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Liu

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(54) **MULTIPURPOSE IMAGING AND DISPLAY SYSTEM**

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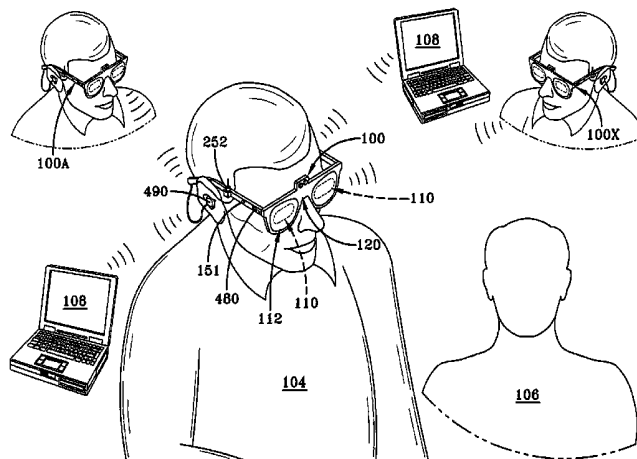
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Bobak Taylor and Weber; Ray L. Weber; Timothy A.
Hodgkiss

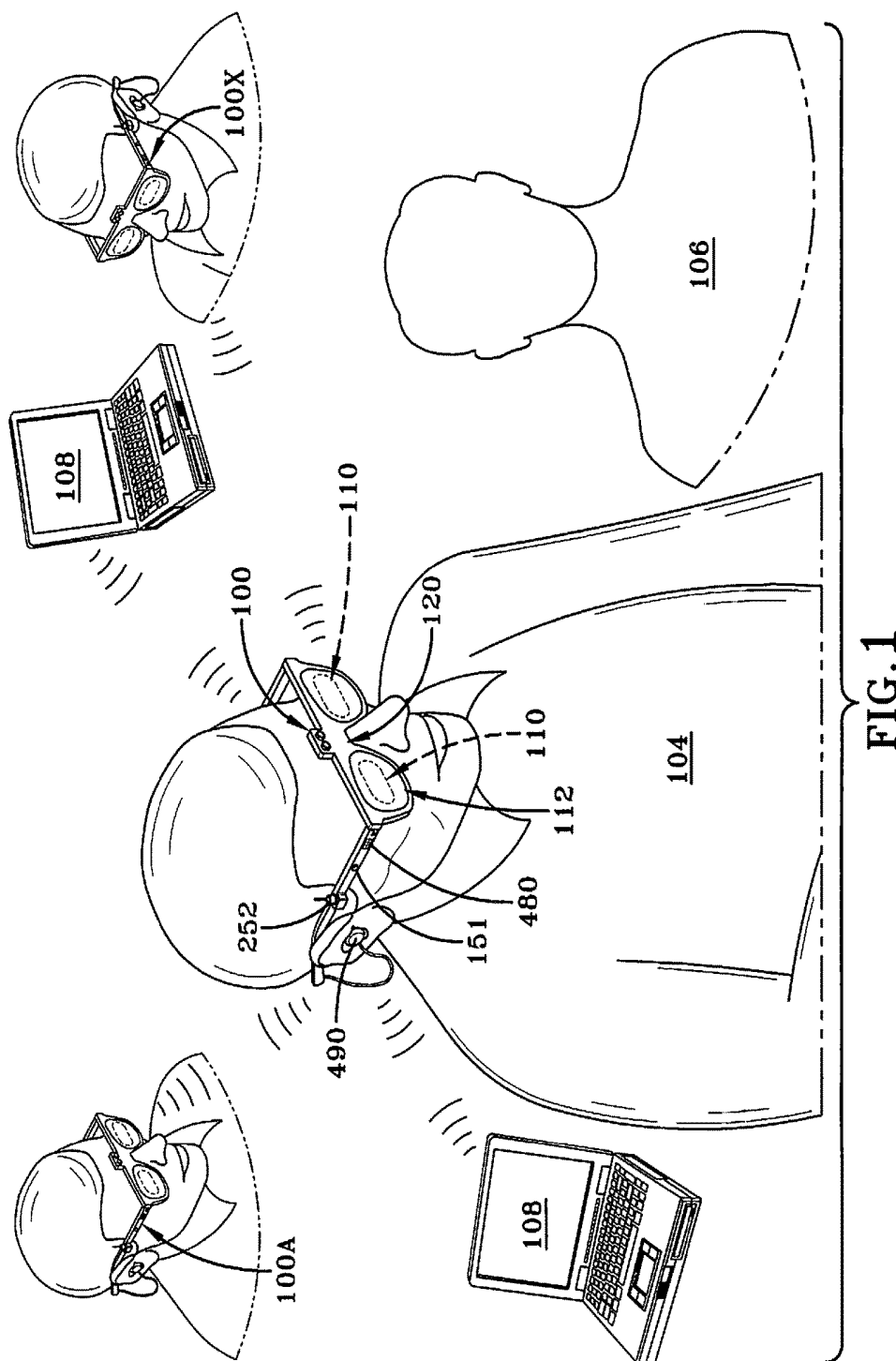
(57) **ABSTRACT**

A multi-purpose imaging and display system includes a display; a detector coupled to the display and having a field of view; and a filter communicating with the detector. The field of view is imaged by the detector through the filter, the filter configured to be sensitive to a first frequency spectrum, so the detector displays only objects within the field of view on the detector that emit one or more frequencies within the first frequency spectrum. The detector and filter can work together in different operational states or modes for acquiring image data of a target object under investigation. A computing device can be included to process acquired image data, and communication interfaces can be employed to achieve networking of multiple systems. A peripheral interface allows a plurality of peripheral devices to be selectively added to tailor the data acquisition and display capabilities of the imaging and display system.

15 Claims, 6 Drawing Sheets



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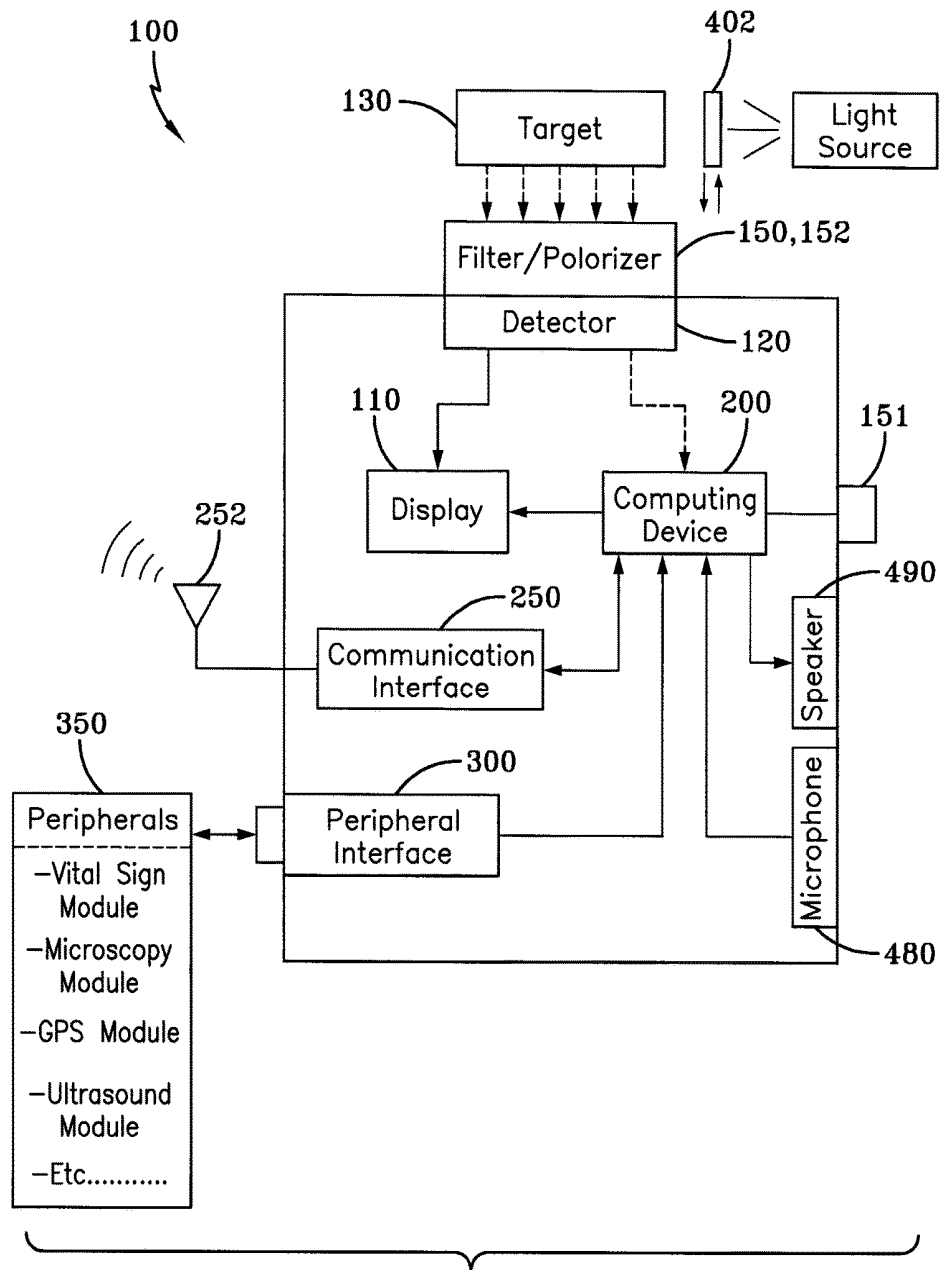


