells moving toward the transducer and negatively shifted for cells moving away from the transducer. The blood velocity is calculated by measuring the phase shift from firing to firing at a specific range gate. Mean blood velocity from multiple vector positions and multiple range gates along each vector are calculated and a two-dimensional image is made from this information. The color-flow module **314** receives the complex I, Q data pairs from the beamformer **254**, **264** (FIG. **1**) and processes the I, Q data pairs to calculate the mean blood velocity, variance (representing blood turbulence) and total pre-normalized power for all sample volumes within the operator defined region.

[0057] The spectral Doppler module **308** operates upon the I, Q data pairs by integrating (summing) the data pairs over a specified time interval and then sampling the data pairs. The summing interval and the transmission burst length together define the length of the sample volume which is specified by the user at the user interface **257**. The spectral Doppler module **308** may utilize a wall filter to reject any clutter in the signal which may correspond to stationery or very slow moving tissue. The filter output is then fed into a spectrum analyzer, which may implement a Fast Fourier Transform over a moving time window of samples. Each FFT power spectrum is compressed and then output by the spectral Doppler module **308** to memory **256**. The 2D video processor module **328** then maps the compressed spectral Doppler data to grey scale values for display on the monitor **262** as a single spectral line at a particular time point in the Doppler velocity (frequency) versus a time spectrogram.

[0058] The 2D video processor module **328** may combine one or more of the frames generated from the same or different types of ultrasound information. Optionally, the processor module **328** may superimpose an image of one type (e.g., B-mode) on an image of another type (e.g., color Doppler). For example, the 2D video processor modules **328** may combine a B-mode image frame and a color-flow image frame by mapping the B-mode data to a grey map and mapping the color-flow data to a color map for video display. In the final displayed image, the color pixel data is superimposed on the grey scale pixel data to form a single multi-mode image frame **334** that is re-stored in memory **256** or passed over bus **338**. Alternatively, the process module **328** may superimpose an image obtained at one point in time with an image obtained at another point in time (e.g., temporal superposition). For example, the processor module **328** may perform image compounding through which two or more images of the same type/mode (but acquired for different spatial regions) are combined to form a larger image.

[0059] Successive frames of color-flow and/or B-mode images may be stored as a cine loop in memory **256**. The cine loop represents a first in, first out circular image buffer to capture image data that is displayed in real-time to the user. The user may freeze the cine loop by entering a freeze command at the user interface **257**. The user interface **257** represents a keyboard and mouse and all other commands associated with ultrasound system user interface.

[0060] A 3D processor module **330** is also controlled by user interface **257**, **267** and accesses memory **256**, **266** to obtain spatially consecutive groups of ultrasound image frames and to generate three dimensional image representation thereof, such as through volume rendering or surface rendering algorithms. The three dimensional images may be generated utilizing various imaging techniques, such as ray-casting, maximum intensity pixel projection and the like.

[0061] Returning to FIG. **1**, the workstation **206** includes an external video processor module **222** that has access to memory **212** and communicates with the control module **208**. The external video processor module **222** controls a separate monitor **224** provided as part of the workstation **206**. Monitor **224** is positioned immediately adjacent monitors **218** and **220** in order that all 3 monitors may be reviewed simultaneously by an operator of the workstation **206**.

[0062] The external video processor module **222** receives video input signals **223**, **225**, and **227** from the x-ray system **232**, the ultrasound system **250** and the IVUS system **252**, respectively. The video signals **223**, **225** and **227** are directly attached to the video signals used to drive the fluoroscopy monitor **290**, ultrasound monitor **272**, and IVUS monitor **262**, respectively. The external video processor module **222**, under direction of the control module **208**, affords a comprehensive image management system under which fluoroscopy and ultrasound images may be viewed in real-time at the workstation **206**. The external video processor module **222** includes additional video input signals (e.g., such as signal **229**) from any standard video source.

