US 20190374298A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2019/0374298 A1**

ALLEN, IV (43) **Pub. Date: Dec. 12, 2019**

(54) **ENHANCED HAPTIC FEEDBACK SYSTEM**

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(21) Appl. No.: **16/385,133**

(22) Filed: **Apr. 16, 2019**

Related U.S. Application Data

(60) Provisional application No. 62/682,204, filed on Jun. 8, 2018.

Publication Classification

(51) **Int. Cl.**

A61B 34/00 (2006.01)

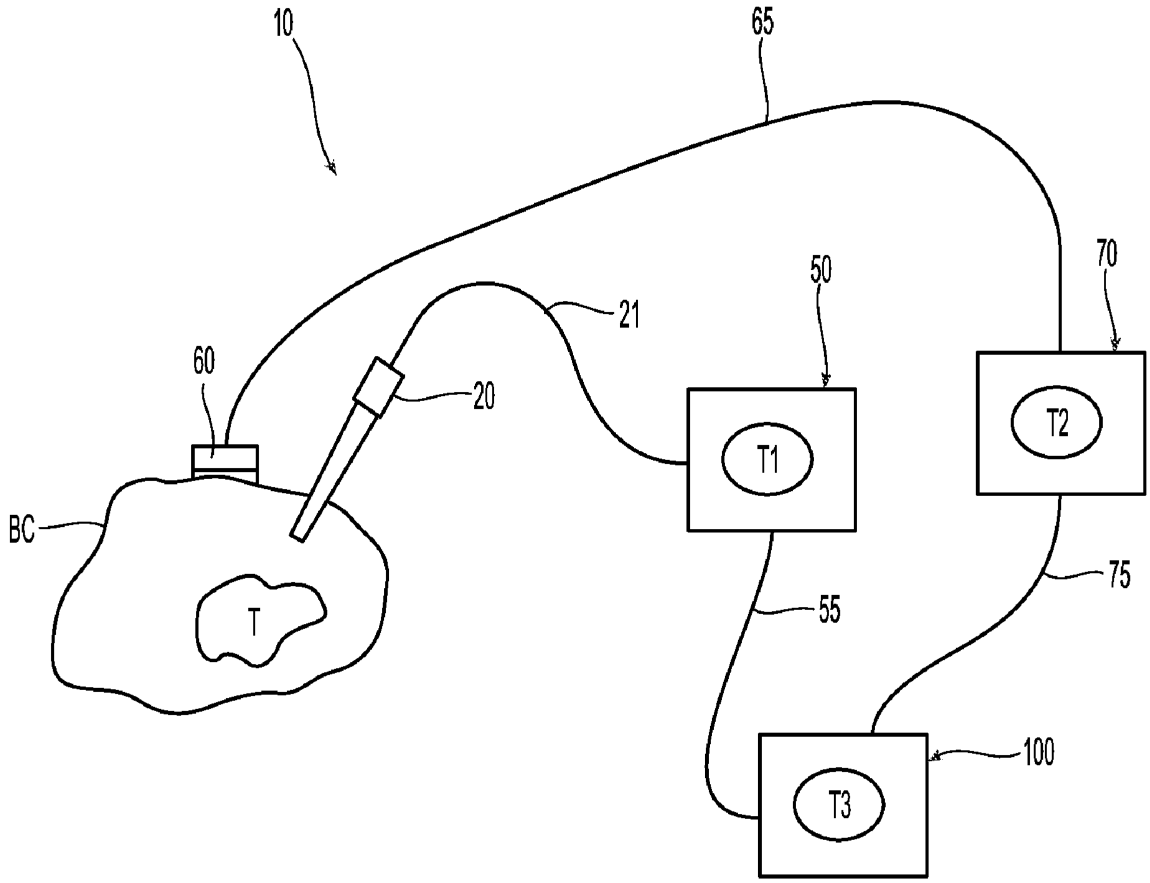
G06F 3/01 (2006.01)

(52) **U.S. Cl.**

CPC ***A61B 34/76*** (2016.02); ***G06F 3/016*** (2013.01); ***A61B 34/25*** (2016.02)

(57) **ABSTRACT**

An enhanced haptic feedback system for medical diagnostics includes a laparoscope configured to be inserted into a body cavity to view tissue and obtain an image of the viewed tissue. An imaging device is configured to acquire physiological data about tissue, process the acquired physiological data, and output the processed data to a graphical user haptic interface (GUHI) capable of generating tangible sensations utilizing one or more haptic interfaces. The GUHI is configured to combine the image received from the laparoscope and the processed physiological data received from the imaging device to provide tangible sensations on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon the sensation of feeling for abnormal tissue conditions between the surgeon's hands.