FIG.2

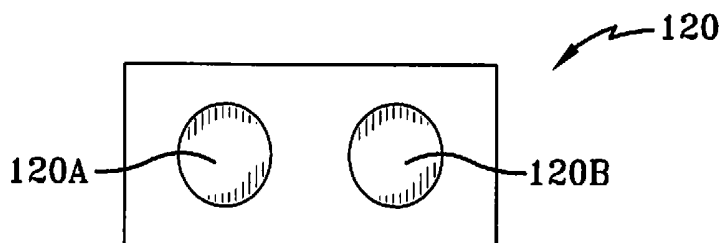


FIG. 3A

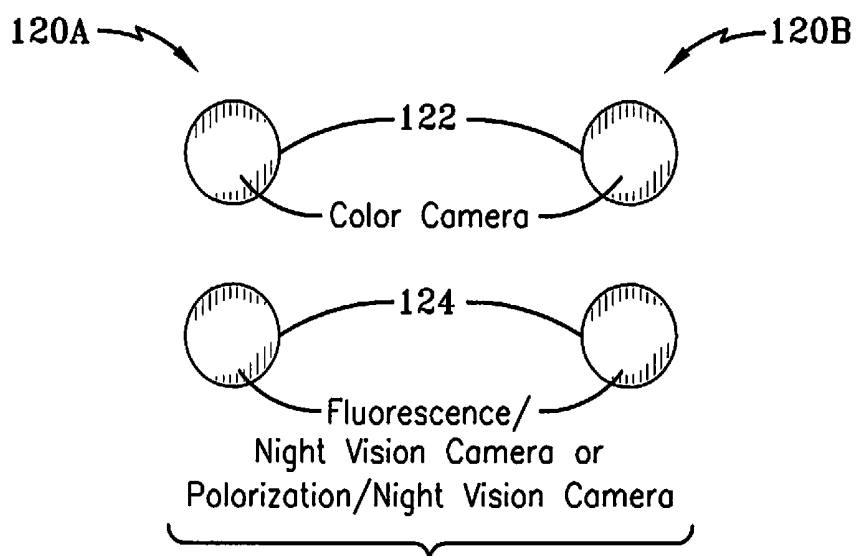


FIG. 3B

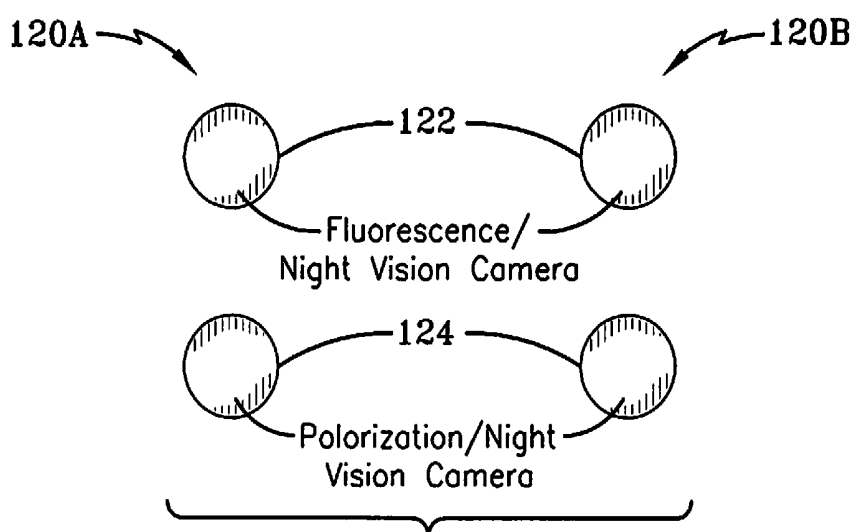


FIG. 3C

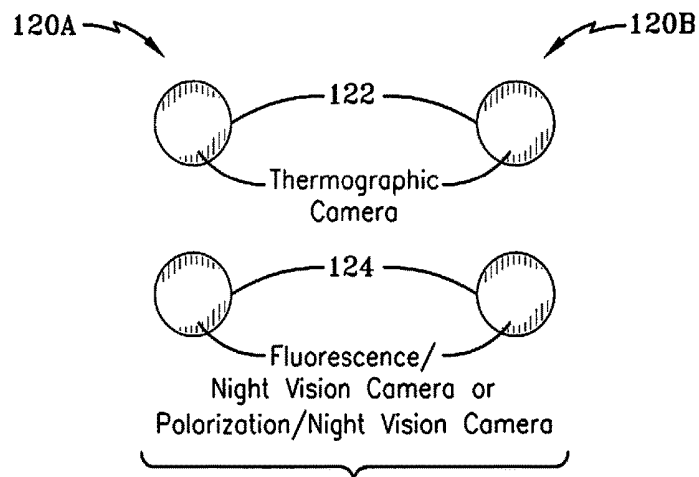


FIG. 3D

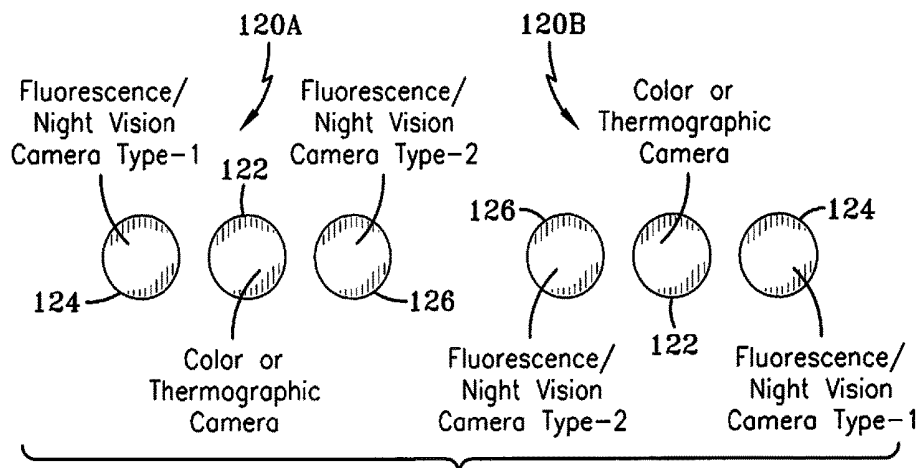


FIG. 3E

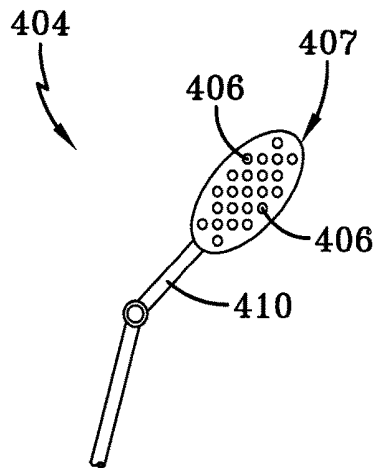


FIG. 4

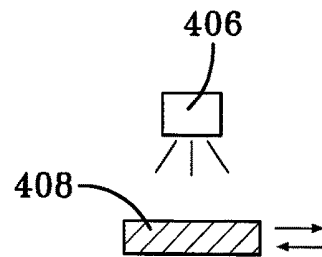


FIG. 5

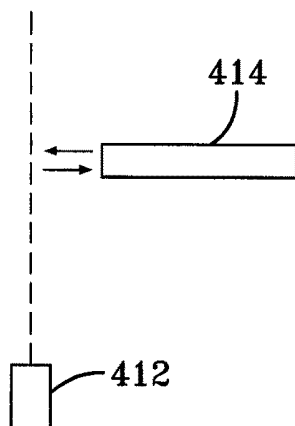


FIG. 6

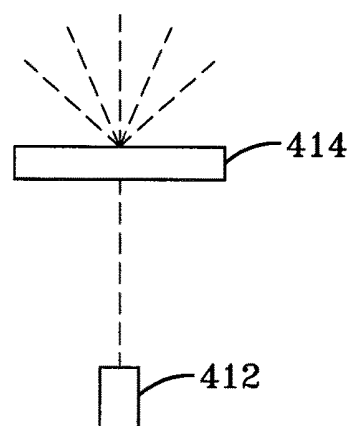
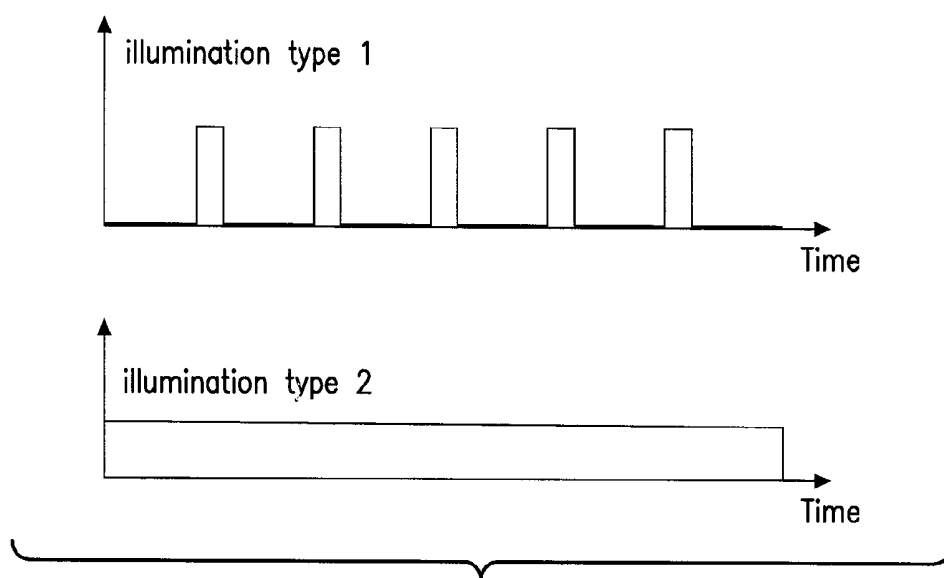
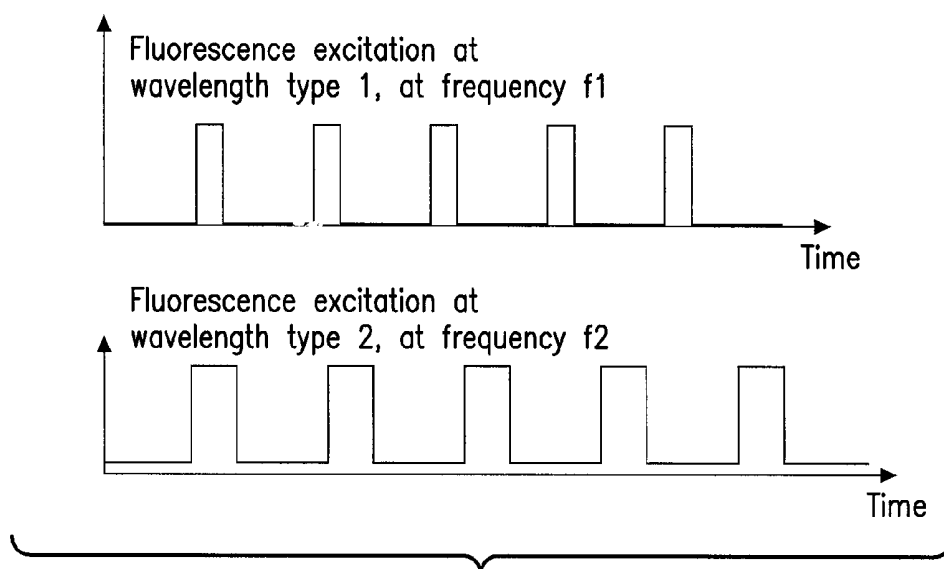


FIG. 7

**FIG. 8****FIG. 9**

1

MULTIPURPOSE IMAGING AND DISPLAY SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 61/895,630 filed on Oct. 25, 2013, the content of which is incorporated herein by reference.

TECHNICAL FIELD

The present invention generally relates to imaging and display systems. Particularly, the present invention relates to a multipurpose imaging and display system having a detector capable of being selectively converted from one imaging mode to another to image various target frequencies in order to acquire image data for viewing on a wearable display. More particularly, the present invention relates to a multipurpose imaging and display system having a wearable display and a multi-mode detector, which provides a network communication link with other imaging and display systems to facilitate collaborative communication, and that provides a communication link with various specialized data acquisition peripherals for attachment to the display to customize the data acquisition and display features of the system.

BACKGROUND OF THE INVENTION

Due to the continued advancements in military defense technology and the medical care field, visual identification and processing of data is critical to support the activities of the various personnel responsible for performing visually intensive analytical tasks. For example, in the case of military operations, improvements in the ability to efficiently identify and diagnose an injury in the field would reduce the mortality rate of injured military personnel. In addition, because the number of medically trained personnel is greatly constrained, there are limited resources that can be allocated to the screening, identification and treatment disease in the military or civilian fields. Thus, the ability to empower non-medical personnel to screen, identify and treat injuries occurring in both military and civilian fields by non-medical personnel through networked communication is highly desirable.