[0063] By way of example only, the monitor **224** may have a resolution of 1600×1200 pixels and acquire 1 k×1 k images at 72 Hz sampling from multiple video signals **223**-**229**. The video signals **223**-**227** may be tied directly to VGA outputs of the monitors **290**, **272** and **260**, which allow images displayed on the fluoroscopy, ultrasound and IVUS systems **232**, **250** and **252**, to be sent directly to the EP workstation **206** and displayed on the monitor **224** as one of various video input signals. Hence, monitor **224** presents, in real-time, identical information to the information presented on the monitors **290**, **272** and/or **260** in the procedure room in real-time.

[0064] Alternatively, the external video processor module **222** may be removed and one or more of the links **223**, **225**, **227** and **229** provided directly to a corresponding input of the monitor **224** (such as indicated by dashed line **231**).

[0065] Optionally, the fluoroscopy, ultrasound and IVUS images presented on monitors **290**, **272** and **262** (and monitor **224**) may be synchronized with one another based upon the timing information stored in connection with each fluoroscopy, ultrasound and IVUS image. The timing information may be derived from a system clock, a master oscillator, the cardiac cycle of the patient (as defined within the ECG signals and/or IC or HD signals detected from the patient). Alternatively, the images presented on the fluoroscopy, ultrasound and IVUS monitors **290**, **272** and **262** may not be directly synchronized with one another and instead displayed simultaneously in real-time, but in a non-synchronized manner with respect to one another.

[0066] FIG. **3** illustrates a pictorial representation of a processing sequence carried out in connection with image management. The memory and various modules of FIG. **3** may be implemented within the external video processor module **222**. In FIG. **3**, an ECG signal trace **350** is illustrated for two cardiac cycles **352** and **354**. Alternatively, the ECG signal trace **350** may be replaced with an IC or HD signal trace. During each cardiac cycle **352**, **354** the x-ray system **232**, ultrasound system **250** and IVUS system **260** (FIG. **1**) each acquire fluoroscopy and ultrasound data and generate corresponding fluoroscopy, ultrasound and IVUS images **356**, **358** and **360**, respectively. A first set **362** of fluoroscopy images **356** is acquired during the first cardiac cycle **352**, while a second set **364** of fluoroscopy images is acquired during the second cardiac cycle **354**. Similarly, first and second sets **366** and **368** of ultrasound images **358** are acquired during the first and second cardiac cycles **352** and **354**. First and second sets **370** and **372** of IVUS images **360** are acquired during the first and second cardiac cycles **352** and **354**.

[0067] The x-ray, ultrasound and IVUS systems **232**, **250** and **252** each receive the ECG trace **350** (such as from the sensor module **244** in FIG. **1**). Thus, each of the x-ray, ultrasound and IVUS systems **232**, **250** and **252** identify a selected, common point in the cardiac cycle (e.g., the P-wave). The commonly selected point in the cardiac cycle is utilized as a common reference point from which all timing calculations are determined. When each fluoroscopy, ultrasound and IVUS image **356**, **358** and **360** is obtained, a time stamp is determined. The time stamp may be based on the ECG signal **350** or on synchronization of the clocks of the processors resulting in identical timing of the systems. The time stamp is recorded with each image to identify the precise point during the cardiac cycle at which the image was obtained. With respect to the fluoroscopy images **356**, time stamps T**1**-T**5** are illustrated as being correlated to the fluoroscopy images **1**-**5** in the first set **362**.

[0068] The fluoroscopy, ultrasound and IVUS imaging systems **232**, **250** and **252** may or may not obtain images at an identical or equal rate. The example of FIG. **3** illustrates that fluoroscopy images may be obtained at a rate of approximately 60 frames per cardiac cycle (e.g., when a patient has a heart rate of 60 beats per second, which corresponds to a frame rate of 60 frames per second). The ultrasound and IVUS systems **250** and **252** may obtain images at different rates as well. For example, the ultrasound system may obtain images at a rate of 30 images per second which correlates to 30 images per cardiac cycle in the present example. Images **1**-**30** are obtained in set **366** during cardiac cycle **352**, while images **31**-**60** are obtained during cardiac cycle **354**.

[0069] The frame rate of the IVUS system **252** may be, for example, 15 IVUS frames per cardiac cycle. In the example of FIG. **3**, set **370** includes IVUS images **1**-**15** which are obtained during cardiac cycle **352**, while images **16**-**30** are obtained during cardiac cycle **354**.