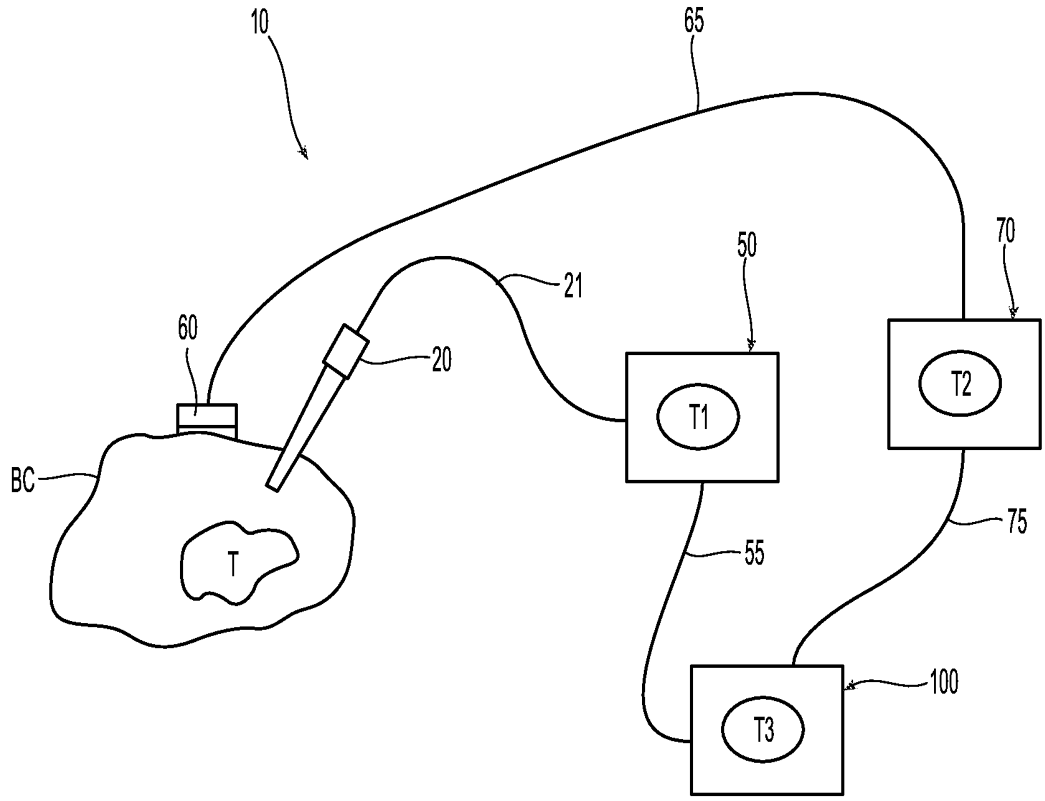


Fig. 1

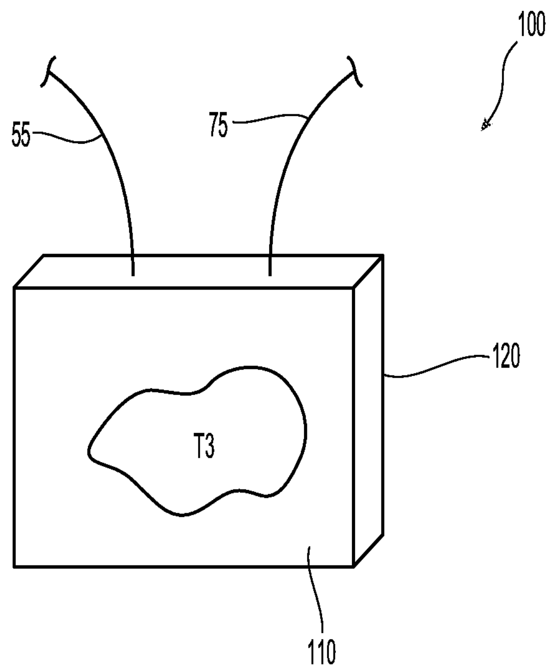


Fig. 2

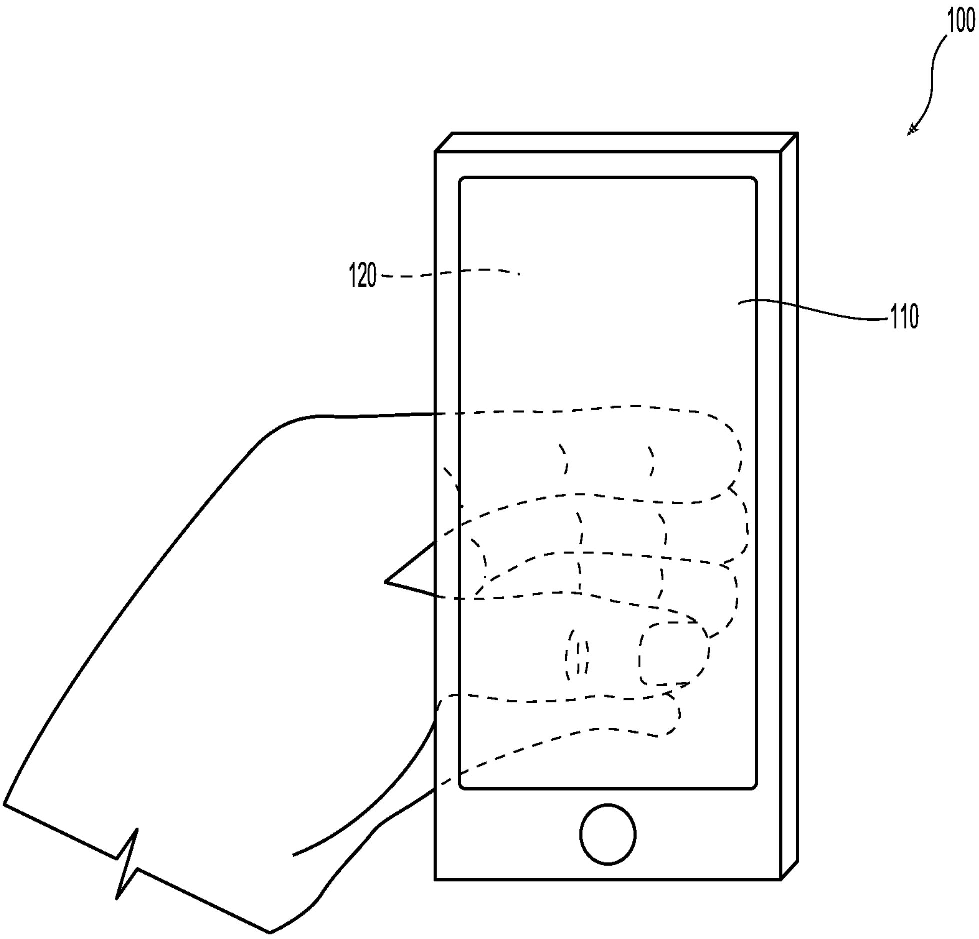


Fig. 3

ENHANCED HAPTIC FEEDBACK SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefit of and priority to U.S. Provisional Application Ser. No. 62/682,204, filed on Jun. 8, 2018 the entire contents of which are incorporated herein by reference.

BACKGROUND

Technical Field

[0002] The present disclosure relates to monitoring instruments for minimally invasive surgical procedures and, more particularly, to an enhanced haptic feedback system for use with various laparoscopic surgical procedures.

Description of Related Art

[0003] In minimally invasive surgery (MIS) and various percutaneous procedures, limited visibility and limited anatomical feedback can often supersede the advantages of the procedure and put the surgeon at a relative disadvantage compared to open procedures. Moreover, many MIS procedures require additional incisions to accommodate an endoscope to improve visibility. These additional instruments typically do not provide any tactile feedback which may be advantageous during particular types of procedures, e.g., tactile feedback allows a surgeon to appreciate relevant physiological information about biological tissues and allows an interactive experience through a haptic interface while operating.

[0004] Rudimentary haptic interfaces have been used in gaming, e.g., gaming controllers, however, in the medical field, haptic technology has mostly been limited to simulators for various medical procedures in a virtual environment, for example, for teaching purposes.

[0005] Medical companies have also implemented haptic feedback systems that provide notification signals and/or vibro-tactile sensations as an alert when too much force is applied or to direct user controlled systems or robotic/telesurgical operating systems. However, these systems do not provide the operator with tangible sensations that are physiologically relevant or reliable, nor do they provide a corresponding visual user interface that conveys the tactile information along with visual images of the body tissue.