Furthermore, in addition to medical care, military personnel are required to fulfill a broad array of duties that requires specialized equipment. Due to the nature of such duties multiple pieces of equipment are typically required to be carried and managed by each individual. Because of the weight, and the complexity of the equipment, which can require several individual modules to be coupled together with a variety of communication cables, such equipment is significant in weight and adds to the burden placed on military personnel who are already under substantial physical stress in the field at times of combat.

Therefore, there is a need for a multi-purpose imaging and display system that provides a display, such as a wearable display, and a detector that is convertible between two or more operating modes, to reduce the total amount of equipment needed by military and medical personnel. Additionally, there is a need for a multi-purpose imaging and display system having convertible operating modes, whereby in a military combat-based mode, the multi-purpose imaging and display system is configured to perform predetermined functions, such as night-vision, remote sensing, and weapon

2

aiming are enabled; and whereby in a medical care mode, the system is configured to perform predetermined functions, such as combat casualty care, image guided surgery for first responders, telemedicine and the like are enabled. In addition, there is a need for a multi-purpose imaging and display system that is capable of monitoring, sustaining and managing injured patients when medical assistance is unavailable, through the use of computer-based analysis or telemedical guidance. In addition, there is a need for a multi-purpose imaging and display system that is configured to enable network communication between multiple users to enable untrained individuals to provide medical care through remote collaboration with trained individuals.

SUMMARY OF THE INVENTION

In a first embodiment, the present invention provides a multi-purpose imaging and display system comprising: a display; a detector coupled to said display, said detector having a field of view; a filter in operative communication with said detector, such that said field of view is imaged by said detector through said filter, said filter configured to be sensitive to a first frequency spectrum; wherein said detector displays only objects within the field of view on said detector that emit one or more frequencies within the first frequency spectrum.

In a second embodiment, the present invention provides a multi-purpose imaging display system as in the first embodiment, further comprising a computing device coupled to said display and said detector;

In a third embodiment, the present invention provides a multi-purpose imaging display system as in either the first or second embodiment, wherein said display comprises a stereoscopic display adapted to be worn and viewed by a user.

In a fourth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said display is carried by a goggle system adapted to be worn by the user.

In a fifth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said display comprises a display selected from the group consisting of: a head-mounted display, an optical-see through display, a head-mounted projection display, a video see-through display, a selective occlusion see-through head-mounted display, a retinal scanning display, a switchable optical see-through display, and a video see-through display.

In a sixth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said detector comprises a detector selected from the group consisting of: an image intensifier tube, a micro-channel plate image intensifier, a thin-film image intensifier, a camera, and a 3D camera.

In a seventh fourth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said detector comprises a sensor selected from the group consisting of: a photodetector sensor, a charge-coupled device (CCD) sensor, a complementary metal-oxide semiconductor device sensor, a photomultiplier tube (PMT) sensor; an avalanche photodiode (APD) sensor, a thermographic sensor, and photodiodes.

In an eighth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, further comprising a communication interface coupled to enable communication with at least one other multi-purpose imaging and display system.

In a ninth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said communication interface enables cloud computing.

In a tenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, further comprising a communication interface coupled to enable communication with at least one other computers, tablet computers or cell phones.

In an eleventh embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said communication interface enables cloud computing.

In a twelfth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, further comprising a communication interface enabling cloud computing.

In a thirteenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, further comprising a peripheral interface adapted to communicate with one or more peripherals.

In a fourteenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is selected from the group consisting of optical spectrometer, absorption spectrometer, fluorescence spectrometer, Raman spectrometer, Coherent anti-Stokes Raman spectrometer, surface-enhanced Raman spectrometer, Fourier transform spectrometer, Fourier transform infrared spectrometer (FTIR), diffuse reflectance spectrometer, multiplex or frequency-modulated spectrometer, X-ray spectrometer, attenuated total reflectance spectrometer, electron paramagnetic spectrometer, electron spectrometer, gamma-ray spectrometer, acoustic resonance spectrometer, auger spectrometer, cavity ring down auger spectrometer, circular dichroism auger spectrometer, cold vapour atomic fluorescence auger spectrometer, correlation spectrometer, deep-level transient spectrometer, dual polarization interferometry, EPR spectrometer, force spectrometer, Hadron spectrometer, Baryon spectrometer, meson spectrometer, Inelastic electron tunneling spectrometer (IETS), laser-induced breakdown spectrometer (LIBS), mass spectrometer, Mossbauer spectrometer, neutron spin echo spectrometer, photoacoustic spectrometer, photoemission spectrometer, photothermal spectrometer, pump-probe spectrometer, Raman optical activity spectrometer, saturated spectrometer, scanning tunneling spectrometer, spectrophotometry, time-resolved spectrometer, time-stretch Spectrometer, thermal infrared spectrometer, ultraviolet photoelectron spectrometer (UPS), video spectrometer, vibrational circular dichroism spectrometer, X-ray photoelectron spectrometer (XPS).

In a fifteenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is selected from the group consisting of fiber microscope, handheld microscope, color microscope, reflectance microscope, fluorescence microscope, oxygen-saturation microscope, polarization microscope, infrared microscope, interference microscope, phase contrast microscope, differential interference contrast microscope, hyperspectral microscope, total internal reflection fluorescence microscope, confocal microscope, non-linear microscope, 2-photon microscope, second-harmonic generation microscope, super-resolution microscope, photoacoustic microscope, structured light microscope, 4Pi microscope, stimulated emission depletion

microscope, stochastic optical reconstruction microscope, ultrasound microscope, and/or a combination of the aforementioned, and the like.

In a sixteenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is selected from the group consisting of ultrasound imager, reflectance imager, Diffuse reflectance Imager, fluorescence imager, Cerenkov imager, polarization imager, radiometric imager, oxygen saturation imager, optical coherence tomography imager, infrared imager, thermal imager, photoacoustic imager, spectroscopic imager, Raman Spectroscopic imager, hyper-spectral imager, fluoroscope, gamma imager, X-ray computed tomography, endoscope, laparoscope, bronchoscope, angioscope, and an imaging catheter.

In a seventeenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more Raman spectrometers.

In an eighteenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more ultrasound imaging systems.

In a nineteenth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more absorption spectrometers.

In a twentieth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more of fluorescence spectrometers.

In a twenty-first embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more of vital sign sensors, said vital sign sensors monitoring one or more of: temperature, blood pressure, pulse, respiratory rate, ECG, EEG, pulse oximetry, and blood glucose.

In a twenty-second embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is selected from reflectance spectrometers, diffuse reflectance spectrometers, and diffuse reflectance imagers.

In a twenty-third embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is selected from in vivo microscopes and ex vivo microscopes.

In a twenty-fourth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more hyperspectral imaging systems.

In a twenty-fifth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more tracking module.

In a twenty-sixth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said tracking module is selected from the group consisting of optical tracking system, electromagnetic tracking system, radio frequency tracking system, gyroscope tracking system, video tracking system, acoustic tracking system, and mechanical tracking system.

In a twenty-seventh embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said tracking module comprise LEDs and spectral filters.

5

In a twenty-eighth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said tracking module comprises software that enable topology sampling using a tracked handheld imaging probe or a tracked handheld

In a twenty-ninth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more global positioning system.

In a thirtieth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more robots.

In a thirty-first embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said peripheral is one or more droid.

In a thirty-second embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, further comprising a light source.

In a thirty-third embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a spectral filter.

In a thirty-fourth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a white light-emitting diode.

In a thirty-fifth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a surgical light having a plurality of individual light sources spaced apart to project light onto an object such that a shadow cast by an intervening object and one or more of said plurality of individual light sources is negated by at least one other of said plurality of individual light sources.

In a thirty-sixth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source is selected from white light-emitting diodes and polarizers.

In a thirty-seventh embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a white light source and a spectral filter filtering out a particular wavelength of light to avoid interference with an fluorescence emission wavelength.

In a thirty-eighth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a laser diode and a diffuser.

In a thirty-ninth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a projector and spectral filter.

In a fortieth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source includes a pulsed illumination device, or may utilize frequency modulation or pulse-duration modulation.

In a forty-first embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said detector may detect signals of a given frequency or spectrum, and the light source may correlate the detected signal with the frequency modulation and pulse-duration modulation.

6

In a forty-second embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said light source comprise illumination that offer adjustable components that overlap with emission spectra.

In a forty-third embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said computing device comprises memory modules that stores educational contents.

In a forty-fourth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said memory modules that stores educational contents comprises memory modules that stores medical training contents.

In a forty-fifth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, wherein said memory modules that stores educational contents comprises memory modules that stores military training contents.

In a forty-sixth embodiment, the present invention provides a multi-purpose imaging display system as in any of the preceding embodiments, where said filter selectively movable out of communication with said detector

In a forty-seventh embodiment, the present invention provides a method for visualizing educational contents, said method comprising: obtaining educational contents from remote computers using a multi-purpose imaging and display system in accordance with any of the preceding embodiments; observing the educational contents using a multi-purpose imaging and display system in accordance with any of the preceding embodiments.

In a forty-eighth embodiment, the present invention provides a method for capturing sending, receiving and visualizing educational contents, said method comprising: capture images as educational contents using a multi-purpose imaging and display system in accordance of with any of the preceding embodiments; sending images from a multi-purpose imaging and display system in accordance of with any of the preceding embodiments to another a multi-purpose imaging and display system in accordance with any of the preceding embodiments; observing the images as educational contents using a multi-purpose imaging and display system in accordance with any of the preceding embodiments.

In a forty-ninth embodiment, the present invention provides a method in accordance with the above embodiment, further comprising: record audio as educational contents using a multi-purpose imaging and display system in accordance with any of the preceding embodiments; sending audio recorded from a multi-purpose imaging and display system in accordance of with any of the preceding embodiments to another multi-purpose imaging and display system in accordance of with any of the preceding embodiments; listen to the audio as educational contents using a multi-purpose imaging and display system in accordance of with any of the preceding embodiments.

In a fiftieth embodiment, the present invention provides a method in accordance with the above embodiment, a method for imaging forensic evidence, said method comprising: applying fluorescent forensic tracers to the environment and observing the environment using a multi-purpose imaging and display system.

In a fifty-first embodiment, the present invention provides a multi-purpose imaging and display system comprising: a goggle having a display for viewing by the eyes of one wearing the goggle; a detector coupled to said display, said detector having a field of view and projecting an image of

that field of view onto said display; a peripheral interface for selectively communicating with a peripheral device, said peripheral device providing an additional functionality.

In a fifty-second embodiment, the present invention provides a multi-purpose imaging and display system as in the fifty-first embodiment, wherein the peripheral may be selected from any of the multitude of peripherals disclosed in any of the embodiments above.

In a fifty-third embodiment, the present invention provides a multi-purpose imaging and display system as in the fifty-first or fifty-second embodiment, wherein the additional functionality is selected from additional imaging, sensing data, and tracking data, said tracking data relating to one or more of the location of an object in the field of view, the location of the goggle and the location of peripherals.