[0070] Time stamps T**1**, T**3**, T**5**, T**7** and T**9** are stored or otherwise correlated with the ultrasound images **1**-**5** in the image set **366**, while time stamps T**1**, T**4**, T**7**, T**10** and T**13** are stored or otherwise correlated with IVUS images **1**-**5** in image set **370**. The time stamps **374**, **376** and **378** are stored in the corresponding memories **380**, **382** and **384** with associated images **356**, **358** and **360**, respectively, in a one-to-one relation. The memories **380**, **382** and **384** may be part of memory **212**, or alternatively, three separate video memory areas or a common video memory **233**. The fluoroscopy images **356** may be loaded directly into the memory **380** by way of example. The ultrasound images **358** and IVUS images **360** may be passed through interpolator modules **386** and **388**, respectively before being stored in memories **382** and **384**. The interpolator modules **386** and **388** may be part of the external video processor module **222** and may perform temporal interpolation between consecutively acquired images to generate additional "synthetic" images (e.g., images not directly derived from raw echo signals) corresponding to the time stamps for which images based on raw data were not obtained. For example, the interpolator module **386** may generate a synthetic ultrasound image associated with time stamp T**2** based on an interpolation between the ultrasound images **1** and **2** which were acquired at time stamps T1 and T3 before and after the time of the synthetic image. The interpolator module **386** repeats this process to generate a number of ultrasound images equal in number to the number of fluoroscopy images **356**.

[0071] The interpolator module **388** may perform a similar interpolation process, but produce two synthetic images to be inserted between adjacent IVUS images acquired from raw data. For example, interpolator **388** generates synthetic images for times T2 and T3 which are inserted between the images **1** and **2** obtained at time stamps T1 and T4. Interpolator modules **386** and **388** may utilize weighting functions to assign a greater weight to one of the images preceding or succeeding the time at which an interpolated image is being generated. Optionally, multiple consecutive images may be combined (e.g., averaged, from which the synthetic/interpolated image are calculated).

[0072] Optionally, the interpolator modules **386** and **388** may not produce synthetic or interpolated images to fill the gaps between acquired images. Instead, the interpolator modules **386** and **388** may simply copy acquired images into the blank image frames. For example, interpolator module **386** may copy U/S image #**1** and assign the copy of U/S image #**1** to time stamp T**2**. The interpolator module **388** may copy IVUS image #**1** into time stamps T2 and T3, or copy IVUS image #**2** (associated with time stamp **4**) into the image frames associated with time stamps T3 and T5.

[0073] Once the fluoroscopy, ultrasound and IVUS images **356**, **358** and **360** are loaded into memories **380**, **382** and **384**, a video processor **390** (within the video processor module **222**) accesses one or more image frames from one or more of the memories **380**, **382** and **384** and stores the corresponding image frame or frames in video memory **392**, which frame(s) is then reproduced on the monitor **394**. By way of example, the video processor **390** may reformat and load fluoroscopy image #**1** into memory area **396**, ultrasound image #**1** into memory area **391**, ultrasound image #**1** into memory area **393** and IVUS image #**1** into memory area **395**. The grey scale and/or black and white information in memory areas **391**, **393** and **395** are reproduced on the monitor **394** in windows **397**, **399** and **401**, respectively.

[0074] Formatting by the video processor **390** may include changing the resolution of the image, such as from a higher resolution to a lower resolution. For example, the resolution of a fluoroscopy image frame may be 2K by 2K pixels, while the monitor **224** (FIG. **1**) may only be able to display a 1K by 1K fluoroscopy image. In this example, the video processor **390** reformats the fluoroscopy image by subtracting every other pixel from the image frame. Alternatively, the video processor **390** may reformat the image frame by applying a smoothing or averaging filter to the pixel values. As another example, the ultrasound image frame may be formatted 1600×1000 pixels, whereas the window into which the image frame is mapped has a resolution of 1200×800. The video processor **390** reformats the image frame by averaging, interpolation, copying of data values, removing data values and the like.

[0075] Individual images may be captured as snapshots under the control of the control module **208** and user interface **210**. The snapshot images may be passed to a library or other memory **212**.