SUMMARY

[0006] As used herein, the term "distal" refers to the portion that is being described which is further from a user, while the term "proximal" refers to the portion that is being described which is closer to a user.

[0007] In accordance with one aspect of the present disclosure, an enhanced haptic feedback system for medical diagnostics includes a laparoscope configured to be inserted into a body cavity of a patient to view internal tissue and tissue structures, the laparoscope is electrically coupled to a graphical user interface (GUI) configured to display an image of the tissue thereon or obtain an image of the tissue. An imaging device is included and is configured to acquire physiological data about tissue, process the acquired physiological data, and output the processed data to a graphical user haptic interface (GUHI) capable of generating tangible sensations utilizing one or more haptic interfaces. The GUHI is configured to combine the image received from the laparoscope and the processed physiological data received from the imaging device to provide tangible sensations on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon the sensation of feeling for abnormal tissue conditions between the surgeon's hands. Normal tissue properties may be assessed in this fashion as well.

[0008] In aspects according to the present disclosure, the imaging device is selected from the group consisting of an ultrasound device, a magnetic resonance imaging (MRI) device, a computerized axial tomography (CT) scanner, and a functional magnetic resonance imaging (fMRI) device. In other aspects, the imaging device is a portable ultrasound probe. In still other aspects, the GUHI is portable and is configured to be held between the surgeon's fingers and thumb.

[0009] In yet other aspects, the imaging device is configured to acquire and process physiological data about tissue in real time and combine the processed physiological data about tissue with the image received from the laparoscope in real time. In still other aspects, the imaging device is configured to acquire and process physiological data about tissue prior to combining the processed physiological data with the image from the laparoscope.

[0010] In accordance with another aspect of the present disclosure, an enhanced haptic feedback system for medical diagnostics includes an imaging device configured to acquire physiological data about tissue, process the acquired physiological data, and output the processed data to a graphical user haptic interface (GUHI) capable of generating tangible sensations utilizing one or more haptic interfaces. The GUHI is configured to combine an image received from a laparoscope and the processed physiological data received from the imaging device to provide tangible sensations on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon the sensation of feeling for abnormal tissue conditions between the surgeon's hands.

[0011] In aspects according to the present disclosure, the imaging device is selected from the group consisting of an ultrasound device, a magnetic resonance imaging (MRI) device, a computerized axial tomography (CT) scanner, and a functional magnetic resonance imaging (fMRI) device. In other aspects, the imaging device is a portable ultrasound probe. In still other aspects, the GUHI is portable and is configured to be held between the surgeon's fingers and thumb.

[0012] In yet other aspects, the imaging device is configured to acquire and process physiological data about tissue in real time and combine the processed physiological data about tissue with the image received from the laparoscope in real time. In still other aspects, the imaging device is configured to acquire and process physiological data about tissue prior to combining the processed physiological data with the image from the laparoscope.

[0013] The present disclosure also relates to a method for assessing tissue maladies ad includes positioning a laparoscopic or camera enabled device into a body cavity of a patient to visualize tissue and display a tissue image on a graphical user interface (GUI). The method also includes: acquiring physiological tissue data from an imaging source, combining both the acquired physiological data and the tissue image on a graphical user haptic interface (GUHI), and generating tangible sensations via one or more haptic interfaces on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon to feel and diagnose various tissue maladies. Normal tissue properties may be assessed in this fashion as well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Various aspects of the present disclosure are described herein with reference to the drawings wherein like reference numerals identify similar or identical elements:

[0015] FIG. **1** is a schematic view of a surgical system including an enhanced haptic feedback system including a laparoscope, a display and a graphical user haptic interface (GUHI) according to the present disclosure;

[0016] FIG. **2** is an enlarged view of the GUHI of FIG. **1**; and

[0017] FIG. **3** is an enlarged, schematic view of the GUHI of FIG. **1** shown in use.

DETAILED DESCRIPTION

[0018] Throughout the description, any particular feature (s) of a particular exemplary embodiment may be equally applied to any other exemplary embodiment(s) of this specification as suitable. In other words, features between the various exemplary embodiments described herein are interchangeable as suitable, and not exclusive.