In a fifty-fourth embodiment, the present invention provides a multi-purpose imaging and display system comprising: a plurality of goggles, each including: a display for viewing by the eyes of one wearing the goggle, a detector coupled to said display, said detector having a field of view and projecting an image within that field of view onto said display, and a communication interface linking each of said plurality of goggles to communicate with each other.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings wherein:

FIG. 1 is a perspective view of a multipurpose imaging and display system in accordance with the concepts of the present invention;

FIG. 2 is a schematic diagram showing the components of the multipurpose imaging and display system in accordance with the concepts of the present invention;

FIG. 3A is schematic diagram showing the components of a detector provided by the multipurpose imaging and display system when configured with stereoscopic imaging sensors in accordance with the concepts of the present invention;

FIG. 3B is a schematic diagram of an alternative configuration of the detector, whereby multiple sensor element types are used for each of the stereoscopic imaging sensors shown in FIG. 3A in accordance with the concepts of the present invention;

FIG. 3C is a schematic diagram of another configuration of the detector, whereby multiple sensor element types are used for each of the stereoscopic imaging sensors shown in FIG. 3A in accordance with the concepts of the present invention;

FIG. 3D is a schematic diagram of a further configuration of the detector, whereby multiple sensor element types are used for each of the stereoscopic imaging sensors shown in FIG. 3A in accordance with the concepts of the present invention;

FIG. 3E is a schematic diagram of another configuration of the detector, whereby multiple sensor element types are used for each of the stereoscopic imaging sensors used for each of the stereoscopic imaging sensors shown in FIG. 3A in accordance with the concepts of the present invention;

FIG. 4 is a front perspective view of a shadowless surgical light in accordance with an embodiment of this invention;

FIG. 5 is a general schematic showing the use of a spectral filter with individual lights of the shadowless surgical light of FIG. 4,

FIG. 6 is a general schematic of a laser and laser diffuser light source, shown with the diffuser out of the path of the laser;

FIG. 7 is a general schematic of a laser and laser diffuser light source, shown with the diffuser in the path of the laser;

FIG. 8 is a graph showing a plurality of illumination pulse patterns output by a light source for use with the imaging and display system in accordance with the concepts of the present invention;

FIG. 9 is a graph showing another plurality of illumination pulse patterns output by the light source in accordance with the concepts of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

A multi-purpose imaging and display system is generally referred to by reference numeral **100**, as shown in FIG. 1 of the drawings. The system **100**, shown in detail in FIG. 2, includes a display **110**, which may comprise any suitable display, and, in some embodiments, is a wearable display that is configured for being attached to and worn by a user **112**. For example, such a wearable display **110** may be included as part of a goggle-type wearable device **114** shown in FIG. 1, which comprises a wearable goggle or eye-piece frame that carries the display **110**.

In one aspect, the display **110** may comprise a single display element suitable for providing a single, continuous display that provides a single display surface that encompasses the totality of the user's field of view, or portion thereof. Alternatively, multiple separate display elements, may be used by the display, such as a dedicated right and a dedicated left display, such as in the case of a stereoscopic display, which provides independent displays, designated as **110A** and **110B** (FIG. 1), to provide the field of view of each user's eye.

Furthermore, the display **110** may comprise an LCD (liquid crystal display) display, an OLED (organic light emitting diode) display, a projection display; a head-mounted display (HMD), a head-mounted projection display (HMPD), an optical see-through display, a switchable optical see-through display, a selective occlusion see-through head-mounted display, and a video see-through display. Furthermore, the display **110** may comprise an augmented reality window, augmented monitors, a projection on the patient/projective head-mounted display, selective occlusion see-through head-mounted display, and retinal scanning display. In another aspect, the display **110** may be configured to display any static or moving image. The display **110** may also comprise a picture-in-picture (PIP) display that can display images from multiple independent image sources simultaneously. In one aspect, the display **110** may comprise a 3D display capable of displaying 3-dimensional images. In still another embodiment, the display **110** may be configured to provide overlaid images of various opacity/transparency to allow simultaneous viewing of multiple images on the display **110** at one time. In yet another embodiment, the display **110** may be at least partially transparent to allow a user to view the image being displayed, while allowing the user to simultaneously see through the display **110** to also view the user's surrounding environment at the same time.

Coupled to the display is a detector **120**, which is configured to capture any desired static or moving image data from a target of interest (TOI) **130**, which may comprise any desired object, such as a wound shown in FIG. 1. That is, the detector **120** includes a field of view that captures image data of the target of interest **103** that is within the field of view.

It should also be appreciated that the detector **120** may be used in conjunction with any suitable optical lens or optical assembly to provide any desired field of view, working distance, resolution and zoom level. In one aspect, the detector **120** may comprise a camera, such as a charge-coupled device (CCD), a complementary metal-oxide semiconductor device (CMOS), one or more photomultiplier tubes (PMT), one or more avalanche photodiodes (APD), photodiodes, and a thermographic camera, such as an infrared detector. In addition, the detector **120** may comprise one or more image intensifier tubes, a micro-channel plate image intensifier, and a thin-film image intensifier.

In some embodiments, the detector is a single detector **120**. In one embodiment, the detector **120** may comprise a stereoscopic detector, which includes multiple imaging sensors or cameras designated respectively as **120A** and **120B**, as shown in FIGS. **1**, which take stereoscopic images that can be displayed at stereoscopic display **110** with depth perception.

In another embodiment, the detector **120** may comprise a stereoscopic detector, which includes multiple imaging sensors or cameras designated respectively as **120A** and **120B**, as shown in FIGS. **1** and **3A**, whereby each individual camera **120A-B** includes multiple individual sensor elements. For example, the cameras **120A-B** may be each configured with a first and second sensor element, whereby the first sensor element provides for full-color imaging and the second sensor element provides selective or switchable fluorescence imaging. Further discussion of various configurations of the various sensor elements that form the cameras **120-B** will be discussed in detail below.

The detector **120** may be configured to perform one or more imaging modes, including but not limited to fluorescence imaging, thermal imaging, oxygen saturation imaging, hyperspectral imaging, photo acoustic imaging, interference imaging, optical coherence tomography imaging, diffusing optical tomography imaging, ultrasound imaging, nuclear imaging (PET, SPECT, CT, gamma, X-ray), Cerenkov imaging, and the like. In addition, the detector **120** may also be configured to perform real-time/offline imaging, including absorption, scattering, oxygenation saturation imaging, fluorescence imaging, fluorescence lifetime imaging, hyperspectral imaging, polarization imaging, IR thermal imaging, bioluminescence imaging, phosphorescence imaging, chemiluminescence imaging, scintillation imaging, and the like.

In some embodiments, the display **110** and the detector **120** are coupled to a computing unit **200**. The computing unit **200** may be part of a wearable version of the system **100** or might alternatively be an external computing unit **200**. The computing unit **200** includes the necessary hardware, software or combination of both to carry out the various functions to be discussed. In one aspect, the computing unit **200** may comprise a microprocessor or may comprise any other portable or standalone computing device, such as a smartphone, capable of communicating with the various components of the system **100**. It should also be appreciated that the computing system **200** may also include a memory unit to store various data to be discussed. In addition, the computing unit **200** is configured, whereby the image data acquired by the detector **120** may be processed and transmitted by the computing unit **200** in various manners to be discussed. It should also be appreciated that the computing unit **200** may include a local or remotely accessible memory unit, which allows the computing unit to store and/or acquire various programs, algorithms, databases, and decision support systems that enable a variety of functions to be dis-

cussed, which may be based on the image data collected by the detector **120**. In one aspect the system **100** may be powered by any suitable power source, such as a portable power source comprising one or more batteries or a plug-in type power source for connection to a standard electrical wall outlet.

In operative communication with the field of view of the detector **120** is a filter **150**. Accordingly, the filter **150** serves to process the light that travels from the target of interest (TOI) **130** before the light is received at the detector **120** in the form of image data. As such, the filter **150** is configured to use any suitable technique to process the image data collected by the field of view of the detector **120**. In one aspect, the system **100** may be configured so that filter **150** is brought into or out of operative communication with the detector **120**, so that the image data collected by the field of view of the detector **120** is selectively filtered or unfiltered. In one aspect, the selective filtering performed by the filter **150** may be carried out by any suitable mechanism, such as an electro-mechanical mechanism, which is initiated by any suitable switching device **151**, such as a mechanical switch, or voice command to move the filter **150**. Accordingly, when the switchable filter **150** is in operative communication with the detector **120**, the system **100** is placed into a first mode for detecting TOIs **130** that emit frequencies within a spectrum of frequencies defined by the physical parameters of the filter, such as the spectrum of frequencies emitted during the fluorescence of materials. Alternatively, when the filter **150** is not in operative communication with the detector **120**, the system **100** is placed into a second mode for detecting TOIs **130** within another frequency spectrum, such as a night vision frequency spectrum.

It should be appreciated that the filter **150** may comprise a filter wheel having different discrete filters of different filtering properties, which can be selectively rotated into operative alignment with the detector **120**. In addition, the filter **150** may comprise a long-pass filter, a band-pass filter, a tunable filter, a switchable filter, and the like. In another aspect, the filter **150** may comprise an 830 nm band-pass filter.

In other embodiments, the filter **150** may be replaced by a polarizer **152** and operate in the same manner with respect to the detector **120** as discussed above with regard to the filter **150**. Furthermore, in other embodiments the polarizer **152** may be simultaneously used together with the filter **150**, whereby the field of view of the detector **120** is processed by both the polarizer **152** and by the filter **150** prior to detection by the detector **120**. It should also be appreciated that the polarizer **152** may comprise a switchable polarizer that operates in the same manner as the switchable filter **150**, or may comprise a tunable polarizer.

Accordingly, the ability to selectively filter or selectively polarize the field of view being detected by the detector **110** embodies a "convertible" system, whereby when the detector **110** is unfiltered, it is in a first mode, which is capable of a first imaging state, such as night vision for military use; and when the detector is placed or "converted" into its second mode, it is capable of a second imaging state, whereby it is capable of fluorescence imaging in medical applications for example.

Furthermore, using the combination of the cameras **120A-B** each having multiple imaging elements together with the selective use of the filter **150** or polarizer **152** allows for a variety of modes of operation. For example, in FIGS. **3B-D** the detector **120** is configured such that each camera **120A** and **120B** has two sensor elements **122** and **124**, whereby the first sensor element **122** is used for a first

imaging mode (or a convertible detection mode that is switchable between among two or more imaging modes) and the second sensor element **124** is used for a second convertible imaging mode, which provides selective imaging among two or more imaging modes. Thus, in FIG. 3B, sensor element **122** of cameras **120A-B** are in a color imaging mode, while sensor elements **124** of cameras **120A-B** operate in a convertible filter mode, that can be switched between florescence imaging with different spectral frequencies; or between polarization imaging with different polarization states. In addition, FIG. 3C shows that the sensor element **122** of cameras **120A-B** is switchable between different modes of fluorescence imaging, while sensor element **124** of cameras **120A-B** are switchable between different modes of polarization imaging. Furthermore, FIG. 3D shows that the sensor element **122** of cameras **120A-B** is a thermographic sensor, while sensor element **124** of cameras **120A-B** are switchable between different modes of fluorescence imaging; or switchable between different modes of polarization imaging. Additionally, FIG. 3E shows the use of three sensor elements, whereby sensor element **124** of cameras **120A-B** offer a first-type of fluorescence imaging modes; sensor element **122** of cameras **120A-B** is offer color imaging or thermographic imaging; and the sensor element **126** of cameras **120A-B** offers a second-type of fluorescence imaging modes.