[0076] FIG. **4** illustrates a screen shot of an exemplary collection of windows that may be presented on the monitor **394**. The screen shot includes a fluoroscopy image window, an ultrasound image window and an image library window. The image library window illustrates a series of previously acquired ultrasound, fluoroscopy or IVUS images, from which the user may select. When the user selects one of the images from the library, it may be illustrated in the image review window, and co-displayed with a real-time image of another modality or saved image of another modality obtained at the same point in the cardiac cycle.

[0077] FIG. **5** illustrates a physiology system **500** formed in accordance with an alternative embodiment of the present invention. The system **500** is distributed between a control room **502** and an a procedure room **504** separated by a dividing wall **506**. Optionally, the system **500** may be provided all in the procedure room **504**. The control includes a workstation **508**, while the procedure room includes an x-ray imaging controller **510**, an ablation device **512**, the backend subsystem **514** of an ultrasound system. EP or HD catheters **516**, an ablation catheter **518** and an ultrasound catheter **520** are shown adjacent a bed **522** on which a patient rests during a procedure. ECG surface leads **524** are provided for attachment to the surface of the patient to monitor the ECG signals. An amplifier **526** receives the ECG signals from the surface leads **524** and receives intracardiac and/or hemodynamic signals from the catheters **516**. The ablation device **512** controls the ablation catheter **518**.

[0078] The backend subsystem **514** includes transmit and receive modules **528** and **530** that control transmission and reception of ultrasound signals to and from ultrasound catheter **520**. A beamformer **532** is joined to the transmitter and receiver **528** and **530**, respectively, and operates in a manner described above to generate RF signals that are passed to an RF processor **534**. The RF processor **534** converts the RF signals to I, Q data pairs associated with ultrasound data samples and stores the I, Q data pairs in the sample memory **536**. A signal processor module **538** may directly communicate with the RF processor **534** and/or access the sample memory **536** to perform various ultrasound processing functions, such as discussed above in connection with FIG. **2**. The signal processor module **538** generates ultrasound images that are passed from the procedure room **504** through the dividing wall **506** along a data transmission link **540** to an ultrasound image memory **542** located in the control room **502** as part of the EP workstation **508**. The ultrasound image memory **542** stores sets of image frames as two-dimensional slices or as three dimensional volumes.

[0079] A pre-procedure imaging system **544**, such as a MR system, CT system, PET, Nuclear System and the like is utilized to obtain medical diagnostic information associated with the patient. The pre-procedure imaging system **544** delivers image data sets to a planning module **546** which stores the image data sets for subsequent processing by the workstation **508**. A hospital network **548** is also joined, via a network link **550** to the workstation **508**.

[0080] The workstation **508** includes a control module **552** that communicates with the x-ray imaging controller **510**, ablation device **512**, backend subsystem **514** of the ultrasound system over a link **554**. The control module **552** also receives, over link **554**, ECG and IC signals from the amplifier **526**. The control module **552** also delivers stimulus signals over link **554** to the catheter **516**. The stimulator **556** is joined to the control module **552** to generate the stimulus signals ultimately delivered to the patient through the catheter **516**. The control module **552** communicates with the x-ray image memory **558** which receives x-ray images over link **560** from the x-ray imaging controller **510**. A user interface **562** is used to control the workstation **508**. The control module **552** stores the ECG signals, IC signals and other procedure related information in the study memory **564**. A video processor **566** accesses the x-ray image memory **558**, study memory **564**, ultrasound image memory **542** and planning module **546** to obtain information and images for display on monitors **568**, **570** and **572**.

[0081] FIG. **6** illustrates a screenshot of an exemplary window presented on one of the monitors of the physiology workstation **206** or **508** of FIG. **1** or **5**, respectively. The screenshot of FIG. **6** represents a hemodynamic window **600**, including three ECG traces, above a graph plotting the pressure at a particular point within the heart. In the example of FIG. **6**, the pressure information is being obtained from an open lumen catheter having an outer end located proximate the mitral valve. The peaks and valleys within the graph represent the diastolic points (DP) and systolic points (SP) in the cardiac cycle. The pressure at each DP and SP is indicated as well. The EDP represents the end diastolic pressure. Along the bottom of the graph are a series of time stamps identifying the time (relative to the system clock) at which each pressure point was measured. The upper and lower controls (UpperCtrl and LowerCtrl) may be adjusted by the operator to adjust the dynamic range over which the pressure is measured.