[0019] Various embodiments of the presently disclosed system enable surgeons to acquire, read, modify, store, write, and download acquired sensor data in real time and display the information on one or more haptic displays. A haptic display is a device that portrays a visual representation of an object (such as a computer monitor, television, or cell phone display) and combines surface haptics overlayed on the image, producing variable forces on a user's finger as it interacts with the surface haptics. This can give the illusion of feeling textures and three dimensional shapes as the user touches the image on the screen.

[0020] CT scans, MRIs, fMRIs and ultrasound probes can detect, among other things, density of tissue. This acquired sensor data can be combined with images of actual tissue in real time. For example, if a laparoscope is used to view the surgical site, the location and orientation of the camera can be tracked so that the focal point has a known location within the patient. Using this known location, density data from a previous scan, e.g., a CT scan or MRI, and even real-time data from a live ultrasound probe (portable or standalone) can be used to overlay haptic data on a screen that the surgeon can then feel with his or her own hands.

[0021] Referring now to FIGS. **1** and **2**, an enhanced haptic display system is shown and is generally identified as haptic system **10**. Haptic system **10** includes an endoscope or laparoscope **20** operatively coupled via a cable **21** to a graphical user interface (GUI) **50** for displaying images "T**1**" of tissue "T" disposed within a body cavity "BC" of a patient. An imaging device **70** is included and includes a probe **60** electrically coupled via cable **65** to the imaging device **70**. Imaging device **70** may be an ultrasound probe **60** that is configured to render images of tissue "T" in real time or imaging device **70** may be CT scan, MRI, FMRI or any other type of imaging device capable of acquiring sensor data relating to tissue or organs either in real time or prior to using the haptic system **10**. Imaging device **70** is configured to measure various tissue properties, e.g., tissue density, blood flow, etc., and convert the acquired sensed data to haptic signal data readable and displayable by a graphical user haptic interface (GUHI) **100**.

[0022] GUHI **100** is operatively coupled via cable **75** to the GUI **50** and is configured to display images of the tissue "T**3**" overlapped with acquired sensor data (haptic data) obtained from imaging device **70**. In various embodiments, the haptic system **10** communicates with the operator (e.g., surgeon) using a symbolic language descriptive of biological tissues physical properties and the characteristics of motors and actuators that constitute the interactive components of one or more haptic interfaces. Typically the haptic system **10** includes a touch screen interface, e.g., front screen **110** or rear panel or rear screen **120** (FIG. **2**), which can provide haptic signals to the user and is thus an active display with touch and/or feedback that programs the one or more haptic interfaces. The haptic system **10** may include haptic signals that confirm programmable or system features (e.g., a palpable click) and provide additional sensor feedback that is descriptive of the events occurring in the haptic interfaces (e.g., vibro-tactile feedback, haptic rendering of physiologic events, audible and visual cues).

[0023] In embodiments, modification of the haptic experience of a user may be accomplished in real time (e.g. during procedures). Visual icons and secondary notations (not shown) may be included to provide a simplified graphical format and to augment the haptic feedback to further reflect relevant physiological information. The various haptic interfaces provide a way to display acquired sensor data from one or more imaging sources **70**, and control the corresponding actions of one or more corresponding actuators or haptic elements within the screen, e.g., screen **110** and/or screen **120**.

[0024] The symbolic language communicated by the imaging device **70** provides the acquired sensor data in both frequency and time and enables a user-friendly means for understanding, interacting with and controlling hardware, firmware and programming software in real time. The presently disclosed haptic system **10** provides an open, universally compatible platform capable of sensing or acquiring physiological signals/data (referred to as acquired sensor data) in any format; processing of the acquired sensor data within an operating system; and outputting the processed signals to the GUHI **100** which generates tangible sensations via one or more haptic interfaces. Tangible sensations are able to be felt or modified by the surgeon in real time on the GUHI **100** which allows a surgeon to feel and diagnose various tissue types and tissue maladies, e.g., tumors. Normal tissue properties may be assessed in this fashion as well.

[0025] The GUHI **100** utilizes various haptic interfaces including motors, actuators, and haptic elements to provide tactile feedback to the surgeon concerning the tissue. For example, the imaging device **70** may provide acquired sensor data to the GUHI **100** concerning tissue density of a liver. During a liver resection, a surgeon may need to feel for lumps in the liver in order to identify the appropriate plane of dissection that will excise an appropriate margin of healthy tissue on the patient side. This is to ensure that all of the cancer is removed, and only healthy tissue is left within the patient. As such, using the haptic system **10**, the surgeon can feel the varying densities of the liver and quickly ascertain lumps or abnormal tissue masses to define an acceptable dissection plane.