Coupled to the computing system **200** is a communication interface **250**, which includes a suitable antenna **252** for communicating wirelessly or via a wired connection with a communication network **260**. The system **100** may communicate via the communication network **260** with other multipurpose imaging and display devices **100A-X**, or any other networked computer system **262**, such as laptop computers, smart phones, and the like, as shown in FIG. 1. In one aspect, the communication interface **250** is embodied as a transceiver that is enabled to both transmit and receive data via the network **260**. In one aspect, the communication interface **250** may be configured to communicate over the network **260** using any suitable method, including RF (radio frequency) signals, such as a low-power RF signals, a wired or wireless Ethernet communication, WiFi communication, Bluetooth communication, and the like. As such, the ability of multiple systems **100** to communicate with each other enables a variety of functions, which will be discussed in detail below. The communication will allow one or more of sharing of detector images and images provided by peripherals (described below) and sound and software educational modules (described below).

The communication interface **250** also enables network and cloud computing features to be carried out by the imaging and display system **100**. In one aspect, the communication interface **250** allows the system **100** to communicate with a remote storage device on a remote network or a remote cloud computing system, generally represented by the numeral **270**, as shown in FIG. 1 to allow access centralized data storage, conduct further computing analysis, access to other software applications, and to enable record storage.

Also coupled to the computing device **200** is a peripheral interface **300**. The peripheral interface may comprise a wired or wireless interface that allows for the addition of one or more peripherals **350** to be selectively added to the imaging and detection system **100**. The peripherals may comprise one or more sensors and detectors. For example, such add-on peripheral **350** may include a vital sign sensor module, that may monitor one or more of: temperature, blood pressure, pulse, respiratory rate, ECG, EEG, pulse

oximetry, blood glucose, and the like. The peripheral **350** may also include an ultrasound module, a spectroscopy module (e.g. Raman spectroscopy, absorption spectroscopy, and reflectance spectroscopy), a GPS (global positioning system) module, a microscope module (e.g. a handheld microscope, a fiber-based in-vivo microscope, and a traditional microscope), and a non-microscopic imaging module (hyperspectral imaging, photoacoustic imaging, optical coherence imaging).

In another aspect, the peripheral **350** may comprise a probe instrument, such as a hand-held probe. As such, the hand-held probe may be used for any desired type of microscopy. In some embodiments the probe is employed for in vivo microscopy. The probe may utilize various detection methods, such as color microscopy, reflectance microscopy, fluorescence microscopy, oxygen-saturation microscopy, polarization microscopy, infrared microscopy, interference microscopy, phase contrast microscopy, differential interference contrast microscopy, hyperspectral microscopy, total internal reflection fluorescence microscopy, confocal microscopy, non-linear microscopy, 2-photon microscopy, second-harmonic generation microscopy, super-resolution microscopy, photoacoustic microscopy, structured light microscopy, 4Pi microscopy, stimulated emission depletion microscopy, stochastic optical reconstruction microscopy, ultrasound microscopy, and/or a combination of the aforementioned, and the like.

In another aspect, the handheld probe used as the peripheral **350** may be a higher resolution imaging device that has not reached microscopic resolution yet. In some embodiments, the non-microscopic imaging method is selected from one or more of the following: reflectance imaging, fluorescence imaging, Cerenkov imaging, polarization imaging, ultrasound imaging, radiometric imaging, oxygen saturation imaging, optical coherence tomography, infrared imaging, thermal imaging, photoacoustic imaging, spectroscopic imaging, hyper-spectral imaging, fluoroscopy, gamma imaging, and X-ray computed tomography. The physical form of the handheld probe may comprise an endoscope, a laparoscope, a bronchoscope, an angioscope, and a catheter for angiography.

In still another example, the handheld probe may be a non-imaging device or a sensing device, such as a fiber-based spectrophotometer. In addition, different spectroscopies may be realized from use of a suitable peripheral **350**, such as various optical spectroscopies, absorption spectroscopy, fluorescence spectroscopy, Raman spectroscopy, Coherent anti-Stokes Raman spectroscopy (CARS), surface-enhanced Raman spectroscopy, Fourier transform spectroscopy, Fourier transform infrared spectroscopy (FTIR), multiplex or frequency-modulated spectroscopy, X-ray spectroscopy, attenuated total reflectance spectroscopy, electron paramagnetic spectroscopy, electron spectroscopy, gamma-ray spectroscopy, acoustic resonance spectroscopy, auger spectroscopy, cavity ring down spectroscopy, circular dichroism spectroscopy, cold vapour atomic fluorescence spectroscopy, correlation spectroscopy, deep-level transient spectroscopy, dual polarization interferometry, EPR spectroscopy, force spectroscopy, Hadron spectroscopy, Baryon spectroscopy, meson spectroscopy, Inelastic electron tunneling spectroscopy (JETS), laser-induced breakdown spectroscopy (LIBS), mass spectroscopy, Mossbauer spectroscopy, neutron spin echo spectroscopy, photoacoustic spectroscopy, photoemission spectroscopy, photothermal spectroscopy, pump-probe spectroscopy, Raman optical activity spectroscopy, saturated spectroscopy, scanning tunneling spectroscopy, spectrophotometry, time-resolved spec-

troscopy, time-stretch Spectroscopy, thermal infrared spectroscopy, ultraviolet photoelectron spectroscopy (UPS), video spectroscopy, vibrational circular dichroism spectroscopy, X-ray photoelectron spectroscopy (XPS), or a combination of the aforementioned.

In other embodiments, the peripheral 350 is selected from robots, droids and global positioning systems.

Tracking and Registration of Multiple Images for Display

In some embodiments, the system 100 includes a tracking module, which can be considered another peripheral 350, and includes software suitable for tracking the spatial location of the detector 120 (or 120A, 120B) and the location of peripherals 350, such as imaging cameras and probes, and registering these locations relative to the image(s) of the detector 120 or detectors 120A, 120B (in stereoscopic modalities). Reference to detector 120 herein will also be understood to be equally applicable to the stereoscopic modalities of those systems 100 employing detectors 120A and 120B. Thus, the corresponding imaging and sensing information obtained from the peripheral 350 can be correlated with the field of view imaged by the detector 120 of the multipurpose imaging and display system 100. That is, the system 100 may be programmed to utilize image tracking and registration techniques to allow for the overlay of multiple images acquired directly by the detector 120 of the system 100 with those images acquired by peripheral image detectors, such as hand-held microscopy probes, or the like. In some embodiments, the tracking module can also track and register the location of other non-peripheral elements, such as the tools being employed by military or medical personnel. For example, the location of scalpels or clamps or stents or other elements of a medical operation could be tracked and registered with the images. It should be appreciated that the software enabling such tracking and registration features may be provided from a remote computer system to the system 100 via the network 260 or stored on any peripheral attached to the peripheral interface 300. Specifically, tracking techniques utilized by the system 100 obtain the position of a patient to be treated using the system 100, the system 100 itself comprising the wearable display 114, and the handheld imaging peripheral 350 coupled to the peripheral interface 300.

The tracking functions may be carried out using optical tracking or magnetic tracking devices that are employed as a peripheral 350. If optical tracking is used, active markers such as LEDs may be attached to detector 120, the imaging or sensing probe employed as another peripheral 350, and the patient or other desired object, to locate their locations, respectively. NDI Optotrak Certus system is an example of optical tracking systems that may be used for this embodiment. Commercially available optical tracking systems may consist of CCD cameras and sequentially illuminated infrared (IR) LEDs, and can be easily integrated as a peripheral 350 into the wearable imaging and display device 100. Alternatively, one may use a videometric system to estimate patient pose (or object positioning) and instrument orientation by identification of passive markers in video-image sequences.

In one aspect, optical tracking using NDI Optotrak Certus may be incorporated as a peripheral 350 to provide tracking, whereby light emitting diodes (LED) are attached to the wearable device 100 that carries the detector 120, and imaging module as another peripheral 350, such as ultrasound and hand-held microscopy probes and patients. As such, the LEDs attached to the detector 120, hand-held probe as a peripheral 350, and patients are tracked by the NDI Optotrak Certus system.

In another embodiment, a novel infrared optical tracking method may be utilized by the system 100. As such, the wavelength of the optical emitters for tracking purposes (such as LEDs) attached to the patient, wearable imaging and display system 100, and intraoperative imaging peripheral 350 may be different wavelengths from the wavelengths detected by the detector 120, and imaging peripheral 350. Methods, such as spectral filtering may be used to facilitate the separation of wavelengths between the optical emitter from the tracking system and the detection of the detector 120, and imaging peripheral 350. Frequency modulation may also be used to separate the signal from the tracking optical emitters from the signal of interest of the detector 120, and imaging peripheral 350.

In another example, gyroscopic tracking in combination with video tracking may be performed using the module 350.

If electromagnetic tracking is used, the peripheral 350 may incorporate small coils or similar electromagnetic field sensors and multiple position measurement devices. The electromagnetic field sensors may be attached to detector 120, the imaging or sensing probe employed as another peripheral 350 and the patients, to locate their locations, respectively.

Alternatively, the tracking functions may be carried out using fiducial markers, such as LEDs, attached to (a) the patient to be treated or an object to be acted upon or observed (in the instance of non-medical applications), (b) the wearable imaging and display device 100, and (c) the peripheral 350. Through the use of fiducial markers, images of the same subject produced with multiple distinct imaging systems—for example, the detector 120 as a first imaging system, and any desired peripheral 350 that generates a second image as the second imaging system—may be correlated by placing fiducial markers in the area imaged by both systems. Appropriate software correlates the two images, and in the case of the present invention, permits viewing of the two (or more) images overlaid together or in a picture-in-picture format.

With the position obtained using the tracking techniques described, enabled by tracking systems as a peripheral 350, registration, or alignment, of the different images obtained by the imaging and display system 100 and the handheld imaging probe employed as another peripheral 350 is performed by using transformation matrices between the object being imaged by the detector 120 (detector image space) and images and locations of the peripherals 350 (peripheral image space) can be calculated. Specifically, the image registration process is carried out such that the image captured by detector 120 and peripheral locations and images can be registered together as a single image. As a result, the co-registered images from the detector 120 of the wearable system 100 and the image peripheral 350 can be displayed in the wearable display in an overlaid and aligned manner.

It should also be appreciated that in addition to the tracking techniques described above, other tracking techniques may be used, such as radio frequency tracking, gyroscope tracking, video tracking (pattern recognition), acoustic tracking, mechanical tracking, and/or a combination thereof. In addition, the tracking method employed by the module 350 may utilize rigid body, flexible body or digitizer methods.

It should also be appreciated that in addition to the registration techniques discussed above, other registration techniques may be used, such as point-based registration, surface-based registration, and/or a combination thereof.

The registration may comprise either intensity-based or feature-based registration. The transformation models used may comprise linear transformation, or non-rigid/elastic transformation. Spatial or frequency domain methods may be used, as well as automatic or interactive methods.

To sample the topology of the object/physical space in the field of view (or the target of interest), digitizers (such as the device from NDI) may be used to sample the points in physical space. Alternatively, topology acquisition systems, such as a 3D scanner may be used to capture the 3D topology, which may facilitate image registration.