[0082] FIG. **7** illustrates a block diagram of an alternative embodiment in which remote control is provided for various systems and devices. In FIG. **7**, a physiology workstation **702** (e.g. EP or H. D. workstation) and includes a physiology workstation processing module **704** that communicates with, and is controlled by, a physiology workstation user interface **706**. The physiology workstation **702** may be located in a new separate room (e.g. a control room) remote from the systems **720-724**. Alternatively, the physiology workstation **702** may be located in the same room as the systems **720-724**. A remote device user interface **708** also communicates with the physiology workstation processing module **704**. The monitors **710-713** are joined to the physiology workstation processing module **704** to illustrate the various information, images, signals and the like explained above. A link **716** is maintained between the physiology workstation processing module **704** and various remote devices, such ultrasound system **720**, IVUS system **721**, x-ray system **722**, ablation system **723** and physiology mapping system **724**. The systems **720-724** may each include the associated types of acquisition apparatus (e.g. catheters, probes, C-arm, coils and the like, as well as monitors and user interfaces).

[0083] The link **716** may include one or more links connected to each of the systems **720-724**. For example, the link **716** may include a single serial or parallel line directly extending from the remote device user interface **70821** of the systems **720-724**, and attached thereto, at a user interface input. Alternatively or in addition, link **716** may include a data bus conveying serial or parallel data between the processors within module **704** and one or more of systems **720-724** (e.g. ECG data, EP data, HD data, image frames and the like). The link **716** may also include one or more video cables extending between a video output (e.g. VGA) at one of systems **720-724** and a video input at one or more of monitors **710-713**.

[0084] Optionally, the link **716** may constitute a network connection, such as supporting an Internet protocol (IP) or the transmission control protocol (TCP), or other protocols. The data may be transmitted over link **716** as raw ultrasound or x-ray data, formatted in the Hypertext markup (HTML) language, and the like. Optionally, the link **716** may be constructed as a local area network configuration, a client/server configuration, an intranet configuration, a file sharing configuration and the like. Communications modules **704*a*** and **720*a*-724*a*** would be provided at each of the module **704** and systems **720-724** configured in accordance with the appropriate configuration. The communications modules **704*a*** and **720*a*-724*a*** may represent USB ports, while the link **716** represents a USB cable. Alternatively, the communications modules **704*a*** and **720*a*-724*a*** may represent serial or parallel connectors, HSSDC connectors, Fiber Channel connectors and the like, while the link **716** represents the corresponding type of communications medium. Alternatively, the link **716** may be wireless (e.g., RF, Bluetooth, etc.).

[0085] The remote device user interface **708** may be used to control the operation of one or more of the systems **720-724**. For example, the remote device user interface seven OA may be used to enter system parameters, settings, modes and the like. The remote device user interface **708** permits the operator of the physiology workstation **702** to remotely control the operation, and remotely adjust the settings, modes and parameters, of one or more of the systems **720-724**. The remote device user interface **708** improves workflow within the procedure room, increases productivity of an EP or HD team in the procedure room and end the review room, and decreases the overall procedure duration.

[0086] By way of example, when the remote device user interface **708** is used in connection with control of the ultrasound system **720** or IVUS system **721**, the remote operator may be afforded the ability to change a modes, adjust the gain of the ultrasound probe or catheter, freeze select images on the monitor at the physiology workstation **702** and the monitor at the ultrasound system **720**, and the like. Optionally, the remote device user interface **708** may constitute a dedicated keyboard identical to a keyboard provided with one of systems **720-724**.

[0087] FIG. **8** illustrates an exemplary remote device user interface **708** constructed one to substantially resemble the keyboard of an ultrasound system. the keyboard **800** includes a keypad **802**, a trackball **804**, various dedicated buttons **806** related to particular ultrasound modes and settings. The keyboard **800** also includes soft keys **808**, the function of which changes depending upon the mode of operation. The selected function of each SoftKey **808** is indicated on the lower portion of the monitor and the SoftKey function area **810**.