[0026] FIG. **2** shows an enlarged view of the GUHI **100** and includes a front screen **110** and a rear panel or rear screen **120**. The acquired sensor data from the imaging device **70** (and image "T**2**" if available) along with the image of the tissue "T**1**" from the laparoscope **20** are combined and displayed on the front screen **110** as tissue image "T**3**". More particularly, the image "Ti" from the laparoscope is displayed on the front screen **110** and the surface haptics from the acquired sensor data is overlaid on the image "T**2**" to produce an image "T**3**" that provides variable forces on a user's fingers or hand as the user interacts with the surface of the front screen **110**. As a result, the user is given the illusion of feeling textures as the user touches the image "T**3**" on the front screen **110**.

[0027] The acquired haptic data can also be combined with images of the actual tissue in real time. For example, the location and orientation of the laparoscope can be tracked so that the focal point has a known location within the patient. Using this known location, density data from a previous CT scan or MRI or even real time data from a live ultrasound probe may be used to overlay surface haptics from the acquired sensor data on the front screen **110**.

[0028] The surface haptics from the acquired sensor data may also be overlaid on the rear screen **120**. This would give the surgeon the ability to feel three dimensional objects such as a lump more effectively. For example, the surgeon can put his or her hand around the GUHI **100** (around both the front and rear screens **110**, **120**, respectively) and feel objects between his/her thumb and fingers (FIG. **3**). It is contemplated that utilizing both the front screen **110** and the rear screen **120** as haptic surfaces will enhance medical diagnostics, e.g., for more effectively analyzing mammograms.

[0029] The disclosure also relates to a method for operating a haptic system **10** including positioning a laparoscopic or camera-enabled device **20** into a body cavity "BC" to visualize tissue "T" and displaying a tissue image "T**1**" on a GUI **50**. The method also includes obtaining imaging information "T**2**" or physiological tissue data (acquired sensor data) from an imaging source (CT scan, MRI, fMRI, ultrasound, etc.), displaying a tissue image "T**3**" on a GUHI **100**, overlaying the acquired sensor data on the tissue image "T**3**", and generating tangible sensations via one or more haptic interfaces on both the front screen **110** of the GUHI **100** and the rear screen **120** of the GUHI **100** relating to one or more tissue properties, e.g., tissue density. Tangible sensations may be felt by the surgeon in real time on the GUHI **100** which allows a surgeon to feel and diagnose various tissue types and tissue maladies, e.g., tumors.

[0030] The various embodiments disclosed herein may also be configured to work with robotic surgical systems and what is commonly referred to as "Telesurgery." Such systems employ various robotic elements to assist the clinician and allow remote operation (or partial remote operation) of surgical instrumentation. Various robotic arms, gears, cams, pulleys, electric and mechanical motors, etc. may be employed for this purpose and may be designed with a robotic surgical system to assist the clinician during the course of an operation or treatment. Such robotic systems may include remotely steerable systems, automatically flexible surgical systems, remotely flexible surgical systems, remotely articulating surgical systems, wireless surgical systems, modular or selectively configurable remotely operated surgical systems, etc.

[0031] The robotic surgical systems may be employed with one or more consoles that are next to the operating theater or located in a remote location. In this instance, one team of clinicians may prep the patient for surgery and configure the robotic surgical system with one or more of the instruments disclosed herein while another clinician (or group of clinicians) remotely controls the instruments via the robotic surgical system. As can be appreciated, a highly skilled clinician may perform multiple operations in multiple locations without leaving his/her remote console which can be both economically advantageous and a benefit to the patient or a series of patients.

[0032] For a detailed description of exemplary medical work stations and/or components thereof, reference may be made to U.S. Patent Application Publication No. 2012/0116416, and PCT Application Publication No. WO2016/025132, the entire contents of each of which are incorporated by reference herein.

[0033] Persons skilled in the art will understand that the structures and methods specifically described herein and shown in the accompanying figures are non-limiting exemplary embodiments, and that the description, disclosure, and figures should be construed merely as exemplary of particular embodiments. It is to be understood, therefore, that the present disclosure is not limited to the precise embodiments described, and that various other changes and modifications may be effected by one skilled in the art without departing from the scope or spirit of the disclosure. Additionally, the elements and features shown or described in connection with certain embodiments may be combined with the elements and features of certain other embodiments without departing from the scope of the present disclosure, and that such modifications and variations are also included within the scope of the present disclosure. Accordingly, the subject matter of the present disclosure is not limited by what has been particularly shown and described.