In some embodiments, a handheld probe employed as a peripheral module 350 may serve dual purposes: serving as stylus/digitizer for sampling topology; and serving as imaging or sensing probe. Specifically, the handheld probe may have optical emitters such as LEDs attached to it, which will allow location of the tip of the handheld probe with the help of the optical tracking system. Alternatively, the position of the tip can be obtained by tracking the electromagnetic sensors attached to the handheld probe using a magnetic tracking system. When the probe is swiped across different points on the surface of the organs, a 3D point cloud can be established, based on the locations of the tips of handheld probe (tip is considered to be just in contact with organs). In this way, the imaging handheld probe also enables similar functionality to sample topology as the non-imaging stylus/digitizer traditionally employed in tracking systems.

In another aspect, a tracking system employed as a peripheral module 350 may track the positions of an imaging peripheral (e.g., a hand-held microscopy probe peripheral) also employed as a peripheral module 350, and register the image taken with the imaging peripheral with the image generated by the detector 120, and display it in the display 110. As such, the images detected by the imaging peripherals, such as an ultrasound probe may then be overlaid with images collected, such as fluorescence images, by the detector 120 of the imaging and display system 100 for presentation on the display 110. The registration of multiple images on the display 110 may be achieved using any suitable technology, including point-based registration, surface-based registration, intensity-based, feature-based registration, and/or a combination of both. The transformation models used may comprise linear transformation, or non-rigid/elastic transformation. Spatial or frequency domain methods may be used, as well as automatic or interactive methods. For example, fiducial markers, such as LEDs, may be used to facilitate point-based registration. In another example, if surface topology or profile is available, the surface-based registration can also be used. In yet another example, the registration may also be based on pattern recognition or feature-based recognition.

Thus, by combining the functionality of the communication interface 250 and the peripheral interface 300, the system 100 is enabled to provide multiple functions. One or more peripherals of a multitude of types, including those mentioned above can be selectively coupled to the display system 100, as needed for providing the system 100 with a desired functionality. If imaging from a probe is needed in a given application, for example for in vivo imaging of a patient, a probe as a peripheral 350 can be coupled to the display system 100 at the interface 250 so that the display system 100 would then have the ability to display the image gathered from the probe. As per the tracking disclosure above, this image could be overlaid onto the image of the patient gathered by the detector 120, placing the in vivo image of the probe employed as a peripheral 350 at the proper location on the image of the patient.

In another aspect, a co-registration of a 4 sensor setup between color and fluorescence imaging, whereby vertical and horizontal disparities are correlated. In particular, this example describes the manner in which a 4 camera setup is used to register intraoperative color imaging to intraoperative fluorescence imaging.

In another embodiment, stereoscopic fluorescence images captured by 2 fluorescence cameras and stereoscopic color images captured by 2 color cameras can be registered together. Both sets of images were placed into side-by-side frames, and the fluorescent side-by-side frame was overlaid onto the anatomical frame by the computing module and sent to the display. For high registration accuracy, we measure the vertical distance from the center of the filtered cameras for fluorescence to the center of the unfiltered color camera as well as the horizontal baseline distance between two filtered or unfiltered cameras. From this information, a correction metric, D_v , was determined from the equation:

$$\frac{L_H}{L_V} = \frac{D_H}{D_V}$$

where L is the measured baseline disparity between cameras in either the horizontal (H) or vertical (V) direction, and D_H is the horizontal pixel disparity between common points in the left and right fluorescent images. The points used to calculate D_H were the peak fluorescent points; if more than one peak existed, one was chosen for the calculation. The fluorescent frames were then shifted up by the calculated correction metric so that, after calibration, the fluorescent image was aligned to the corresponding color image.

In addition, GPS and wireless communication between multiple imaging and display systems 100A-X can be integrated, such that information relevant to military or medical environments is labeled with GPS data. Thus, in one embodiment, information acquired by each system 100A-X can also be transmitted or received wirelessly, to guide battle or medical interventions. Using telemedicine functionality of the system 100, medical operations can be performed by first responders using the system 100 under the guidance of medical practitioners that are located remotely but who are also using the system 100. It should be appreciated that the systems 100 A-X may also communicate with any other suitable computing device, such as a tablet, mobile smart phone, or the like.

In addition, the system 100 may include an illumination or light source 400 to illuminate the field of view used to image the target object of interest 130 being imaged by the detector 120. It should also be appreciated that the light source 400 is configured to deliver a light having the appropriate intensity and frequency spectrum that is compatible with the particular imaging being conducted with the detector 120, with or without the filter/polarizer 150,152. For example, it may be necessary to have a light source 400 that emits a first frequency spectrum for use in a first imaging mode, such as a night vision imaging mode, and that emits a second frequency spectrum for use in a second imaging mode, such as a fluorescence imaging mode. In one aspect, the light source 400 may be coupled to the computing device 200 for automated control over the functions provided by the light source 400, or may be unattached from the computing device 200 and operated manually by the user of the system 100.

It should also be appreciated that the light source 400 may serve different purposes in both the military environment

and the medical environment. For example, the light source **400** may be used in military applications for enabling weapon aiming, for guiding laser guided weaponry, or for night vision. Furthermore, upon conversion of the detector **120** by removal or the filter/polarizer **150,152** or by selecting the necessary filter/polarizer **150,152** the illumination of the light source **400** may be used for florescence imaging, optical imaging, photodynamic therapy, laser surgery, sterilization, and the like. It should also be appreciated that multiple light sources **400** may be used.

It should also be appreciated that the light source **400** may comprise a laser light; a light emitting diode (LED), such as a white LED; an incandescent light; a projector lamp; an arc-lamp, such as xenon, xenon mercury, or metal halide lamp; as well as coherent or in-coherent light sources.

The light source **400** may also comprise a digital (LED-based) projector lamp, and additionally the light source may project spatial frequencies for patterned illumination. In addition, the light source **400** may emit a continuous or pulsed output, and may generate light that is within any desired spectral window of electromagnetic waves.

It should also be appreciated that the light source **400** may also include a light diffuser.

In some embodiments, particularly when it is desired to observe a fluorescence emission spectra from the object being illuminated and observe through the imaging and display system **100**, the light source **400** selectively shines through a spectral filter **402** (FIG. 2) that blocks the wavelength of the emission spectra to be observed, such that the light source **400** does not interfere with the observance of that emitted wavelength. For example, if the object is to be observed for fluoresce at a certain wavelength, the spectral filter **402** would be chosen to block that wavelength from the light source so that the light source does not interfere with the observance of the emitted fluorescence. In some such embodiments, the light source is a white light source thus providing a broad spectrum, and the spectral filter is appropriately chosen based on the emission spectra to be observed. In some embodiments, the light source is one or more white light emitting diodes (LED). In some embodiments, the individual light sources are white light emitting diodes (LED) that are filtered by a 775 nm low-pass filter. In another embodiment, the low-pass filter may be replaced with a polarizer, or may be used in conjunction with the filter the light source shines through a spectral filter.

With reference to FIGS. 4 and 5, in another embodiment, the light source **400** may comprise a shadow-less light **404** which is desirable for use during surgery (i.e. a surgical light). The shadow-less light **404** includes a plurality of individual light sources **406** spaced apart in a support **407** to project light onto an object such that a shadow cast by an intervening object and one or more of the plurality of individual light sources is negated by at least one other of the plurality of individual light sources. For example, the shadow-less light **404** can be a surgical light and a surgeon may interpose a hand and arm between the shadow-less light **404** and the patient and thus certain individual light sources would tend to cast a shadow onto the patient but for the fact that other light sources will not have the hand/arm of the surgeon interposed between the shadow-less light source and the surgeon such that those lights will negate the shadow, thus leading to shadow-less lighting. As known, the support **407** is on the end of a swing arm **410**, or a goose neck or other connection providing the ability to position the light **404** as desired. This concept of a shadowless light source is separately at invention herein outside of the imaging and display system **100**.

In some embodiments, particularly when it is desired to observe an emission spectra from the object, the individual light sources **406** of the shadow-less light **404** selectively shine through a spectral filter **408** (FIG. 5) that blocks the wavelength of the emission spectra to be observed, such that the shadow-less light source does not interfere with the observance of that emitted wavelength. In some embodiments, the individual light sources are white light emitting diodes (LED). In some embodiments, the individual light sources are white light emitting diodes (LED) that are filtered by a 775 nm low-pass filter. In another embodiment, the low-pass filter may be replaced with a polarizer, or may be used in conjunction with the filter.

In a particular embodiment, the light source **400** is a fluorescence-friendly shadow-less surgical light, which can provide white light surgical illumination and florescence illumination without leaking frequencies overlapping with fluorescence emission. This shadow-less light offers both well-rendered surgical illumination (looks like white light to naked light) and fluorescence excitation at the same time. In one embodiment, such light source comprises a plurality of white light emitting diodes (LED) coupled with Notch Filters that are Optical Filters that selectively reject a portion of the spectrum, while transmitting all other wavelengths. With the notch the frequencies overlapping with fluorescence emission, which are emitted by white LEDs, are rejected. It should be appreciated that in some cases edge filters can be used to achieve similar results in blocking the frequencies overlapping with fluorescence emission. In one example, the shadow-less light source comprises a plurality of white light emitting diodes (LED) that is filtered by a 775 nm low-pass filter. It should be appreciated that thin films or other devices may play similar role as notch filters or edge filters in the fluorescence-friendly shadow-less surgical light. In one aspect, the shadow-less light **400** may comprise an array of white lamps with edge filters or notch filters. In another embodiment, the spectral filters may be replaced with polarizers, or may be used in conjunction with the filters.

In some embodiments, the light source is a traditional projector (lamp based) or digital projector (LED-based) selectively used in conjunction with spectral filters or polarizers (as described with other light sources). The projector can also selectively project spatial frequencies (i.e., provide patterned illumination). The spectral filters can be in a filter wheel as already described. The projector beneficially provide a well-defined illumination area. The projector can be set to project any desired wavelength of light and can project without brighter and dimmer areas (i.e., provides consistent light).

With reference to FIGS. 6 and 7, in another embodiment, the light source **400** comprises a laser diode **412** and a diffuser **414** movable to be selectively interposed between the laser diode **412** and the object. Without the diffuser **414** interposed, the laser diode **412** simply shines a focused beam of light, while, with the diffuser **414** interposed, the laser shines over a greater surface area and is suitable for general illumination. In some embodiments this can allow for switching between laser aiming and night vision (with diffuser out of light path) or fluorescence-guided treatment (with diffuser in light path). In addition, the laser diode with diffuser **400** may also use a filter. In addition, the laser diode **400** may also be pulsed, or frequency modulated to reduce the average amount of light energy delivered.

As seen in FIGS. 8 and 9, in some embodiments, the light source **400** may comprise a pulsed light source, or may utilize frequency modulation or pulse-duration modulation.

In one aspect, the detector **120** may detect signals of a given frequency or spectrum, and the light source **400** may correlate the detected signal with the frequency modulation and pulse-duration modulation. In one aspect, the light source **400** may modulate the emitted light using an electro-optic modulator, optical chopper, or the like. Alternatively, if the light source **400** comprises one or more light emitting diodes (LED) the light source **400** may operate to adjust the intensity of light being output by adjusting the frequency of the AC (alternating current) that is supplied to power the LEDs.