[0088] FIG. **9** illustrates a processing sequence that may be carried out by the physiology workstation **206** (FIG. **1**) to provide a region tagging feature. Region tagging **900** permits an operator of the physiology workstation **206** to tag regions/points of interest in images obtained by various diagnostic systems (e.g., ultrasound, IVUS, x-ray, CT, MRI, NM, PET, physiology mapping and the like. At **902** physiology workstation **206** obtains one or more diagnostic images from one or more of the IVUS system **260**, ultrasound system **250** and x-ray system **232**. At **904** the diagnostic image is displayed on one or more of monitors **218**, **220**, **224**, **262**, **272** and **290**. The control module **208** may also passes the diagnostic image over network **209** and link **213** to a remote network site **211**, or a consultant may be located.

[0089] The operator of the physiology workstation **206** utilizes the user interface **210** to identify and to tag or designate a region or point of interest (ROI) within the diagnostic image (e.g. a lesion, a pulmonary vein, the mitral valve and the like). Optionally, a consultant at the remote network site **211** may identify and tag or designate the ROI. By way of example, the ROI may be designated by moving a cursor, at a review or physiology workstation, to a point within the diagnostic image through manipulating a trackball or mouse or arrow keys, and then pressing a key or mouse to select the position of the cursor. Alternatively, a trackball or mouse may be used to draw a boundary around the ROI by selecting a series of points as the cursor is moved around the ROI. The ROI may represent a point or an area having a predefined contour and dimension which may be adjusted dynamically during analysis of the diagnostic image, or pre-procedure based on an individual user's preferences. In addition, the user at the physiology workstation **206** or a consultant at the remote network site **211** may add annotations proximate the ROI, such as a label identifying the region of interest. Optionally, the annotation information may include comments and notes that are not directly imposed upon the diagnostic image, but instead are attached to the file containing the diagnostic image as a separate text file.

[0090] At **908**, the diagnostic image, ROI tag and annotations information are stored in memory **212** and/or video memory **233**. When a consultant at the remote network site **211** receives diagnostic images, and adds ROI tags and annotations, a tag image file is created including the diagnostic image, ROI tags and annotation information. The tag image file is returned over link **213** and network **209** to the control module **208**, which stores the tag image file in memory **212** and/or video memory **233**. At **910**, the control module **208** accesses the memory **212** or video memory **233** to obtain and display the combination of the diagnostic image, tag and annotations information on one or more of the various monitors **218**, **220**, **224**, **262**, **272** and **290**. Following **910**, the operation may stop.

[0091] Alternatively, following **910**, processing may continue to **912**, at which an ablation procedures performed such as on the region of interest. Following the ablation procedure, the tag the diagnostic image may be retrieved from memory and redisplayed. The tag the diagnostic image may be presented alone or co-displayed (at **914**) with post ablation lesion information. The post ablation lesion information may represent a computer estimation of the area exposed to ablation, a direct visual observation of the region of elated (such as obtained through IVUS imaging) and the like. For example, the post ablation lesion information may be presented as a two-dimensional image (actual or computer generated) similar in format and scale to the diagnostic image obtained at **902**. For example, when the diagnostic image represents a two-dimensional B-mode ultrasound image formatted as a sector scan, the post ablation lesion information may be presented in a similar format to facilitate review.

[0092] In accordance with the procedure of FIG. **9**, the physiology workstation **206** affords the ability to visually tag any point in ultrasound image, either from the procedure room, a review room or a remote network site. Candidate ablation points may be tagged by either an operator or a remote consultant, thereby affording a high standard of care, increased staff confidence, increased procedure speed and minimal interference of the consultant's time. The visual tags may be placed anywhere on the diagnostic image and may be marked by the system operator or by a remote operator with a remote keyboard interface. Tags marked by the system operator or a remote operator may be displayed on multiple monitors, such as the ultrasound monitor and a monitor at the physiology workstation **206**, as well as at a remote monitoring suite.