What is claimed is:

1. An enhanced haptic feedback system for medical diagnostics, comprising:

a laparoscope configured to be inserted into a body cavity to view tissue, the laparoscope configured to obtain an image of the viewed tissue;

an imaging device configured to acquire physiological data about tissue, process the acquired physiological data, and output the processed data to a graphical user haptic interface (GUHI) capable of generating tangible sensations utilizing one or more haptic interfaces, the GUHI configured to receive the image from the laparoscope, combine the image received from the laparoscope and the processed physiological data received from the imaging device, and provide tangible sensations on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon the sensation of feeling for abnormal tissue conditions between the surgeon's hands.

2. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is selected from the group consisting of an ultrasound device, a magnetic resonance imaging (MRI) device, a computerized axial tomography (CT) scanner, and a functional magnetic resonance imaging (fMRI) device.

3. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is a portable ultrasound probe.

4. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the GUHI is portable and is configured to be held between the surgeon's fingers and thumb.

5. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is configured to acquire and process physiological data about tissue in real time and combine the processed physiological data about tissue with the image received from the laparoscope in real time.

6. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is configured to acquire and process physiological data about tissue prior to combining the processed physiological data with the image from the laparoscope.

7. An enhanced haptic feedback system for medical diagnostics, comprising:

an imaging device configured to acquire physiological data about tissue, process the acquired physiological data, and output the processed data to a graphical user haptic interface (GUHI) capable of generating tangible sensations utilizing one or more haptic interfaces, the GUHI configured to combine an image received from a laparoscope and the processed physiological data received from the imaging device to provide tangible sensations on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon the sensation of feeling for abnormal tissue conditions between the surgeon's hands.

8. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is selected from the group consisting of an ultrasound device, a magnetic resonance imaging (MRI) device, a computerized axial tomography (CT) scanner, and a functional magnetic resonance imaging (fMRI) device.

9. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is a portable ultrasound probe.

10. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the GUHI is portable and is configured to be held between the surgeon's fingers and thumb.

11. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is configured to acquire and process physiological data about tissue in real time and combine the processed physiological data about tissue with the image received from the laparoscope in real time.

12. An enhanced haptic feedback system for medical diagnostics according to claim **1** wherein the imaging device is configured to acquire and process physiological data about tissue prior to combining the processed physiological data with the image from the laparoscope.

13. A method for assessing tissue maladies, comprising:

inserting a laparoscope into a body cavity of a patient to visualize tissue and obtain a tissue image;

acquiring physiological tissue data from an imaging source; and

combining both the acquired physiological data and the tissue image on a graphical user haptic interface (GUHI) and generating tangible sensations via one or more haptic interfaces on both a front screen of the GUHI and a rear screen of the GUHI allowing a surgeon to feel and diagnose various tissue maladies.

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专利名称(译)	增强的触觉反馈系统		
公开(公告)号	US20190374298A1	公开(公告)日	2019-12-12
申请号	US16/385133	申请日	2019-04-16
[标]申请(专利权)人(译)	柯惠有限合伙公司		
申请(专利权)人(译)	COVIDIEN LP		
当前申请(专利权)人(译)	COVIDIEN LP		
[标]发明人	ALLEN IV JAMES D		
发明人	ALLEN, IV, JAMES D.		
IPC分类号	A61B34/00 G06F3/01		
CPC分类号	A61B34/25 G06F3/016 A61B34/76 A61B5/0035 A61B5/055 A61B5/7435 A61B5/7455 G16H20/40 G16H30/40 G16H40/63 G16H50/20		
优先权	62/682204 2018-06-08 US		
外部链接	Espacenet USPTO		

摘要(译)

用于医学诊断的增强型触觉反馈系统包括腹腔镜，该腹腔镜被配置为插入体腔中以观察组织并获得所观察组织的图像。 成像设备被配置为获取关于组织的生理数据，处理所获取的生理数据，并将处理后的数据输出到能够利用一个或多个触觉界面产生有形感觉的图形用户触觉界面（GUHI）。 GUHI被配置为组合从腹腔镜接收的图像和从成像设备接收的处理后的生理数据，以在GUHI的前屏幕和GUHI的后屏幕上提供明显的感觉，从而使外科医生感到异常感觉 外科医生手之间的组织状况。