Specifically, as shown in FIG. 8, the DC component of the light source **400** detected by the goggle system **100** are the fluorescence image type-1, and the AC component of the light detected by the goggle system **100** are fluorescence image type-2. The goggle system **100** may use a 2-camera setup or a 4-camera setup. The goggle system **100** is configured to detect the signals, correlated with the frequency modulation or pulse-duration modulation. Various ways of modulating the light may be used, such as an electro-optic modulator, an optical chopper, or the like. If LEDs are used, the illumination output by the light source **400** can be modulated by supplying AC current of desirable frequency through the LEDs. A lock-in amplifier may be used by the system **100**. It should be appreciated that light bulbs, lamps, laser diodes, lasers or the like could be used instead of LED based light source **400**.

Furthermore, as shown in FIG. 9, the frequency component of the light source **400** designated f1, which is detected by the goggle system **100** will be the fluorescence image type-1, and the frequency component of the light designated f2 that is detected by the goggle system **100** is the fluorescence image type-2. The goggle system **100** may use a 2-camera setup or 4-camera setup, and the goggle system **100** will detect the signals, correlated with the frequency modulation or pulse-duration modulation. Possible ways of modulating the light may comprise electro-optic modulator, optical chopper, or the like. In addition, if LEDs are used, the illumination output by the light source **400** can be modulated by supplying AC current of desirable frequency through the LEDs. In addition, a lock-in amplifier may be used by the system **100**. It should be appreciated that light bulbs, lamps, laser diodes, lasers or the like could be used instead of LED based light source **400**.

It is also contemplated that the system **100** includes a microphone **480** and a speaker **490** to enable verbal communication between the various systems **100A-X** and other computer systems (i.e. tablet computers, smart phones, desktop computers), and the like.

Thus, with the structural arrangement of the various components of the multipurpose imaging and display system **100** set forth above, the following discussion will present various embodiments of the system **100** for executing specific functions.

The system **100** may be configured whereby the filter **150** is placed in a first state, such as in military applications, so that it is moved out of the field of view of the detector **120** (i.e. filter not used) to provide night vision imaging of the target **130**. Alternatively, the filter **150** may be placed in a second state, such as in medical applications, so that the filter **150** is in the field of view of the detector **120** (i.e. filter is used) to enable fluorescence imaging of the target **130**. In addition, any suitable contrast agent, such as indocyanine green (ICG) may be used that is compatible with the frequency spectrum for which the filter **150** is sensitive to facilitate the fluorescence detection enabled by the filter **150**. As previously discussed, any suitable filter **150** that is

sensitive to a desired spectrum of frequencies may be used so that only the particular targets **130** emitting the desired frequencies are imaged. It should be appreciated that either autofluorescence or extrinsic fluorescence from contrast agents could be detected. In addition, such fluorescence imaging has application in medical applications such as intraoperative imaging, wound assessment, but also in military applications to carry out the detection of biological and chemical warfare.

The system **100**, as previously discussed by use the polarizer **152** in a convertible or selective manner, such that when polarization is invoked in a first state, the detector **120** provides polarization-gated imaging, polarization difference imaging, spectral-difference polarization imaging, Mueller matrix imaging for both military and medical applications.

For example, the system **100** may also use traditional division of time techniques, as well as tunable liquid crystal polarization filters or division of focal plane technology (e.g. Moxtek micropolarizer arrays).

As previously discussed, the detector **120** provided by the system **100** may also comprise a thermal imaging sensor, which can be used for both night vision and thermal vision. As such, vascularity, micro-circulation, ischemia can be assessed based on the thermographic images collected by the system **100**. In one aspect, the detector **120** may comprise a FLIR Compact A-Series LWIR thermal camera. In one aspect, the thermal imaging sensor comprising the detector **120** may comprise a cooled infrared image detector or an un-cooled infrared image detector.

The system **100** may also be used to perform hyperspectral imaging for both remote sensing and intelligence gathering in military fields, and various medical applications. Furthermore, such hyperspectral imaging is achieved by using a tunable filter **150** or spectrophotometer employed as a peripheral **350** that is configured to be sensitive to the spectrums being imaged.

It should be appreciated that the system **100** may be configured so that the detector **120** and the filter **150** selected allows near-infrared (NIR), thermal, and hyperspectral imaging to be performed by the same system **100**. The selective employment of different peripherals **350** offer additional capabilities to system **100**.

The system **100** may also be used to detect biohazard agents, such as viruses, bacteria or any other pathogens or any chemical warfare agents. Tracer or contrast agents may be applied to highlight the biohazard agents. Possible contrast agents include, but are not limited to: fluorescent agents, photosensitizers, nanoparticles, peptides and their conjugates, antibodies and their conjugates, small molecules, and the like.

The signal emitted by the contrast agents (such as fluorescence) can be detected by the system **100**. In addition, through employments of different peripherals **350**, additional capabilities can be provided to facilitate the biohazard detection. For instance, hyperspectral imaging can be used as a peripheral **350**. Devices such as absorption spectrometer, fluorescence spectrometer, diffuse reflectance spectrometer, Raman spectrometer or surface enhance Raman spectrometer can be used as peripherals **350** to provide additional information as appropriate.

It should be appreciated that the system **100** still has the capacity to offer night vision, or medical imaging guidance. Different imaging or sensing devices may be employed as peripherals **350** to achieve different purposes.

As previously discussed, each imaging and display system **100** includes the detector **150** and a communication interface **250**, which allows a plurality of systems **100A-X**

to communicate various data with one another and/or with one or more remote computing devices. It should be appreciated that the system **100** may be configured to form ad-hoc networks between each one of the individual systems **100A-X**, or may be configured to join any existing wireless communication network, such as a cellular data network, radio-frequency communication, wireless LAN, wireless PAN, WiFi or Bluetooth network for example. As previously discussed, each system **100** has the ability to be a sender of data and a recipient of data. As such, the network of systems **100** may be used for both military/defense and medical purposes.

In one embodiment, the detector **120** of one system **100** may capture image or video data that is transferred over the network to one or more other systems **100A-X** or any other computing device (i.e. tablet, computer, smartphone) that are connected to the communication network. Such image transfer may occur simultaneously between the systems **100A-X** in real-time or in near real-time. The real-time or near real-time transmission of image or video data, such as viewing an injured person in the field, from one system **100** may be used by recipients of the image or video data at one or more other users of the system **100**, or any other users of other computer systems connected to the network, in order to analyze and provide medical guidance to based on the transferred images. In addition, such networked systems **100** allow the point-of-view or field-of-view of the system **100** at which the image originates to be relayed to the other network systems **100**, to facilitate medical training, diagnosis, and treatment. As a result, the point of view or field of view of one system **100** can be presented to other networked systems **100** or computing systems.

In addition, the network of systems **100** may also be used to enable the visualization of educational content, including but not limited to medical training, intelligence, and military training and the like.

When the system **100** is configured with a GPS peripheral **350**, the system **100** is able to provide navigational information. As such, the system **100** may be able to report the location of the device **100**, communicate the location to another remote location over the communication network to which the system **100** is connected. Furthermore, all navigational information can be used by the system **100** to tag all data that is gathered by the system **100**, such as images collected for example.

The system **100** may also include microscopic imaging features. In one aspect, the detector **120** may include the necessary optics to provide microscopic imaging. In one aspect, the detector **120** may have built-in optics to conduct microscopic imaging or may have interchangeable optical components for microscopic imaging. In another aspect, the microscope may be provided as a separate peripheral **350** that is coupled to the peripheral interface **300**, such that the image supplied by the microscope may be presented on the display or communicated through the network other systems **100** and networked devices, as previously discussed.

The system **100** may also be utilized to facilitate telemedicine functions. For example, the system **100** allows a surgeon in remote areas to perform surgery under the supervision of an expert surgeon. The system **100** can also assist combat medics to perform procedures under the remote guidance of a clinician. Additionally, the system **100** can also load the location-specific patient/military information to another site where the data can be stored and organized; the system **100** can upload patient information for data storage, medical record keeping, diagnosis, tele-

medical consultation, epidemic tracking and epidemiology. Other systems **100** may communicate via the network simultaneously.

A central networked computer unit may maintain a database of all records, such as medical records, from where reminders can be sent to clinician/technicians for point-of-care check-up or follow-up with patients. In one embodiment, the system **100** can enable telesurgery where a remote medical clinician may control a local surgical-robot using the network to perform surgery from a remote site.

It should also be appreciated that the system **100** may be used achieve a variety of functions using the imaging, display, and collaborative communications features of the present invention. As such, the following discussion presents a variety of applications demonstrating the beneficial aspects of convertible operating mode provided by the system **100**, whereby examples are provided in which the system **100** is placed in a military operating mode or a medical operating mode. Moreover, while the examples are descriptive of a variety of applications of the system **100**, such examples are not limiting. In particular, the system **100** may be used to image, monitor and treat injuries and wounds using the collaboration between a user of the system and remote medically-trained personnel that are in collaborative communication with each other. Similarly, the system **100** may also be used to perform medical interventions with limited resources/military constraints before evacuation, and to guide and enable first-responders to perform medical tasks, including surgeries, and wound debridement. The ability for multiple users of the system **100** to collaborate also allows the users to provide medical assistance and advisement to one another. Additionally, the system **100** allows the users to guide a triage of large numbers of casualties, as well as staged treatment in the field; enable telemedicine that allows for 2-way telemedical collaboration between first responders and medical advisors; enable remote triage, monitoring and management of casualties, aided by experts; provide medical decision support with automated algorithms in conjunction with telemedical advisement from a remote site; guide treatment of hemorrhage, detection of vascular collapse and significant tissue damage due to perfusion deficits; facilitate diagnosis of brain and spinal cord injury; monitor and guide treatment to reduce secondary damage such as ischemia/perfusion injury after trauma; offer guidance to decontaminate, debride, protect and stabilize hard and soft tissue wounds; offer diagnostic and prognostic algorithms for non-medical and medical professionals; guide the assessment and treatment of dental injuries; guide the assessment and treatment of maxillofacial trauma repair, as well as orthopedic injuries.

It should also be appreciated that the system **100** may be used to facilitate medical biological defense; provide medical countermeasures for biological warfare agents; guide prophylaxis and pretreatment to prevent casualties; to allow the identification and diagnosis of biological agents, such as infectious agents including, but not limited to: anthrax, plague, Glanders, Ebola, and Marburg viruses, as well as the Venezuelan, western and eastern equine encephalitis viruses; and the poxvirus models of variola virus. Examples of toxins detectable by the system **100** may include those derived from plants, such as Ricin, and those derived from bacteria, such as staphylococcal enterotoxins and botulinum.

The system **100** may also be used to facilitate medical chemical defense; provide diagnostic and prognostic indicators for chemical warfare agent casualties; and provide detection of chemical agents that may include vesicant or blister agents (e.g. sulfur mustard), blood agents (e.g. cya-

nide), respiratory agents (e.g. phosgene) and nerve agents (e.g. GA or Tabun, GB or Sarin, GD or Soman, and VX).

In addition, the system **100** may also be used to characterize the mechanisms of vesicant agent pathology to identify medical countermeasures against vesicant agents; provide rapid and accurate analysis of human tissues and body fluids for detection of chemical warfare agent exposures.