[0093] FIGS. **10**A and **10**B illustrate images acquired by an echocardiography (ICE) catheter. The ICE catheter is positioned in the right atrium proximate one side of the right atrium and is directed toward the opposite side of the right atrium. The images indicate a "Coil" representing, in the example, an ablation catheter coil. The indicia TV denotes the tricuspid valve. The area denoted ICE presents a second echocardiography catheter inserted in the right atrium. In FIG. **10**A the coil is located against the wall of the right atrium, while in FIG. **10**B the coil is not in contact with the wall of the atrium.

[0094] FIG. **11** illustrates an ultrasound image obtained by an ICE catheter located on the right side of the inter-atrial septum positioned to image the left pulmonary veins. The indicia LA denotes the left atrium, while the indicia LS and LI denote the left superior and left inferior pulmonary veins, respectively.

[0095] FIGS. **12**A and **12**B represent ultrasound images obtained by an ICE catheter. In FIG. **12**A, the indicial LAA denotes the left atrial appendage, and LUPV denotes the left upper pulmonary vein. An ablation catheter and lasso catheter are also present in the left atrium. In FIG. **12**A, the indicia RUPV and RLPV denote the right upper and lower pulmonary veins, respectively. A lasso catheter is also present in the left atrium. The ICE catheter, ablation catheter and lasso catheter were inserted into the left atrium from the right atrium by puncturing the fossa ovalis.

[0096] The figures illustrate diagrams of the functional blocks of various. The functional blocks are not necessarily indicative of the division between hardware circuitry. Thus, for example, one or more of the functional blocks (e.g., processors or memories) may be implemented in a single piece of hardware (e.g., a general purpose signal processor or a block or random access memory, hard disk, or the like). Similarly, the programs may be stand alone programs, may be incorporated as subroutines in an operating system, may be functions in an installed imaging software package, and the like.

What is claimed is:

1. A physiology workstation, comprising:

a physiology input configured to receive physiology signals from at least one of an intracardiac (IC) catheter, a hemodynamic catheter and surface ECG leads provided on a subject, the physiology signals being obtained during a procedure;

a video input configured to receive image frames, in real-time during the procedure, the image frames containing diagnostic information representative of data samples obtained from the subject during the procedure;

a physiology control module controlling physiology operations based on user inputs; and

a display module controlled by the physiology control module, the display module displaying the physiology signals and the image frames simultaneously, in real-time, during the procedure.

2. The workstation of claim 1, further comprising a video processor module formatting the physiology signals into a display format.

3. The workstation of claim 1, further comprising an physiology video processor and an external video processor receiving and controlling display of the physiology signals and image frames, respectively.

4. The workstation of claim 1, wherein the image frames include at least one of ultrasound images obtained from a surface ultrasound probe, intravenous ultrasound images obtained from an ultrasound catheter and fluoroscopy images obtained from a fluoroscopy system.

5. The workstation of claim 1, wherein the physiology signals and image frames are displayed in a synchronized manner based on one of a system clock and a cardiac cycle of the subject.

6. The workstation of claim 1, wherein the physiology signals and image frames are displayed in a non-synchronized manner.

7. The workstation of claim 1, wherein the display module includes first and second monitors, the first monitor displaying the physiology signals and the second monitor displaying the image frames both in real-time during the procedure side-by-side for viewing by the operator of the physiology workstation.

8. The workstation of claim 1, wherein the display module is located in a control room remote from a procedure room in which the subject is located.

9. The workstation of claim 1, wherein the video processor module performs interpolation between consecutive image frames to form synthetic frames, the display module displaying the image frames and synthetic frames in an interleaved manner.

10. The workstation of claim 1, wherein the video input receives image frames at a first frame rate, the video processor module processing the image frames to present the image frames on the display module at a second frame rate that differs from the first frame rate.

11. The workstation of claim 1, wherein the video input receives image frames with the diagnostic information formatted with a first resolution, the video processor module processing the image frames to present the diagnostic information on the display module at a second resolution that differs from the first resolution.

12. The workstation of claim 1, further comprising memory storing the image frames in an image library.

13. The workstation of claim 1, further comprising a user interface offer the operator a snapshot function, the physiology control module obtaining a single snapshot image frame from the image frames received at the video input when the snapshot function is selected.