The system **100** is also configured to serve as a training platform for military and medical purposes, whereby the system **100** utilizes augmented reality/virtual reality for training procedures and for combat casualty training for soldiers and combat medics.

Furthermore, the system **100** also provides biomonitoring and telemedical assistance in hospitals, the home and in the field.

In addition, the system **100** may also be integrated with medical robots and telesurgical applications.

In one aspect, the memory unit of the system **100** may store software to simulate a medical or military training procedure that is based on virtual reality or augmented reality. Two dimensional or three dimensional images or video may be stored at the memory unit of the system **100**, or in a remote server coupled to the network to which the system **100** is connected, which enables visualization of educational content, such as medical training, intelligence training, and military training.

In another aspect, the training software may include audio-visual training tutorials with step-by-step instructions for carrying out particular procedures via the display **110**. In addition, the tutorials may outline tasks for how to prepare for an examination, how to operate ultrasound, and how to position a patient. Ultrasound techniques, such as how to manipulate the ultrasound probe and use the keyboard functions of the ultrasound system may be included. The tutorials may also include various examination protocols; reference anatomy information with reference ultrasound images; procedures for how to make a diagnosis; and procedures for how to treat patients and treatment tutorials may be included. With networked systems **100**, the training can be augmented by having educators networked in by having their own system **100** to interact with students with their own system **100**. This is particularly adapted to use of a goggle system **100**.

In another embodiment, the system **100** may be used to detect blood or any other target **130** based on intrinsic absorption, auto-fluorescence, or extrinsic fluorescence and chemiluminescence. In one aspect, a mixture of predetermined fluorescence tracers, such as Hemasein for example, may be used to spray an area or region being investigated, which reacts with a desired target of interest **130** to cause the target **130** to fluoresce so as to be detected by the system **100**, as previously discussed. In this case, a 475 nm band-pass filter **150** may be used with the Hemasein to detect blood as the target of interest (TOI) **130** using the system. It should be appreciated that the system **100** may be used to detect other forensic evidence. The networking feature of system **100** may be used as appropriate to enable communication between systems **100A-X**.

In addition, through employments of different peripherals **350**, additional capabilities can be provided to facilitate the forensic detection. For instance, hyperspectral imaging can be used as a peripheral **350**. Devices such as absorption spectrometer, fluorescence spectrometer, diffuse reflectance spectrometer, Raman spectrometer or surface enhance Raman spectrometer can be used as peripherals **350** to provide additional information as appropriate.

It should be appreciated that the system **100** still has the capacity to offer night vision. Different imaging or sensing devices may be employed as peripherals **350** to achieve different purposes.

In one aspect, the light source **400** may have components that overlap with emission spectra, referred to as bleed-through components. The bleed-through components can be tunable to achieve desirable level of background. For example, in the case of indocyanine green dye, if the emission filter is an 820 nm long-pass filter, the component of illumination is >820 nm will pass through the emission filter (if emission filter is 820 nm long pass filter) and become the background, or the bleed-through component. The illumination could have both 780 nm LEDs for fluorescence excitation and 830 nm LEDs for bleed-through. By changing the intensity of the 830 nm LEDs, the level of background can be adjusted, which is useful in a variety of situations.

Based on the foregoing, the advantages of the present invention are readily apparent. The main advantage of this invention is to provide a convertible system, which has application in both military and medical fields. Still another advantage of the present invention is that medical applications can be enabled in part based on existing defense technology platforms. Yet another advantage of the present invention is that only one system is needed for use in both military and medical fields, such that same equipment used for military uses can be used to provide enhanced medical care, without increasing the amount of equipment needed. Still another advantage of the present invention is that diverse tasks can be performed with one system, such as to diagnose, monitor, provide wound treatment, identify infectious diseases and spinal cord/brain injury, and the like. Another advantage of the present invention is that triage and treatment can be guided with automated mechanism and/or remote telemedical guidance, such that treatment from non-medical professionals can be facilitated. An additional advantage of the present invention is that countermeasures against biological and chemical warfare can be facilitated within the system without additional equipment. Still another advantage of the present invention is that first responders can use the system to perform complex tasks, provide self-aid and aid to others, while empowering medical personnel to do more within military constraints. Another advantage of the present invention is that the system is lightweight, easily transportable, battery-operated and self-contained. Yet another advantage of the present invention is that the system provides microscopic imaging capability. An other advantage of the present invention is that GPS and remote communication are provided by the system to facilitate warfare and medical management.

Thus, it can be seen that the objects of the present invention have been satisfied by the structure and its method for use presented above. While in accordance with the Patent Statutes, only the best mode and preferred embodiment has been presented and described in detail, it is to be understood that the present invention is not limited thereto or thereby. Accordingly, for an appreciation of the true scope and breadth of the invention, reference should be made to the following claims.

What is claimed is:

1. A multi-purpose imaging and display system comprising:
 - a display carried by a goggle;
 - a detector carried by said goggle, said detector having a first set of sensing elements and a second set of sensing elements, said detector in operative communication

25

with said display, wherein said first set of sensing elements is configured to be converted from a night vision imaging mode to an imaging mode other than said night vision imaging mode, and said second set of sensing elements configured to perform fluorescence imaging;

a computing unit in operative communication with said display and said detector, said computing unit adapted to receive a peripheral image;

wherein said computing unit is configured to selectively co-register said fluorescence image with said peripheral image or display said night vision image for presentation on said display; and

a filter in operative communication with said detector; wherein said filter is selectively movable out of communication with said detector such that at least one of said first and said sensing element detects an image other than said respective night vision image and said fluorescence image.

2. The multi-purpose imaging and display system of claim 1, wherein at least one of said first and second sensing elements comprises a stereoscopic sensor.

3. The multi-purpose imaging and display system of claim 1, further comprising:

an interface in operative communication with said computing unit, said interface adapted to communicate with a peripheral that is configured to acquire said peripheral image.

4. The multi-purpose imaging and display system of claim 3, wherein said peripheral is selected from the group consisting of: optical spectrometer, absorption spectrometer, fluorescence spectrometer, Raman spectrometer, Coherent anti-Stokes Raman spectrometer, surface-enhanced Raman spectrometer, Fourier transform spectrometer, Fourier transform infrared spectrometer (FTIR), diffuse reflectance spectrometer, multiplex or frequency-modulated spectrometer, X-ray spectrometer, attenuated total reflectance spectrometer, electron paramagnetic spectrometer, electron spectrometer, gamma-ray spectrometer, acoustic resonance spectrometer, auger spectrometer, cavity ring down auger spectrometer, circular dichroism auger spectrometer, cold vapour atomic fluorescence auger spectrometer, correlation spectrometer, deep-level transient spectrometer, dual polarization interferometry, EPR spectrometer, force spectrometer, Hadron spectrometer, Baryon spectrometer, meson spectrometer, Inelastic electron tunneling spectrometer (IETS), laser-induced breakdown spectrometer (LIBS), mass spectrometer, Mossbauer spectrometer, neutron spin echo spectrometer, photoacoustic spectrometer, photoemission spectrometer, photothermal spectrometer, pump-probe spectrometer, Raman optical activity spectrometer, saturated spectrometer, scanning tunneling spectrometer, spectrophotometry, time-resolved spectrometer, time-stretch Spectrometer, thermal infrared spectrometer, ultraviolet photoelectron spectrometer (UPS), video spectrometer, vibrational circular dichroism spectrometer, or X-ray photoelectron spectrometer (XPS).

26

5. The multi-purpose imaging and display system of claim 3, wherein said peripheral is selected from the group consisting of: fiber microscope, handheld microscope, color microscope, reflectance microscope, fluorescence microscope, oxygen-saturation microscope, polarization microscope, infrared microscope, interference microscope, phase contrast microscope, differential interference contrast microscope, hyperspectral microscope, total internal reflection fluorescence microscope, confocal microscope, non-linear microscope, 2-photon microscope, second-harmonic generation microscope, super-resolution microscope, photoacoustic microscope, structured light microscope, 4Pi microscope, stimulated emission depletion microscope, stochastic optical reconstruction microscope, ultrasound microscope, or a combination thereof.

6. The multi-purpose imaging and display system of claim 3, wherein said peripheral is selected from the group consisting of: ultrasound imager, reflectance imager, Diffuse reflectance Imager, fluorescence imager, Cerenkov imager, polarization imager, radiometric imager, oxygen saturation imager, optical coherence tomography imager, infrared imager, thermal imager, photoacoustic imager, spectroscopic imager, Raman Spectroscopic imager, hyper-spectral imager, fluoroscope, gamma imager, X-ray computed tomography, laparoscope, bronchoscope, angioscope, or an imaging catheter.

7. The multi-purpose imaging and display system of claim 1, further comprising a tracking module.

8. The multi-purpose imaging and display system of claim 1, further comprising a light source.

9. The multi-purpose imaging and display system of claim 8, wherein said light source includes a laser diode and a diffuser.

10. The multi-purpose imaging and display system of claim 1 further comprising:

a tracking device configured to track a position of one or more objects, said tracking device in operative communication with said computing unit; and

wherein said computing unit co-registers said position of said one or more objects with either of said fluorescence image or said peripheral image in real-time.

11. The multi-purpose imaging and display system of claim 1 further comprising:

a communication interface in operative communication with said computing unit, said communication interface configured to link said goggle to at least one of a plurality of said goggles to communicate said co-registered image thereto.

12. The multi-purpose imaging and display system of claim 1, wherein one or more of said first and second sensing elements is a stereoscopic sensor.

13. The system of claim 1, wherein one or more of said images are different opacities.

14. The multi-purpose imaging and display system of claim 11, wherein said peripheral image is an in vivo image.

15. The multi-purpose imaging and display system of claim 8, wherein said light source is a pulsed light source.

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专利名称(译)	多功能成像显示系统		
公开(公告)号	US10447947	公开(公告)日	2019-10-15
申请号	US15/031791	申请日	2014-10-27
申请(专利权)人(译)	阿克伦大学		
当前申请(专利权)人(译)	阿克伦大学		
[标]发明人	LIU YANG		
发明人	LIU, YANG		
IPC分类号	H04N5/33 A61B5/00 H04N13/204 A61B5/0205 H04N7/15 G02B27/01 A61B5/1455		
CPC分类号	A61B5/0002 A61B5/0059 A61B5/0071 A61B5/0077 A61B5/7445 H04N13/204 A61B5/02055 A61B5/14552 G02B27/0172 G02B2027/0138 H04N5/332 H04N7/15		
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其他公开文献	US20160248994A1		
外部链接	Espacenet		

摘要(译)

一种多功能成像显示系统，包括显示器；连接到显示器并具有视场的检测器；以及与检测器连通的过滤器。探测器通过滤波器对视场成像，该滤波器配置为对第一频谱敏感，因此探测器仅在探测器上显示在视野内的物体，这些物体发射第一频谱内的一个或多个频率。检测器和过滤器可以在不同的操作状态或模式下一起工作，以获取正在研究的目标物体的图像数据。可以包括计算设备以处理获取的图像数据，并且可以采用通信接口来实现多个系统的联网。外围接口允许选择性地添加多个外围设备，以调整成像和显示系统的数据采集和显示能力。