14. The workstation of claim 1, further comprising a user interface offer the operator a snapshot function, the control module storing a single snapshot image frame from the image frames received at the video input when the snapshot function is selected.

15. A method for managing a physiology workstation, comprising:

receiving, at a physiology workstation, physiology signals from at least one of an intracardiac (IC) catheter, a hemodynamic catheter and surface ECG leads provided on the subject, the physiology signals being obtained during a procedure;

receiving, at the workstation, image frames, in real-time during the procedure, the image frames containing diagnostic information representative of data samples obtained from the subject during the procedure;

controlling physiology operations based on user inputs; and

displaying the physiology signals and the image frames simultaneously, in real-time, during the procedure at the workstation.

16. The method of claim 15, further comprising formatting the physiology signals into a display format.

17. The method of claim 15, wherein the image frames include at least one of ultrasound images obtained from a surface ultrasound probe, intravenous ultrasound images obtained from an ultrasound catheter and fluoroscopy images obtained from a fluoroscopy system.

18. The method of claim 15, further comprising synchronizing the physiology signals and image frames and displaying the physiology signals and image frames in a synchronized manner based on one of a system clock and a cardiac cycle of the subject.

19. The method of claim 15, wherein the physiology signals and image frames are displayed in a non-synchronized manner.

20. The method of claim 15, further comprising displaying the physiology signals on a first monitor and displaying the image frames on a second monitor both in real-time during the procedure side-by-side for viewing by the operator of the workstation.

21. The method of claim 15, further comprising interpolating between consecutive image frames to form synthetic frames, and displaying the image frames and synthetic frames in an interleaved manner.

22. The method of claim 15, wherein the image frames are received at a first frame rate, the method further comprising processing the image frames to display the image frames at a second frame rate that differs from the first frame rate.

23. The method of claim 15, wherein the image frames are received with the diagnostic information formatted with a first resolution, the method further comprising processing the image frames to display the diagnostic information at a second resolution that differs from the first resolution.

24. The method of claim 15, further comprising storing the image frames in an image library.

25. The method of claim 15, further comprising offering the operator a snapshot function, and obtaining a single snapshot image frame from the image frames received when the snapshot function is selected.

26. The method of claim 15, further comprising offering the operator a snapshot function, and storing a single snapshot image frame from the image frames received when the snapshot function is selected.

* * * * *

专利名称(译)	生理工作站，具有实时荧光透视和超声成像		
公开(公告)号	US20070016029A1	公开(公告)日	2007-01-18
申请号	US11/182910	申请日	2005-07-15
[标]申请(专利权)人(译)	通用电气公司		
申请(专利权)人(译)	通用电气公司		
当前申请(专利权)人(译)	通用电气公司		
[标]发明人	DONALDSON BRENDA RAZ ISRAEL VADODARIA SACHIN		
发明人	DONALDSON, BRENDA RAZ, ISRAEL VADODARIA, SACHIN		
IPC分类号	A61B8/00		
CPC分类号	A61B5/0215 A61B5/0245 A61B5/7475 A61B6/03 A61B6/12 A61B6/5247 A61B8/582 A61B8/12 A61B8/14 A61B8/461 A61B8/467 A61B8/5238 A61B8/565 A61B6/541 A61B8/463 A61B8/465 A61B8/468 A61B8/469		
外部链接	Espacenet USPTO		

摘要(译)

提供了一种生理学工作站，其包括生理学输入，该生理学输入被配置为接收来自插入受试者的心内（IC）导管和受试者上提供的表面ECG导联中的至少一个的生理学信号。在手术过程中获得生理信号。视频输入被配置为在过程期间实时接收图像帧。图像帧包含代表在手术期间从受试者获得的数据样本的诊断信息。控制模块基于用户输入控制生理操作。显示模块由生理控制模块控制。显示模块在手术过程中实时同时显示生理信号和图像帧。可选地，工作站可以包括视频处理器模块，其将生理信号格式化为显示格式。视频处理器模块可以包括视频处理器和外部视频处理器，其分别接收和控制生理信号和图像帧的显示。图像帧可包括从表面超声探头获得的超声图像，从超声导管获得的静脉内超声图像和从荧光透视系统获得的荧光透视图像中的至少一个。